Towards adaptability in structures to extend the functional lifespan of buildings related to flexibility in future use of space

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PAPER

The contemporary building stock in the Netherlands is not very sustainable, if you compare the average lifespan in utilization with the technical lifespan of a building. For example in the non-residential building sector there's a surplus of dysfunctional office buildings. Companies prefer a new building to a used one, because of communication-services, lack of free space or the image the company stands for.
In the residential building sector also a lot of older buildings do not live up to the requirements of the occupant anymore, these are nevertheless still inhabited because of the quantitative housing shortage. The fact that the average tenant moves to another dwelling every seven years clarifies that the dwelling doesn't match with the ever raising demands of the inhabitant, for example because of family-growth or higher comfort.

A building built in a traditional way has an expected technical lifespan of 50-100 years, but after 20-30 years it isn't economically valuable anymore. Demolition seems to be the only cure, but it does not help solving the problem in general.

This is a problem that has to be beard socially. Demolishing a building which is technically still in order, is nothing else than a destruction of capital with problematic side-effects such as waste, emission of CO_2 and energy consumption. Rehabilitation of office buildings to houses is possible to a limited extent, but to solve the problem in the long run it must be tackled from the root of it.

Slimbouwen®

A manner to anticipate on these developments is to design and build the future building stock according to the view of Slimbouwen®. Slimbouwen® is not a building system, but *"an integral view on building and possibly a system of agreements and guidelines at strategic level"* [Lichtenberg, 2005]. This view is developed to tackle social problems which are caused by the building industry, like the before mentioned building stock problem, but also to reorganize the building process, to make it more efficient.

Slimbouwen® aims particularly at the following aspects:

- Flexibility and comfort;

- Reduction of waste, energy saving and emission of CO_2;
- Efficiency (reduction of failure costs, weight saving, reduction of volume, gain of construction time by reorganisation of the construction process)

These aspects are considered related to the basic principle that design freedom may not come in danger. This means that the characteristic identity of a building, and with that for example the image of a company occupying it, will not be limited, which generally is the case when a industrial building system is used. Therefore freedom of design is a good starting principle or may even be a boudary condition to create a sustainable building stock.
Moreover it is important that adaptability and flexibility are embedded into the design, so when user requirements are changing, the building can anticipate to it, both on the level of 'support' and 'infill'.

Lifespan and flexibility in utilization

Generally seen the 'support', as put by Habraken [1961], is considered a rigid building component. The 'infill' is entitled as flexible in this matter. That's why the open space, enclosed by the 'support', is commonly seen as freely partitionable in former attempts to embed adaptability in buildings (for example: Open building, IFD).
The building structure in fact is put as a boundary condition, not as a limitation. However flexibility and the extension of building lifespan involves more than spaces that are freely partitionable. A separation wall can be easily replaced, but what about all the pipes and ducts needed? What happens when a rigid column in the centre of a room is an obstacle for the layout of it? The question then is how flexible a building really is and how bothersome the boundary conditions concerning flexibility are experienced. A flexible building normally does always live up to the demands of the first user, but actually the level of flexibility will be really put to the test by the second user. Mostly then it isn't as simple as expected.

Flexibility is a much-discussed and much-used term, however never exactly specified. Therefore a research is running at the University of Eindhoven focussed on the qualification of buildings to a certain degree of flexibility. This research is primarily related to the building structure, which is actually the boundary condition for flexibility. In this research a distinction is made between *structural adaptability* and *structural flexibility* [Blok, 2005] to prevent confusion of tongues.

The definition of structural adaptability is described as: *"The capacity of the building structure to be able to undergo changes to the structure itself, with or without only small consequences for the remaining building storeys."*
Structural flexibility is described as: *"The capacity of the building structure to provide changes in other building storeys, without the necessity to modify the bearing structure itself."*[Blok, 2005]

Based on these definitions the conclusions can be made that the 'support' in contemporary and earlier projects is not adaptable. Yet the 'support' does facilitate flexibility for the 'infill', in fact it defines the degree of flexibility in utilization of the building. In this view the 'support' functions as boundary condition. Currently in existing projects the attempt is to introduce structural flexibility to extend the lifespan of a building. However the lifespan of a building can be extended more by implementation of structural adaptability. In that case the degree of flexibility will not be limited by the 'support', but it will be expanded by it.

In the sequential steps in the building process according to the Slimbouwen® building philosophy (fig. 1), the structure of the building is placed first.

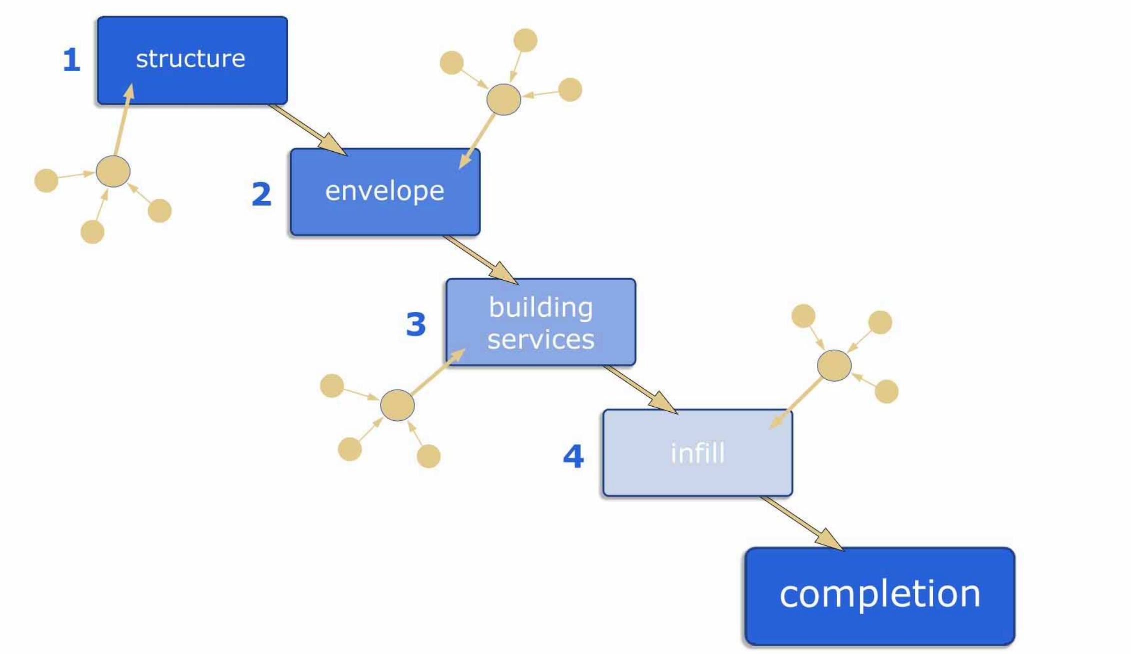

fig 1: sequential building process according to Slimbouwen®

In contemporary building projects entitled 'flexible', flexibility is embedded in theory after the first process step. However in practice most of the times it is only implemented in the fourth step (infill), but it should be noted that the first three steps are mostly optimized in the design process to achieve maximum flexibility in use of space on infill-level.
In these cases a freely partitionable space is offered wherein the placing of structural elements, facade-openings and building services are the limitatations. To maximize the flexibility of the building it would be sensible to implement flexibility into the first step in the building process. A possibility would be to make structural elements movable. This can only be without losing connection with the boundary conditions of the other building elements, because every decision taken in a design or process step has a direct consequence for the following steps in a sequential process. A decision in a subsequent step on the other hand can also undo the advantages of a decision in a former step.

It is expected that the economical lifespan can possibly approach the technical lifespan by structural adaptability. The building then serves the purpose for all future users, and the owner has a building which can adapt to the wishes and demands of the moment. The question is whether investors will take notice of the additional value of flexibility. Are they willing to invest in a surplus which will repay itself in the long term?

Structural adaptability

The first step in the research to physical structural adaptability is to find out in which structural components adaptations are desired. Moreover it is important to know the possibilities of the individual structural components to provide adaptability and to predict the consequences an adaptation beholds for the building as a whole and for its components.

Within Slimbouwen® there is the strive for weight saving and reduction of volume in building design and construction. Clearly the structure is largely responsible for the overall weight of a building and it defines the boundaries of volume of spaces. Because of the weight saving, Slimbouwen® concentrates particularly on skeleton constructions. A link to steel construction techniques is easily made then. To facilitate adaptability within a skeleton structure, the idea is to develop movable columns. The expectation is that movable columns can offer such flexibility to the utilization of space that the lifespan of the building is not limited anymore to the rigidness of the load bearing structure. For example the column can be movable within a certain area or grid so the architect has a broader range of space-layouts (fig 2 & 3).

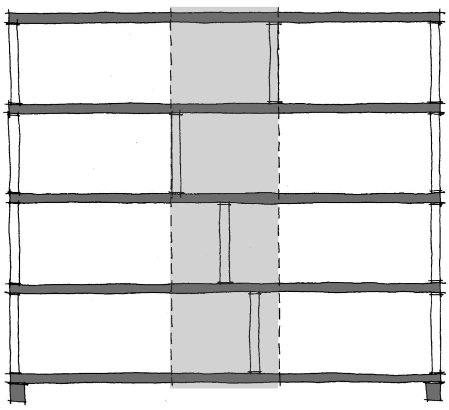

fig. 2: Section of a structure providing movable colums within a predefined area

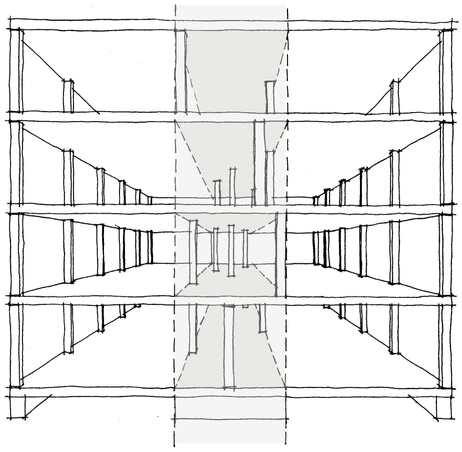

fig 3: Perspective view of a structure providing movable columns within a predefined area

A skeleton structure, in comparison to a wall structure, requires other supplies in regard to stability.
The use of x-bracings, which are normally used, may limit the freedom of space-utilization in some places, for example for placing doors and windows or maybe to combine certain rooms.
Research is needed to ascertain whether it is possible to disconnect stability supplies from flexibility-determining structural elements, for example by implementing stability supplies into fixed building elements such as vertical circulation spaces and shafts.
In case of a wall structure, stability is much more uncomplicated, because the structural elements themselves provide stability. A structural wall however is a rigid element, therefore it affects the structural adaptability. The possibility offered by a wall structure is that openings can be made to bring two spaces in connection, without the loss of structural qualities. Such a structural wall could standard contain openings which are filled by a lightweight infill. In time these infills could be taken out to combine the two spaces. A possible solution can be a development such as a “pre-programmed structural separation element” (fig. 4).

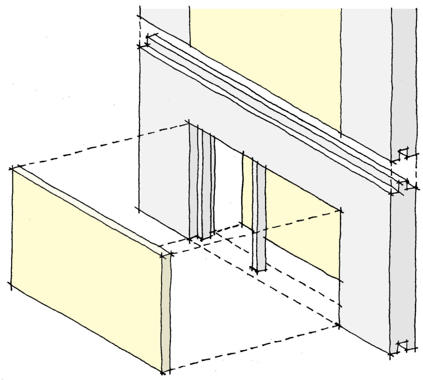

fig 4: pre-programmed structural separation element

Sustainable building stock

It would make no sense to implement adaptability into all structural elements. Research will sort out which structural elements provide a possibility and an additional value to flexibility in utilization by adaptability. By regarding the structural possibilities concerning adaptability and to facilitate flexibility in space-utilization, there will not merely be stated a boundary condition for flexibility, but moreover an extra possibility to gather and deal with the aforementioned Slimbouwen®-aspects. An integral view on building methodology does comprehensibly cover all facets, and if well-implemented the Slimbouwen®-approach will serve as a useful link to these facets mutually, starting with the building structure.

To provide buildings with a sustainability appreciated in the future, the assumption is that structural adaptability in the right places offers maximum flexibility in utilization. In collaboration with other aspects represented by Slimbouwen®, it must be possible to extend the lifespan of the future building stock. After all, building is for the future.

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Briefing for Change

Case study from the field of sports- and cultural facilities.

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Introduction
A large number of new facilities combining functions for sports and cultural events are constructed these years. Many of these facilities are intended to be highly multifunctional in order to provide activities for people from many different social groups and many different disciplines. At the same time there is a constant change in the preferences of the users of these facilities. In order to meet the demands of multi-functionality and flexibility, it is necessary to think beyond well known typologies and develop new hybrids. If this search for new types of facilities should bring forward substantial innovation, action should be taken already in the briefing process. This paper reports on a case study from the briefing phase of a project set out to transform a typical sports hall into a multifunctional cultural centre of a Danish town.

Preface
Innovation projects
When a client is starting up the long process leading to a construction project, he should decide whether the emerging project is intended to become an implementation project or an innovation project [Engwall 2000]. An implementation project is characterized by seeking to reach a goal that has been set outside the project it self. An innovation project on the contrary is developing the goal as an integrated part of the process. The involved parties in this type of process should be in a progress where interaction between the creative solutions of the architect, the factual knowledge of the technical advisers and the users realization of there own needs should lead to new solutions that are appreciated by everybody.
This case describes an innovation process, where both the contents and the physical appearance of the project have been developed simultaneously during the process.
Frank Gehry has said in an interview that "clients often don´t know what they want. And if clients do spell out what they want, it usually turns out to be precisely what they already have". [Weick 2003]
If Gehry is right most projects are likely to end up as implementation projects thanks to the conservative forces carried by clients and users. Clients therefore need the creative input from external experts to hold on to the innovative aspects of the project. On the other hand it can not be left to experts alone to develop innovative solutions, if the users´ views of their needs are not developed simultaneously. *Needs and solution must develop in a parallel evolution.*
The practical consequence of Gehry´s statement in an innovation perspective is, that `clients do not know what they want until they have seen what they can have´. As a result the advisers should be able to show the client different solutions to different needs, and the client can then choose which solutions and which needs he values most. Iteration between needs and solutions should enable the client and the users to decide ´where they want to go and what it takes to get there´. We emphasize that this decision should be based on a concrete foundation, because the majority of clients and users can only appraise a given solution when it is presented in a tangible form, that can be sensed and understood immediately. Abstract formulations of visions and goals can be valuable to create an overall coherence

and direction of the innovation. But the choice between one solution and the other is not really qualified until we have some certainty that the client can sense the tangible differences between the solutions.

Concluding we can state, that in the early phases of an innovative building project stakeholders (clients and users) and advisers (architects, engineers etc.) must be able to cooperate on creating an iterative interaction between new needs and new solutions to these needs. This cooperation must be planned in order to facilitate innovation through an iterative interaction between visions and goals on an abstract level and tangible solutions on a concrete level. These principles have been guiding for the process plan for this case.

Case description

A local community in a small Danish town set focus on the future culture and leisure activities of the area and a local group proposed to develop the local sports hall, now used only be sport clubs, to become a cultural centre of the area. In order to reach this goal it would be necessary to upgrade the existing buildings and construct a set of new facilities. The community hired The Centre for Sports and Architecture at the Copenhagen School of Architecture to take on a role as process managers of the initial phases of the project, and to plan a course of development, where the local stakeholders in cooperation with an architect and a group of technical advisers could map the emerging local needs and simultaneously sketch possible solutions to these needs. The process management assisted the client in choosing an architect and technical experts in acoustics, light design, energy design and statics. The process management had a double competence as they were both experienced in leading this type of process and had a specialized knowledge about the planning of sports facilities.

The existence of these two fields of interest was mirrored in the criteria for success that the process management set up for their own contribution. The process goal was to carry out an experimental process successfully, using new principles and tools and ending up with a special kind of brief referred to as the illustrated brief. The process strategy was to reveal the present and coming needs of the users by confronting them with different statements and concrete future scenarios that where well documented thanks to early involvement of artistic and technical expertise. The content goal was to develop a new hybrid building for culture and sports that was open for new types of activities and the strategy was to reach this goal by involving the users in the design process journey in order to prepare their acceptance of something radically new.

The workshops: The first public event was an open reunion with the primary target of creating attention to the coming development process. At the reunion the process management organized a so called future workshop where the attending people (app. 45) were asked to express their opinion about 7 verbally formulated future scenarios concerning the area and the sports hall. The most important effect of the reunion was though that it was made clear to everybody that participation in the coming innovation process was not restricted to the existing users but was open to all possible future users and any citizen of the area. The workshops were from the beginning planned to consist of activities that could secure a constant interaction between an abstract level and a concrete level leading to a synthesis that could materialize in an illustrated brief.

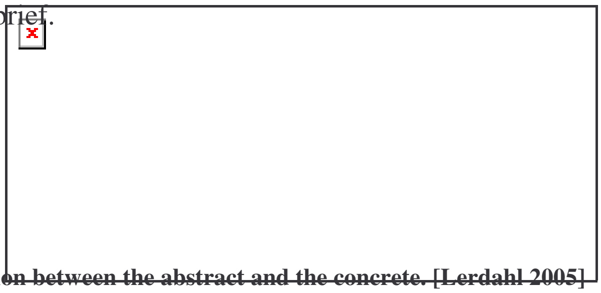

Fig.1. Iteration between the abstract and the concrete. [Lerdahl 2005]

The stakeholders were expected to describe their opinions, wishes and visions at the workshops, and the architect should then create concrete manifestations of these during the periods between the workshops. To avoid the classic problems of a linear process where early decisions and visualizations could exclude all other possible solutions, three parallel scenarios called ´The Open Hall´, ´The flexible Hall´ and ´The Hall as Centre of Town´, were developed. The three scenarios represented a compromise, as the process management suggested three typologies based on functional differences where as the architect thought it wiser to investigate different spatial qualities. It was the intention to assure an equal attention to all three scenarios, and from workshop 3 and forward the scenarios should then be merged into one scenario that could be represented by the illustrated brief.

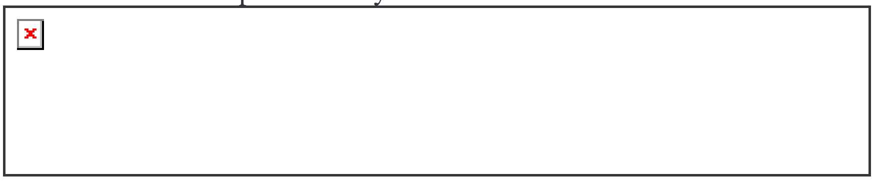

Fig. 2. The initial process plan.

The people who showed up for the workshops represented very different user groups ranging from knitting clubs to music teachers, football players and fitness freaks. All workshops were not attended by everybody but there was a fairly stable core group of app. 20 stakeholders who came regularly and made a continuous learning process possible.
The sketches produced by the architect seemed more concrete than verbal descriptions and represented a more outspoken reference point for the stakeholders´ abstract considerations about functions and values. Sketches and other types of concrete visualisations are often left out in the early phases because the development process can be halted by lay people's (and architects´) tendency to get caught by concrete images. Some of the visualisations presented at workshop 2 seemed to have this effect and the situation emphasized the importance of keeping three equal alternatives open.

Workshop 1: At the first workshop a new priority game was introduced. In this game, stakeholders should assign priority to a number of concrete and abstract statements about the three scenarios by placing statement cards on a game board. (I.e. "More daylight in dressing rooms" or "Cultural activities can enter the hall which is no longer a closed sports world".) The purpose of the priority game was to make the stakeholders themselves choose which qualities in each scenario they found most important. In order to structure the contents, the statements were divided into the 4 categories communication, organisation, activities and facilities that again were subdivided into more specific categories.
This categorization came to have the double purpose of structuring the present inputs and serve as a checklist for new inputs throughout the process.
At the end of the workshop stakeholders were asked to think 5 years ahead and from this point of view describe why the project had become a success. The success criteria were afterward discussed in order to reveal the more general values. The architect collected all the priorities and value statements as a foundation for sketching concrete suggestions for the three scenarios.

Workshop 2: The architects´ concrete visualisations of the three scenarios were presented by models, sketches and pictures of references. The stakeholders were asked to formulate and later prioritise pros and cons to the three scenarios through a strength/weakness game, based again on the four categories communication, organisation, activities and facilities. The architect had interpreted the three scenarios in a way in which they came to represent different sub-issues of a larger consistent project unity. This was in opposition to the overall strategy formulated by the process management. The aim of this strategy was to maintain three completely autonomous scenarios, and emphasize the function of the sketches as tools to investigate possibilities on a programmatic level, and not as early attempts of a final solution. The architects´ handling of the scenarios can possibly be seen as a result of a general tendency among architects to create major synthesis at an early state, and avoid the interference of others in the evaluation of alternatives. In order to secure an open investigation of alternative solutions, the process management suggested using workshop 3 for creating three new scenarios, this time partly structured by the local stakeholders.

Workshop 3: For workshop 3 the architect prepared plans of the existing building and exteriors in a large format. The participants were asked to form three groups that each worked with different sizes and placements of additions to the existing building. The groups first placed different rectangles of cardboard representing spaces of different sizes on the plan. Then they considered which functions could share which spaces by placing one or more activity icons in each space. Finally the participants discussed different architectural qualities that were wished for in the different spaces. They visualized this discussion by placing prefabricated quality cards with concrete images of different types of skylight, filtration of daylight, view to the outside, flexibility and atmosphere in each space, including the existing spaces. This way of sketching did not imply any special competences, and seemed to let more participants be active than if they had been asked to draw or build models.

Workshop 4: Based on the plan sketches from workshop 3 the architect now sketched a relatively detailed architectural interpretation of the three new scenarios visualized through drawings and models. Contrary to the scenario sketches for workshop 2, the sketches for workshop 4 represented three completely different and separate alternatives. Before the presentation at workshop 4 the three new design sketches were introduced to the process management and the technical advisers, who all worked out written comments to the solutions concerning acoustics, daylight, energy design, statics and functionality. The comments by the technical advisers deepened the stakeholders understanding of the possibilities and potential problems, and gave them a certainty of no important issues left out. At the workshop the participants were asked to add their own view of the strengths and weaknesses of the three scenarios and finally mark all the comments they found most important. The markings revealed a primary interest in two of the three scenarios. The process management then produced the illustrated brief combining the decisive architectural sketches with a number of chosen statements, wishes and priorities gathered through the entire process, and the architect made the final synthesis.

Workshop 5: The client (the local county) did, by the beginning of the process, not wish to assign a fixed budget to the project. This decision seemed to be based upon the unspoken strategy of letting the project develop, observe the interest it could bring out, and then consider how much funding it was realistic to aim for (a ´funding follows form´ strategy). After workshop 4 a fixed budget was presented to the architect leaving him with a difficult task of creating a valuable hybrid within very narrow economical borders. The architect succeeded in creating a powerful synthesis that was presented to the stakeholders at workshop 5. The project was received with enthusiasm among the local stakeholders and by the city council. Most stakeholders expressed that the end result was rather innovative and that the entire development process from their point of view had been a success. The project is now carried on by the architect and the technical advisers.

Fig. 3. The final process plan as executed

Concluding comments

Process management and stakeholders

It is rather unusual that an institutional client chooses
a´funding follows brief´ principle and leaves it to the local stakeholders to decide freely the form and the contents of a rather large publicly financed construction project. Politicians normally seek to ´sell´ projects to their voters by presenting a simplified description of the contents of the end result at a very early stage and thus fixing the project contents before deeper investigation of the needs and possibilities have taken place.
A more thorough stakeholder analysis followed by a conscious choice of resourceful and representative stakeholders might have caused a more lean and operational workshop group. On the other hand an open access to the workshops legitimizes the end result, (´if someone wanted things differently they could just have showed up´) and a fairly large number of participants make group work on parallel alternatives possible.
The games that were introduced made it easy for the stakeholders to get started but they also showed that too many artful simulations of real situations are tiring in the long run.

Iteration between needs and solutions:

The overall criteria of success for the design of this case has been to create circumstances that would allow both clients, users, citizens, architects and technical advisers to cooperate in a meaningful way and develop an innovative result. There is no doubt that the architectural innovations have been developed by the architect in a traditional creative process back home by the drafting board. Still the architect has been sketching on basis of the considerations of the workshop participants and these considerations also form the precondition for the participants´ later recognition and understanding of the concrete solutions presented by the architect. It can be said that the stakeholders have created the preconditions for the form and at the same time the preconditions for the recognition of this form as valuable. The value of a process where concrete solutions are used as a tool for recognition is not based on the stakeholders´ production of solutions, but on the fact, that stakeholders are guaranteed a fast translation of their abstract formulated values into concrete solutions that can then be used to test the same abstract values creating a so called ´double loop´ [Stacey 2000].
The technical experts have contributed to this process by presenting explicit knowledge to the stakeholders and the architect and thus qualifying the participants judgement of the concrete solutions. The injection of knowledge has been important but has also hit a limit. In workshop 4 where the large amount of information in the technical advisers´ comments to the scenarios came close to pacifying the participants completely. The architect in this case was not skilled in working openly with equal alternatives, but experienced along the way, that he was able to defend his artistic integrity although he was working under the instructions of the process management and was left to the grace of the stakeholders when it came to choosing the future scenario

Evaluation of the criteria for success
The process goal of carrying out an experimental process has been reached and new strategies and tools have been developed leading to an illustrated brief. Some future needs that were not previously known have been discovered by confronting the stakeholders with concrete solutions. The content goal of developing a new hybrid building for culture and sports has been reached, especially because stakeholders from different user groups have obtained ownership to the same spaces that can then be shared in new ways. It is an open question to what extend a brief produced by a single adviser and followed by an architectural competition would have produced a final result of the same quality as the present project. There is not much doubt though, that the enthusiasm of the stakeholders in the voyage towards the final result would not have been the same in a traditional architectural competition. Therefore both the process and the project have, through the ownership of the stakeholders, obtained a special validity. It is the combination of this validity and an innovative product that is unusual and often hard to reach in traditional development processes.

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Process performance indicators in project pre-design stage

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Performance measurements, performance indicators, stakeholders' requirements, communication

ABSTRACT

Traditionally performance in construction is measured based on the "iron-triangle"- time, cost and quality. In recent years indicators have been developed to include the measurements of other aspects of project performance. The main shortcoming of these however is that most of them are lagging indicators and hence are of little use for controlling the performance during the projects. This paper reviews the existing key performance indicators, their types, use and shortcomings. The paper describes a proposed conceptual framework for developing performance indicators for the pre-design stage, of which the briefing process is an important part. In this framework a process mapping methodology is suggested to identify the main activities that take place in the pre-design phase, the dependencies between them and the stakeholders involved. Initial investigation of the proposed framework has shown that it is a viable model that has already helped in identifying the relevant processes of the pre-design phase and the related indicators.

INTRODUCTION

The construction industry is project-based, dynamic in nature and involves many participants and stakeholders. The concept of project success is not yet clearly defined in the construction industry. Project success is the ultimate goal for every project. However, it has different meanings for different people. While some consider time, cost and quality to be the predominant criteria, others suggest that success is more complex. The overall objective for all stakeholders is the same: they all want the project to succeed.

In many ways, performance measurement is ultimately aimed at improving performance and hence achieving success. In construction, attempts have been made over recent years in several countries to establish and measure construction management performance over a range of its activities to meet a set of improvement targets. The results of such attempts have produced a number of measures and indicators; see for examples KPI in the UK [KPI, 2000] and the construction performance measures developed by the CII in the United States [CII, 2000].

The aim of many of the developed indicators in different countries was to assess the overall project performance or to measure the performance of its main activities. However, most of those indicators are static in nature and are used to measure the performance after the work or the project is complete. Hence, they reflect a statement of the "post-event" without any opportunity to change the process while it is in progress. Many of indicators are also focused on product and not on the process. There are few existing indicators that inform stakeholders about how well their process is going during the various stages.

The work described here is part of a wider research project to develop performance indicators for the whole construction process. In this paper the work describes a proposed framework and a methodology for developing process performance indicators for the pre-design stage. The intention is not only to compare actual performance with target performance, but also to use the indicators to inform the management for the need for control during all stages of the phase including that of the briefing process.

PROJECT PERFORMANCE AND MEASUREMENT

Performance measurement process is an essential part of conducting and controlling projects. The process aims to establish goals and to provide a mechanism for controlling performance. Therefore it provides continuous improvement and prepares the ground for making decisions.

Performance indicators are some of the tools that have recently gained popularity in the field of performance measurement. They can be very diverse and include process or product related indicators, and can be either qualitative or quantitative. A performance indicator can be defined as 'a measure used to provide information about the performance of a process and the degree to which its objectives are achieved'. To be effective, performance indicators need to be valid, accurate as well as being relevant.

The concept of using indicators to assess performance originates from the theory of benchmarking used in many industries for improving business processes and products. The concept involves measuring one or more aspects of the business or part of it and comparing it with the best in its specific sector. The approach aims to continually improve the business activities and leads to the setting of higher targets. Benchmarking can be defined as a process of continuous improvement based on the comparison of organisation, processes or products with those identified as best practice. The best practice comparison is used as means of establishing achievable targets aimed at obtaining process or product improvement. Since most of indicators are based on the comparison of actual performance with targets or desired processes they therefore also provide a basis for project production and process control. There are many indicators that are proposed by other authors in previous studies for use in construction. Some of them are aimed at the industry while others are aimed at project or activity levels.

Different authors have classified performance indicators in different ways. Beatham [2004], for example, stated that performance measurements could be classified into the three groups, based on European Foundation of Quality Management (EFQM), as Key Performance Indicators, Key Performance Outcomes and Perception measures.

Robinson [2005] classified all performance measures as either financial which include turnover, return on capital and discounted cash flow or non-financial such as customer satisfaction, quality, environment and safety.

Costa & Formoso [2004] classified performance indicators as primary and secondary. Primary indicators include product client-satisfaction, service client satisfaction, construction cost, construction time, defects, predictability-cost, predictability-time, profitability; productivity and safety whilst secondary indicators are used for operational and diagnostic aspects of the project.

Other authors classify performance indicators as being "soft" and "hard". "Soft" measures include, for example, qualitative assessments whilst "Hard" measures include quantitative appraisal, see [Chan 2004] and [Beatham 2004].

Chan has also categorised indicators as objective and subjective. Often, the objective indicators are calculated, using mathematical formula. This group includes indicators such as construction time, speed of construction and unit cost. The subjective indicators are normally based on personal judgment of the stakeholders involved in the construction process. Judgments about quality, functionality, stakeholders' satisfaction are examples of subjective measures [Chan 2004].

Other variations of indicators suggested by other authors include external, "iron-triangle" and psychosocial indicators [Bryde 2005]. External indicators focus on client perception. Psychosocial performance indicators are focused on team member and individual development, reward and recognition of project team from financial and non-financial aspects. "Iron-triangle" is related to the estimation of cost, quality and time. In fact many of the indicators developed in the past are based on this approach as can be seen from the various financial indicators developed by [CII 2000].

Ghalayini & Nobel [1996] distinguished between lagging and leading indicators. Lagging indicators are post-event oriented and self-evidently do not offer the opportunity to influence the construction process. Leading indicators are those, which measure the construction process during its execution and therefore allow the changes to be made during the process. Examples for the lagging indicators are almost all KPI, whereas for leading indicators all are perception measures, such as sickness, qualifications, training and team working.

In spite the aforementioned variations in the classification of indicators and their depictions of the various aspects of construction, many of them still have considerable shortcomings. These shortcomings include:

- they are static in their nature; most of them aim to measure the performance results after the project completion;
- most of them are product or production oriented and not process oriented;
- they are lagging type and hence are of little use for control;
- very few of them are useful for identifying communication problems between stakeholders during the process;
- they can be useful from the point of view of a particular stakeholder but of little use for measuring the overall project performance or those of other stakeholders.
- some indicators are purely theoretical and cannot be implemented in practice, and the required data for their measurement are not easy to collect;

In addition, many of the indicators developed so far are specific to their country of origin because of particular aspects of the construction industry, the economy and the business culture of the country. They have not gained universal acceptance, but they do appear to have had some success in improving the industry in their country of origin.

PROPOSED FRAMEWORK AND METHODOLOGY

The objective of this research is to develop indicators that are relevant for measuring the performance of the main activities and processes that take place within the pre-design stage. To achieve the objective of the research a research methodology has been adopted that consists of a number of steps that include: Dividing the pre-design phase into main sub-stages; Identifying the main activities with the sub-stages, their inputs, expected outputs and targets; Determining the stakeholders involved with each activity, their requirements and the way in which they communicate with each other and; Developing indicators that can be used to measure the performance of the activities involved.

Fig.1 depicts the framework adopted from Winch [2001] to facilitate this objective. The main sub-stages, which are considered as parts of the pre-design stage are: inception; feasibility and scheme design. The activities and processes within the sub-stages are identified and selected based on literature and experts' opinions. The targets and the main expected results of each activity are yet to be determined from interviews and questionnaires that will be conducted during the project. Based on information collected, the outcomes of the main activities and processes will be translated into indicators. The framework uses solid lines to represent the dependencies of the information and processes between the activities and dotted lines to represent the communication lines between the stakeholders.

Initial investigation of the pre-design stage has shown that an important part of this phase in any construction process is the brief. Briefing is the process of defining and translating the client's wishes into clear requirements. According to the RIBA plan of work, there are three main stages that can be recognized in the briefing process. The first stage of briefing represents an initial statement defining the client's need for the project. The second stage is the strategic brief that follows the feasibility study stage. The final stage is when everything is summarized in the form of project brief at the end of the detailed proposal stage [RIBA 2000].

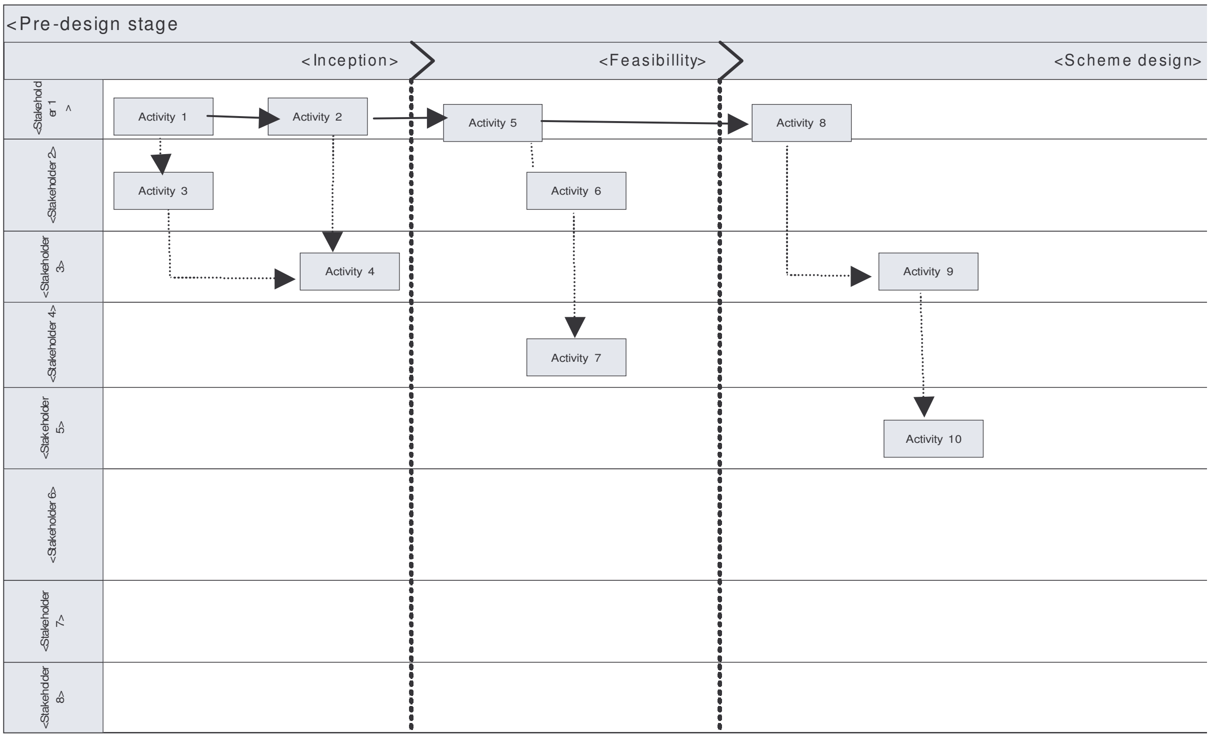

Fig.1 A conceptual framework for the pre-design phase

Barrett et al.[1999] have stated that an important problem of the briefing process in any project is that it can suffer from the subjective approach of the brief-taker. The brief-taker can include the information relevant for him in the project brief but skip the information important for other stakeholders. In this work it is assumed that the proposed framework will minimise this problem by providing clear assessment of the main activities and the stakeholders' requirements relevant to these activities.

Another problem with the briefing process is that sometimes information collected and used in the brief has a contradictory character that increases time of selecting the "right" information. It is believed that the proposed framework will help to concentrate on the more relevant information and skip the irrelevant so that the time for the briefing process will be saved. Useful information will reduce uncertainty and will add value to the project [Browning, Deyst et al. 2002].

In construction there are usually many stakeholders involved in a project. These stakeholders are the parties which will gain direct benefits or suffer losses as a result of the project; see [Winch 2002].
There is also a basic assumption within construction project management that the client is capable of fully articulating the views of all of these stakeholders on the demand side. That is to say that the client has the capability to authoritatively brief the project team. Evidence however has shown that this is often not the case and that, for example, the needs of a building's users are, in many cases, not fully understood or articulated by the client.

The identification of the main activities outputs proposed by the framework is aimed at creating a basis for measuring how the construction process is performing and to provide the information necessary for all the stakeholders involved in the process. The stakeholders will have the opportunity to follow and measure the progress of the process. As a result of this, it will improve their satisfaction of the project and increase the project's value.

The work carried out so far has shown that it is important that the stakeholders' objectives are aligned to achieve their own success and that of the overall project. Stakeholders' alignment is therefore one of the indicators that will be used to measure the alignment or lack of it in the pre-design phase of the construction process.

CONCLUSIONS

The paper has provided a review of the need for performance measurement in construction and the available tools. This review included descriptions of the many developments in the area of performance indicators reported by other authors, their types and use. The paper has shown that, despite of these developments, there are still many problems associated with the use of performance indicators and their suitability in construction.

The paper has described a proposed conceptual framework for developing the various indicators for the processes within pre-design stage. It has also outlined a methodology for achieving this objective. The work described in this paper is still in its early stage. However, the paper has demonstrated that the proposed conceptual framework is viable and that some indicators that are relevant for the pre-design phase have already been identified using this framework.

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Quantifying Structural Flexibility for performance based life cycle design of buildings

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KEYWORDS

Flexibility, Adaptability, Building Structure, Structural Flexibility, Service Life

ABSTRACT
When we try to specify minimum performance levels for the whole life cycle of a building we have to face the problem of how to deal with the uncertainties of future functional use. In stead of specifying minimum functional requirements we could opt to specify minimum levels of flexibility. To achieve this, it becomes necessary to quantify and compare "flexibility". To do this flexibility is defined more precise. Because the building structure is usually the longest lasting building layer the possibilities to quantify the flexibility of the building structure, "Structural Flexibility", is looked at in more detail. A definition of Structural Flexibility is given and a framework to measure and compare Structural Flexibility is discussed.

1. Mimimum functional performance levels.
In Performance Based Design it is necessary to define minimum requirements and to use suitable models for behaviour. These models should include the expected service life of the building. Reliable checks must ensure that the proposed design solutions will actually meet these minimum performance levels, not only at the start but also during the Service Life of the building.

Because the Service Life of a building also depends on its functional qualities (Functional Working Life), it is essential to specify minimum levels of functional requirements. However, future user demands (specially for second and later users) have a large degree of uncertainty. Because of this, flexibility is often used as a strategy in the Life Cycle Design of buildings. Two different fundamental ways to respond to change or uncertainty can be distinghuised:

- Active Flexibility: The ability to respond by changing, reacting or adapting. In building we call this Adaptability

- Passive Flexibility: There is no need to react, because of sufficient tolerance or capacity. This second type of flexibility is in other disciplines sometimes referred to as "robustness". For various reasons here the word Flexibility is used for passive flexibility.

In stead of specifying minimum functional requirements for a given (fixed) functional use, we can opt to specify minimum levels of Flexibility (and / or Adaptability) in order to ensure a better way of coping with future changing demands.

2. Framework of definitions

The words flexibility and adaptability have become very popular. To prevent the delution of meaning, we need to define them very precise. Research undertaken at the TU/e with regard to the relations of the building structure with the other building layers: envelope, services, access and space plan (including the way the space is used), has resulted in a clear frame-work of definitions of the different kinds of Flexibility.

2.1 A flexible building

In general, a Flexible Building can be defined as a building with the (passive or active) capacity to accommodate, in a relatively easy way, (future) changes. This definition poses the problem of how to regard, or how to define “relatively easy”. In the chosen definitions a change to a certain building layer is regarded as “relatively easy” if it can be achieved without the necessity to affect or change other building layers as well.

For example: A building with a load-bearing elevation wall combines the layers of Structure and Envelope. It is not possible to change the Envelope layer without also changing the Structure. Regarding this aspect the building is not flexible. It is possible however, that the same building is flexible with regard to other building layers, for example the Servant elements or the Space plan (partition walls).

Flexibility involves many levels. However, with the use of a simplified building model, [for example Brand 1994; Leupen 2002], Flexibility and Adaptability can be defined at building level by looking at the relations of the building layers with eachother.

Adaptability of a given building layer (f.i. structure, services, envelope etc.) is defined as:

The capacity of the building layer **to accommodate changes to the layer itself**, without or with minor consequence to other building layers. (This implies that other building layers can obstruct the Adaptability of the layer in question.) For example: Structural Adaptability means that the structure itself can (easily) be changed. (“Active Flexibility”)

Flexibility is defined likewise. Flexibility of a given building layer means:

The property of that building layer **to accommodate changes to other building layers,** without the necessity to change that particular building layer itself. For example Structural Flexibility means that the structure acommodates changes to one or more other building layers (for example space plan, services) without the need to change the structure itself. (“Passive Flexibility”)

3. Adaptability and flexibility relations

The possible flexibility and adaptability relations are considered at building level. They can be derived from the adopted building model. These theoretical relations of the building layers are shown in [fig. 1]. Within the building 10 primary relations (two way arrows) can be distinghuised.

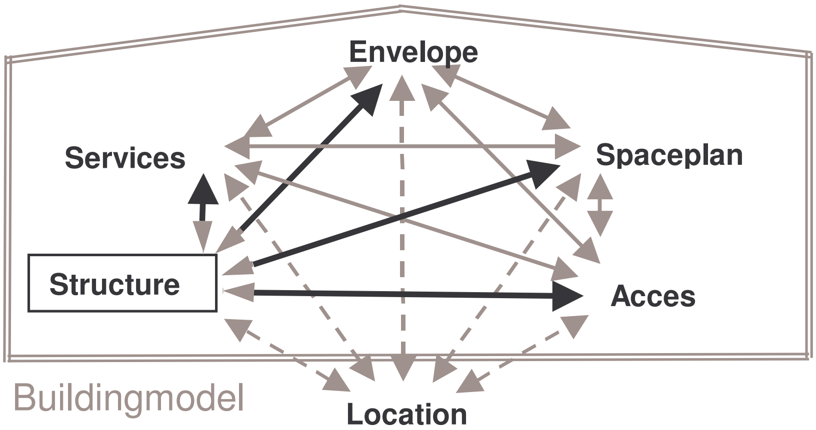

Fig. 1 Theoretical adaptability and flexibility relations at building level.

In this model, the arrows ***towards*** a building layer represent the relations influencing the ***adaptability*** of that particular layer. The arrows leaving ***from*** a building layer represent the ***flexibility*** of that particular building layer (accommodating possible changes to other building layers).

The four flexibility relations of the ***structure*** are drawn in ***bold***. (The flexibility relation of the structure with its Location (dotted line) denotes the aspect of Mobility of the structure.). Note that adaptability at building level is not possible without (a certain degree of) flexibility of other building layers.

At a deeper level, within a building layer, it also becomes clear that adaptability of certain elements is not possible without sufficient flexibility of other elements. For example an Adaptable Structure, in which columns can be added, removed or changed in different positions is only possible with sufficient flexibility of other elements, for example the beams, by providing sufficient bearing capacity.

An example of flexibility of the structure at building level is given in (Fig. 2). The prefabricated holes in the concrete beam make it possible to change or adapt the position of the service ducts.

Fig. 2 Flexibility of the structure: Service ducts can be adapted and can cross the concrete beams

where needed. (Hospital Laboratory, Lyon, France).

4. Structural Flexibility

Structural Flexibility is regarded as one of the most essential forms of flexibility, because in general the structure's qualities and relations are very influential in the decision process regarding refurbishment or demolition of our existing building-stock. To investigate the structure's flexibility three main questions rising from the structures primary functions and qualities need to be answered:

- Is the building layer Structure **sufficiently independent** of other building layers?
  A: Does the structure share parts with other building layers?
  B: How are the connections with other building layers. Are they reversible (bolted, etc)?
- Does the structure **provide sufficient space** to each of the other building layers?
- Does the structure **provide sufficient load-bearing capacity** for each of the other building layers?

4.1 Quantifying Structural Flexibility

These three qualities of the structure, independence, space, and load-bearing capacity, are each evaluated with respect to the other four building layers. A large provided space and bearing capacity together with a high degree of independence from other building layers, will result in a high score on Structural Flexibility.

The following (simplified) matrix [fig. 3] shows the principle flexibility relations of the structure with the other building layers:

Structural Flexibility Relations		Building layers:				
		Space Plan	**Envelope**	**Services**	**Access**	
Structure	**Independence** Layer Function					$R_{independence}$
	Layer Connections					
	Load Bearing Capacity					$R_{load\ bearing\ capacity}$
	Space (H)					R_{space}
	(A)					
Resulting scores:		$R_{space\ plan}$	$R_{envelope}$	$R_{services}$	R_{access}	

Fig.3. Matrix showing flexibility relations of structure with other building layers.

The aim of the research is to investigate, evaluate and quantify each relation, and finally come to resulting scores $R_{layer\ i}$, representing the Structural Flexibility with regard to each of the other building layers. The resulting scores indicate to which degree the structure accommodates (not blocks or obstructs) the Adaptability of the other building layers. To achieve this overall indicators and partial indicators representing the qualities of these relations of the structure with the other building layers are defined and further investigated.

An example of a partial structural flexibility indicator is given in [Table 1].

Flexibility class: Life Floor Load	Allowable Life Floor load P_{rep} (kN/m2)	Minimum values for life floor loads depending on the building functions according to Dutch building regulations	Partial Flexibility indicator
I Not Flexible	$P_{rep} <= 1{,}75$	Houses	0,2
II Limited Flexibility	$1{,}75 < P_{rep} < 2{,}5$	Apartment buildings	0,4
III Average Flexibility	$2{,}5 <= P_{rep} < 4{,}0$	Schools, Hotels, Hospitals, Offices	0,8
IV Very Flexible	$4{,}0 <= P_{rep} < =5{,}0$	Shops, Museums, Public Buildings	1,0
V Extreme Flexible	$5{,}0 < P_{rep} < 10{,}0$	Industrial Buildings, Warehouses	1,0 -2,0 (Depending on value of P_{rep})

Table 1. Partial Indicator: Allowable Life Floor Load

The example shows a partial indicator denoting the structure's qualities with regard to load bearing capacity in relation to the building layer Space Plan. This load bearing capacity is classified in five different categories, from "not flexible" to "extremely flexible". After scoring and weighing the partial indicators (still subject of the research) the aim is to visualise the resulting scores. An example of the quantification of the Structural Flexibility of a given structure in a single multi-criteria chart is given in [Fig. 4]

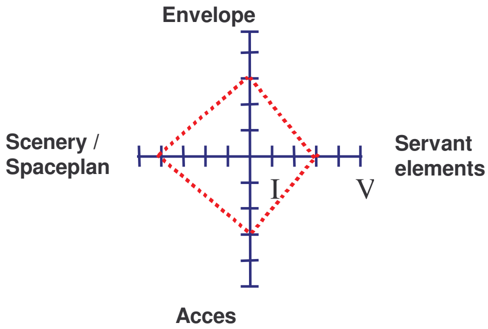

Fig 4: Multi-criteria Structural Flexibility Chart (From centre outwards: Flexibility class I (Not Flexible), to V (Extremely Flexible).

5. Discussion.

With the proposed definition of Structural Flexibility (and Structural Adaptability) together with the proposed framework for evaluation it will become possible to quantify, evaluate and compare both existing as well as newly designed building structures with regard to their Flexibility. A high Structural Flexibility will increase the building's performance by allowing for possible future adaptions of the building layers, for example caused by changing user requirements. This might result in a higher probability of a long Functional Working Life of the building. The relations between on one hand the realised Structural Flexibility and on the other hand the expected service life of the building structures needs further research.

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Stakeholders' Participation towards Sustainable Building Literacy.

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KEYWORDS

Sustainable building, Learning, Participation, Stakeholders, Participation appraisal.

ABSTRACT

The progress towards sustainable cities requires a population aware of the goals of sustainability including that of reversing the loss of environmental resources. The lack of knowledge by the general public on sustainable buildings prevents the building market from a rapid change. The decision making in present building practice is the result of interaction among different types of stakeholders. This participation arrangement applied to the building practice enables the transmission and understanding of sustainable building knowledge. Proper selection of stakeholders, the role of the facilitator and the assessment of the participation process are discussed. However, the stakeholders' variety of interests may adversely impact the decision making process as multiple ethical paradoxes may appear.

INTRODUCTION - sustainable building literacy for the general public.

Sustainable construction literacy is a critical goal to cope within the international agenda for sustainable development. The progress towards sustainable cities requires a population aware of the sustainability goals including that of reversing the environmental resources loss. Within the general sustainability goals, it is necessary that citizenry be capable of reflecting on the importance of the buildings' contribution for reversing the environmental degradation despite its complexity. It is known that construction activity is responsible of the consumption of large quantity of natural resources and energy during its life cycle. Its complexity is due to the fact that building practice involves human, financial and technological aspects. Therefore a knowledgeable general public on sustainable building supports ensuring the general goals of sustainable development.

The Agenda 21 for sustainable construction in developing countries stresses several problems to achieve sustainable construction learning mainly related to the formal education[1] system. Lack of appropriately trained professionals is among those identified problems as well as lack of awareness amongst general public. Such lack of education amongst general public on sustainable buildings raises two issues including user misinteraction with the technology embedded in buildings and the prevention of the built environment from a rapid transformation towards sustainable development.

[1] Formal education occurs when society or a group or an individual sets up a curriculum to educate people, usually the young. Formal education can become systematic and thorough.

Nevertheless, professionals and general public can become knowledgeable through formal and non-formal education[2] mechanisms. Traditionally, general public awareness is tackled through mass media mechanisms due to its wide coverage. In contrast to mass media in terms of coverage, present decision making on building design is carried out through the collaboration of a small number of stakeholders where learning can be generated. The central idea of this paper is that through this collaborative atmosphere the objectives of awareness and learning on sustainable buildings can be reached, though on small scale. This view can be expressed by the old Chinese saying, “many little things done in many little places by many little people will change the face of the earth”. This brief paper elaborates on the theoretical aspects of participatory processes in order to boost learning amongst stakeholders committed in the building processes.

2. Misinteraction with technology and market transformation slowdown.

In the last years the environmental design has gradually become a necessary aspect of buildings. Environmental design involves the incorporation of technology in buildings including: flexibility and adaptability of components and elements, low energy cooling and heating systems, water saving devises and so forth. This technology has proved to be quite effective to ensure reversing the adverse impact of buildings in the environment; but unless the users understand and interact properly with it, the technology itself will not be able to completely accomplish its sustainability mission (Zenjoyi and Takiguchi, 2005). Users are unable to effectively utilize building technology due to the lack of knowledge.

On the other hand, the beneficial impact of sustainable buildings although gradually growing is still limited. At present, not enough number of buildings applies environmental design and technology; as a consequence, the actual beneficial impact on the environment of existing sustainable buildings is limited. In general, the existing sustainable buildings constitute mainly an example of the potential of the environmental design and technology. If the general public stays unaware on the worth of such type of buildings for supporting sustainable development, the transformation and dissemination of the building market will continue being slow.

In order to cope with the user misinteraction with technology and market transformation slowdown, stakeholders are able to become aware on environmental issues and specifically knowledgeable on environmentally friendly buildings through participatory activities during the decision making process.

3. How stakeholder participation can generate sustainable building learning?

Building decision making is increasingly the result of the interaction among different types of stakeholders[3]. Stakeholder -as a part of the general public- are individuals or groups capable of significantly influence the design of a building. Such influence could be experienced directly or indirectly and could result in beneficial or adverse impact. Further classification is possible distinguishing between professional stakeholders and non-professional stakeholders.

Professional stakeholders refers to architects and engineers who are knowledgeable on building environmental design and are able to transmit that knowledge, whilst non-professional are those agents who provide input to the design in terms of the benefit they wish to get from it, but are not completely aware of what environmental design or technology of building aims to. Non-professional agents include investors, occupants, contractors, managers, tenants etc. Within the participatory activities as an educational mechanism, the non-professional stakeholder is the learning subject.

Katz et al. 2005, suggest that participation enhance the sustainability of building delivery. They sustain the idea that participation in building process is justified by the need to pursue fairness, equity and

[2] Non-formal education describes a number of approaches to teaching and learning other than traditional run in schools.
[3] In this paper the stakeholders who are not knowledgeable on sustainable buildings or environmental design will be considered as part of the general public.

mutual learning. Through the open dialog of participatory activities within the building process the possibility of learning on matters wider than the private interest of participants including environmental issues can be generated. Participatory processes constitute thus an alternative for sustainable building knowledge transmission. Further relevant aspects of participatory processes to be taken into account are: proper selection of stakeholders, the role of the facilitator and the assessment of the process.

3.1 Democracy and participation in building decision making.

Participation is a channel for attaining democracy. According to Pateman 1970, democracy is a method or certain type of arrangement for arriving at decisions. Democracy can be reached through participation by providing opportunities to discuss and express opinions on matters of common interest. Participation involves action and commitment to the decisions taken. It is a method for decision making that:

- provides inclusiveness to the process by taking into account different relevant types of agents.
- provides equity by empowering to those agents who usually do not have power over those agents who traditionally have it.
- ensures transparency through open interaction among participants and
- enables learning by allowing participants to reflect on what is discussed by other stakeholders.

Participatory rationale is built on the fact that a group of persons is more likely to provide innovative solutions than a single person working in isolation. A decision making process through participation enables consensual acceptance of decisions.

3.1.1 Levels of participation

In order to maximize attributes of democracy such as inclusiveness and transparency, different methods and techniques corresponding to different levels of participation can be considered when organizing a participation process. See Wulz classification of levels of participation combined with examples of participatory methods in Table No 1.

Passive participation ← → Active participation

Level of part. / Method of part.	Representation	Questionnaire	Regionalism	Dialog	Alternative	Co-decision	Self Decision
Survey (general population)		☆					
Survey (local population)			☆				
Interview				☆			
Voting					☆		
Post Occupancy Evaluation						☆	
Workshop						☆	
Focus Groups						☆	
Planning Cell						☆	
Self-build							☆

Table No 1. Wulz Levels of participation

In the left side of the participation scale shown in table No1, the requirements of the user are assumed completely by the architect. In the other side of the scale, self-decision refers to the non-professional of buildings who decides all building features, leaving to the architect an advisory role. A selection of methods that combines different levels of participation provides balance between the necessities of the user and the competence of the professional. The interaction necessary for raising fruitful dialog and learning is more likely to be produced in the active side of the participation's scale.

3.2 Selection of the appropriate stakeholders.

Taking into account that building processes involve a variety of stakeholders with different interests and different ways of influencing the decision making (power), it is necessary to balance the diversity of backgrounds and powers of participants. Groups that are composed by members with diversity of backgrounds are more likely to contribute with creative solutions. Fruitful dialog is generated through a variety of perspectives and inputs.

On the other hand, inclusiveness can not be met if groups or individuals are segregated from the participation process. Conscious or unconscious exclusion of key groups from the dialog arena undermines the decision making process as critical points of view may not be taken into account. Examples of traditionally excluded groups from participation activities are indigenous groups or female groups. Efforts to include all relevant agents will result in richer dialog and holistic understanding can be possible.

3.3 The role of the facilitator.

The facilitator is a linkage agent within the participatory activities. As the decision making gets more specific and complex, the process is likely to shift to a more active interaction. In order to conduct an organized process an intermediary entity often called "facilitator" acts as a mediator between professional and non professional. Facilitator's mediation role becomes relevant as he/she constitutes a communication bridge promoting understanding among participants.

The role of the facilitator may begin since shaping the process' structure and the selection of participants. This process manager is also in charge of the clear transmission of the objectives, procedures, rules, and schedule so that players could have the whole picture of the process. More importantly, the facilitator helps to understand other agents' points of view as well as building's features. Further elements to be taken into account by the facilitator are: to provide equal opportunities to contribute, discuss and to decide.

- To contribute refers to the opportunity of stakeholders of actively participate in the dialog.
- To discuss means the opportunity of stakeholders to deliberate about the proposals raised.
- To decide implies that the participants must be able to actually influence the outcome of the process.

4. Appraisal framework of participatory activities.

Assessment of the process is necessary for redirecting the course of activities. In order to ensure that the participation process fosters learning an assessment framework is proposed. This framework includes questions to evaluate the process as well as to evaluate the learning outcome by asking changes in participants' behavior towards the operation of buildings. Examples are provided in Table No 2.

No	*Question*	*Criteria*
1	Were the objectives of the process clearly stated?	Procedural
2	Was the process described in detail?	Procedural
4	To what extent there was opportunity to express opinions and comments during the participation process?	Procedural
6	Did all participants have the same opportunity to express opinions?	Procedural
7	Did the facilitator help to explain and describe concepts between different participants when necessary?	Procedural
8	Did the building features were described including those related to the environmental performance of the building?	Substantive
9	At some point during the process, Did you realize that other participant's opinions were as relevant as yours?	Substantive
10	Based on the information exchanged during the participation process, did you modify your building operation habits at your home or workplace?	Substantive
12	Was the building design actually modified as a consequence of participants' input?	Substantive
14	If you invested in the construction of a building. Would you promote the integration of environmental design in the building?	Substantive

Table No 2 Participation assessment framework

Procedural criteria refer to the structure and development of the activities while substantive criteria refer to the insight as a result of the learning produced during the process. What can be noted from table No 2 is that questions from substantive criteria that attempt to evaluate the change in attitude touch the terrain of environmental ethics where the moral aspect of the decision making becomes relevant.

5. Environmental ethics and participatory processes.

Participation processes may produce ethical paradoxes. Stakeholders committed in the decision making process during building design have different interests to protect. Yashiro 2005 states that individual interests may undermine the collaboration process as economic, societal and environmental objectives may be confronted. However, the participation process has also the opportunity to cope with those potential ethical paradoxes by explicitly stating principles on environmental ethics. Yashiro 2005 goes on.

> *If members of project's organizations can share vision and ideas of environmental ethics, they are able to make appropriate, adaptive and comprehensive solutions under specific and complicated conditions through collective decision making process.*[4]

6. Conclusions

This paper has discussed the theoretical aspects of participatory processes as a non-formal educational mechanism for sustainable buildings dissemination. Education on sustainable building is very important because it influences actions of the citizenry. Present decision making in building practice provides the opportunity to generate understanding on matters beyond the individual concern including environmental design and technology. In order to foster learning, the decision making process should be structured taking into account a well-balanced level of participation, an inclusive selection of participants and more importantly a skillful facilitator capable of serving as a communication bridge between specialists and laymen. The process assessment provides feedback for redirecting the activities if necessary. Nevertheless, this collaborative arena may face the risk of environmental ethical dilemma as different interests may be confronted; therefore an explicit statement of environmental ethics becomes relevant. An environmentally aware citizenry will eventually use its selection power to produce a change in the market towards sustainable buildings.

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Managing Flexibility Programming and Overall Design


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KEYWORDS

Building construction, design systems, building flexibility, open building

1 Introduction

The practice of starting a construction project before the user requirements are specified is increasing and thereby changing the construction market. Also, modern implementation planning is increasingly utilizing the knowledge of the bidders and the partial component suppliers during the procurement phase [Kiiras *et al.* 2002]. This paper introduces a model for flexible systematic facility programming and for the presentation of an adaptable overall design developed in the TKK research project "Developing a Design System for CM contracts" (FinSuke). The objective of the ongoing FinSuke research project is to develop solutions for late user requirement and overlapping problems. The suggested solutions have been tested either retrospectively or through prospective implementation in actual projects. The present number of cases evaluated in the research project is approximately 50. The focus of this paper is on the overall design phase. The implementation phase of the model is presented in Kruus *et al.* [2005].

An application of the programming model is illustrated through an adaptability and flexibility testing project for undefined communal services and exhibitions: Polo Tecnologico for the City of Quarrata in Italy. The project was based on a Finnish architect team's winning proposal in an international architectural competition. The preliminary phase began in 1996 and the construction works were completed in 2004. The project size is roughly 4,500 m2, which was divided in the final solution into two separate, but connectable buildings: a 1,500 m2 library building designed by an Italian architect group and the Polo Tecnologico Project, a 3,000 m2 multipurpose building.

2 Project scope for flexible buildings

Past traditional Finnish project briefings included an evaluation of the site, condition surveys (in refurbishment projects), preparation of the facility program and charts, budgeting, and overall project scheduling. Such a project was traditionally designed for a predestined use with a fixed facility program, which indeed didn't support the concept of flexibility i.e. the principle of the open building. In addition, the Scandinavian tradition of defining the exact use for a building in the local detailed plan (town plan) may also be an impeding factor. The flexible programming is based on a systemic definition of the scope of the building's modifiable spaces. The scope is defined according to the divisibility (divisibility for separate users), and to the properties of the facilities (space flexibility). The key idea in the FinSuke model is to define the range for the chosen facility program and for the chosen variation of the uses of the spaces. The scope of the modifiable spaces is by definition [Saari 2002]: (1) the divisibility for separate users i.e. the number, the sizes and the definitions of the premises, the separability of the premises, and the conversion time; and (2) the space properties i.e. flexible programming; special facilities; interior requirements; adaptability, and conversion time. The base building (the core) includes the fixed parts that remain unchanged within the predefined range of user variation. The definition of the fixed base building is by definition [Saari 2002]: the fixed facilities, the fixed body, and the fixed HVAC components. In the preliminary phase, the City of Quarrata couldn't define an exact program for the project. The city could give only an open functional scope ranging from communal and cultural services to temporary and permanent exhibitions. In addition, the scheduling was extremely obscure, and in contrast to modern overlapping, the phases were hardly linked at all. Still, a fresh architectural impact on the townscape of Quarrata was expected. Hence, the project scope was demanding [Formichella 2003].

3 Fixed overall design of buildings

The overall design consists of both the base building designs and the modifiable interior designs. The modifiable interior is designed by laying alternative interior concepts at the beginning of the overall design stage; additional alternative layout solutions are examined for the base building. The solution that best meets the flexibility goals is selected, and the final overall design is completed for the procurement of the base building (the core) and for further detailed designing. The fixed base building is designed, procured, and built irrespective of the infill variation. For the infill, the agreed number of different interior solutions (concepts) is designed. The implementation planning of the infill is started after the user requirements are specified (e.g. through lease agreements).

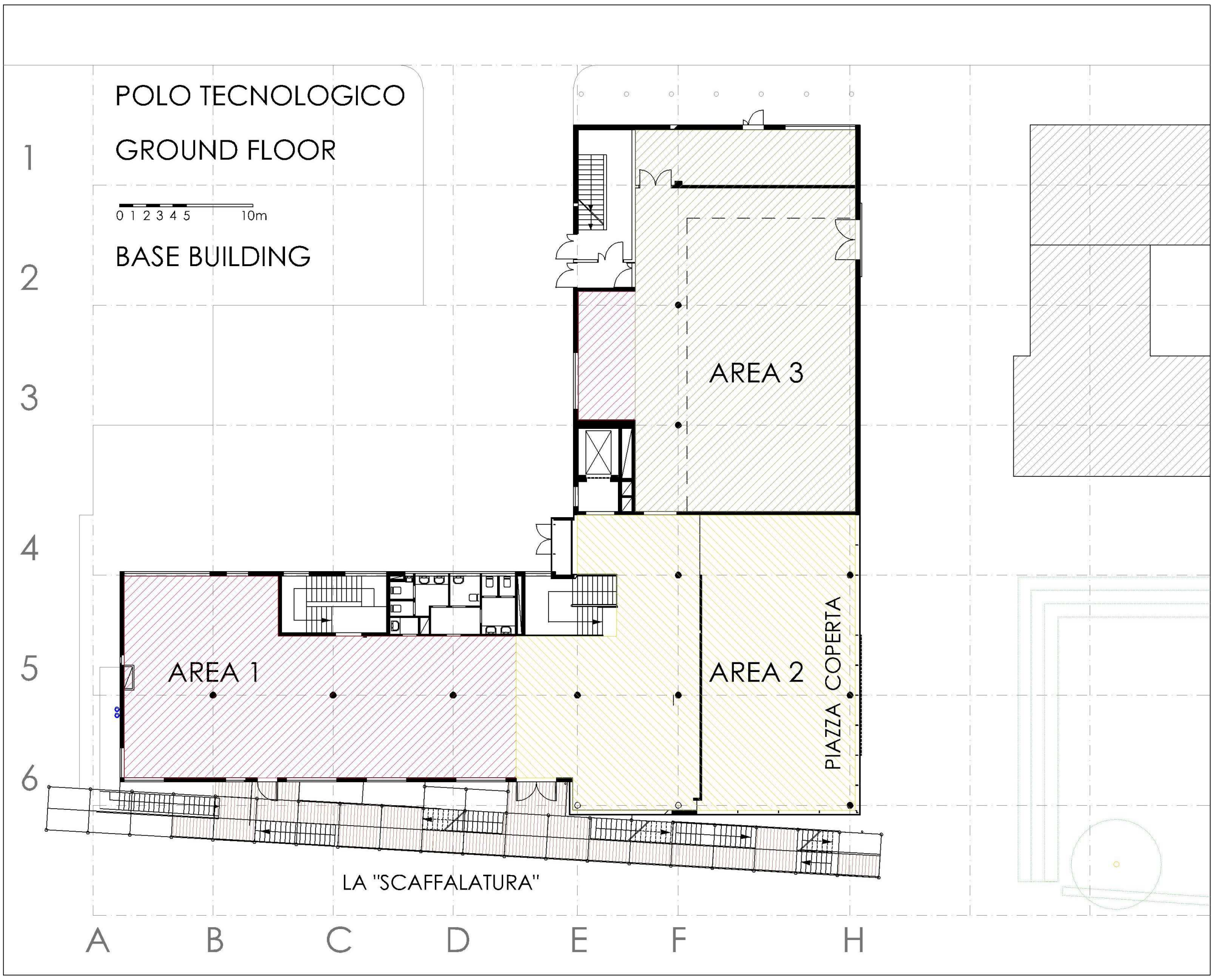

Figure 1. Ground floor: the base building

The range of the proposed functions in the case project was solved by dividing the base building into two separate local interior areas; one section for more flexible functions such as classrooms (Area 1) and the other section clearly meant for exhibitions (Area 3). Exhibition space differs essentially from other functions in lightning, height, and other interior requirements. Because of the height differences, the modular system was three-dimensional using 0,8 m high vertical modules, which lead to a junction area (Area 2) consisting of a semi-heated glazed entrance space (Piazza Coperta) that is also suitable for exhibitions and for a multipurpose area in two floors corresponding to the height of the main exhibition hall. The floor structure was a plane carpet reinforced concreted plate with no beams, which allowed a free HVAC layout. Several interior concepts were designed for Area 1 with different weightings: didactical, exhibition, and communal services. The didactical version included class rooms and educational laboratories. On Area 2 the focus was more on multipurpose use and office rooms, and additionally, the natural skylight system designed for exhibition use was extended on the first floor of Area 2. On the other hand, for Area 3, the exhibition section, no interior concepts were designed, but the adaptability of the base building was improved e.g. by including a modular hanging system for items such as acoustic panels and exhibits to be hung from the structural ceiling system.

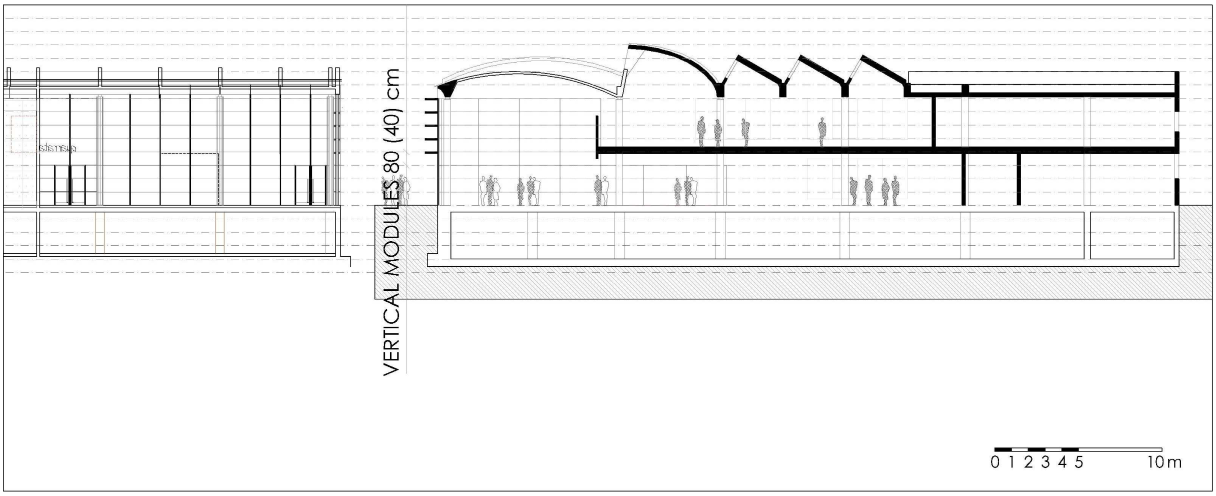

Figure 2. The section: vertical modular (40 + 40 cm) and skylight systems.

The overall design had more open space and a mediatheque (an extension of the library) on the ground floor. The scaffolding structure ("la scaffalatura") was an experimental flexible structure designed for exhibitions, information screens, temporary cultural events and the like. The structure can be modified as scaffoldings and it serves also as an extension for the square (Piazza A. Fabbri).

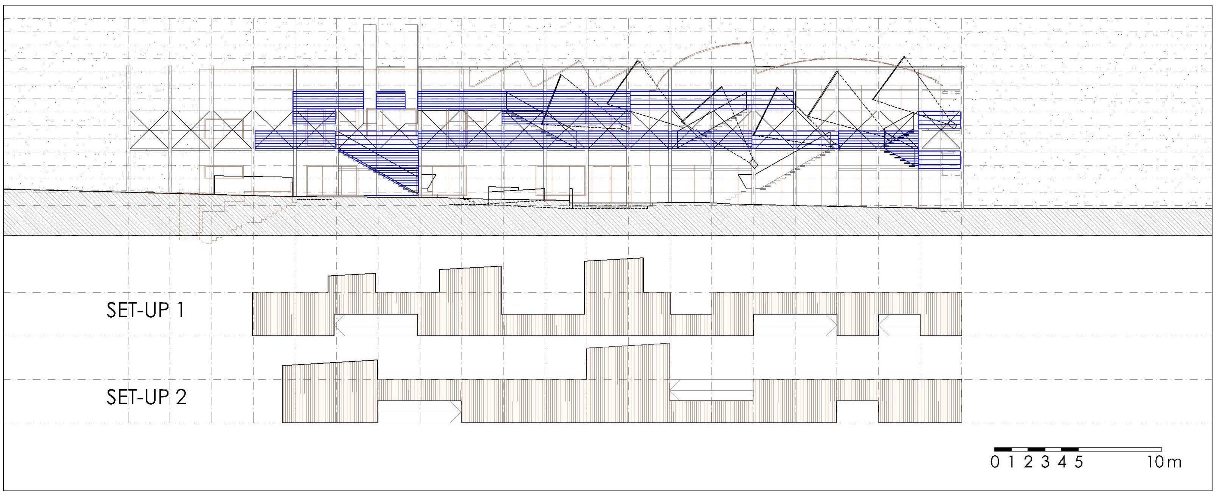

Figure 3. A semi-public flexible structure ("la scaffalatura, scaffolding") for temporary exhibitions and informative items

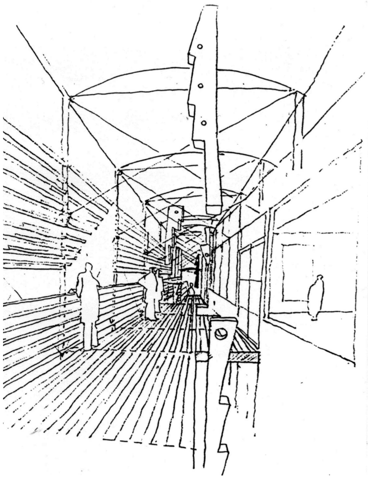

Figure 4. An illustration of the flexible scaffolding structure space in exhibition use compared to the constructed realization.

4 Implementation phase

When the construction was completed in 2004, the city suffered from a lack of communal office space. Thus, the concept taken in use was that which maximized office space and the rest was left for temporary exhibitions in Local interior area 1 and Piazza Coperta – part of Local interior area 2.

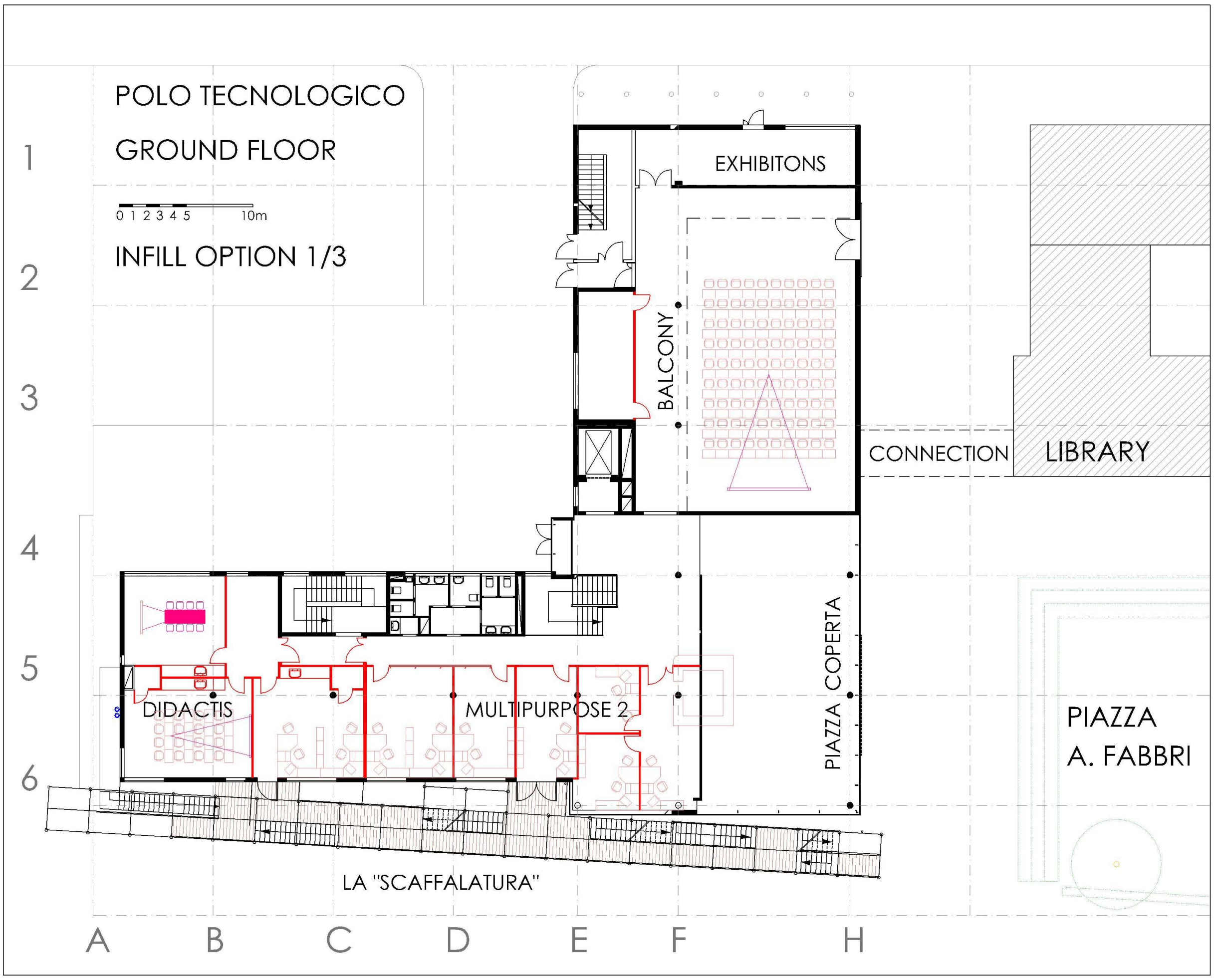

Figure 5. Ground floor: the infill option 1, partly taken in use (red)

5 Conclusions

The project size and a wide range of functions don't seem to limit flexibility. The principle of open building can be applied also in cultural and communal services [Kendall 2005]. The changing age structure of society is extending the demand for flexibility even to buildings such as kindergartens. The case project also implies that when modifiable systems become too sophisticated, they may become less utilized than planned, as was the case with the flexible schools of the seventies in the Scandinavian countries. In the case project, the complicated scaffolding structures have not been utilized and the modular hanging systems have been used only for permanent hangings. This may be also an information problem to be solved in facility management. Further, an interesting observation is that the Italian design tasks, especially between the structural engineers and the architects, are less integrated in respect to the base building and the infill than is the case in Finland.

Figure 6. The east elevation: the "scaffolding" (view axis) and north elevation: vertical modules,

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Upgrading the Adaptability of Buildings

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KEYWORDS

Open Building, Adaptable, Flexible, Support and Infill level.

Introduction

The ever-changing demands of users make it unavoidable that both houses and offices must undergo structural modifications regarding their spatial, architectural and technical installation characteristics. It is therefore necessary when building new properties and renovating existing ones that adaptation to users' needs is possible. This makes flexibility, adaptability and changability crucial concepts that cannot be ignored.
A distinction can be made between process flexibility and product flexibility. Process flexibility is flexibility in a decision-making process, for example one that takes place in an organization and involves people with managerial positions. Process flexibility also refers to flexibility in a development process, from initiative and design to construction and operation of buildings. Product flexibility is flexibility in the structural design and the technical aspects of specific projects, buildings or building components. This paper mainly addresses the technical adaptability of buildings and its components.
The Foundation of Architectural Research (SAR) in Eindhoven, the Netherlands, revealed the measures that can, in general, be taken to increase the adaptability of both existing buildings and those still to be developed [Geraedts 1985, 1987, 1996, 2001]. This paper formulates a number of recommendations to increase the adaptability of buildings by considering a case study, involving a building- and installation analysis [Geraedts & Cuperus 1999].

Recommendations to upgrade the adaptability of buildings

The recommendations formulated in this paper for upgrading the adaptability of buildings apply equally to buildings and building products. Further, a distinction is made between recommendations for building technology and those concerning installation technology.

1 Integrate the design of installation systems into the structural building design.

Developing an oversight of a building's adaptability, and the adaptability of its installations are inseparably bound to each other –both should be integrally developed. The adaptability of buildings is inextricably linked with the adaptability of their installations, which more and more constitute an important component of buildings. The development-, construction- and operate processes must distinguish between two different decision-making levels – the support level and the infill level – to ensure that buildings can be optimally modified to meet changing (future) use.

2 Avoid using penetrating connections between support structures and installation systems.

Accommodation of installation systems in load-bearing walls and in floors leads to a confusion of different systems and causes problems in the coordination of each individual system. Bearing future adaptability in mind, it is also strongly inadvisable to incorporate installation distribution components in walls or floors that form part of the architectural construction; see 'Fig.1'.


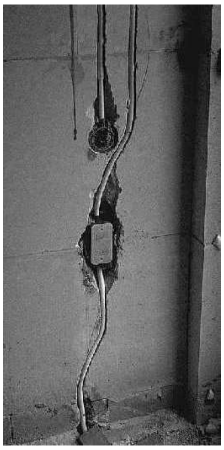

Figure 1. Cables and pipes housed in weight-bearing floors (left) and walls (right): not adaptable

Since modifying rooms involves moving inner walls, it is much better to leave them free of ducts or pipes. If installation components are built into structural components because they have to be accessed for future modification, they should not be built into weight-bearing architectural constructions.

3 Keep a support structure disconnected from infill elements.

Use both the structural design of the building and the technical design of an installation system to make a distinction between support and infill elements, collective and individual aspects, permanent and variable flexibility and long and short life cycles. If the support and infill elements are easily separated, and well-interfaced, this reinforces the building's adaptability. A flexible system of inner walls also contributes to overall adaptibility. However, it is just as important to ensure that connections to support structures are of a loose-fit type, with no male-female connections. It is also possible to distinguish between support and infill at the installation level, in a similar fashion to what is more or less applied already at a building level. Support structures and their various components are designed and implemented to fulfil various long-term functions as well as possible. Infill components are designed and implemented to meet short-term changes in organizational and individual requirements.

4 Base the structural design for construction and installations on a maximum partition plan.

Base the structural design for building construction and installation systems on a maximum partition plan, based on the smallest independent and connectable unit. The repartitioning of a building means that both the spaces and the installations can be split up, depending on changing user requirements, into smaller independent units. Units can also combine to form a number of larger units, and be redivided. It is therefore recommended to base the design of a building or installation on the smallest possible independent connectable unit. In this case, combining smaller units into larger ones presents no problems. If the design is based on larger independent units, a future division into smaller units can be problematic.

5 Make the support structure a partitionable one.

A partitionable support structure gives a repartitionable building that can accommodate various types of functions and units, including residential ones, as the functions change and vary in number and size over the years. The possible future independence of departments, or the partial disposal of building components, places different demands on the building from the point of view of efficient control. Consider in this respect the separate or collective use of entrances, lifts, stairs and facilities, the individual measuring of energy and using the data infrastructure. The ability to easily compartmentalize a building for various independent users or occupiers increases its adaptability, see 'Fig.2'.

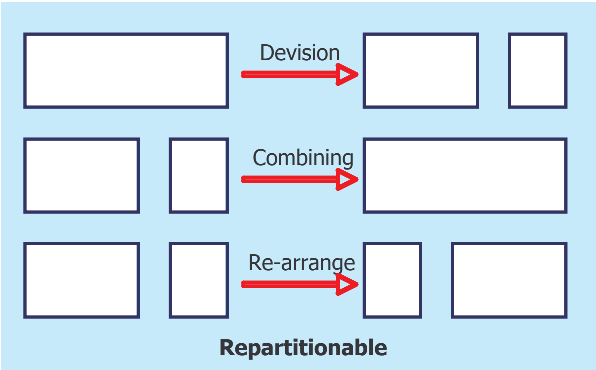

Figure 2. Various kinds of repartitionability

6 Set specific requirements for the interconnection of construction and installation components.

It is important that construction and installation components can be easily disconnected, removed or repositioned. Constructable connections must meet the following requirements:

- Disconnectable. This refers to the possibility of disconnecting various components from each other in order to limit the knock-on effects of changes. In other words, ensuring that changes or modifications at a lower level have no influence or effects on higher levels, and that they take place independently of each other. It is recommended to use pluggable connections or plug & play components.
- Standardized connections. The specifications of the connections are standardized so that components from one connection can be used with other components, which is necessary during changes or modifications to a building or installation. To make this possible, connections must have standardized fittings.
- Size, shape and position tolerances. To maintain adaptability, it must be possible to remove construction and installation components from a building and refit them elsewhere (such components are called open or project-independent products). If cables and power lines are present, it is necessary to ensure that position- and dimensional tolerances are taken into account in the connections (modular coordination).
- Individual removeable. The connection must allow for the removal of single construction and installation components without the need to first remove or replace other components.
- Direct usable. An construction or installation component must be usable immediately after positioning and mounting (plug & play) without requiring any further maintenance, adjustment or control.

7 Use modular coordinated systems.

Agreement on size and position of construction and installation components enables easy exchange and repositioning of components. The applicable position and size systems must facilitate dismantling, repositioning and mutual exchange of construction and installation components. In this respect, refer to the various standards for modular coordination, and to building measurements (size tolerances), and the advice they contain that applies to zoning for the various systems, see 'Fig.3'.

Figure 3. Position- and measuring components with respect to modular coordination and zoning

8 Make construction and installation components readily accessible.

Access is improved considerably when elevated floors, suspended ceilings, skirting or trunking are used to duct installation systems. Installation components that are easy to access are closely linked to their level: infill level or support level, see 'Fig.4'. Construction and installation components at infill level are easy to access and, as a rule, have a short technical, functional and economic lifespan.

Figure 4. Distribution ducts and control facilities in an easy-to-dismantle ceiling

9 Provide local (individual) and central measurement and control facilities.

Provide local and central measurement and control facilities for individual units, for individual partitions or for the building as a whole. The separation of support installations and infill installations involves two kinds of transferals. The transfer of heating, cooling or, for example, lighting at a support level, which amounts to at least the largest common denominator of possible user requirements, and the transfer of the same installation functions at a local level to meet individual needs.

10 Ensure that there is surplus capacity.

Make sure that the various levels have an overcapacity or surplus. This should exist at both location and building levels for both horizontal and vertical expansion of the building, at space levels to allow floor surface areas to be usefully deployed and at the construction level in weight-bearing walls and floors, and finally at the installation level. Whenever the power or capacity of an installation can be adjusted to different values, users have the flexibility to react to changing circumstances.

11 Restrict distribution facilities and ducts.

Restrict distribution facilities and ducts, for instance by using remote control facilities. Maximum adaptability is achieved when distribution cables (both in- and outgoing) are not necessary. In this respect, product development plays an increasing role. Cable-free systems are increasingly appearing on the market, which are sometimes equipped with low-current, infra-red, acoustic or presence switching.

This particularly applies to information and computer technology, but also applies to lighting, heating, ventilation and cooling. Control adptability is considerably increased if distribution systems are kept to a minimum.

12 Make removable user facilities.

It is advisable to shift the balance from high levels to low levels, from support to infill and from infill to furniture. By locating architectural and organizational elements at the lowest possible levels, they will be closer to the user, and consequently easier to change and replace. For example, a table is easier to move than a fitted kitchen unit (see 'Fig.5'), and a free-standing storage cupboard is easier to move than a built-in cupboard. Free-standing inner wall elements are easier to dismantle, relocate and reuse than fixed elements.

Figure 5. Moveable kitchens on furniture level, according to the plug & play principle

13 Flexible thinking.

A final recommendation is flexible thinking. Take notice of other opinions and standpoints, new developments and particularly of the continually adapting needs of users. This applies not just to the program, design or construction phases, but also during the user or rental phases. The success or failure of a project strongly depends on the human factor. This means that customers, architects, contractors and advisors should not be afraid to change a project, should new information come to light, while it is being developed or implemented.

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Evaluation of Flexibility Options in Different Housing Projects, an Exploration of Possible Flexibility for Second Users in Multi-storey Housing

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KEYWORDS

Adaptable Housing, flexibility, second user, multi-storey building, open building.

ABSTRACT

Flexibility in lay-out of the floorplan is often one of the important reasons to apply the open building method (Habraken 1961). In principle, the open building method should not only provide flexibility for the first inhabitant, but also for the second user. In practice however, most of the 'open building' projects offer little flexibility to the next users (Heynen, Leupen et al. 2004). In this article a selection of case studies is analysed to investigate if and how the technical possibilities for creating flexibiltiy were used in the past, and if we can derive technical conditions for creating flexibility and adaptability for all the inhabitants in the future.

1 Introduction

In the Netherlands as well as in other industrialised countries, the home building industry is moving from a push market to a pull market. Customers demand more quality which can be reached by giving them more individuality. Housing corporations have to anticipate to the changing housing market. Creation of more flexibility, by using Open Building principles of Habraken (Habraken 1961), could help the Dutch housing corporations to provide more quality for the customer. However, the hypothesis in this paper is that, besides the participation of the customer in the initial building phase, flexibility or adaptability is seldom used after a period of use. In order to test this hypothesis, eight projects are selected to study their options for flexibility in shell and infill in the initial phase and the options in the present situation, after 10, 20, or even 30 years.

Open Building, or the concept of support and infill, was introduced by professor Habraken in his book: "De dragers en de mensen"(Habraken 1961). Habraken claims that the support level and the fit-out level is not only a technical separation but also a way of responsibility. He rather speaks of 'base building' for the structure and of the 'fit-out' for the infill that specific people want. A lot of theory has been written about this concept since then, but only a few housing projects are built according to this concept. It is not surprisingly that most of them are owned by housing corporations, who take the responsibility for the base-building.
In this paper the word 'flexibility' is used for both the adaptability of the support level to make rearrangement of houses possible, as for the adaptability of the house itself, by changing the infill.

Furthermore this paper distinguishes the initial flexibility at the moment the houses are built as well as flexibility for the next user.

This study is part of a PhD project which focusses on the possibilities of innovative building technology for customised housing in the urban environment. During this PhD project, a design for a new concept for industrial houses for the urban environment (Eekhout, Haagsman et al. 2004) will be developed, which involves on the one hand the future satisfaction of the consumer and sustainability issues, and on the other hand production, logistics and regulations. In the past, many projects already delt with these problems, but those projects are never evaluated on their flexibility concepts since their first years. This article will fill-in this gap by showing the current situation of some projects after 15-20 years.

2 Case studie analysis

Analyses of case studies can show how flexibility is used in the past. The selected case studies have in common their intended flexibility and the publicity they got for that in the time they were built. Only those projects have been selected that have options for adaptability by a (simple) technical solution. Projects with only functional flexibility are left out, they often use oversizing in order to make different functions possible.
Information about two of the selected projects was gathered by visiting their curent housing corporations, the information of the other projects was revealed by two master graduation projects: Mieke Hoezen (Hoezen 2003) has interviewed both inhabitants as the owners of several projects in order to get information about the influence of flexibility on the customer satisfaction. Gabrielle Stienstra (Stienstra 2004) studied several projects and focused mainly on the management and financial factor in the process of flexibility. In table 1 the studied projects are presented, combined with further project information.

		Year	*Place*	*Architect*	*Current owner*
1.	Keyenburg	1984	Rotterdam-Zuid	Werkgroep Kokon Frans van der Werf	Vestia Rotterdam-Zuid
2.	Kruisplein	1985	Rotterdam-Centrum	Mecanoo architecten	De nieuwe Unie
3.	Sterrenburg III	1973	Dordrecht	architektencombinatie de Jong, van Olphen	
4.	Molenvliet	1974	Papendrecht	Werkgroep Kokon Frans van der Werf	Woningstichting Papendrecht
5.	Beatrixlaan (renovation)	1991	Voorburg	Rijenga Postma Hagg	Vidomes
6.	Honingerdijk	1984	Rotterdam	Jan Mulder and Wytze Patijn	
7.	De andere woning	1984	o.a. Borssenburgerplein in Amsterdam	Luzia Hartsuyker	Woningbedrijf Amdsterdam Zuidoos
8.	Meerfase-woningen	1990	Almere	Teun Koolhaas	Goede Stede

Table 1. The list of studied projects with their year, place, architect and current owner (mostly housing corporartions.

The design for Keyenburg in Rotterdam was one of nine pilot projects for the use of the modular system in the Netherlands (Stichting Architecten Research 1985). In this project the support and infill principles of Habraken were used. The infill could be changed within the support boundaries, and in addition, the support itself is flexible giving the opportunity for rearrangement of the apartments by sawing out the

non-reinforced concrete slabes in the concrete structure. Recently a plan has been posponed for reconstruction of the whole area. In this plan a complete renovation of Keyenburg, necessary in order to get rid of the rather small 50 m2 units, is made possible by rearranging the floorplans to 75 m2 and 100m2 houses. The flexibility in the support is really being used. Conversely, the flexibility of the infill is not coming back after renovation, because the housing corporations did not have good experience with the specific infill system during the last 20 years.
Also 'Sterrenburg', 'Molenvliet' and 'Beatrixlaan' were experimental projects in which the open building principles were used and in these cases the inhabitants had a say in the fitting out of the house (TH Delft Afdeling der Bouwkunde Vakgroep Bouwmethodiek 1979) (Werf van der 2005) and (Kendall and Teicher 2000).
The other four projects did not refer to the open building principles, but they nevertheless had options for adaptability (Eldonk and Fassbinder 1990). The design for Kruisplein was the first project of 'Mecanoo Architecten' (Döll and Egeraat 1985), and a result of a competition. One of the specifications in that competition was the combination of different size apartments and the possibility of separating and joining them. Both Kruisplein and Honingerdijk were designed in the eigthies to create living space for groups. Meerfasewoningen and 'de andere woning' were aimed at easy adaptability in order to adapt to life-changes of the inhabitant.
In the four Open building projects infill systems of Bruynzeel (twice), Nijhuis and Matura were used. Bruynzeel was also used for the infill of 'de andere woning'. For adaptabilty of the support level, Keyenburg, Honingerdijk and Molenvliet used so called 'fontanellen', which are parts in the concrete structure without reinforcement, or gaps that are later filled with sand-lime bricks in order to make it easier to break through. Kruisplein used timber frame walls to make rearrangement possible.

3 Results

In table 2 the most important results of the research are shown. In the next paragraph those results will be further explained by more detailed descriptions of the interesting aspects of these projects.

	initial use of flexibility in the shell	*Initial use of flexibility in the infill*	*Current use of flexibility in the shell*	*Current use of flexibility in the infill*
Keyenburg Rotterdam-Zuid	is used	technical flexibility is used	rearrangement is used during renovation	is not used anymore
Kruisplein Rotterdam-Centrum	is used	no technical flexibility, only functional flexibility	is not used anymore	no technical flexibility, only functional flexibility
Sterrenburg III Dordrecht	is used for the depth of the houses, the width is fixed	is used	is not used anymore	no data
Molenvliet Papendrecht	is used	technical flexibility is used	might be used if renovated	is not used anymore
Beatrixlaan Voorburg	has never been there	has never been there	has never been there	original infill sytem is not used anymore, but there is good regulation about tentant's modifications
Honingerdijk Rotterdam	is used	both technical and functional flexibility is used	might be used if renovated	no technical flexibility, only functional flexibility
De andere woning	has never been there	technical flexibility is used	has never been there	original system is not used anymore,

Amsterdam				regulation is in development about tentant's modifications.
Meerfase-woningen Almere	is used	is used	No data	No data

Table 2. Different possible ways of flexibilty and the way they are used in the studied projects.

4. Analysis of results

Most projects originally offered the possibility to make different typologies and house arrangements. Only in 'De andere woning' and 'Beatrixlaan' all houses are the same sizes. In 'Sterrenburg' all the houses have the same width, but they have the option for an extention in the depth of the house. At this moment only in 'Keyenburg' flexibility of the shell is used by a rearrangement of houses. This rearrangement was made possible by a renovation project, because the flexibility option was caused by the possibility to break through a concrete wall. 'Molenvliet' and 'Honingerdijk' have the same possibilities, but there it is not used yet, because rearrangement would give too much trouble and will take too much time and money to do it while the flats are still inhabited. But also in 'Kruisplein' the options for rearrangement are not used, although in this project the in built options are simpler because of the use of timber frame walls. The owner of 'Kruisplein' explains that rearrangement of houses has not only to do with the technical solution, but it simply never happens that occupants want to join together two apartments, or want to rent an extra room when a neighbor moves out. And if the housing corporation would like to rearrange two apartments, it never happens that they become available at the same time.

On the infill level all studied projects had some kind of flexibility, both technical as functional flexibility. In table 2 it can be seen that of all projects with a technical flexibility, non of the original technical systems is currently still in use. As a matter of fact, two housing corporations, the owners of Kruisplein and Molenvliet, explicitly explained the interviewer that they do not tell their new inhabitants about the flexibility options in their complex, because they don´t want to deal with the trouble anymore. In Keyenburg, Molenvliet, Sterrenburg and 'De Andere Woning' the original infill system of Bruynzeel or Nijhuis is not used anymore. The corporations give as the main reason for this that the system has become too expensive, because of the fact that the system is worn out soon. Other reasons are that the system has disappeard from the storage room, or is not known to the current craftsman. The matura infill system that was used for the Beatrixlaan project, could only be used for ten houses before the matura compagie got bankrupted. In the Beatrixlaan this problem was solved by making a good regulation about tentant's modifications. Within this regulations the inhabitants are free to do everything what they want. If they do it with approval of the corporation, the modifications do not have to be reconditioned into the original situation. Also Kruisplein and 'de andere woning" are working on such regulations. The corporations give more responsibility to the inhabitants and as a result they also have less managementload. The inhabitants are also satisfied with these regulations. In the interviews with Mieke Hoezen they said: "why should I use an expensive system, if I can do the same with a simple metal-stud-wall".
A second reason for not using the flexibility, is that the design of the support level, does not have enough possibilities for variation. In bot Keyenburg and 'de andere woning' inhabitants explain that the total space is so small, that only few different floorplans are possible. In Molenvliet, Beatrixlaan and Sterrenburg inhabitants complain that variation in floorplan was limited by the position of the services duct. In the Matura system, which was used in the Beatrixlaan, this was not a technical problem. Technically it is possible to place the bathroom everywere, but the further away it was from the service duct, the more expensive it got.

5 Conlusions

This research is based on a quick scan on some, more or less famous, 'open building' projects. Most of them were multi-storey housing complexes. For a more thorough research, also detached houses and row houses could be analysed, although the expectation is that some of the conclusions will count for all kinds of buildings.
The main hypothesis was that the built-in flexibility is not being used according the way the designers developed it. To check this hypothesis a difference should be made between the flexibility of the support level and the flexibility in de infill level.
The flexibility in the support systems is not used as much as the designers thought it would be, at least not during the firtst 15 -20 years of the use of the building. Of course the rearrangement of houses is complicated to manage, but more important for this research is that the technical solutions that were used in those options were too complicated for a simple reconstruction. This is probably caused by the strong regulations for walls between houses, mainly the ones regarding the sound-insulation. Not any of the used systems for infill walls complies with those rules and therefore they are not suitable as a house seperation wall.

The lack of use of the flexibility in the infill level is partly caused by the technical disadvantages of the different used infill systems and partly by a badly designed support system. In the future more attention should be given to oversize and neutrality in the support level. Oversize can solve the often mentioned problem that rooms are too small for a special pupose, like the livingroom. Special attention should be given to the neutrality of the different places in a house, this function neutrallity can not only be reached be the oversize of the different rooms, but also has to do with the acces to installations and the built environment which influences the entrance, the entering of light, the noise of the street or the use of the backyard.

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A challenge on adapting existing buildings: to accept under optimal performance

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1 Introduction

On new buildings, good design can lead to optimal performance towards current needs and requirements. Professionals can also be very creative on imagining ways to ease the adaptation of these buildings in the future, increasing its life cycle. But it must be taken into account that there is a huge stock of buildings that are becoming inadequate and inefficient as times goes by, as other needs arise and as performance levels are soared by new requirements. Most existing buildings can not be easily refurbished and are a challenge for anyone concerned on sustainability.

The Federal University of Santa Catarina can be used as a example to discuss the management of the built environment. Its campi has been impacted by the introduction of information technology, changes in the teaching and learning process and new regulations regarding performance. It faces now a dilemma on managing its facilities: is it feasible to improve existing systems to adapt the old buildings to present needs? Would it not be better to demolish these buildings? So far, public administration decisions are based on technical and economical criteria. To update old buildings in order to meet present needs might be economically expensive or technically unjustifiable. This might condemn these buildings, and systems, to demolition. Maybe other parameters must be taken into account. This article aim is to discuss decision basis for the sustainable management of public built environment in educational facilities. It proposes co-responsibility of the users so that lower levels of performance are accepted in adapted buildings.

2 Challenges on managing educational facilities

UFSC is located in the city of Florianópolis, capital of the state of Santa Catarina, in the south of Brazil. Such university is known in many teaching, research and extension fields. It has more than thirty thousand students, offers 50 graduation courses, 100 master programs and 25 doctoral programs preparing professionals for performing in it's area and region. It has an important role in preparing teachers for the state schools. It is also involved in many social actions, including free medical and dental care to the community in general and special groups in particular, as handicapped, poor students, unemployed workers and old people. It's maternity is a national reference and also prized by UNICEF. It is also worth to mention its researches regarding the creation of income, which transformed the region of Florianópolis in a big area of sea farming of international reference.

The physical structure of the main campus is implanted in an area of over 100 hectares with around 300.000 square meters of built area. There have been built an average of over seven thousand square meters per year over the last 40 years, in an expansion that happens in the horizontal as well as in the vertical, featuring an increase of the density affecting the free areas and also to the urban identity of the campus.

The model used for the university buildings, still nowadays, follows partly the guidelines formulated in the 70s by some foreign consultants as Rudolph Atcon and Harry Ebert [1974]. They accessed the execution of the international agreements for the expansion of the higher education in Brazil. This resulted in an economical and standardized architecture. The characteristic buildings are blocks for classrooms, labs or administrative rooms. They are three floors height and organized around a connecting block, where vertical circulation as well as the sanitary facilities are concentrated. The constructive technology uses reinforced concrete structure, vertical panels in ceramic blocks without coating; roof in cement-asbestos and aluminum frames. Layout in configured by light dividing to ease future adaptation. Except in the restrooms, the building systems are entirely exposed and only the floor has a finishing, typically of ceramic tiles.

UFSC has as a major challenge the increase of the callers. But, as it happens with others institutions [Hardmann, 1998] on managing its built environment, UFSC needs to become adequate to the changes that the legislation, technologies and society are facing over the last years. New rules determine conditions for accessibility, update of protection and safety disposals, and improvement in the conditions of lighting and air renovation, effluent treatment and residual management. Energy conservation and orientation for solar efficiency are still searched. Information technologies, as well as changes in the teaching and learning processes depend on an entirely new infrastructure.

3 Buildings life cycle and performance

Life span is the period in which the edification, building system or component may be used under satisfactory safety, health and hygiene conditions. From the present state of art it is impossible to have it well predicted. Life span is the sum of the project life span in which the product attends all the forecast criteria in the respective performance level informed by the supplier, and the residual lifetime, when there's a performance decrease, but the satisfactory safety, health and hygiene conditions may depend on expensive maintenance. Total life span is the period that refers to the project useful life, the residual useful life and an over-life, in which the safety conditions start to be affected [ABNT, 2002].

The performance of the edification is its usage behavior, facing pre-set exposing conditions. It involves the structural, fireproof, usage and operation safety. It is also about habitability and maintenance. The habitability refers to staunch, temperature and moisture comfort, acoustic and technical lighting, health, hygiene and air quality, the functioning and accessibility and also to the tactile comfort. Regarding the performance, the sustainability of the edification, building system or component, refers to the lasting is the capacity of the product to keep its matching properties with the preview usage throughout time [ABNT, 2002].

The construction norms might be an hindrance for rehabilitation works. Its requirements are expressed in performance terms, the rules are for entirely new buildings. The present norms may stop the use of existing buildings done with lower standards, realized for norms previously applicable [AEC, 2001]. Some adaptations into new requirements may make the extension of the useful life of some edification less viable, due to the cost, or to the loss of its characteristics.

4 The call for sustainability

Growth is, several times, confused with development. Growth can be understood as an increase of the physical scale of the material and energy usage. Development is a qualitative improvement on the usage of the resources. The development may come from technical improvement, which minimizes the resources usage, or from a more thorough understanding of purpose, which minimizes the consumption. The stable state is when the withdrawal of natural resources is kept constant. In a stable state, there may be some development, but not growth. In this way, the development may lead to an increase of the piece stock as a result of an optimized usage of the resources and also as a result of the technical progress, which increase the durability of the artifacts [Demanboro, 2004].

Sustainability is a condition in which the present needs are fulfilled without compromising the possibility of future generations doing so. The ´Agenda 21´ calls attention to the importance of the improvement of production through technologies and processes which make use of the resources in a more efficient way, making more using less. Achieving sustainability requires the stabilization or reduction of the environmental load. This load refers to 3 factors: population, affluence and energy. As it seems undesirable to reduce population, or affluence, the sustainability shall be obtained through radical changes in the technology used nowadays to create richness, so that it is possible to provide what is essential for everyone [Hart, 1997].

Development by doing more with less is a challenge that faces managers and decision makers. As a first stage, technology shall prevent pollution. In a second stage, the environmental load may be reduced by the management of the environmental impacts associated to the life cycle of the product. Finally, as the third stage, the use of entirely clean technologies shall be searched, with radical changes in the base of industrial production. However, the use of new materials or processes may not be enough. Perhaps it is necessary a broad new vision. We must replace the economic growth ideology by the idea of an economic and social development and ecological sustainability, admiting that we are fit in nature cyclical processes, as individuals and as societies. [Colombo, 2004].

5 Difficult decisions

There are three main spaces in the University buildings: class rooms, laboratories and teachers rooms. All of these spaces got some kind of improvement, like information technology infrastructure including more electric sockets and furniture. This was enough to upgrade the teachers rooms. In classrooms it was installed mechanical ventilation or air conditioning and curtains, to improve temperature and lighting control. The labs where radically changed, presenting new layout.

Standard buildings are still in fairly good condition. The structure performance is totally satisfactory and is still in its designed life span. It has low fire risk and adequate safety devices, but in terms of usage and operation they do not fit present requirements since they do not have alternative escape routes. Concerning habitability, these buildings perform well on watertightness but poorly when air moisture, acoustics and natural light are taken into account. Some of the design criteria must be reassessed like the lack of internal coating. Solar protection by a single model of *brise soleil* is not effective on most of the building sides, rooms do not ventilate and indoor light is wrong. Its sanitary systems performance should be checked.

The critical point, however, is that these buildings upper floors are not accessible to people with special needs: there are neither ramps nor elevators and there is no place where it can be installed. Some extensions were made without care, making it even more difficult to adapt it to adequate safety and accessibility conditions.

So far, managing decisions have considered that, besides the difficulties regarding the reconditioning process, entirely new buildings, or systems, perform better, meet present requirements and will last longer. It' s the logic that it is easier to build something new rather than improving it. It is a logic justified by an extreme trust in decisions of technical character. On one side, the technicians are not autonomous to incorporate the socio-environmental dimensions to the projects due to the performance requirements. On the other hand, the administrators, by the nature of their responsibilities, have no way to go against the technical manifestation.

However, a closer and more detailed look on such buildings show us that most of the components, foundations, structure, isolations, frames and part of the building systems are totally useful and still reach the previewed performance in the project. In terms of cost, this may represent 2/3 of the entire edification. Such amount could be recovered with investments in the improvement of the systems with poor performance and the safety and accessibility conditions. Even when it is not possible to reach optimal performance it might be viable to optimize the existing systems.

6 New criteria

The decision to invest in order to extend the life span of most existing buildings depends on principles, which do not have any economical or technological basis. Even when the cost of adapting the existing buildings to the present performance requirements becomes expensive, and when it is not possible to reach optimal performance levels, there are some socio-environmental aspects that must be taken into account due to the emergency of the planet degradation. It demands a new thinking.

Environmentally responsible decisions do not need to be systematically justified by the viability of the technical and economical aspects. The economical aspects shall be justified as viable from the environmental point of view. Existing buildings, their systems and components shall not only be kept due to a matter of costs, and demolishing shall be justified based on the sustainability. The optimal performance may not be the most responsible criteria for decision.

When people become concious of their co-responsability on the environmental problem, they are able to change attitudes and to admit restrictions in name of the sustainability. Optimal performance sets a narrow standard wich can mean a heavy burden. Understanding can lead people to accept under optimal performance in respect to nature limited resources. In this way, the Federal University of Santa Catarina has an important role as example and reference for the whole society.

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The Adaptability of Two-by-Four Wood Framing Construction

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ABSTRACT

Building for living adaptation requires spatial flexibility and constructional openness. Spatial flexibility deals with dimensional coordination by 'grid' and 'zone' [Wang 1997], constructional openness deals with level separation and interface decomposibility and recomposibility [Lin 2002]. Spatial flexibility is the job of designers, its method had been fully developed by J. N. Habraken, while constructional openness involves designers, manufacturers, contractors and even users, there are a lot of technical issues remained. For the two-by-four wood framing construction, the above-mentioned two criteria of constructional openness can not be reached at the same time because of its unique structural system.

The deveopment of the two-by-four wood framing construction represents a history of immigration and industrialization. It has a great deal of advantages in design and construction, such as low-tech, light-weight, handy, fast erection and human-feeling, and wood is revalued as green material today, but its inherent limitations for living adaptation in a sustainable way is not negligible; The bearing wall structure discourages wide openings, studs align in the framing confuses the relocation of bearing walls, and the rapidly innovated M/E building equipment entangle with the structure. In a word, although its constructional interface is relatively open, the intergration of building level with infill level unavoidably causes all the problems for adaptation.

In this study such problems are discussed, but it is very difficult to find out solutions for improvement. A new module to deal with those problems was tested but failed, minor suggestions are made : (1) Adopting 2x6 as one stud system may simplify the dimensional coordination on structural level and to accommondate to the grid of infill level at the same time. (2) Consolidating mechanical and electrical systems into fewer locations with shafts and troughes so that notching and boring of the structural framing could be minimized, and the rearrangement of facility lines for adaptation could be easier.

1. Background

Wood construction has a long history in human settlement and is recognized as a kind of "green building" today. Due to the progress of wood protection measures, and the rediscovery of wood property of structural protection from fire, wood material for construction is considered as not only healthy, comfortable but also energy conserving, resource reusable and recyclable, and earthquake tolerable.

But a “green bulding” may not be a “sustainable building” in terms of the model published on CIB Agenda 21 in 1998 to keep balance in three dimensions: environment, economy and the social-cultural. Green building is in favor of the environment but has little to do with the social-cultural. In which open building can play a significant role especially for the social-cultrual inheritance and transformation through living adaptation in bulding life cycle.

In Taiwan, green building has become a popular term in public and private sectors. Recently the two-by-four platform wood framing construction system was promoted by Taiwan government in the name of “green building”. Although this constructional system is prevalent in North America today and Japan opened the door to it after Kobe earthquake in 1995, it is still alien to local professions. In terms of living adaptation, there are several technical and cultural barriers worth furthur study.

2. Two-by-four wood framing construction

The construction is structured by a two-by-four system framing, which is also called light wood framing or stick-framing. Since Professor George Snow developed the balloon framing in 1833, the structural system has transformed to platform framing and become the most prevalent construction method in North America today. Therefore, this study focuses on the platform framing construction. Instead of full-height wall framing members for two-story construction, platform framing features the construction of each floor on top of the one beneath.

2.1 Structural system

The two-by-four system framimg is composed by rafters, joists and closely spaced studs, which are generally 2 in. x 4 in. or 2 in. x 6 in. nom. in section, spaced a maximum 16 in.(40 cm) or 24 in.(60 cm) on center, combined with sheathing to form a structure to resist lateral loads or racking.

It is acturally a bearing wall structural system. Two factors are contributing to the strength and stiffness: load sharing and composite action [CWC website 2006]. Load sharing means that alternate paths of load transfer become available when the primary path fails. Thus, the structure is not prone to sudden collapse. Composite action is the reinforcement that sheathing and fasteners make to the lumber members. See ‘Fig. 1’ below.

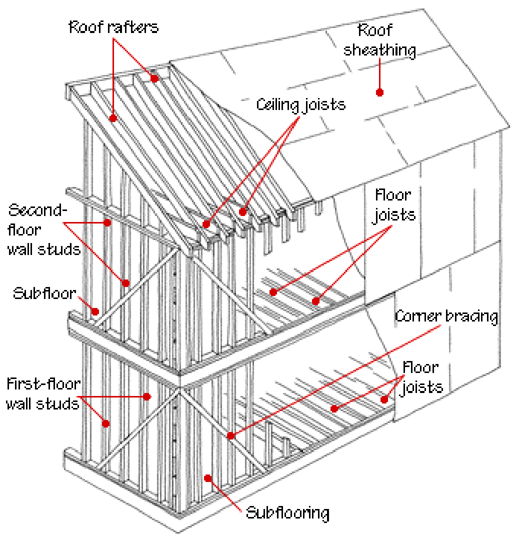

Figure 1. Typical platform framing (source: http://www.hometips.com)

Bracing is one of the most critical structural elements to resist horizontal forces such as wind and earthquake (the seismic ground motion). The stick type lateral bracing (i.e. nominal 1'x4' let-in bracing) is commonly used but gradually replaced by the "continuous wood structural panel sheathing" because of its superior structural performance that allows narrower minimum width requirement by the US building code.

"Braced wall panel", termed by the US building code (IBC and IRC) in 2003, consists of the wall panel (e.g. plywood or OSB[1] Rated Sheathing), the framing and the fasteners. And multiple braced wall panels align to form a "braced wall line" or "shear wall line"(see Fig. 2). These shear wall lines should form a right-angle intersection plan in a building, and a braced wall panel or shear wall segment shall be placed at each exterior building corner, every two panels or segments shall not exceed 25 ft (7.6 m) from their center to center. See 'Fig.2' below.

Besides, the building dimension, i.e. length and width, shall not exceed 80 ft (24 m). Single spans of floor framing members shall not greater than 26 ft (7.9 m). Headers shall be provided over all wall openings, and they shall be supported by wall studs, hangers or anchors.

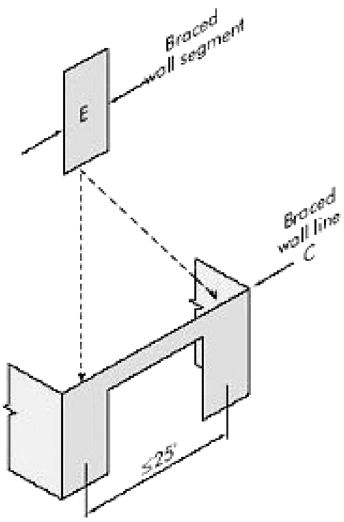

Figure 2. Braced wall panel and braced wall line (Source: http://www.apawood.org)

2.2 Jointing method

Platform framing is erected with sticks, which are jointed mainly by nails and metal connectors. There is almost no mortise-and-tenon joint technique involed. See 'Fig.3 and 4' and [Table 1]. As to nails, placing the right length of nails and in right directions is critical.

[1] OSB: oriented strand board

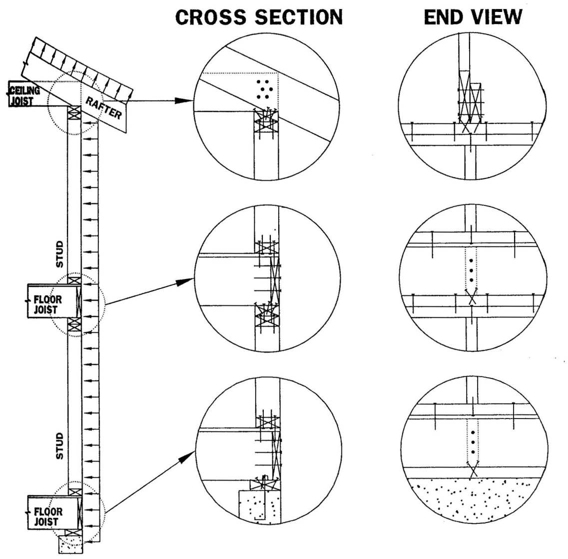

Figure 3. Typical lateral framing connections (Source: AF&PA 2001)
Adaquate connections between roof, ceiling, wall and floor assemblies shall be provided to transfer lateral forces acting perpendicular to the wall surface.

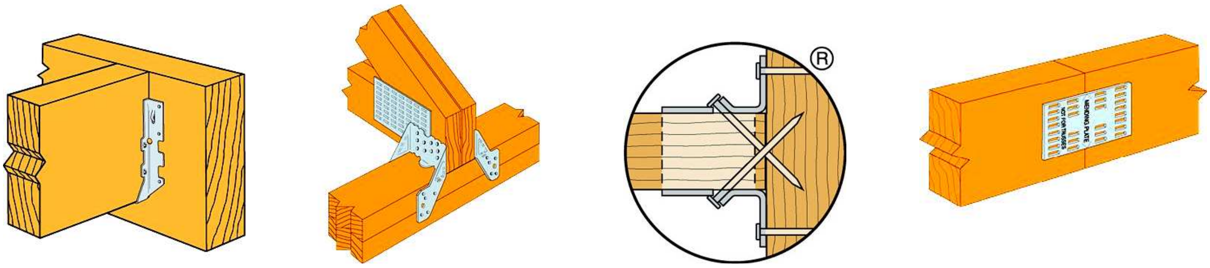

Figure 4. Jointing methods (Source: http://www.strongtie.com/products)

Interface Function	Jointing Product
Spacing	Wood blocks, wedges, nail stoppers
Sealing	Silicon, strips, trim
Linking (connectors)	Caps, bases, hangers, holdowns Straps, ties, anchors: tiedowns
Fixing	Nails, anchor bolts,Srews, Toothed plates, anchoring adhesives
Strengthening	Enhancers, bracers, post bases, joist-hangers

Table 1. Jointing materials used in wood framing construction.

3. Adaptability analysis

With a view to examining how open the two-by-four building system can afford for change, the common or typical ways of change in daily life have to be clarified and focused. Five situations of making change or adaptation were observed [Lin & Wang 2000]:

(1) Changing floor plan
To rearrange space layout for different uses, the renovation construction may involve removing the existing walls and erecting new walls. Floor, ceiling and facility lines (i.e. ducts, pipes, outlets, switches, etc.) will be modified accordingly.

(2) Changing infill elements
To change style or spatial atmosphere, infill elements may be reconfigured in size, shape, color or material. For instance, a wood Dutch window in living room is enlarged to be a metal French door.

(3) Expanding spaces
To enlarge the existing interior space by covering sundeck, cantilevering or attaching new structures, the renovation construction may involve removing the existing walls and erecting new walls and windows or doors. Floor, ceiling and facility lines (i.e. ducts, pipes, outlets, switches, etc.) will also be modified accordingly.

(4) Maintaining existing functions
To renew the functions of building elments or equipments, the renovation construction may involve removing the existing one and install a new one with the same size and shape.

(5) Upgrading functions
To improve the existing functions of building elments or equipments, the renovation construction may involve removing the existing one and install a new one with different size, shape or material.

Except the fourth one — maintaining existing functions, which only involves on-site work of replacement, nothing else will be affected in a noticable way although partial deconstruction may be indispensable. The other four situations of renovation construction work will directly affect the structural framing. That means, these adjustments or adaptations will be made mostly on building level for the two-by-four building system.

3.1 Criteria of Adaptability

Building for living adaptation requires spatial flexibility and constructional openness. Spatial flexibility involves dimensional coordination with grid and zone, which had been fully developed by Habraken [Wang 1997], therefore, it is not an issue to be discussed here. While constructional openness involves level separation [Habraken 1998] and interface decomposibility and recomposibility [Lin 2002]. The latter requires components of generic shape, joints detachable and working process simple enough to DIY (Do It Yourself). See 'Fig. 5' as below.

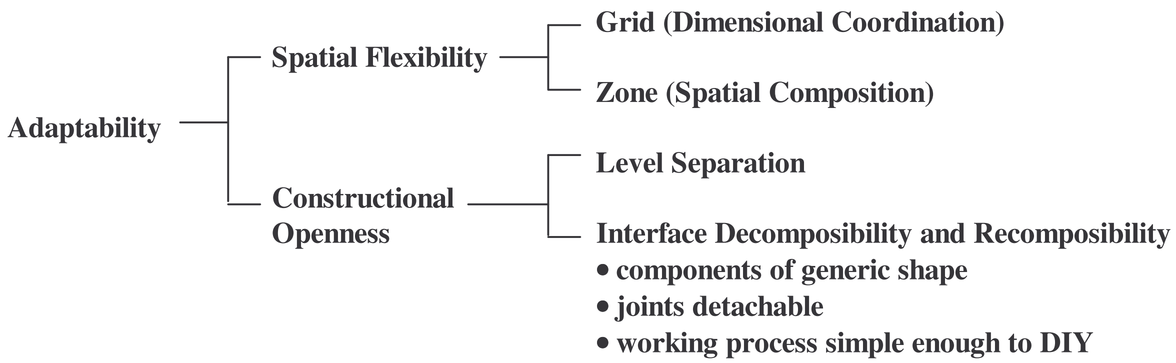

Figure 5. Criteria of building adaptation

3.2 Constructional adaptability examination

But for the two-by-four wood framing construction, these two criteria of constructional openness can not be reached at the same time because of its unique structural system. Although it is in favor of DIY which deals with lightweight, small-sized components, easily handled tools and simple working process, plus the component shape and jointing method are applicable for interface decomposition and recompodition, its building system can hardly distinguish the building level with the infill level. There are three major constraints observed and discussed as follows.

(1) Bearing walls should line up with their supports, which cause difficulties to relocate wall studs. And the rules of shear wall line restrict the change of wall.

When bearing wall perpendicular to joist, its supporting bearing wall below should not be offset a distance equal to the depth of the joist, that is 45° [AF&PA's WFCM/ANSI Canvass Committee 2001]. See 'Fig. 6' below. Thus, bearing walls must be stacked closely above one another, which bothers the removal or relocation of upper or lower floor wall because they are hidden or blocked by the platform so that it is not easy to find the exact positions of the studs above or below.

There are two factors related to this problem; One is the dual stud spacing system, that is 16 in. (40 cm) max. for 2x4 studs o.c. and 24 in. (60 cm) max. for 2x6 studs o.c., they can hardly line up with each other vertically. But their common divisor is 8 in. (20 cm), and the offset is always 8 in. (20 cm) which is shorter than the depth of joist (10-12 in. or 25-30 cm), so they can work together without exceeding the allowable offset when at the same wall line. Nonetheless, 2x6 framing is better for load bearing and environmental-proof materials installation, it is more welcome today. In this case, 2x6 as one stud system may simplify the dimensional coordination and structural coordination.

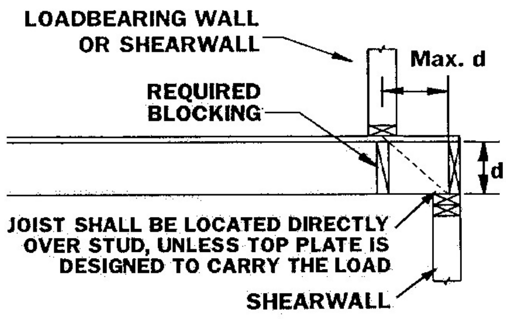

Figure 6. Bearing walls should line up with their supports. (Source: AF&PA 2001)

A new and only one module of 18 in. (or 45 cm) stud spacing was tested in this study, due to the limitations on opening, that is the requirement of additional full-height jack studs, the dimansional coordination is not applicable.

The other one is the "shear wall lines", which should be overlaped or within the allowable offset among floors. Since the platform interrupts the linkage of studs and blocks the visual connection, careful investigation and confirmation of the locations of the lines before renovation are critical.

(2) Openings such as windows, doors on the bearing walls are limited in size and location. No openeing is allowed on shear walls (i.e. braced wall panels).

No matter what is the stick type lateral bracing (i.e. 1'x4' let-in bracing) or the continuous wood structural panel sheathing on the bearing wall, a header above the opening should be inserted to carry the load of the interrupted studs above, and the header should be supported by full-height jack studs (also called king studs) at each end. See 'Fig. 7'.

Although the diagonal let-in bracing could be changed to K-shape bracing when an opening on the wall is needed, the size and location of the opening is restricted. See 'Fig. 8' below.

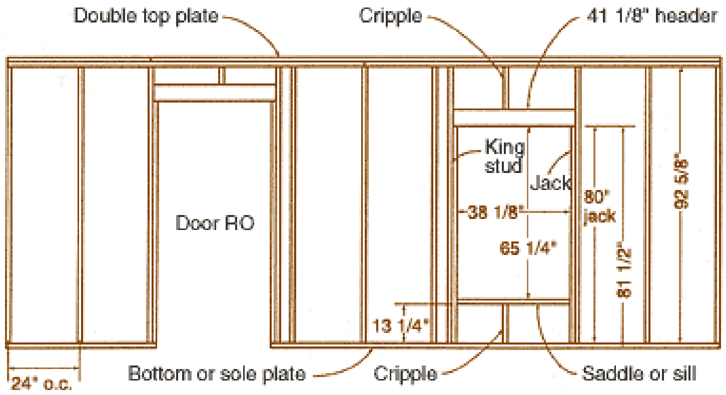

Figure 7. An opening with header and king studs (Source:http://www.taunton.com/finehomebuilding)

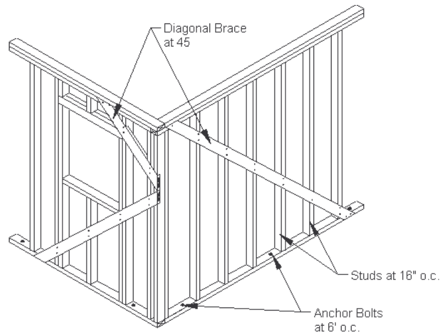

Figure 8. Changing diagonal let-in bracing to K-shape bracing when making an opening
(Source: http://www.tdi.state.tx.us/)

For a wide opening such as a garage door, the narrow return walls on its sides are among the weakest points in a house because they are inherently difficult to be braced properly against high lateral loads. A minimum 32 in. width for garage return wall is required by the Uniform Building Code, and its width can be reduced to 24in. even 16 in. when carefully engineered as a shear wall [Utterback 2000]. Although there are some advanced bracing products available in the market, they work more like prefabricated columns instead of on-site stick-framing walls. See 'Fig. 9' below.

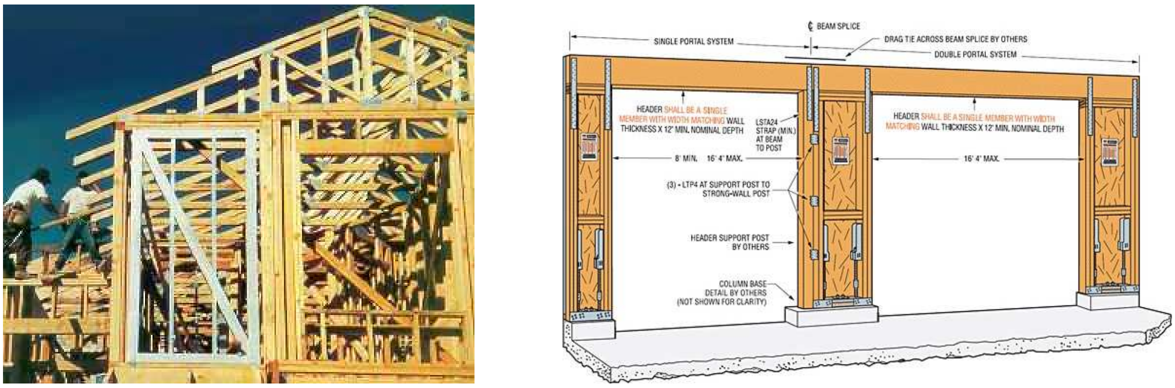

Figure 9. Advanced braced wall panal (Source: www.hardyframe.com & www.simpsonstrongwall.com)

(3) Conduits, pipes and ducts penetrating floor joists or wall studs are limited in size and location, meanwhile these facility lines and fixtures are inserted into the cavaties of the framing thus entangled with the framing. Which add difficulties to renovations. Consolidating mechanical and electrical systems into fewer locations with shafts and troughes may help relatively.

For joist notching and boring, the maximum joist notch is one-fourth of its depth at the end and one-sixth of its depth in the outer thirds of the span. The maximum diameter of a hole is one-third the depth of the joist and minimum 2 in. from the top or bottom edge. No notching in the middle one-third of the joist span. As for the stud, maximum notching is 25% of its depth for bearing wall and 40% for nonbearing wall. Maximum boring is 40% of its depth for bearing wall and 60% for nonbearing wall . See 'Figs. 10' as below.

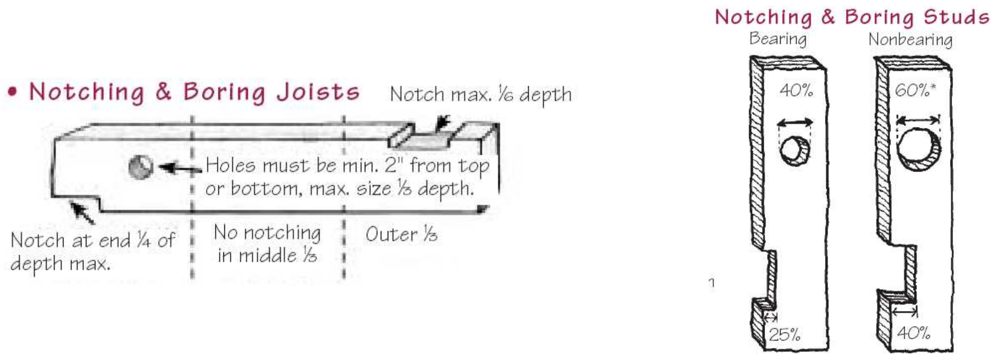

Figure 10. Limitations for notching and boring (Source: http://www.taunton.com/finehomebuilding)

With a view to minimizing the notching and boring on the framing, and to disentangling the facility lines with the framing, systematically gathering and organizing the electrical , plumbing and HVAC lines should be taken into account. Shafts and troughes may contain those lines in a consolidated way, but they are inevitably fixed by the framing, thus the capacity for change is limited.

3.3 Other challenges

(1) New market trend
Recent observations found that large windows on exterior walls become possible in climatic design due to the progress of glass performance, and the open-view atmosphere these windows provide seems more welcome and fashionable. Therefore, wider opening and more opening become a challenge to the two-by-four framing construction, especially on the ground floor, such as the french doors in living room or dining room and wider windows in other rooms. These demands would inherently weaken the bearing wall structure and the auxiliary strengthening methods would become more complicated. See 'Fig. 11' below.

Figure 11. Wide opening with narrow braced wall panels (Source: APA publication)

(2) Cultural difference
The extent of familiarity with a building system may also affect the free will of adaptation. In the regions where people like Taiwanese are used to post-and-beam concrete construction or timber-frame related construction, which has a long history and the idea of post-and-beam has been deeply rooted in Chinese culture, people know very little of the two-by-four wood framing construction, even in the professional circle. Therefore, general education before officially adopting this alien construction

method is absolutely necessary. On-site practice without comprehensive instructions may lead risks on making mistakes when doing adaptation work.

(3) Inconsistent measring system
In the regions where metric system is prevalent, English system may confuse the teams in practice and cause inconvenience. Therfore, adoption of internationally recognized dimensional system is critical in open market.

Besides, although nails are mechanical fasteners, and the detachment of nails from sticks is not very difficult, when there are too many nails jointed togather and in different directions, it becomes a work load for decomposition and recomposition of renovation.

4. Conclusion

The deveopment of the two-by-four wood framing construction represents a history of immigration and industrialization. Although it has a great deal of advantages in design and construction, such as low-tech, light-weight, handy, fast erection and human-feeling, and wood is revalued as green material today, its intrinsic limitations for living adaptation in a sustainable way is not negligible; The bearing wall structure discourages wide openings, studs align in the framing confuses the relocation of bearing walls, and the rapidly innovated M/E building equipment entangle with the structure. In a word, although its constructional interface is relatively open, the intergration of building level with infill level unavoidably causes all the problems for adaptation. The trial to find out the responsive solutions is basicly failed, only a couple of minor suggestions are concluded as the following:

(1) Adopting 2x6 as one stud system may simplify the dimensional coordination on structural level and to accommondate to the grid of the lower level (i.e. infill level) at the same time. 24 in. (60 cm) spacing as a module for door, window and wall cabinets, etc.

(2) Consolidating mechanical and electrical systems into fewer locations with shafts and troughes so that notching and boring of the structural framing could be minimized, and the rearrangement of facility lines for adaptation could be easier.

Besides, adoption of internationally recognized dimensional system, that is metric system, is critical in open market.

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Adaptation to new requirements in residential buildings. Possibilities, performances and innovations of gypsum plasterboards

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KEYWORDS
Residential buildings, dry-assembled components, improved performances, innovation, plasterboards.

Introduction

The paper deals with a study carried on by a group of researchers of Polytechnic of Milan in collaboration with BPB ITALIA and with the support of apprentices coming from architectural degree courses. The study starts from the observations of several phenomena in Italian society and consequently in residential building industry, such as:

- important processes of renovation regard residential real estates, due to the ageing of buildings [EUROCONSTRUCT,2005] and the refurbishing works associated with the high number of purchase agreement for dwellings (about 800.000 in 2004 [Agenzia del Territorio, 2005]);
- composition and characteristics of families are significantly changing, causing changes in the needs of spaces, in the ways of living at home and in the functions related to residential activities [ISTAT, 2002];
- obsolescence of existing equipment and increasing presence of information and communication technologies inside residential building;
- users are becoming more and more conscious, expressing quality requirements and increasing needs of personalization of their home.

Considering the effects of these changing scenario from the point of view of residential buildings, it is possible to state that new requirements are emerging either for living and using the home and for the works execution: possibilities to easily change the space organization; to be fast in interior renovation and refurbishing works; to minimize demolition works for reasons of time, money and environmental sustainability; to maintain and renovate equipments quickly, etc. It is therefore possible to think that from these aspects a potential demand rises, regarding dry-assembled components for interior spaces in residential buildings, even if in Italy some problems are still present in architects' and users' perception. Starting from these considerations, the study aims to investigate the possibilities for a wide diffusion of dry-assembled gypsum plasterboards also in residential buildings, by considering different levels of innovations: product performances , construction processes and design of components.

2 Innovations in product performances

The first level of the study deals with performances and has a motivation in the actual lack of knowledge of architects and users. On the basis of the definition of main requirements related to residential functions and activities, a comparison between performances of traditional building elements (partitions, interior finishes over external walls, ceilings, floors) and of different kinds of dry-assembled plasterboards has been carried on. The comparison considers the main requirements (acoustic insulation, thermal insulation, fire behaviour, impact resistance, mechanical resistance, health and safety in construction and use, etc.), comparing different building elements either on single performances and a mix of performances and characteristics (weight, total thickness). The aim of this part of the study is to

organize, through comparison tables, the complete state of performances to be considered and evaluated in design phases, trying to help architects and users to get over some prejudices about dry-assembled boards for residential functions. At the same time the aim is both to underline the innovations in performances of dry assembled elements coming from the researches and developments that manufacturers have been carrying on in the last years and to stress the directions that improving innovations of products can still take.
In table 1 are summarized some of the results of the comparison between traditional building elements (*white cells*) and elements fully or partially composed of gypsum plasterboards (*grey cells*). It is possible to notice that gypsum plasterboards can lead to significant improvements in many performances (*red borders in table 1*). In design phase this kind of comparison table can help both in selecting components on the basis of specific performances and in developing a complete evaluation considering, for each type of element, the mix of performances in relation with variations in weight, thickness and cost.

Elements	Characteristics		Performances				Costs (€/m^2)
	weight (kg/m^2)	thickness (cm)	Acoustic insulation Rw (dB)	Thermal insulation (m^{2}K/W)	Fire resistance	Security (anti intrusion)	
Shell - Exterior Enclosure - Exterior walls							
Cellular brick wall (with structural performance)	285	23	51,5	1,403	REI 180	Yes	43
Cavity brick wall (with structural performance) with thermal insulation in the air space	170	25	55	2,519	REI 180	Yes	55
Furred gypsum plasterboard finish (on brick cavity wall) with steel supporting structure and thermal insulation.	178,4	32,5	56	2,538	REI 180	Yes	20
Shell - Roofing - Roof Coverings							
Wood roof framing	Variab	Variab	40	2,8	R/REI 30	Yes	50
Suspended ceiling made with gypsum plaster boards fixed with screws on galvanized steel studs	11	Variab	53	1,15	REI 90	Yes	25
Interior construction - Partitions (vertical)							
Partition made with hollow clay tiles and plaster	164	14	41	0,343	REI 120	No	25
partition made of 4 gypsum plaster boards (standard type) on stud 75 mm	43	12,5	52	1,053	REI 120	No	32
Interior construction - Partitions (horizontal) - False ceiling							
Hollow block floor (concrete and clay hollow blocks)	275	24	47,5	0,41	REI 120	Yes	47
Suspended ceiling made with gypsum plaster boards fixed with screws on galvanized steel studs	10	Variab	60	1,15	REI 180	Yes	24
Suspended ceiling made with gypsum plaster boards fixed with screws on double galvanized steel studs	12	Variab	60	1,15	REI 180	Yes	30

Table 1. Comparison between traditional building elements (white cells) and elements fully or partially composed of plasterboards (grey cells). Red frames identify best performances.

From this part of the study, and from a market analysis conducted through focus groups of users and architects, it has been possible also to recognize some possible areas for product innovation. In table 2 are summarized some of the most recurring requirements for domestic spaces, the design and technical strategies proposed to improve gypsum plasterboard products, and the results obtained through studies and experimentations.

Requirement	Strategy	Technical solution	Result
To increase living spaces	Reduction of thickness of interior partitions	Reduction of dimensions of metal studs	Reduction of 1 cm of the total thickness of partition
High impact resistance	Development of high resistant gypsum plasterboards	Production of gypsum plasterboards with a high density core that increases hardness and mechanical resistance (special boards with density of 888 kg/m^3 instead of standard boards with density of 752 kg/m^3)	Collapse load (according to EN 520): 483 N for the high density plasterboard (improvement of about 10% compared with standard board)
To hang heavy loads	Application of high resistance screw anchors	Polyamide screw anchors reinforced with glass fibres High performance galvanized steel screw anchors	Breakout force up to 60 kg for high performance galvanized steel screw anchors
To increase security (anti intrusion)	Reinforced plasterboards for separating partitions between dwellings	Double layer of gypsum plasterboard with interposition of a light cement board or a galvanized steel sheet	Evaluation of intrusion time for plasterboard partition

Table 2. Areas of product innovation

2 Innovations in the construction processes

The second level of the study deals with construction phases and has a motivation in the problems connected with organization of operational teams. Through observations carried on in different residential construction worksites, in which dry-assembled plaster boards are used, it is apparent that construction firms and works planners manage construction phases following the same sequences adopted for usual techniques with traditional partitions and interior finishes over external walls. In this way many benefits of dry-assembling techniques are lost, and on the contrary several problems rise in the coordination between operative teams. This level of the study has therefore the aim to suggest improving innovations for building process by tracing guidelines for correct construction organization, comparing, through simplified planning method as bar-chart (GANTT diagram), working phases for traditional techniques and for dry-assembled elements.
Figure 1 shows an example of bar chart reference. It is possible to notice that with a correct organization of the activities sequence, the number and the duration of works (lower part of the diagram) can be reduced using dry-assembled plasterboards.

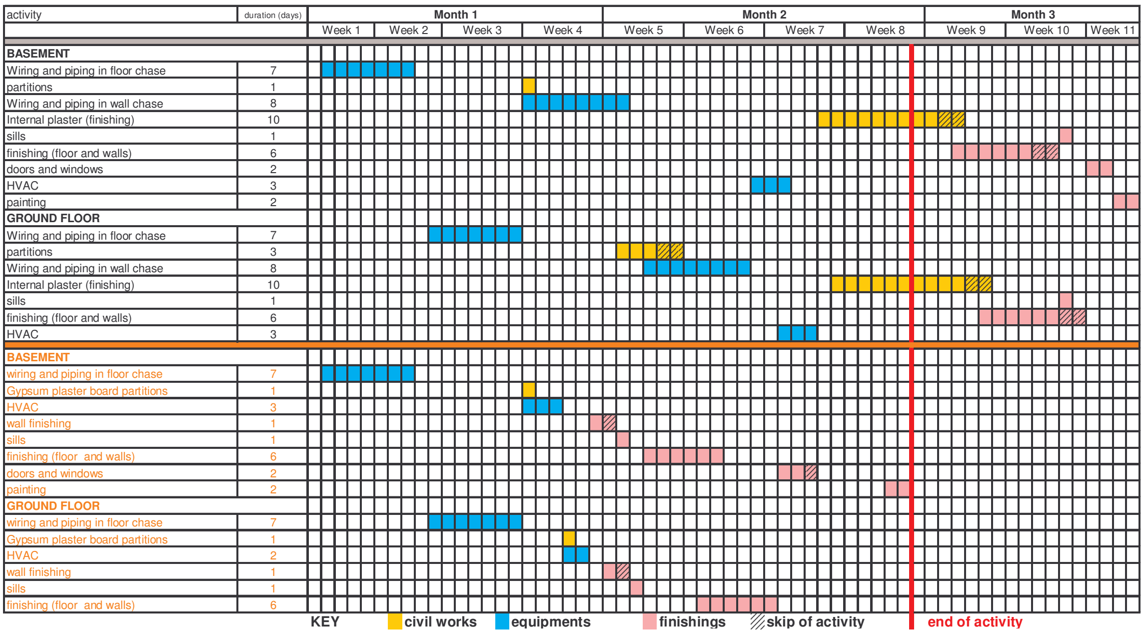


Figure 1. Comparison of works durations (traditional and dry-assembled plasterboard partitions).

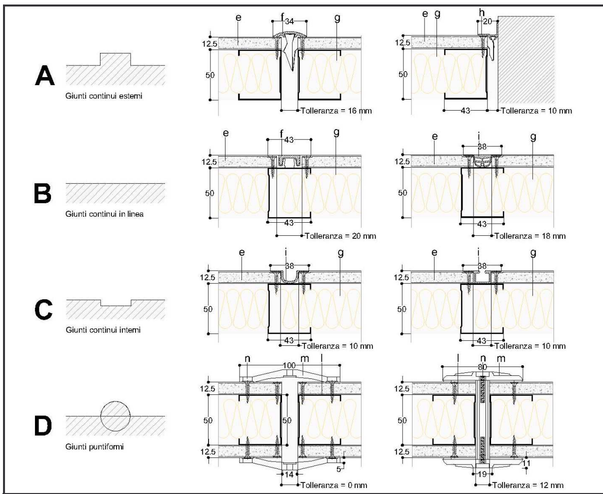
3 Innovations in the design of components

The third level of the study deals with the subject of design of the components and has a motivation in the need of a new conception and an innovative image for dry-assembled plasterboards, more adherent to their essential feature of reversible and removable components for varying and flexible spaces. Trying to intercept new – more dynamic - ways of living residential spaces, the study develops some proposals of dry-assembled plasterboards starting from some assumptions such as, for instance:

- not to hide, but show connections or joints that enable assembly and disassembly. A study has been developed in order to set up a catalogue of different kinds of visible joints (figure 2) that allow the total dry assembly of boards and the easy disassembly , and that permit to vary over the time the composition and the position of the partitions, following the different dwelling users' requirements (figure 3);
- not to emulate traditional wall elements, but to look an original imagine of dry-assembled components. Modular boards and the system of visible joints allow to interchange elements (for instance gypsum plaster boards can be interchanged with translucid methacrylate sheets) and to compose different configurations that clearly declare the dry-assembled approach (figure 3);
- to facilitate self-construction techniques. Different systems of templates and guides have been studied (figure 4), in order to make easier the positioning of plasterboards for the users, as well as to reach a further reduction of working time for operators in the construction phase (figure 1)

- to contain wires, nets and equipments with high levels of maintainability. In respect of the logic of total dry assembly systems, it has been studied the way to contain nets in the walls and to allow to change their path and the use points. All the nets lay in the cavities obtained in the system of vertical studs and crossbars of the support structure and they can be inspected by opening the different flaps that constitute the cover joints between boards (figures 5-6-7). These flaps allow also to change the points of utilization of the nets, depending on the users' need. In the same way, using high resistance plasterboards with cellulose additives, it has been studied a dry-assembled floor system that allow to host different equipments (heating, water, etc) easy to be inspected and possibly repaired or modified, so reaching a high level of maintainability (figure 8);
- to be able to include a system of fittings. It has been studied a solution that allow to hang heavy furniture. It is composed of H steel profile vertical stud (figure 9), that support and connect the plasterboards and that, at the same time, hold a special cover joint to which different elements (cantilevers, guides, grids, etc.) can be anchored in order to hang fittings.

At present these proposals - about new possible components that could be added to the current production - are at concept stage, and they can become object of future, deeper reflections and experimentations about their feasibility.



Key
e. dry-assembled plaster-boards
f. continuous joint
g. insulation
i. plastic joint
l. vertical steel support for boards
m. point joint
n. anchor point of the boards to the support structure

Figure 2 horizontal sections of continuous and point joints between gypsum plaster boards.

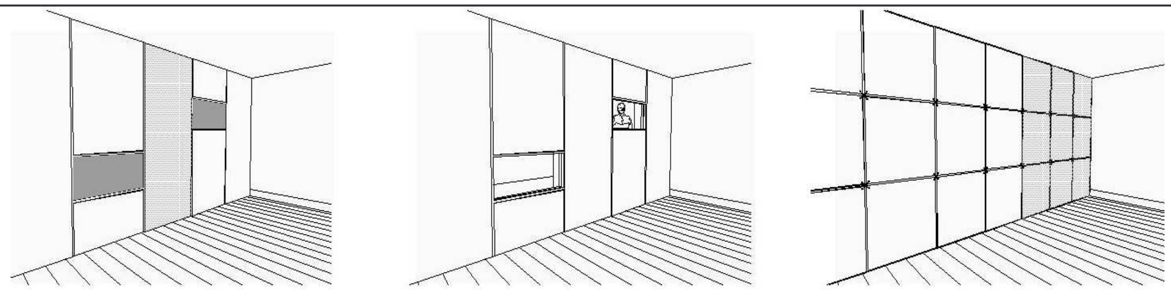


Figure 3. schematic views of possible configurations of partitions

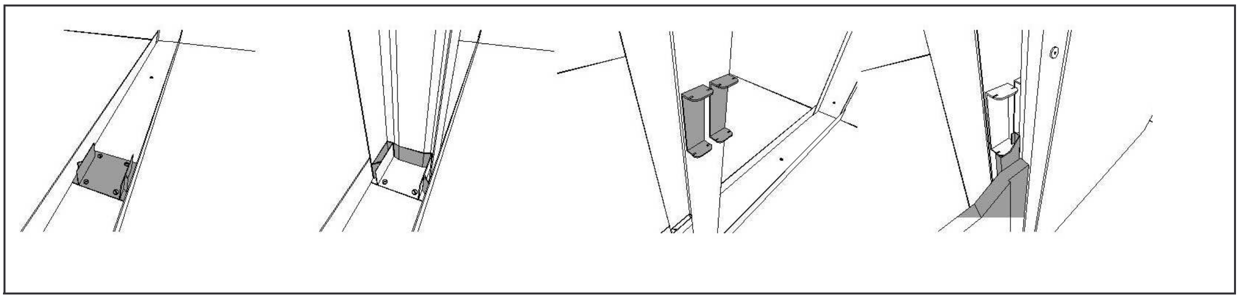


Figure 4. Assembly diagram for self-construction of a plaster board partition with templates and guides

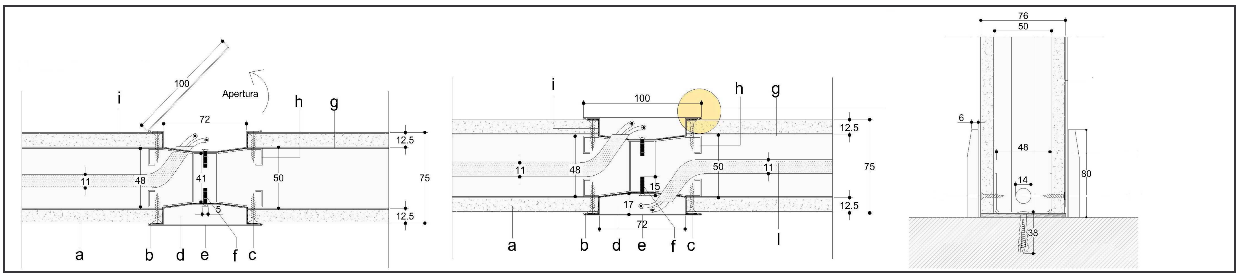


Figure 5. cutaway view A-A' of the stud for the integration of equipments

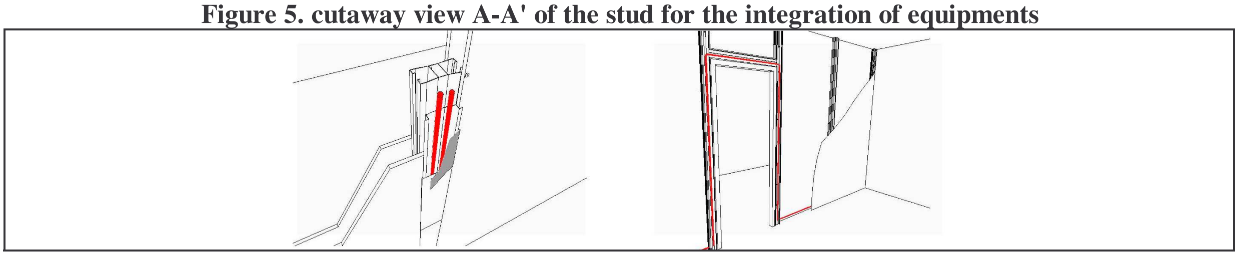
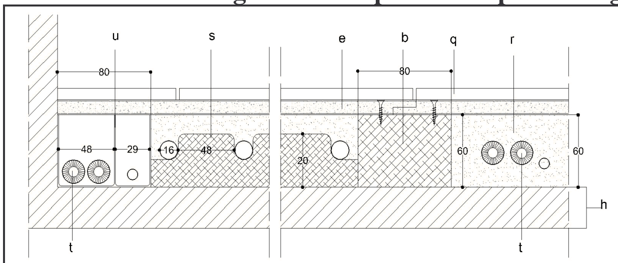


Figura 6 examples of the positioning of wires and cables in the partition



KEY

b – wood backing for application of plaster boards on floor
e – gypsum plaster boards (thickness 25 mm) reinforced with cellulose
q – tiles flooring
r – floor foundation (for underfloor raceways)
s – underfloor heating system
t – underfloor raceways in the floor foundation
u – cables and pipes duct

Figure 7 Vertical section of dry floor foundation with under floor heating system

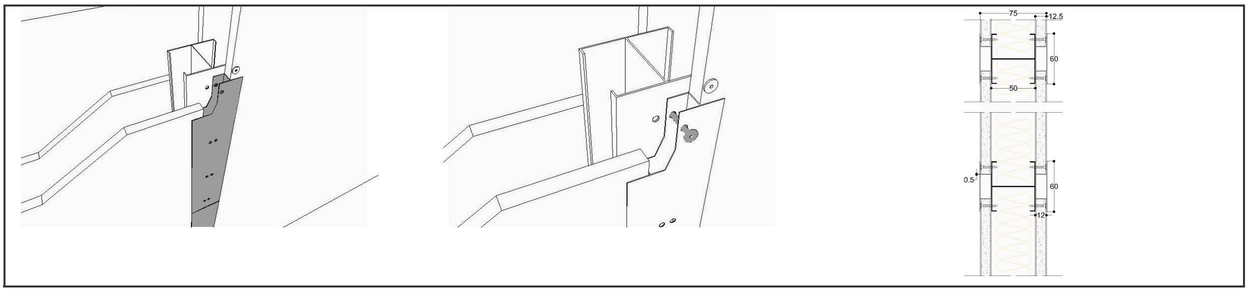


Figure 8 diagrams of the stud to be equipped and horizontal cutaway B-B' of the partition

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Adaptation to new requirements in residential buildings. Possibilities, performances and innovations of gypsum plasterboards. Talamo C., Paganin G., Boventi F., Salomone A.

A Study of Conversions in Japan
- A Case Study of Community Centers and City Banks -

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KEYWORDS

Conversion, Public Community Centers, City Banks

1 Introduction

This paper describes present situation of conversions in Japan.
For example of public buildings, vacant buildings used for "Koumin-kan", the public community center established more than 50 years ago, were researched. There were 18,500 "komin-kan" buildings in Japan. In 1999 Facility-management systems of "Koumin-kan" was changed by modifying the Public Social-education rule, at the same time there were mergers of towns and villages. As a result, many vacant buildings used for "Komin-kan" were produced and used for another uses.
For example of private buildings, vacant bank buildings were researched. To 2005 from 1996, eleven city banks merged into five, and many branches closed or merged. As a result many vacant buildings were produced. Most of these vacant buildings had big spaces and were placed at the center of downtown, near the station or on the main street. They should be converted efficiently because of space-resource in a city.

2 Method

1) "Koumin-kan"

The 1991-edition list of "Komin-kan" was compared with the 2005 one in metropolitan area. We picked up the facilities which changed their names after 1991. Changing of name means conversion of facility. Questionnaires about present uses and circumstances were carried out to these facilities. After then, interested conversions were surveyed.

2) City Bank

The 1996-edition list of city banks was compared with the 2005 one in Chiba prefecture. We picked up the facilities which changed their names after 1996. All picked up buildings were surveyed to know present uses. At the same time, the author asked to The Tokyo Fire Department for investigating before and after uses of conversion on recent applications for building confirmation.

3 Result

1) "Koumin-kan"

From researching, it was found out that 7% of "Kominkan" changed their names according to the revision of Social-education rule and mergers of towns and villages. Fig 1 itemaizes researched results. Buildings were not changed so obviously. 59% of these buildings were changed their names without any architectural works : to "A Assemmbly Hall, "B Comyunity-center", or "C Meeting-Center"from "A

Kominnkann". Because substance of these facilities were not changed so much. 24% of these buildings were converted with a few repair works. Case-Study 1 is an example.

A few buildings were converted with remodeling works, but they were not so convenient for new uses. It is one of the reasons why good conversions were rare that "Komin-kan" buildings were designed for specified uses. They had to have some specified small rooms, for example a library-room, a projection-room, according to the facility-standard for receiving government financial help. Case-Study 2 shows one of such facilities. Functioned small rooms became barriers for easy conversions. Another type of conversions was the preservation of historic buildings. Case-Study 3 is an example.

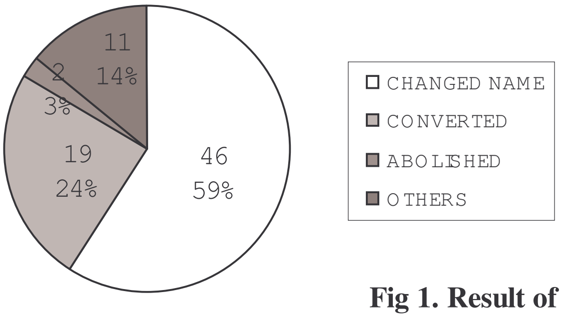
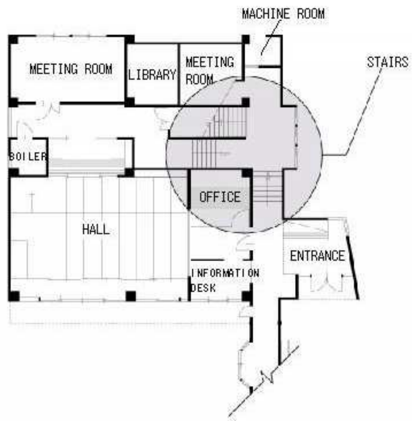


Fig 1. Result of research about "Koumin-kan"

Case Study 1- Facility for Disabled Children

This building was established as "Koumin-kan" in 1970. In 1996, when new "Koumin-kan" building was built, this building was lent for disabled children committee by public. Disabled-Children-Committee has not so much money to repair building that has many problems. Stairs are too sharp for children to climb, panes are too thin to control inside noise, rooms are divided too small for children to play and so forth.



Case Study 2-Facility for Old People

This building was converted to facility for old people to do group activities. In a hall of the first floor *shogi* play or *go* play is performed, and handcrafts lecture is held in a meeting room.

One of the big problems is rest room. It is placed in the mezzanine, like the time of having been "Koumin-kan". Without using stairs people cannot go to rest room, wherever they are. For old people it is very hard to use it.

This building has three stairs which comes from place name Mihashi. This composition makes people difficult to use.

Case Study 3- Facility for Museum

This building was established in 1931 as branch of elementary school in fishing village. By the unifying with neighboring town school, it was closed and converted to "Koumin-kan" in 1970. City wanted to preserve, because it was historical wooden architecture.

Now it is used as museum which exhibits tools of fishery.

2) City Bank

Fig 2 shows Present condition of closed city banks in Chiba prefecture. Vacant buildings and vacant lots were used effectively different from "Kominkan" buildings. New uses of the buildings were commercial uses, which would be selected according to the location of lots and the size of buildings. Case-study 4 shows one of most typical commercial uses, Pachinko-Hall, a Japanese popular amusement facility which need to be placed on a busy street and have a big space. Case-study 5 shows another type of bank-building's conversion, the preservation of historic buildings. From modernization of Japanese industry, banks' buildings were built in Western-style to show their grate position in a city. Now they became important historic buildings.
Table 1 shows new-uses of vacant banks, which were based on recent applications for building confirmation of The Tokyo Fire Department. Most of new uses are private uses same to Chiba prefecture. There was not any building used for public use. In Japan now it is not so popular to use private buildings for public facilities. But it is very important to make the best use of vacant buildings in the center of city.

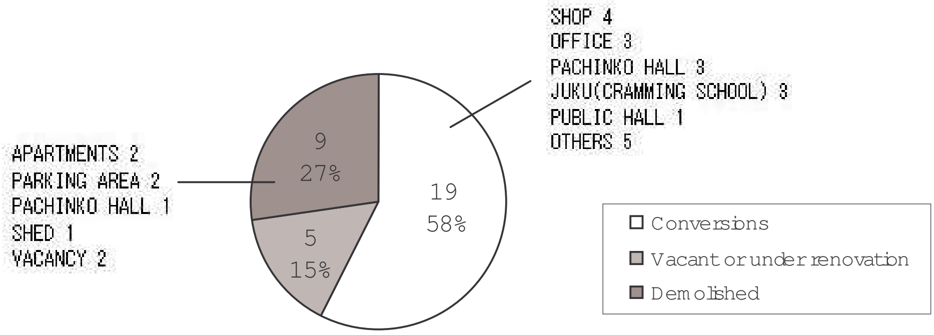


Fig.2 Present condition of closed city banks in Chiba prefecture

AFTER / BEFORE	PACHINKO HALL	KARAOKE LOUNGE	CAFFEE SHOP	RESEAURANT	BAR	OTHER RESTAURANT	DEPARTMENT STORE	MARKET	CONVENIENCE STORE	DRUGSTORE	BOOKSTORE	OTHER STORES	APARTMENTS	CLINIC	PRESCHOOL	UNIVERSITY	OFFICE	OTHERS	TOTAL
BANK	5	1	10	8	5	11	2	8	15	6	4	12	2	5	1	1	2	4	102

Table. 1 Recent applications for building confirmation of the Tokyo Fire Department

Case Study-4 Pachinko Hall

This used to be bank building faces to the station square.
After the conversion, it is consisted from five different kind of stores, pachinko hall, amusement arcade, bar, karaoke and bowling alley.
According to the location of lot and size of the building, stores are all commercial uses.

Case Study-5 Public Hall

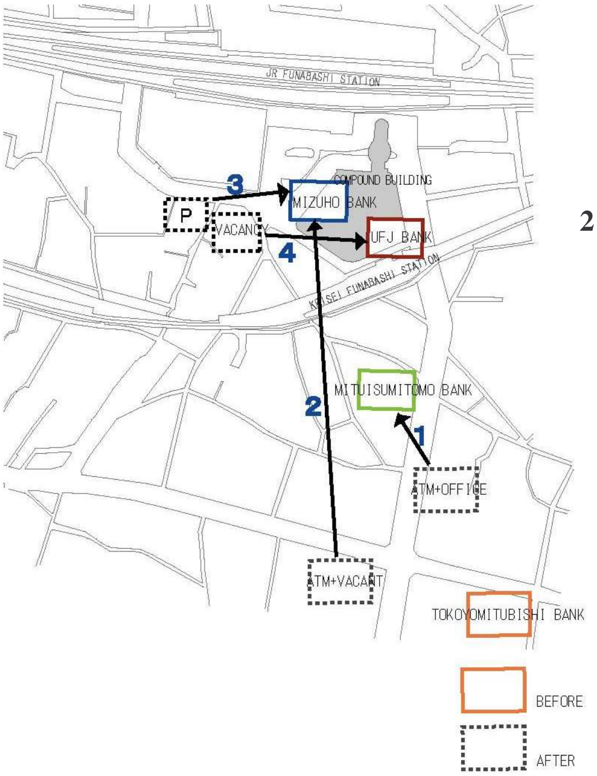
This building was established in 1914 as local bank. Passing several changes between local banks and city banks, and building new bank next to it, it became public hall. Building was saved because of designated the construction cultural property of Chiba Prefecture.

Case Study-6 Around Funabashi Stastion

This Case-study shows present conversion situation around the station.

3

4



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A Study on the Typology of Flexibility of Support in Apartment According to Occupants'Requrierment

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KEYWORDS

Apartment in Korea, Flexibility, Type, Reform requirement

1 Introducion

1.1 Background and purpose

An apartment house in Korea is becoming a representative residential type by the government policy to solve the problem of housing storage. In answer to quantitative apartment supply policy by government and supplier's needs to maximize profits, construction of apartments has provided uniform and fixed residential spaces without coping with changes of sense of value, standard of living and life cycle of residents. However, at a point of time that current housing supply ratio is more than 100% it is required that construction of highly qualified apartment is able to cope with a various needs of residents. On this, construction firms are trying to develop flexible apartments to accept various occupants' requirements.
However, it is not always good for apartments to be possible to deal with all the flexible requirements of occupants because of following reasons. Firstly, in occupants' view, all of them may not want flexibility and flexibility itself becomes purpose due to an excessive emphasis on it, causing that basic design items of living space are in danger of negligence. Secondly, considering supplier's place, they will be faced with various problems of cost, technology, profitability and the like to cater high qualified flexible apartments. Therefore, to be able to provide flexible space with considering both sides of residents and suppliers, first of all, the reasonable range of applicable customer's requirement about flexibility need to be determined by understanding residential characteristics and needs exactly.
Then, this study analysed the reform requirement of apartment residents, through it, to draw out the occupant's requirement about flexible space, and classified the applicable flexibility of space in apartment. Type of flexibility can be used as basic data for deduction and systematization of design techniques for flexible space.

1.2 Methods

To draw out occupants' requirement about flexible space, first of all, reform requirement items and the reasons were surveyed. Survey items are related to reform parts within a house and enlargement of a

house under the condition that cost, technique, and law relative to reform are provided. Survey was accomplished by questions and drew their reform requirement items in a drawing by hand. The period was from June 30, 2003 to July 14.
Secondly, reform requirements which related to space flexibility were drawn out from various reform requirements. On the basis of this, space flexibility which is capable to face each space reform requirement, is classified for several types.
Finally, in order to satisfy the space flexibility, every requirement is examined through application of the space flexibility by selecting one case from apartment units' plan.
The residents' reform requirement is surveyed from the flexible apartment residents. The reason is to observe what degree the space flexibility provided by the supplier is agreed to residents' requirement.

2 The flexible requirement of the space and space flexibility

The flexibility means the ability to change the formation and organism and the ability of the adaptation, while other qualities are secured. And also it means the change of the space composition for the effective adaptation of the unit size. This flexibility includes both the furniture as a space to divide item in indirect method and the infill system which is a direct method.
In order to have the space flexibility, residents must be allowed to change the location of the infill system. In spite of having the changeability of the infill system, if support can not accept it, its changeability becomes meaningless. Therefore primarily support must be designed for infill system to be able to change its location freely.

3 The Analysis of the occupants' space reform requirement

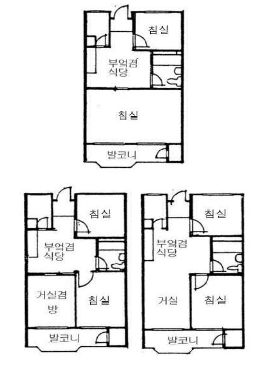
3.1 Characters of the reform requirement of the surveyed apartment residents

At first, after examination of the basic document and studies of flexible apartment, 7 apartments are selected such as; Sange Jugong Apt, Ansan Sonkyung Apt, Neunggkok Jugong Apt, Youwon Sanhwan Apt. We surveyed 190 dwelling units.

Name of apartment	year	units	numbers of survey units				names of apartment	year	units	numbers of survey units				
			total	basic	alter I	alterII				total	basic	alter I	alterII	alterIII
Sange Jugong 16	1987	80	30	13	9	8	Ansan Sonkyung 31	1991	360	30	12	7	11	.
Sange Jugong 20	1987	72	30	30	.	.	youwon samhwan 37	1993	272	30	30	.		
Ansan Sonkyung 23	1991	80	24	24	.		Ansan Sonkyung 49	1991	44	16	10	6	.	
Neunggok jugong 26	1996	319	30	26	4		Total		551	114	93	13	8	0

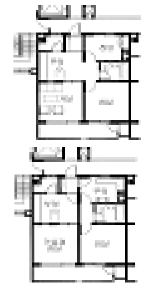
Table 1. Survey of Objects

From the observation of the characters from each apartment, for example, Sange Jugong 16 suggested the 2 or 4 selective unit plans. Common selective items are to control the each room's size through either installing or removing the movable partitions which are located between the living room and bedroom, bedroom and bedroom, kitchen and bedroom, reading room and living room.

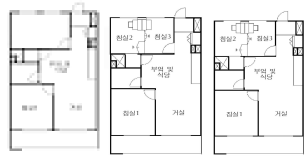


①Sange Jugong 16

②Sange Jugong 20



③Ansan Sonkyung 23



④Neunggok jugong 26

⑤Ansan Sonkyung 31

⑥youwon samhwan 37

⑦Ansan Sonkyung 49

classification		①	②	③	④	⑤	⑥	⑦	classification		①	②	③	④	⑤	⑥	⑦
elements of changing space	drawer partition				•				flexible space	living room-bedroom integrate-division	•	•					
	partition	•	•	•		•	•	•		kitchen-living room integrate-division	•	•					
	sliding door	•	•	•						kitchen-bedroom integrate-division					•		
	change of entrance			•				•		bedroom-bedroom integrate-division				•		•	
	wet-zone			•				•		room-kitchen change			•				•

Table 2. Characters of surveyed unit plan

3.2 Survey of the reform requirement of the residents'

a. Reform requirements of the occupants' in units

132 occupants out of 190 units(69.5%) were asked to reform requirement. And only 14.4% of them required to be reformed original plan to the other selective plan type. Except the selective type of the reform requirements, 147 items came up to be reformed.

As a result of the survey of the reform requirements, 7 requirements were asked to be reformed the alteration of the size through the integration and the separation of the rooms, to be expanded and minimized through reforming the space between the rooms, and to be reformed to expand the balcony or to relocate the kitchen and toilet.

b. The reform requirements for the unit size

47 occupants out of 190 units(25%) were required to remodel the size.

	Vertical								horizontal					
	integration of vertical units						integration of public space		change 2 units to 1 unit				partial integration	
	division of units	privacy	large space	mood of private mansion	noise problem	lights	large space	lacks of rooms	division of units	large space	lights	convenience to use	large space	increase of room numbers
Sange Jugong 16	.	2	2	.	1	1	.	.	.	.	1	.	3	1
Sange Jugong 20	4	.	1	.	.	.	.	.	.	.	.	.	4	.
Ansan Sonkyung 23	.	1	1	1	.	.	9	.	.	.	.	.	.	.
Neunggok jugong 26	1	2	1	.	.	.	3	1	.	.	.	1	4	1
Ansan Sonkyung 31	2	2	.	1	.	.	1	.	1	.	.	.	.	.
youwon samhwan 37	1	.	2	.	.	.	.	.	.	.	.	.	.	.
Ansan Sonkyung 49	.	1	.	.	.	.	1	.	.	.	.	.	.	.
Totals	8	8	7	2	1	1	14	1	1	.	1	1	11	2
	40.4%						27.7%		10.6%				21.3%	

Table 3. Reasons of the reform requirements for the unit size

4 The types of space flexibility on the basis of the analysis of the space reform requirements.

4.1 Types of the space-flexibility

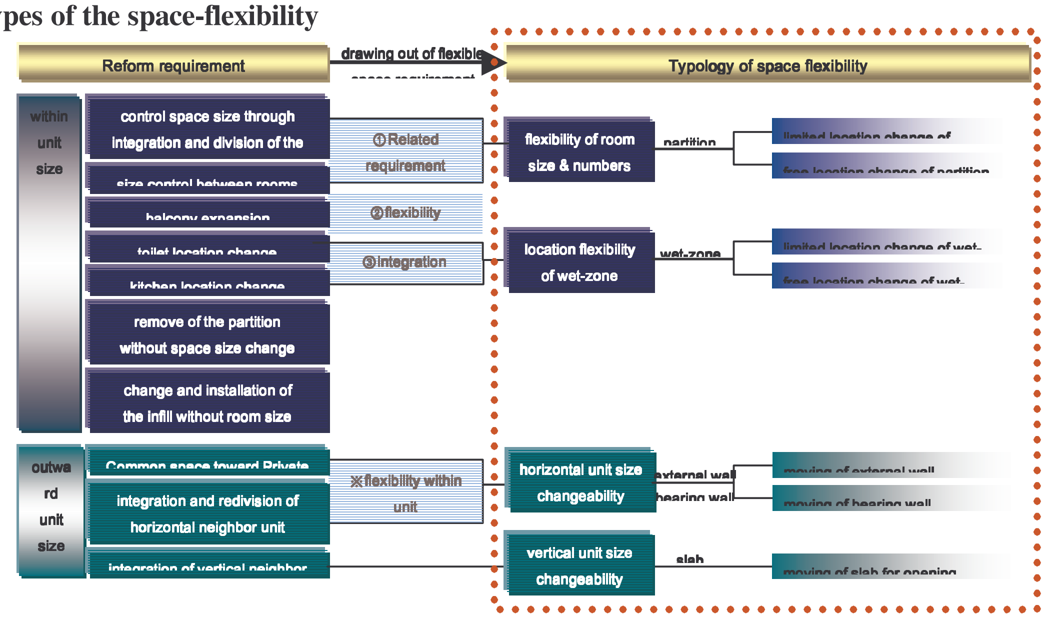


Figure 1. Types of space flexibility

On the basis of the survey, space-flexibility is classified for the following types. In order to do that, firstly, its relative requirements from various reform requirements were drawn out. The space flexibility requirements except the private space were excluded.

The space flexibility is possible from the changeability of the infill. There are infill elements which directly influence on the space flexibility. On the basis of the infill elements, 4 types of space flexibility were suggested such as sizes and numbers of room, change of location of wet-zone, change of horizontal unit size, change of vertical unit size.

4.2 The design method of space flexibility according to the case application type

The method of design requirements was studied for the achievement of four space flexibilities through the case-application. Case apartment is Ansan Sonkyung Apt. The reason to select this Apt as a case is due to the result of survey which shows that the residents require four types of space flexibility. The obstacle elements are drawn out on the basis of previously stated theoretical observation.

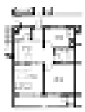
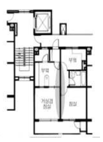
flexibility type	examples of reform requirements			drawing out of the design method		
				basic method	detail method	
change of room size & number				change of partition location	changeability of partition	component of partition
						joint method with neighbor components
					change of location of indirect infill	floor heating installation
						electricity installation
	basic unit plan	kitchen-living roon integration	bedroom space expansion		support design which does not hinder the partition location change	external window location
						enough large space
change of wet zone location				change of wet-zone location	changeability of partition	component of kitchen, toilet
						joint method with neighbor components
					change of location of indirect infill	location of private shaft
	change of kitchen location				support design which does not hinder the wet-zone location change	location of public shaft
horizontal size flexibility				change of external wall location	changeability of external wall	nonbearing external wall
						joint method with neighbor components
					support design which does not hinder the external wall location change	enough large space
				change of bearing wall location	changeability of bearing wall	nonbearing external wall
	privatizing public space	unit separation	change of 2 units to 1 unit			joint method with neighbor components
vertica lsize flexibility				change of external wall location	remove of slab for opening	nonbearing slab for opening

Table 4. Design methods for space flexibility

5 Conclusions

Even though it is resident who asks the space flexibility, the supplier is the one who makes space flexibility possible. Previous studies on reform survey put emphasis both on the analysis of the relation between resident's character and reform character and on suggestion to upgrade unit plan. But in this study, space flexibility which can face the occupants' requirement is classified for several types. And design method which is to satisfy the typological flexibility through case study was drawn out. Even though this method is limited to Ansan apartment 23, it will be important item to decide the support design. Therefore, on the basis of the result of this study, further studies on systematic examination of typological space flexibility as well as on the development of support design element are needed.

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Dwellings Defined by Situations

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KEYWORDS

dwelling typology, changeability, design tools, architectural expression

PAPER

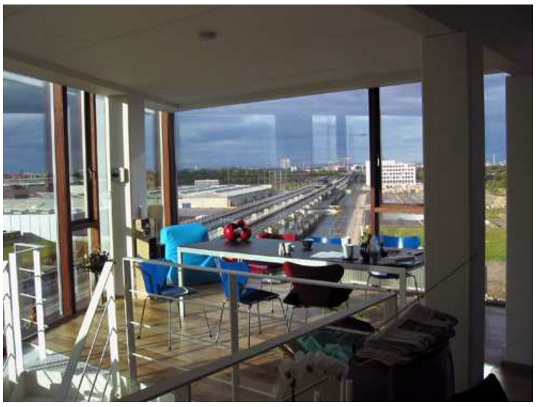
Quote:
Architecture is the simplest means of *articulating* time and space, of *modulating* reality and engendering dreams. It is not only a matter of plastic articulation and modulation expressing an ephemeral beauty, but also a modulation producing influences in accordance with the eternal spectrum of human desires and the progress in realizing them.
Ivan Chtcheglov, Formulary for a New Urbanism, 1953

One of the challenges being placed before architects working in the present day is that of designing living quarters that can accommodate the unknown and the unpredictable. The requirements associated with settlement have come to be more composite, especially due to the ongoing evolution of serial relationships, broken family relationships and family forms stemming from foreign cultures. No longer is the monogamous relationship necessarily the ultimate goal of adult life; now it is *friendships* that are exalted. There is a greater focus on the immediate, on the experiential, on what is comfortable and on whatever is less binding – and of course, it is expensive to marry and raise a family [Frønes & Brusdal 2001]. But how is this challenge being faced by architects and by others who have an influence on how the residential dwellings of the present day and of the future are going to be designed? Our research project explores changeable dwellings that offer the possibility of satisfying spontaneous activities and needs arising from today's changing family patterns. It deals with dwellings that provide people with room for development and flexibility - an open framework, which can be adapted to new values and needs in different situations, lifestyles and stages.
In recent years, a number of basic attitudes toward dwelling have been undergoing changes. Where previously one lived in a certain quarter for a lifetime and where one developed a network, today people often live in one area during their childhood, move a number of times during their youth and perhaps to the suburbs when they establish a family [Ærø 2002]. In his essay on lifestyle and housing, Carsten Thau [Thau 2001] expresses a more fluid notion of the concept of 'home', which can perhaps be better described as 'no sense of place'. To an increasing degree, children are brought up by institutions and the traditional upbringing by parents in the home is reduced. Children have become nomads, moving between institutions and different 'homes', which are constantly redefined by their parents' changing relationships. Families with different cultural backgrounds make this housing pattern even more complex. In addition, the city and the home are under significant influence from the media. Since the 1980's, urban life has experienced a renaissance, and among builders and planners, there has been an increased interest in multistory housing. The considerations for sustainability also support the ideals inherent in the compact city. The urban renewal in the harbor areas offers a breeding ground for

experimentation with a number of new and more open housing types, where future users can be involved in the design of their homes.
Housing policy for the municipality of Copenhagen is based on the tacit assumption that new residential dwellings must be of a high architectural quality and of a high standard with respect to building technology and that they ought to manifest themselves in a contemporary idiom. Additional, new dwellings ought to be designed with some kind of experimentation in mind, taking a point of departure in the surroundings' urban character and potentials [Lundgaard & Beedholm 1996]. These aims pose great demands – and not only on the architectural trade. The demands are imposed on the entire construction branch, on the authorities and on the users, who exert their influence on the market as a consequence of supply and demand.

Our research project involves the registration, photographing and analysis of three new urban housing schemes. The first two selected schemes are *Fionia Hus* near the Copenhagen waterfront, and *Pærehaven*, which lies near Ølby station ca. 50 km south of Copenhagen. These schemes consist of a number of dwellings that are organized with completely open plans within a fixed framework and with central installation cores. The architects for these housing types had the intention of offering the users a greater influence with the plan, choice of materials and flexibility as well as via structural features allowing the users, who in time move in with their own needs and dreams, to alter the room partitioning. The question is: can this housing type be adapted to the present users and can they be adapted to those in the future?
The persons recruited are the users whose names and telephone numbers we could acquire from the sellers or landlords, and who had lived in the apartments for at least one year. There was no form of selection or prioritization among those recruited. All those who returned a completed questionnaire were contacted for possible participation in an interview study and photo registration. A telephone call was the auditive contact form and finally, the personal, qualitative interview has been the final phase in the user contact and gathering of information. This method gives both the user and the researcher the possibility of relatively quickly creating a relationship of mutual trust, as a prerequisite for identifying areas of the users' realities and needs. It has been our intention as well to come back again and again to the same problems by approaching them through different kinds of questions - in order to arrive eventually at a common understanding of the specialized professional approaches [Ryhl 2003]. The questionnaire contained questions that can provide information of a data-like character: age, the household make-up, etc., supplemented by questions that can give us an indication of the users' housing experience, time/activities in the home, the extent of the dwelling, the division and zoning as well as the possibilities for storage in or outside the home/housing scheme. An apartment plan was included on which we asked each individual user to indicate the room divisions, furnishing as well as main activities in the respective areas and /or rooms. Our approach to the analysis of the material parallels Nylander's analysis project. We have focused on the interaction between the measurable and non-measurable qualities inside the homes [Nylander 1996], the synergy of which is significant with respect to the analysis of the residence's occupancy.
The response from the *Fionia Hus* scheme revealed a surprising uniformity in terms of age, household make-up and level of education. The users here are young, well-educated couples with a relatively high household income. Inside the residences, the openness with respect to the view and the orientation toward the sunshine give rise to a directional line that moves from the indoors to the outside. There is clearly a front, a back and a defined middle. A division of the basic type's rearmost zone, reserved for the rooms, strengthens the hierarchy, the diversity in the influx of light and the rooms' functional clarity. The kitchen is expensive and exclusive: it is not going to be remodeled right away. It is dominant, of course. But at the same time, it represents that small measure of flexibility in materials and colors, which can serve to individualize the dwelling's architecture. Time keeps pace with the light and the visual relationship to what lies outside – the diurnal rhythms and the year's rhythms. In general, the units' supplementary finishing seems to have been solved in a quite uniform fashion by the users. This is perhaps due to their demographic homogeneity.
The basic layout in *Pærehaven* [The Pear Tree Garden] can be partitioned up with walls into smaller rooms, which are basically equal with respect to the influx of light, to their relation to surrounding

environment – and to their potentials for use. They can be redefined and re-converted in synch with the residents' changing needs. The kitchen stands as one particular possibility, which has been designed in such an elementary way that it provides the user with the freedom to choose or to abstain. Time as it unfolds inside the residence is slow; it embodies generations' and life cycles' rhythms. Generally speaking, the residents in *Pærehaven* entertained no appreciable expectations about the apartments. The typical resident moved in with the expectation that the apartment was a good investment commodity. Some of the residents could see the spatial possibilities in the elementary layout of the dwelling. Others were inspired by taking a look at how their neighbors arranged *their* living spaces. And this contact created fertile soil for close social relationships. There were, as a matter of fact, some residents who had never before seen an apartment without spatial partitions. Most of the people, as a matter of fact, first caught sight of the spatial qualities *after* they moved in. The drawback about the concept is that this is a process that can be experienced only by those people who are the very first to move into the units. Those who move in after these occupants will never have the opportunity to experiences the same challenges. The problem is that the residential units, with respect to both their manner of construction and their constituent materials, were not really created for this changeability. In the long run, the floors and the ceilings will come to bear the scars of successive impacts. For this reason, the subsequent owners will frequently be inclined to veer toward simply accepting the given partitioning of the various rooms. On this account, the flexibility will be forfeited in the course of time.
The examination of the basic residential layout in *Pærehaven* casts light on both its strong and its weak points. Some of our main comments can be mentioned here: The process of moving in and the building activity connected with this have resulted in a unique sense of solidarity among the residents. In the apartment, as a setting, there ought to be opportunities to opt for putting extra windows into the walls and as far as the dwellings on the top floors are concerned, for putting in skylights. In addition, there ought to be a chance to opt for adding balconies. In those dwellings that are furnished with long closed wall surfaces, there are dark spaces in the middle of the apartment. A subdivision of the apartment in its longitudinal direction results in an open space that is all too narrow, because the basic residential layout is relatively narrow and long beforehand. The bathrooms, as self-contained cores, are focal points inside the spaces and could be even more distinctive elements, while retaining their own intrinsic flexibility.
In the *M-house,* on the other hand, there is no basic layout. There is rather a series of different dwellings that have all been built up of relatively autonomous architectonic layers following a set of common principles. The walls enclose, open up and conjoin. The constructions are contrasted and what are created are heterogeneously varied places and relationships to the surrounding environments inside structures that appear to be invisible. You position yourself freely inside the residence, while hovering and meeting the edge's challenge, that is to say, the light – and then you draw back. The apartment manifests itself in the optimum way when there are no partitioning walls; in many instances, the apartment doesn't need to have any walls at all. The kitchen is functional but neutral – it is not in focus: the users are free to focus on other features. The mirror images in the window surfaces and in the glass dividing walls are juxtaposed with the surrounding milieu's pictures into a timeless simultaneity in the present moment.



(text belonging to these illustrations: next page)

Dwellings Defined by Situations
By H.G. Welling

Illustrations: two photographs, that illustrate the transition from the traditional dwelling to the residential dwelling of today. The picture on the left is from *Pærehaven*. The one on the right is from the *M-house*. The apartment in *Pærehaven* is introverted. The walls are representations that set life on the outside into perspective. The articles of furniture are pedestals for centerpieces and diverse kinds of still lifes, which tell something about the resident's life story. The dweller controls his/her very own scenographic staging. The apartment in the *M-house,* on the other hand, opens itself toward the new city. The commuter railway tracks form part of a dynamic composition, in dialogue with the interior. In its function, the wall/window oscillates between framing, mirroring and transparency. The resident is tuned into a direct dialogue with the surrounding environment.

In the course of the project, we have aimed our focus at both older and newer urban residences. The dwellings that have just been discussed here are current examples of residential dwellings situated in the Copenhagen area that play on the possibilities which can supervene when the architect's prerogative is entrusted to the user. When carried to its most extreme consequence, one could draw the conclusion that the highly over-determined residential type would be that which, paradoxically enough, is the most changeable. We know, however, that this is not the case. Functionalism's residences were designed on the basis of very scrupulous analyses of the average family's behavior patterns. The family patterns were relatively stable and it was well within the realm of plausibility to "calculate" the spatiality which was the most practically expedient for this "average" family's residential needs. However, these dwellings were so very "customized" that what comes to light today is that their elaboration certainly has its limitations.

In the Nordic countries, there is a century-old tradition of dwellings that can be adapted, rebuilt and recycled regardless of time and place. These older dwelling types possess architectural qualities, which we will include in our analysis. Here we will mention a few examples, in chronological order. Jørn Ørum-Nielsen has pointed out that there are only a few consistent dwelling types in the Nordic countries [Ørum-Nielsen 1996]. The dwelling type appears again and again with only slight changes, regardless of the advent of new technology and changing conditions in society: the simpler the dwelling type, the greater its adaptability and flexibility.

A common feature in many of the early workers housing schemes in Denmark, such as the *Kartoffelrækkerne* [Potato Row Houses] in Copenhagen, 1873-89, is the flexibility that the individual plan offers. Over many years in the *Kartoffelrækkerne,* constant adjustments have been made to the apartments' composition and size by addition and/or division. The original, extremely small apartments have quite naturally prompted this development. This has resulted in all the preserved house rows being altered or reorganized in order to create larger and more spacious apartments. The most interesting feature here is that these alterations often have been possible without major structural changes.

Københavnerlejligheden [The Copenhagener Apartment] is a fairly spacious dwelling with a floorage of 100 m^2 or more, constructed as one of the most common residential types in Copenhagen from around 1860 up until the turn of the century. During this period, the ordinary arrangement was to have the domestic staff living in the home. The area of transition between the resident family and the quarters of the domestic staff was normally "the dining room". Today, conditions are essentially different. Without the domestic staff and with fewer children living in the home, the dwelling has become considerably more spacious. The dining room is now an antechamber and has come to be an undefined and multi-functional room with an entirely new set of possibilities for use.

A competition proposal from 1973 by architects Hoff and Ussing reveals a production strategy aimed at allowing the users to participate in the building process. The basic concept was to organize a multistory building as an artificial landscape of column-supported concrete decks stepped back to create terraces, and to use the decks to build row houses. The dwellings were planned to be designed and built by the users, with the help of professional craftsmen when needed. As an alternative, the users could take over a basic unit, which they could complete and enlarge as desired. An especially interesting feature was that the concrete decks were dimensioned either for lightweight housing or for 50 cm of soil, which offered the possibility of establishing a garden on the 'unbuilt' areas.

The reaction to functionalism and mass production was flexible dwelling. Architects have incorporated a maximum number of possibilities for room subdivisions within a limited framework. The most experimental examples, such as Flexibo (1975), designed by Fællestegnestuen for Copenhagen's Public Housing Association (KAB), contain lightweight, movable construction elements where connections and beam systems dominate the spatial expression. A wall depot allows the users to acquire, move and erect walls and thus design their own apartment plans. The system still functions as envisaged and today the scheme resembles an adventure playground. The constructive system is, however, very predominant in a visual respect and it steals the spotlight from the users' individual adaptations of the space.

In 1999, the City and Housing Ministry and the Ministry of Culture invited thirty young architects to a series of meetings on the development of a dogma concept for architecture. This resulted in the so-called Architectural Basic Space - Charter 99: the main idea being to enrich architecture with distinctive and important spatial experiences. The basic space should be created by architecture's permanent elements: the building's structure, the city's infrastructure, the landscape's terrain and vegetation. The basic space should be completed for use by the tenant with doors, windows, floors as well as surface coverings and furnishings at all scales. This finishing represented the secondary level, which in its design is subordinate to the basic space and in principle changeable in the future.

A differentiation between the parts of the building that are very functionally determined as well as the parts of the building that offer multi-usage has been developed in different forms such as in Rem Koolhaas' design for the headquarters of Universal Studios in Los Angeles. The idea behind the above-mentioned tendencies revolves around the problematics between the fixed and defined on one side and the fluid and unpredictable on the other. Can the goal of architectural quality be maintained together with greater possibilities for individual development and influence? Certainly, it is a painstakingly informed attitude about the boundary between the permanent and the changeable that constitutes, in our estimation, an essential precondition for attaining architectonic quality. One of the intentions of our project is to define a categorization of housing, which as permanent frameworks of high architectural quality can survive changes in the inhabitants' life conditions.

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Dwellings Defined by Situations
By H.G. Welling

The Polyvalent Dwelling

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Introduction

The word ‘polyvalent’ has been known for years in the context of the *multi-purpose hall* or *salle polyvalente*, the kind of building that is to be found in every French village or small town, which can be used for weddings and parties, for musical and theatrical performances and as a cinema. The word was introduced into the architectural debate by Hertzberger, some of whose ideas on polyvalence can be seen in the Diagoon houses he designed for Delft (1967-71). Here too polyvalence means that the building can be used in different ways without adjustment to the way it is built. There is a difference, however: the various uses of a *salle polyvalente* take place consecutively, but a dwelling must be able to provide space for all the different activities which it is capable of accommodating to take place at the same time. Polyvalence in the context of housing relates primarily to the interchangeability of activities between different rooms.

Palladio etc.

Until the 1920s people built homes with a relatively high degree of interchangeability in the use of space. It could be said that homes always used to be polyvalent to some extent. Rooms derived their meaning more from their status than from any precise definition of their function. If we look at the ground plan of the *piano nobile* of Palladio’s Villa Rotonda we see large and small rooms alternating, rooms that by virtue of their decoration are all equally prestigious. You cannot tell from the plan what activities are supposed to take place where. In practice the use was defined by the occupant’s preferences. A room was furnished as a bedroom or living area based on whatever was convenient, and this could change with the season or mood. Nor did the presence of a bed necessarily rule out using a room for the receptions that took place regularly at the villa. The nineteenth-century bourgeois house is also made up of a series of large and small rooms whose dimensions do not necessarily define their functions. Their siting in relation to service areas such as the kitchen and bathroom, of course, betrays what they are intended for: the dining room is adjacent to the kitchen and connected to it by a serving hatch, and the parental bedroom is next to the bathroom, to which it has direct access by way of a door.

Determinism or changeability?

At the beginning of the twentieth century architects seized upon the problem of providing homes for the working classes. The urbanization that had taken place in the nineteenth century had produced rapidly growing world cities with inexpensive housing. The housing developments built there purely for profit were notorious for their poor hygiene and cramped conditions. This was the first time that progressive architects took on building homes for the masses as their responsibility. Neither the various types of nineteenth-century workers’ dwellings nor the houses of the bourgeoisie provided the basis for a good solution to this problem. The new homes for the working classes had to be developed from scratch—and on a scientific basis.

Time and motion study was the right tool for this: in the Netherlands, for example, Willem van Tijen analysed the activities that take place in the home. He recorded home life in terms of dimensions and motion diagrams (Tijen, 1966, p. 44). In Germany Grete Schütte-Lihotzky similarly developed the Frankfurt Kitchen, based on ergonomic studies. After World War II this research led to such things as the *Functional Principles of Dwellings (Bouwcentrum, 1958)* and the *'Regulations and Tips' (MVRO, 1965)* in the Netherlands. The latter document, with which every subsidized Dutch home had to comply during that period, provided the general specifications for the homes built as part of the post-war reconstruction programme.

The ergonomic studies, and above all the way they were translated into building regulations for subsidized housing, provide a snapshot of the typical post-war family. When building many of the homes for post-war reconstruction these requirements were for a long time set in reinforced concrete. The dimensions complied with the minimum sizes laid down in the building regulations. The space is squashed in between a large pipe duct and a reinforced concrete load-bearing wall, and thus unchangeable.

As set out in Frame and Generic Space (Leupen, 2006, p. 18), we are faced with the following contradiction in terms: the more precisely we are able to decide what requirements a dwelling should meet at the start of its life, the greater the likelihood of a discrepancy arising between the dwelling and its future use. The more precisely architects were able to define the measurable aspects of living and convert them into a design, the more the design neglected the uncountable and unmeasurable aspects.

Instead of freedom of design, ergonomic studies brought determinism, leading to a deterministic functionalism. Hertzberger says of this type of functionalism: *"if there was anything to which these concepts were not resistant, it was time"* (Hertzberger, 1991, p. 146). Later on in the same book Hertzberger proffers a solution.

> *"Flexibility therefore represents the set of all unsuitable solutions to a problem. On these grounds a system which is kept flexible for the sake of the changing objects that are to be accommodated within that system would indeed yield the most neutral solution to specific problems, but never the best, the most appropriate solution.*
>
> *The only constructive approach to a situation that is subject to change is a form that starts out from this changefulness as a permanent - that is, essentially a static - given factor: a form which is polyvalent. In other words, a form that can be put to different uses without having to undergo changes itself, so that a minimal flexibility can still produce a optimal solution."* (Hertzberger 1991, pp. 146-7).

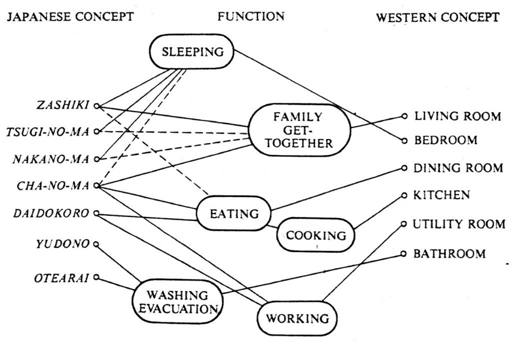
Six basic activities

If we are to gain a better understanding of polyvalence, we need to know about the activities that a home generally needs to accommodate, since it is these activities that need to be able to change places in order for it to be polyvalent, as I argued in the Introduction. As a general rule, all living, irrespective of culture or degree of wealth, can be reduced to six basic activities. The differences between cultures, stages of development or degrees of wealth can be seen in the relationships between these basic activities and how they are carried out. As regards the latter, the nature of the objects required (furniture, appliances, crockery etc.) plays an important role: while one person may cook on a wood fire and another on a six-ring electric cooker, there will be cooking taking place.

In the diagram shown here (Fig. 1) Nishihara compares traditional Japanese domestic culture and Western domestic culture in terms of six activities (Nishihara, 1968). In present-day domestic culture we find particular rooms being set aside specifically for particular activities, whereas the traditional Japanese house has a number of multi-purpose rooms which derive their meaning from the objects used there. If the box of tea ceremony paraphernalia is brought out, the room is the tea ceremony room; if the sleeping mats are rolled out and the tea ceremony box put away again the same room becomes a bedroom.

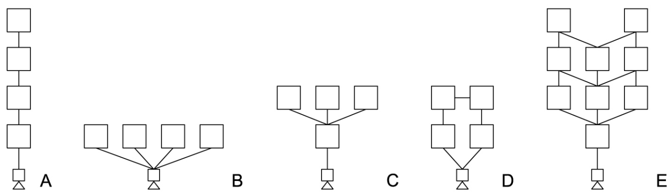
The case we analyzed aims to provide an understanding of the polyvalence of dwellings, and in addition to test the hypothesis that the polyvalence of a dwelling depends on its spatial organization. We can examine the first point by seeing to what extent the six basic activities can be located in different ways.

This was done by applying various programmes to the dwelling. These various situations can be expressed in an activities graph, based on the six basic activities. The analysis identifies the following six basic activities: **S**leeping, **G**et Together, **E**ating, **C**ooking, **B**athing and **W**orking.[i]



1. Comparison between the traditional Japanese house and the Western house (Nishihara, 1968)

For four thousand years now dwellings have provided a place about four by four metres in size where people can get together. Only single-person flats and temporary accommodation such as hotels do not have a space of this kind for each unit; this space is often found at a different level, e.g. the foyer of a hotel, or the communal kitchen-diner in a student hostel. In practice this means that a house must at the very least have a room where this four-metre space fits, in other words a room at least 4m x 4m.
To test the hypothesis that the polyvalence of a dwelling depends on the pattern of relationships between the living/sleeping areas we show the spatial organization of the dwellings in a graph to permit comparison.[ii] For the case study below two kinds of graph were drawn, one of the spatial system and one of the activities and their interrelations[iii]. A number of activity graphs can be drawn for one and the same spatial system, depending on how polyvalent that system is. As a general rule we can identify five basic models: A Chain, B Star, C Star with central room, D Circle, E Grid (entrance = Square + arrow). These are shown here in graph form (Fig. 2).



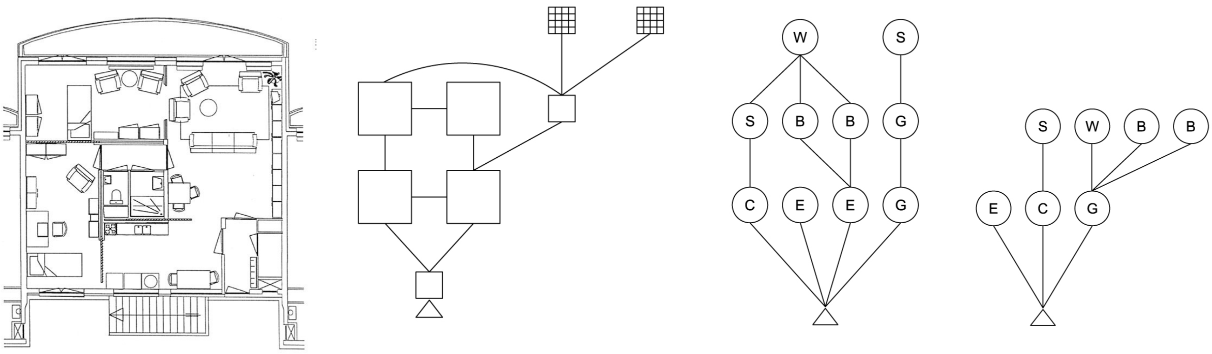
2. Graph of dwellings. A Chain Model, B Star Model, C Star Model with central room, D Circle Model, E Grid Model (entrance = Square + arrow).

Say there are six basic activities and six rooms where they can be located, and assuming all the rooms are the same size, then all the models of spatial organization (star, circle or chain) are equivalent as regards the number of possible arrangements of activities. Theoretically this is 6 factorial = 720. If we lay down rules on the arrangement of activities, however, (e.g. the activity Get Together must not be accessible only via the activity Sleeping) or on the location of specific activities (the room for Cooking and the room for Bathing are fixed), we find differences between the six basic models in the possible arrangements, or the degree of polyvalence. We find that, when specific conditions are laid down, the star model has a larger number of possible arrangements (i.e. it scores better on polyvalence) than the chain model. This number can be calculated arithmetically, but the essential factor is the conditions laid down, which are culturally determined (we are not used to entering the living room via a bedroom) and differ from one domestic situation to another.
The projects we analyzed have been selected for their unusual spatial organization. All of them are to some extent polyvalent, enabling them to be lived in in various ways. In most cases the polyvalence only applies to some of the rooms, and the place where people get together—the living room—is determined by its place in the organization and its size. For this study we made analysis of the following five projects: MVRDV Ypenburg, Diener and Diener IJ-burg Amsterdam, Pantillon Rotterdam (Student

project[iv]), Duinker and Van der Torre Dapperbuurt Amsterdam, Riegler and Riewe Graz. As an example we show her an abstract of the analysis of de Duinker and Van der Torre project.

Duinker & Van der Torre

The project designed by the firm of Duinker & Van der Torre for the Dapperbuurt district is a classic of polyvalent housing. Here too doors play an important role in manipulating the spatial system, in this case two-way doors and sliding doors. Large doors and sliding walls can increase polyvalence. Although the sliding doors change the spatial system to some extent the dwelling is still polyvalent, as it can be used in different ways without moving a single nail (Leupen, 2006, p. 191). Duinker & Van der Torre's dwellings have a circle structure (model D), which in principle enables a room to be accessed from two directions. This increases the polyvalence, provided the circle is not too large, as otherwise it turns into a chain structure (each room is only accessible from the next one). To reduce this effect Duinker & Van der Torre have provided a shortcut between two of the rooms in the circle: the centrally situated vestibule that forms the shortcut also provides access to the bathing and toilet facilities. The polyvalence of this dwelling is restricted to a large extent by the fact that only one room is large enough to accommodate the activity Get Together. If the three rooms were all large enough for this purpose the dwelling would be far more polyvalent.



3. Duinker & Van der Torre, Dapperbuurt district, Amsterdam, Grafe of the spatial system and two grafes of posible activities

Conclusions

In theory every dwelling has the capacity to be used in various ways: a room defined as a bedroom, for instance, can be used equally well as a study or hobby room. Things get more interesting, however, if a dwelling can accommodate different living patterns. A home that can be occupied, without modification, by either a family with two children or three or four singles can be described as highly polyvalent. Clearly there are degrees of polyvalence, a scale of polyvalence. The extent to which a dwelling is polyvalent could be said to depend on the number of possible arrangements or combinations of activities it permits. This number is related to five factors:

1. The size of the rooms
2. The number of large rooms
3. The underlying spatial structure of the dwelling
4. The relationship to rooms with fixed activities such as the bathroom and kitchen
5. The kind of relationships between the rooms

Ad 1. Living/sleeping areas larger than 16m² have the potential to accommodate any basic activity.
Ad 2. The more rooms larger than 16m², the more freedom there is to distribute the basic functions among them.
Ad 3. The case study shows that e.g. a star or circle structure has more potential than a chain structure. Rooms that provide access to other rooms with no alternative route are less suitable for basic activities such as sleeping.

The polyvalent dwelling by B.A.J. Leupen

Polyvalence is restricted by having only one large room. In a domestic situation with two adults and one small child, for example, Diener & Diener's design and Duinker & Van der Torre's are equally polyvalent. Systematic research into how a large number of dwellings regarded as more or less polyvalent actually function in practice could increase our understanding of this fascinating phenomenon. Putting knowledge of polyvalent dwellings into practice could result in a new generation of homes with interesting spatial organizations and substantial expectations (sustainability) as regards changing and unpredictable uses.

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i I differ from Nishihara in using Get Together rather than Family Get Together, as living in a home does not by definition involve a family. Instead of Washing/Evacuation I use Bathing for short.

ii The method of drawing has been developed from that used in Decoding Homes and Houses. (Hanson 1998)
iii Analyses by Esther Stevelink and Sophie Pfeiffer
iv Daniel Pantillon graduated from the New Concepts for the Dwelling studio at the Faculty of Architecture, Delft University of Technology.

The Study for Facilitating Residential Open Building in Korea

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Residential Open Building in Korea, Facilitation, Specialists' Interview Survey, Systematic Improvement Plans

1 Introducion

1.1 Research Background and Research Purpose

When we look at the problems of inadequate development of residential building technology in the country, delays in their propagation, and the reality of propagation delays outside the country, the reason why technological development of residential buildings does not propagate even when it is completed is that nationally, there are obstacles such as increases in construction expenses for new constructions and absence of support plans such as policies that can accommodate the development. Accordingly, unless a plan that can solve these problems is discovered, realistic dissemination will be difficult, and we must, therefore, discover a standard and a guide, organizational improvements, and support plans regarding these problems. Accordingly, this paper has as its goal to examine the current situation of residential open buildings in the country through literature and investigate the opinions of related policy experts, field professionals, and researchers in order to grasp the general situation and the problems of policies for turning open buildings to residences, and from the results, look for plans for improvement and future development directions.

1.2 Research Contents and Method

This study will provide the approach on the process and systems to facilitate residential open building by examining obstacles to popularisation and items using F.G.I(Focused Group Interview).
Based on the survey of experts engaged in construction companies and architectural design offices, the research method and contents are as followings: 1) Examining basic data of participants in this survey. 2) Collecting the information in the situations of flexible housing and the understanding of companies and architectural design offices. 3) Organizing obstacle factors and alternatives from the survey. 4) Suggesting plans on process and systems to facilitate residential open housing.

2 Trends in Legislation Regarding Residential Open Buildings in KOREA

In the midst of increasing interest in remodeling recently, there has been an upsurge of interest in plans and design methods that consider remodeling from the start when open buildings are designed. Such design technique for remodeling newly constructed open buildings ultimately contains within it the concept of open buildings, and this paper will investigate the current status of systems related to Korean

open buildings by examining systems that have applied major concepts of open buildings and related systems that make it easy to remodel newly constructed open buildings.
Starting from 2000, Korea began improving the system for revitalizing building remodeling, and from September 2001, when it started revising the Building Enforcement Ordinance, to the present, it has been promoting the work of improving related systems. Also, a systematic foundation is being laid by including the flexibility and remodeling convenience related to open buildings in the performance evaluation list of open buildings announced on January 9th, 2006. The contents of the Building Enforcement Ordinance and housing performance grades are as follows. The main content of the Building Enforcement Ordinance says that when a structure that allows easy remodeling makes it possible to wholly or partially merge perpendicularly or horizontally adjacent units, to separate the structure and its furnishings, the inside and outside finishing materials, and to obtain flexibility of space and interchangeability of composition materials inside individual units, when it satisfies these conditions, it is allowed to adapt 120% of floor area ratio. Among the evaluation items for recognizing housing performance grades and management standards, the remodeling, maintenance, and flexibility of structure-related grades related to open buildings are included, and their contents and evaluation methods are as follows. In the remodeling and flexibility-related list, the items are classified as grades 1 to 4 according to evaluation items, such as wall volume related to the dimensional ratio occupied by columns and load bearing walls, plans for making renovation and inspection easier, and plans for merging and separating units perpendicularly or horizontally. The list evaluates flexibility and remodeling, and its significance lies in the fact that it is world's first legislation of performance grades. In this and other ways, Korea is in the process of promoting the provision of systematic foundation for providing and revitalizing open buildings, but currently, detailed and systemized standard and research are still needed.

3 Outcome of the Analysis

3.1 Overview of the F.G.I Survey

The survey of experts was carried out from February 13th 2006 to March 24th 2006, and as for the method of selecting the experts, those with experience of participating in planning, designing, or researching projects similar to residential open buildings (4 in charge of policy and administration, 1 from a construction design team, 11 from a construction company's product development office and design department, 1 from a construction company's technology laboratory, and 2 from a design firm's design team), for a total of 19 people, were used as subjects for the interview(table 1).

Eemployment		*Department*	*Number*
Government and Public Offices	Administrative Organ City Hall Ward Office	Housing City Policy Team Housing Improvement	4
Public Coporation		Residential Environment	1
Construction Company		Architectual Design Housing Design Building Works Housing Research	12
Architectural Firm		Design Team	2
Total			19

Table 1. Overview of F.G.I.

As for the content of the survey, it was divided into technical, systematic, and social viewpoints, and it was composed of opinions regarding factors for why residential buildings cannot currently be activated, matters that need to be improved, and direction of development, as well as background and reasons for introducing plans and designs of open buildings similar to residential open buildings, and actual application methods.

3.2 Current Situation of Residential Open Buildings and Factors Limiting Their Activation

The results of the responses from each survey subject were as follows: the ones in charge of policy and administration mainly focused on systematic aspects, the construction design team on technical aspects, the construction company on systematic, technical, and social aspects, and the design firm on systematic aspect.

1) Systematic Aspect

The need for plans for realistic materializations such as legalization is presented. In case a structure allows for easy remodeling from the revitalization plan of the Rahmen construction method, with which residential open building is possible, the experts agree in their opinions that the systematic environment is fairly well equipped through such things as adaption of floor area ratio, strengthening of earthquake-resistant design standard, and strengthening of heavy weight impact noise design standard. However, an unconditional rise of permitted floor area ratio may adversely affect the comfort level of residential environment, in turn hurting profitability. Such underlining of the problems caused by wholesale incentives emphasizes the need for a close examination of various alleviation plans, as well as a clear-cut establishment of guides and standards, which are currently ambiguous. The absence of laws and policies to bolster the enhancement of the quality of residential open buildings was cited as a primary flaw of the en bloc application of policies with no regard for the basic characteristics of residential open buildings. In other words, the most crucial legal and institutional support was seen to be that which can accommodate the application of new technologies and materials that can actualize residential open buildings. A representative problem in this last case would be the government's narrow-minded residental policy, concentrating exclusivly on the stabilization of residential market, rather than on the quality enhancement of residents.

2) Technical Aspect

The level of technological application was shown to vary according to the survey subjects. Between the units, buttress structures were considered, and for unit interiors, buttress structures employing pillar-type flat slab structures mixed with pillar-type structures. In this method, a plan which takes into account the selection of pillar-free construction method that takes away pillars in the unit interiors, and the changes in the location of water usage spaces in the unit, such as the kitchen and the bathroom, were considered. With the exception of the mixed buttress and pillar method, as a design plan, there were limitations in producing the accurate current situation and problemshooting through actual verification. In the case of construction, however, the results of the survey based on actual construction experiences are as follows:

The dry construction method, selected with the aim of shortening the construction period, consisted of drying the front and back of the apartment, as well as the unit interior walls, in order to promote flexibility of remodeling and space, and make remodeling more convenient. In the applied construction materials' physical living performance and economy, there was no disadvantage compared to the wet construction method; however, there was a limit to the application of materials and parts due to their shortage, and there were problems with the shortage of skilled laborers.

There were also problems in the supply and performance of the infill parts. There was a limited product range available, resulting in an unprepared material testing and performance evaluation system for such things as design limitations, noise between units, and interior environmental standards for the dry construction method. There were difficulties in acquiring the data required to set up a repair cycle for the residential open building design process. Distractive issues in the construction itself were various as well, including a lack of skilled workers, of parts systemization and standardization, of development of various infills, and the higher costs caused by the infill work, as well as the costs entailed in the detailed construction plans for the dry wall and structure. It was pointed out that the separate construction of the infill and its support required separate designs, causing a rise in design costs that could contribute to lowering the effectiveness of residential open buildings.

3) Economic and Social Aspects

The limited demand for residential open buildings is an important factor that decides the profitability of a project. There is a unanimous agreement that the construction and objective behind such residential open buildings need to be preserved through accurate surveys and research on the concept of such residential open buildings, as well as the level of the demand. Also pointed out as a root problem is the

fact that out of the many flexible structures that a unit interior may take on, only the basic structures are considered with the future sale of the unit in mind, and residential open buildings are still viewed as a thing of property rather than as that of residence.
The independent supply and construction of the support and infill parts pose a problem of losing their operation and aim, and independent supply similar to one being used in Japan is viewed as still premature for Korea. The rise in start-up expenses due to higher design and construction costs is the biggest limiting factor against revitalizating open residential builings, and a solution to this issue is most urgent. Cost was found to be not the only issue, but because in case the wall structure and infill are independently supplied and constructed, a building permit is not granted, which makes independent supply itself an impossibility. The construction companies themselves agreed that it is difficult to separate interior construction, from which a large part of their profits is gained. Even if it does become feasible, the forecast is that it would be difficult to come up with a solution to the popular complaint that would follow the separate constructions. Finally, it was agreed that in case of unit division or merging, an incentive plan would need to be prepared for when units are merging, as moving to an existing larger unit is much more advantageous.

4 Policy Improvement Plans for Revitalizing Residential Open Buildings

1) Systematic Aspect

From the perspective of laws and policies, new systems that can accommodate new technologies, together with the preparation of attractive incentives, are urgently needed. Experts must work to ease construction regulations, giving profitability to the construction of residential open buildings, and the methods through which the regulations should be eased are as follows: The easing of permits linked to housing performance grades, the easing of basic facilities allotment as a solution to the step-wise application of residential open building design standards that consider remodeling, the operation of a national housing fund that permits a part of the restitution of development gain and basic facilities installation expenses to be used for it, the right of light as a floor area ratio incentive solution following the application of green building certification, the control of maximum height and easing of housing act permits, the allotment for special repairs, the reserve for residential repairs, a plan for operating a national housing fund and many others have been proposed. The application plan is also proposing a step-by-step application that is carried out at unit level, not radical applications. The subjects of application are also subject not to a lump application but rather to their special local characteristics, and there have even been minus-incentive plans proposed, as opposed to a uniform plus-incentive plan. It was agreed that, considering the independent supply and construction of support and infill, each individual unit's completion inspection should prepare a standard for separating the work and a plan to ease the policy to require companies to complete up to the installation of the water sprinklers but leave out the interior finishing materials, and opinions were also presented with respect to supporting tax-related policies that would enable units to merge.

2) Technical Aspect

The development of technologies and structures for residential open buildings is being proposed. The need for research and development of such things as lightweight wall structures and ceiling materials was also underlined. Such would be supported by the technological development and introduction of new support and infill appropriate for residential open buildings, such as development and distribution of structural forms, and R&D of various interior finishing methods and designs. The gradual development of partially flexible wall placement within units, the positioning of which can be changed by the residents themselves by gradual application of flexible forms, is being proposed over the development of fully flexible method for the unit interior.

3) Economic and Social Aspects

As this is a new project, the government's active support and publicity were chosen as the most important factors for the project's success, and it was agreed that consumer attitude toward the concept of residential open buildings urgently needed to be changed to accommodate them. It was viewed that systematic research and Korean mentality should be sufficiently considered through short and long-term roadmaps for residential open buildings, and that improvement was needed in the consciousness of residents through education regarding the maintenance, management, and residence of open buildings. It was also viewed that detailed standards regarding such things as structural forms, materials, or construction methods were called for, along with the preparation of standardized design plans, as well as the need for developing and introducing new technologies, economic support for development, and an accurate demand appraisal.

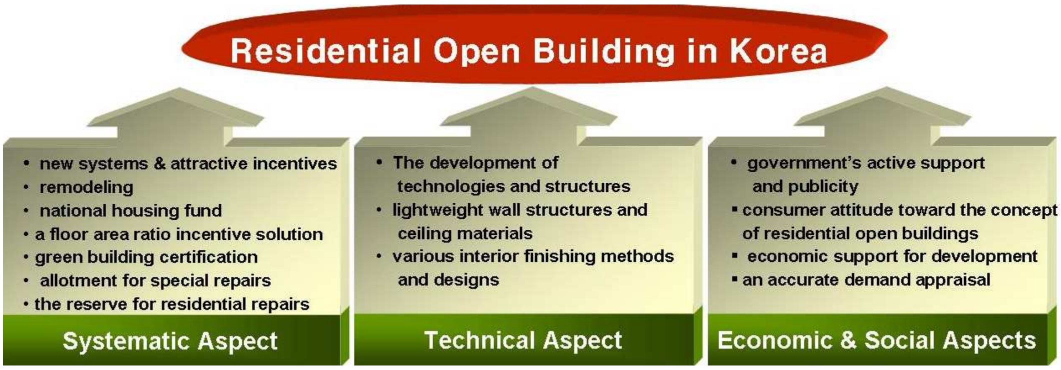

Figure 1. Improvement Plans for Revitalizing Residential Open Buildings

5 Summary and Conclusion

The results of surveying the experts show that the ways to realize and revitalize open buildings as residential open buildings could be examined in three large categories: the systematic, social, and technical aspects.

In the systematic aspect, a step-by-step implementation of solutions, such as a detailed examination of incentives, tax support when merging units, and easing of permits and various allotments was presented, and in the technical aspect, it was viewed that there was a need for development of structural forms, construction methods, detailed standards, and new materials. In the socioeconomic aspect, it was viewed that such things as government's active support and publicity, examination of accurate demand levels, and changes in the consciousness of residents were needed.

Because the factors that limit the revitalization of open buildings as residential open buildings are influenced by a combination of domestic economic and social conditions, we believe that it will be important to create the conditions that can actively develop residential open buildings in Korea through a comprehensive analysis and step-by-step improvement of these limiting factors. To this end, this paper has presented improvement plans for each of the above aspects. Specifically, during the beginning stages of revitalizing residential open buildings, we believe that the preparation of systematic standards and government support in terms of policies are most urgently needed. Also, for the continuous growth of the residential open buildings, steady progress must be made in the development of construction methods, and there must be continuous effort to support the transformation of consciousness that open buildings are not a way to increase one's fortune but are places of permanent abode.

6 Acknowledgments

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Conversion of Public Buildings in Japan

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KEYWORDS

Conversion, Public Buildings, Stock-oriented Society

1 Introduction

This paper shows the problems of building reuse in Japan by case study on public building conversions.

The conversion (change of use of the building with renovation) activity has just launched recently in Japan. However, construction market did not shift from "scrap and build" to conversion and renovation, "stock-oriented society", yet.

On the other hand, public buildings have converted sometimes corresponding to social change, for example, form schools into nursing institution [Sone 1989]. We have a law for sale the public buildings.

Therefore, we focused on the conversion of public buildings as a case study of conversion business that contributes urban renewal. We investigate the process from sale to buy public buildings and the scheme of the conversion projects. Our objective is to find problems of how to promote reuse of existing buildings.

The main points of this research results are as follows.

- Provide information to public more positive
- Seller should request to buyers to reuse the buildings
- Create a new value to existing buildings

2 Research method

We have interviewed with some national institute, as a public building seller, about its process from vacant to sale. Moreover, we have interviewed with some corporations and individuals, as a buyer, about their conversion projects.

3 Sale process of public buildings

Government sells public buildings conforming to the laws, “National Property Law” and “Accountant Law”. ‘Figure 1’ flow chart shows this process, from “Vacant” to “Sale”. We found three important phases in this process, “Vacant”, “Evaluation” and “Announcement”. The detailed explanations are as follows.

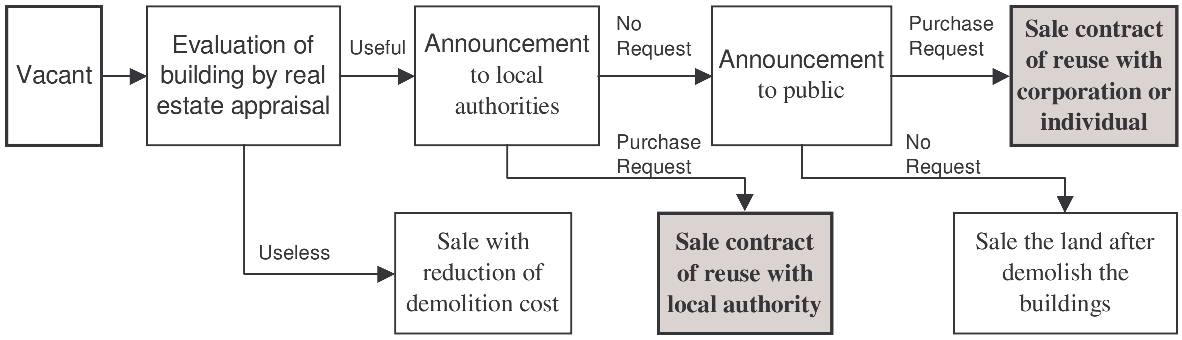

Figure 1. The process of conversion of public buildings from “vacant” to “sale”

Vacant
There were two main reasons to make public buildings vacant in these days. The one is restructuring of governmental organization. The other one is financial difficulties of government. When the public building is vacant, government does minimum maintenance.

Evaluation by real estate appraisal
Government asks real estate appraiser to evaluate vacant public buildings. It means that the result of evaluation proofs the building “useful” or “useless” by government. If the result is “useless”, government sells the building with reduction of demolition cost.

Announcement
Local authorities have priority to receive the information of vacant public building from government by “Accountant Law”. The ways of announcement are public tender, documents and asking directly. If there is no request for purchase from local authorities, government provides the information to public. The ways of announcement are public tender, Internet, local papers, asking the candidates directly and so on.

4 Case study

Government organized special meeting to promote sale of national property in 1999. They decided 157 ‘useful’ buildings for sale with land during 1999-2002; Local authorities bought 55, corporations bought 72 and individuals bought 30.

We inquired to some government, ex-owner of those buildings, and then we found 27 reuse projects. We selected 10 conversion projects as a case study among them that we could observe the project and interview with the buyers. The detailed information of that 10 conversion projects are as follows.

	Case-A	Case-B	Case-C	Case-D	Case-E
Buyer	Local authority	Local authority	Local authority	Local authority	Corporation
Ex-use (completion year)	Post office (1973)	Post office (1971)	National public office (1965	Office (1978)	Post office (1976)
New use (renovation year)	Public library (2003)	Public office (2001)	High school (1999)	Garally (2000)	Shop and office (2003)
Structure* / Stories	RC / 1 above	RC / 2 above, 1 below	RC/ 5 above, 1 below	RC/ two above	RC/ 2 above, 1 below
Site area	621sq.m	3239sq.m	4882sq.m	1104sq.m	3086sq.m
Total floor area (change)	551 (+136)sq.m	4059sq.m	7788sq.m	486sq.m	4888sq.m
When did you make a decision of new use?	Before purchase	Before purchase	Before purchase	After purchase	After purchase
Who did provide sales information?	Government	Government	Buyer asked to government	Buyer asked to government	Government
Who did propose this project?	Government	Local authority itself	Local authority itself	Local authority itself	Government and architect as buyer's business partner
Motives for purchase	Location and quality	Location, quality, scale and price	Location, quality, scale and price	Location	Location and quality
Renovation plan	Extension and better access with adjoining buyer's land	Clearance of exiting interior walls	Light renewal for temporary use	Light renewal for disabled pepole	Renewal of cellings for enlargement of existing
Renovation detail	[interior] Renewal of finish [facade] Renewal of finish [structure] Seismic reinforcement [equipment] Renewal of plumbings, Newly-built electricity and water [others] Renewal for	[interior] Renewal of walls [facade] Renewal of finish [structure] Seismic reinforcement [equipment] Almost newly-built [others] Addition of exteria stairs	[interior] Renewal of walls [others] Addition of exteria stairs and waterproofing	[interior] Renewal of finish [equipment] Renewal [others] Renewal for disabled people and waterproofing	[interior] Renewal [facade] Renewal of finish partially [equipment] Renewal of air conditioner [others] Addition of exterior stairs
Currency problems	-	-	Lack of space	Lack of space	Some vacant space on second floor

	Case-F	Case-G	Case-H	Case-I	Case-J
Buyer	Corporation	Educational foundation	Individual	Individual	Individual
Ex-use (completion year)	Post office (1982)	Training institute (1981)	Post office (1973)	Post office (1968)	Sanatorium (1970)
New use (renovation year)	Office (1999)	University (2002)	Detached house (2000)	Warehouse (1999)	Dormitory (2005)
Structure* / Stories	RC and S/ 2 above	RC / 3 above	RC / 1 above	RC / 2 above	RC / 2 above
Site area	1339sq.m	2751sq.m	511sq.m	864sq.m	1492sq.m
Total floor area (change)	1084sq.m	3654sq.m	401 (+104)sq.m	450sq.m	872sq.m
When did you make a decision of new use?	Before purchase	Before purchase	After purchase	After purchase	After purchase
Who did provide sales information?	Real estate intermediary	Buyer asked to local authority	Government	Real estate intermediary	Government
Who did propose this project?	Buyer himself and constructer as buyer's business partner	Government	Buyer himself and architect as buyer's business partner	Government	Buyer himself and constructer as buyer's friend
Motives for purchase	Location, quality, scale and price	Location, scale and price	Quality and price	Location	Location
Renovation plan	Light renovation as possible	Reuse 2 of 3 buildings and built a new building	Addition of second story	Very light renewal	Addition and better access with adjoining buyer's land
Renovation detail	[interior] Renewal of finish [facade] Renewal of finish [structure] Sheer walls [equipment] Newly-built	[interior] Renewal of finish [facade] Renewal of finish [equipment] Newly-built partially	[interior] Renewal of finish [facade] Renewal of finish [structure] Seismic reinforcement [equipment] Renewal [others] Waterproofing and insulation	Almost nothing	[interior] Renewal [facade] Renewal of finish partially [equipment] Newly-built air conditioner and renewal of plumbing
Currency problems	Almost vacant in second floor	-	Too large space	-	-

**RC; Reinforced Concrete, S; Steel Frame*

Table 1. Detailed information of case study conversion projects

Example 1; Case-C [Fig. 2 and 3]

This conversion is from government office to local authority's high school. The local authority requested government to provide the information of vacant buildings before this building became vacant. The reasons why the local authority bought this building were that it was hard to find enough large building in central area and it needed to open a new school for temporary use as soon as possible.

Figure 2. Façade

Figure 3. Interior of Case-E

Example 2; Case-E [Fig. 4 and 5]
This conversion is from post office to shop and offices. The buyer, a construction corporation, received the information of this vacant post office directly from ex-owner, post office government because they have been business partner. The scale and location of this building fitted the corporation's future business plan that they wanted to set a foothold in that area and contribute for its neighborhood. Therefore, the corporation bought and planned conversion project. He could find only one tenant for first floor before re-open. However he had a scheme of risk management. If he could not find any tenant for second floor, he planed to move their office to vacant second floor.

Figure 4. Façade

Figure 5. Interior of Case-E

Example 3; Case-K [Fig. 6 and 7]
This conversion is from sanatorium to dormitory. The ex-owner asked the buyer to purchase this building. The buyer had land next to this building by chance, and he planed adjoined this building to his land. Therefore the accessibility got much better and he could enlarge the parking and use the building more effective.

Figure 6. Façade and parking

Figure 7. Interior of Case-K

5 Analysis

We analyzed those projects, and found three factors, as follows, are important in conversion of public buildings.

Proposal of reuse building
It was natural for local authorities to reuse the buildings by law, such as Case-A, B, C and D. Government, as a seller, asked to buyers to reuse the buildings, such as Case-A, E, G and I. A third party played an important role in some cases. Architectural professionals propose the idea of reuse, such as Case-E, F, H and J.

Receive the information of vacant buildings
We found three types of how to receive the information of vacant buildings. First one is that the buyers received it after request for purchase vacant public building to government, such as Case-C, D and G.

Second one is that the seller asked buyers directly, such as Case-A, B and H. Third one is that real estate intermediary asked to buyers, such as Case-E, F, I and J.

Risk management
The demands about building location and scale were different between buyers. In Case-E, if the buyer could not find any tenant for vacant floor, he planed to move their office to vacant second floor as risk management. Some conversion projects are subsidized by government that grant for conversion projects to public use, such as Case- A, B, C and G.

Value-up plan
If the buyer owned the land next to vacant public building, the buyers created a new value, better access and enlarge parking space etc., to exiting building with adjoining buyers land, such as Case-A and J.

6 Conclusions

We found following three problems of how to promote reuse of existing buildings.

Provide information to public more positive

When the buyer is corporation or individual, they tend to get the information of vacant public building accidentally. On the other hand, national government provides the information to every local authority as buyer. It is natural for local authorities to reuse the buildings. The government as seller should provide the information more positive and make the buyers can find suitable building more easily.

Seller should request to buyers to reuse the buildings

If the evaluation by real estate appraisal proves vacant building useful, the building owner can sell it with no reduction of demolishing cost. Buyers can plan reuse project because of the proof. Therefore, the proof of building value is a profit for both of them.

Create a new value to existing buildings

The buyers created a new value to exiting building with adjoining buyer's land in some cases. A lot of vacant buildings demolished and turned to parking in local cities in Japan [Eguchi *et al.* 2005]. Therefore, this kind of design can make more chances to reuse the vacant buildings.

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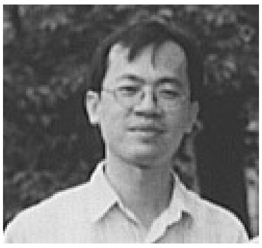
The Architecture of Computational Design System for Capacity Design Methodology



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KEYWORDS

design theory, Open Building, CAAD, capacity design methodology

1 Introduction

The capacity design methodology (CDM) for the built environment relies on two important concepts: the separation of support and infill; and the use of levels. The concepts are taken from Open Building, a design theory and method developed in Holland in the early 1960s. Originally known as the SAR methodology, it is characterized as being a rigorous way of dealing with the issues of design flexibility and design variations.

Based on our previous studies, the data structure of unit analysis as well as the six analytic operations of capacity design methodology has been discussed (Lin and Wang, 2003). Type analysis determines the common spatial features of a specific built form and provides the knowledge base for the methodology. It defines the design domains when applying the CDM. Type refers to the spatial form rather than the functionality. Table-1 shows the relations between the other five operations and the concepts of support and infill. Each analysis comprises several procedures that depend on the specific content at each environmental level. Those analyses will be used to define the core of a method-specific design assistant: a computer-aided architectural design (CAAD) system in which the methodology will be embedded into its design process.

Concept	Support: *spatial form*	Support: *material*	infill
Operation	Zoning analysis	Structure analysis	
	Sector analysis	Facility analysis	Unit analysis

Table 1: Concepts of the capacity design method and applicable analysis

As the pilot study toward building the method-specific CAAD system, the aim of this research is to establish the architecture of computational design system which embedding certain design methods. The first step is implementing the capacity design methodology as the instance of such generic architecture of design system.

2 Abstract conceptual model

According to the data-processing viewpoint, the most basic architecture of a CAAD system is composed of operands and operations. On the abstract conceptual level, the following topics will be studied. First, the fundamental data types and necessary design patterns for building the CAAD system should be analyzed and established. These built in types and patterns define the basic data objects and the communicating interfaces between objects. Secondly, the possible generic forms of algorithms that include testing the capacity of spatial support layouts construct the functional part of the computational design system. Furthermore, the architecture of CAAD system should be adaptable to integrate the data and algorithms while being applied to the different environmental levels in the design methodology. (Figure 1)

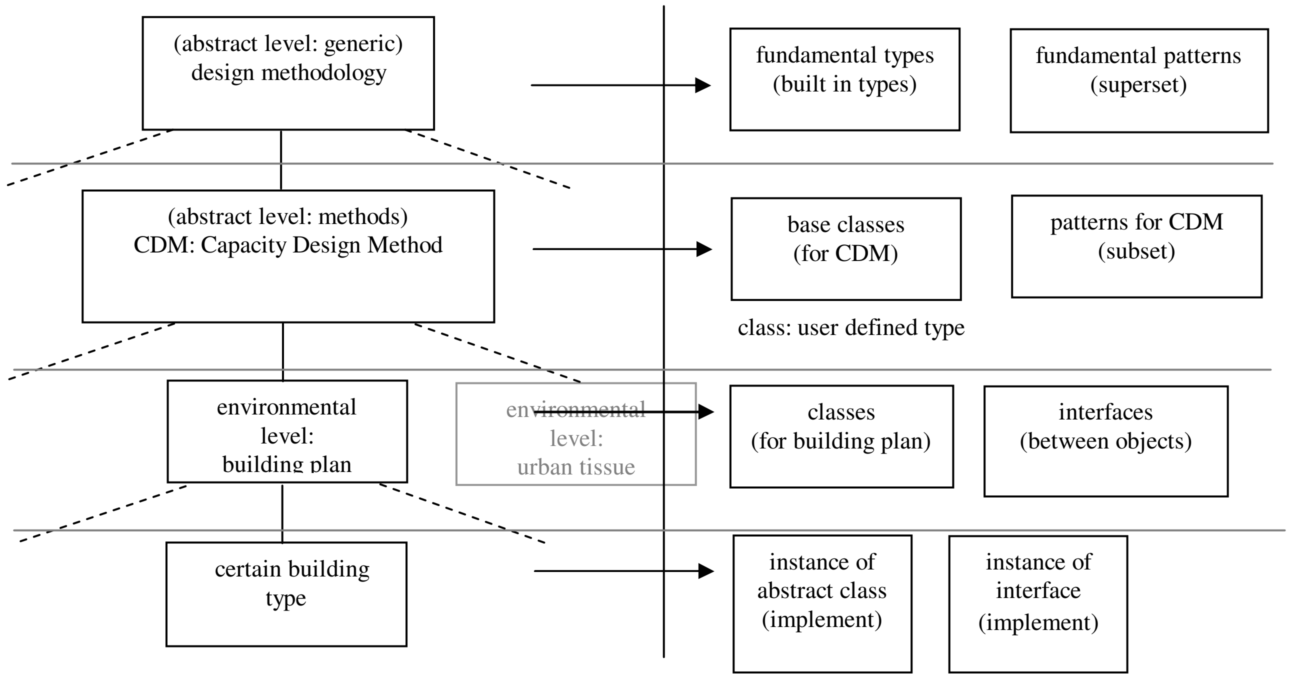


Figure 1. The levels and scope of the computational design system

3 Architecture for CAAD system embedding design method

The software structure is component-based which means the objects, as pieces of programs are reusable, and could be assembled into larger modules. On the abstract conceptual level, the system architecture is the more generic the better to be suitable for design methods. Thought the essence of design method has not been discussed in details here. Based on the studies of capacity design methodology, we divided the system into five categories:

(1) Level: the level defines the scope that the thematic design method was applying to. According to the capacity design methodology, the environmental levels include interior, building, urban tissue and urban district. However, there exist other hierarchical views of architectural design concerning design process, and constructing procedures.

(2) Operand: it is the data that the design method deals with. For example, they include but not limit to component, element, unit, plan, and street block.

In the architectural design domain, there are two types of arrangement in brief: the arrangement of spatial units, i.e. rooms, buildings, parking lots, green etc., and the composition of elements that including the columns, beams, and windows etc. The former facilitates to find the ideal spatial layouts, and the latter emphasizes on exploring the constructional aesthetics of architecture.

(3) Coordinate: for positioning objects in space. For example, the Cartesian coordinate system, modular grids, and zones and sectors which are the spatial form of support in capacity design methodology. Importantly, the zone distributions can reflect the characteristics of certain dwelling type as well as urban fabric.

(4) Algorithm: for validating the layout arrangements. In general, the types of algorithms include checking the adjacency, the overlaps and leftovers between spaces, and rotating or mirroring the objects.

(5) Interface: for being a protocol of communication between objects. In order to systematize the CAAD architecture, several types of interfaces should be provided: for connecting procedures, for passing the values, for providing the end user to input the instructions, for meeting the requirements with algorithms.

These five categories could be seen as a set of toolboxes (Figure 2). As an instance, the designer selects the tools from each category to build up his CADD system, which might be capable of design method. Consequently, the system could be refined on the strength of designer's experience and knowledge.

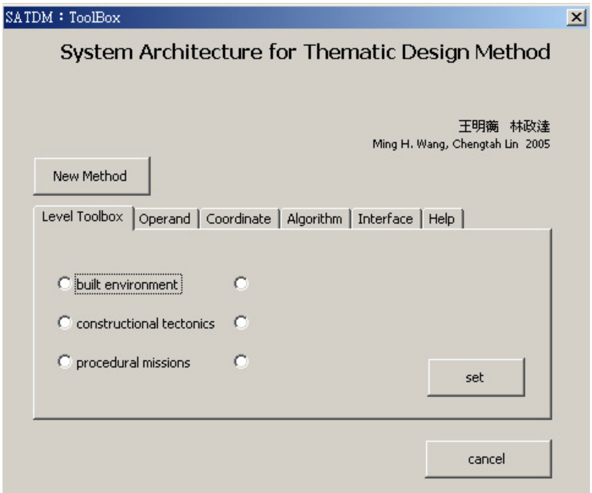


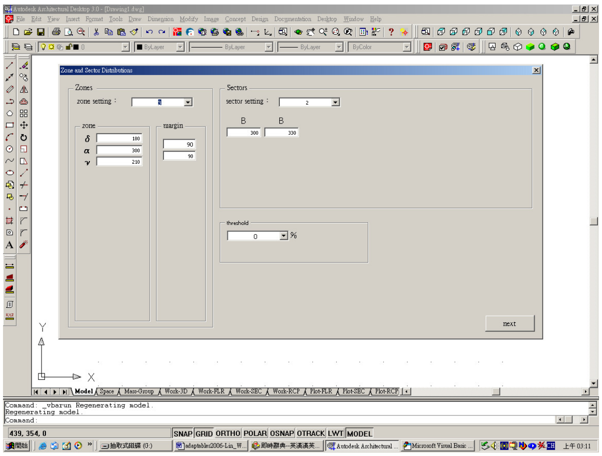
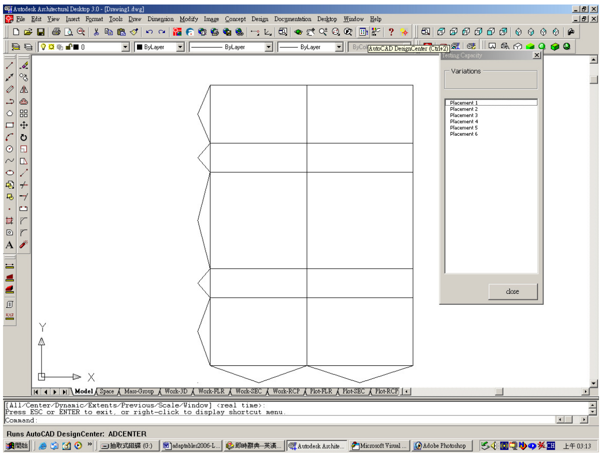
Figure 2. The architecture for building the CAAD system embedding design method

4 Demonstrations of computational design system embedding CDM

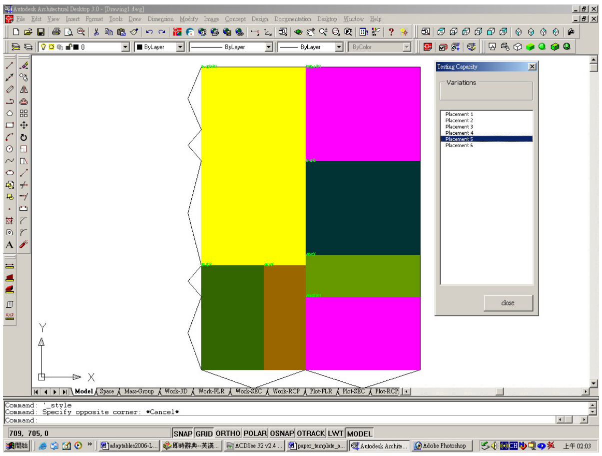
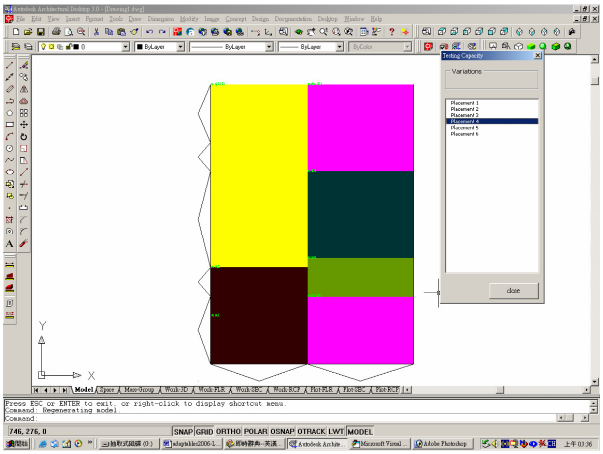
Capacity design methodology derived from Open Building and Thematic design method is a rigorous way to explore the variations of certain spatial type with the flexibility of infill and support. In addition, capacity design methodology could be applied to solve spatial problems in the different levels of built environment.

On the concrete level, a primary structure of computational design system for capacity design method has been implemented and demonstrated. The purpose of building the system is obvious. It's not only for reviewing the methodology, but also for extending the CAAD system architecture for more design theories.

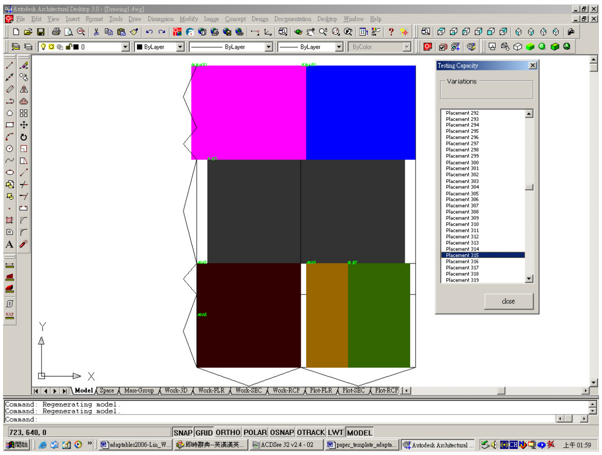
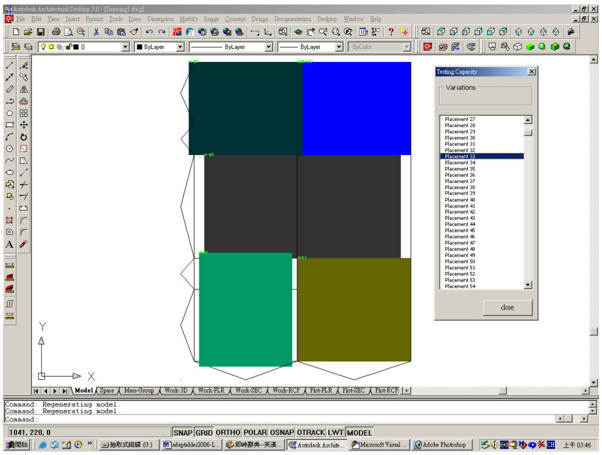
At present, the primary prototype of the CAAD system with CDM embedded has been established. There are mainly three parts: setting the zones and sectors, database of diverse units, and the algorithm for testing the capacity (Figure 3).

3.1.zone and sector distributions 3.2.zones and sectors as the support

3.3.testing capacity: variations with strict constrains

3.4.testing capacity: variations with loose constrains

Figure 3. The demonstrations of CAAD system embedding CDM

5 Conclusions

In the first phase to build the CAAD system for thematic design methods, we have implemented a preliminary model to generate flexible plans according to the capacity design methodology. At present, we are trying to apply the system on urban fabric level. However, there are still lots of tasks regarding building up the specific CAAD system remaining to be examined carefully and comprehensively. For example, the interfaces are designing for a designer friendly more than for a computer user. The system like a design assistant provides the information that the designer just wants to know rather than hassling the user to fill out forms and digits during the design process. The system is capable of the domain knowlegde of architectural design, not only the mathematic formulas for functions.

Therefore, the design methodology which could be embedded into the CAAD system should be able to characterize in four aspects: 1) it has to restructure the design program into well-defined problems; 2) the computational mechanism is adaptable while applying in different scopes of design task; 3) based on the previous requirement, suchlike design methods adopt reusable algorithms as many as possible; 4) there are qualifications to verify the design outcomes of good quality.

Acknowledgments

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The Adaptability Study for Barrier-free Dwelling

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KEYWORDS

Adaptable building, Autonomous Change, Assisted mobility, Independent Living, Barrier-free.

Paper

1 Introduction

Considering the transition of life styles, from one's prime toward old age, or, from physically fit toward handicapped, the needed effectiveness of mobility and activity at home signifies the demand of a dwelling state that allows easy and autonomous changes by the dwellers. In everyday life, people experience temporary low functional ability when they get sick, and pregnant women often are restricted from certain activities with different conditions. These circumstances draw attention of product designers with universal design intent. Moreover, recent development in the area of smart environment provides us the alternative of conceiving the building with sensitive, responsive and adaptive way of interaction (Chiu 2005). With independent living in mind, when life style changes, the mechanics of our ordinary day also changes. Starting from the intent of integrating construction systems with barrier-free design, the mechanics of the application of assisitve devices and smart features in the dwelling area points out a brand new prospect for the research and development of adaptable building. By bringing together the ubiquitous computing based context-aware environment and the adaptable barrier-free building design, an environment that support high quality of living and autonomous change of space configuration thus further enabled. The prospect of adaptable barrier-free dwelling might not be the exact match of the 'dwelling is building' (Habraken, 1961) ideal, but certainly an onset of the "natural relationship".

The following sections first discuss the functional ability development of human body, and then exhibits a four-level categorization of assistive devices to provide a systematic order of their usage according to the scale of the needed support. In section four, the mechanics of the ordinary is discussed to provide a new perspective of building structure arrangement. In section five, a conceptual structural configuration for adaptable barrier-free dwelling is proposed.

2 Functional ability development of human body

Sloane (1992) suggests a useful rule of thirds for considering functional declines in older people: 1/3 due to disease, 1/3 to inactivity (disuse), 1/3 caused by the aging process itself (senescence). If we perceive life as a process spanning a continuum stretching from birth to death, popular wisdom suggests that most people perceive a pattern of aging similar to the one shown in Fig. 1 grey line (Pirrkl 1994), which illustrates the four phases in life span. (1) Growing and functional improvement, A-B: During this phase, both mind and body develop to prepare us for the challenges awaiting us in our adult years. (2) A constant, nearly level period, B-C: It is underscored by responsibility and accomplishment, and characterized by freedom of choice, independence, and self-sufficiency, often lasting well into retirement. (3) A period of functional decline, C-D: Functional decline induced by impairment in our motor capacity and perception produce a corresponding lost in our ability to perform the activities of daily living (ADL). (4) A rapid decline following the onset of aging manifestations, D-E: As our activity level drops, our bodily systems begin to atrophy, accelerating the deterioration of our biological processes until death occurs. After reaching point C (CSP), we depend more and more on environmental support to compensate for the progressive decline of our functional ability. Such support, however, becomes increasingly critical during this phase, enabling many persons to remain independent and perform their normal ADL (Pirrkl 1994). Nevertheless, the dynamics of our life span concerns us as well as the exigencies of our disabilities. The ideal of adaptable building in a sense provides alternatives for the conception of better suited environment, which also means a raise of functional ability for the dwellers (Fig. 1 green line).

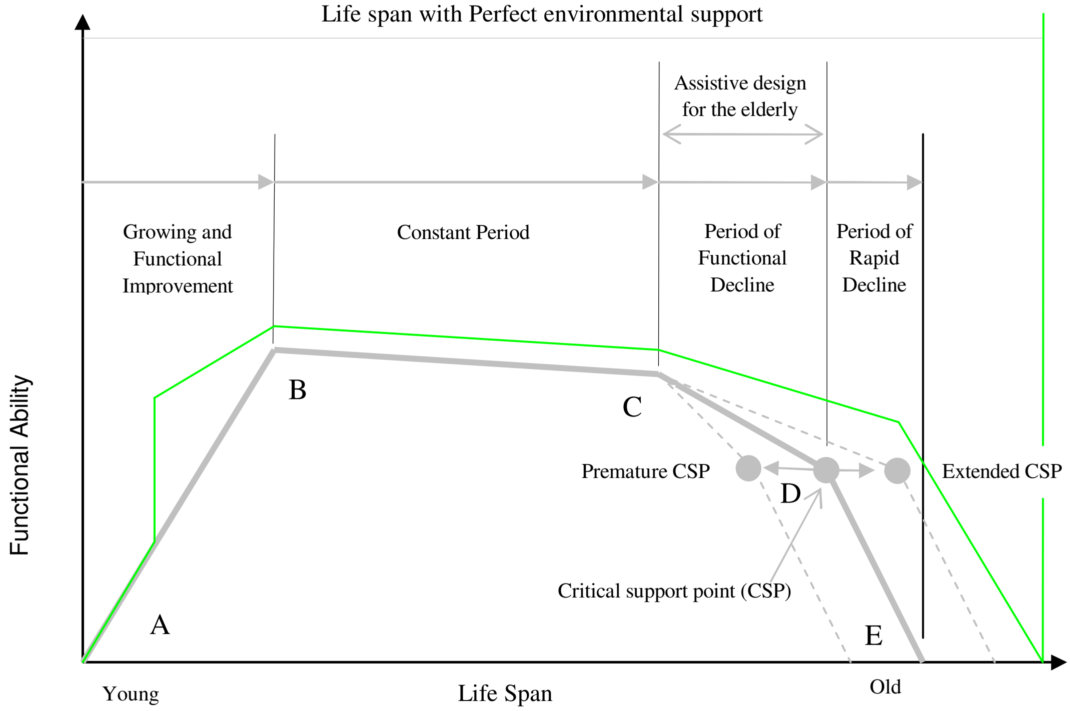

Figure 1. Four-phase life span model (grey line), and

Ideal model of four-phase life span with perfect environmental support (green line)

3 Rationalization of the usage of assistive devices

A wide range of specialized "supportive devices" intended for the elderly are marketed for use during phase C-D (Fig. 1). They include a variety of reachers, can openers, electric powered seats, walkers and wheelchairs with carry-on accessary, etc.. Table 1 exhibits a four-level categorization of assistive devices according to the scale of the needed mechanical support. The resulting system provides a control relationship that can be referred to for the construct of adaptable building configuration (Fig. 5) in the future research and development as well as the new breed of assistive devices design. The assistive devices are categorized as Level 1: Self-helping devices and daily living aids, Level 2: Light furniture and accessories, Level 3: Light reinforcement for adaptability, Level 4: Heavy-duty reinforcement for adaptability.

Table 1. Four-level categorization of assistive devices

	Assistive device name	*System category*	*Spatial attributes, mechanical consideration and adaptability prospect*
1	Reacher	Level 1: Self-helping devices and daily living aids	Need convenient placement. User of reacher might experience extra stress for the extra length and weight imposed by such device. The extra effort needed could induce an imbalanced body posture. Support for standing position might be needed. Direct support of the device would be ideal.
2	Can opener	Level 1: Self-helping devices and daily living aids	The user of this device maybe in standing or sitting position. Need to consider the effort required to handle it. Direct support of the device is necessary.
3	Electric powered seat	Level 2: Light furniture and accessory	Flexible spatial requirement, need direct and firm support. Preferably on surface that provides good friction.
4	Walker and wheelchair with carry-on accessary	Level 2: Light furniture and accessory	Strict spatial requirement, need extra space and convenient positioning of the carry-on tray or multi-pocketed bag.
5	Walking aids	Level 2: Light furniture and accessory	Flexible spatial requirement, need storage space and extra space for convenient positioning
6	Electric powered toilet seat	Level 3: Light reinforcement for adaptability	Fixed spatial requirement for dynamic operation. The user of this device possesses very little motor capability. Need to consider the position that the attending nurse or family will usually take to reduce effort needed.
7	Retractable kitchen cabinet	Level 3: Light reinforcement for adaptability	Fixed spatial requirement for dynamic light-operation. This device can reduce effort needed to reach upper cabinets without others'help. It also provides versatility for space configuration.
8	Height-adjustable electric powered kitchen sink	Level 3: Light reinforcement for adaptability	Fixed spatial requirement for dynamic light-operation. It also provides versatility for space configuration. The knee space underneath should be kept clear of the movement of the sink.
9	Chair lift	Level 3: Light reinforcement for adaptability	Fixed spatial requirement for dynamic heavy-operation. Its an easy way to solve the vertical transportation at home. The only requirement would be the width of stairway.
10	Handrails and Grab bars	Level 3: Light reinforcement for adaptability	Handrails and grab bars installation is a must for all spaces with level changes. The installation should start with planning on comprehensive layout of handrails and grab bars. The structural reinforcements should be carefully examined.
11	Hoist and Sling systems	Level 4: Heavy-duty reinforcement for adaptability	Cross space requirement for dynamic heavy-operation. The hoist system is very important for people who need to attend to patients with little motor capability. It can effectively reduce stress in assisting the disabled to move from place to place, and help positioning them to proceed on daily hygiene and rehabilitation exercise. The related spatial issues can be extended to the innovation of building system.

4 Rethink the mechanics of the ordinary

It is quite often that people attribute the spatial barriers to the obstructions encountered on the ground, and yet, the installation and the use of assistive devices are arranged mostly on the ground or against the wall where the devices could easily constitute new barriers. On the other hand, most upper half of building structure are left unused which give adaptable building design an open field to develop useful supports for mobility, activities and smart devices. For example, by turning the entire set of furniture upside down in a flat, the floor will be left for a barrier-free environment (Fig. 3). Vice versa, the ceiling of a regular flat is almost empty and available for concepts that could provide adaptability in a building that support barrier-free requirements (Fig. 2 and 4).

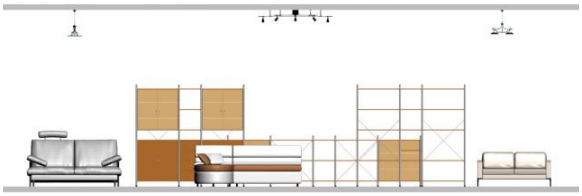

Figure 2. Normal setting of a flat

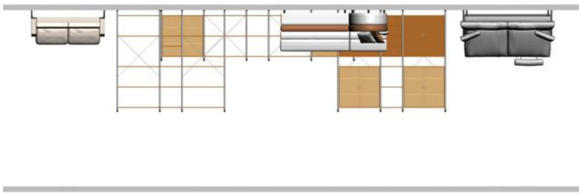

Figure 3. Upside down setting of a flat

5 Conclusion: the future development of supports for adaptable barrier-free dwelling

The conceptual configuration for adaptable structure and smart environment proposed here may look familiar to most people, especially those work in factories (Figs. 4 and 5). Fig. 5 exhibits a four-layer configuration to accommodate the widest range of adaptability needs. The structural configuration includes 1. main structure: to provide root support as a rigid body, 2. adaptable layer: fixed to main structure, capable of accommodating various scale of loads with adaptable mechanism, 3. adaptble feature support: provide two-way adaptable connection with special mechanism for different adaptable features, 4. adaptable features: functions and mechanisms provided according to assistive needs. The mechanics of the ordinary and smart technology play central role in developing an ideal environment. By incorporating all spectrum of assistive needs in one system (transgenerational design), the use of assistive devices becomes universal, instead of being proprietary for the disabled. This strategy may as well lift the long hated "negative self-labeling". According to Moos, Lemke, and David (1987), "leads older persons to view themself as sick or frail," and expose them to such psychological and social stress as frustration, lack of confidence. With independent living in mind, the premise of this research is to originate the integration of adaptable spatial configurations and assistive technologies by applying innovative barrier-free building concepts. The standardization of such structure would need much more in-depth work including theoretical discourse and cross disciplines cooperation.

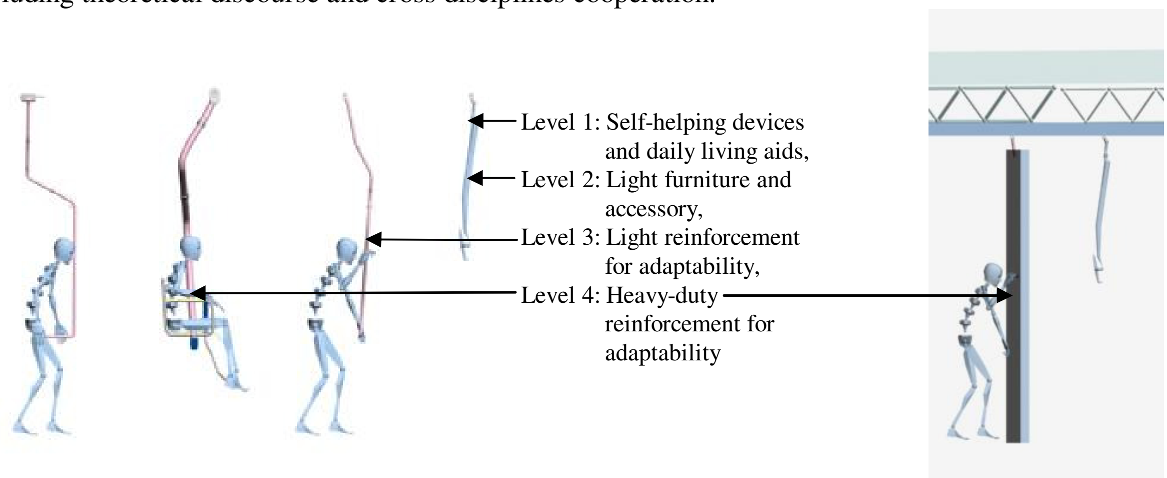

Figure 4. Examples of adaptable features for all spectrum of assistive needs

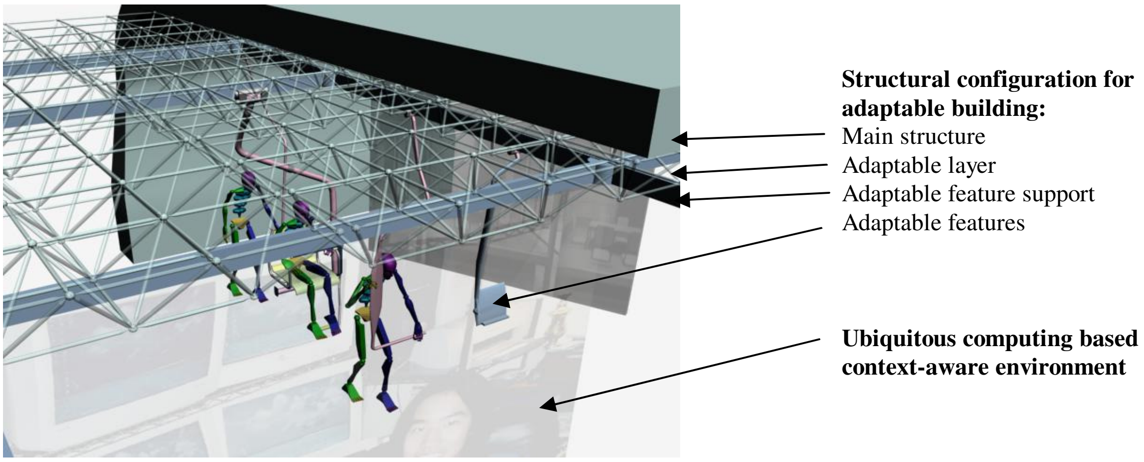

Figure 5. Conceptual configuration for adaptable structure and smart enviornment

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A Study on the Continues Customization of an adaptable housing by KEP System

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KEYWORDS

Housing, Adaptability, Flexibility, POE, Customization, Industrialized components

Abstract

This research studies how each unit of apartments, which were equipped with movable partitions and movable storage units, has been transformed by the residents since it was built more than 20 years ago. The purpose of this research is to verify how the design ideas to respect the individuality of the residents and the changes of living environment in time have been efficiently employed for the life of each resident. The resident's family structures have changed since they started to live in the estate in 1982, and the new tenants have moved in. Therefore, the needs to change the position of partitions, the specification of equipment apparatus, etc. have occurred, and remodeling construction has been carried out. We studied the movable partitioning system has been used by the residents as it was planned originally. We visited all the 184 residences individually, and when it was allowed to come in to the units, we observed the actual changes of each dwelling unit and interviewed why and how they changed their units. This paper reports the outline of results of our studies, especially on the changes of the room arrangement (layout changes).

1 Research purposes

Since 1970's till present, the multifamily housing in Japan was paid more attention on its quality than quantity through the reflection of mass housing. We investigated the housing estate “Tsurumaki -3” of Tama New Town in the suburb of Tokyo. It was the first experimental project, named KEP (Kodan Experimental housing-Project) which Japanese Housing Corporation started in 1973 in order to research and develop the flexibility and adaptability of housing. The most important object of our research is to investigate how the original design concepts affected to the residents’ life in these 23 years since the estate was built in 1982. This paper tries to find out the effectiveness of the movable building elements with flexibility and adaptability by Post Occupancy Evaluation (POE).

2 Research methods

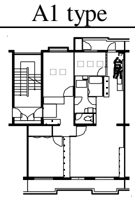
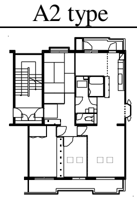
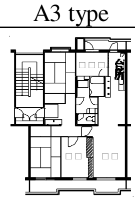
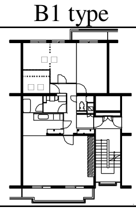
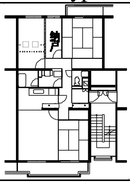
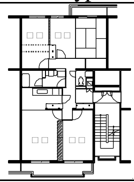
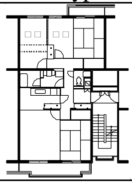
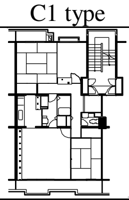
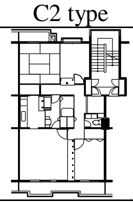
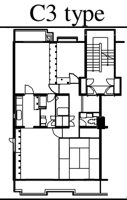
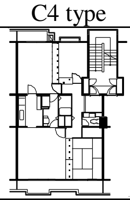
At first, we developed the questionnaire survey to the residents. When we were allowed, we took the pictures of the interior layout of each unit. We asked how the residents adapted the room arrangement by changing the position of KEP movable partitioning system and/or conventional partitioning system. Similar investigations were performed in 1982 just after the completion of the estate and also in 1995. We analyzed the transformation of the room layout of each units through 23 years by comparing the results of the researches in 1982, 1995 and 2005.

3 Results of the survey

The answering rate of the questionnaire (the number of the answers / the number of housing units in the estate) was 48.4%. There are three types of plans for units in the estate; A, B and C type. The A type can be subdivided into A1 - A3 types, the B type into B1 - B5 types and the C type into C1 - C4 types, in all 12 types for all units. The C type are not equipped with the KEP movable partitioning system. We did not studied B3 type because it has not been studied in the preceding two researches. Table 1 shows the plan of each 12 types and the location of movable partitioning system in each unit.

The residents' awareness for permanent residence has been changed in these 23 years. In 2005, 26.2% of the residents are 50's and 17.2% are in 60's. A household with child whose age is over 18 is more than 40% of all the households in the estate and a household without child is 34%. Aging of residents and maturity of a family has proceeded in the estate. The awareness of permanent residence has increased and 62% of the household think that they wish to live in their units permanently. The residents came to be conscious of their housing units as their permanent home by aging.

Table 1. The plan of each type and the location of the movable partitioning system (mentiond below of each plan)

A1 type	A2 type	A3 type	B1 type
			
Multi purpose room-Kitchen, Multi purpose room-Private room	Living room-Private room	Multi purpose room-Kitchen, Living room-Private room	Private room-Storage
B2 type	B3 type	B4 type	B5 type
	Not studied		
Private room-Storage		Private room-Private room, Living room-Private room	Private room-Private room
C1 type	C2 type	C3 type	C4 type
			
NA	NA	NA	NA

4 Change of the room arrangement

4.1 Change of the room arrangement according to the three types

Both the KEP method and the other traditional construction methods were used for the changes of the room arrangement. 29.5% of households {26 units /88 units (the number of the effective answers)} experienced some changes in their room layout. 38.8% (14 units /36 units) of A type units and 47% (9 units /19 units) of B type units have carried out some room layout changes. On the other hand, only 9% (3 units/33 units) of C type units, those do not have the movable partitioning system as A and B type units, have carried out room layout changes. In most cases, the room layout has been changed in order to make the living room or private room larger and in many cases the households whose children have left home experienced the layout changes. This seems to be caused by the characteristics of KEP system which allow a living room or a private room to become larger by changing the position of the partitioning wall and/or partitioning storage walls separating two rooms. It also seems to be caused by the fact that, in 2005, the children of many households in the estate have left their homes already.

4.2 An example of the room arrangement changes in A type unit

Figure 1 shows the example of the change in the layout of a A (A3) type unit, who has lived here for 23 years since 1982. The diagram expresses the use of a room, location of movable partitioning wall, family member attributes (M:adult man, F:adult woman, m:child boy, f:child girl) and the age of them (number shows age). In 1982, this family had children whose age were before entering school. Afterwards children entered schools, finished their schools and left home. In 1995, the mother has started to teach playing a piano at home and moved the partitioning storage walls to connect living room with adjoining private room to make large single room. This example shows how KEP system has adapted to the changes of the individual needs.

Figure 1 An example of the room arrangement changes in A type unit

4.3 An example of the room arrangement changes in B type unit

Figure 2 shows a example of the layout changes in B (B4) type. This family also has been living in this unit for 23 years. In 1982, their children were at school age. Their children finished their schools and left home afterwards. At the time of children's independence, this family moved the partitioning storage walls and connected the living room with the private room to make it larger.

Figure 2 An example of the room arrangement changes in B type unit

5 Analysis of the room arrangement changes in each unit

5.1 Room layout changes to make a living room larger

The residents can make their living rooms larger by changing the position or moving away the movable partitioning walls and/or the movable partitioning storage walls. 10 out of 12 families made their living rooms larger by using KEP system, another 2 family used a conventional construction method. 9 out of 12 families started to live in this estate in 1980's. 8 out of 10 families who used KEP system began to live here in 1980's. Many families have made their living room larger mostly at the time when their children left home and they got an extra room in their unit.

In the 1995 survey, many examples were observed that families changed the layout of their unit when they came to live in this estate. At the time, children were still young and at the ages before entering schools in most family. They connected their living rooms with the adjoining private room in order to make a large single room.

5.2 Room layout changes to make a private room larger

The residents can make their private rooms larger by moving the partitioning wall and/or partitioning storage walls, as they can make the living room larger. 8 of 11 units which changed the layout have used the KEP partitioning system. Many of the residents who made their private rooms larger were those who came to live in the estate after its completion in 1982. Many of the residents changed the room arrangements to have enough space for their children who began to go to school or to use the children's room in another purpose when their children left home.

The 1995 survey pointed that many families enlarged the private rooms in order to fit the rooms arrangement for their way of living at the time when they came in, not to fit it according to the changing needs after they began to live.

5.3 Layout changes to increase the number of rooms

In this paper, we define "the layout changes to increase the number of rooms" as the reinstallment of KEP movable partitioning walls and/or partitioning storage walls which had been once taken away. We found two examples of them in 2005 survey. One family which came in to this units by reinstalling the partitioning walls which were dismantled by the previous residents. The other family dismantled once and reinstalled afterwards the partitioning walls and partitioning storage walls as their children grew older.

The survey in 1995 pointed that the number of children's rooms increases as children had grown and resulted the increase of total number of rooms in a unit. Many of the families which changed the room arrangements have children whose ages were high-teens.

6. Conclusions

We studied the post occupancy changes of the housing units which have KEP movable partitioning system. As children grew, and mostly at the time when children left home, many families used the KEP system to adjust the room arrangements to fit to their ways of life. We may be able to say that KEP system has worked very well as it was planned in these twenty three years. We heard from the residents through the interviews that some of the mechanical parts of the movable partitioning system has become rusted and did not work properly for the residents to move and/or reinstall by themselves. Some of the residents think the sound insulation performance of the movable partitions are not good enough because of the detail of the joints between the partitions. They think it does not make sense to compensate the sound insulation quality of the partitions those had been moved only once in a decade. The residents' experiences and comments suggest important topics for us to research further.

Acknowledgments

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Improvement and Development of Infill System for Residential Open Building in Korea -Focused on the Interior Movable Partition Wall-

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KEYWORDS

Residential Open Building, Interior Movable Partition Wall, Infill System, Flexibility

1. Introduction

1.1 Background

In Korea, the housing supply ratio was over 100% in 2002. About 300,000 to 400,000 housing units are newly constructed every year and multi-family housing takes over 90% of them. Most multi-family housing has a bearing wall and slab system that resulted in monotonous spaces, insufficient flexibility, and difficult remodeling. In order to cover these problems, Residential Open Building has been searched for recently.
A lot of studies on residential Open Building had been carried out from the end of 1990s in Korea. The first experimental residential Open Building was constructed in Korea Institute of Construction Technology (KICT), sponsored by Government, in 2000. Recently, the basic design for the second experimental residential Open Building has been completed for further studies on Support and Infill technology and policy that will lead on the technical development of residential Open Building in Korea.
In association with this trend, "Housing Performance Indication System" in order to represent performance grades at the design stage has been forced as a national law since January 2006. And as a new provision "a Special regulation for the Preparation of Remodeling", which grant some incentive in case of any structures that make remodeling much easier is adopted into multi-family housing, will be established in May 2006.
As a result, with relation to Support system, the bearing wall and slab system of multi-family housing has a trend to be changed in to the frame structure. And various housing components for Infill have been developing.

1.2 Methodology and Scope

This study is to improve and develop a component of Infill focused on movable partition walls that can meet structural system changes in multi-family housing.
Mainly, two directions are shown in this study. One is an improvement of movable partition walls in order to utilize them from office use to housing use. The other is a development of movable partition

walls for a residential use. After carrying out a fundamental study centered on domestic/overseas cases and reports, the improvement and development conditions of the movable partition walls were established including size and materials, joint design and performance such as an easy installation, sound insulation and flexibility.
Some existing partition walls were selected for adaptation into dwelling houses. Through analyzing the existing partition walls, unnecessary or complementary parts were discovered. Based on this analyzing, improvement types had been proposed and they were manufactured by factory-made.
For a development of new partition walls, new installation systems and joint methods for movability in spaces were devised and made up. After that, development types were tested for sound insulation in acoustic laboratory in KICT.
Both development and improvement types were examined for installation inside experimental residential Open Building in KICT.

2. Current Status of Interior Partition walls in Korea

A) Current Status of interior Partition Walls in Korea's Multi-Family Housing

Current partition walls such as gypsum drywall system, ALC block, ALC panel and extrusion concrete panel have been partially installed between the children's bedrooms or between the bedroom and living room in multi-family housing consisted of bearing wall and slab system. Especially, gypsum drywall system consisted of steel stud and gypsum boards is used representatively in multi-family housing.
In Korean residential buildings, partition walls are installed on concrete slab first and set-up Ondol-layer(floor heating system of Korea), which is consisted of lightweight foam concrete and heating pipes, for floor finishing. And then, ceiling installation is followed. This construction method causes the partition walls to be fixed walls and it prevents them from having changeability in spaces for user’s needs. When replacement or remodeling of these partition walls are needed, the Ondol-layer and the ceiling must be removed causing damages to structures or finishing, waste producing and making construction difficult.
Since the adoption of various structural systems such as frame, flat slab and composite structure at the beginning of 2000s, the needs for the development of various partition walls have been increasing. Nevertheless, this development has been stagnated because of the lack of understanding about Infill components, new structural systems and high construction cost.

B) Current Status of interior Partition Walls in Korea's Office

There are two types of partition walls used in offices. One is a fixed type that adopts the method of fixing panels into guide rails installed on floor finishing and ceiling. The other is a movable type that consists of a hanger, trolley and guide rail for space changes in banquet or exhibition halls.
Also, various finishing materials such as steel sheets, wooden sheets and CRC boards, and installation systems are mass-produced, and assembly is easily carried out through partial cutting and on-site assembly.
To change these types into multi-family housing use, there are some problems such as difficulties in replacement, fixing methods with anchor, a low performance for sound insulation and unsuitable finishing materials for housing.

3. Suggestions of Movable Partition Walls for Residential Open Building

A) Basic conditions of Movable Partition Walls for Korean residential Open Building

In order to apply movable partition walls for Korean residential Open Building, preconditions on the performance of the partition walls have been established based on researches on that wall system. The basic performances are the following: easiness for assembly, constructability, movability according to user’s needs and life cycle, easiness for remodeling, sound insulation performance between rooms,

impact resistance, easy wiring inside the wall or using a component that can install wires inside it (e.g. baseboard or cornice box) in advance or on-site and easy reusability.
The movable partition walls for dwelling units are made up that panel materials are attached to a steel frame or wood frame. Assembling work of movable partition walls produced at a factory is a very simple and installation process of them on site is minimized, therefore the volume of waste is also small. As for the size, a multiple of 300mm in accordance with the module of Korea's multi-family housing and a multiple of 100mm for the direction of height have been established as the standard. The weight is assumed at about 40Kg~50Kg for easy handling by two people normally. The partition wall is divided into a panel part and an adjusting part. The adjusting part is in charge of adjusting the height and fixing the wall system. And the panel part is responsible for sound insulation, impact resistance and wiring installation. Whenever space arrangement occurs, wiring work is devised to be able to change easily inside the movable partition walls or components such as a baseboard or cornice box.

B) Description of Movable Partition Wall Types

The movable partition wall was processed in two directions: system improvement of the existing partition walls and the development of new movable partition wall.
The existing partition wall can also be used in residential Open Building by changing installation system and improving sound insulation performance. Although the existing partition wall materials and arrangement method of them was used, sound absorbing materials were filled inside the walls for improving sound insulation performance. And partial changes of installation system were made.
The development of movable partition wall mainly focused on performance aspects of the partition walls especially on movability and sound insulation. According to these performances, it was composed of lightweight wall materials and installation system (e.g. adjuster bolt or gear).
With this improvement and development types, installation experiment was conducted and applicability was examined.
Five types were suggested. Three types of them were improved from the existing office use and two types were developed. The following table shows the details of these types.

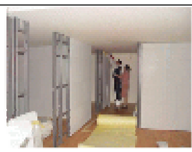
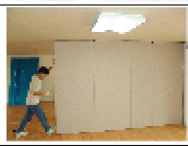
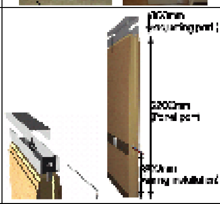
Division		*Wall material*	*Size*	*Installation system*	*Figure*	*Remarks*
IMPROVEMENTS	Type1	Plywood 7.5mm + Steel frame +Rock wool 50kg/m³,50mm+Steel frame+ Plywood 7.5mm	W1200/900mm× H2200mm× D100mm	Adjuster Bolt		Before: Low partition After: Attached a adjuster bolt on steel frame
	Type2	MDF 9mm+ Plywood 7.5mm+Polyester 24kg/m³, 30mm+Plywood 7.5mm+MDF 9mm	W1200/900mm× H2200mm× D83mm	Jack		Before: Installed trolley and guide rail After: Removed trolley and guide rail/ Changed height adjusting part
	Type3	0.8mm Steel plate + Rock wool 50kg/m³,50mm +0.8mm Steel plate	W900/600mm× H2200mm× D60mm	Adjuster Bolt		Before: Fixed partition wall with screw After: Attached dual lock (adhesive tape) on ceiling and floor guide rail / Filled sound absorption material
DEVELOPMENTS	Type4	MDF 9mm 2ply+Wooden Frame +Polyester 40kg/m³, 50mm + MDF 9mm 2ply	W1200/900/ 600mm× H2200mm× D100mm	Adjuster Bolt		Patent application
	Type5	MDF 9mm 2ply+Wooden Frame +Polyester 40kg/m³, 50mm + MDF 9mm 2ply	W1200/900/ 600mm× H2200mm× D100mm	Gear		Patent application

Table 1. Improvement and Development types of movable partition wall

C) Movable Partition Wall's Sound Insulation Test and Result

Sound insulation test was carried out at acoustic laboratory in KICT using the test method of KS F 2808:2001, and the sound reduction index was measured. Type 4 among proposed wall types was chosen for Sound insulation test. It was made into another four types with changing material arrangement of the movable partition walls except installation system and examined their performance. There are no sound insulation standards for partition walls used in households. However, FHA(The U.S. Federal Housing Administration) recommend STC for between dwellings is from 35 to 55[1]. According to Figure1, STC of movable partition walls was measured STC39,41,42,43. Even though sound insulation standards are not existing in dwelling units, it was estimated that the movable partition walls are usable according to comparison with the STC suggested by FHA.
The types of movable partition walls used in the sound insulation tests are as following.

Type4	1st Test (Type A)	(MDF 9mm + air layer 65mm (Square timber 65mm, Polyester 40kg/㎥, 50mm) + MDF 9mm, total thickness: 83mm
	2nd Test (Type B)	(MDF 9mm 2 ply + air layer 65mm (Square timber 65mm, Polyester 40kg/㎥, 50mm) +MDF 9mm 2 ply, total thickness: 101mm
	3rd Test (Type C)	(MDF 12mm + MDF 9mm + air layer 42mm(Square timber 42mm, Polyester 40kg/㎥, 50mm) +MDF 9mm + MDF 12mm, total thickness: 84mm
	4th Test (Type D)	(MDF 9mm + CRC board 9mm + air layer 65mm (Square timber 65mm, Polyester 40kg/㎥, 60mm) + CRC Board 9mm + MDF 9mm, total thickness: 101mm
Size		W600mm×H2300mm (six panels), W800mm×H2300mm (one panel)
Installation System		Adjuster Bolt system
Test Method		KS F 2808:2001(Laboratory measurement of airborne sound insulation building elements), which corresponds to ISO 140-3.
Installation		Movable partition wall for sound insulation test was installed at the test frame (W4400mm ×H2300mm). Conditions in order to install the same with the circumstance of multifamily housing.
Joint Method		- For joint between the movable partition walls, spline joint was used. - For filling between the movable partition walls and the test frame, rubber plate was used instead of silicone caulking.

Table 2. Summary of movable partition wall for sound insulation test

The following graph is the result of sound insulation performance test

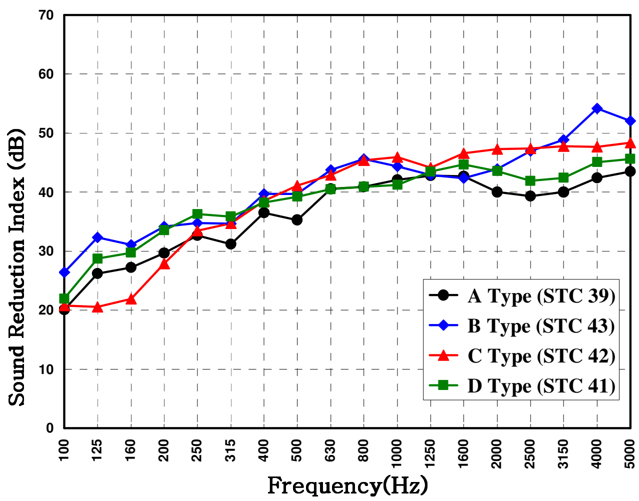


Figure 1. Sound Insulation Test Result

1) Egan, M.D. 1988, *ARCHITECTURAL ACOUSTICS*, McGraw-Hill, New York, pp.245

D) Installation in Experimental residential Open Building

The experimental residential Open Building (KOHP21) constructed in KICT is Korea's first experimental Open Building in June 2000. It was composed of two stories and three dwelling units regarded as the middle story in multi-family housing. Skeleton and infill were designed separately and constructed to allow easy remodeling and flexibility. It was planned that any columns were not existed in spaces by applying frame structure using reinforced concrete for the first floor and steel for the second floor. Double floor and double ceiling were installed.
Within this experimental residential Open Building, the movable partition walls were installed to examine the constructablity and flexibility. The installation experiment for the five wall types included the examination of easy assembly and replacement, joint methods and easy wiring inside the walls or components such as a baseboard or cornice box. As a result, it was estimated that the movable partition walls were highly suitable for using in dwelling units.
However, it was found that they were needed further development. First of all joint details are necessary to develop at floor and ceiling, between fixed walls and movable walls, and between movable walls. Detailed finishing also is needed for covering the adjusting part, and detailed construction for space height and manufacturing the wall systems with exact sizes are very important for installation. In addition, the various developments of components such as a baseboard or cornice box for wiring and door systems combined with wiring including outlet and switch box are needed.

4. Conclusion and Future tasks

This study is purpose for the improvement and development of interior movable partition walls for flexibility and easy remodeling in residential Open Building. And it is a part of component development in technical studies in order to meet Korean-styled Open Building. In this study three improvement types and two development types were suggested, and concluded that such types can be usable as a housing component through installation experiment and sound insulation test.
As future tasks, there is a specific plan to construct the second experimental residential Open-Building in Korea. Within this building, the examination and verification for a wide application will be conducted constantly in considering of joint details, various components and high performance for sound insulation. Also, economic effects from the development and use of Infill will be reviewed, and policies for a broad use of Infill will be generated as a national scheme.

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Development and Application of a Infill Customizing System for Condominiums

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Infill customizing condominium procurement

1 Introduction

As the competition of new condominiums becomes severer and severer in Japanese housing market, customizing of floor layout and interior finish of each housing unit has been more or less applied. Although most of them are only to prepare several choices in a menu and make residents select one of them, a few companies are to respond to any requirements of residents to change ready-designed floor plan and interior finish.This paper introduces the most advanced customizing system in Japan and make clear how it works.

2 Customizing process and the role of the new company

The new company named as Design Club, which was established in the latter half of ‘90s, has been engaged in arrangement with each resident, re-design of floor plan and interior finishes without changing building structure, estimation of cost difference between former design and re-design and shop drawings which makes general contractors’ procurement works easier. The customizing company is asked to join the building process and paid by real estate companies which are to sell condominiums.(**Fig.1**) For, generally speaking new condominiums are sold during the construction, especially before interior works in Japan.

At the beginning of the process, a resident can select one from four kinds of customizing services, namely no cutomizing service, light one, medium one and heavy one. While in case of light one, each resident can have four meetings at the most with a coordinater of the customizing company, in medium one’s case eight meetings at the most and in heavy one’s case ten or more.

The company documents all the meetings and confirms the final decision of residents about the changes of floor plan and finishes as well as additional cost for such changes. What the company must do after this confirmation are preparation of documents for the contract- such as meeting documents, a finish schedule, a floor plan and shop drawings-, cost estimation, inspection of the construction site and accompanying customers for checking the completion of construction.

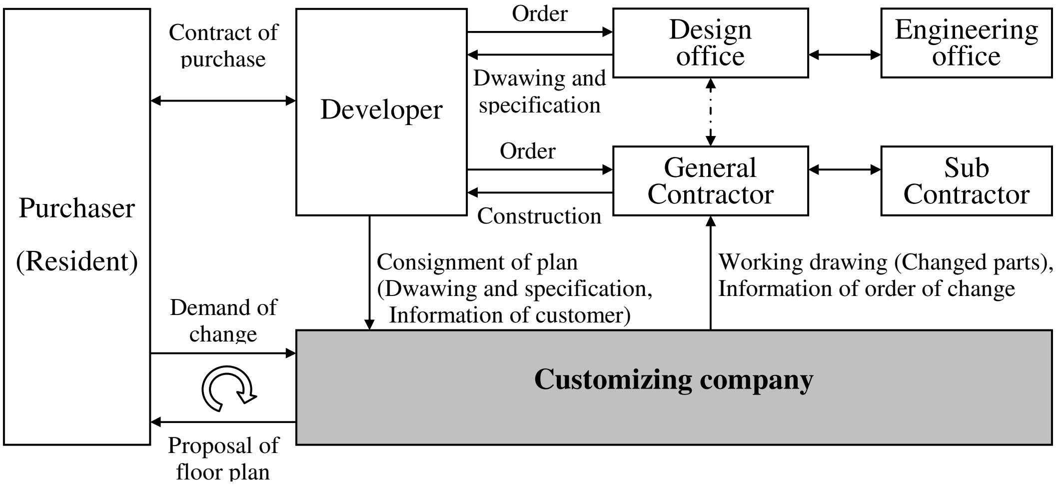

Fig.1 Project organization including the customizing company

3 Analysis of changes after customizing process

The company has already done the cutomizing process of over 1700 housing units in over 80 condominiums. Here actual changes from ready-designed floor plan and interior finishes of 405 housing units in 23 condominiums done during 2003 and 2004 are analysed based on drawings and documents which the company made. This analysis clearly shows differences between what the real estate companies and architects supply and what residents want for their own housing units.

No.	Completion Year	Stories	Structure	Total Units	Changeable Units	Changed units	Raito of Change	Construction cost per a Unit (Yen)
1	Jan. 2003	3F1B	RC	22	10	6	60%	868,911
2	Feb. 2003	9F	RC	63	14	10	71%	473,478
3	Mar. 2003	14F	RC	60	40	24	60%	912,931
4	Mar. 2003	15F	SRC	130	2	2	100%	2,053,453
5	Mar. 2003	15F2B	SRC	133	60	24	40%	276,656
6	Mar. 2003	15F	SRC	75	50	40	80%	445,834
7	Mar. 2003	10F1B	RC	50	20	9	45%	308,653
8	Mar. 2003	10F	RC	36	10	3	30%	215,708
9	Mar. 2003	5F1B	RC	53	20	3	15%	143,136
10	Mar. 2003	11F	RC	127	10	13	130%	360,408
11	Jum. 2003	5F1B	RC	18	10	3	30%	501,298
12	Aug. 2003	12F	SRC	91	10	5	50%	1,868,201
13	Sep. 2003	6F	RC	69	50	32	64%	1,450,050
14	Oct. 2003	31F, 35F	RC	467	28	7	25%	2,061,278
15	Dec2003	15F	RC	265	20	19	95%	363,163
16	Jan. 2004	6F, 7F1B	RC	67	40	19	48%	976,850
17	Mar. 2004	29F1B	RC	155	70	48	69%	267,945
18	Mar. 2004	30F3B, 28F3B	RC	495	99	67	68%	499,062
19	Jul. 2004	3F1B	RC	75	20	17	85%	561,464
20	Aug. 2004	4F	RC	38	20	8	40%	805,350
21	Oct. 2004	15F	SRC	130	14	12	86%	656,333
22	Nov. 2004	14F1B	RC	283	26	18	69%	1,847,025
23	Nov. 2004	6F	RC	17	17	16	94%	957,928
				2919	660	405	61.4%	703,332

Table 1 The outline of 23 condominiums during 2003 and 2004

While in those two years 660 housing units could be changed with the consultancy, the number of the residents who asked the company its cusomizing service was 405 in total. It means that more than 60% of residents wanted to change ready-designed floor plan and interior finishes. They needed not pay additional fee for the company at all. (**Table 1**)

Detailed analysis of the documents and drawings of 186 housing units of 16 condominiums shows what kinds of changes were done. (**Table 2**) More than a half of residents ordered such changes as movement of partition walls and change of interior finishes (93%), change of the position of switches and outlets (91%), change of closets and fixed furnitures (76%), change of the position of electric lights and devices on the ceiling (72%), change of doors (66%), addition of swiches and outlets (64%) and addition of closets and fixed furnitures (56%). It was only 12% who ordered the change of floor plan except for movement of partition walls.

Additional construction cost for each of 405 housing units caused by such changes varies. (**Table 3**) While almost a half of housing units costed 100 to 500 thousand yen, about 20% costed more than one million yen and about 10% costed less than 100 thousand yen. **Table1** shows the average is 703 thousand yen per housing unit.

Items of Changes		Changed Units	Rate of Changed Units (%)
Movement of partition walls and change of Interior finishes		173	93.0
Switches and outlets	Change of position	170	91.4
	Addition	119	64.0
	Cancellation	60	32.3
	Change of kind	42	22.6
Electric lights and devices on the ceiling	Change of position	134	72.0
	Addition	77	41.4
	Cancellation	46	24.7
	Change of kind	15	8.1
Closets and fixed furnitures	Change of position	18	9.7
	Addition	104	55.9
	Cancellation	89	47.8
	Change of kind	141	75.8
Doors	Change of position	60	32.3
	Addition	57	30.6
	Cancellation	62	33.3
	Change of kind	123	66.1
Change of floor plan		23	12.4

Table 2 Changes done for 186 housing units

Construction cost	Less than 100 thousand	100 to 500 thousand	500 thousnad to one million	More than one million
Nomber of Housing units	43	191	92	79
Raito (%)	10.6	47.2	22.7	19.5

Table 3 Additional construction cost for each of 405 housing units

4 Necessary technologies for the customizing business

What were necessary technologies for such customizing business? While no new construction technology has been strongly required, new information technologies have been essential. The typical difficulties are in the procurement process, because complete customization means different parts and componets as well as different quantity of them in every housing unit. In order to make such complicated general contractors' procurement works easier, a computer aided system for shop drawing and quantity survey was developed and implemented.

The basic idea of the system is the application of layer structure of drawings with color. **Fig.2** shows its example of application.

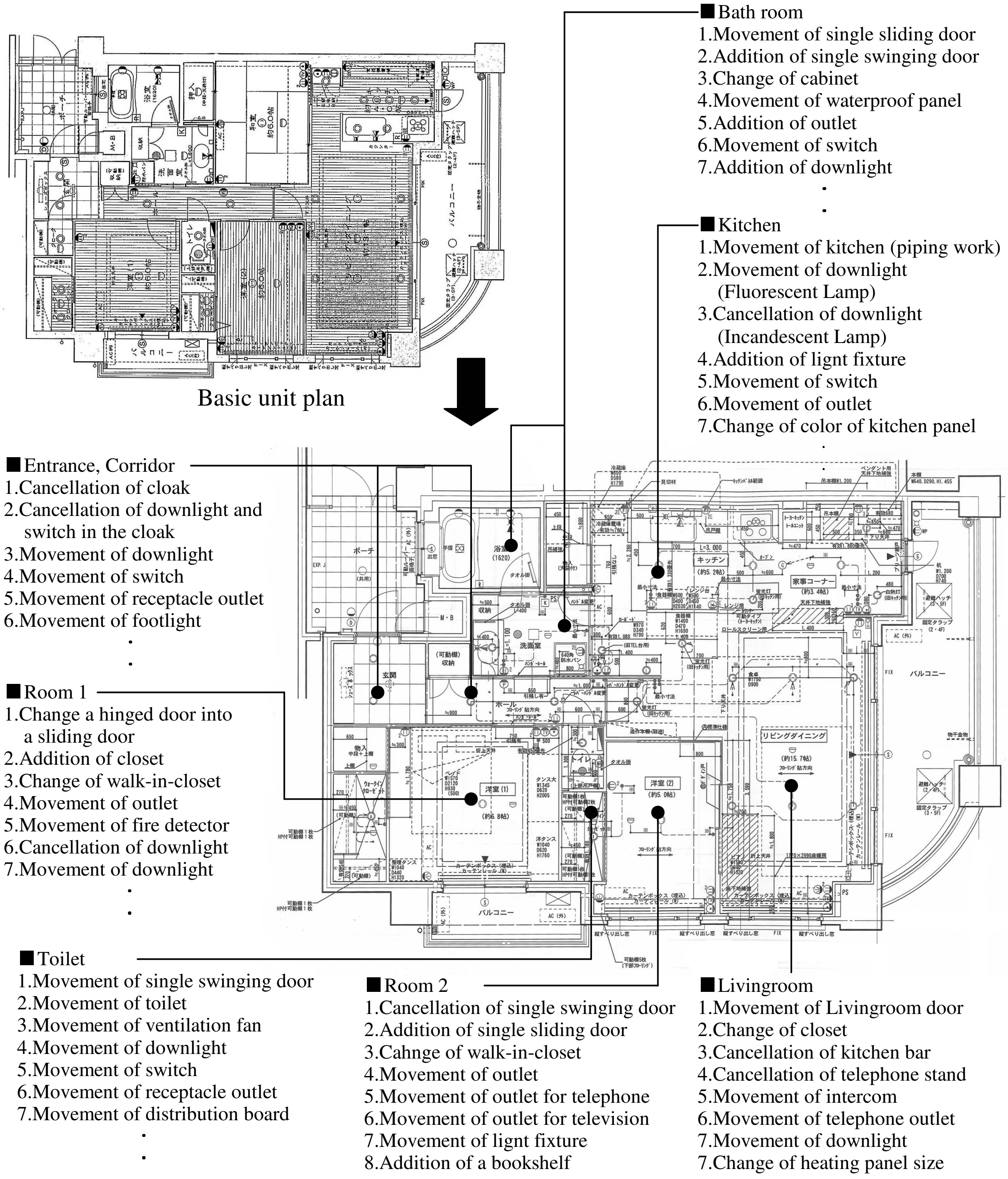

Fig.2 The application of layer structure of drawings

5 Conclusion

Indeed the customizing service concerning changes of floor plan and interior finishes has been welcomed by many residents of condominiums in Japan. Actually 61% in average, all residents in some cases, enjoyed the service and were willing to pay additional construction cost in order to realize more comfortable and convenient living space.

But as real estate companies pay for the customizing service in case of this customizing system, the residents could feel enjoying a kind of free service. This means that the foundation for such customizing business can be unstable and dependent on the sales strategy of real estate companies which can easily change. In order to make customizing business stable, two ways must be pursued at the same time. The one is to make residents recognize the worth and its corresponding fee for the customizing service. The other is to reduce necessary effort and fee of the customizing service by preparing computer aided cutomizing systems for residents' use.

Adaptable residential architecture in South Africa:
exploring the possibilities of technological and cultural transfer in partnership with small-scale, local industries in Mamelodi, Pretoria

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Local industry, universities, technological and cultural transfer, adaptability

ABSTRACT

This paper explores the possibility of increasing adaptability in low- and medium- cost residential buildings in South Africa. The suitability of the concept to this particular context will be tackled in terms of existing industries, the need for sustainable and labour intensive technologies, participation and changing ideas regarding professionalism.

The urban design principles of phasing, privacy, variety and integration in the creation of dynamic urban contexts are emphasised. It is also attempted to challenge the perception that limited funds mean poor quality or that low cost means that a flexible, enabling, inclusive, accessible environment catering for the needs of all sectors of the target population cannot be addressed through creative design.

At the core of this argument is the understanding that housing is not just the individual living unit but encompasses all aspects in the macro- and micro- environment. Within these urban structures, the house is seen as a flexible/adaptable product rather than a fixed final product. The idea of urban design as an inseparable component of housing is reinforced as well as the acknowledgment of the various levels of the environment differing in the degree of permanence and changeability thus allowing for more involvement and affordability. This allows for an understanding of informal economies, settlements and structures and our role as professionals in interacting with these alternative systems and "ways of doing/living".

Modular coordination may facilitate quicker construction and save costs. A rudimentary form of modularisation is already being used in the townships of South Africa and in this paper collaboration between academics and these simple construction industries is proposed, using local technologies to adapt open building to the South African context. Partnering with existing industries could possibly increase the chances of acceptance and affordability.

Some examples of local industry from the area of Mamelodi, a historically-designated black township near Pretoria, are investigated. A plan for meaningful partnerships and intervention is proposed. The value of this approach is that local technology and "what exists on the ground" is taken as a point of

departure for research and intervention, and not some obscure and possibly irrelevant theory far removed from reality.

The Housing Research Field at the Department of Architecture has had good relationships with community members and representatives in Soshanguve, Nelmapius, Mamelodi and Ivory Park in Tembisa. The contacts that we have built up in these townships have added much value to our teaching and have assisted us in bringing an aspect of realism to our student projects.

It has proved to be a process of mutual learning. Community members have contributed in project criticisms and our students have made presentations to government subsidy beneficiaries, local councilors and various government officials where we hope we have managed to portray a more enlightened approach to housing issues and design.

Our partners in the townships have assisted us in identifying student projects; they have been our guides and have helped us gain more insight and understanding into a context that we ourselves and many of our students are far removed from. One student researched a builder's yard in Mamelodi township and proceeded to offer a proposal on how to develop shacks (or zozos). This a paper acknowledges that contribution as well as the contribution of our Italian research partner with whom we are investigating implementation of projects in the township.

A workshop approach will be followed "knowing by doing", through using the builder's yards and the building sites as locations for technological and cultural exchange. This will potentially create more understanding between academic institutes and emergent township enterprises. Appropriate solutions to housing systems may be identified from the everyday realities of a specific context. Taking locally available skills as a starting point for a design process needs to be tested, in a sense reinforcing the idea that technological innovation has to adapt to local capacities and not vice-versa.

This is a three year project funded by a research programme of the University of Pretoria, with the ultimate aim of achieving long-term collaboration between the university, local industries and communties in the region. This would provide for excellent learning opportunities for ourselves and our students.

2 Theoretical premise

The argument at the core of this paper is the understanding that housing is not just the construction of individual living units but encompasses all aspects in the macro- and micro- environment, including communal facilities, job creation and enterprenership. Within urban structures, the house is seen as a flexible/adaptable product rather than a fixed final product. Urban design is an inseparable component of housing [Dewar & Uytenbogaardt 1991] and this acknowledges the various levels of the environment differing in the degree of permanence and changeability thus allowing for more involvement and affordability. This challenges our understanding of informal economies, settlements and structures and our role as professionals in interacting with these alternative systems and "ways of doing/living".

Current development and housing policy claims to be "pro-poor" and with a focus on "in-situ" up-grading of informal settlements. While a world-renowned housing programme is in full swing in South Africa, the housing backlog is not decreasing. Informality, emergence and the so-called "2nd economy" are aspects of the South African social/economic scene that will probably remain for many years to come. Designed and emergent systems [Hamdi 2004], are equally important and it is strongly believed that any approach that does not acknowledge the presence of the 'informal' as a force that cannot be eradicated and as a legitimate power, energy and form of expression is doomed to fail. Current debates regarding development, in general, and housing, in particular, attempt to position the

issues in the broader perspective of the 'south', the African continent and new policy directions in South Africa.
The built environment is not static: it is interesting to study the relationship between stability and transformation [Habraken 1998]. These notions, however, take on a different meaning when speaking of informal settlements. In squatter settlements transformations happen at an enormous rate compared to formal (more static) designed environments. Furthermore, the relationship between structural supports and detachable units is unclear. There is a degree of permanency in a squatter settlement – such as the layout of the site, but the overall set up is experienced as short term. Any design intervention will need to support a process, which will evolve quickly over a short period. Transformations will not only apply to structural elements but also to location and function. Because there is no security of tenure, shack owners are reluctant to invest substantially to convert an informal dwelling into something more permanent. This often results in people living in structurally compromised buildings for years. This volatile nature of squatter settlements inhibits long-term development, thus professional interventions are essential.

3 The description of the context

Mamelodi, the mother of melodies, is a large, historically designated black township in Pretoria. It is similar to other townships on the peripheries of all South African cities planned by the apartheid authorities as temporary dormitory zones for black labour. Its problems are typical of other townships that are mono-functional residential areas, isolated from the CBD and job opportunities, with poor quality housing and a large component of informal settlements. As a typical dormitory town it is dependent on the city of Pretoria and does not have an economic core and sufficient job opportunities. A density of 15 dwellings per hectar estimated in 1997 probably hides a higher occupancy density [van Stigt & Verhoef 1997]. Almost 10 years later Mamelodi has expanded uncontrollably, perhaps only stopped by natural ridges on the north and eastern sides. And with large tracts of land being occupied illegally as well as many backyard shacks in formal dwellings it is difficult now to estimate what the real population of the township is. Yet, it is unofficially estimated at one million, a very large proportion of the total population of the city, in about 10% of its area.

The socio-economic dynamics of the area are not clearly evident and still need to be fully appreciated and understood. There is no cohesive industrial centre or business centre. An initial analysis of the area, in consultation with a resident of the area assisted us in identifying some of the small-scale, informal industries. We had initally assumed that there would be a concentration of industries and businesses at various nodes which we assumed were important in the structuring of the township. We identified the nodes as follows:

1. Mamelodi Extension 15 along Tsamaya Avenue being a main access route into the township from the city.
2. Mamelodi Extensions 20, 8, 11, 18, 22 along Han Strydom Avenue as the area further east with a concentration of informal dwellings.
3. Mamelodi Extensions 3, 4, 5, 6 on Hans Strydom Avenue and near and around the satellite campus of the University of Pretoria and very close to a large informal settlement.

We were quickly proved wrong in our assumptions as the industries were scattered with no apparent structure that can easily be detected, many of them located in the middle of residential areas even though some were quite noisy and disruptive. We however documented the locations and types of industries that we could partner with, with the ultimate aim of participating, on location, in the development of the rudimentary techniques in use to benefit the construction of houses, communal facilities and the exploration of other possibilities such as the development of partitioning systems and furniture. It is acknowledged that emergent systems could become catalysts for future development interventions.



Figure 1. A building material supplier.
Figure 2. A typical shack construction yard.
Figure 3. A canopy maker – it is evident from the collected scrap that they also recycle old vehicals for various uses.



Figure 4. A metal welding workshop.
Figure 5. An upholtstery workshop.
Figure 6. A cement block making yard.


Figure 7. A rubbish recycling yard.
Figure 8. A wooden door workshop.

3.1 Shack-making yards: the zozos

The most visible industry as one drives through the area is no doubt that of the zozos or shacks. Many people in Mamelodi live in shacks, either in areas occupied through illegal land invasions or on legalised plots still awaiting the queue for government-provided houses or in backyard shacks. Backyard shacks on legal plots provide rental accommodation for many and are an additional source of income for informal landlords.

Construction yards provide squatters with prefabricated walls that can be put together in more or less standardised sizes of shelters. When a house is bought, the walls and the roof are transported to the plot of the new owner, where it is assembled first, then the floor is finished with a sand cement mix. It lays on the ground surface with no foundations. A simple roof of corrugated sheeting is nailed on purlins and the gaps between the walls and the roof sheet are filled in with a plaster mix – this is according to Cedric who sells his zozo components on the side of a main road in the area. These flimsy shacks are built with slight variations depending on the construction yard and the availability of materials. Despite this, one can assume that the sizes of the zozos are roughly similar – and basically standardized; and although the types of materials used may not be exactly the same, the features are the same.

The price of a zozo depends on the size. One yard has the following pricelist:

1. 1-roomed house (3m x3 m) for R900 (app. $140)
2. one and a half roomed house (3m x 4m) costs R1150 (app. $177)
3. 2-roomed house (3m x 6m) costs R1500 (app. $230)

The materials that are used for the construction of the zozo are the following: galvanized corrugated metal sheeting, coated metal sheeting and timber frames. Some of these are purchased from stores, such as the corrugated galvanised sheets, the rest is discarded material, such as the coated metal sheeting which is comes from a refrigerator factory close by – it is bought as scrap metal (priced per kg). Most of the timber is bought, but smaller pieces are waste material from the crates of the Ford factory in the neighbourhood; this is obtained for free, thus only transport costs need to be covered. This system seems to not be as profitable as initially assumed as much of the scrap is discarded because of unsuitable sizes or poor quality. Corrugated sheets are nailed onto the frames to form an exterior barrier. The assembling of the four "walls", and only in conjunction with each other, creates a relatively stable structure. Windows and a door are only made in the front side of a zozo, which is generally higher than the back side – so that a slightly sloped roof is formed.

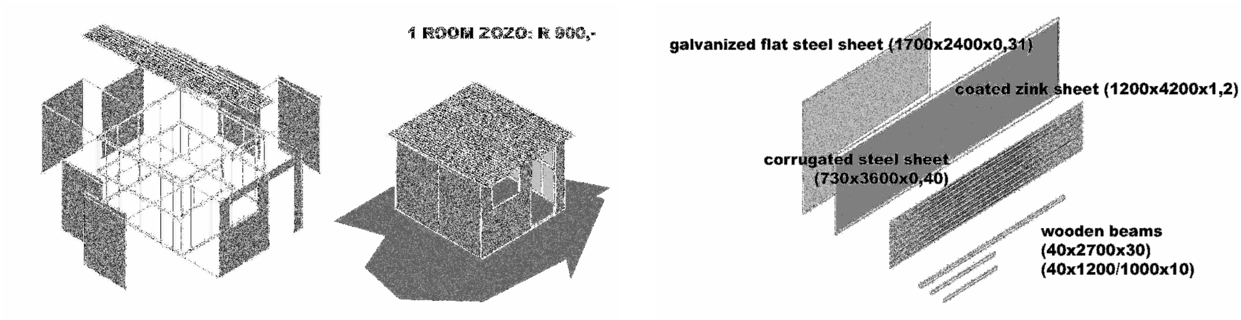

Figure 9. This is a typical 1-roomed zozo as it is being constructed now and the materials used in its construction.

3 The research project: informality and emergence

The fact that many people live in shacks, be they on legally-owned land or not and be they a part of the formal rental market or not means that there is a potential for academic involvement in meaningful ways. Firsty, in learning from what is happening on the ground, thus changing our mindset and ridding ourselves of professional arrogance. Secondly, in being able to work with students on location in developing the quality of the buildings that in any case house so many people and community functions. Thirdly, in investigating the possibility of these informal industries in having a role in achieving adaptabilty and affordabilty in the local residential market. It is also hoped that these small industries may play a role in formal, government-subsidised housing projects planned in the vicinity. The possibilities are endless and through this 3-year project we hope to investigate to what extent academics can play a role in making these possibilities a reality.

A workshop approach will be followed "knowing by doing", through using the builder's yards and the building sites as locations for technological and cultural exchange. A main research question being addressed is the need to re-direct professional efforts towards the needs of the poor rather than the ideals of the middle class. Traditional "expert"-driven design approaches are questioned in terms of their relevance. Taking locally available skills as a starting point for a design process needs to be tested, in a sense reinforcing the idea that technological innovation has to adapt to local capacities and not vice-versa.

Through the above research questions and processes it is hoped that innovative solutions could be arrived at a long-term partnership established between the Department of Architecture, UP and our Italian and Belgian partners and township enterprises in Mamelodi. It is hoped that a process for application of knowledge can be established and that the results of this project may be seen, on the ground in real projects at the end of the 3-year period through specific technological solutions.

4 Student projects

4.1 A proposed new zozo building system

Modular coordination may facilitate quicker construction and save costs. As explained above, a rudimentary form of modularisation is already being used in the township. It is hoped that through using local technologies, open building principles can be adapted to this particular context. One student analysed the system used at a specific shack-builders yard and proposed modifications to the system in order to improve the quality of the shelter. Using the same materials, it is proposed that the panels be broken up into smaller modules which are then staggered to achieve more stability. They thus become easier to transport and easier to use for alternative combinations which may ultimately offer more variety. The modules are, as far as possible, based on the dimensions of existing materials in the workshop or yard. The juxtaposition of smaller panels offers more stability and allows for space for insulation or various coverings to be applied. At the junctions of these panels, hollow columns may be formed which may be filled with loose sand, offering more stability without loosing the potential to move the structure easily. Current entrepreneurial initiatives of the shack-builders yards were discussed and a strategy for convincing existing yards to adopt the new system was devised as follows: The new shelters maintain the benefits of existing zozos by being easily transportable, re-sellable, extendable and adaptable. The proposed system may ensure a better quality shelter immediately that also has more potential to be up-graded into a more permanent house with complete facilities and services.

Solutions however need to be proposed for a specific "yard", at a specific time, depending on availability of materials and need. In this context, a pre-determined and measured response may be inappropriate. The cost implications of this system still have to be researched. Groups of students have already researched and designed alternative panel constrution systems including the one described above. The intention is to test these out on site in agreement with yard owners that we have already identified. How the system may be adapted to other uses such as the construction of trading stalls, partitioning sytems for formal housing, furniture (see 4.2 below), multi-functional boundary structures (see 4.3 below) or play equipment is still being investigated. Art works or follies may also assist in creating landmarks and creating interest, variety and excitement in a somewhat bland landscape.

4.2 Out of context: targeting a wider group with furniture and partitions at the zozo yards

Having looked at the materials in use at the zozo yards, one group of students decided to investigate the possibilities of building furniture and paritioning systems with which the could target a wider, perhaps higher-income, consumer group from outside of Mamelodi. By surveying the surrounding areas in the vicinity of Mamelodi it is noticed that there is already a flourishing market for garden furniture and shelters for the wealthier residents of these areas. It makes interprenierial sense for the yard owners to try and access that market.

This project is being presented for a student competition in South Africa titled: The Legacy of Tectonics in Architecture where the notion of tectonics as a constructional craft is being encouraged. The competition also calls for a need to be identified in a community and a solution to emerge from the available resources of the locale. The brief calls for: "The development of an appropriate tectonic tradition informed by a search for architectural legacy… essential for the future development of architecture in our region… Legacy in this instance also refers to the power of architecture to evoke an awareness of a common past and a collective memory." (Des Baker Competition brief, 2006).

Five pieces of furniture have already been built from the same materials used at the yards or easily obtained from the surrounding industrial and commercial areas. The process of skills sharing and technical transfer still needs to be implemented at a later date during the year at selected yards.

4.3 A multi-purpose "wall"

Again, as a combination of the research project and the competition project mentioned above, a group of students propose to build a multi-purpose wall in Nellmapius, near Mamelodi. The intention is to show, through built example, the possibilites of locally-sourced materials and simple construction techniques to create a wall with the potential for many uses within a certain setting. A wall, as a support structure may be used for seating, storage, planting, partitioning and as a children's play area. Thus, in the process also manipulating certain functions and levels of intervention in the neighbourhood: including both support and infill, furniture and partitioning, being controlled and adjusted by various agents such as the public on the one side and the residents on the other. The possibilities are numerous. A site and client have already been identified and the project will be reconcilled with a garden project to be developed on the site by the Botanical Institute in Pretoria through community participation.

5 The way forward

This study is in its preliminary stages. The intention at this stage is to propose an approach to the problem rather than to suggest a conclusive resolution. A calculated and precise response would be inappropriate in this context and the research needs to be approached through an adaptive method. The proposals need to be tested through actual application and a response from the community needs to be obtained. This study believes that enterprises emerging from informal settlements are more suitable for low-income groups and that support of the informal sector better addresses the urgent need for poverty eradication.

The interesting aspect of the project could prove to be the skills sharing and cultural/social transfer that happens between historically-disadvantaged, black, emerging entrepreneurs and white students from historically-advantaged settings with the main interaction happening on site rather than on campus. The students appear to be overwhelmed by the context of Mamelodi and they perceive it as an alien setting that does not seem to be functioning according to their understanding of how they believe cities should operate. The concept of mutual learning is not easy to grasp and the idea that the township is a worthwhile setting to implement projects of architectural merit is being promoted through the research project. We are challenged as professionals to investigate beauty and efficiency in informality as an anti-thesis of a middle-class interpretation of how life should be lived.

6 Acknowledgments

3rd Year students (2006, University of Pretoria) are fully acknowledged as well as Nele Peeters, a Belgian exchange student (M.Sc. 2005, University of Pretoria) as well as the community members who are acting as guides, advisors and supporters of this project.

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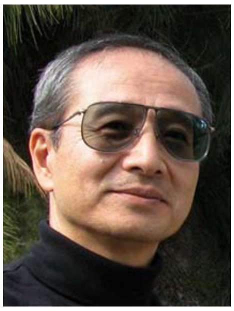
Function of Grids in Adaptable Buildings



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KEYWORDS

Grid, Function, Buiding System, Dimensional Coordination

1. Preface

The grid has various functions in building systems. In the 1960's numerous arguments were developed concerning modular coordination, but nowadays it is seldom discussed. However, the issue of dimensional coordination is still important for the design and construction of buildings. The problem is that the function of the grid in building construction is not clear. In this paper the author describes the process of applying the grid in three architectural works, and analyzes the function of grids in each case.
In the Japanese traditional wooden construction system or the industrialized systemsbuilding developed in the 1960's, a simple grid of parallel lines based on an interval unit from 900mm to 1500mm was used. In such case, the centers of columns are set to the axes of the grid. On the other hand, the dimensional coordination method for materials such as plywood or tatami mats is different, with the edge of the material adjusted to the reference line. The same holds for three-dimensional components such as bathroom units. For components such as partition panels, both the axis system and surface system are used.

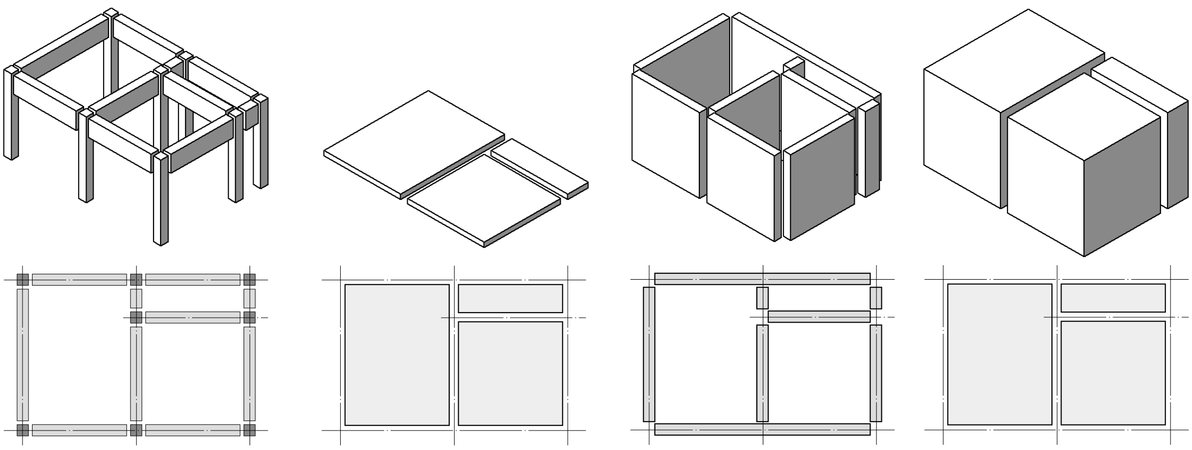

Figure 1. Types of components and reference lines

In the past, many attempts have been to resolve the conflict between the two systems. To comprehend this problem, it must be understood that there are several types of building components that relate to dimensional coordination.
Figure 1 shows the 4 types of components. The relation between component and reference line is different for each type. Therefore, suitable grids for determining the position of each component differ from one another.
It is also important to distinguish between two functions of the grid. The first function is to control the disposition of components belonging to the same group of components, and the second function is to coordinate the interface between different groups of components, i.e., the interface of building subsystems. It is difficult to make a simple single grid serve both these functions, but this can be accomplished by a sophisticated superimposition of a group of grids.

The followings are three architectural works in whose building system different interval grids are superimposed.

2. Science & Information Center of Musashi University

Figure 2. Science & Information Center of Musashi University

Figure 3. Structure of the Science & Information Center

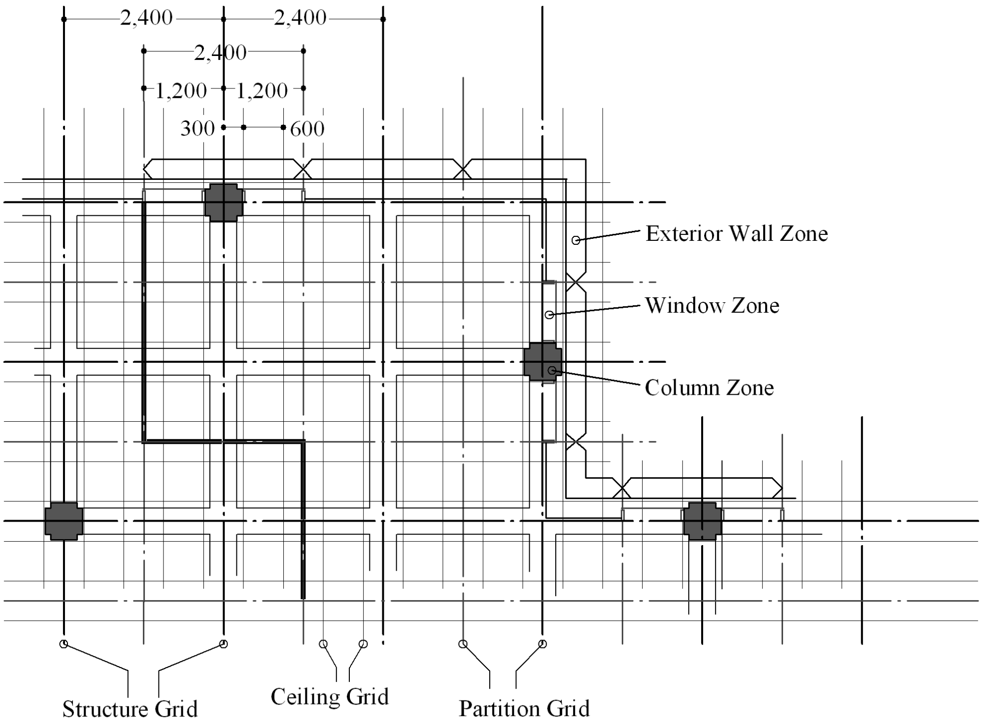

Figure 4. Grid for the Science & Information Center

For the Science & Information Center of Musashi University built in 1988, the design team, including the author, used a 2,400mm single grid to control structural members such as columns and beams. A 600mm grid was used for ceiling panels, superimposed over the structural grid. In this case, the 600mm grid was dislocated, matching its midpoints to the structural grid. The grid for partitions was also 600mm, and superimposed on the structural grid in the normal way. Thus, the positional relationship between ceiling and partitions was unusual but effective for control their interface.

Figure 5. Ceiling panels and partitions

Figure 6. Ceiling and mechanical equipment

3. The Experimental Housing NEXT 21

In the Experimental Housing NEXT21 built in 1993, the design team, including the author, introduced a more sophisticated series of grids. The grid for structural components was 3,600mm. The centerline of reinforced concrete columns was fitted with the grid line, and the size of columns was 750mm.

Figure 7. Experimental Housing NEXT 21

Figure 8. NEXT 21 Structure

Figure 9. NEXT21 External Wall

Figure 10. Floor ceramic tiles

In NEXT21, 13 architects designed 18 houses based on the predesigned structural skeleton, determining the position of their own external walls. The grid for external walls was a tartan grid with a 150mm band whose center corresponded to the structural grid. Figure 11 shows the relation of the superimposed grids. Using these superimposed grids, the surface of external wall is uninterrupted by the structural columns.

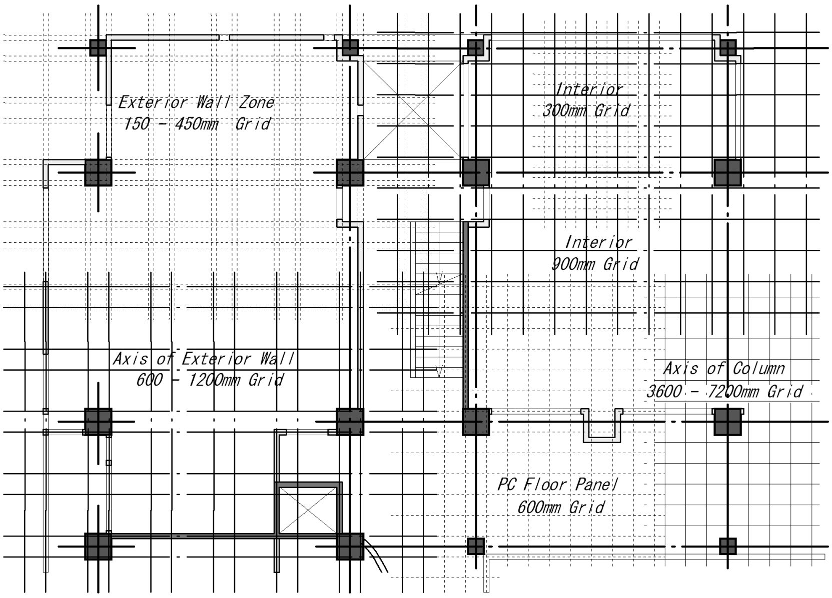

Figure 11. Grid pattern for NEXT 21

4. Shigebashira House

In Japanese traditional wooden houses, we use a 909mm Grid. Traditionally we used the *shaku/sun* system of measurement. One *sun* is 30.3mm and ten *sun* make one *shaku*, therefore, one *shaku* is 303mm, close to a foot in length. The grid interval in the traditional wooden house system is 3 *shaku*.
The author designed "Shigebashira House" in 1996 using the conventional construction system, but in this work, in addition to the 909mm grid, a 5-*sun* (151.5mm) grid was adopted, providing two levels of dimensional coordination.

Figure 12. Shigebashira House **Figure 13 Shigebashira House interior**

The basic construction system of the Shigebashira House is traditional Japanese post-and-beam, but the density of columns is extraordinarily high. The column interval is 5 *sun*.
The curved wall was produced by positioning the columns on a sine-curved line. A 151.5mm interval corresponds to 7.5 degrees, and 12 columns form a 90-degree curve.
Figure 16 shows the detailed plan. In post-and-beam construction, the centerlines of columns correspond to the grid. In this case, the function of the grid is to specify the position of the components. But we can also represent this as in Fig. 17, in which the function of gridlines is to specify the area of the components. What is the difference between Fig. 16 and Fig 17 ? For the dimensional coordination of the columns, the functions of two methods are the same. But concerning the coordination of the interface between groups of building components, the gridlines of figure 16 and figure 17 have different meanings. The philosophy how to assign tolerance for components also differs.

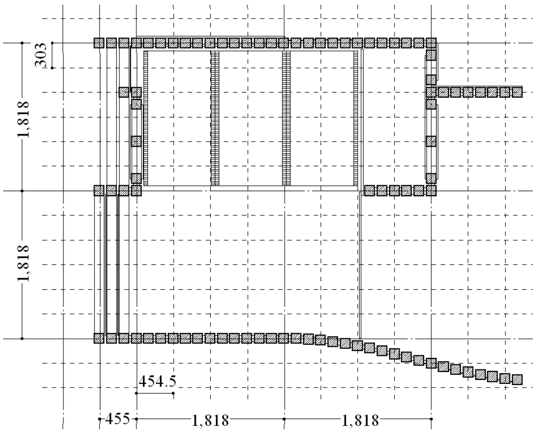

Figure 14. Plan of the Shigebashira House

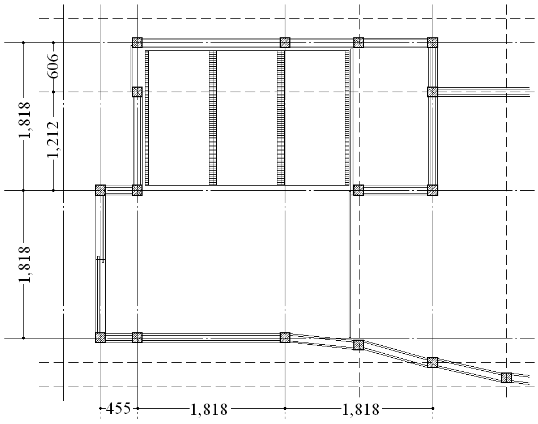

Figure 15. Conventional Construction

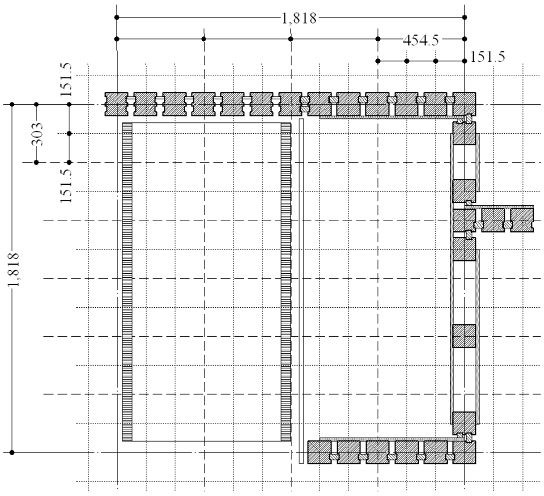

Figure 16. Detailed plan, axis system

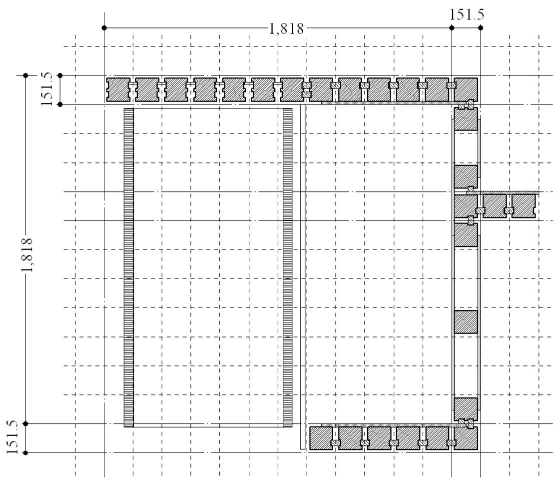

Figure 17. Detailed plan, surface system

In the Shigebashira House, plywood was used to resist horizontal load. The plywood was nailed to the columns according to the grid lines. In Japan the standard width of plywood is 3 *shaku*, and at the corners of walls the full size of plywood was used without cutting. (Fig.16)

5. Conclusion

For good architectural design, it is effective to achieve dimensional coordination using multiple grids of various levels superimposed on one other. The suitable grid system differs depending on the nature of the building components. An adaptable building system can be obtained through the use of a sophisticated grid system. A halfway-dislocated grid system is useful for such dimensional coordination.

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Managing the Design and Delivery Processes of Building Services under Construction Management Contracts

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KEYWORDS

Open building, design management, construction management, building services, HEPAC works

1 Introduction

Many owners begin the construction phases of their building projects either before users are known or when users are not yet ready to specify detailed design requirements for spaces. It is not easy to change from traditional sequential design and construction practices (a chain model) to **a construction management (CM) fast track approach** in which design and construction are overlapping (a concurrent model). In Finland, exceptionally difficult problems are being encountered during the working design process and the selection of a delivery method associated with building services (BS) or HEPAC systems under CM contracts. BS problems are usually caused by the established practices, i.e. users must specify their detailed design requirements for spaces before construction works begin. Examples of causes of such problems include: (a) a standard scope of design tasks, (b) software based design, (c) design compensation practices, and (d) traditional delivery forms.

This paper is a part of the **”Developing a Design System for CM Contracts” (FinSUKE) research project** conducted in the Construction Economics and Management Unit at the Helsinki University of Technology. The purpose is to develop design management procedures for concurrent CM projects, i.e. for an environment in which the particular uses of the building spaces are specified not until during the construction phase. So far, the sub-results have been presented at seven international conferences. The underlying FinSUKE Open Building concept is introduced in Saari et al. [2006]. The second paper focuses on the management of flexible programming and overall design [Saari & Raveala 2006].

The Open Building concept enables the division of a building into two parts: a permanent base building (or a ‘support’) and modifiable spaces (or an ‘infill’). The basic idea is to establish the principles for dividing and combining subsystems in a way that minimizes their interdependencies, i.e. subsystems are transformed without a need to redesign or renew the entire building. The same principles have been found to be applicable in concurrent design process management. So far, the applications of generic open building principles have primarily involved residential buildings. In turn, the FinSUKE project is focused on commercial and other premises. Both the prospective and retrospective tests concerning the selected properties of University of Helsinki have demonstrated that the principles of Open Building are effective in managing BS design processes and selecting the related delivery method as well as in managing the projects as a whole. It has been easy to separate the design and the procurement of the permanent element (e.g. exterior walls) and the 'infill' element (e.g. interior walls) from each other. However, the application of the principles of Open Building seems to be more challenging in the case of BS. Traditionally, HEPAC systems are perceived as one whole which cannot be divided into a permanent base building and a modifiable infill.

Thus, **the aim of this paper** is introduce the new FinSUKE solutions for managing a working drawing process and selecting a delivery method for building services and HEPAC installations, based on the division of a building into its two primary constituents as follows, under CM contracts.

Besides the Open Building concept, some key principles inherent in set based design [Sobek et al. 1999; Bogus 2004] and those of overdesign [Ballard 2000; Bogus 2004] have been adopted. In particular, the overdesign concept in FinSUKE research means the dimensioning of the permanent support according to the targeted range of space variance.

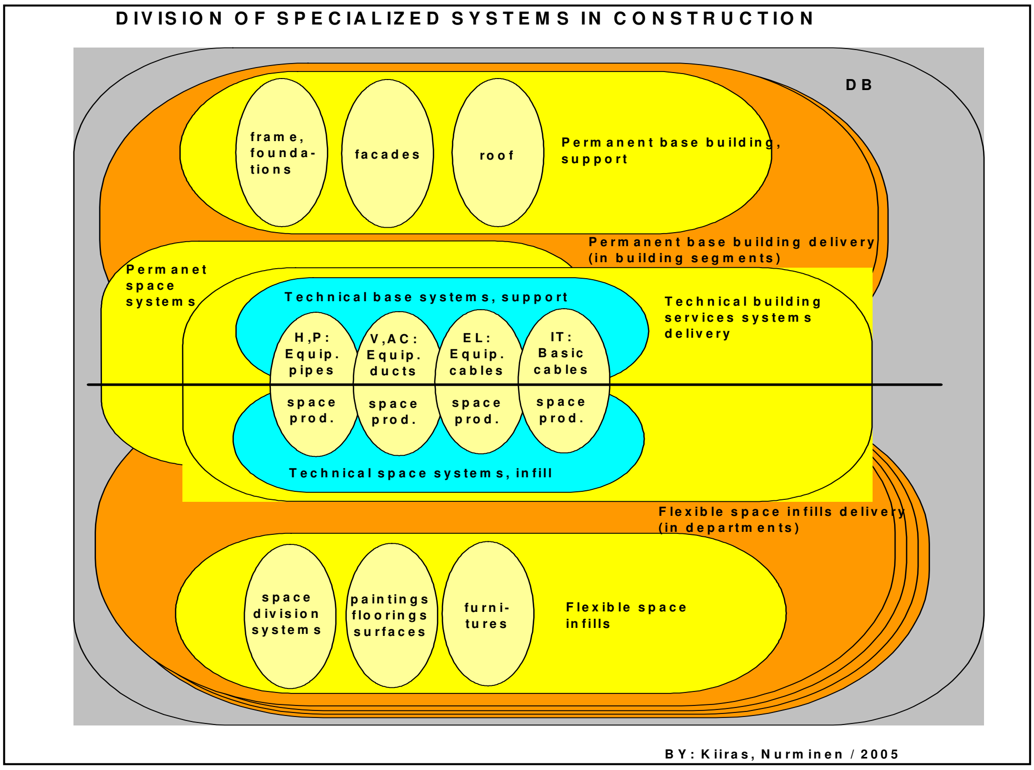

Figure 1. Dividing building services and construction into a permanent base building and a modifiable infill.

2 Flexible design process

The essential feature of managing flexible building projects is that **flexibility targets** are defined for the division of a building into a permanent base element and a modifiable element as well as for the allocation of a space programme into a set of particular open spaces [Saari & Raveala 2006]. **The overall design phase** is divided into: the preparation of the proposals and the actual overall design. In a proposal phase, alternative design solutions are examined for both the permanent base building and modifiable spaces. The overall design documents match to the selected permanent base building. In turn, alternative space concepts cover a set of the modiable infills. A borderline between the permanent support and the modifiable infill is determined building by building. Typically, much attention is placed to building safety systems like fire alarm or sprinkler installations if the first space areas will be taken into use while the infills of other space areas are still under construction.

In the FinSUKE model, **a working drawings preparation process** is managed by design packages. A CM-based model includes a list of standardized design packages with their basic contents [Kruus & Kiiras 2005]. The criteria for design packages formation involves the principles of Open Building, not a trade based procurement breakdown.

Working drawings for modifiable spaces are completed concurrently with a selection of users (e.g. tenants). Design changes occur only if a particular space-specific decision leads to a change in the permanent support. This happens when space decisions does not fit into a range of variation of space requirements or the borderline between the permanent support and the modifiable infill were defined poorly.

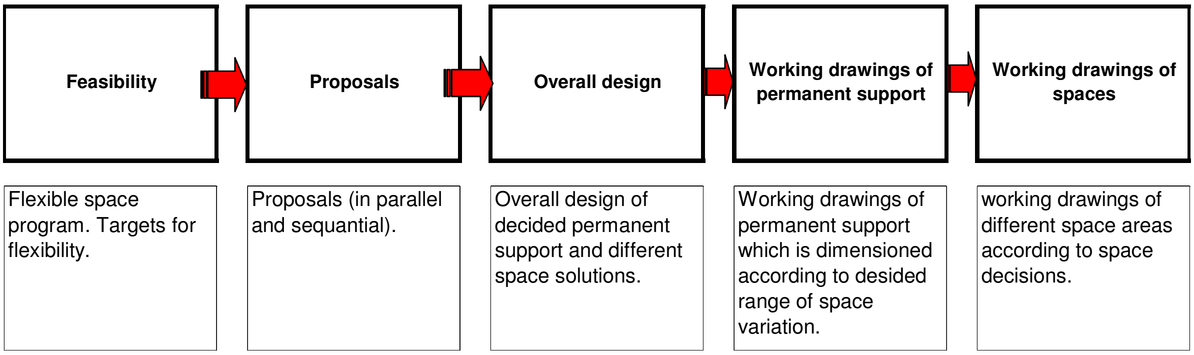

Figure 2. Design process of building services.

3 Selection of a delivery method for flexible building services

Five alternative delivery methods for BS are compiled in Table 1. In **(1) Building Services Management (BSM) contracts,** an owner hires a building services contractor to work like a CM contractor. A BSM contractor makes a procurement breakdown in which the total works are divided into HEPAC systems and products, installation works, or a combination of those. Based on the working drawings, the installation works could be performed by a BSM contractor's own labor force with a compensation as a lump sum. An alternative solution is to use additional installation works contractors. In the case of BS, there are many advantages when own labor force is relied upon, i.e. the ineffective and costly use of the labor is avoided by the pre-specified accounts for the installation work contracts.

In Finland, traditional delivery methods for building services involve **(2) lump sum prime trade contracts** under the coordination of a main contractor. All design documents are needed before the construction works start. These contracts cannot be applied to flexible projects where most space requirements are finalized during a construction phase. This hindrance is avoided by using design options, i.e. prices for modifiable space solutions (options) are specified as unit prices [Saari et al. 2006]. In **(3) building services multiple contracts,** a client (a CM contractor or an owner) splits a procurement breakdown in many parts (contracts) based on trades, infill areas, building phases, or a combination of these. In **(4) building services design and build (D&B) contracts**, design is incorporated in the same contract [Pernu 1997]. A D&B contract form enhances the evaluation of alternative design solutions by a client. The responsibilities over the life-cycles of the HEPAC systems can also be incorporated to a BS D&B contract. This form is suitable for projects where space requirements are known in the beginning and there is a plenty of time for a design phase.
In turn, **(5) space contracts** enable a fast and effective increase in contractors' resources. A particular space contract can combine an overall building design commitment with both civil construction works and HEPAC installation works. The permanent support can be constructed under the other contract

form (e.g. a traditional BS trade contract). In this way, a client avoids many problems inherent in a trade based procurement breakdown (e.g. when a large area needs to be completed with a short lead time, the control of the use of the various subcontractors' resources is lost).

	1 BS CM contracts	2 Traditional BS contracts	3 BS multiple contracts	4 BS D&B contracts	5 Space contracts
Description	Building services contract using CM principles	Traditional lump sum trades (HEPAC plus building automation)	Multiple contracts: trades, areas, building phase or a combination of these	Building services design & build contract	Building services procured with other works for the same spaces (space by space).
Procure-ment break-down	20-60	1-4	7-15	1-2	Particular space 1. Permanent support separately.
Budget, bargain	* Budget for a space concept * Possible target price	* Lump sum, unit prices, options	* Multiple trades with lump sum	* Lump sum, unit prices, options	* Lump sum, unit prices, options

Table 1. Alternative delivery methods for building services.

4 Case Biomedicum 2

Biomedicum 2 was developed and commissioned by the Technical Department of the University of Helsinki in order to provide versatile facilities for different hi-tech medical enterprises for lease. The case project consisted of 11 000 sqm enlargement for Biomedicum 1. The users were chosen before, during, and after the construction works. In particular, **a high variance inherent in user requirements** is being encountered during the life cycle of Biomedicum 2, i.e. the users' (tenants') research programs last only some years and, thus, new programs bring along changes in space requirements. The building was divided into a permanent support and a modifiable infill. The permanent support was designed to meet the targeted high range of space requirements variation. The five sets of the alternative solutions were developed for the modifiable infill. The decisive restrictive factor was the maximum numbers of the fume chambers to be placed in each section. When the space requirements were delayed, the BS working drawings could not be prepared as a continuous flow.

After the excavation works, the building construction works were carried out under a Finnish CM contract ("CM-at-risk"). The other possible delivery method could have been a CM Agency contract. The permanent support could have been constructed also under a lump sum contract (and the space areas under a separate set of space contracts). The delivery method for the building services was **a set of the BS CM contracts** assigned with the CM contractor. One of the BSM subcontractors is liable for the performance of each HEPAC system as a whole. The owner's prior experiences favored the selection of this hybrid CM contract form, i.e. it enabled to make many true quality-price choices.

5 Conclusions

Herein, the validity of the suggested FinSUKE model is dealt with in terms of **applicability**. Some key Finnish owners have had many negative experiences when trying to manage the working drawing processes and to select the optimal delivery method for BS (or HEPAC systems) in their CM based projects. In this paper, both some primising theoretical solutions for those problems are introduced and the outcomes of their testing are demonstrated with the help of one case project. In addition, the suggested FinSUKE model have been tested and found to be useful in refurbishment projects involving both historically valuable sites and those with a small range of space requirements variation. Likewise, the Open Building concept is applicable to such building projects where the first users are readily known before actual construction begins. In some prior cases, it ensured that the permanent base building is dimensioned to allow the targeted range of user requirements variation.

Some current software programs for HEPAC systems design have caused problems for managing flexible working drawing processes. This software requires the detailed solutions of the modifiable spaces before the dimensioning of the permanent support. Thus, **new software** is needed for HEPAC design processes to allow the adoption of the suggested FinSUKE design principles.

Finally, **the chains of competition** can be compared between various contract forms. In lump sum general contracts, a chain of competition is long. For example, each HEPAC products and materials purchase must pass 3-4 price competitions. All these competition stages are based on the cheapest products that meet the owner's requirements [Kiiras et al. 2005]. The number of alternative eligible HEPAC products is reduced too much. Thus, these owners are left with all the low bid problems such as weak quality, chained price competition, decisions made prematurely, and low flexibility for possible design changes [Kiiras et al. 2002]. On the contrary, when the suggested BSM contracts are adopted, selection procedures result in high performance due to e.g. the freedom of BS providers to offer their most applicable solutions and to assume life cycle responsibility for the same.

In Biomedicum 2 case-study flexible working drawing process and delivery method selection was applied to enable flexibility in design and construction phase. Authors believe that presented flexible process enhance the **flexible design solutions** as well. In Biomedicum 2 case-study many flexible design solutions were used. For instance building services installations were integrated in precast concrete hollow-core slabs. When the building will be in use the changes for plumping and draining system could be done without disturbing neighbours above or below. Presented systematic process support the flexibility to design, construction and utilization phase.

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Adaptability in self Produced Housing in Mexico

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KEYWORDS

self produced housing, adaptability of self help housing.

PAPER

Self production of housing accounts for more than 60% of the housing stock in Mexico. Nevertheless little attention and support has been given to it by the public or private sectors. Low income families are unable to afford house produced by both public and private sectors. They can only access self produced house and generally prefer it because it's a production process that adapts better to their economy, needs and changes in lifestyle.

Self production processes in Mexico adapt to several backgrounds, very diverse and complex according to the different natural and cultural environment of our country.
In this paper we make a synthesis of these different environments in Mexico, picking one region as an example. We will make a brief history of the vernacular housing produced mainly between the self produced housing and the one produced by the private sector, by contrasting the structure that prevails (support) from the one that suffers changes (infill).

Housing regions in Mexico.

We used the study presented by "taller de vivienda" to the "Instituto Nacional del Fondo para la Vivienda de los Trabajadores" (INFONAVIT) in 1994 (Andrade et al 1994), to define regions of self-produced housing.
According to that document, there are two main factors which are basic to define housing regions, these are natural and cultural environments. Cultural factors are determinants and natural factors are condition ants (Rapoport 1975)

The following aspects were considered: in order to define cultural regions:

1. - The location of indigenous communities.
2. - The location of different religious orders in the colonial time.
3. - The location of current vernacular housing.
4. - the location of socio-economic urban regions.

By Doing so three main zones were found in Mexico:

- The south zone rich in both historic and cultural backgrounds as well as in natural resources but with slow and poor economical and technological developments.
- The north zone which in contrast to the latter, has limited historical background and limited natural resources. However it counts with a dynamic economical and technological process of development.
- Finally the central zone wich could be considered as a collage of north and south zones.

The case study presented here is located in the south zone of the country.

Housing typology in Salina Cruz Oaxaca.

This part is based in a broader study carried out for the national government (Andrade 1982)
The main purpose of this study developed in the early 80s was to present urban and housing design criteria for housing developments to be done next.

In this case we will put emphasis on the adaptability of one kind of dwelling unit designed and built by an english company at the beginning of the 20th century in Salina Cruz Oaxaca.

This project was part of an ambitious plan which connected by train the Atlantic Ocean to the Pacific Ocean through the Tehuantepec Isthmus. A seaport was built at each extreme of that train line: Salina Cruz (Pacific Ocean) and Coatzacoalcos (Atlantic Ocean).
(see fig 1 and 2)

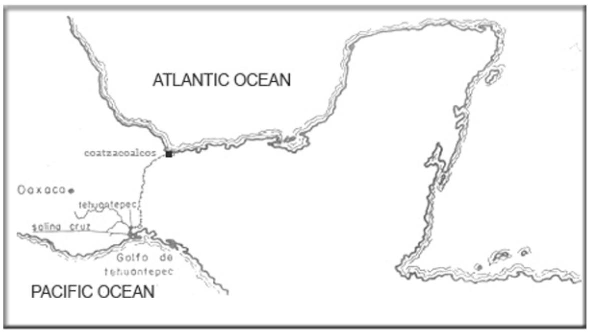

Figure 1.

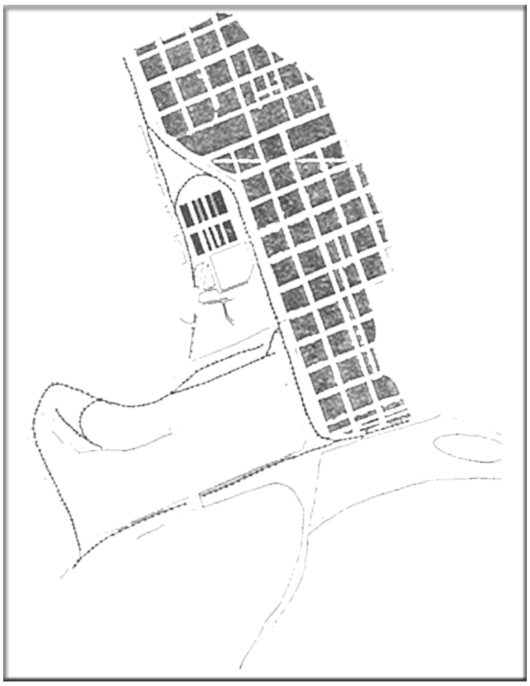

Figure 2.

The dwelling type presented here was part of a group of dwelling types planned and designed by the english company. They were designed and classified according to the role played by the different train line building workers:

The blue collar workers type, the artisans one, the technicians' type, the engineers' type and finally the company representatives dwelling. Here we will just study the case of the blue collar workers' dwelling, before that we will see general characteristics of vernacular dwelling types in the south port of the Mexican pacific coast.

According to Covarrubias (1980) and Morales (1987), there were three main types of vernacular dwelling in the Oaxaca coast, their differences were mainly the materials used and the socio-economical levels of their inhabitants.

The first type of dwelling is the original an the oldest. It is named “Casa de Palma” (fig 3). It has a rectangular plant; the roof was made with palm tree leaves and the walls with mortar and bamboo plants. This kind of house sometimes used to have a small porch.
The second dwelling type had the same shape but the roof was made with clay tiles and the wall with mud
Their inhabitants had higher economical level; the third type was a variant of the second one but it had clay walls instead of mud walls.

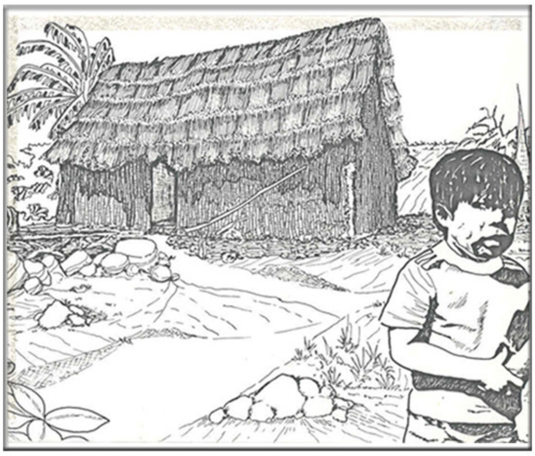

Figure 3.

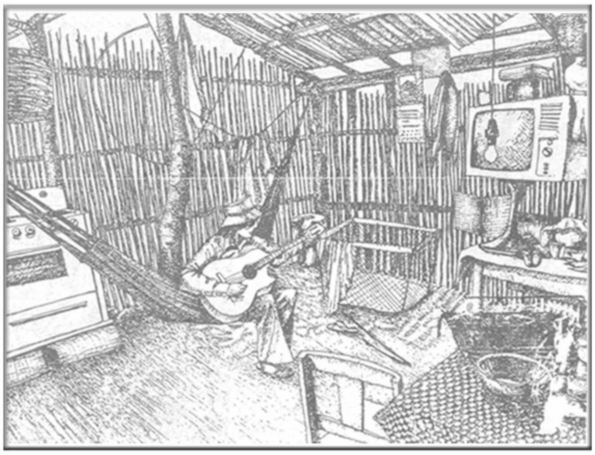

Figure 4.

Nowadays, those three dwelling types remain almost the same but with some changes. These changes have to do basically with new materials, buildings or the location of electro domestic appliances as T.V. sets, gas ovens and of course, plastic objects (fig 4). However, both the size and configuration of the vernacular house remain alive.

The blue collar dwelling type, those dwellings are located at the west side of Salina Cruz and they are separated from the city by the train line (fig 5)

Figure 5.

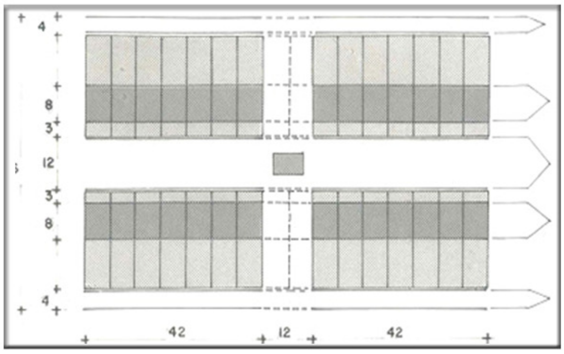

Figure 6.

At urban level we identify six lines of row houses five of which are the same size. Each line of row houses is divided in four sections with a main street dividing them into two symmetrical groups. We also observe four rectangular and nearly squared buildings; they were public baths. Those dwelling remained almost without any change until the 70’s. The same thing happened with the public space between them. Until that time they were dwellings for rent. At the beginning of the seventies they were sold to their dwellers, and some part of the public space was added to each dwelling unit as frontal and back yards. The study carried out 10 years later (Andrade 82), showed many changes at urban and dwelling levels.

By applying thematic design rules (Habraken et al 73) to the housing scheme, (fig 6) we find "B" zones of eight meters width, "OB" zones of 3 meters width facing the public street, and "OB" zones of 10 meters width facing the small alley street on the back side.

Figure 7.

The main street facing the frontal side of dwelling became a multipurpose space and a mixture of public and private territories. As an example: The shadow of a tree became a place of social encounters and parties (fig 7).

At dwelling unit level we find four ways (figs 8, 9) of dividing space: 1) the dividing wall. 2) the small wall. 3) The lattice window and 4) the furniture located mostly parallel to the depth side of the dwelling unit.

Sometimes the dwelling units at the corner street changed their use from house to small shops.
The front and the back yard changed too. The front yard had three options: it remained as a yard, 2) It became a porch, 3) It became a new room (fig 10). And the back yard had at least three options too: 1). - Rooms added at the back side of the yard. 2). - Rooms added next to the old ones. 3). - An alley covering completely the open space (fig 11).

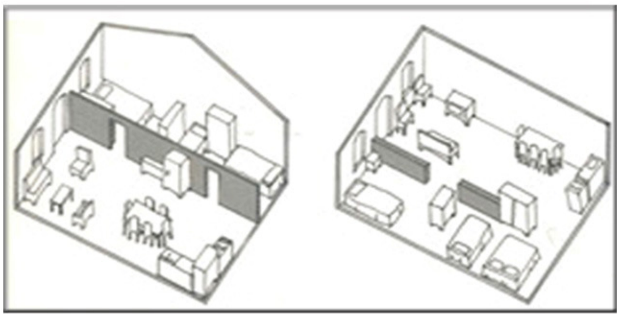

Figure 8.

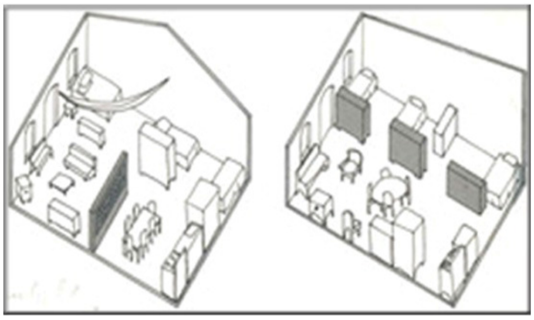

Figure 9.

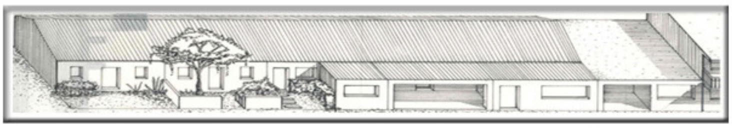

Figure 10.

A complete new change came about in the early 80's: the duplex dwelling type unit appeared, this is of course, a different type of unit and it shows us that the life of dwelling types is limited and that urban issues are in a constant transformation process.

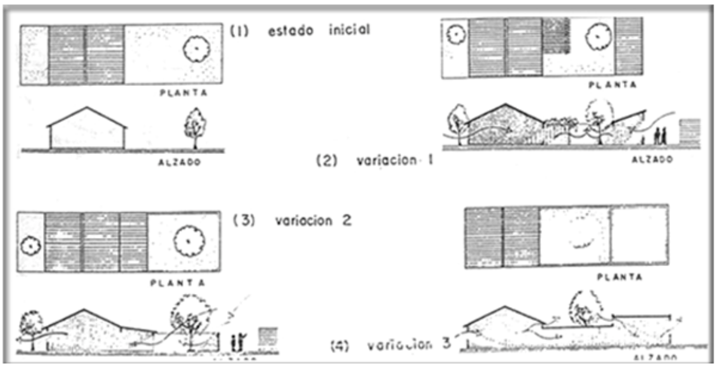

Figure 11.

Final Remarks.

From this case study we can draw the following conclusions:
1). - The morphology prevails longer than materials and new technologies, by adapting the old structure to new materials, objects and ways of using, them.
2). - The territorial hierarchy (Habraken 98) is always necessary to allow inhabitants to adapt, to appropriate and to change the space.
3). - Due to climate and cultural requirements the particular or local way of dividing and adding spaces, must be considered.
4). - It is necessary to know the history of a place before trying to improve its quality
5).- We finaly concluded from this particular case study the blue collar dwelling unit type success might reside within the similarities which it has with the vernacular dwelling type.

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Built to Last

Culturally durable construction method for architecture and public

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PAPER

The last few years' house construction finds itself in an impasse. Through a rut of use and production habits houses are offered as a consumption article. Within a false freedom of choice occupants are fobbed off with a standard article or have to turn too dolled up collective house construction. Thus the perception value of the habitation product comes within the scope of the real residential needs of the occupant.
Thanks to the same economical perception a possibility arises of challenging the occupant to play an active role in the housing process. Within an established framework opportunities are awaiting to give in to the dynamic accommodation process. 'Built to Last' demands a personal touch, in order to come off unscathed from a gnawing feeling of satisfaction 'fig 1.1'.

1.1 Figure Built to Last

1 Introduction

In this research the central issue is the design as a relation between the architect and an unknown public. Architecture is frequently labelled as applied art. In this case the building is an appliance of which the aesthetic design is important. However the architect and the consumer look at the built surroundings from a total different perspective 'fig 1.2'.
Looking at the current house-construction one could resign in the idea that everything will turn out well. Houses are being built according to particular patterns and traditions and even though the process doesn't happen quickly enough, everything will come together. Generally people are satisfied with the houses they're offered. A more critical response could be that the current interpretation of the housing market does not comply with the quality and diversity in demand. Adaptability could offer a solution to this problem.

1.2 Figure gap between architecture and public

2 The house with a through lounge sees the light

The Netherlands have a rich tradition within the field of flexible or adaptable housing. In 1901 the housing law is passed. It is a social ideological act which offers the government the ability to supervise a way to make better housing accessible for everyone. For the first time in history concepts such as light, fresh air and hygiene related to living are made subject of discussion. These notions which make a house comfortable to live in have to take room in a minimal area. The cause to an investigation of the adaptability of a house is a maximal efficient use of space so that an accommodation needs a minimal area; it has to remain inexpensive.
After the Second World War also the Netherlands have to contend with a quantitative housing shortage. The Study group Efficient House-construction wants to answer this problem by rationalizing the floor plans and thus give room to a rational production process. During the CIAM congress in Frankfurt minimal housing standards are discussed. Those minimal standards are developed on in Germany and in the end entered in the reference book of Neufert.

2.1 Figure house with a through lounge, 6,5 miljoen woningen

Thus minimal proportions become applied proportions. With the standard house plans still in mind and this maximal functionalism of dwelling, the 'house with a through lounge' sees the light 'fig 2.1'.

House construction still embroiders on this housing typology. As a result the same construction techniques are applied which results in rigid standard housing solutions. Nevertheless standard occupants vanished a long time ago. Because of this lack of adaptability houses are rarely able to cope with the ravages of time.

3 Collective satisfactions

Thus a market appears for the residence which expresses 'this is my castle'. The rigid, minimal but above all uniform housing market gives in no respect elbow-room to a personal interpretation of dwelling. The offer is directly opposite to the current dynamic and diverse necessities of life. The man in the street wants to stand out, people won't fall for mass-production. One of the methods to give housing a personal interpretation is the 'homemade' house. However this is only granted for the middle classes. The market is manipulating this demand for example by means of catalogue house-construction.
Extraordinary to the results from a situation in which the occupant may choose all possible alternatives and no restrictions are imposed to his fantasies, is the similarity with the archetype of the farmhouse. Apparently this is the image formed of the perfect house. The only slogan remaining to stand out from the mob is 'the bigger the better' 'fig 3.1'. In case the building contractor doesn't accept full responsibility for discovering the actual living demands of his customer, the wish for the perfect house remains platonic.

3.1 Figure the dwelling will always be the symbol of its occupant, Smeets

Housing consumers who can't afford building their own homemade house, have to turn to collective housing-construction. Housing corporations nevertheless still use the same old standard construction techniques and approach the project still as a fixated final solution. The housing corporations own, especially in developing unreclaimed regions such as Vinexlocations, large sections of building land. They built for an anonymous market which forces them to reflect in target groups. Within this niche there is no place for individuals.
Because of their interpretation of the building process, by means of techniques and philosophy, and constructing for an anonymous market, the building stock is saturated with inadaptable houses.
Because of this way of offering residence to the housing consumers, they find themselves forced in a passive position. There is no opportunity left for occupants to add a personal touch to their house. The act of taking possession denied.
This way the development of personal living demands is suppressed by unnatural means. These houses are disguised in façade architecture or dreamed up perception of the environment which has to express a collective satisfaction. The occupants have to arrange themselves to the offered space. Housing consumers which are served by this anonymous market express the same demand on dynamics and diversity. Therefore inadaptable houses are the slums of the future.

3.2 Figure collective house construction Leidscherijn, Utrecht

The current legislation, post-war construction methods and a design process which is fixed on the final product, degenerate into a uniformity of rigid newly-built houses. Occupants must arrange themselves to their house. The moment on which the consumer takes residence in the building is considered as the end of architecture. Within this approach adaptations by use affect the architectonic design.

4 House and Home

A discrepancy arises between architecture and its public which particularly expresses itself within public housing architecture. This friction often appears when the creator has to let go of his design so as it can be experienced and adjusted by its occupants without his supervision. Therefore the art of especially public housing architecture is to make a design process interesting for both sides. 'We make buildings which have the willingness to be occupied, not occupation itself.' [Reeth 2000] House construction is a grateful subject of research to narrow the gap between architecture and its public. Everyone has a know about living in a house; in the end we already occupy our entire life.

Family compilations are more divers than ever and furthermore subject to changes. Living is directly connected to the social circumstances of people. Occupation means living in a house and living is characterized by an uncertain future. The family compilations, financial situations, state of mind occupants are in, their interests, spare time, working at home and age are circumstances which influence the interpretation of residence.
With changing wishes the demands made on the house are shifting. By way of time-durability a project comes forward to this unpredictable process. The ways across which those processes are developing, are just as unforeseeable as the wishes and demands the occupants are making. *Dwelling is a process.*

Residential-wishes are unforeseeable, because everyone has his own ideas about how he wants to live 'fig 4.1'. A difference between standard demands and a personal interpretation of occupation can be indicated by distinguishing 'house' and 'home'. The issue is that a house only gets an added value as 'home' when it is capable to comply with the personal ideas of her occupants. A time-durable housing complex has the willingness to fulfil those demands, because durability obviously means adaptability for new functions ánd individual living-demands. *Dwelling is personal.*

4.1 Figure dwelling is personal, MVRDV Lloyd Hotel

Finally the average occupation lasts for ten years at the most, whereas a house lasts for a hundred years. Designing a new time-durable building one has to memorize two important issues: the technical and the functional lifespan of a building. The technical life span of the building depends on the adopted building techniques. Most of the time the technical conditions of a building becomes the decisive factor in the discussion between demolition and change of use. The functional life span is the duration in which a building can accommodate different functions. Planning in a timeless and durable way means not to restrain the geometry of the building to be specialized in its first functional purpose. Indefinable design to serve an unknown public. The less a building is custom-made the better new purposes will fit in this garment. The technical life span of a building is more sustainable than its functional life span. *Dwelling is temporary.*

'The shell as intelligent ruin is the key to durable buildings. History has demonstrated it to us. […] Durable buildings are designed towards unpredictable occasions.' [Reeth 2002] The only constant factor in occupation is change. Especially the personal, temporary and processing characteristics of dwelling make the difference between 'house' and 'home'. Therefore architects cannot translate residence as a fossilized programme of requirements 'fig 4.2'.

4.2 Figure old building adopting a new function, MVRDV ism Joep van Lieshout Lloyd Hotel

5 Firm frameworks

A housing complex which cannot be reinterpreted in its functionality is not durable. 'Without a framework changeability is impossible and without changeability life in a house cannot breathe.' [Leupen 2002] Anticipating on flexibility and durability is one side of the medal. The side for which a lot of experimentation on the field of building technology is done. The other side of time-durable construction means deriving an unconditional public support from its surroundings. The point on which architecture acquires significance with its public. A cultural durable building.

A building with a lack of adaptability towards a second purpose fits for the scrap heap after a few years. When such a building is in perfect technical conditions, demolition would mean destruction of capital. However this economical disaster concerns not only the base materials and components which could be suitable for recycling. The fact is that the value of a building increases as its growing old.

Adaptability to various uses is the solution for occupation, though it is not the complete answer to develop a culturally durable construction method. The other condition to which every time-durable product has to come up to is a public support. Frank Bijdendijk distinguishes two different qualities which support this public base.
‘A ‘Solid’ is a durable building, in economical, functional, technical and emotional use of the word.’ [Bijdendijk 2001] A durable building fulfils an ‘accommodation capacity’ as broad as possible and responses to a particular idea of ‘preciousness’. Housing Corporation ‘Het Oosten’ is firmly confident that preciousness cannot only be expressed in a certain feeling of esteem, but also in a pecuniary advantage. These ‘Solids’ derive this preciousness from their aesthetic design and ease of use.

Even though many architects would rather not believe aesthetics will not guarantee. In ‘How Buildings Learn’ this ‘preciousness as added value’ is strikingly described by the words of recognition from the occupants of an anaesthetic, climatologically disaster. 'Like most Low Road buildings, Building 20 was too hot in the summer, too cold in the winter. […] The ability to personalize your space and shape it to various purposes. If you don't like a wall, just stick your elbow through it.' [Brand 1994]
Those desires of the users of Building 20 on the MIT territory are from all years and are so outstanding obvious that architects easily overlook them. In this case all the remarks of the occupants highlight the fact that the ease of usage of building derives appreciation. The authority about and ease with which adjustments to there direct surroundings are made, exceed the appearance by far.

Preciousness depends on aesthetics and ease of use. By introducing the concept of ‘manual’ these two terms can be combined. The design which is pursued by a developer of a time-durable building is the articulation of the accommodation capacity within a permanent framework. The appearance of the design needs to express which methods are deployed to expand the adaptability of the building. In a univocal manner, so even layman in the field of architecture are able to read its design. ‘The forms that we make have to be truly understood by consumers.’ [Hoeven 2003]

6 Field of tension

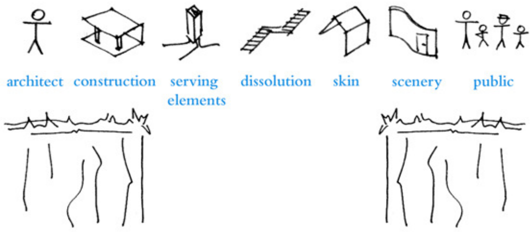
With ‘Built to Last’ a bridge is spanned between the architect and public. This bridge is the building itself. Design office ‘Droogdesign’ launched a production line called ‘Do Create’ that includes products which are not yet completed. The consumer is forced to intervene and by this way add his personal touch. ‘Do’ should be the brand which is demanding something from the consumer, which needs so to speak a personal touch to be completed ‘fig 6.1’. ‘Do Live!’ deals with the laziness of the consumer. ‘It recalls the image of contentment’ gives no satisfaction. This concept assumes a more active attitude from its occupants. This to provoke him to engage on his real living demands. After all the occupant only starts to live for real in case of interaction with his built environment. Thus the opportunity arises to reflect a way of living. Within this project the housing consumer is given the change not only to recall an image of contentment, but to be satisfied!
The concept ‘Do Live!’ defines a design method in which adaptations by usage compliment the building. This way the adaptable design becomes the field of tension between the architect and the occupant. The core idea of the designer has to be that life within a building makes them even more interesting; a defiant design approach.

6.1 Figure field of tension between designer and consumer, Droogdesign Do Hit

John Habraken realises that both architect and occupant leave their mark on the built environment. For this reason he suggests attaching an additional level to house construction; called built-in. This way he is separating the collective support construction from the individual built-in. This new interpretation from the housing-construction programme had many followers. Freedom of choice is brought forward as main issue. Thus a vertical hierarchy arises by means of town to district and neighbourhood, to support and built-in. From top down, the degree of adaptability increases just as the authority of the occupant. This way the architect puts himself above the occupant.
Another risk within is the house forcing to be adaptable. This approach of the adaptable house demands a sophisticated coordination between the support structure and the built-in. The designer loses himself in puzzling out a technical and perishable system. Within a vertical hierarchy of authority the point of interest is focussed on the generic part.

Another approach to make a draft for an adaptable housing complex is to think of the permanent part as point of departure. As such the authority is expressly not the central keynote, but the capacity of the building to compromise to a new functional interpretation.
Bernard Leupen analyses house-construction at the same level of scale ‘fig 6.2’. This separation between the permanent and the generic part dissects the housing complex in different layers. Some of the layers construction, serving elements, skin, dissolution and scenery belong to the framework. The remaining layers make up the generic space. This way a segmentation of control at a horizontal level arises. It is not necessary to attach an additional level of authority to make house construction durable. Emphasize shifts from ‘flexibility for the occupant’ towards ‘adaptability of the building’.

6.2 Figure concept, Leupen



Key-concept is accomplishing adaptability within the building as a solid framework. The architect concentrates on devising the permanent framework, which accommodates a diverse application. The occupant is forced to enter into interaction with the built environment within the framework put by the architect. In this way a tendency develops where the individual interpretation of living-demands is a priority.
Adaptability implies freedom for the occupant, bound to the resistance of the building. The unexpected is challenge for the architect. *Adaptability concerns modifications within a firm framework.*

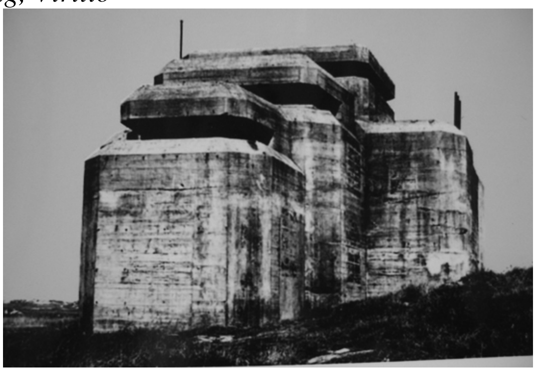
7 Meaning of architecture

Under the cover of flexibility a lot of experimentation occurred. To achieve a worthwhile interpretation for the adaptability of the framework to devise, a number of flexible projects have been inventoried.
In case of projects with a high level of self regulation by the occupants mutations frequently occur. Landlords do not encounter disadvantage because of lack of authority; not by means of expenses or illogical adoptions and either by means of time-consuming to manage transformations in the right direction. In addition the tenants are more satisfied because they experience the advantages of adaptability better. Because of this perception of flexibility the sense of preciousness increases. Strikingly both the landlord and the tenant are highly appreciating the diversity of the residences within a single complex. Within the current architecture debate prevention of a monotonous arrangement of buildings and occupants in a neighbourhood, is a touchy subject. By those means anticipating adaptability could entail a solution.
Change of functionality of a room has direct influence on the everyday surroundings of occupants. This functional flexibility occurs without any intervention considering the division of the available space. Polyvalence is the most elementary and occurring form of flexibility.
In addition to functional adaptation of living space occupants utter a wish to modify the living capacity. They have definite notions about how they would realize extensions to their houses, in case of offered possibilities. One of those ideas of which little practical experimentation has occurred is the reallocation of living space within a single housing complex. An urgent need appears for an apartment complex which derives its adaptability from the reallocation of polyvalent spaces ‘fig 7.1’.

7.1 Figure reallocation

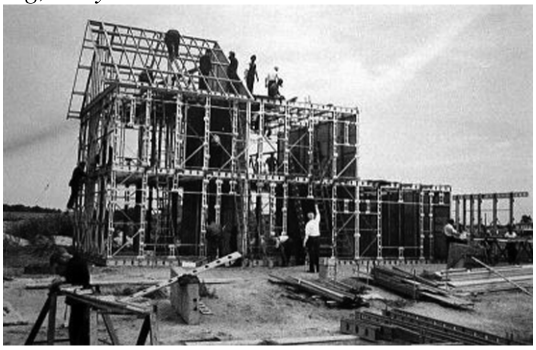
Jos Lichtenberg wonders if architects aren’t programmed the wrong way. He notices that ‘technically a lot of experimentation is already happening, without the participation of architects.’ A number of design guidelines to improve the accommodation capacity of buildings are over-dimensioning, minimisation and detachable detailing.
Over-dimensioning is not only related to the supporting power of construction ‘fig 7.2’. Excess is also connected to the floor to floor dimension, continuous open floor area and reserved space for installations and dissolution. Concerning over-dimensioning being a method to anticipate on change of use bigness is prevailing.

7.2 Figure over-dimensioning, Virilio



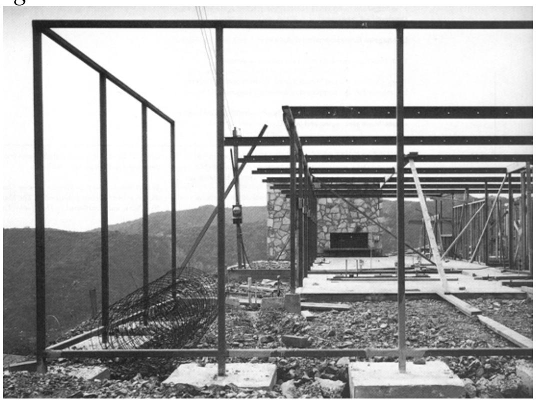
Detachable detailing encourages reusing buildings because those assemblies are said to be easily disassembled ‘fig 7.3’. ‘Are said to be’ because taking parts of those constructions to pieces is often very specialistic craftsmanship. ‘You’re familiar with them, buildings showing up to and including the very last screw how they can be dismantled and thus are materially recyclable. More often they are twice as expensive and temporary, in other words not durable as without a trace.' [Reeth 2002] According to Mieke Hoezen a disadvantage of a complicated built-in system is the fact that only the supplier can handle it. [Hoezen 2003] When the time arrives adaptations are to be made the system will no longer be provided and it will be hard to find any craftsman. In case knowledge of handling the system is lacking, the detachable IDF system runs the risk to be treated just like any other wall to become an obstruction.

7.3 Figure detachable detailing, Polynorm Houses Eindhoven



In this case minimisation means to determine the division of the floor plan as less as possible 'fig 7.4'. An anonymous indefinable space confirming those basic principles qualifies by definition for an increasing diversity of utilizations. To come forward to the credo 'less is more' an exceptionally well-considered architecture is necessary. This does not hold out prospects of a meaningful contribution of architecture on the subject of time durable design.

7.4 Figure minimisation, Grag Elloid



8 Sculptures

The question remaining is which role can be put aside for the architect 'fig 8.1'. By considering a building being just a sculpture, a closer investigation has been done about the influence of the geometry of a building structure on the allocation methods of housing units.
The concept is to give the consumer the opportunity to have a second opinion on this kind of architecture, because of the freedom to interfere with his daily environment and thus discovering and learning to appreciate the intelligence of the rigid framework. 'In this sense a house or building is lines without words but imbued with significance. Lines which tell us about the history of the house and about his present inhabitants.' [Neumeyer 1993] During the quest for a method in which design is able to support the possible connections between living units, it is highly important to check the models on articulation of strategy within the architecture of the framework. The building is merely a sculpture.

8.1 Figure influence of sculpture?, Frank Gehry Experience music project

A number of geometrical properties which have influence on the adaptability of a structure emerge. It is favourably when all separate units can be connected to one continuous volume, in which all living units are opened up separately. The diversity to house typologies increases as the number of adjacent housing units grows and all of these spaces serve themselves of a neutral supply level.
The legibility from the method of reallocation, expresses the manual of the building in its façade 'fig 8.2'. Through this design approach architecture emerges which a layman in the field of architecture can truly understand. 'Even more interesting is the question about the effect of the articulation of the framework on the occupants. In a wider sense the central question is about the meaning the architecture of a house can obtain from its occupants.' [Leupen 2002]

8.2 Figure scenario senior citizens

9 Conclusions

The shape investigation is based on capacity for accommodation. This functional flexibility has predominated the development of this design. The adaptive capacity towards new utilizations is increased by connecting different living units. In elaborating this unit construction special attention is paid to accentuate the expression of the framework. An evident articulation of the framework magnifies the legibility of the project. An architecture arises which is comprehensive to everybody. Durable constructing means particularly a consideration between permanence and ephemerality.

The theory of Bernard Leupen becomes a useful steppingstone to explain the way the definitive design anticipates on legibility and accommodation capacity. The architect expresses himself in the permanent layers while he leaves the generic space vacant to be adopted by the consumer. By those means the architecture of the framework remains preserved for a long period of time and thus is given the opportunity to evoke a certain feeling of recognition from the occupant. This recognition is reinforced because of the ease of use of the design and by the space which is offered to appropriate the house for real. This design doesn't only encourage the occupants to interfere with their surroundings, it even forces into intervention. The rules of the game are implicit in the framework expressing its own manual.

For this framework a tectonic architecture has been used to achieve a clear geometrical style. The manifestation of the building refers to the constructive scheme. The constructive composition accommodates diversity of occupation. The representation of the façade becomes meaningful towards the occupants as a manual. Thus a bridge is spanned between architecture and its public.

Architecture has no performance such as expressive art.
Architecture is a performance.

3.2 Figure scenario office by night

'Beautiful or not, that doesn't matter, as long as they know what is happening.' [Janssen 1981]

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Development of a New Elevator Addition System for Aged Residential Buildings

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KEYWORDS

elevator addition, public residential building, barrier free, renovation, experimental construction

Paper

1 Introduction

In Japan, a huge volume of public housing was built in the mass-housing era between 1955 and 1973, and many related problems have arisen in recent years. Today, due to an increase in the number of aged residents, one of the most significant pending problems concerning public residential buildings is barrier removal and customization for elderly people. Several local authorities and housing corporations have added new elevator towers to the old walk-up buildings, however, certain problems remain. This paper proposes a new elevator addition system that solves the problems of the existing methods, and presents the results of an evaluation of an experimental construction of this new system.

2 Actual Circumstances Concerning Addition of Elevators

Firstly, we analyzed architects drawings of approximately 30 public residential buildings to which elevators have been added, and classified the buildings according to type. The most common type is that of buildings with the addition of an elevator tower to the outside of each of the staircases in the building. This method does not result in totally barrier free access to the dwellings because the elevator car has to stop at the landings of stairways, so that residents have to go up or down half the story height on foot.

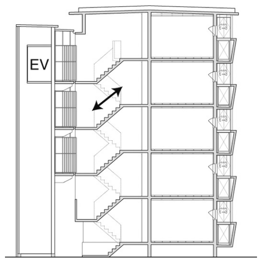

Figure 1. Building before and after the renovation work involving the addition of elevator towers, and section view

3 New Elevator Addition System

The new method we propose is an elevator tower unit consisting of an elevator shaft and stairs installed in a spiral design encircling the shaft. The construction is very simple. Firstly, the tower unit is installed on the outside of the existing staircase. Next, the existing stairs are removed and new floors are installed in the vacant stairwell on each floor level. Finally, the tower unit is connected with these new floors.

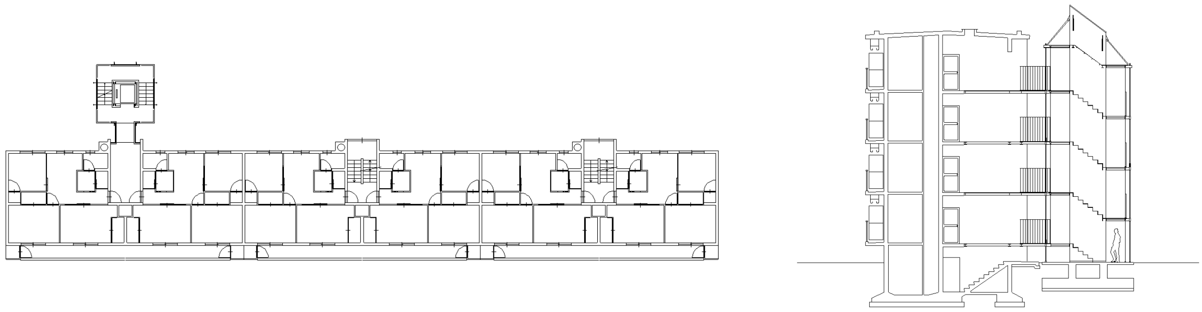

Figure 2. Plan and section of the building with the new elevator system

The advantages of the new system are: achieving barrier free access and facilitating renovation work. Moreover, new, attractive spaces are also created. The first space is a new approach lobby for all residents sharing the same elevator unit, generated at ground level within the unit. This lobby consists of a space for waiting the elevator and a space for mailboxes. The other space is the new entrance porches for each dwelling, which are generated on the additional floors in the stairwell. These spaces contribute to improving the utility of old buidings.

Figure 3. Structural diagrams of new system and photograph of the new elevator addition system applied

We designed this system to be compatible with a compact elevator. In Japan, elevators are generally high quality, but large and expensive. Although large elevators are structurally stable, it makes the existing staircase dark and unattractive. So, we propose a structural system that uses slender tension rods around a compact elevator shaft, which provides not only structural enforcement, but also gives a lighter impression of the elevator tower unit.

4 Outline of Experimental Construction

We constructed an experimental construction to evaluate the effects of new system. This new system was applied to a vacant residential building located in 'Y' housing estate, including a typical selection of aged residents.

The first phase of the construction took place from December 2005 to February 2006. In this phase, only an elevator tower unit consisting of an elevator shaft and stairs were constructed. Inside the elevator shaft, the elevator machine and lift did not need to be constructed. In the next phase, it is scheduled that the existing stairs are removed, new floors are installed and the elevator tower unit is connected to the floors.

Figure 4. Process photographs of construction site

After finishing the design in detail, steel pieces were fabricated in a factory. At the same time, the ground was excavated and the foundations was laid. After finishing the prefabrication, the steel pieces were delivered to the site and the steel skeleton was errected. Then, the steel rods around the elevator shaft were tensed up. Hereafter, construction work was carried out in series; the exterior wall of the elevator shaft was set, the elevator shaft was covered with a roof, metal work was completed, the steelwork was painted, glass panels were set in the stair landings and the floors were finished.

5 Analysis of Experimental Construction

We recorded the progress of construction work, noting each task and the time requried for each task. After completion of work on site, we analyzed the relationship between each task using the data obtained. The analysis was important in order to reduce the construction period and lessen the residents' burden so that construction could take place while the building was occupied by residents.

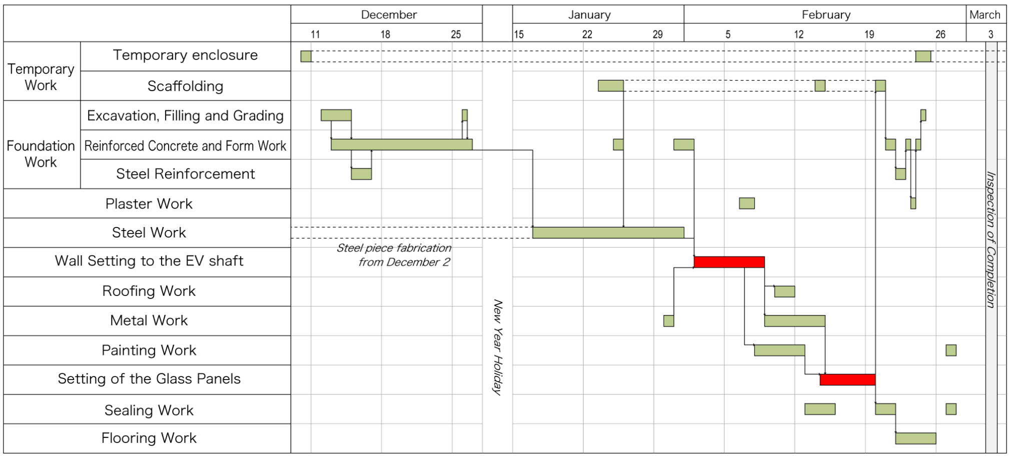

Figure 5. Construction flow diagram showing relationship between each task

The construction flow diagram shows that in the first half of construction, tasks were completed one at a time, such as laying the foundations and errecting the tower unit. In the latter half of construction, many tasks were carried out simultaneously. When tasks are tightly scheduled, it is essential to prioritize the wall setting to the elevator shaft and the setting of the glass panels. Once these tasks are completed, other tasks can begin. Thus, it is important for reducing the construction period that working these tasks promptly and scheduling tasks to be worked simulataneously with other works where possible.

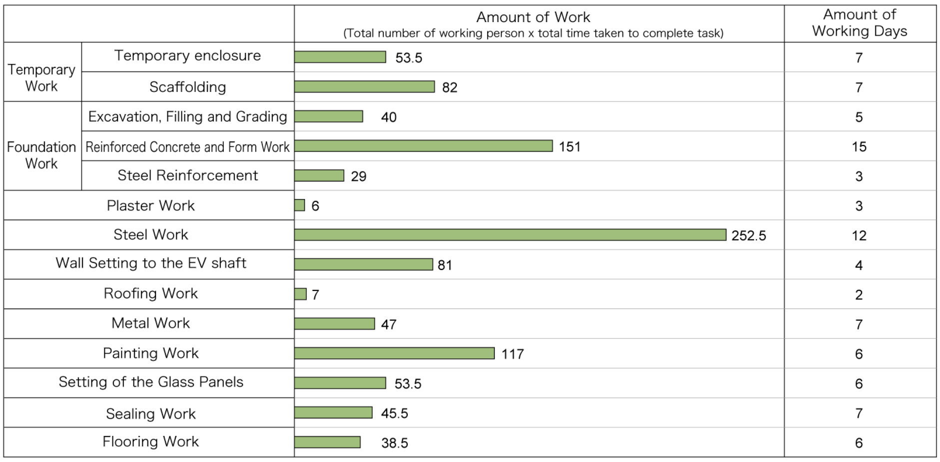

Figure 6. Total amount of work

Figure 6 illustrates the total amount of work, which was derived by multiplying the total number of working persons and the time taken to complete each task together. In this construction, increase in the amount of steel work was unavoidable but the amount of work in laying the foundations should be decreased. Laying reinforced concrete foundations was time-consuming, so another foundation material such as steel should be used.

Figure 6 also shows the increase in the amount of painting work, wall setting to the elevator shaft and temporary work, compared to other tasks. The increase in the amount of painting work and wall setting are avoidable by careful organization of construction progress and arrangement of designs in detail. In addition, decreasing the amount of temporary work would reduce the overall construction time, so we should arrange the tasks to be completed without temporary scaffolding, especially in setting the glass panels.

6 Conclusion

Evaluation of the progress of the experimental construction reavealed that in this system, arrangement of construction progress and changing the foundation material increases the efficiency and reduces construction time. In addition, the new space generated as an approach lobby at ground level provides a good place to wait for the elevator, check mail, and enter the building. This experimental construction is still in the first phase, in the next phase the existing stairs will be removed and new floors will be installed. After completing phase two, we will analyze all construction data and consider how we can improve the system.

The records of experimental construction were updated on the website (Japanese). For further details of the construction process, see *"Under Construction : Elevator Addition System for Aged Residential Buildings,,* http://coea111.exblog.jp/

7 Acknowledgments

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Open Building in steel, development of a steel framed housing system.

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KEYWORDS

Open Building, Mass Customization, Steel construction.

ABSTRACT

1. Open Building, two perceptions

The advocates of Open Building Implementation organized in CIB Working Commission 104 share a strong focus on the customer and his needs for flexibility and adaptability. Members consider the changing needs and preferences of tenants as the main driver for developing Open Building concepts. Such concepts are caracterized by raised floors, light partition walls and cable plinthes. {Kendall 2000]

But in Open Building there are two interests groups to be observed. On one side there are the home owners and tenants. The Clients. On the other side there are the manufacturers of building systems and components. The Suppliers. Clients are primarily interested in internal flexibility. They want in the design stage the opportunity to personalize the lay-out and out fit of their new build house. Later after some years of occupancy they need the possibility to modify their home. To adapt it to a new era in their family life cycle or to new technological features.

Suppliers have other interests They want the possibility to supply elements – facades, sanitary modules, atticks etc. – to existing houses undependant of the system by which the house was build originally. They need what they call “Open Systems” to enlarge their markets. Clients may benefit from such supplier independent systems through the competition between suppliers.

Suppliers need standardized building knots, system independent knots, knots that are accepted by all parties in the market.

A question that comes up here is whether or not these two perceptions of Open Building can go together. The first impression is that though the objectives are quit different the resulting technologies may work perfectly together. But there are differences. Clients will need flexibility in cabling and ducting. Raised floors and cable plinthes could serve such a need. Not the first interest of building system suppliers. But clients need also easy to install extensions to the house. And their suppliers of open systems may offer exactly the easy to mount extra room that clients ask for.

2. Research project Inprest

With financial support of the European Union a research project was set up in 2004. The official title being: Integrated Pre-fabricated Steel Technologies for the Multi-Storey Sector. The objective of the study was specified as:

The development of Open Building System(s) considering the following objectives:

- Customisation, allowing for flexible and individual application of components.
- Standardisation of dimensions and connections allowing for simplified planning and interchangeability of elements.
- Technological advantages by mixed steel technologies, easy assembly, fast construction, integration into planning and production chain.
- Significant improvements of performance (fire resistance, noise and thermal insulation, aesthetical acceptance)

The research proposal was written by representatives of the steel industry. Big steel suppliers like Corus with headquarters in the United Kingdom and The Netherlands, Finlands Rautarukki and Luxembourg based Acelor were involved. Other partners were representing the steel research community. Leading institutions such as the steel construction research institutes from England, Germany and France. The author of this paper was invited to join after awarding of the funding, because of his membership of CIB working commission 104 on Open Building. From the first meeting it was apparent that W104 maintains a definition of Open Building which is far apart from the definition used by the industrial parties that proposed the research project.

After some comparison of definitions it was decided that the client focus of W104 and the suppliers focus of the mayority of the research team could joiuntly be taken into consideration. In the definition by Kedall and Teicher (2000) Is said that in Open Building responsibility for decision making is distributed on various levels. W104 is mainly concerned with the infill level, where tenants and private owners are the decision makers. The suppliers in the research project showed primarily interest in the base building or load bearing structure where decision making is mainly with the suppliers.

Another difference between client and supplier is found in the attitude towards the building knots. Clients are mainly concerned with the demountability of infill elements. Standardization of the dimensions and connections of alternative elements are not a critical subject. Kitchen systems, sanitary systems and partition systems are designed to fit in all structures. For suppliers of fasades and voluminous units standardization of the building knots and of the dimensions of elements are of mayor importance. Without standardization it is hard to fit prefabricated elements from one system into another.

It should be said here that the border line between the territory of the tenants and the territory of the system supplier is not very strickly defined. In the among Open Building supporters well known Next 21 project in Osaka, Japan, the fasades are demountable and can be replaced by other elements to the tenants choise. Of course, fasade elements in Next 21 cannot be fully different from adjacent elements. The tenant must make his choise from a limited number of pre-designed standard elements. But this does not deny the fact that the tenant is the decision making party.

3. Methodology

The research project started with an inventorie of the existing building stock. From litterature, web search and company brochures an overview of existing Open Building technologies and strategies was made. The found systems were evaluated against a number of criteria such as:

- Environmental impact
- Safety
- Occupational health.
- Demountability
- Cost
- Speed of erection
- Mass customization
- and others.

The performed evaluation was based on the expertise of the team members. The evaluation of all parties involved was merged into a collective opinion.

The project passed recently the half-way milestone. After the evaluation of the findings the next step will be the design of a design guide and tool kit for an open system that is likely to cover the needs and preferences of a mayority of the market for Open Houses.

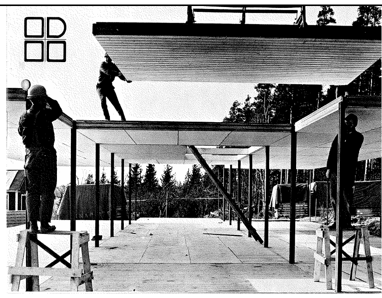
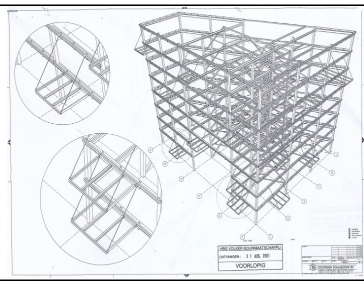
4. Categorization

To categorize Building System there were four different structural approaches identified. The oldest systems are based on columns and beams (one-dimensional or skeletal elements).The columns and beams provide a load bearing frame or base building. This frame is closed with floor elements and façade elements. Alternatively beams may be integrated in the floor slabs. And wall elements may be load bearing. In such a type of building system we speak of a system based on two dimensional or planar elements.

The latest development in building systems are the systems based on voluminous units (three-dimensional or modular elements). These units are stacked to built multi-storey houses and offices. Most three-dimensional elements have an integrated load bearing frame. These units do not need any additional support system. Alternatively there are systems based on units whit a light internal frame. To stack these units an external load bearing frame is needed.

In 1- and 2-dimensional systems a comparable split is seen. In some systems the 2-dimensional floor and façade slabs are provided with integrated frames. These elements are able to support multi storey structures. Basically different are the systems where only the one-dimensional elements have a load bearing capacity while floors and facades are non structural.

The research team found also mixed systems. In particular a number of systems combined modular units with slabs.

Open Building Systems	3-dimensional elements	1- and 2-dimensional elements
Structural elements		
Non-structural elements		

5. The inventory of existing projects and technologies.

After the definition stage a world wide inventory of Open Buildings projects was performed by the research team. A great variety of systems and one-off projects was found. From single family houses to multi storey systems. From 30 year old mature systems to experimental ones. And the Ino hospital in Bern as a proof that Open Building is not limited to housing and some straight forward office buildings. What we found was such wide spread in its approach that we had to conclude that there is not such a thing as a typical Open Building architecture. This may console those architects who worry about the consequences of standardization and industrialization.

The next step was an inventory of available load bearing structures. Technologies for the design of fasades and technologies for the design of floorslabs.
The study of façade and floor systems (in the category 2 dimensional systems) turned out that 10 typical floor systems and 9 typical facade systems can be distinguished. The project team wanted to make a choise of the most feasible systems for an Open Building system. For that reason all systems were scored against a list of criteria as mentioned above under methodology. The outcome of the project so far is an overview of suitable technologies for OB systems ranked in order of potential for a feasible system development.

In the floor study there was special focus on choise between a flat floor and a recessed floor. In cases where sanitary units are prefabricated the floor of the unit will force tenants to step-up into the cubicle. A recessed floor allows positioning of such a cubicle without stepping up. Disadvantage is that there is less space left under the floor of the cubicle for waste water pipes.Flat floors cause unevenness in the appartment floor but allow unrestrickted positioning of sanitary units all over the place.

When investigating fasade options it was found that fasades, much more then floors are subject to local rules and culture. Where some countries like The Netherlands have a precasrt concrete tradition others like the United Kinfgdom seldomly choose Prefab Concrete fasades. Where brick is commonly used in some countries, it is almost non-existant in neighbouring ones.

Also a dimensions sytudy was performed. Some differrences in local building laws were found, mainly concerning minimal required dimensions. For example minimal distance between floors and ceilings in residential buildings appeared to vary between 2.4 and 2.5 m. Not a big difference. But because of cost saving developpers tend to build only according to the allowed minimum. Therefor a standardized system may cause additional cost in some countries. These differences may hinder the development of a commercially attracktive international market. But it is assumed that European standardization will soon smoothen these differences.

6. Protocol for Open Building Systems

In the framework of the evaluation it was a necessity to assess what are the essential requirements for an Open Building System and which requirements are optional. For each recognized requirement it was also assessed wether it was in the clients interest or in the suppliers interest. Apart from that the team discussed wether a requirement was in the clients reach of decision making or in the suppliers range.

The team decided to consider following requirements essential for an open building system.

1. Flexibility in use of private space, including partitions
2. Flexibility in services,
3. Ability to extend or modify the building in the future
4. Customisation, input by user in design stage.
5. Flexibility in architectural solutions, including fasades,
6. Familiar technologies,
7. Inter-changeability and compatibility of components
8. Wide geografical applications.

The first 5 items are clearly client focussed, while the later 3 items are typical based on suppliers interests.

Apart from the esential requirements also optional, attactive but not essential items were identified such as:

1. Flexibility in future change of use,
2. Open construction technology,
3. high level of prefabrication,
4. high construction speed,

Here the W104 members certainly will advocate that future flexibility should be among the essestial requirements. The other three items are typically industrial interesting for the suppliers from a commercial point of view, but in the ens clients will benefit from the price reductions that come with it.

The ranking above is only based on the vision of the resaerch team. In the next stage of the project this provisional ranking will be tested by interviewing a number of experts and users.

Finally an environmental analysis of existing open building systems was performed. Feasible Open building systems should meet high standards of environmental quality. Not only in the production and assembly stage but during the whole life-cycle including use and demolition the Open building systems to be developped must meet the highest possible environmental performance requirements.

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PATH Concept Home

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KEYWORDS

Concept Home; Open Building; Production Process Improvements; Market Research

ABSTRACT

As part of the process of designing a Concept Home that establishes a vision for the future of housing in the United States, PATH has developed a whole house technology road map, conducted market resesarch with builders, architects and homeowners, explored homebuyer demographics, and researched state-of-the-art technologies.

Concept Home principles

This research has resulted in the identification of six key principles for improving the future of U.S. homebuilding:

1) *flexible floor plans* feature designs and building systems that enable interior spaces to be reconfigured more easily;

2) *organized and accessible systems* reduce interdependencies by disentangling mechanicals from each other and separating them from the structure and floor plan. This organizes the systems so they are laid out efficiently and logically, and provides easy access to the systems for repairs, upgrades, and remodeling;

3) *improved production processes* encompass management systems, information and communications technology, manufacturing processes, and assembly processes that improve building quality and efficiency while reducing production time;

4) *alternative basic materials* are new advanced materials or those adapted from other industries and applied to home building;

5) *standardization of measurements and component interfaces* simplifies the installation of products and enhances design flexibility by adopting a standardized approach throughout the design and fabrication of a house; and

6) *integrated functions* combine systems to promote increased efficiency, reduced equipment needs, and multi-functional designs.

Market research

The results of recent market research indicate that builders are interested in reducing cycle time and solutions for the ongoing labor shortage as well as reducing the impacts of price spikes for building materials and costly landfill fees for wasted and scrap materials. Architects envision energy efficiency, affordability, and the design flexibility to meet different homeowner demographics, as the most important issues in the future. Additionally, the results of consumer

research show that Americans are interested in "flexible" homes that can be easily updated and renovated as their needs change over time or as technologies advance.

Changing demographics

For a better picture of the homebuyer of the future, PATH reviewed an analysis of changing household demographics (Ahluwalia, 2005), which demonstrated that American homebuyers are increasingly diverse and household size is getting smaller. And, while the relative portion of traditional family households (married with their own children) is shrinking, the percentage of single households is growing. As the first of the infamous Baby Boomer generation nears retirement, their desires need to be considered. In fact, one statistic suggests that 83 percent of those 45 and over want to "stay-in-place" as they age (Fletcher, 2006). According to the US Census (2000), nearly one in five Americans have some type of long-lasting condition or disability.

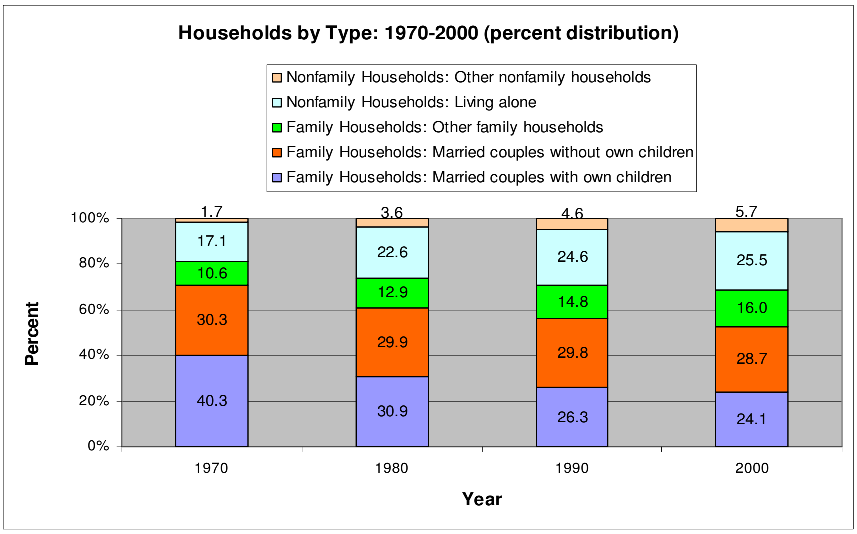
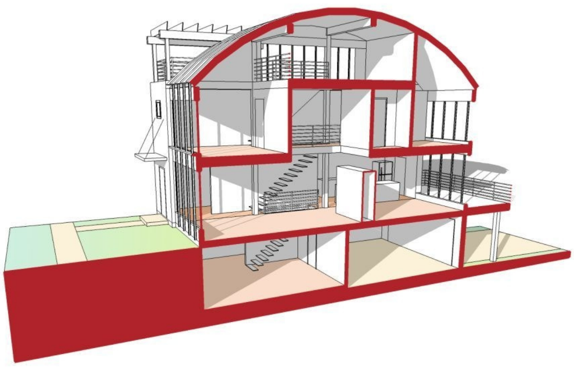


Figure 1. Changing American Household Demographics; ***Source: Ahluwalia 2005***

Figure 2. Concept Home Townhouse Design ***Source: Torti Gallas and Partners***



Modern Concept Home design

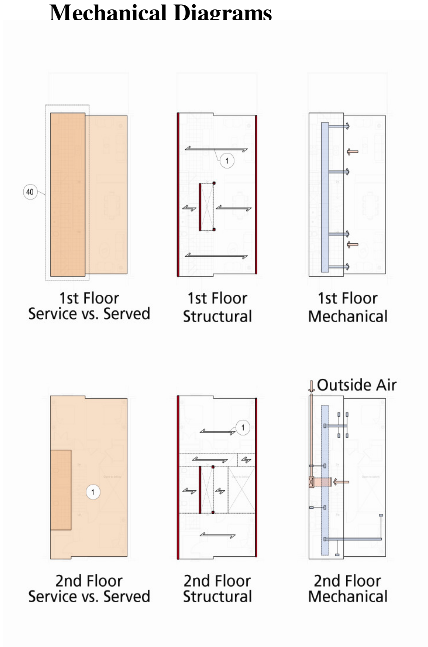
Based on these demographic changes and the market research conducted for this project, PATH developed scenarios for the people who might live in the "home of the future." Armed with occupancy scenarios and the Concept Home principles, PATH contracted with two architecture firms to design the first series of Concept Homes. Torti Gallas and Partners created a modern townhome suitable for urban infill and Steven Winter Associates created a more traditional design appropriate for the New Urbanist communities being built in the suburbs throughout the United States.

Mark Bombaugh, Torti Gallas' lead architect for this project, explains the townhouse design in terms of its spacial organization and flexibility. "The organizing principle for this project was to divide the house into two distinct zones: the service area and the served area. The majority of the building

Figure 3. Concept Home Townhouse Design (Basement and Loft not pictured here); ***Source: Torti Gallas and Partners***

systems are contained in the spatially efficient service zone. This frees the served zone for complete flexibility of use and adaptation to changing needs over time."

Figure 4: Service, Structural and Mechanical Diagrams

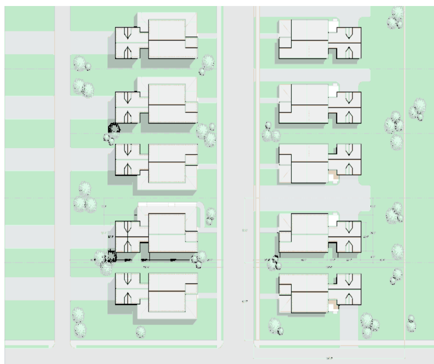


The service core, which can be seen on the left side of the floor plan in Figure 3, holds nearly all of the mechanical systems for the 1,828 square foot (170 square meter) dwelling. This service section could easily be manufactured as a module and craned into place on the site. Depending on the style of the development and the repeatability of the units, the prefabricated module could include utility rough-ins only or be significantly finished including finishes and appliances. This creates production efficiencies that reduce on-site cycle time and ease the need for skilled labor on site. The service core features rationalized mechanical system components which organize system layout, reduce entanglements with the structure, and provide means for access to systems. Examples include manifold-fed PEX plumbing supplies, air admittance vents, wireless light switches, minimized run HVAC system, and an attractive dropped ceiling assembly which provides access to the mechanical area between the first and second floor.

Figure 5. Front Elevation of Traditional Design; *Source: Steven Winter Associates*

On the opposite side of the floor plan, the served area is an open, flexible area that can adapt to different finishing arrangements based on homebuyer preferences. As the system diagrams in Figure 4 illustrate, the structural layout of the served area accommodate a flexible placement of interior partitions. In the prototype design the open floor area is actually divided with a movable furniture wall to distinguish the Great Room from the Family Room area.

Figure 6. Community Schematic
Source: Steven Winter Associates



Traditional Concept Home Design

The other PATH Concept Home design by Steven Winter Associates has the curb appeal of a traditional home with all of the innovation on the inside. This design incorporates efficient production approaches and standard measurements along with building systems which reduce entanglements and enhance flexibility. The dimensions for the house and the floor plan arrangement would easily accommodate a modular building production approach for the main structure, with the garage being panelized. "This PATH Concept Home is designed in a traditional, Arts and Crafts style that could adapt to either New Urbanist or conventional 50' wide subdivisions. The 2,200 square foot [204 square meter] home could be substantially reduced in size without seriously changing the amenities. One key design element is the flexible floor plans. The plan responds to a growing family by allowing the later finishing of second story spaces, especially the playroom/loft over the garage. Aging-in-place or provisions for a disabled family member is accommodated by means of space for an added elevator as well as fulfilling visitability requirements," described Alexander Grinnell, the lead architect on this project with Steven Winter Associates.

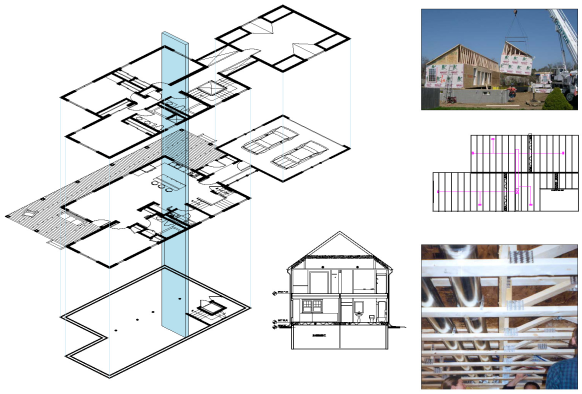


Figure 7. Mechanical core, disentangled utilities and craned modules*: Source: Steven Winter Associates*

The home is envisioned in the context of a community that features traditional neighborhood design with a "sense of place." The community is high density with small lots. It is pedestrian-friendly so that people can walk to schools, stores, restaurants, etc. The homes have front porches and rear-loading garages to keep the people facing the street and their neighbors to promote community. The site diagrams shown in Figure 6 also demonstrate that the design has the flexibility to adapt to various site configurations, including side load garages for developments without alleyways and double driveways to accommodate more narrow lots.

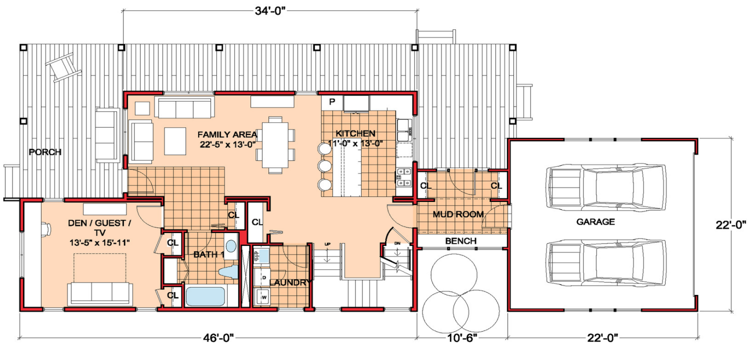


Figure 8: First Floor of the detached House with a Flexible Front Room*: Source: Steven Winter Associates*

Technologies

Both Concept Home designs feature flexible floor plans and building systems that enable interior spaces to be reconfigured more easily. In the traditional design, expandable spaces include the area over the garage, which can be finished at a later time, and a front room on the first floor. In one scenario, this front room is envisioned as a den or television room without direct access to the first floor bathroom (Figure 8). However, the floor plan can be easily modified to provide this room with access to a full, private bathroom is this space was to be used as a first floor master bedroom or an in-law bedroom. This room is also equipped with wireless switches for lighting which can be located according to occupant needs, and removable molding that is used to run and access cabling for electronics, communications devices.

The designs specify organized and efficient mechanical system components like central plumbing manifolds, dedicated flexible plastic water piping to fixtures, and prefabricated plumbing cores also known as wet walls that are manufactured off-site and craned into place. The HVAC designs rely on minimized duct runs to reduce material usage and system entanglements. Expandable spaces such as the loft area in the townhouse design are also built to accommodate an independent HVAC system, simplifying the finish work when these areas are completed. Other areas, such as a garage area that could eventually become a living space of some type, could utilize a "radiant-ready" rough-in in which radiant piping is laid in the slab during initial construction. This would also simplify the eventual finishing of this space. Mechanical ventilation is integrated into the main ductwork system for the house, providing a controlled amount of fresh air to dilute indoor pollutants and control moisture levels. By integrating the ventilation system in with the main house duct system, the system installation is simpler and additional entanglements are avoided. Wireless lighting systems and wiring and cables that run through removable baseboards mean that updating the home to incorporate the latest telecommunications technology is straightforward. The specified wireless switches are quite easy to program, enabling 3- or 4-way switches to be programmed – not re-wired - in just a few minutes. The switches are also self-powering, meaning they won't require battery change-out and the disposal of old batteries.

In terms of structure, both designs call for systems like open-web floor trusses which provide good span capabilities as well as great ease in routing mechanical systems perpendicular through these members. This aspect of the open-web trusses reduces installation time, can lead to more direct and efficient system layouts, provides better operating performance for systems like plumbing and HVAC, and eliminates the need to frame and finish bulkheads that may otherwise be necessary to conceal ductwork. The detached house also calls for a plenum truss system in the attic, which creates a conditioned pocket within the attic to rout HVAC ductwork. These trusses effectively create extra conditioned space up in the attic, which greatly improves HVAC efficiency compared to routing ducts in an unconditioned attic. Access hatches to this plenum also make it easy to add or change lighting, run new wiring, etc.

The designs also call for several alternative materials such as synthetic gypsum, electrochromic windows, and composite decking. The synthetic gypsum and composite decking products both offer resource-efficient alternatives that can be used to achieve the function of more traditional materials. The electrochromic windows are an alternative that goes well beyond the convention role of a window by providing the ability to manually or automatically tint the window to control heat gain and maintain privacy.

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Consumer oriented Building, the connection between Open and Lean Construction

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KEYWORDS

Open Building, Lean Construction, Consumer oriented housing.

Introduction

There is a natural friction between consumer oriented and building, since the construction industry optimizes on its financial results rather than on its product, the built environment. Open Building's main concern is the quality of the built environment and how it interacts with people. Although Open Building concept connects the built environment to construction activities, it has never really been successful in having their directions, such as modular coordination implemented in the construction industry. Lean Construction aims to improve the efficiency of the construction process by implementing the Toyota production system and its spin off Lean Production. Although Lean's first question is 'what is the value wanted by the end user?' the end user so far has hardly played a role in Lean Construction. This paper aims to overcome the limitations of Open Building and Lean Construction by connecting these concepts into synergy.

The Almere Monitor

The uneasy marriage of the consumer and the construction industry was demonstrated in the evaluation of fourteen housing projects in the Eilandenwijk, Almere, and the Netherlands in 2001 [Gemeente Almere, 2000].
Five years ago the Eilanden quarter in the new town Almere was under construction. The municipality wanted it to be an example of user participation, showing in the architecture of the neighbourhood. It was required that all dwellings should be made in close collaboration with the new dwellers and that no two units should be the same. The construction activities should be finished well before the official presentation in September 2001. The brochure said: 'while the dwellings are series made, the individual dweller should be able to find a house that fits its demand and taste. Theoretically every house should be different'. This was a unique opportunity to apply mass customization: all dwellings should be according to the dweller's wishes in terms of size, equipment and finishing. The municipality invited twelve developers and three housing corporations, who commissioned their architects. SBR, Foundation for Building Research has documented and evaluated these projects [Cuperus, 2003]. It identifies ways to determine the desired size: a core dwelling that can be extended, a Lego type system that allows the client to combine room size elements into the new house or super structure of which sections can be bought. The suppliers had their own way of setting the price. One chooses for a basic price for the core building and left it to the imitative of the dweller to finish the

house: a builder had to be found and a price had to be negotiated. Others offered fixed prices per element added. Yet other suppliers offered a basic price for a reference unit with additional costs for contract overruns. Implicitly and as interviews with architects demonstrated many times without knowing, the 45 year old Open Building principles of a separated support and infill were applied. Initially Almere looked like the perfect test ground for consumer oriented building. However, due to the time pressure of the launching exhibition most of the units had to be finished, before clients could be found. This was not consumer oriented at all. This is how it always was done and always worked in a seller's market. This is less successful in today's buyer's market. An economy in decline, the introduction of the Euro resulting on a decrease of spending power resulted in a stagnant demand and over supply of dwellings in Almere.

The paradox of consumer oriented building

Established expressions sometimes fade or lose their original meaning and then confuse. We all know what is meant with dwelling consumer, consumer electronics and consumer oriented housing. However after years of use it meaning has got blurred and it is time to refocus and rethink its meaning. Consumption is not only 'the act of consuming, or the state of being consumed, esp. by eating, burning etc. but also 'a wasting away of the tissue of the body, esp. in tuberculosis of the lungs'. [Collins, 1988]. The consumer consumes. Ones consumption has started on something it will disappear after a while. A car is a consumer product with an finite lifetime. Market research teaches us which cars are in demand and by applying flexible production methods the consumer can be served accurately. The built environment as a product of the construction industry is more complicated. Some parts of the built environment are being consumed. After a certain time they depreciate due to wear-out, fashion or other ways of aging. Think of the mechanical systems such as HVAC, kitchen and bathroom equipment or interior decoration. Other parts on the contrary gain value. This is best illustrated with the prices of real estate in historic town centres. They do not depreciate, rather than appreciate in value. And to add to the complexity: the value of real estate depends for a great deal on its location, not its configuration of brick and mortar. The owner/ user consumes part of its property and by regular maintenance he has a modest return on its investment. The owner has no personal control over the location of its property. Here lies the dilemma of consumer oriented building as the construction industries aim. Only part of the built environment is being consumed and writes off, other parts accumulate value. In addition to the owner/ user there are more users of the real estate, such as the passer by, who also contributes the quality of the immediate environment as well as the future user. We could call them 'client' of the built environment. Therefore, is it not better to talk about client oriented building instead of consumer oriented building?

External and internal clients

But who is the client of the construction industry? First of all there is a chain of external clients. The builder delivers the building to the developer, who then passes it on the dweller. In addition there is a network on internal clients: contractors and sub contractors who make temporary coalitions, working simultaneously at different sites. This hard to control network creates a lot of waste, drives up the price, which in turn translates in narrowing the profit margins. The demand for buildings remains and is supplied by a construction industry with a self-induced low performance.

1. A chain of external clients and the quality of the built environment

Construction is the means to create the built environment. In the search for value we can optimize the construction process and aim at a high quality built environment. Usually little attention is given to the client. Bertelsen at al (2005) conclude that in approximately 400 papers presented at twelve annual Lean construction conferences none has dealt in depth with the client as an important player in the process. They state: '(...) even though the term client appears to be a single person or a well defined group of persons or an entity, each client is naturally a very complex system'. Emmitt et al

(2005) raise the question 'Value to whom? This seems to be an easy question to answer, but it becomes increasingly difficult as we investigate the interests of the participants in the project'. The contractor is sub contractor's client, consequently there is a client relationship in the value delivery team, and this is a network of internal clients. In line with this thought, Emmitt et al have introduced the concepts of internal value ('by and between the delivery team') and external value ('which is the client/customer value'). There is a network of external clients as well. The institutional client such as a developer of a housing corporation is the first in a chain of clients: the buyer, the tenant and then the second generation of buyers or tenants. This is very much the concern of the first client, since the value of his property depends on its future re-sale potential. In addition to this chain of direct clients there is also a network of indirect clients: the passers by, who see their built environment being shaped by built objects they cannot control. The people who occupy the street in turn also determine the quality of the street. The interaction between people and the street is hard to design; it nevertheless contributes to the quality of the built environment. Since location highly contributes to the value of the property. The built environment is physical. Quality is subjective and value can be measured. Quality and value the built environment connect people to the environment. Habraken (2005) is concerned about this relationship. He says about Built environment: (...) but is still leaves out people. Built environment cannot sustain without a population Once abandoned, nature reclaims it; eventually, it is reduced to ruins'.

The Open Building concept suggests a subdivision of the built environment and its related construction and user process along lines of decision-making. This connects well to consumer oriented building. The fit-out belongs to the domain of the consumer, depreciates and is replaced on a regular basis. The base building is the part of the building that, if maintained well, easily can keep up with the price index and grows in value. It therefore makes sense to keep these spheres separated and to have them supplied by different industries. In the eighties of the past century this has resulted in detailed proposals to coordinate dimensions and positions of building parts. This decoupling was intended to make construction more efficient. Separated base building and fit out industries could keep clear distinctions between trades, thus preventing them to interfere with each other. In the mean time, efficiency on the building site and the demands of the unskilled DIY-er have resulted in new families of high quality and easy to use connecting systems for wiring and piping. Still the repair costs remain high. As long as the construction industry optimizes on the lowest price (and there is always somebody out there who wants to undercut) the risk of repair work remains high. Contracting the whole project blurs the borderline between base building and fit out. There is no reason for in between completion and its related quality control mechanisms. Failures only show in a late stage, resulting in expensive repairs. Separated tendering of base building and fit out result in separate completions with intermediate quality controls. The sequence of failure on failure has stopped and the final result includes a natural division between the depreciating consumer part and the appreciating real estate part. However, as long as the consumer can be ignored there is no reason not to optimize on price and the industry will not change its habits. Positional and dimensional coordination as well as level based tendering have never been implemented on a large scale except in experimental projects, *possibly because it was in the interest of the external client rather than the internal client who had to implement it.*

2. A network of internal clients and the efficiency of the construction process

How do the internal clients contribute to the construction process, vice versa? The construction industry performs tasks according to precise specifications and optimizes on its process. Lean Construction is an approach that helps to make the construction process more efficient.
TPS, the Toyota production system [Womack, Jones, Roos, 1990] resulted in lean production, which in turn laid the groundwork for lean thinking [Womack, Jones, 1996]. Lean thinking applied in the construction industry is called Lean Construction. The basic idea of Lean is simple: create value, banish waste. Already in 1950, Taiichi Ohno of Toyota understood that any activity that does not create value for the client is waste and should not have taken place. When, in the mid eighties, the

American and European automotive industry was in a deep recession, they analysed Toyota Production System, applied it successfully and then it became idealized. TPS, applied in the construction industry was named Lean Construction, which in turn has become a discipline in its own right. This can be summarized as follows [Cuperus, 2003]
The five steps of Lean Construction, in line with Lean Thinking [Womack at al, 1996]:
- Value: determine what the client wants;
- Value stream: determine the method to create this value. In Almere this was interpreted as the external client demands: ways to chose about the size of the house and rules how to establish the price;
- Flow: after the construction process has been described, based on the design de technical specifications, it is important to let the value stream flow. In almere this was interpreted as the internal clients considerations, such as lead times in the process and the choice of technical systems. A process will not flow process flow if the participants have to compete with each other and contracts are used to keep them short. It is important that all parties concerned can perform best and then rewarding them with long-term contracts;
- Pull: Listen to the client instead of making things that wait to be sold;
- Perfection: this is an ongoing concern.

It is evident that in order to create value for the client, one needs to know what the client wants. This is straightforward for consumer goods with single clients at the end of the value chain. However is far more difficult to identify the client of the construction industry. Fifteen years of Lean Construction has, besides some contributions from European partners shown little interest in the end user of the built environment. By focussing on the internal client, Lean Construction has concentrated its energy on banishing waste from the construction process on the building site. Like Open Building, Lean Construction also has developed its tools. The Last Planner system is one of them

A Lean Construction tool: Last Planner System

By applying Lean thinking the groundwork was laid for a method, specially developed for the constructing industry; this is called LPS, Last Planner System. It recognizes the important role of the person who takes decisions what an when to do. It is the last planner that can be addressed. Not complex preparations, but precise agreements on the site contribute most to the creation of value. Problems are not solved afterwards by mediation or in court, rather than being prevented by commitment and personal agreements between site managers of trades, that share the same interest, being the project the work on.
Instead of cost reduction for the main contractor by squeezing sub contractors, Lean construction aims at reducing the construction time by introducing trust between the internal clients. This increases the profit margin and by the reduced time more jobs can be attracted: a higher turn over against better margins.
Although the first step of Lean is to determine what the end user wants, we can conclude that this is not the major concern of Lean Construction, *possibly because there is a direct connection between optimizing on the internal process and direct profit. Since there is no single client but a chain of clients, it is much harder to relate client value to direct profit.*
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Conclusion

An interesting difference between Open Building and Lean Construction has been revealed. 'Open ' aims at improving the construction process by eliminating discussions between the parties concerned, waste is banished by decoupling and coordination of building parts along lines of decision-making. 'Lean' aims at creating value and banishing waste and creating flow in the process by optimizing on contacts and trust between trades amongst others, through daily meetings. Waste is banished by flow, thus reducing redundancy, idle times and work overflow, because that is waste. 'Open' identifies the negotiation room for the external client, 'Lean' concentrates on the internal client's value.

Five years after Almere, consumer oriented building is still not common for many construction companies. The client is seen as a disturbing factor in the construction process rather that a steering force. Only if there is no way out, we are willing to see our rescue. Open Building offers a practical order; Lean Construction shows us how to learn from other industries. Its combination opens the way for a healthy construction industry and a happy user.

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SATO-PlusHome

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KEYWORDS
Integrated Open Building Internet Concept

1 Open Building in Finland

General development of Open Building theme in Finland has accelerated gradually in the past 20 years. Main milestones leading up to the current state are:
+ Research and teaching at Helsinki University of Technology from the beginning of 1990s organized by architect Ulpu Tiuri, who also served later as a coordinator of the CIB-W104 Open Building committee
+ The first technology competition was held in Helsinki in1992, organized by the City of Helsinki and the Finnish Technology Agency. Two winning entries based clearly on OB-principles were built, one of them by Kahri&Co Architects. Several other projects were also constructed in the 90s based on OB-principles.
+ The second competition was in Helsinki "Arabia Shore" area in 2001. The winner was the entry called "PlusHome" by Kahri&Co architects and Tocoman, data-cost office with the SATO Corporation.
+ PlusHome Company was founded on equal basis in 2002 by Kahri&Co and Tocoman in order to concentrate OB know-how and services on a specialized firm. After two years of R&D work, Pilot Project was successfully constructed and SATO made the decision to start OB-production.
+ The respected award was given to PlusHome Pilot in 2005 by Finnish Association of Civil Engineers based on the prize-rules: "To the building project of the year which has caused the best promotion of technology and social development in our country." The Chairman of the Finnish Parliament and former long time Prime Minister in the 90s Paavo Lipponen selected from three top projects PlusHome to win award with key-words: "The Arabia-Shore project combines in a unique way advanced building technology, high quality architecture, use of IT-technology and resident's participation."

Fig.1 The competition and award winner project courtyard side

2 SATO Corporation & PlusHome concept

The SATO-Corporation, established in 1940, is one of the largest housing companies in Finland. SATOs' main owners are private Finnish insurance companies, trade companies and banks. The aim is to provide the best housing services for customers. The business is comprised of housing investment, development and construction. Geographical focus is in the Helsinki metropolitan area, but there is also activity in other large cities in Finland. SATO owns roughly 23,000 rental and shared-ownership apartments. The annual volume of production is around 1,500 homes, of which 700 – 1,000 are owner-occupied homes.

One of main strategies in SATO Group is ***customer orientation***, which SATO believes to be the key-factor for successful future housing production. Key-factor in connection with this is also *functioning partnerships* by creation of networks, as PlusHome-partnership one successful example. In SATO plans PlusHome concept estimates in the future good chances to satisfy SATOs' customer orientation aims. SATO has outlined in 2005 a strategic plan concerning Open Building to use the PlusHome-concept constantly. The Corporation has made a decision to widen the concept in the next few years to all their production of owned apartments. In SATO plans the concept includes three levels:

+++ open building technology (structures, renovation) / variable apartment sizes
++ different lay-outs in fixed apartment size (life style, phase of living)
\+ selection of surface materials, fixtures and accessories / some floor plan variations

One-plus level selections are available in the both upper level categories. The PlusHome system is based mainly on wide range of alternatives, where price of each solution / alternative is fixed. Customer service is looked after both through advanced internet service and personally.

3 The PlusHome pilot project

The project was carried out by *ArkOpen Ltd (former Kahri&Co)* architects Esko Kahri, Petri Viita, Juhani Väisänen and *PlusHome Ltd* project team authors Esko Enkovaara, Timo Taiponen. The project base is the winning entry to a "Arabia Shore" technology competition, a new housing area on the sea shore about 5km from the centre of Helsinki. The pilot building was finished February 2005.

The two buildings are 6-storey high with 77 residential apartments in sizes between 39m2 and 125m2. Also on the street level there is one 84m2 shop and seven workshop spaces (31-46m2) for artisans, etc., four of which are connected to the upper floor apartments by inner staircases. The residents have the use of a laundry and drying room, two meeting rooms and two roof saunas with terraces overlooking the sea. In the cellar there are individual and common storage rooms and a fall-out shelter.

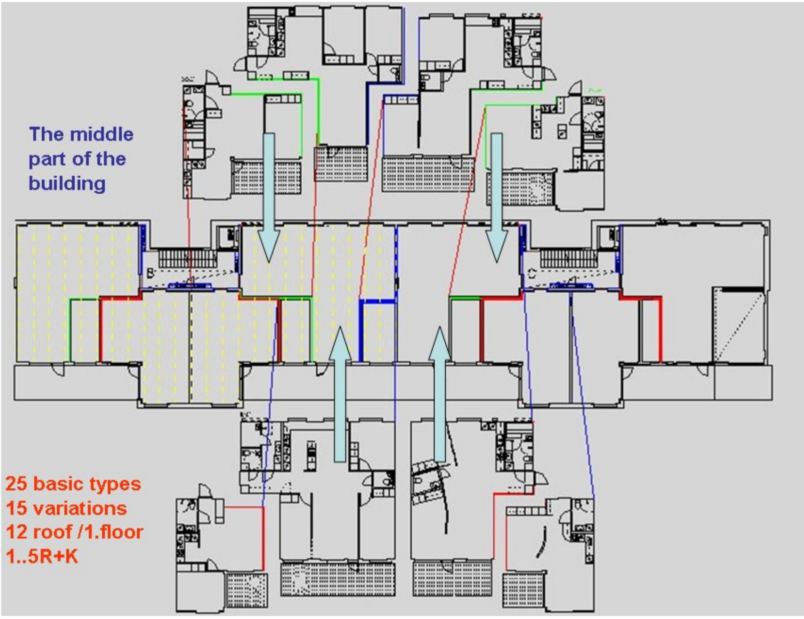

Fig.2 The main parts of the building was filled according customer's orders and therefore all floors were individual; most usual flat types also had variations.

The project is based on Open Building principle aiming at highly sustainable solution. The construction frame for the building contains some features that differ from the traditional way of building in Finland:

- The load-bearing walls are the outer, longitudinal walls instead of the cross-walls between the apartments to provide a flexible space for varying lay-outs on different floors.
- The load-bearing structure inside the walls is steel columns at max. 3m intervals. Connected to the columns are Z-formed steel beams, which bear the concrete slabs.
- Most of the slabs are concrete hollow-slabs of about 10m span. On the zones of sanitary spaces a two-layer slab is used, which allows flexible plumbing.

The steel-framework makes it possible to prefabricate the walls in large elements. This makes construction on site very quick. Also the construction work is dry with very little in-situ concrete casting, which is favourable in our climate.

Fig.3 The pilot project allow high flexibility by advanced steel constructions

The Facade design is free allowed by steel-structured external walls elements with almost unlimited window placement and many types of outer facing on site. The exterior is of red brick or clad with thermal plastering, some parts of profiled metal plate. The balcony slabs are made of concrete with concrete filled steel pillars. The rails and dividing walls are aluminium-glass construction, balcony glazing is optional. On the outside of the balconies there are sliding aluminium grids for sun protection and view blocking. The glass rails can be fitted with roller blinds for providing more privacy. The balcony façade has an ever changing appearance to the, reflecting the individual variety of the residents.

Fig.4 The street side has area's brick look, the balcony side an ever changing OB - appearance

4 The In-fill and customer choices

The walls between the apartments are light construction with double frame – insulation – double plasterboards. The ventilation system is individually adjustable including the reclaiming of heat. The electric installations are made using an open distribution profile on the upper part of the partition walls, which provides flexibility and enables the adding of service networks.

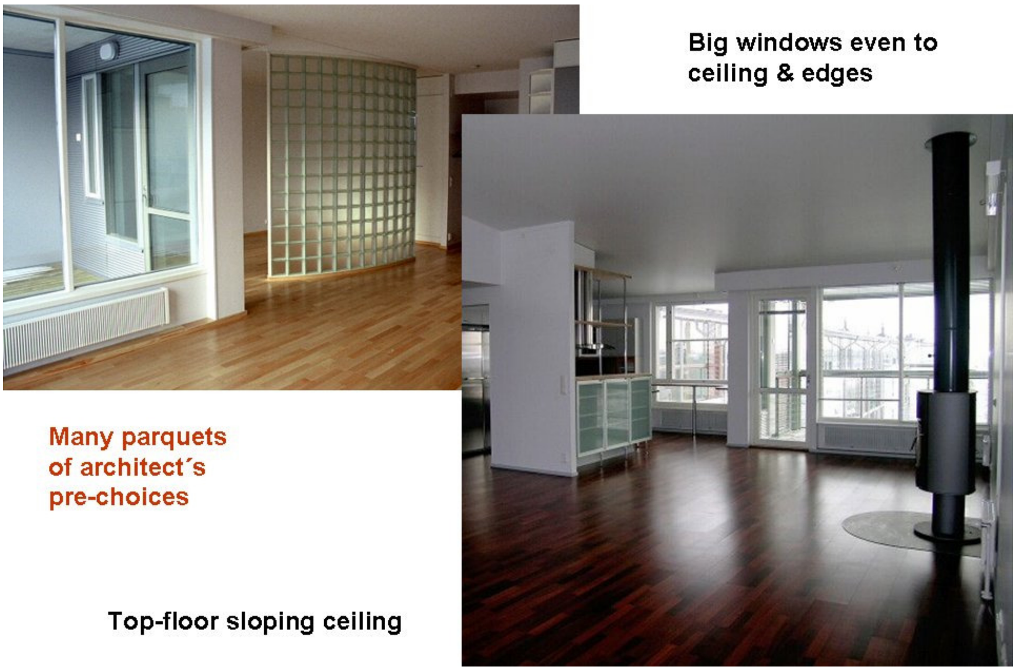

Fig.5 Interiors had individual look due to both different floor plans and material choices.

Residents could choose between alternative floor plans in the pre-marketing stage via internet: A wide selection of floor plans was offered, both different apartment sizes and variations. This stage was open till about 6 months after the construction started. The building was filled with floor plans according to customer's choices. After this stage the residents had another 3 months for the selection of surface materials, fixtures and accessories with fixed prices. The buyers could see the total price of their apartment directly after making their choices, and could also go back and revise.

Fig.6 Selection of surface materials, fixtures and accessories is available via internet.

5 PlusHome further projects

The pilot project was selling well and had a lot of positive publicity. The next PlusHome project was in the sub-urban area by Kahri&Co architects (later ArkOpen Ltd). There were some more limitations in constructions methods and therefore flexibility. This occurred to achieve cheaper price, but maintaining all essential OB-features.

Fig.7 After the pilot project the second project two blocks of flats was finished recently. This project received the best feed back grades by buyers SATO ever has reached.

Most of the new projects are blocks of flats, but detached housing will be built increasingly. In the next years several new architect offices are also involved. Three projects will be finished before 2007. In next two years 22 more projects, together about 700 flats by 10 different architects, are in the design stage.

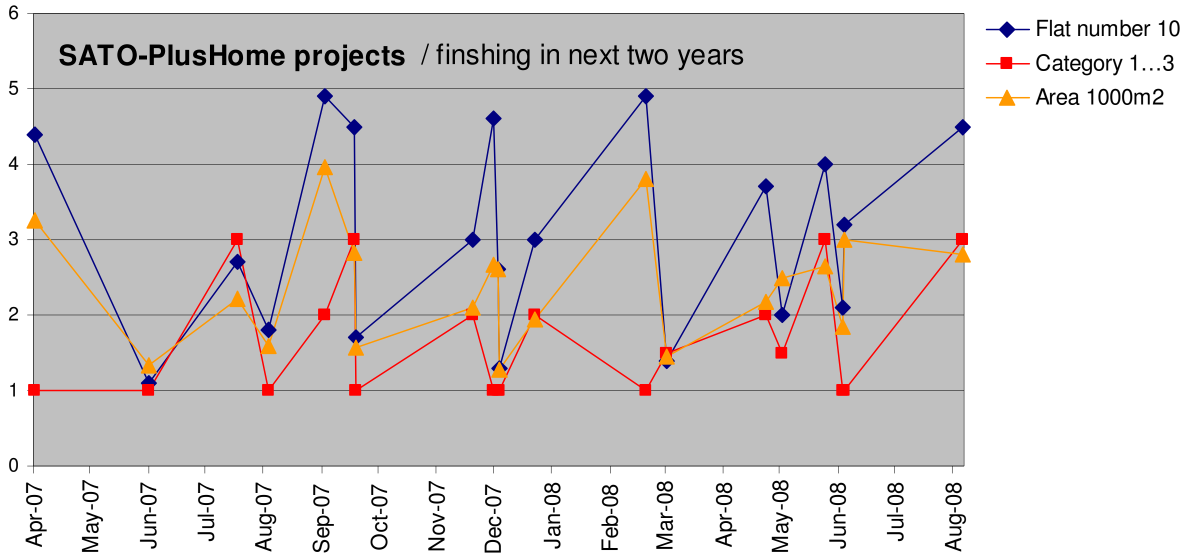

Fig.8 SATO-PlusHome projects >2008, average size of some 30 apartments / 2400m2 floor area

When the amount of projects will increase, the tendency of different categories will be emphasized more one-plus level. There are also projects, which can be classified between categories like +(+) or ++(+). Intended PlusHome categories in next two year production are: + cat. 12 projects / ++ cat. 7 projects / +++ cat. 5 projects. Presumed amount of categories could be in the future some 60% / 30% / 10% in the whole Finland's SATO-production. Most of the later projects will have more traditional building structures, which makes some limitations when compared to the Pilot Project. However main Open Building qualities will be maintained and all internet services continuously improved.

5 The PlusHome internet and information concept

The complex information system of the PlusHome-concept was developed and carried out by IT- and data consultant company Tocoman Group, which will be the future main party owning and developing the concept. The R&D started already since the beginning of 1990s with several projects. Advanced system is necessary for rational processing of large amount of information caused by customers' individual choices.

Fig.9 Behind PlusHome customer service there is a complex and sophisticated technology.

Customers demand more is the main issue in the whole process, where the good project management requires main features: *Idividual products at reasonable price level / Individual service / Transparent process / Fast delivery.* The key-question is how the building industry can answer this. One good example in other industries is Volvo Car with their customer tailoring process. This is also in principle the PlusHome system: *to give alternatives,* which satisfy residents as far as possible. This differs from idea of close participation. In our experience it is necessary in keeping the production cost reasonable. To satisfy customers with the internet selection succeeded in Pilot project only up to 60%, but in the next project already over 80%. This is a constant learning process, but also some tailoring will be available.

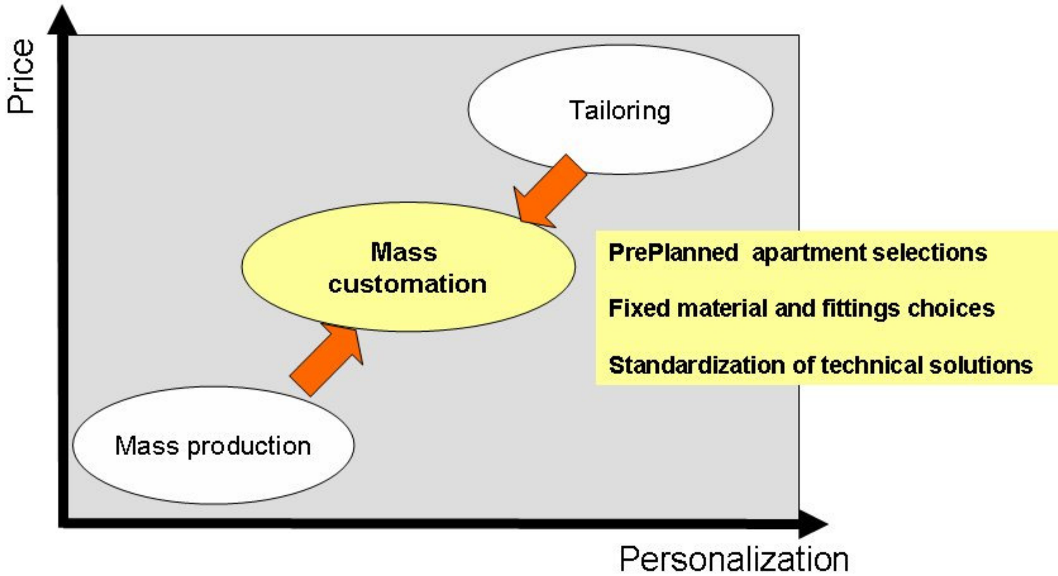

Fig.10 Key idea behind PlusHome concept is based on Open Building principle

Our customers require more and more individuality. To serve them *current process is not properly managed.* With current tools customer tailoring processes is expensive, information flow is labor-consuming handcraft and liable to mistakes, also responsibilities are unclear. For individual demands ICT-technology gives proper tools, which have been successfully introduced in the PlusHome process.

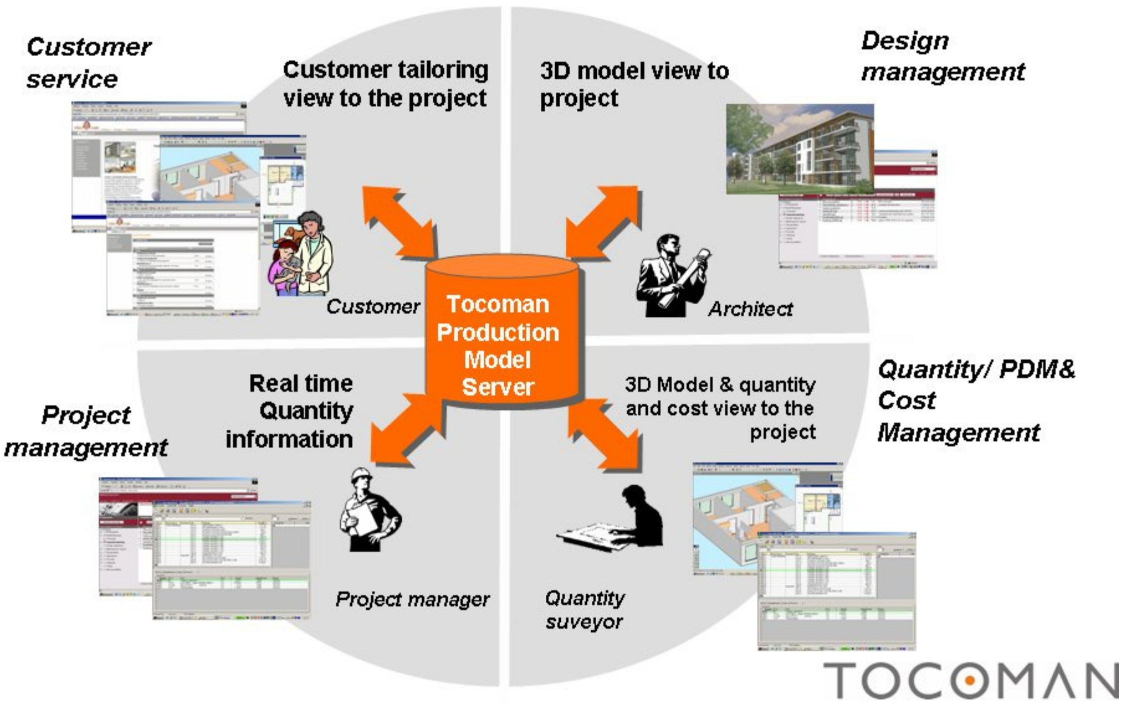

Fig.11 PlusHome information service uses the same basis and forms an integrated process

The procedure must have much better Customer Interface. In comparison with *Volvo car* – ***PlusHome apartment*** the analogy is following: *selecting car model* – ***floor plan*** / *selecting acessory options* – ***materials, fixtures and accessories*** / *viewing instant car price* - ***total price of apartment***. The design base is computer modeling. This starts with sketches as an "architect-model", which will be developed with IT-specialists to an "information model". In this field the progress is today rapid.

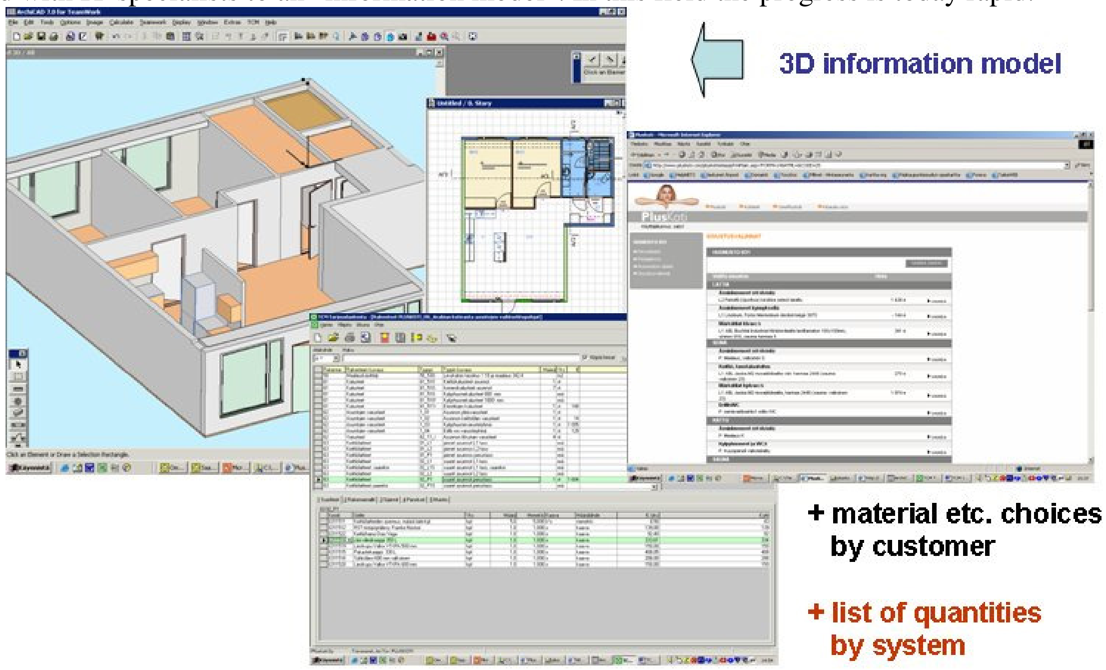

Fig.12 PlusHome 3D - information modeling of apartment

In the final project stage all building and apartment parts are recorded with quantities included. PlusHome Pilot Project already used this method, which is now in rapid progress.

6 PlusNet customer and sales service in internet

In the PlusHome system the opening project sites are open for all. For customers it contains general information of the area, site and the building with perspective views and preliminary construction and available choice information. Furthermore the customer can open closer pages for floor plans with alternatives, amount is dependent on the PlusHome category of the project.

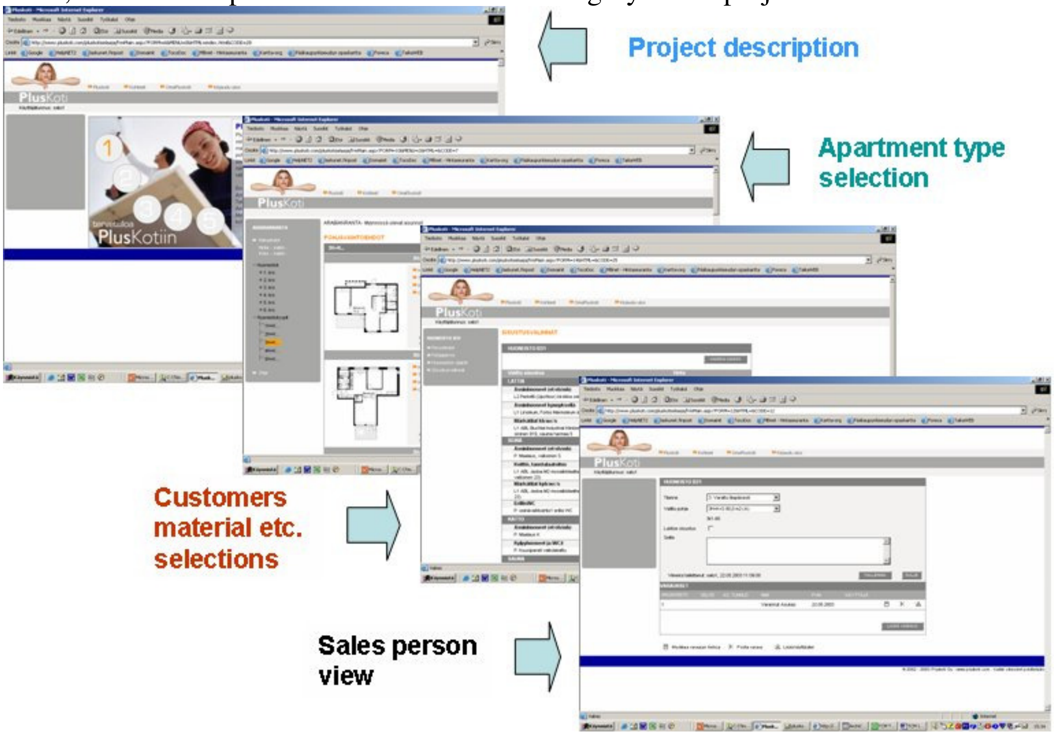

Fig.13 PlusHome internet views, two most above are open for all

After customers´ preliminary reservation, the password will be given to customize own apartment via internet. This includes materials, fixtures and accessories with illustrative pictures and prices. The service calculates the apartment's total price at once with all alternatives. This is possible through the modelling method with connections to the cost data bank. For this service a SATO-selection has been developed.

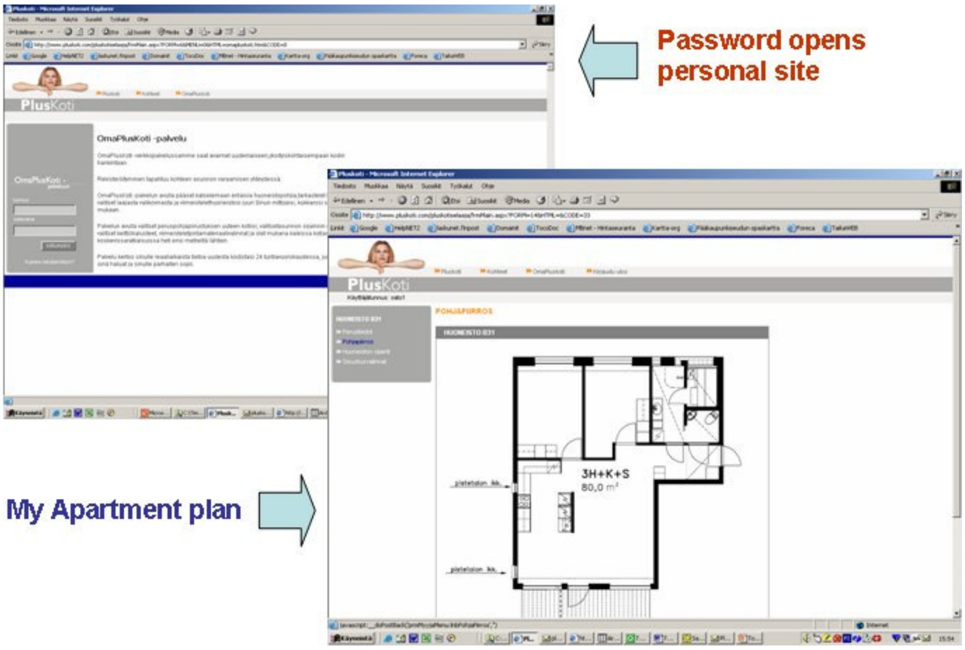

Fig.14 MyHome customization after preliminary reservation with prices.

The sales personnel uses the same PlusHome service. They control booking features with tools shown in the next picture. They can open and close for individual flats different status: booking / reservation / sold. After customers' choices the MyHome customization will be closed by given dates. Customers' ordered materials, fixtures and accessories will be fixed and confirmed.

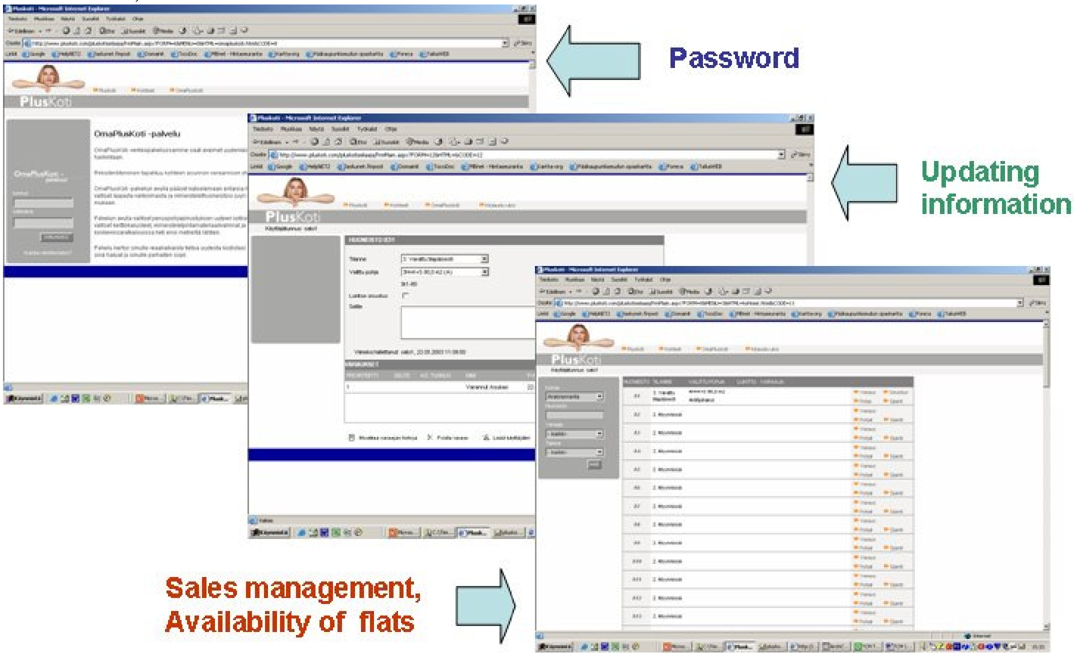

Fig.15 PlusHome sales person view with control tools for all selling features

7 Design and production data management

Management behind the views represented above is a sophisticated data-system, which allows carry through all individual choices in a rational manner and at reasonable price.

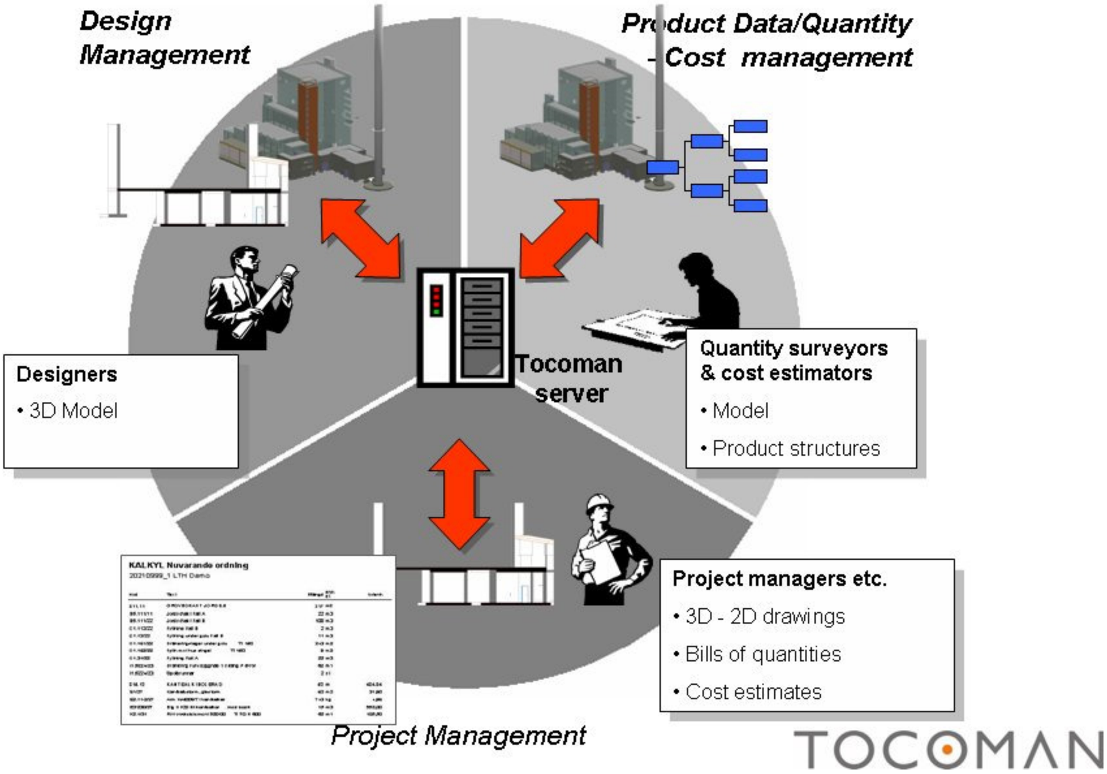

Fig.16 Tocoman Project Collaborative platform

The key is the right information to all parties. In the production it means lists of materials, deliveries and schedules for all contractors and suppliers. When system is based on alternatives for the customers and pre-bargaining with suppliers, the big variety of choices turns mainly to a logistic problem.

Producers have always bigger selection, than can be used and pre-selection is needed. Few choices are only lack of organization ability in the building sector. To automate logistic solves the selection problem.

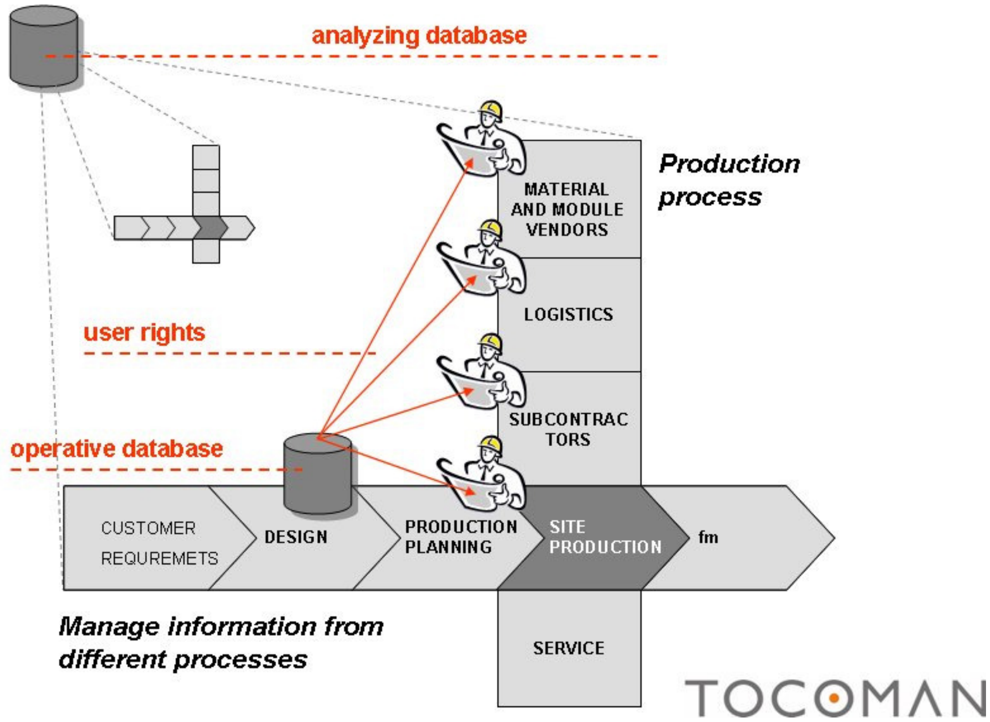

Fig.17 Information management trough whole supply chain

SATO has the PlusHome Sole Right in Finland to the Finnish name “PlusKoti” and the service system, except the basic one-plus level, which is open to be used by other builders as well.

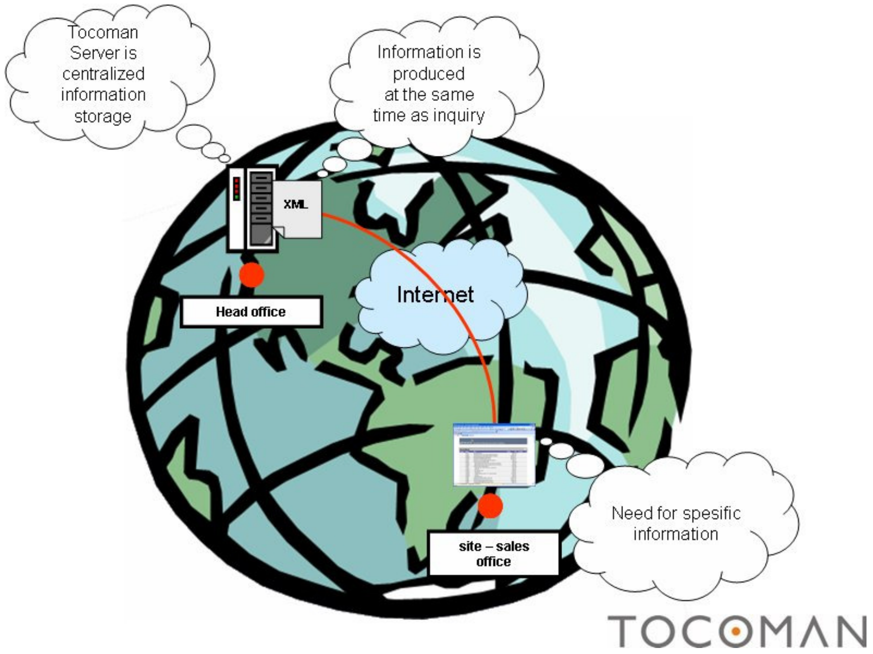

Fig.18 Real time project - Globally

The Open Building qualities of the PlusHome Concept, both customer content and internet services, are continuously improved within significant amount of new building projects and also R&D work, which will be supported by TEKES, the Finnish Technology Agency. This is the PlusHome integrated building and information system and how it works in practice. The information system is available and for sale in the whole world.

Minimizing C&D Waste through rehabilitation

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KEYWORDS

Reuse, Reprocessing, Recycling, Integral Chain Management, Rehabilitation

ABSTRACT

The Construction and Demolition Waste stream is becoming one of the largest waste streams. With the current attitude of society, this will generate serious problems. Landfill sites will be overloaded; the planet more polluted, and even, in countries were actions are being taken, society might deal with the overload of warehouses and recycled material stock.
To subvert this tendency the waste management should be changed into Integral Chain Management (ICM), not only when designing new buildings, but also when we are dealing with existing building rehabilitations. Supervised by the PhD researcher A. Pereira Roders and P. Erkelens, this paper was developed with the purpose of determining the viability of the Integral Chain Management, normally suitable for new building designs, when reframed for existing building rehabilitations. Hence, the ICM will have to deal with a pre-existence, where a considerable amount of natural resources has already been transformed and assembled without considering dismantling, deconstruction and adapt abilities.
To determine the viability of ICM, a scheme was developed were the ICM is adapted to deal with the existing building stock and the different methods to achieve ICM are explained. In conclusion, we can state that ICM is viable theoretically for the existing building stock; however, it may vary according to the design and building.

1 Introduction

The Construction and Demolition (C&D) Waste stream is becoming one of the largest waste streams. For example in the Netherlands, it had reached already 18 millions tonnes per year in 2001 [Ministry of VROM 2001]. The construction industry does not intend to stop building, neither intervening nor demolishing the existent built environment.
If society does not change attitude, in the near future, landfill sites will become more and more overloaded, and the planet more and more polluted. Moreover, in countries where the building sector already has some experience in reusing, reprocessing and recycling building elements and materials, society might deal with a "next level" phenomenon, which is the more and more overload of warehouses and recycled materials stock.
We believe that this problem can no longer be ignored; therefore, the current waste management should be altered. The problem already emerges in the design stage, when determining the building substance and characteristics. So, designers should start designing buildings, enabling them of dismantling, deconstruction and adapt abilities, not only with new, but also with "second-hand"

components and materials. But is it possible to use all "second-hand" components and materials, i.e. to keep them in their own life cycle, when we are looking at existing building rehabilitations?

2 The Integral Chain Management

An option to minimize the C&D waste is to improve the current waste management, changing it into an Integral Chain Management (ICM). With ICM integrated in the building sector, all building materials must be kept in their own life cycle and degradation of materials must be limited. To achieve this goal, Growther [2000] describes four different scenarios in the figure "The four scenarios for materials reuse in the built environment": recycling, reprocessing, reuse and relocation.

This figure also describes their viable placement within the building process: the process from extraction of natural resources till waste for dumping, through processing into materials, manufacture into components, assembly into buildings, building use, and disassembly. To keep all materials within the built environment, they should go from the disassembly stage back to one of the other stages. It becomes then visible that relocation and reuse are preferable to reprocessing and recycling because in such case, materials only go one or two steps back in the building process, and the waste of resources and energy to convert it into functional is not so difficult for its effective achievement. It can then be concluded that according to Growther's theory relocation and reuse are the most environmentally beneficial uses of waste.

3 The parallel realities in rehabilitation

If relocation, reuse, reprocessing or recycling must be an option at the end of the service life, the design stage becomes very important. When designing a new building it is relatively easy to enable the design with dismantling, deconstruction and adapt abilities, but when dealing with the existing building stock it becomes harder to materialise such ideologies. When developing rehabilitation designs of existing buildings, a designer will have to deal with different realities: subtractions, remainings, connections and additions. Pereira Roders [2006] shows in the figure 'The four parallel realities in rehabilitation' the relation between these realities, within the pre-existence and new existence of existing buildings. When target of rehabilitation, the building's pre-existence is divided in subtractions and remainings while the new existence combines the pre-existent remainings and the new additions. The connections are added as a fourth parallel reality because they form a very important factor between the remainings and the added components, when considering future options.

4 ICM in existing building rehabilitation

When dealing with rehabilitation, the designer has to deal with a pre-existence and develop a new existence. This also means that ICM can be achieved, when keeping both subtractions and remainings within the built environment. The subtractions should be re-integrated in the building process of the rehabilitated building, or even of another building (new or existent). Not only the subtractions, but also the additions should be controlled in such design developments.

Pereira Roders [2006] has studied both Landsink [SDU, 1980] and Delft Ladder [Hendriks, 2000] and proposes the Eindhoven Ladder, oriented towards rehabilitation designs. The Eindhoven Ladder, based on ICM, is composed by 5 levels, plus level 0 (six in total), which in ideal procedures, should be only considered when the materials have surpassed their durability and can no longer fulfil any other purpose. Due to the fact that level 0 removes the subtractions out of the built environment range, it is not considered in the ICM method for rehabilitation designs, even if it is theoretically part of it.

Perceived through a ladder, level 0 is the first degree, but the worst environmental option regarding waste management. Level 5 can be seen as the last and the 'unreachable' degree, but in fact it is the best environmental option. When levels 1 till 5 can be applied, ICM is achieved, when dealing with rehabilitation designs of existing buildings (Fig. 1). The following subchapters will briefly describe the five levels of the Eindhoven ladder.

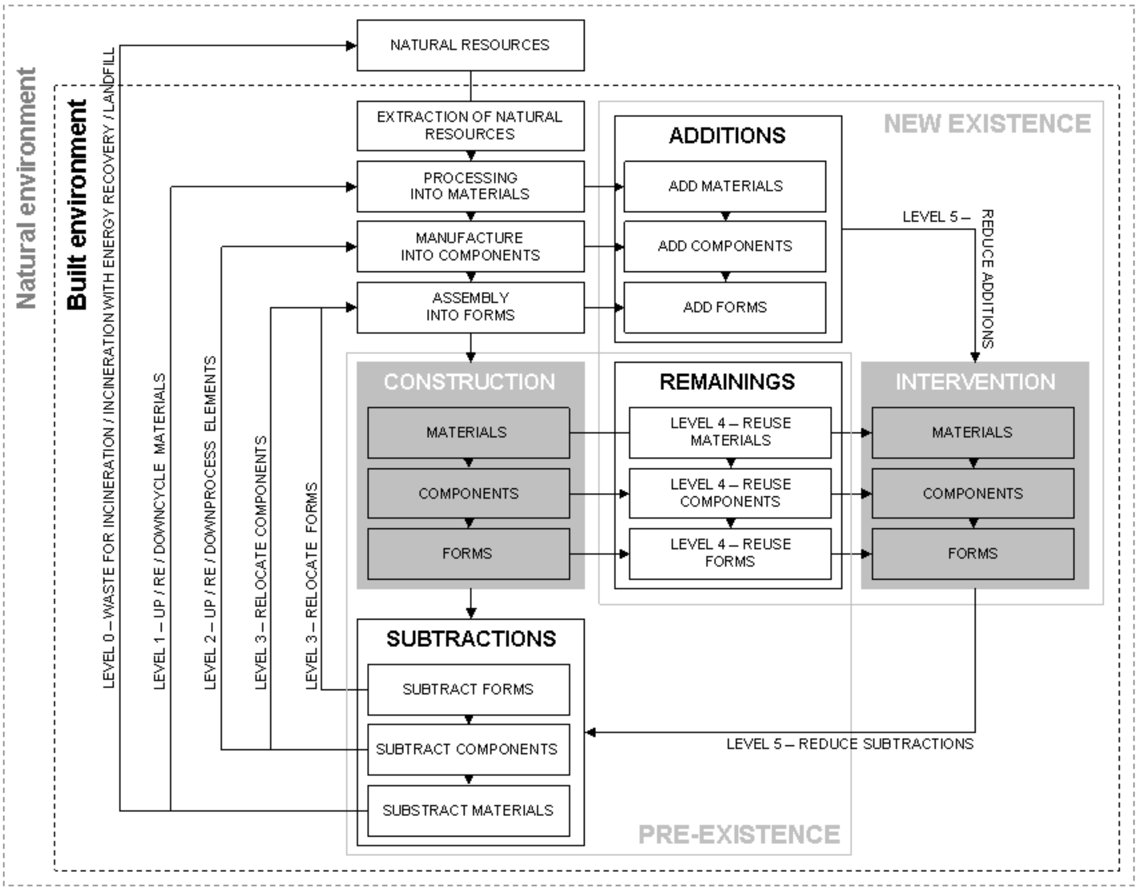

Figure 1. The ICM method integrated in the rehabilitation design stage [Pereira Roders, 2006]

4.1 Level 1 – Up / Re / Downcycle materials

The recycling is a process where 'waste' materials are manufactured to fulfil a new function. Three different recycling methods can be distinguished: downcycling, recycling and upcycling. These three methods can be defined as follows (De Jesus, 2005):

1. Upcycling: this means turning a low-grade material into a high-grade material. Up-cycling may include conversion of timber into wall-panelling.
2. Recycling: this means the manufacture of a new product using reclaimed or waste material, for example, turning scrap steel into new steel bars.
3. Downcycling: this means turning a high-grade material into a low-grade material. An example of down-cycling is converting concrete slab into coarse aggregate.

Recycling puts waste to new uses, thereby not only reducing waste ending up at landfill or inceneration sites, but also helping to conserve energy and resources. However, additional energy is still spent on manufacturing the materials. In the Netherlands some examples can already be found using recycled materials in new buildings, e.g. the ten 'Respecthouses', in Tilburg, realized by IBC Vastgoed (Fig. 2). Due to the large percentage of recycled materials used, this project received EU-subsidies. The emphasis of this project aimed at the making of new products from C&D waste, e.g. window frames made of old roof trusses.

4.2 Level 2 – Up / Re / Downprocess elements

The reprocessing of elements involves reconfiguration of existing elements or systems to restore its condition to "as good as new" (Durmisevic, 2002). Similar to recycling it can also be distinguished as: downprocessing, reprocessing and upprocessing. Respectivelly, the quality of the remanufactured product should retreat, meet, or surpass the tolerances and capabilities of a new product. Such methods, as recycling, also encount additional energy to be spent on remanufacturing those elements into components or systems. In the rehabilitation design of the Town Hall in Utrecht between 1997 and 2000, the architect Enric Miralles created a new façade with some subtracted elements (Fig. 3).

Old limestone frameworks of the demolished Registry Block were reprocessed and used as architectural elements in the façade [Jamar, 2000].


Figure 2. Respecthouse, Tilburg [van Hal, 1999]


Figure 3. Town Hall, Utrecht

4.3 Level 3 – Relocation of components / forms

The relocation of components / forms is based on prolonging the life of the building components by dismantling the component at the end of the buildings functional life cycle and relocating it to another (new or existing) building [Durmisevic, 2002]. The relocating components / forms can reduce or avoid embodied energy [Growther, 2000]. Therefore, relocation is more environmentally beneficial than recycling and reprocessing. However, energy is still required to dismantle the building and to transport the components.

In Portugal the architects Victor Mestre and Sofia Aleixo realised the rehabilitation of the Carlos Relvas Photographic Studio, in Golega, between 2000 and 2004 (Fig. 4). They chose to remove some elements of the previous intervention, in order to restore the coherence of the original photographic studio. So, the building was partly dismantled, and those components which were not relocated in the design, were sent to an archive. For example, the roof tiles were dismantled from the Photographic Studio and were relocated in the roof of the additioned building [das Neves, 2004].


Figure 4. Carlos Relvas Photographic Studio [das Neves, 2004]


Figure 5. Polynorm outside [Timmermans, 2005]

An example of relocation of forms is the Polynorm house, in the Netherlands (Fig. 5). The Polynorm houses (1950) were built with an industrial manufactured system based on structural steelwork (the polynorm system) in the district Strijp in Eindhoven. The 212 houses were dismantled at the end of 2005 and at the moment two of these houses will be relocated and rebuilt at the Eindhoven University of Technology [Timmermans, 2005].

4.4 Level 4 – Reuse remainings

The materials, components and forms of the building that will remain can be reused and form the new existence, together with the additions. This way of keeping the building materials in the built environment is the more environmentally beneficial than the earlier options, because hardly energy is required to keep / preserve the materials in the built environment. On the grounds of the Eindhoven

University of Technology an example of reusing the remainings of a building can be found: Vertigo, the building for the Department of Architecture, Building and Planning. The main structure of reinforced concrete (primary elements) of the building, was reused, which lead to a reduction in the use of reinforced concrete of about 13.800 tonnes [de Jonge, 2002].

4.5 Level 5 – Reduce additions / subtractions

With a rehabilitation design, there are always sutractions and additions. Level 5 intends to integrate into the rehabilitation design stage, the reduction of unnecessary subtractions, as well as, of unnecessary additions. By not extracting natural resources for the additions, the designer will be preventing and preserving the natural resources. Consequently, also by not subtracting from the pre-existence, the designer will have more remainings to reuse, and won´t spend energy for the subtractions. Of course, there cannot be rehabilitation without additions and subtractions because the rehabilitation intervention improves the performance of the building. However, when considering the ICM, while designing and taking decisions, the probability of reaching higher degrees in the Eindhoven Ladder are considerable.

5 Conclusion

The viability of ICM for existing building rehabilitation designs, has reframed Growther´s four scenarios, within Pereira Roders's four parallel realities. The scheme shows the possibilities of keeping the building materials within the built environment. The examples presented show that it is already possible to use recycled, reprocessed or relocated building materials, components and forms, so it is possible to apply ICM to the existing building stock.

However, it is hard to determine if the materials in these examples, which went still to incineration / landfill sites, were effectively highly degraded or just had no other destination. If designers start using more second-hand materials, this market will grow and the possibilities for ICM in the existing building stock will increase. When the five levels are followed, as much as possible, the C&D Waste will decrease. However, the viability of these methods may vary according to the design and building.

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Lightweight, adaptable and reversible construction: sustainable strategies for housing

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BUILDING DESIGN; OFF SITE CONSTRUCTION; REVERSIBILITY; TEMPORARY; PREFAB

Introduction

Some key-paradigms emerge in the contemporary construction scenario, in the present society distinguished by the immateriality of human work, from the absence of capital weight and from the real time exchange of information at the speed of light.
"To be big and imposing is becoming an handicap and it is not an advantage anymore. For capitalists who would exchange with pleausure their big office buildings with a hot air balloon, the aerostatic lift is the most coast-effective and the most wished of the benefits […]" [Bauman, 2002].
The lightweight, adaptability and reversibility paradigms are becoming more established in architecture and introducing or re-introducing in the construction sector weight and material reduction criteria; adaptability and flexibility capabilities according to changing circumstancies or uses; assembly and disassembly capacity for the reintroduction in the productive cycle itself (recycling) or to plan a new functionality (reuse). These issues are in accordance with contemporary social tendencies and cultural changes which are characterised by high levels of job flexibility and mobility. A new nomadism seems to mark contemporary society, a "liquid modernity" in which nothing is anymore definite, durable, solid, and instead all appears as transitory, modifiable [Bauman, 2002]. People are on the move for work, study, or entertainment, for necessity or for choice. Journeys and mobility are now global trends, and there are many migration flows of different lenghts of time all across the world. Particularly metropolis are ever more exposed to migration flows generating housing problems and precariousness, in the outskirts too. The housing supply, in many European countries, has became a big problem: in Italy, there is a more difficult situation then the one registered in the 80's and 90's. Primary housing supply in 2005 is approximately in the region of 300.000 and 500.000 dwellings (in 1991 housing supply was of 173.000 dwellings) [CRESME data]. Besides, there is a great demand not only by weak social strata, but also by old people, students, singles, and regular immigrants with their family (2,5 million residence permits until 2004). The situation of the gypsy camps is constntly creating more problems in the periphery of Milan. So new and old gypsies, with different housing demands, both in need not of permanent, unchangeable, everlasting, heavy architectural structures, but lightweight, adaptable and reversible homes as a result of an open and error friendly approach. A sustainable development ethic presupposes a planning attitude oriented towards social, economic and environmental issues. Currently the building sector is causing the widest environmental impact because of the exploitation of non-renewable raw material, in addition to land use, and energy consumption throughout the life cycle of the building product, make it a must to implement concrete strategies to improve the economic and envrironmental efficacy and efficiency of the sector. Lightweight adaptability and reversibility criteria in housing construction can allow for sustainable strategies at the three social, economic and environmental levels.

Adaptability in Off-site construction Modern Methods of construction

The off-site construction and Modern Methods of constructions (MMC) offer great capacity in support of lightweight, adaptable and reversible buildings, in achieving social, economic and environmental issues for a sustainable development. Off-site construction is a term used to describe the spectrum of applications where buildings, structures or parts thereof are manufactured and assembled in a different location from the building site prior to installation in their final position. Recently off-site construction, and MMC, are providing interesting outcomes and benefits to sustainability issues: Energy conservation; Waste reduction; Pollution control; Kyoto Protocol, due to materials being easier to control in a factory environment. Some of the most important benefits of factory manufacturing are: superior quality and less defects; more Health & Safety benefits; a faster construction result in savings on on-site management and on-site activities. Off-site construction is based on the manufacturing of lightweight components which are then assembled through dry construction methods. The reduction of weight elements allows low carbon emission construction. Factory manufacturing allows greater predictability of completion, greater predictability of cost. Finally off-site construction may be a key to achieving more agile, adaptable buildings in harmony with principles of sustainability. As well factory manufacturing enables product "design for assembly and disassembly". An emerging theory suggests that the interface between technical systems should allow the replacement of one system with another performing the same function. Interface with other elements, relatively simple construction processes allow open, flexible and adaptable space and deconstruction rather than demolition so allowing reuse and recycling for a sustainable whole life costing approach. Alternatives to traditional building methods will not always be appropriate, but they could be used cost-effectively for different residential use, far more than it is currently done. In effect all off-site construction is a mix of off-site manufacturing and on site installation and completion. Just as most traditional construction today may incorporate significant elements of off-site manufacture. The difference is a matter of degree. Whether the main elements of the building are formed off site, or in situ really determines the extent to which it can be classified as a "Modern Method of Construction". The Term was recently adopted by the Housing Corporation and the ODPM as a collective description for both off-site-based construction technologies and innovative on-site technologies based on balloon frame system. The term MMC applies to all different material types: wood, cold formed steel, steel, precast concrete. There are different forms of MMC: *Stick build construction; Panellised Construction*; *Volumetric construction*; *Hybrid construction* [Ross, 2005]. MMC show great benefits in high density housing, such as meeting affordable housing targets, immediate availability of buildings, high level of buildings customization (not standardisation), high level of flexibility, adaptability and assembly/disassembly capacity. The most important problem with MMC is the cost issue. People think it is more expensive because simplistic cost analyses show it to be more expensive and because many of the savings are hidden. Time and quality savings may not actually bring benefits anyway. So the thing is: "Are we prepared to pay for quality and future environmental benefits?".

Lightweight or heavy construction?

There is a relative great diffusion of Modern methods of construction in residential house building, especially in USA and Japan, and recently in some European countries, particularly in northern Europe (Sweden, Germany and UK). But in European Mediterranean countries and especially in Italy there is a greater resistance to MMC diffusion and a scarce diffusion of lightweight, adaptability and reversibility in buildings. Historically USA buildings were based on balloon frame, so there is a great diffusion of lightweight and adaptable buildings, and many mobile homes, following housing mobility demand and American nomad way of life. In Japan the cost-effective and streamlined production progress allow sophistication of the Japanese prefab factory. Instead European prefabrication experiences in housing were usually associated with concepts of precarious, low quality and unreliable homes. In Europe there is a greater and more consolidated use of MMC paricularly in Scandinavia, Germany and recently the UK saw the building of many interesting and innovative multi storey residential buildings using MMC. In these buildings one can find an appreciable mix and

balance between all benefits of MMC and architectural quality, high-levels of repairability, adaptability, personalization, and lower environmental impact in the whole life cycle.
In France, Spain and especially in Italy MMC application is really rare or almost negligible. An interesting application of MMC is being achieved in Spain with an important development of *stick build system* in CFS single family housing, and this kind of construction is acquiring a large share of the residential market. The limited popularity of this construction method in Spain, a country economically, socially and culturally similar to Italy, represents an important example that suggests positive perspectives to the application of these methods even in Italy. In Italy infact the use of construction methods which include lightweight, adaptability and reversibility features are not largely accepted. Italy (and in part Spain and France) is traditionally anchored to heavy construction, with brick and block masonry built in. In Spain the relevant push to MMC has arrived from the manufacturing firms and this allowed to overcome the initial distrust from the building sector operators. The great distrust in Italy has many reasons: the strong bond with traditional construction methods; the diffidence to innovations, especially in housing, and the general refusal of prefabricated construction systems, but also due to the lacking knowledge of technological and environmental MMC performances. Certainly MMC and off-site construction cannot be indiscriminately adopted for every kind of construction and in every situation but they can meet many housing targets in relation to the benefits of these construction methods in achieving a balance between all levels of sustainability. MMC may also give a more qualitative alternative to low quality buildings and constructions in Italy, particularly buildings built before 1977 (marked by fixed and unchangeable typological solution, scarce flexibility, and ineffectiveness of construction techniques employed), projections for Italy foresee investments in the range of 70% of the total value of the construction market [ENEA, 2004].

What in support of adaptable and sustainable residential building in Italy?
The specific objective of the current research is to understand how methods of construction oriented towards lightweight, adaptability and constructive reversibility, in a sustainable development ethic, could find application and a greater penetration in house building sector in Italy and particurarly in the metropolitan area of Milan. To achieve this, it is important, above all, to understand which are the possibilities of the productive industrial system, how much it is possible to convert existing manufacturers (semi-manufactured structures factories for containers and box) and which are the motivations to move investors. Although currently in Italy there aren't projects involving the above-mentioned methods of construction, the research is looking into the productive market which could potentially be oriented towards the application of these methods. We are researching the potentialities of italian market in the productive sector for steel, wood, box and emergencies containers, according to investigated data analysis, quantity and importance of the actual productive market, it appears that the sector could be qualified and oriented towards products that could allow the application of modern methods of construction. Moreover Italy has some considerable precedents, for example in steel production, and especially of Cold Formed Steel which date back to the 70's. The CFS, together with semi-manufactured precasts in wood and concrete, are some of the most used elements in the Modern Methods of Construction. Today a substantial part of the italian iron and steel production is represented by CFS categories, wich however are used only as secondary elements (for example roof framing and internal partitions), while the structural use is limited and applied only to commercial and industrial buildings. Only 10% of the single-floor constructions in Italy is carried out in CFS (72% in France, 83% in UK) [Ermolli, 2006]. In Italy in buildings, over two storeys high, the structural use of CFS is particularly dependent on regulations for the dimensioning of thin sections is provided in pairing with elements that can guarantee higher values of inertia. But interesting signals of vitality are forthcoming from the manufacturing factories. For example, in France, in a cultural and social context similar to the Italian one, there were some cases of conversion of the box and container manufacturing market towards the production of prefabricated modules with higher quality exterior finishes and comfort. Within this research we are trying to involve Italian manufacturers (mostly from the region of Lombardy) of prefabricated modules and CFS into the implementation of their production. Aiming to sustainable and adaptable buildings that have the in-built ability to adjust to changing circumstances and technologies, without excessive waste and conflict. They are functionally "agile",

demonstrating accommodation capacity far in excess of tightly integrated and functionally determined buildings.

Adaptable housing: from a "temporary use for necessity" to a "temporary use by choice"

This article presents a summary of work carried out in the field of design for adaptability and application of reversible methods of construction in the building sector, at the Politecnico di Milano – Building Environment Sciences and Technology Department. This research delves in the field of off-site construction and innovative construction techniques in emergency installations and more long term housing, for which a greater penetration is desirable in the building sector. Particularly the article focuses the attention on the job developed in the didactics, and particularly at tertiary level of education of teaching activity and also in the research activities, e.g. a research entitled "Over the emergency", co-financed by the Italian Minstry for Education, University and Research, 2000-2002 (national coordinator prof. Franco Donato, title of the national research "Technologies of intervention for the innovation of emergency intallations" - operational Unity in Milan, Director prof. Andrea Campioli. Our Research Unit has focused its attention on questions relating to the flexibility and adaptability of constructions in relation to changes in the use and evolution of housing requirements, proposing light type construction systems as suitable techniques to meet these needs for transformation. From this research we have developed further ideas about the temporary housing, that go beyond emergency requirements and suggesting new potentialities and perspectives for light-oriented, adabtable-oriented and reversible-oriented construction methods: we believe that from the emergency housing these new construction methods can take new housing spaces, more in conformity with durability and maintenance, beginning from the most provisional houses to the more durable ones. In this context our research group has also applied the new construction methods during several degrees' thesis particularly on the university residential house building (pod houses) and in the renovation of an existing historical building (agricultural ability) expressing the technical and formal potentiality in the new building and in all the buildings renovation. The PhD thesis I'm working on is developed withint this framework. The energy and environmental crisis of the 70's have pushed Italy to reorganize only the provisional habitat themes to some functional sectors: tourism, the building sites, emergency housing. The industry showed interest in this sector, without reaching great qualitative results and without great innovations in the typology of proposed solutions. It's important, before everything else, to point out that in this productive sector, the container is the most widely used typology. It deals with "turnkey" construction systems, conceived to set up short and temporary installations, easily dismantled and whose cells are easily reusable in new installations. Therefore the container is the solution mostly employed in emergency situations. But the containers' supply for emergency uses still represents a marginal and discontinuous production activity, that a factory cannot consider as its principal production line. There is however a potential market for prefabricated structures for living quarters and offices, which are characterised by their transportability, easy to assemble and disassemble, economically convenient, able to satisfy application requirements for temporary spaces, in different sectors such as tourism, military camps and working sites, refugee communities or gypsy groups. This is the productive sector that, when required, provides the modules for emergency situations. Provided that a specific production sector for emergency situations doesn't exist, but that there is a more generic production set up for temporary and provisional structures, based on the employment of the non specialized container, the objective of my study is to identify the producers that could be interested in the application of alternative structures which are different from the containers, and which could be adaptable not only to emergency situations but also in general to the wider range of temporary situations. Then it is also necessary to understand how the construction system can adapt to this productive structure. The success of the container is due to the simplicity in its assembly, whereby any metalwork company can assemble it in a short span of time.

The problem with containers used as live-in units is instead related to the interior finishes that need a craftsmanship intervention.

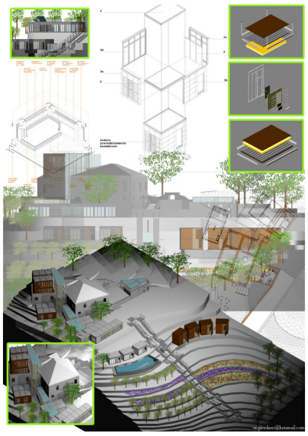

**Figure 1. "Agricultural ability.
Marmoreo oil mill retraining and high reversibility construction"
degree's thesis by
Valeria Giurdanella, Martina Sofia Francesca, Moreno Manuela
academic year 2002-2003, Politecnico di Milano, tutor prof.
Alessandra Zanelli, co-tutor arch. Monica Lavagna.**

Within this context, it is possible to identify some manufacturers of modules or parts that can potentially become producers of prefabricated housing systems at different levels of time frames, in relationship to the emerging targets from the current dynamics.
It is useful to underline a scale of different levels going from a "temporary use for necessity" to a "temporary use by choice". On the one hand the "temporary use for necessity" responds to an urgent need of protection and safety, following natural disasters or war emergencies, humanitarian aid and sanitary situations, having the tendency therefore to provide at times also immediate answers to the detriment of the quality in the production process.
On the other hand, a new temporary dimension can be found in the scenario of current constructions: it represents a more sophisticated and elegant temporary solution, able to answer to new needs of housing and working nomadism. As a watershed between the two ways of temporary solutions is the adaptability of the structures that is their ability to resolve the different environmental requirements and climatic situations, thanks to practicality of the modules of the system and to ease to modify it.
Adaptability represents therefore a prerogative that a living space has when from a "temporary use for necessity" space it passes to a "temporary use by choice" unit. In the container-based temporary construction system, adaptability is often sacrificed to the transport requirements and installation facilities and therefore it results at the minimum level possible, while it tends to increase when is changes to a "temporary use by choice" unit.
In structures with higher levels of durability the basic module of the container (e.g. in the residential units built with the volumetric methods) is integrated with components that increase insulation, acoustic, and conmfort performances, and with detailed finishing design that personalises the interior environ and plan customization. The integration with additional lightweight elements such as textile membranes or flexible panels allows a greater expressive dynamism and an adaptability to different uses. The use of lightweight material and the dry mounting of all the components, the choice of reversible junctions for the assembly and disassembly offer in this type of construction great opportunities to implement flexible and adaptable spaces that constitute a paradigm that directs the building towards the ethics of sustainable development and which is in a position to express the need for personalisation and change in time of the human being in his housing requirements.

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Contained Cinema: A collaborative, cross disciplinary project to aid in emotional disaster relief though cinematherapy.


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KEYWORDS

Mobile Architecture, Adapted Cargo Containers, Cinematic Architecture, Disaster Relief

Introduction to the Project

The Contained-Cinema Film Festival is a collaborative, cross disciplinary project to bring together professional and academic communities of different disciplines to aid in emotional disaster relief. Schools of architecture will collaborate with film schools and psychology departments to create a place of cinematic transcendence and community building, mobilizing architecture to transmit films capable of healing communities after a disaster. Mobile oral history collection containers will also be situated throughout the festival to provide participants with the opportunity to make their personal stories heard around the world. The Contained-Cinema Film Festival aims to bring relief and healing to communities affected by disaster and to collect and transmit oral and filmic documents to other parts of the world.

Project Conception and Financing

Students of architecture will work with film students to develop conceptual analogies between cinematic language and architectural tectonics and apply them spatially, materially, and programmatically to adapted shipping containers. Film and architecture students will consult with disaster-relief counselors and cinema-therapy experts to define the festival's filmic content in relation to specific disaster-related need-groups and ensure the containers embody and promote a message of belonging and self-empowerment for an effected community. Intermodal professionals will be consulted for practical concerns of structural alterations and transportation requirements. Professionals in architecture, film, intermodal transport and construction will mentor student volunteers to ensure compliance with codes, regulations and copyrights, and will oversee the development of design schematics into the final construction, sitting and operation of the cinematically adapted cargo containers. Architectural academies will contribute to the pioneering of mobile design, and film institutions will contribute to the innovative transmission of film media to aid affected populations; and relief agencies and community groups will be provided with an adaptable staging area for other related humanitarian efforts.

Private and public sources of funding are being sought to cover the operations of the mobile film festival and oral history project for an initial period of three years, traveling to multiple disaster sites. Ongoing fundraising efforts will seek to widen the scope of the festival to include expanded areas of research, political action and dissemination of oral history archives.

Collaboration does not cease after the design, conception and construction of the cargo container film festival. It is hoped that a culture of collaboration will be catalyzed, and as survivors communicate and bond with volunteers, community unity will be stabilized and reinvigorated. The mobile film festival creates a vehicle to connect, discover, recover and rebuild in the post-disaster environment.

Adapted Container Precedents

ISO Containers (International Standards Organization) are available world wide and have been a topic of research for their possible adaptation into buildings for human habitation. Shipping containers are constructed at an adequate human scale and can be expanded by adjoining containers side to side or stacking them vertically. Containers are engineered to be water-tight and are transportable by ship, train or truck making them suitable for any location. Researchers and designers have determined containers to be an inexpensive, basic “building block” ready for adaptation. FXFOWLE Architects designed a competition entry for the Boston Society of Architects 2003 “Density: Myth and reality” Competition (fig.1). The entry explored the possible adaptation of shipping containers as building blocks to create an independent live/work neighborhood. The focus was on an integrated, natural, civic, retail, office and housing community. Shipping containers were arranged and stacked in an arching spine. The design begins to explore the possibilities of using shipping containers to erect instant urban communities.

Figures 1, 2, & 3

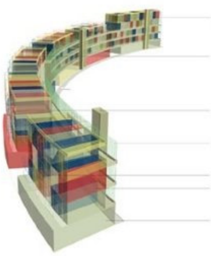


Figure 1. FXFOWEL Architects Competition Entry
Figure 2. LOT-EK Mobile Dwelling Unit Vertical Harbor
Figure3. LOT-EK Constructed Mobile Dwelling Unit

The Mobile Dwelling Unit (MDU), an adapted container project by LOT-EK, offers a mode of mobile housing for the global traveler. (Figs. 2&3) The containers house all the live, work and storage functions for a single individual. The living functions are located in extendable sub-volumes leaving the interior of the container open. When it is time for travel the interior volumes are slid into the container, maintaining the standard container’s exterior skin. The units are then shipped to the traveler’s next location and erected in a MDU vertical harbor. A similar technology is used to transform the entrances of the contained cinema. The entrance is a layered composition of the exterior container skin and interrior panels that revel the interrior architectual language and provides a transsition for the exterior to the interior. Unlike the FXFOWLE and LOT-EK projects, the Contained Cinema project strives to create an instant and *temporary* urban festival as a catalyst for housing and community re-development, rather than the housing itself.

Background of the Mobile Cinema

The Contained Cinema Project aims to recall the earliest roots of cinematic architecture as mobile, temporary, and intimate a lineage lost in today's ever-expanding "mega-plex." Early films were shown in existing buildings not specifically designed as cinemas, then in demountable fairground booths. These fairground booths, called bioscopes, were the first structures built purposely for film and were responsible for introducing film to the broader public for the first time. They where demountable, colorful and had elaborate façades that were meant to get the attention of bystanders. Jean Desmet designed a traveling bioscope that traversed the Netherlands and Belgium during the first decade of the twentieth century. (Fig. 4) [Heathcote 2001]

Figures 4

Figure 5. Traveling Bioscope by Jean Desmet

Cinematherapy

Of note in relation to the contained cinema-therapy project is the fact that film was invented at the same time as psychoanalysis. Both were new ways of seeing invisible relationships between the inner and outer world: while psychoanalysis provided a new way for people to measure and reflect upon their lives in relation to others around them, film brought a new visual language to define and re-define the structure of the physical and meta-physical world. Flashbacks, dream scenes, animation, and editing (strategies of both film and psychoanlaysis), enabled for the first time, free movement and free association within time and space. Psychoanalysis was allowing people to construct and deconstruct complex scripts of their conscious and subconscious lives through fantasy scenes, discovery of the subconscious and the analysis of dreams, and films were giving concrete presence to those scripts. Fascinated with the emotional effects caused by cinematic encounters, therapists have linked the benefits of cinema to a psychological healing process. Cinematherapy is a form of counseling based on ideas from biliotherapy and the technology of cinema. Films contain a representation of our potential environment, our hopes and fears. [Sinetar 1993] Films may be based on real-life situations that relate to the viewers own life. Films are also capable of solving life's problems through a metaphorical relationship between the viewer's life and the screen, and inner strength can be found by developing a connection to the characters in the film. [Solomon 2001]

Cinematic Language and Building Tectonics

Film and architecture are complementary to each other, both dealing with representation and illusion of visual space [Rattenbury 1994]. The architectural design process can bridge the vocabulary of film production borrowing concepts such as scene, montage, frame, cut, motion, recurrence, illusion, edit and depth of field to create an alternative way of designing architecture. For example, the overhead plane of our Contained Cinema is designed to adapt to the sound qualities within a particular film or film genre. When a film of the genre to be housed within that container is watched, dialogue, sound effects, and music are lapped with spatial and structural rythyms in the overhead plane. The suspended ceiling contains properties of sound absorption and reflection that are compatible with the film. These overlaps are registered by the participant, who is now enveloped both inwardly and outwardly by the resonance between the film and the space it is shown within. By linking cinematic language to the architectural transformation of the shipping container, it is hoped that the resulting construction will resonate with a functional and tangible compatability between space, materiality and film and contribute to a new language for mobile cinemas that are more intimate, more interactive, and more adaptable to local needs than today's mega-plex.

Occupant Interaction

Connection of person to place is a challenge in mobile, non-permanent or adaptable architecture. The adaptabilty of cinema pods, and their communal configuration within a site, actually contributes to a greater sence of interactivity and thus also, we hope, to create a sense of connection to place at multiple scales. Inside the container one does not merely pick a seat. Participants are invited to create individual or family pods as personalized places to view the film. (Figs. 5 & 6)

Figures 5 & 6

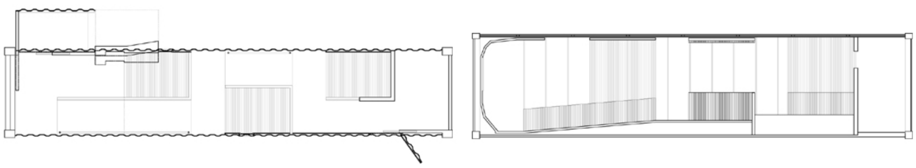


Figure 5. Mobile Cinema Plan
Figure 6. Mobile Cinema Section

Container viewing pods are designed as transformational compartments with folding panels, platforms and cushions. Panels are unfolded from the floor to create one form of seating arrangement. Platforms are unfolded from the wall to create a table or bench. Other platforms are slid along tracks within the floor to be positioned into a table, chair or foot rest. These transformational spaces reinforce a psychological sense of belonging and empowerment. Once each space is defined and a sense of attachment to their space, to the film and to others within the container, the lights are lowered and the film begins. Portions of the containers exterior skin can be folded or pealed away to reveal slivers of light and sound, connecting the atmosphere within to outside court yards. Containers are located within clusters defined by film types. The container arrangements within each cluster form exterior courtyards for congregation and conversation. Projections of film previews, advertisements, news, and information aids are cast onto the walls of the sounding containers with the courtyards. Thus, the individual is connected to the screen, to their family viewing pod, to the container itself, to the genre cluster, to the festival overall, to their community and to the world through the oral history component.

Mobilization and Deployment

Common container sizes used in international commerce are 20 ft, 28ft, 40ft, and 48ft. The most common containers are the twenty-foot equivalent units (TEUs) and the forty-foot equivalent units (FEUs). The typical container height is eight feet six inches, and the standard width is eight feet. A "high-cube" is another option that is nine feet six inches tall. Containers may be stacked as much as eight high in storage and on some ships. Containers are transported on the highway via semi-trucks attached to chassis, metal framework with container connection points and wheels. Multiple containers can be transported by purpose-built well cars designed to handle only containers. Often containers are transported across the U.S. by a "land-bridge" train. These trains connect the East and West Coast ports. An ocean carrier, for example, may move containers between Asia and Europe via the land-bridge across the United States [Robal 2002].

Mobility of the Contained Cinema Festival

The Contained Cinema project uses containters transformed from "high-cube" FEUs, allowing for standard forms of transportation to and from a site. Travel from one landmass to another can be achieved via current shipping lines. Containers can be inserted into the normal shipping schedules to be sent anywhere in the world. The container cinema will be loaded alongside containers of food goods, building products, medical supplies and other relief-orientated items. Once landfall is achieved, the cinema containers are sorted and unloaded following normal port procedures. Depending on the containers final destination they will be transferred to chassis then rail cars and chassis again to reach the festival location. Side loaders will be loaded on to flat bed semi-trucks and transported to site. Crews are scheduled to arrive before equipment and containers to make final preparations for the containers. Side loaders will arrive before the first containers. After the arrival of containers on the chassis, they will be unloaded by side loaders and arranged and stacked on site according to a cluster label diagram located on the exterior of the container. All equipment, furnishings and interior finsihes are stored and shipped within the container from the student volunteers home-base institution. After containers are arranged, stacked and locked into position, transformation of standard FEU to a contained cinema begins.

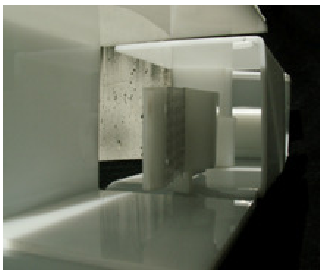
Disaster Related Site Conditions and Festival Adaptations

Festival site design strategies aim to bring a sense of coherence to the disharmony, discomfort, disorientation and displacement of the post-disaster context. As the project aims to construct an temporary urban setting for gathering and communication geared toward regeneration with a local connection to place, the container cinema cannot be pre-designed for a specific site. Flood, tornado, hurricane, earthquake, wild fire, mud slide, drought, political unrest, volcanoes and man made disasters present different contextual challenges and potentials. However, certain pre-design site arrangement strategies can be identified and defined to react to probable site conditions caused by certain disasters. Pre-designs can also be designed for more predictable typical site typologies such as a cleared parking lot, school playground, sports arena, open field, beach, river bank, wooded lot or a closed street. Examples of pre-design concepts for the Contained Cinema Project range from dense container networks to create courtyard-like spaces in parking lots to engineering elevated walkways raised above the ground level in a flood region to creating isolated entity in an area affected by an earthquake. However, final site design arrangements must be made on site at the time of construction.

Oral History Transmission

Within the Contained Cinema compound is a special container dedicated to *recording* rather than projecting film. The *collective transmission container* provides multiple spaces for the recording of personal encounters with loss, hope and rescue. Transmission containers are located within each genre cluster throughout the festival. Individuals or groups may activate the recording process within the container by approaching the constantly recording media wall.

Figure 7 & 8



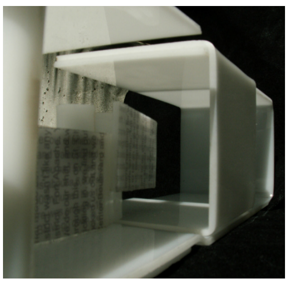


Figure 4. Proposed Collective Transmission Container

Contained Cinema: Acollaborative, cross disciplinary project to aid in emotional disaster relief through cinematherapy. Freida Speicher and Nancy Sanders

Portions of the media wall are concealed from outside view while other segments of the wall record a constant stream of video of the activity in the outdoor court yards of the festival, allowing individuals to record their story in a public or more private condition. (Fig. 7 & 8) Recording stations would contain audio visual equipment built into the walls. The technical applications of the equipment will inform the design of the architectual elements within the cointainer. The recordings are compiled into an oral history archive and later dispersed around the country as a traveling exhibit. Global transmitting of the recordings is shared with the rest of the world via the internet and satellite feed. The Contained Cinema Project for Emotional Disaster Relief will use NPR's *StoryCorp* project as a precedent and guide for staging and disemminating oral histories. This is a national initiative to record the oral histories of Americans. The first story booth was a free-standing soundproof recording studio in New York City's Grand Central Terminal and a second booth opened in March at the World Trade Center site in New York. Over a ten year period, StoryCorps plans to open mobile and permanent booths across the United States.

Festival Relocation and Container Re-depolyment

The life of the Contained Cinema Festival is dependent on the rate of reconstruction for the community and on the occurance of other disasters where the festival might be needed. The festival will rarely sit long in storage because of the reality that there is always a disaster somewhere. Relocation is achieved thought the same standard shipping infrastructures that assisted with arrival. Containers will be scheduled for pick up and begin the journey to the next location. New containers may be added to the festival at any time and containers may be removed for retrofitting. Another festival will be constructed to aid in disaster relief and generate another chapter of the oral history archive.

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Massive rapidly erected structures for the Seville Feria.

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KEYWORDS

Steel structures, rapidly erected structures, temporary architecture

ABSTRACT

Every year, the City Council build a giant gateway to the international well known Feria of Abril area. The design is always conditioned to the traditional patterns of architectonical local motives.
The dimensions of these constructions are limited in Fifty meters wide, forty meters height and four meters dept (Figures 1 and 2).
The structure is always a massive pile of pipes connected by clamps (Figures 3 and 4).
Our objectives are to diminish so much as possible the numbers of pieces and to make as light of possible the total weight.
Otherwise one of the problem is the design so much quantity of pieces and to analyze these structures. To it we have developed methods of rapid generation of meshes and new ways of calculus by groups of them.

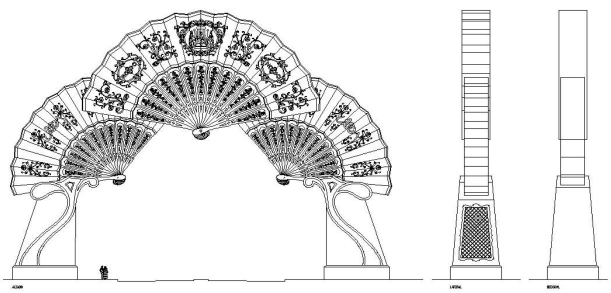


Figure 1. 2005 gateway of the Seville Feria.

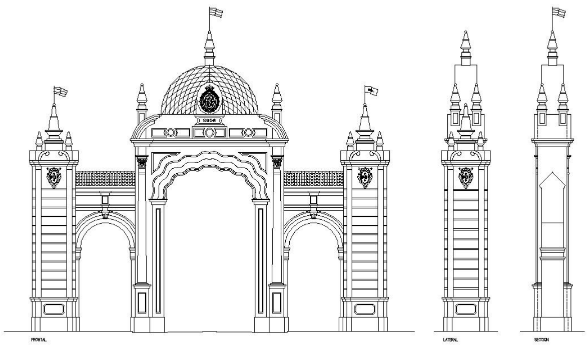


Figure2. 2006 gateway of the Seville Feria.

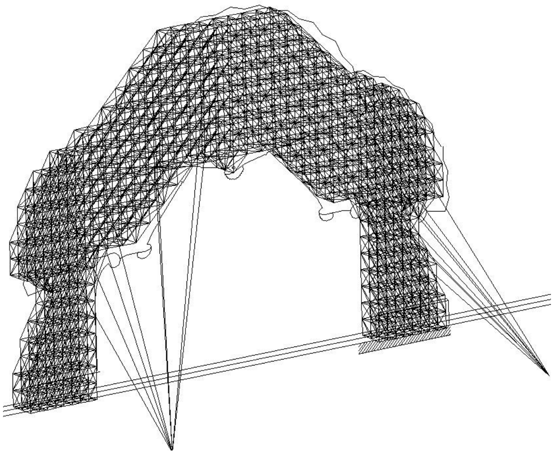
1. Concepts.

The subject of the paper is to consider these meshes as a fibrous mass to be analyzed as a whole. Then it not means which piece is full loaded because other pieces can assume the residual loads. It is clear that a non linear analysis solves this question without difficulty, but our objective is including in a single process of linear analysis the complete calculus.

We introduce the concept of "density of mass", "density of stresses" and "plastic adaptation of geometry". To obtain these parameters, that are not uniformly distributed we use "perimeters of mass" with variable depth, geometry completely triangulated, although it is not necessary by introducing the concept of "shear density".
With these methods we analyze massive structures by FEM considering linear properties.

2. Analysis.

The result is that we have dismissed the total weight of massive structures in a 30%, with respect to traditional and conventional methods within safety conditions.
Two examples can be shown. Figure 4 shows the first steps of a structure designed by conventional methods at the initial levels and the enlighten at next levels (Figure 5)



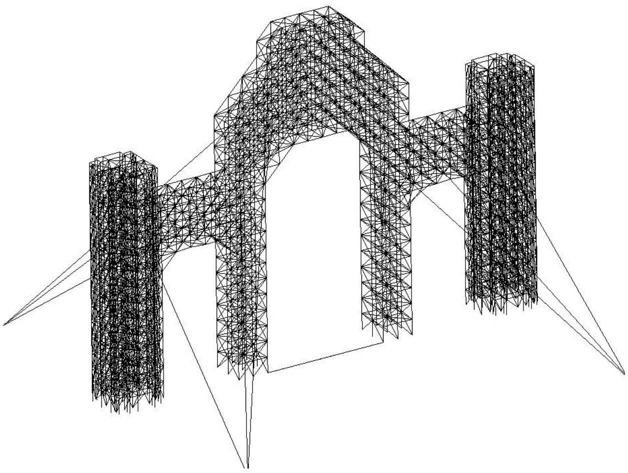
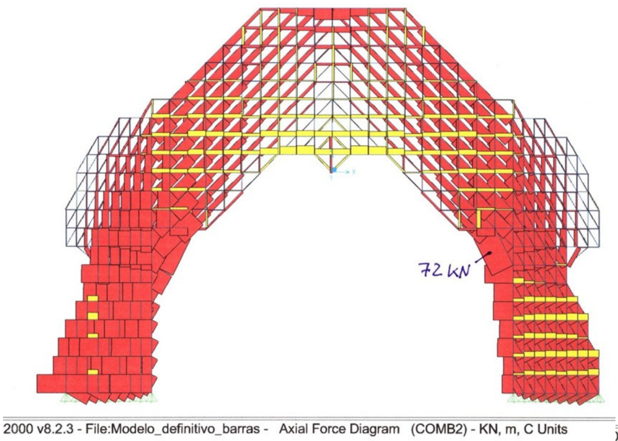


Figure 3. 2005 structure of the Seville Feria. Figure 4. 2006 structure of the Seville Feria.

The 2005 structure has been analyzed by two methods. The one considering a lot of straight pieces as single elements. The other considering the whole as built with three-dimensional blocks of similar mass density connected by its nodes.
The method used to achieve the similarity of both models is to obtain the reactions due to self weight and thus we obtain the mass density. After this we know the stresses by comparison of reactions.
The stresses obtained by model of bars are shown in figures 5 and 6. In these cases the stresses considered are due to load case 2.



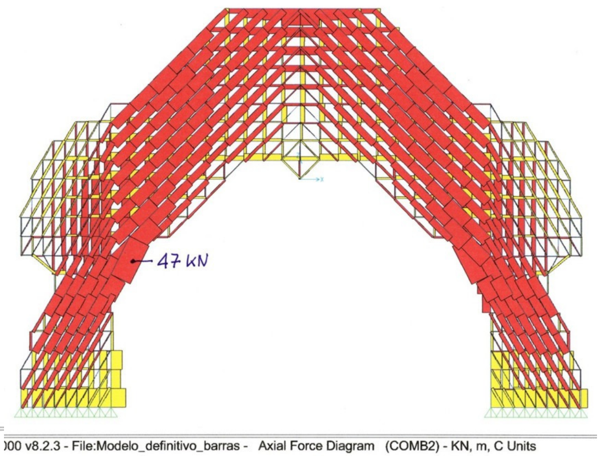


Figure 5. Vertical stresses in the inner side **Figure 6. Vertical stresses in the outher side**

Loads considered are self weight (SW), panel loads (PL), wind forces (W) and prestressing loads (P).
Load case 1 : 2(SW) + 1.5(PL) + (P)

Load case 2: 2(SW) + 1.5(PL) + 1.5(P) + 1.5(W).
If we consider the same load cases in the solid mode we obtain the stresses shown in the figures 7 and 8.

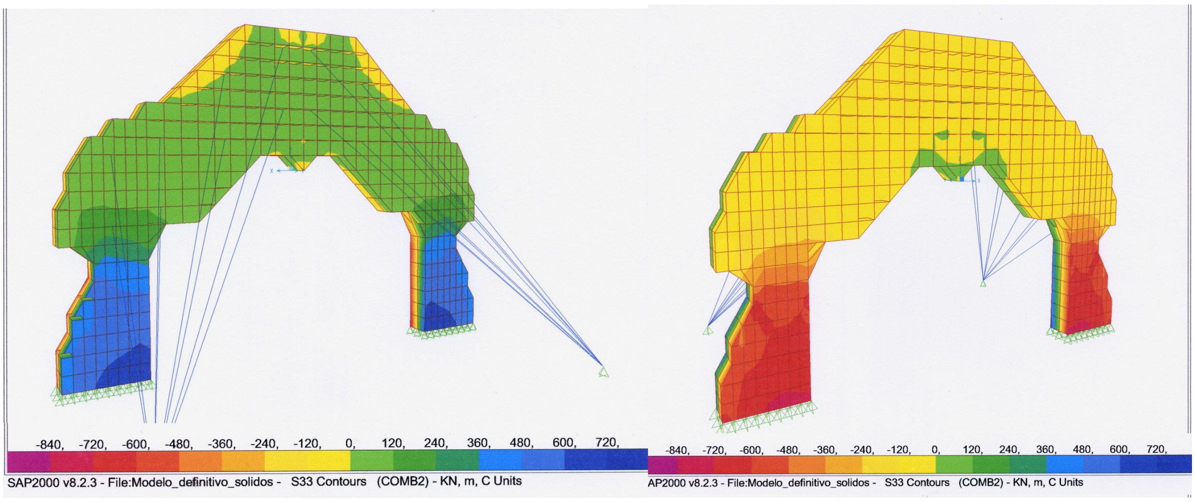


Figure 7. Vertical stresses for load case 2 in both sides.

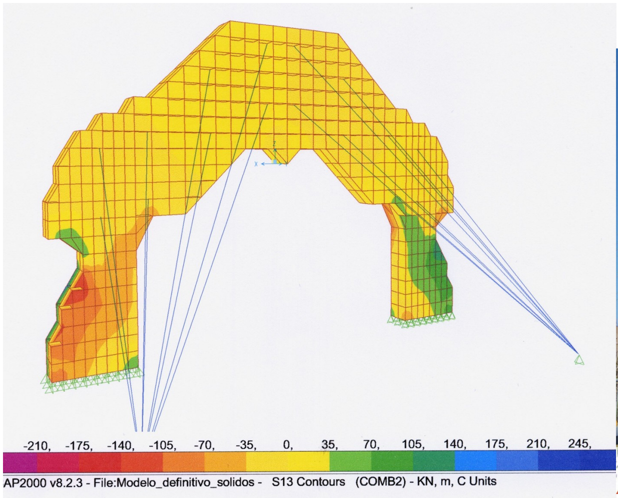


Figure 8. Shear stresses in the outside plan. **Figure 9. Structure of the 2005 gateway.**

Figures 10 and 11. The structure of 2005 gateway in the day and in the night.

The figure 9 shows the building process that we can see concluded in figures10 and 11.

For the 2006 gateway for the Seville Feria of Abril we have done the same with the next load cases.

Load case 1 : 1.35(SW) + 1.35(PL) + 1.5(W) + 1.35(P)
Load case 2: 1.35(SW) + 1.35(PL) + 1.35(W).

The analysis made with bars is shown for the worst load case 1 in the figure 12, while in figures 13 and 14 we propose the results for a solid model.

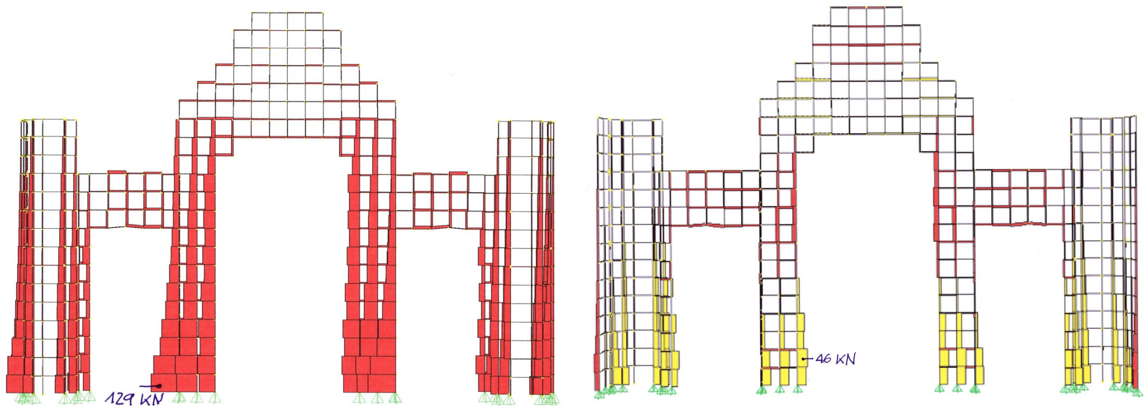


Figure 12. Vertical stresses in the both sides of the gateway for the load case 1.

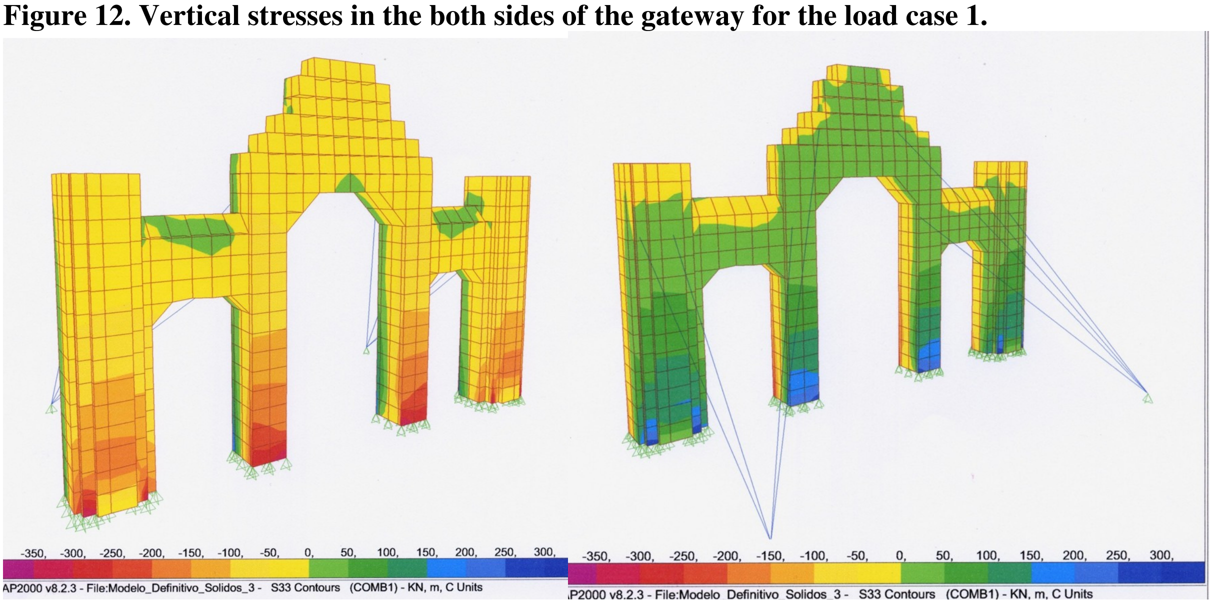
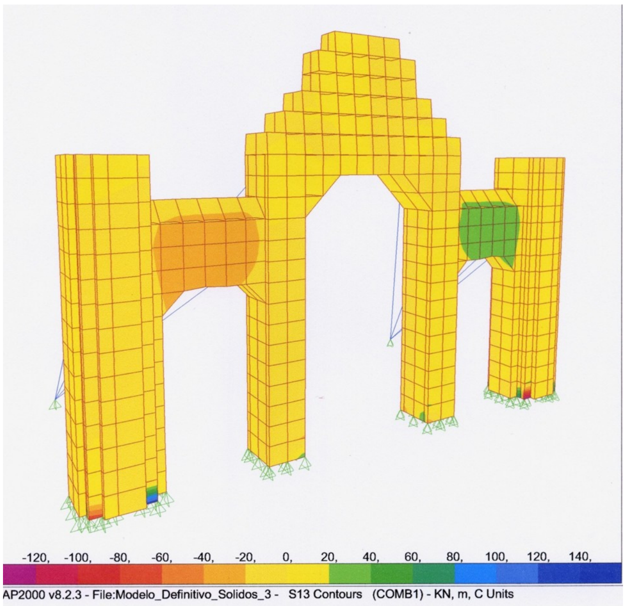


Figure 13 Vertical stresses in the both sides of the gateway for the load case 1

3. Conclusions.

We can conclude in the next synthesis:

a) The method of substitution of a fibrous structure by a solid structure is valid because the results are similar although not very accurate.
b) For our purposes the accuracy is enough because all pipes used are with the same area, and then we can divide the total load stress/solid modulus by the ultimate load of each pipe (approximately 15 KN for 2 m. length).
c) Reactions coincide because we have used them as an adjusting parameter considering a total number of bars in each module of 9, corresponding to the total length shown in the figure 15. This is an approximation that we have checked in the real structure as a good average.



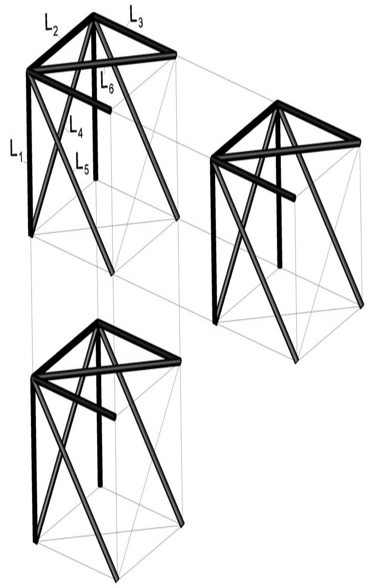


Figure 14 . Shear stresses for the solid model. **Figure 15. Number of bars in each solid element**

Figure 16 Building process of the 2006 gateway.

4. References.

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ManuBuild, an European project which incorporates both research and practice on the subject of Open Building

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KEYWORDS

ManuBuild, Open Building, open system, customer oriented building, industrialized construction

ABSTRACT

The research domain of Open Building has been around for a while. It all began when Habraken started to divide the process of designing and building into different levels, from which base building and infill are the most familiar [Habraken, 1961]. Since then a lot of effort has been put in this research area. To name a few important books that have been published on this topic: Structure of the Ordinary [Habraken, 1998], Residential Open Building [Kendall et al, 2000] and Customized industrialization in the residential sector [Van den Thillart, 2004]. Quite some remarkable projects have been realized based on these principles, for example in the Netherlands, Finland and Japan. [Kendall et al, 2000] The underpinning principles are however still not applied on a large scale in Europe. This is truly a loss, since this will help incorporating change in our build environment, which is necessary to maintain its usefulness, safety and its attractiveness in a changing world. For this reason the European Committee has co-funded ManuBuild, a European consortium with representatives from 10 individual countries. This research program, with the main focus on the supply of housing, is worth €20 million and stretches out over a four-year period, starting April 2005. It is the largest amount of EU funding ever awarded to the construction industry and promises a step change from the current situation in construction on four different aspects:

- From technology push towards market pull
- From mass production to mass customization
- From production on the building site towards prefabrication
- From a project oriented focus towards a service-centred focus.

ManuBuild is a so-called Integrated Project and is part of the 6th European Framework Programme.
The presentation will concentrate on the vision and organisation of the ManuBuild project, together with some preliminary research results.

Vision of ManuBuild

The ManuBuild vision is of a future where customers will be able to purchase high quality, manufactured buildings having a high degree of design flexibility and at low cost compared to today's products. For the first time, inspirational unconstrained building design will be combined with highly efficient industrialised production. ManuBuild targets a radical breakthrough from the current "craft and resource-based construction" to "Open Building Manufacturing", combining ultra-efficient and ambient manufacturing in factories and on sites with an open system for products and components offering diversity of supply in the market. Enabling business processes, ICT systems, new materials and technologies, smart components interfaces and connections will underpin this. Potential impacts include significant reductions in the number of construction industry accidents, waste, costs and time to construct buildings. This will allow Europe to improve it's building stock, whilst also releasing resources that can be allocated to other income generating industrial sectors.

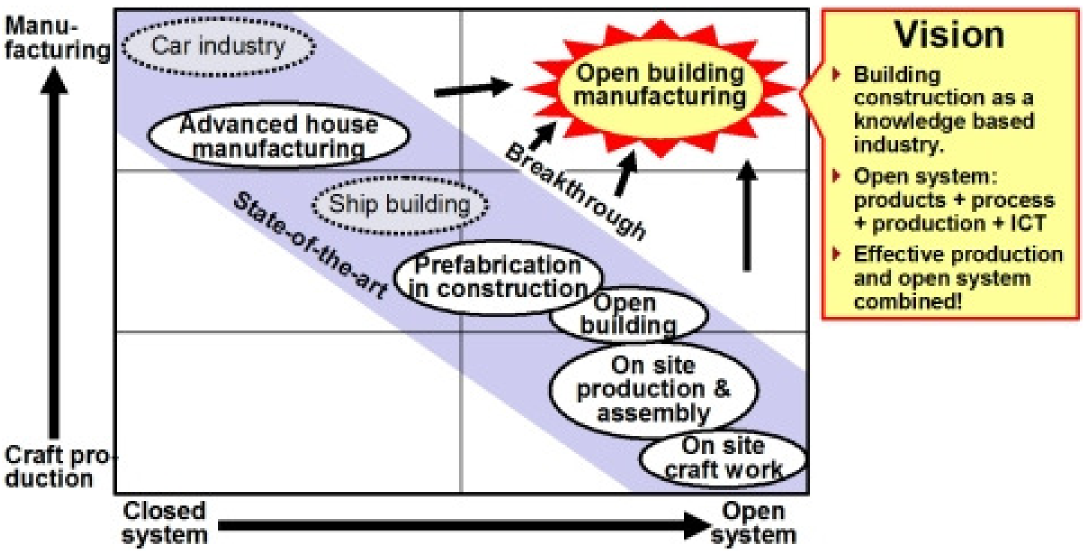

Figure 1. Picture of the ManuBuild Vision.

Partners of ManuBuild

Within the ManuBuild 24 different partners are involved of 10 different countries.

Partner	*Country*
CIRIA	UK
Consolis	Finland
Corus	UK
DRAGADOS S.A.	Spain
EMVS - Empresa Municipal de la Vivienda (Madrid)	Spain
Enterprixe Software Ltd	Finland
FCC Construcción S.A.	Spain
Fraunhofer Institute for Industrial Engineering (IAO)	Germany
Graphisoft	Hungary
IAT (Institut Arbeitswissenschaft und Technologiemanagement) University Stuttgart	Germany

IVF	Sweden
ITB	Poland
Labein	Spain
Mostostal Warszawa S.A.	Poland
NCC Construction Sverige AB	Sweden
Nuova Quasco	Italy
Saint Gobain	France
Salford University	UK
Taylor Woodrow Construction Ltd.	UK
TNO	the Netherlands
TUM (Technical University Munich)	Germany
Universidad Carlos III de Madrid	Spain
VTT (Technical Research Centre of Finland)	Finland
YIT Construction Ltd	Finland

Organisation of ManuBuild

The work is structured in different work packages in which a subgroup of relevant partners is contributing. Every work packages is divided into different tasks with it's own planning and required deliverables.
TNO for example is contributing in following work packages:

- WP1 on stakeholder requirements
- WP2 on building concepts,
- WP5 on ICT support tools
- And WP9 on dissemination of the results

ManuBuild is based on a modern research approach where the linear model of development of knowledge in universities, research institutes operating as intermediaries and companies applying the research results is put aside. [ ] In this project research is jointly executed by universities, research institutes and companies, including a professional client. This according to insights that knowledge generation and application is a circular process [ ]. But it will not stop there, ManuBuild seeks to prove it's own results by realising demonstrations of tools and processes developed, as well as to prove it's principles will actually work in practice by the realisation of three to four building projects.
At the moment the process for the first building project has started. It is an apartment building with approximately 40 social homes to be located in Madrid. For this project a restricted European competition is held for architectural ideas. The goal of the competition is to obtain a high level of architectural quality on types of flexible housing, at the Mediterranean scope, with the application of construction systems that are industrialised, open and sustainable. Fundamental is the presence of the user from the start of the process.

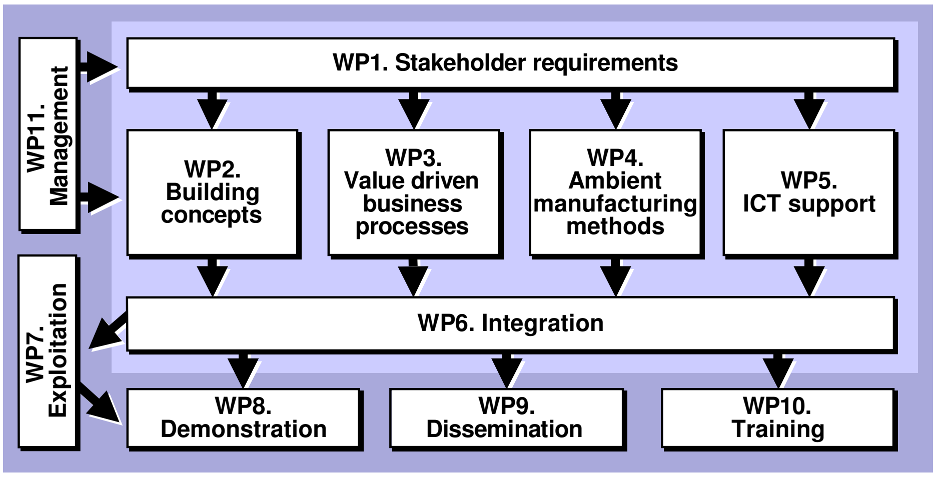

Figure 3. Work plan.

Preliminary results

The project started with the setting up of communication and working procedures. A detailed planning was made of the forthcoming work. To make a link with people outside the consortium, the Community of Interest was set up (www.ManuBuild.net) in addition to the more general internet site (www.ManuBuild.org). The Community of Interest is a place people can get information about on-going developments via newsletters. The forum is used to organise input and feedback on ManuBuild results.
The first results from the project are an overview of requirements from different stakeholders in different countries.

Summary

ManuBuild is a very ambitious European project that is targeting at a breakthrough in the construction industry. The aspects in which it hopes to contribute to this industry transition is on the following aspects:

- From technology push towards market pull
- From mass production to mass customization
- From production on the building site towards prefabrication
- From a project oriented focus towards a service centred focus.

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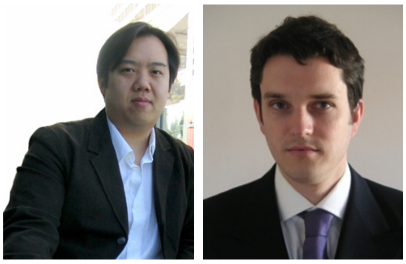
Adaptive Product Modules for Mass Customization: Lessons from Vehicular Architecture Development



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KEYWORDS

Variety, Adaptability, Mass Customization, Wheel Robots, Product Architecture

1 Abstract

Developing adaptable and flexible product architectures provides for meaningful levels of cosmetic, electronic, ergonomic, structural, and material customization. Today, automobiles are the result of intricate supply chains, integrated manufacturing techniques and just-in-time manufacture of component modules. While these changes have compensated for increased complexity and sophistication at component and system levels, the automotive industry has relied on vehicle platforms to create vehicle family lines that reduce engineering costs, yet limit radical changes and high levels of customization. The challenge of designing successful mass customized products is balancing product variety and adaptability. To achieve this, the Smart Cities group of the MIT Media Lab in collaboration with General Motors has developed a new vehicle architecture consisting of two primary elements: 1) self-contained, digitally controlled "Wheel Robots," which incorporate all drive-train elements and, 2) a highly customizable passenger cabin and chassis.

This paper is divided into three sections consisting of 1) a study of the relationship between adaptability and variety, 2) the role adaptability plays in different stages of the product lifecycle, and 3) the creation of a comparative map of mass customized products. Using these metrics we will illustrate how Wheel Robots are designed for highly adaptive use while also exhibiting high variety.

2 Introduction

The promise of mass customization has been the manufacturer's ability to create products to specific preferences, needs, and tastes of the consumer. This is evident in the customization of many products. For example, automobiles can be customized cosmetically by color and trim selections or ergonomically adapted to fit the driver's unique anatomical characteristics. However, a distinction should be made in the term adaptability. Adaptability is defined to be the ability to change or be changed to fit changed circumstances [WordNet 2003]. An automobile can adapt over its lifetime to different drivers or owners only in a limited way. The seating can adjust to fit different users, but the color cannot be easily changed. Furthermore, any radical user needs such a new propulsion system requires a drastic overall haul and is cost prohibitive. This paper examines the role of adaptability in the mass customization of products at every phase of the product lifecycle.

3 Variety Versus Adaptability

It is exceedingly apparent that adaptability has its distinct value in differing contexts. Product lifecycles can be divided roughly into three stages 1) Pre-Production, 2) Production, 3) Post-Production. The value in adaptability in pre-production stages of mass customized products is manufacturer centric. Adaptability allows manufacturers to reduce inventories, quickly make radical design changes by using product modules, and reduce engineering time and costs; whereas, adaptability in post-production is user centric. Once a product is configured and produced a user may want to re-configure depending on new software or hardware options.

Another key variable in mass customization is variety. Pine and Gilmore's book, "Markets of One" describe the importance of product variety and the desire for uniqueness [Gilmore & Pine 2000]. Striking a balance between infinite variety (with potentially unnecessary variety) and minimal product differentiation can create the optimal breadth of variety. To gain a better understanding of adaptability we will examine the relationship between product variety versus adaptability of a wide range of simple to complex products. The degree of adaptability at every stage of the product development process and product lifecycle has dramatic affects on the design, engineering, manufacture and use of the product. For example:

> A product that is adaptable after production is the Adidas 1 Shoe, with sensors and motors embedded inside; it is adaptable by continuously reconfiguring itself to the running patterns of the users. On the contrary, a regular Mi Adidas Mass Customized shoe is not adaptable, as it is customized once and then fixed. This is true for most conventional Mass Customized products. There are several degrees of adaptability: The Adidas 1 shoe is very adaptable, infinitive changeable, but the solution space is small (the range of adaptation). On the other hand, take a Benson Woods Open Build House. They claim users can easily exchange modules of the construction either to replace a part or to adapt the house to changing needs. A traditional brick house for sure is much less adaptable [Piller 2006].

4 Product Lifecycle

Let us breakdown the affects of adaptability and its relationship to variety throughout the product lifecycle process.

4.1 Pre-Production

Conceptual design development plays a major role in pre-production activities. If we consider that any product can be described as a parametric 3D model (either virtual or physical) at any phase of the product lifecycle, then a pre-production product has extremely high levels of both adaptability and variety. The design of a door assembly will illustrate this point. A door comprised of door panel and accompanying hardware. The door panel itself can be modeled parametrically given a height, width and thickness. In a parametric model these can be described as a set of values. “Assigning values to all the parameters specifies an instance of the type. In principle, values may be real numbers (as in the length of a sleeve) -- i.e. continuous, or integers -- i.e. ordered but discrete (as in discrete shoe sizes), or discrete and drawn from an unordered menu of some kind (as in finish options). The space of instances is the Cartesian product of the ranges of the parameters.” [Mitchell 2006] Therefore, in pre-production the door possesses infinite variety because of the product of all the possible parameters. As we will see later, as the product lifecycle moves forward in time, the product of instances reduces as more constraints are applied and irreversible decisions are made.

4.2 Production

Production (especially of mass customized products) can be described in two distinct stages: component fabrication and final assembly. In the case of the door assembly, hardcore components will be fabricated separately from the door panel itself. Different hardware components like locks and hinges can be substituted to create an array of possible door assemblies. “Different parts maybe substituted at some point, and some parameters (like the type of handle) may be adjusted at any point in a finished product's life. There will be nested spaces of instances [Mitchell 2006].”

In the United States, door height dimensions are more rigidly defined. For example, door heights are usually 6’8” (80 inches), whereas widths of doors are more flexible because of varying conditions like handicap access, varying room layouts, and other geometrical constraints. “Some parameters will have values bound to them before parts are fabricated. These choices will generally be irreversible (like the door height). The remaining capacity of the instance to vary in response to changing needs is the Cartesian product of the remaining unbound parameters [Mitchell 2006].”

As production moves forward, decisions to bound parameters affect the fabrication of components and eventually the assembly of those components. In the case of the door assembly, once the decisions have been made on the number and type of hinges, irreversible tooling operations will be performed on the door panel (drill holes for the particular type of hinge). Other operations will be reversible such as the substitution of differing hinge types with a congruent drill hole number and location. “The remaining capacity to vary is a still smaller Cartesian product [Mitchell 2006].”

4.3 Post-Production

The level of adaptability of a product after production is typically determined by the user. A cell phone can be customized and therefore adapted to a user’s preferences such as the ring volume or background settings. The door assembly is typically installed post production to fit exactly to the door opening specifications, thus adaptability is low in this respect because that door will only fit in openings of the same dimensions. However, angle to which the door is open is adjusted at the time of use and is reversible (just like the volume adjustment of speaker). “The Cartesian product of these choices defines the adjustability in use.” [Mitchell 2006].

5 Comparative Product Map

We have developed a diagram (Fig. 1) that examines the relationship between adaptability and variety for products in the post production phase of the product lifecycle. A wide range of products (some of which are mass customized) were used to illustrate the tradeoffs when designing products that try to accommodate changing needs while providing for differing levels of personalization. This heuristic is divided into 4 quadrants with 4 key axes 1) high variety, 2) high adaptability, 3) low variety, and 4) low adaptability.

5.1 High Variety, Low Adaptability

Tailored suits occupy the extremities of this quadrant because each suit is customized ergonomically for each customer. Suit makers can combine different materials and styles to create infinite variety. Once the suit is made, changes are difficult to accommodate. Puma introduced in 2005 its line of customizable shoes [Puma 2005]. To design the shoe, customers select components of the product which was are sent to the factory to be assembled and then sent back to the retailer. Like the tailored suit, variety is very high, but once configured the product has very little adaptability. More infamously, Levis introduced custom jeans by offering a website that allowed customers to specify the exact fit of the pants. In the building industry, brick and concrete homes inherently have high variety because of the endless combinations of brick types and formwork that can yield endless designs. However, once built in place these architectural expressions are very static and offer very little adaptability by the users. Concrete buildings are less adaptable than brick buildings because of the monolithic nature of concrete construction.

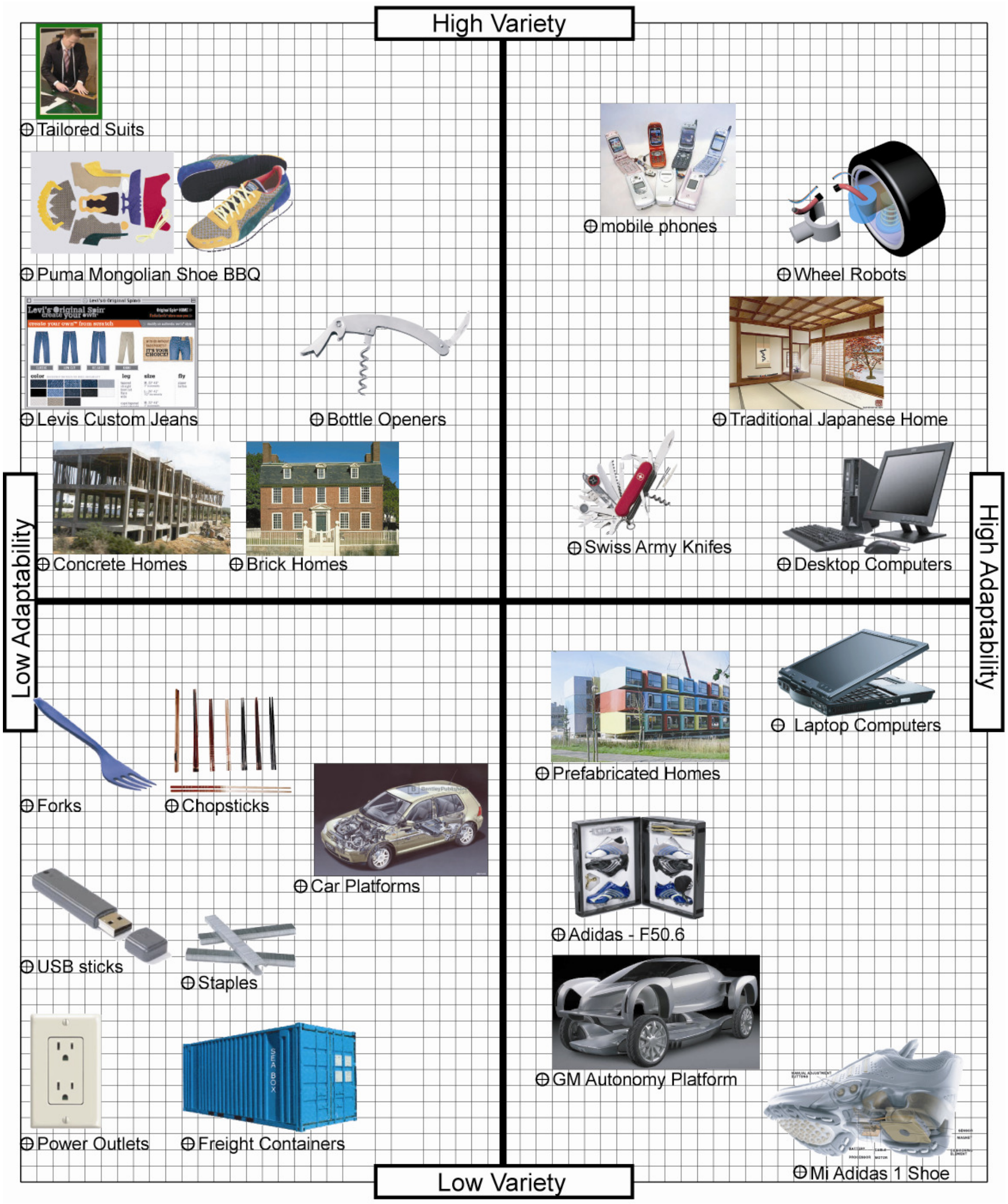

Figure 1: Variety versus Adaptability (Post-Production)

5.2 Low Variety, High Adaptability

The Mi Adidas 1.1 shoe anchors the low variety, high adaptability quadrant [Mi Adidas 1.1 2006]. In contrast, the Adidas F50.6 TUNIT Premium ClimaCool® Set shoe offers a highly modular yet adaptable shoe architecture, whereby users can reconfigure the shoe by switching the shoe chassis and body to differing weather and comfort positions [Mi Adidas F50.6 2006]. Similarly, the GM AUTOnomy vehicle platform provides future customers an adaptable skateboard like chassis which can fit to different body cabins [Burns *et al.*2002]. However, variety is limited to three sizes of platforms. Prefabricated homes are adaptable to different *in situ* conditions. Often prefabricated modules can be clustered together to create new combinations for given space requirements. With increasing adoption and improvements in rapid prototyping, variety will increase in the next decades. Laptop computers (like desktops) are fundamentally adaptable products due to their product and software architecture. Laptops are designed to be mobile, therefore adaptable to the user's environment; whereas desktops are less mobile, but have much freer packaging constraints thus are more adaptable for hardware additions.

5.3 Low Variety, Low Adaptability

This quadrant of the diagram is dominated by mass produced products. Household power outlets have very little variety (except for the cover plate) and negligible adaptability. Freight containers come in only a few standard sizes. Truck beds, ship cargo bays, etc. have all been designed to fit those dimensions. USB memory sticks have more variety than power outlets and freight containers, but less than utensils like forks and chopsticks. Collectively, these products have very little adaptability aside from creative uses (i.e. using chopsticks to hold a hair bun). The automobile industry has perfected the use of product platforms because of the intensive capital investment necessary to develop a vehicle platform. For example, the Volkswagen group's A4 platform is the basis for 8 different front- and all-wheel drive model ranges [A4 Platform 2006].

5.4 High Variety, High Adaptability

Swiss Army knives can be adapted to solve a myriad of problems. Differing sizes and colors also make Swiss Army knifes a high variety product. Mobile devices like cell phones exhibit high degrees of variety not only because of the numbers of designs, but the endless ways a user can personalize the product (physical/virtual skins, downloadable ring tones, etc.). Cell phones are also very adaptive in post production because the modular architecture allows users to switch and replace batteries, SIM cards, face plates, and other physical components. The traditional Japanese home is designed and built based on the 'Ken,' a traditional proportioning system [Ching 1979]. The product of this proportioning system is architectural form of infinite variety and high levels of adaptability. With the introduction of flexible and movable wall partitions (which were also proportioned using the Ken), spaces could be adapted to fit differing spatial needs. Desktop and laptop computers straddle the line between low and high variety and with the continued demand for more customizable products will only see an increase in both variety and adaptability.

4 Wheel Robots

Faced with the challenge of developing a highly customizable concept vehicle, the Smart Cities group of the MIT Media Lab set forth to rethink the product architecture of traditional vehicles by re-modularizing its key components. Our plan was to create a highly modular architecture which would redistribute typically integrated mechanical systems into new configurations, thus freeing up the design of the body and cabin. This resulted in the Wheel Robots (Fig. 2), independent snap-on, snap-off units which contain all drive-train functions such as, steering (360 degrees), braking, and suspension, in close vicinity to the wheels. This eliminates the need for components like engine blocks, gear boxes, and differentials. A car would be composed of a number of Wheel Robots and a connecting body/chassis. Once configured mechanically and digitally, the Wheel Robots work in concert to give the vehicle high levels of maneuverability.

The product architecture allows for substitution of Wheel Robots for performance upgrades or repair. Equally important is the ability to design and manufacture a highly customizable passenger cabin to exact specifications for each user. Because of the dramatically reduced mechanical complexity compared to today's car platforms this is possible. Highly standardized wheel units benefit from economies-of-scale, thus shifting the development

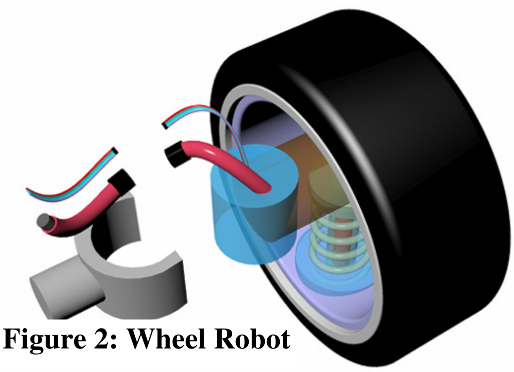

Figure 2: Wheel Robot

costs towards the customizable elements most meaningful to the user. Wheel Robots are highly adaptive because they allow for infinite number of body designs. The design of the Wheel Robot itself can evolve by providing open source architectures for which lead users and manufacturing innovators can build upon [von Hippel 2005]. Families of Wheel Robots can be produced to accommodate differing conditions, thus providing for high levels of variety. For example, small Wheel Robots that are compact will help save space in the tight packaging conditions of a city car. Larger and more rugged Wheel Robots could be used in large trucks or hauling equipment. Supply chains become more flexible because of the distinct and separate manufacturing paths taken by the Wheel Robot and the rest of the vehicle. Wheel Robots can be manufactured centrally and then distributed to regional centers where the passenger cabin and body are made.

5 Conclusion

The increased demand for personalizable and adaptable products has created a shift in the design strategies for manufacturers. Many have been resorted to creating new product architectures that depend on flexible product modules in order to streamline the production process. The key enablers to this new architecture are high levels of standardization (particularly in interfaces) and open innovation by manufacturers, suppliers, and users. Our wheel robots are highly adaptable to an infinite number of passenger/body configurations and vary in size depending on performance criteria. In post production, the wheel robots also allow the users to upgrade and repair each module in a timely and efficient manner. The mapping of products along variety and adaptability lines differentiates the inherent versatility of the design during all phases of the product lifecycle. The heuristic developed in this paper only begins to tell these differences, yet more scientific measures need to be developed to fully comprehend the complex balance between adaptability and meaningful variety.

6 Acknowledgements

The basis for much of the research discussed in this paper stems from the Concept Car project with General Motors developed at the MIT Media Laboratory. Under the leadership of Professor William J. Mitchell researchers and students from all parts of the MIT community have contributed via the 5 design workshops that have been conducted by the Smart Cities research group. I would like to acknowledge the contributions of the core group including William Lark, Jr., Phil Liang, Axel Kilian, Mitchell Joachim, Marcel Botha, Raul-David "Retro" Poblano, Peter Schmitt, Susanne Seitinger, and Franco Vairani.

7 Tables and Figures

Figure 1: Variety versus Adaptability (Post Production)
*The following images and associated references were used to create Figure 1.

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Blue fork:
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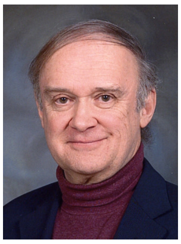
Individualisation & Industrialisation



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KEYWORDS

Adaptability, User Needs, Strategies, Industrialised Processes, IFD Systems

PAPER

As paradoxal as it may look and despite the unfavorable prejudices still prevailing, industrialisation is offering to the vast majority of people not only an architecture of quality but also more individualisation than what is presently available with the traditional handicraft approach.

1 Distinction between adaptability and individualisation

Adaptability itself is the capacity to alter a course of action when new information becomes available or when new conditions arise. As everyone is different from his or her neighbour and different with him/her-self through time, the same changes will often necessitate different configurations to correspond to the needs and personality of the individuals involved: that is precisely the purpose of individualisation.

2 Individualisation as the key asset to industrialisation and cost reduction

Basically, industrialisation means aggregating the participants in a continuous operation serving a market large enough to amortise a technology capable, in turn, of simplifying the production and thereby reduce the costs [Richard 2003]: that is the power of quantity. Nowadays, such a large market could never be reached by a standardised product: manufacturers have learned how to introduce variety and even individualisation within their technology without any significant cost surcharge.

The ready-to-wear clothing industry has fully applied this approach: the same process generates different sizes, different types, different designs, using different materials while accomodating the various movements of the human body; within that diversity, a client-buyer will be looking either for a model compatible to his/her taste or for a model in fashion or for a combination of both. Same with the shoe manufacturers: the cutting & sewing machines will produce different sizes for the same model out of the same leather or different leathers.

3 Four strategies to generate individualisation within mass-production

As demonstrated by most industries, the four strategies described hereafter can generate diversified and even individualized products. Separately, each strategy may seem limited, but together they are complementary and able to cover a wide range of options.

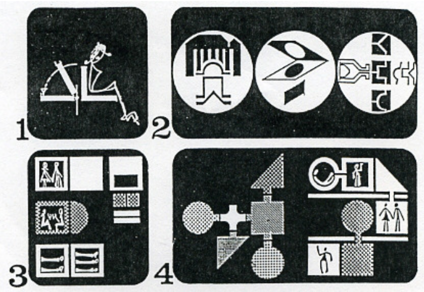

Figure 1. Schematic representation of the four strategies to generate individualisation within mass-production: 1- Flexibility of the Product, 2- Flexibility of the Tool, 3- Multipurpose Framework and 4- Combinability.

3.1 FLEXIBILITY OF THE PRODUCT: The product itself is capable of geometrical variations while in use in order to respond to different needs over space and time.

The automobile industry is giving us a example of Flexibility of the Product: the same model can accommodate seated passengers or, by folding down the rear seats, transform itself into a small freight carrier. For the manufacturer, it is a single product: obviously a more complex product due to the mecanisms related to that very flexibility, but cost-effective because amortised over a wider market.

In the building domain, various factory made partitions are applying Flexibility of the Product:

- DEMOUNTABLE, where removable panels with some type of back grips are supported by notched studs;
- MOVABLE, responding only to a ceiling channel and dismantled in a single operations;
- MOBILE, made up of lightweight panels connected with continuous hinges.

The flexibility offered by the partitions is greatly facilitated when the service core is located in a "neutral" position, right at the center of the space or in a linear configuration perpendicular to the façade, thereby generating a completely transversal area. Compact lightweight relocatable service cores are also available: clustering the bathroom / kitchen / laundry, they can simplify the organisation of a "loft" or allow an easy redistribution of the space.

The exterior envelope should also offer some degree of flexibility, not only to follow the positioning of the flexible partitions, but mainly to give to the users the opportunity of expressing their personalities: some will want a more open facade, others will prefer more discretion; some will want to identify themselves, some will want anonymity.

NEXT-21, the Osaka project designed under the direction of Professor Yositika Utida, is offering such a level of flexibility: within a post & beam precast concrete framework, suspended ceilings and overfloors are permitting the relocation of partitions and service units (kitchen, bathroom, laundryroom, etc.). The façade is composed of modular glazing panels and small opaque horizontal staineless steel insulated cladding units, both being easily handled by the occupant and allowing different façade expressions [Osaka Gas 1993].

Figure 2. The NEXT-21 prototypical project in Osaka.

3.2 FLEXIBILITY OF THE TOOL: The tool itself becomes the generator of diversified products.

A diversity of results can be generated from the same machines by operating at the level of:

- the CONTROLS i.e. feeding a digital model to a CNC (Computerized Numerically Controlled) machine in order to generate diversified molds by milling blanks (e.g. the precast concrete panels of the Der Neue Zollhof building in Dusseldorf by Frank Gehry), to produce a form through the addition of layers (e.g.contour crafting), etc.;
- the LAYOUT i.e. modifying the pilot pattern (e.g. pantographic tracer) or transforming a master mold (e.g. inserting blockers or spacers);
- the MATRIX i.e a key interchangeable form-giving apparatus is generating the output of a large and complex machine (e.g. changing the "die" of the extrusion machine or the "mould" of an injection machine, etc.).

Obviously, Computer–Aided Manufacturing (CAM) has accelerated and magnified this approach up to a point where the individualisation & industrialisation partnership is now called "Mass-customisation".

3.3 MULTIPURPOSE FRAMEWORK: The same product acts as a framework to different options.

These options are obtained through the addition of specialized components or the introduction of secondary modifications.

The automobile industry, to mention it again, has adopted the specialised components approach out of a framework called « platform ». An automobile platform is a shared basic framework common to a number of very different models, like sedans, sports cars and a SUVs; the specialised components are added afterwards. The aircraft manufacturers are mmainly turning to the secondary modifications strategy: the same fuselage can be powered by engines from different manufacturers or/and be subjected to different interior arrangements; the same fuselage can also be stretched to offer more payload, etc.

The S.A.R. [Habraken 1976] and the Open Building [CIB 104] approaches are applying the Multipurpose Framework strategy: an identical "*Support Structure*" is open to a variety of "*Detachable Units*", modified over space and time according to the needs and resources of the occupants.

The Japanese 3D modules ("units") manufacturers use the same skeleton structure framed at the edge to support various interior and exterior infills, while leaving some bays completely open when two or more modules are joined in order to procure a larger room. Prefabricators are also offering secondary options to "personalize" their units: bay windows, dormers, carports, etc.

4.4 COMBINABILITY: Generating a multitude of combinations from a set of basic components produced in large quantity.

Combinability works through modular co-ordination and/or simple interfacing rules for the joints**.**

The most universal application of Combinability is music: the same seven notes modulated on a stave have been used billions of time by hundreds of composers and interpreters for many centuries and yet we are still amazed by new melodies that come up almost evey day.

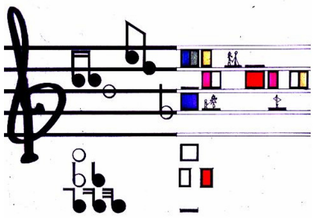

Figure 3. Schematic representation of the analogy between music and Combinability.

The "Meccano" kit is the model of that approach: numerous types of variations can be obtained at the outset or throught demountability. The prerequisites are modular spacing of the holes and simple jointings through the nuts & bolts.

Many Post & Beam systems are inspired by the Meccano:

- a typical column with a corbel at every half storey can accommodate split-levels and/or 1½ storey rooms, like at the Genterstrasse housing project by Otto Steidle in Munich;
- two typical beams, an orthogonal one and a diagonal one can generate several column free sizes of room as well as a variety of planning geometries.

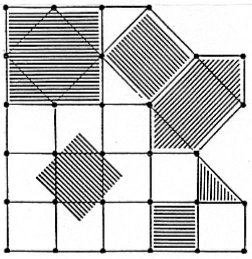

Figure 4. Schematic representation of the variations generated by two typical beams, an orthogonal one and a longitudinal one.

Factory-made modules can generate various housing types both for single family townhouses as well as for horizontal multifamily clusters; besides contributing to fireproofing, the double layer created between them is the best way to provide soundproofing.

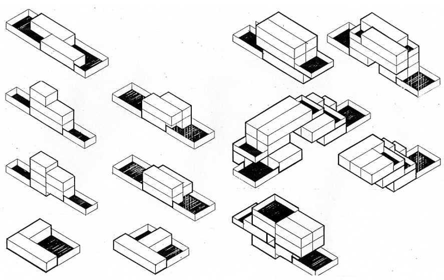

Figure 5. Schematic representation of the various housing types generated by combining factory-made modules.

5 IFD Systems

The IFD (Industrialised / Flexible / Demountable) systems offer a major opportunity to apply these individualisation strategies to the sustainability agenda: combining the quality & economy features of industrialisation with the adaptability to accommodate the evolution of its occupant [Di Giulio *et al.* 2004].

Industrialisation is meeting the sustainability goals by:

- Aiming at processes capable of simplifying production, thereby avoiding the repetitive human efforts and energy required in the handicraft methods of traditional construction;
- Providing a higher quality (due to the processes as well as to the climatic protection offered in the factory) to assure better performances and more longevity;
- Avoiding the 3% to 5% of material waste occuring at the traditional construction sites.

Flexibility is meeting the sustainability goals by providing aptability to the household scenario, thereby avoiding the major wastes associated with renovations.

Demountability is meeting the sustainability goals by reusing the same components when a reconfiguration or even a relocation of the building is necessary, thereby avoiding any demolition (demolition being the contradiction of sustainability). Therefore bolted joints as well as dry assemblies & finishes are the pre-requisites.

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A flexible topfloor system with integrated heating and cooling for the Infra+ floorsystem

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ABSTRACT

Adaptability and flexibility are frequently used but not well defined terms in the building industry. Due to the complexity of the building process and the wide variety of people and interests, adaptability and flexibility have different meaning and value for the different participants in relation to comfort and financial aspects. Therefore we determined that the starting-point is that "flexibility must not be a option but has to be a standard feature of a building component at no or little additional cost".
This has been the main goal of designing a top floor for the Infra+ floor.
The design has been divided in several stages:

- The SlimBouwen® philosophy was used to define a design strategy for building products
- The Infra+ floor system is one of the existing products that fits very well the SlimBouwen® philosophy but does not completely fulfill all criteria. This is mainly due to the fact that the existing top floors for Infra+ do not meet the expected adaptability and flexibility standards, especially when heating and cooling need to be integrated.
- The defined design strategy led to a completely new design of a top floor which integrated heating and cooling.

The new top floor is based on the SlimBouwen® philosophy of prof. dr. ir. J.J.N. Lichtenberg from the University of Eindhoven. This philosophy states among others that the nowadays building industry is very conservative, inefficient with space and materials, produces lots of waste and that innovations are mainly based on "Innovation by Addition". Designing a top floor system for the Infra+ floor according to this theory proves that a highly flexible and adaptable system is possible and, not necessarily an option but can be a standard feature of the product at competitive cost.

SlimBouwen®

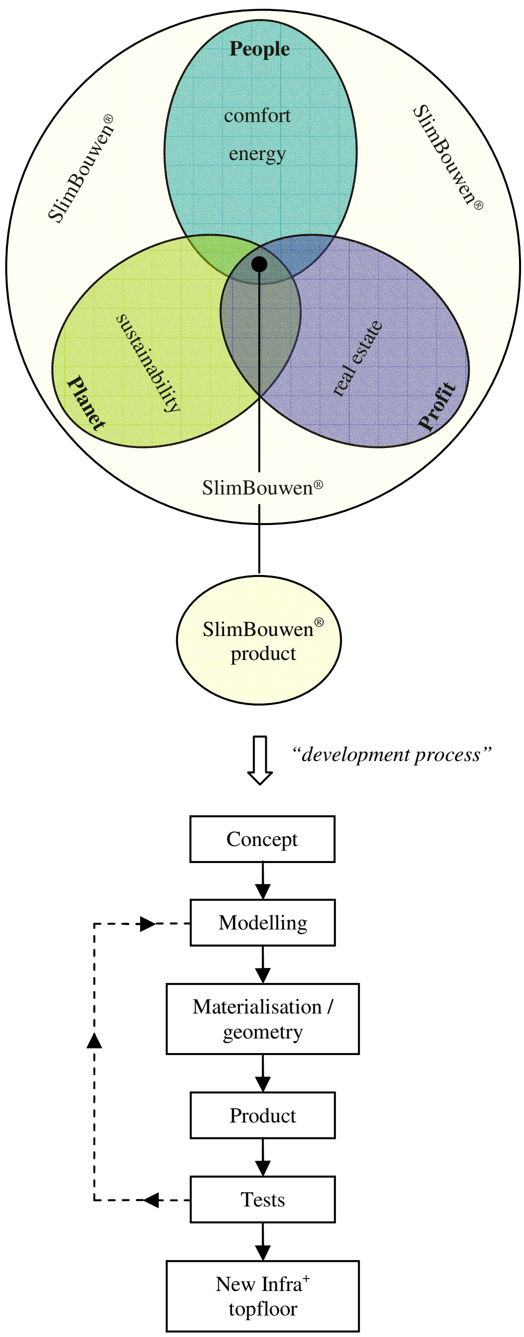
Slimbouwen® is not a building system, but *"an integral view on building and possibly a system of agreements and guidelines at strategic level"* [Lichtenberg, 2005]. SlimBouwen® aims particularly at the following aspects:

- Flexibility and comfort (People);

- Reduction of waste, energy saving and emission of CO_2 (Planet);
- Efficiency (reduction of failure costs, weight saving, reduction of volume, gain of construction time by reorganisation of the construction process)(Profit)

Moreover it is important that adaptability and flexibility are embedded into the design, so that when user requirements are changing, the building can anticipate to it, both on the level of 'support' and 'infill'.

Instead of Innovation by Addition, the following approach was used:
SlimBouwen® is a philosophy which can be used as a guideline for designing building products that, have standard features like flexibility and comfort and, which were designed from an *integral* point of view. For example not only the user or constructor are regarded as main users but also the building process and the end users comfort and flexibility are taken into account.



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Background on the design method for product development in the building industry according to SlimBouwen Strategy

In the last decades the tendency has arisen in the Netherlands to deal more carefully with the available land/space. In this context the Dutch government has taken measures to use land optimally by means of multiple and intensive space usage (MIR). Primarily MIR has been meant as an instrument for building and investing in urban area with as objective optimum use of available ground.
This means explicit that on the available ground housing space is created, which is not function-tied. I.e. the space is suitable for numerous application and possibilities without high investments when the function changes.

This requires naturally creative solutions of architects and builders, but also of investors.
Investors have one goal and that is maximum output on own capital.
The output on a property investment is a combination of direct output arising from direct net turnovers and indirect output which is the change in value of the property investment. Both, direct and indirect output are influenced by the mechanism of supply and demand. Space, for which no tenant has interest, remains without rental incomes and therefore without positively direct output. The same applies to real estate, which is not let or can be let. This has a lower value then real estate that is long-term let.
However, it must be taken into account that the location of the present real estate has a substantial influence on the value appraisal; a building due for demolition on own ground in the center of Amsterdam has a significant higher value then a similar object on the country side.
Investors have been therefore interested in real estate, which is readily marketable and is well located.
The foundation is in fact laid for a number of investment risk to overcome; vacancy and value development.

The Dutch society is continuously developing; the population increase continues to persevere, the need for living space per person increases steadily and the demographic composition of the population modifies, etc…
This development has unmistakably its repercussion on the Dutch real estate market. Looking at the current Dutch office market, one deduce, that there are approximately 200,000 employees necessary to fill the current vacancy in the offices. To this subject several studies have been dedicated, which do reflect unmistakably that this problem cannot be solved on short term.

Unfortunately a large number of office buildings have been build for a fixed function. This leads to restrictions with respect to function conversion, on account of the applying land-use plans and the tight Dutch laws and legislation. Due to this, owners of office premises are faced with structural vacancy and a lot of insuperable considered problems like investment results.

Aforementioned developments ask for another approach and interpretation of the real estate market. From numerous sectors we know the phenomenon, in which production resources are deployed as a company means and are as such also managed. Anticipating on the market requires coordination of the production resources and the interpretation of this market needs. Financial modifications and/or developments in the market are taken into account from the start.

Eversince, the real estate market has used traditional building methods to interprete and meet the current market needs without anticipating on future changes in the market needs. Housing constructions are still made from poured concrete structures or stacked constructions, offices are mainly realized by means of concrete elements - columns, beams and floors - and curtain walls. All these construction methods lead to buildings without considerable flexibility to provisions.

The choice for new innovative construction methods, which create flexibility and quality in buildings, united with ingenious financing methods, offer investors for the future less score risk and a more positive value development of their well portfolio. Investors, however, have to be prepared to leave the conventional out-of-date manner of building. Only in this way the space arises for new construction concepts, which simply can anticipate on future market developments.

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In times of high dynamics in the use of spaces (housing/offices), it appears that function-tied buildings can anticipate on the requirements and demands of the user/investor. The requirement for flexible construction systems originates from non function-tied building and the resulting requirements and demands. Flexible construction systems have the advantage that modifications in the design, implementation, and use stage modifications can be processed until a late stage.
Within these flexible construction systems floors have a distinguished role. This is due to the large quantity piping which is present in the floors. Choices which are made, in whatever stage of the construction process or use phase has thus, generally have large consequences for existing piping and therefore for the floors.
A solution for the piping problems in the floor can be found in constructive flexible piping floors. These floors ensure a separation of the constructive function and the piping installation. The constructive flexible floors have been designed in such a way that the piping at each stage of the process (design, implementation and use) can remain accessible. A good example of a constructive flexible control floor is the Infra+ floor (supplier: Prefab Limburg).
With the development of such constructive flexible control floors one problem has been solved, but leads ensures directly to a new problem. All constructive flexible control floors which are available on the market, are not the result of an integral approach. This has led to semi-finished products, which still must be provided with a top floor. The current generation of top floors do not meet all boundary conditions and requirements of the underlying semi finished product (constructive flexible floor). As a result of that, the advantages of the constructive flexible floors cannot be used.

The new top floor is based on the SlimBouwen® philosophy of prof dr ir J.J.N. Lichtenberg from the University of Eindhoven. This philosophy states among others that nowadays the building industry is very conservative, inefficient with space and materials, produces lots of waste and that innovations are mainly based on “Innovation by Addition”. Designing a top floor system for the Infra+ floor according to this theory proves that a highly flexible and adaptable system is possible and, not necessarily an option but can be a standard feature of the product at competitive cost.

With the newly developed top floor, installations are easy accessible in the constructive floor. Necessary changes in the installation structure due to function changes of the building are easy to achieve. The accessibility and pattern of the installations is no longer connected to the function of the building.

The newly developed top floor is a result of the optimum flexibility in combination with low temperature floor heating/refrigeration.
The flexibility of the top floor ensures a longer life span of the building. Changes in relation to the control course can be achieved easily. By the detaching the accessibility of piping from the building function an important cost factor is controlled.

In other words, function free buildings with integrated heating and cooling are made possible by this top floor (in combination with constructive flexible floors).
The presence of low temperature floor heating and high temperature cooling, has big advantages, like for example healthier indoor climate. Furthermore, the advantage of the building users is the lower usage costs for such a system in comparisement with a traditional system (radiators).
The substantial extra value for the investor and user by the application of the new developed top floor, is therefore gained by combining low-energy heating/cooling with optimum flexibility. Because of this, shifts in the market which lead to function changes in buildings can be catched by the flexibility of the top floor with conservation of low temperature heating/refrigeration. This can be realized without many incremental costs for the investor or user.

The constructive Infra+ floor system

The Infra+ floor system (see figure 1) was one of the first products that resulted from SlimBouwen® philosophy.

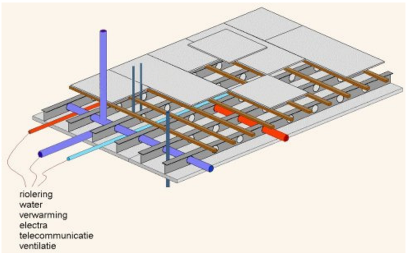

Figure 1. A schematic overview of the Infra+ floor system, which is standard to facilitate installations at a high flexibility and adaptability level

Method

In the current Infra+ floor system, its flexibility can be limited due to the currently used top floor systems. Especially if floor heating is desired, the top floor is mostly constructed as an anhydrite top floor, which is heavy and not flexible. A flexible top floor system with integrated heating and cooling was not available for the Infra+ floor up till now. Therefore, de SlimBouwen® approach has been used to define a design strategy for building products and as result a new top floor was developed.
The development stages are:
- idea to concept
- from concept to laboratory product
- from laboratory product to industrial product.

The following topics were regarded while developing a concept and a product:
- flexibility (fully)
- low temperature heating (T_{water} 35 °C) and high temperature cooling (T_{water} 18 °C)
- thermal comfort aspects for the user (no radiation asymmetry)
- thermal comfort in relation to the heat demand of the building (less air movement)
- costs of production and installation (cost comparable with traditional equipment without flexibility)
- construction strength, weight and height (according to legalization)
- fire resistance (depending on building function)
- labor legislation (< 20 kg. per tile)
- installation requirements (accessibility)
- acoustics (according to legalization, extra: SlimBouwen® demand on low noise radiation)

Results

The evaluation of these topics have led to a concept which, could be materialized into a laboratory beta product by choosing appropriate materials. In the concept stage, no choice of material was made or required. By calculations and research several appropriate materials have been chosen and adequate material dimensions have been calculated. This has led to the newly designed top floor which meets most of the requirements of the SlimBouwen® philosophy and the People/Planet/Profit requirements.
A detailed picture of the newly developed floor cannot be shown due to the patent procedure. Figure 1 is an impression of the existing infra+ floor with the newly developed top floor.
The use of the SlimBouwen® philosophy as a design method for product development in the building industry has proven to be highly effective and resulted in the newly developed top floor.

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(Mass-)Customization in Architecture – Hype or Innovation?

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KEYWORDS

Mass-customization, custom fabrication, building systems, design configurator, CNC fabrication

1 Background

Mass customization (MC) is a business concept of the 1990's that responded to the need of the consumer products industry to offer highly diversified products. Joseph Pine first introduced the concept to a broader audience and outlined its major components. According to him MC solves the dilemma of offering individualized products at the price of standard products by eliminating inefficiencies and waste throughout the ordering to production process [Pine 1992]. Early implementations were seen in the apparel and shoe industries that still feature some of the most successful mass-customizers. Segments of the construction industry adopted principles of MC about 10 years after its introduction [Schodek et. al. 2005]. For many architects MC seemed to promise the end of conformity of industrially produced components. Indeed, for an industry largely geared towards producing custom work the repetitive use of uniform industrialized products has always been a limitation. As sophisticated digital modeling and analysis environments allowed designers greater formal complexity, architects increasingly challenged the need to repeat identical components in order to lower construction cost. MC is often mentioned when computer-aided design and manufacturing approaches are described to realize non-traditional and complex constructions. Highly complex projects, often misleadingly labeled as MC, have indeed been facilitated by computer-numerically controlled (CNC) manufacturing techniques, but many other innovative approaches towards customization in more normative design schemes were largely overlooked. As the design profession is once again catching up with developments in other industries there is widespread confusion as to what MC actually is.

This paper presents conditions for custom work in architecture in the context of digital design and fabrication techniques. Common approaches are presented in five categories, ranging from full mass-customization to one-off custom fabrication. Traditional on-site building methods such as light timber construction or masonry construction were not considered in the context of this study, as they are largely unaffected by recent trends in computer-based design and production techniques.

2 Parameters of customization

The author analyzed case studies in order to propose categories of customization that are driven by digital design methods. The cases include, among others: Andersen Windows, Marvin Windows and

Doors, BAM AG, Xella Kalksandstein, Cabnetware, E-Sklylight.com, Freitag, IKEA, My Virtual Model, British Museum Courtyard, Mero, and InVido.

A key factor in customization is *production volume*, here understood as an annual volume for a fabricator, or a project-related volume. The range starts with a single custom unit, goes to several thousand individual members (such as for the grid shell of the British Museum Courtyard), and reaches up to 6 million windows and doors in 600,000 possible configurations in the case of a large manufacturer [Andersen 2006]. Most other parameters can be closely related to volume, as the efforts to optimize the design to production process are generally more sophisticated if supported by larger production volumes that justify the development time and cost.

Closely related to volume, and a key factor when large numbers of parts are handled, is a *modular design* approach. Any MC approach is inevitably based on a carefully thought out modular system that consists of a limited set of parts and standardized part interfaces. As a potentially wide range of choices may be present, MC concepts rely heavily on applications for *product configuration*. These enable the customer or client to configure a product in a guided process either online or through a standalone application. For a high-volume producer the investment in a configurator application is justified, because once in place the cost of generating orders is much lower than when handled through the traditional approach of sales personnel. The online interface to configure Freitag's custom bags, for example, may take one person 2 - 4 months to develop [Klaus 2006], but the investment pays off as production volumes are approximately 120,000 bags annually. A key element of MC is to transfer the data generated in the configurator directly into an order submittal process, and ultimately into the enterprise resource planning software and production (*information flow*). A discontinuous information flow generates additional cost as the product configuration needs to be essentially duplicated when placing the order (Andersen, Marvin). Checking for *system compliance* – and, as the case may be, for code compliance in the building industry – should be equally automated in a MC setting. Robust configurators enable only those versions that can actually be manufactured by the fabrication facility. Tracking which versions are ordered is extremely valuable for any MC approach as decisions are taken on which variations to continue, which ones to discontinue or how to extend the range of choices. Equally important is to establish *learning relations* to the customer, in MC this means recording customer profiles and types of orders to make future orders easier and shape the modular system according to demand. MC implementers have to make every effort to eliminate waste during production. Principles of *lean manufacturing* are key to accomplish that goal. These include on-demand fabrication, flexible manufacturing cells as well as just-in time delivery, to just name a few.

3 Modes of customization

Following Pine's definition of mass-customization a mapping was developed that evaluates the primary seven parameters on a horizontal scale (see Figs.1 and 3).

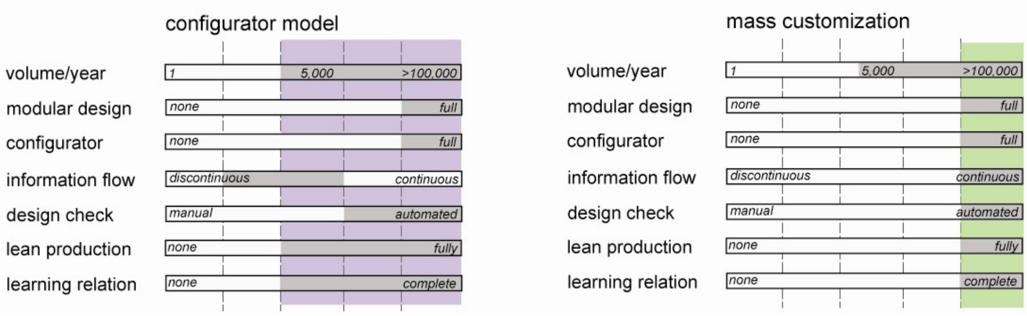

Figure 1. Mapping of the configurator model (left) and mass-customization (right).

<u>3.1 Mass-customization</u>: Key for MC are high production volumes that justify investments in a design configurator and the type of integrated design-to-order processing that eliminates the potentially costly process of collecting large numbers of individual orders. A good example for a successful mass-customizer in architecture is E-Skylight.com, producer of modular skylights, and described in detail in [Schodek 2005]. Customers can configure their units online while a 3D CAD model is generated in real time on the company's server. Detail drawings, quotes, and data for CNC production are all generated from the 3D model.

<u>3.2 Avoiding mass-confusion – the configurator model</u>: The configurator model is by far the most common approach if the objective is to facilitate choices within a modular design system. The configurator software allows the user to configure the product in question, be it a window, clothing and accessories, kitchen appliances, or automobiles. These applications vary greatly in sophistication, ranging from simple search interfaces to a database of pre-set configurations, to complex interfaces with built-in expert checks for system compliance. Online and stand-alone applications are both used. Common in this model is that the data generated in the configurator is <u>not directly used</u> to place the order and trigger production mechanisms. Instead, the order needs to be placed in a separate step that inherently leads to inefficiencies.

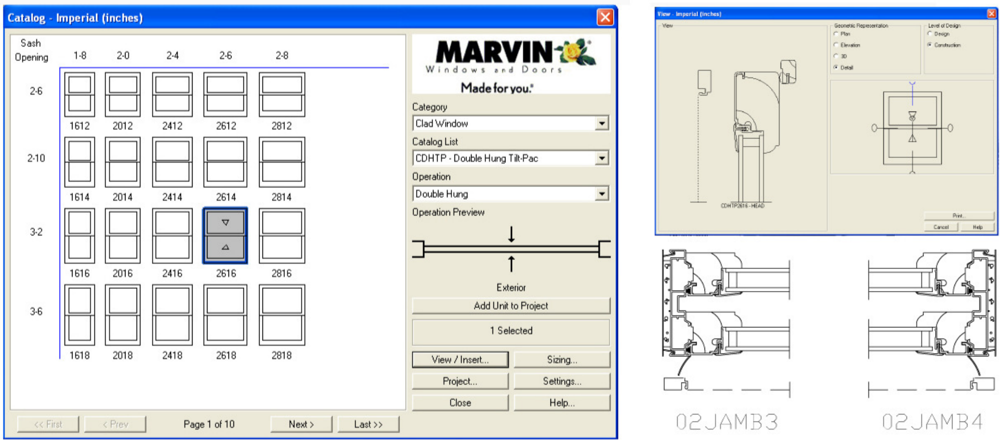

Figure 2: Configuration of a window starts by choosing a standard model and then customizing it. Details can be saved as *.dxf files. (Image: Marvin Windows and Doors © 2006)

A prime example for the configurator model is the process of selecting and specifying windows. Two detailed case studies were conducted of two major US manufacturers, Andersen Corporation and Marvin Windows and Doors. Product configuration for windows is complex as a large number of different models are available. Dimensional variation (window size) is an obvious need, as are color and finishes, glass types, hardware, screens and dividers. Geared towards building professionals, brand-specific window configurators can be downloaded for use on personal computers. Designing a custom window starts by choosing a standard window or assembling one from modular parts and then adding custom features to it. Users may be able to specify custom dimensions (Marvin) as production facilities are prepared to cater to these types of custom orders. Once complete the information can be saved, plotted, or exported as text files or dxf drawing files. Placing an order and obtaining a quote is handled exclusively through dealers with access to the order submittal software. Orders are generally submitted electronically to manufacturing facilities. The production is at least partially organized using CNC machining centers, and custom windows are shipped 2- 5 weeks after the order is placed.

Clearly the configurator model is close to an integrated MC approach except for the missing link between configuration and order submittal. Efforts are currently under way to streamline the information flow. Marvin is working on integrating the dealer based ordering system with the design configurator, while Andersen is introducing an online design configurator that will also deliver instant quotes and photographic views. Similar configurator approaches are present in other areas as well. When choosing kitchen cabinets and appliances, for example, the configurator visualizes the future kitchen that ultimately consists of standard modular units.

3.3 Fabricator's islands of automation - building systems: For decades fabricators have sought to streamline the construction drawing and shop drawing process by introducing specialized design systems for timber, steel, or concrete design and detailing. Many allow for geometry data to transfer to CNC production facilities. All generate bills of quantities. These standalone design and detailing systems derive all data views from a parametric 3D model in the effort to reduce errors and enhance productivity. Building system applications remain largely disconnected from the design team's CAD model. Even integrating structural analysis capabilities with detailing and construction packages has been challenging, as the structural data view is based on member centerlines and the construction view of the same model is based on top of member elevations. The potential efficiency of building systems in managing and producing many different structural members has benefited in particular complex projects such as Gehry's MIT Stata Center. But compared to MC the approach is missing essential components such as modular design, high volumes, lean production, and learning relationships. Building systems, after all, represent a solution for fabricators, not a business model.

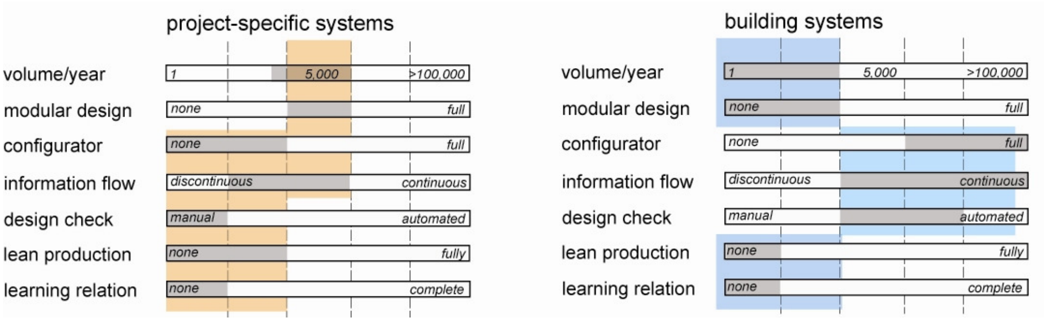

Figure 3: Project specific systems and building systems are common approaches in practice.

3.4 Enabling parametric variation - project-based systems: A more systematic approach to variation is present in recent projects that fully harnessed parametric design methods and were able to extend parametric variation into fabrication. Examples are the grid shell roof for the British Museum Courtyard (architect Foster and Partner, structural engineer Buro Happold, fabricator Wagner Biro) or the envelope of the Singapore Esplanade theater (architects Michael Wilford and Partners and DP Architects, structural engineer Atelier One, fabricator Mero International GmbH & Co. KG.). In each case a complex structural envelope was designed as an assembly of parametrically varied elements. These elements follow a complex geometry that leads to varying member lengths and many different node configurations. Structural optimization dictated varying cross-sections of members in response to stresses and deflections, generating thousands of individual members.

This type of work necessitates the integration between the CAD design environments and CNC fabrication processes. Re-entering geometry data on thousands of individual elements would be prohibitive for time and cost reasons. Project-specific file translator applications are often encountered, custom-coded to translate data between the design team and fabricators. The volume of work also justifies investing the time needed to partially automate certain steps in the manufacturing process; for example, a welding robot was programmed to weld custom bar stock to custom CNC cut nodes for the British Museum roof. For the Esplanade project. Mero used their proprietary spaceframe system consisting of spherical steel nodes with CNC cut threaded holes that connect to CNC custom cut steel sections. Construction logistics employ management systems that track bar-coded elements throughout transport and erection. Clearly, project-based systems are hardly conceivable without the ability to enable large data sets to migrate between the various participants in the design to production process. But is it mass-customization? Project-specific systems undoubtedly remain an area where innovative approaches have been able to thrive as they were funded by relatively large projects that posed complex challenges. But calling it mass-customization blurs the boundaries between two ultimately different philosophies – one a business concept, the other a systematic construction solution that creatively harnesses parametric design and CNC fabrication.

3.5 One-off custom fabrication: Architecture has a long legacy of unique, intricate, and complex designs that can only be realized by resorting to unconventional methods and participants that may even be drawn in from outside the industry. Be it a laminated sandwich shape for a suspended library built by a boat builder (Goetz Custom Boats for Yazaki Corporation), or custom bent glass by a prototype shop for a cafeteria (c-Tec for the Conde Nast Cafeteria), the nature of the work in this category is such that specialists from outside the industry often need to be consulted. But solutions are equally specific and do not usually translate easily to other projects. As is typical in custom fabrication set-up costs tend to be high and the cost of the end product is much higher than the cost of a comparable standard product. There is no doubt that this type of work has greatly benefited from computer-aided design and manufacturing techniques as these have made it easier for designers to communicate their design intent and prepare the design for fabrication. Fabricators rely heavily on CNC machines, but issues of data exchange between specialized CAD and CAM environments continue to be obstacles in production.

4 Customization in the building industry - a conclusion

The hype surrounding mass-customization has obscured many interesting approaches towards customization in the building industry. MC was conceived of as a business strategy and not as a solution to custom fabrication. Its potential remains significant in the medium to high volume production of architectural components with clearly defined interfaces to the remainder of the building. Skylights are a prime example of this type, but large window manufacturers are slowly moving towards a more aggressive adoption of MC principles. Compared to the consumer products industry many obstacles remain for MC in architecture. Codes and standards are complex and often beyond the scope of software-based expert systems. Legislation may be difficult to overcome, as was the case when Streif GmbH, a German producer of manufactured houses had to remove a sophisticated online house configurator from its website because in Germany only registered design professionals are eligible to submit documents as requests for planning permission. Other obstacles to customization remain the fragmented nature of the industry combined with the lack of robust and rich data exchange mechanisms. But it is clear that digitally supported design and manufacturing techniques have greatly facilitated custom design, as well as giving birth to a group of digital craftspeople with skills that bridge traditional trades and disciplines. Many innovative approaches to customization are poorly served by equating them with MC as such labels tend to obscure more than clarify their true nature.

5 Acknowledgement

I am grateful to my research assistant, David Celento, who has pursued and supported the development of case studies that this paper is based upon.

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Transformation of the Organisational Structure of Construction Companies for the Purpose of Mass Customization

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Construction companies, organisational structures, mass customization.

1. Introduction

For successful realization of mass customization strategy in a construction company, it is essential to form a flexible organisational structure of the company that would be capable of adjusting to the needs of every individual investor. As a basis for forming process organisational structure of construction companies in this paper, the following structures have been chosen: pure project organisational structure and matrix organisational structure. On transforming traditional organisational structures into process organisational structure, it is possible to achieve high efficiency characteristic for mass production, and shape personalized products (construction structures) of high quality. The development of process organisational structure is established on combining key advantages, improvements and changes from the selected traditional organisational structures in order to ensure optimal conditions for project realization, that is, the realization of individual construction processes for every individual investor. Since, in the organisational structure developed in this paper, key processes that directly emerge from the exterior customer's needs have a complete advantage over company's interior needs, the developed organisational structure is referred to as *process organisational structure*. Process organisational structure can be efficiently utilized for companies of every size and every surrounding condition, and their advantages are especially perceived with large companies running their business in unstable surroundings.

2. Characteristics of pure project and matrix organisational structures

In a *pure project organisational structure,* an independent team is established for the realization of every project; it entirely manages the project realization resources and it has, as its members, all the people necessary for the realization of all project aspects. The connections between organisational structure of the project and organisational structure of the entire company (parent organisation) in pure project organisational structure are very weak. Advantages of pure project organisational structure, summarized from [Meredith & Mantel 1995], [Moore 2002] are as follows: project manager has full line authority over the project; unity of command and responsibility; shortened lines of communication; maintenance of a near permanent group of project managers in a company; high level of commitment from team members; rapid decision making; easy to understand and implement; and supported holistic approach to the project. Disadvantages of pure project organisational structure, summarized from [Meredith & Mantel 1995], [Moore 2002] are the following: fully staffed individual projects lead to duplication of effort; stockpiling of resources by project manager; technical experts can fall behind in technology developments outside their project; possible inconsistencies in carrying out procedures and policies; projects may take life of their own; uncertainty amongst team members regarding their employment after the project termination.

Matrix organisational structure is founded on combining the advantages of functional and pure project organisational structure, that is, on establishing pure project organisational structure on the level of the project into the functional organisational structure on the level of the entire company. In matrix organisational structure, project manager decides what and when is to be done on the project, and sector managers decide who is to work on the project and which technology is to be used [Moore 2002]. The connections between organisational structure of the project and organisational structure of the entire company in matrix organisational structure are strong in *co-ordination model* of the organisational structure, medium strong in *overlay model*, and weak in *secondment model*. Advantages of matrix organisational structure, summarized from [Meredith & Mantel 1995], [Moore 2002] are as follows: project is the point of emphasis; an individual takes responsibility for managing the project; project has access to the reservoir of technology in all functional divisions; when several projects are in progress at the same time the duplication found in the pure project organisational structure is significantly reduced; response to client's needs is as rapid as in pure project organisational structures; response to demands made within the parent organisation is rapid. Disadvantages of matrix organisational structure, are summarized from [Meredith & Mantel 1995], [Moore 2002]. In co-ordination model – project manager acts as a project coordinator, and the responsibility for project realization is divided among all the sectors involved in the realization. Sector managers have more power in relation to project manager. In overlay model – there is an attempt to make a balance between project manager's powers and sector manager's powers by compensating temporary loss of resources from the sector for the needs of the project and by the participation of project income into sector income. The main drawback of this model is that one person has both project and line responsibilities. In secondment model – function departments provide human resources through full-time secondment to the project team for the duration of the project, after which they return to their line function within the parent organisation.

The application of traditional organisational structures suitable for the closed systems (prevailing in manufacturing) onto the open systems (prevailing in construction) results in the fragmentation of processes being performed in a construction company and weak performances of construction companies. The main reason for construction process fragmentation is inadequate flow of information through all mutually dependent subprocesses of the entire process, which take place in different company sectors. Traditional organisational structures are not suitable for construction companies that do business in the conditions of fierce competition and demand constant business improvements.

3. Main factors in process organisational structure

Main factors in process organisational structure of a construction company are the following: exterior clients (investors), top management, development and training centre's owners, process owners (of key processes, accessory processes, subprocesses), management teams (for processes and education centres), executive process teams. Top management in a company and development and training centre's owners present long-term functions, which can achieve continuity and stability in a company's business. Other factors are chosen in accordance with their personal abilities and process demands, and their position is short-termed. This is a way to achieve the balance between the needs of a company itself to have business continuity, and the exterior client's needs for optimal management of each construction process, which is, as a rule, unique for every facility.

Exterior clients present a component part of a company's process organisational structure, since the processes in a company are designed on the basis of the real needs of exterior clients, since exterior clients actively participate in construction process, and since process performances are valuated on the basis of degree of satisfaction of the client's real needs.

Top management in a company is made from management board and director. Director of a company is the owner of all processes and all departments in a company and they are directly responsible for operative conductance of business goals defined by management board.

The owner of the development and training centre in a company in co-ordination with the management team of the development and training centre runs the centre, and presents a more long-term factor than the process owner, giving a company the necessary stability. The owner of the development and training centre names the top management of the company from the experts capable to transfer knowledge and skills, as well as to motivate the employees. Development and training centres solve company's developmental issues and conduct knowledge and skills proficiency of all the employees (students), who will be engaged on the processes being developed in the company, and in development and training centres. The priority for the development and training centre's owner is to enable and stimulate knowledge and skills acquisition, and not to force the employees to advancement. In comparison to sector management in functional or matrix organisational structure, the development and training centre's owner does not manage the resources for process realization. Construction processes are managed by *the process owner* in co-operation with the process management team, while the process executive team performs the working activities. Construction process for an individual exterior client in construction is not of permanent character; it commences with the unsatisfied exterior client's need for building a structure, and it terminates after the need has been satisfied. Therefore, construction processes are changeable in a construction company, and following the fact that construction structures are unique or rarely repeated, each construction process has to be designed separately, from one case to another, which requires adequate changes in process team members, together with the changes of process owner and management team. *Key subprocesses owners* are the owners of adequate construction processes on the proposition of the development and training centre's owner. *Accessory subprocesses owners* names the top management in a company after the proposition of the development and training centre's owner, following the same criteria as for selecting key subprocesses owner. The difference in determining key and accessory subprocesses owners appears with the difference in their nature, since one accessory subprocess can serve several key subprocesses and mainly it remains present longer than key subprocessess. The work of accessory processes owner is estimated on the basis of the degree of satisfying key process needs it serves.

In order to qualitatively manage the complex processes of a large scale, a *process management team* is established, which sublimes large data amounts into the information useful for the owner of the observed process and operatively realises process management. *Management team of the development and training centre* is established if the owner of the centre cannot adequately perform the training of all students in the centre, that is, solve developmental problems appearing in the centre. The task of the centre's management teams, besides data processing, implies student's advancement, which is the main difference in relation to the task of the process management teams.

Process executive team consists of the company's employees with adequate expertise, which are at disposal in the established time period. *Process team* consists of all employees engaged in performing working activities directed towards the process realization in accordance with the plan – process owner, management team and executive team. One employee can be engaged in several parallel processes.

Advancing the proficiency of the employee's knowledge is a permanent process. Education and training of the experts employed in companies with fierce competition must not stop after graduation. Therefore, the attendants at the development and training centres who are organized within process-oriented companies are referred in this paper as *students*, emphasising the continuity in knowledge improvement in practice after knowledge acquisition within formal education. From the company's point of view, all the employees in the company under observation are students whose permanent knowledge and skills improvement in the development and training centres receive the same attention as their performances shown in the processes being performed in the company. For successful realization of mass customization strategy in a construction company, thorough change in approaching the employees is necessary. Construction workers are narrow-specialised, without being directed towards further knowledge and skill development. On the other hand, to apply mass customization strategy instead of the specialized one, universal workers, capable to perform qualitatively a range of similar jobs, are necessary. Depending on the presented performances in *the realization of assigned jobs and professional advancement*, the employees in a company go higher in a company's hierarchy. The improvement can be observed after being appointed to more responsible places in management processes or development and training centres, that is, in their engagement on the processes of greater importance.

4. Process organisational structure model

As a starting point for modelling process organisational structure, a large company is used, which is able to perform all jobs concerning construction, that is, capable for realizing overall large scale construction process. Process organisational structure models for smaller companies are established by joining activities of main factors in the structure. Organisational structure of a construction company can be divided into production and non-production segments. Organisational structure production segment includes the following: exterior clients, production processes owners and teams, accessory production subprocesses owners and team, development and training centre – production, and top management. Organisational structure non-production segment encircles all the other development and training centres. Non-production segment is not a subject for analysis in this paper. Process organisational structure model of a construction company is defined on the level of production and non-production processes, as well as on production subprocesses level.

Process organisational structure of a construction company on the level of production and non-production processes is shown in Figure 1. Following the needs of exterior clients (investors) the key processes – production processes, are established in a process-oriented construction company. Following the needs of the company under observation, accessory processes – non-production processes are established. Production process results are given for usage to the exterior client. Non-production process results are necessary for the functioning of the company under observation and they indirectly contribute to the value created for the exterior client.

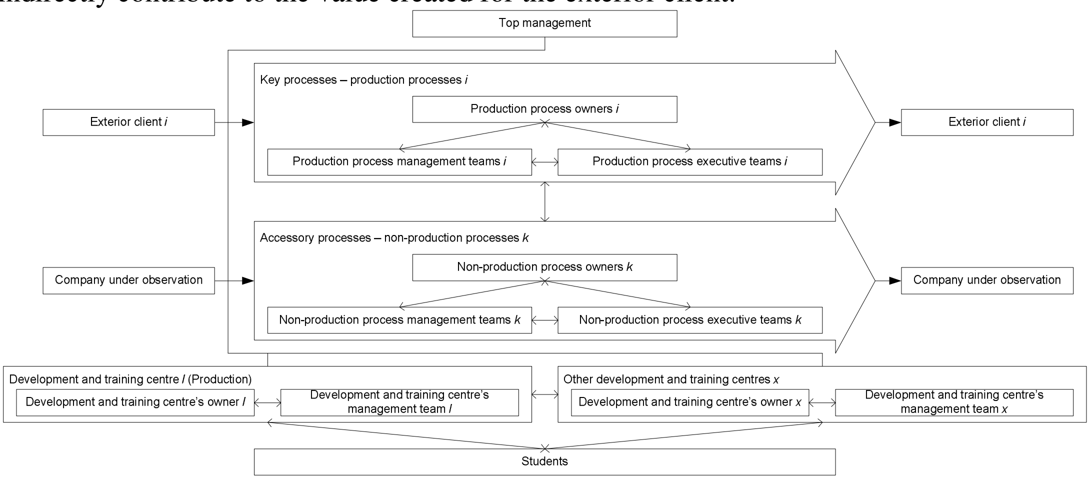

Figure 1. Process organisational structure of a construction company –production and non-production process level

Process organisational structure of a construction company on the level of production subprocesses is presented in Figure 2. Based on interior client's needs (key subprocesses – *i.1.* on-site production; *i.2.* managing construction process results), the following is established in the process-oriented construction company: accessory subprocesses, those being *i.A.* – ensuring information and documentation for the construction process; *i.B.* – ensuring financial resources for construction process; *i.C.* – ensuring construction process quality. Accessory production subprocesses results enable optimal work of key production subprocesses.

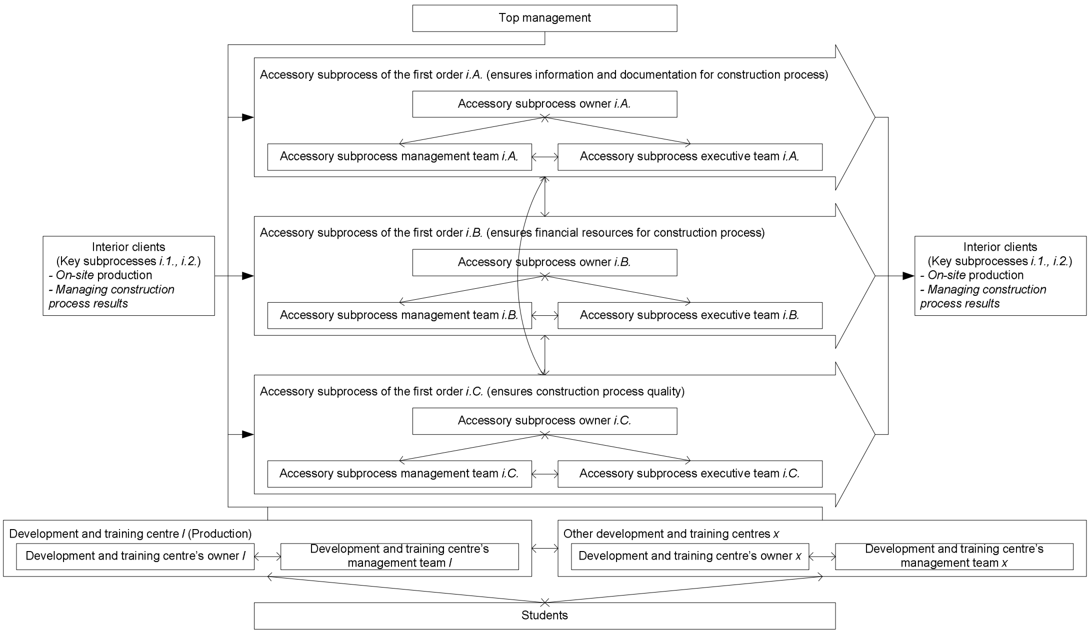

Figure 2. Process organisational structure of a construction company – production subprocesses level

5. Conclusions

In a process-organized construction company, there exists no order duality between sectors and processes, since there are no sectors. Development and training function, performed in the sectors of traditionally organized companies, is taken over by development and training centres. Production function that is completely or partially performed in the sectors of traditionally organized companies is entirely taken over by construction processes. Other functions of traditionally organized companies are completely taken over by non-production processes. Two organisational structure levels characteristic for traditional organisational structures (organisational structure on the level of the entire company and organisational structure on the level of the projects – processes) are united in a unique whole, where the primacy in organisational structure is given to processes. Development and training centres ensure centralized information processing and unique database, improvement of the existing business methods and the development of new ones, increase of knowledge, skills and human resources, competence evaluation and recommendation for human involvement in the development and training centres and in processes. The introduction of development and training centres, proposed in this paper, prevents resource management by sectors themselves (characteristic for functional and matrix organisational structure), prevents employee's specialization for individual process types followed by the loss of knowledge and skills in other fields (characteristic for pure project organisational structure), enables the foundation of a united database in a company and the development of a learning organisation. The determination of process owner, and process management and executive teams, which directly communicate with the client and completely arrange process realization resources, obtain client-orientation of the company and holistic approach to every construction process.

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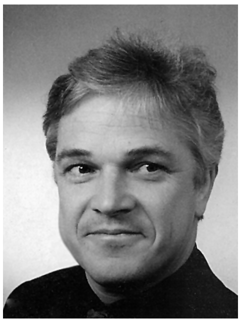
The GRP Shell Structures for The Rabin Center in Tel Aviv



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Keywords: Liquid Architecture, Blob technology, one-off industrialization, 3D composite components, custom components

Abstract

Technical design of roof and façade structures for architecture has accelerated in the last 3 decades. After stretched membrane structures, systemized metal space structures, sophisticated tensegrity structures, glass envelope constructions and load bearing glass structures it is now ‘Liquid Design’, ‘Free Form’ or Blob architecture that sets the trend. This type of architecture is computer-based rather than culture-based. Hence it cannot be regarded as a new style of architecture, as it does not have its roots in philosophy and human behaviour. In a sense it is the result of technology driven interest of architects, having learned the newest generation of 3D design computer software, capable to design complicated virtual 3D buildings that seem like they are realistic. Yet the route to reality is paved with technical experiments to produce the technical 3D components of these ‘Blob’ buildings. Often these components will be 3D-curved, but one-offs in their shape and non-repetitive. So the contradiction is: custom-made components versus the low budgets of the building industry on one hand and developing innovations in order to acquire new affordable technology on the other. The aid of other design professions like aeronautics, ship design and industrial design is necessary in order to develop a new ‘Blob’ technology with the 3D forms, yet fitting within the modest average m^2 budgets of the building industry. Enlarging the traditional integration is necessary in order to develop CAD/CAE, CAM/CAB procedures and special production and geodetic surveying technologies. In this case producing one-off GRP stressed skin sandwich components made it possible to make larger spans and in a arbitrary form in order to become true 3D-roofs. Each initial experiment in the first years of a new type of architecture is an extremely complicated process, but one where design dominates. This article describes the design process of the liquid design roofs for the Rabin Center in Tel Aviv, that owes much to the interdisciplinary design vocabulary from the different designing faculties at the Delft University of Technology.

1. Introduction

Designing and developing structural systems for use in architecture – including the necessary research, but always leading to actual realizations – is the core of our interest. Many of the designs we have made have followed an incremental approach of step-by-step with ever increasing know-how and elevated insight. This started for smaller projects in the Netherlands and lead to applications of increasing scale both in the Netherlands and abroad. The projects are performed in my company Octatube and some in my architects office. The university offers an excellent opportunity for contemplation and to sharpen the mind with scientific design colleagues from different disciplines. Design is to tunnel results of scientific research to society. Close traditional relationships are kept between architecture and civil or structural engineering. When struggling with an alternative technical design for the new cladding of the Atomium of Brussels (dating from 1958), TU Delft's professors Adriaan Beukers and Michel van Tooren (Faculty of Aeronautical Engineering) stated in their inaugural speeches that aeroplanes always leak and condensate [van Tooren 2003, Beukers 2003]. This resulted in only 20% of the joint length. The joints could be detailed as the old-fashioned 'Double Improved Dutch Roof Tiles' with double internal joints that never had to be replaced or maintained. We even applied for a patent.

2. Post-invention Competition & the Continuous Quest for Innovation

One of the ever-recurrent activities in component design and product development is the 'me–too' effect. After the initial product design and developments have resulted in successful applications, this results in professional publications. Then the eternal fate of Octatube is to look for new horizons: either new markets for existing products or new products for existing markets. Luckily a number of 'me-too' competitors in Israel made a mess of their copies, but then again these projects were already lost in the tender stage. For the Hashalom project in Tel Aviv the client changed his mind, withdrew the contract from an Italian consortium and contracted Octatube, who engineered, produced and installed the project in a miraculously short time. Although experimentation on a large distance (Israel compared to The Netherlands) adds to the possibility of a negative outcome, the Rabin Wings are an example of a well-defined experimental component design & development for one specific project. After successful completion this could lead to an entirely world-novel technique of engineering and producing roofs for liquid design buildings.

3. Receipt of Tender Documents

In November 2002 we received tender drawings of a design by architect Moshe Safdie from Boston USA as a part of the Yitzhak Rabin Center in Tel Aviv. The design of the building was an elaboration and extension of a former auxiliary electricity plant near a university campus in order to become a memorial building for the late president Rabin who was murdered in 1995. He was seen as a peace maker and was rewarded the Nobel price for Peace (1994). The tender we received provided for two building parts: the 'Great Hall' and the 'Library'. These two big rooms both have large glass façades facing south towards the valley below. Both hall designs have remarkable and plastically designed roofs that resemble dove wings as a tribute to Rabin. Moshe Safdie is well known since he designed the 'Habitat' of Montreal as a part of the World Exhibition of 1967 when he was a 27 year old architect [Kohn 1996].

We worked for Safdie before on the glass cone of the Samson center in Jerusalem, overlooking a valley adjacent to the old city near the Jaffa Gate. In my eyes he is an almost prophetic designer who designs beautiful interior spaces. Safdie was very satisfied with our alternative design proposals and with the realized accuracy.

The complicated liquid design roofs of the Rabin Center contained in the tender were analysed by ARUP New York to be made of a system of arbitrary open steel profiles with a layer of concrete on top. The specification left the roof cladding up to the contractors. On top of this the architect requested a seamless solution in the roof.

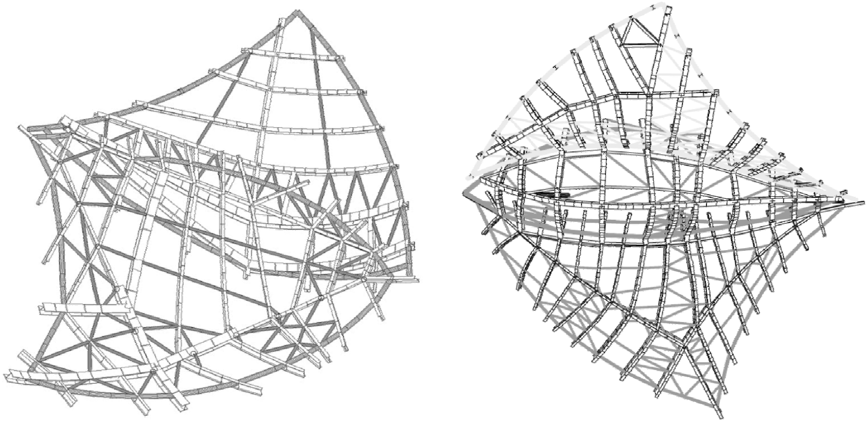

Figure 1. Tender drawings of the steel structure for the Library (left) and the Great Hall (right) made by ARUP.

4. Preparing for Tender

The 'seamless' requirement would make any prefabricated system very difficult and the success would depend entirely on local labour and supervision, which we do not like as a producer of industrial and prefabricated systems. However, the client and his building manager kept on reminding us of the tender date. One year before we had engineered and built the Municipal Floriade pavilion of Asymptote Architects from New York. We had struggled with 3D-aluminum panels of 5mm thickness which were deformed through explosion on negative concrete moulds (based on machined positive polystyrene moulds). This process took place at Exploform in Delft, established on the premises of TNO-research institute because of government regulations concerning the use of explosives. This complete production procedure from engineering drawings up to the finished and installed watertight and coated panel product proved to be a feasible, but also a laborious process to fabricate 3D-curved panels. Although we successfully made this Floriade project, but the m² price was too high for a next project in the building industry (at the edge of recession at that time). We were determined to develop a cheaper system for the next project.

Haiko Dragstra, a very inventive mechanical/electrical engineer with his company Complot BV, Delft, cooperated in this project and came up with the idea to take thinner sheets of aluminium, laminate a foam panel with transverse sleeves and an epoxy laminate behind it in order to make a strong and stiff panel. One step further was to make the complete panel out of two composite skins with a foam core and have the outside skin coated, if needed in an aluminium metallic colour. You do not see the difference form painted aluminium or steel panels in cars. Haiko Dragstra was able to machine foam blocks into any desired form by the machines he built himself. Machining according to CAD data is possible both for the top and bottom layer of the foam. One could subdivide the total surface of the roof into blocks and glue the machined blocks of foam together and provide them with a structural layers of glass-fiber reinforced polyester or epoxy resin of each side.

5. The Principle of the Stressed Skin Sandwich

So in a few brainstorms this was the basic idea: make the roofs as giant surfboards of foam with stressed GRP skins on both sides. The size of the roofs, subdivided into 5 different roof wings was max. Although I did not like the randomness of this design (by architect Maurice Nio) that did not refer to any traditional bus stand form – but rather was a self-secluded form in itself – the very realisation meant a possible step forward in larger sized architectural objects. It was the technology and the resulting technical product that fascinated. Polyproducts was invited to join the tender team of Octatube, as well as Haiko Dragstra. In a month time we organized three successive brainstorms on the product idea, the structural concept and the logistics & pricing. We decided to work out and price our stressed sandwich skin alternative as well as the original tender specification of the steel structure with a non-described, free covering as the variation. The steel deadweight of the steel structure was estimated by ARUP, so a price of the original with cladding variation was easy to make. The cladding we proposed for the original tender design was derived from the mega-sandwich idea, but now in a thinner scale version of 50 to 80 mm thickness, as it only needed to span the space between the steel structure elements (max. 3m).

The budget calculations came out on a level of 2.5 million Euro for the original design with a thin 80 mm thick GRP sandwich cladding instead of concrete. The alternative design with the full load bearing stressed skin sandwich would add up to more than 4 million Euro, largely due to the high estimates of the production of the polyester parts. We argued that the maximum extra costs could not exceed one million Euro, resulting in a total price of 3.5 million Euro. We were sure that any architect would fall in love with the alternative idea of the self-supporting stressed skin sandwich. This was what we faxed to Israel, just in time before the tender closing date, accompanied by a letter explaining the two quoted systems.

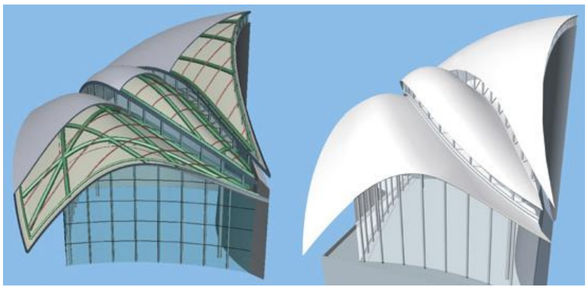

Figure 2. The tubular steel structure with GRP cladding (left) and the GRP sandwich alternative (right)

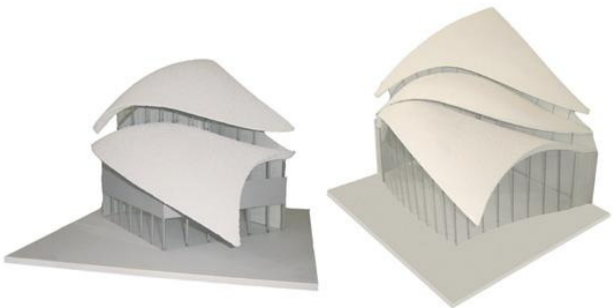

Figure 3. Models for tender of the Library (left) and the Great Hall (right)

6. "An Amazing Solution!"

Only two days after the tender closed we received a telephone call from the local representative architect Avi Halberstadt, speaking on behalf of Moshe Safdie. He gave us the compliment that the architect saw the alternative proposal as "an amazing solution". Halberstadt invited me to come over the Tel Aviv for a meeting, so I could present my ideas to the building commission. At the presentation I showed the polystyrene models that Haiko Dragstra had machined in a demountable model scale 1 to 40. The model showed that the corner details in the design had not yet been accurately designed and that the overall stability was not satisfactory. The design needed a lot of engineering work.
The building commission was astonished after hearing the explanation of the construction and the consequential logistics of the alternative proposal. The big wings would have to be constructed in one of the empty ship building halls in the Netherlands. This was necessary as the wings would have to be turned upside down after application of the stressed skin layer on top in order to apply the lower layer.

We would move the polystyrene machine nearby this production hall and install it adjacent to the assembly area. After gluing the polystyrene blocks, the top skin could be applied. That is, if the polystyrene blocks would form a roof wing in horizontal position. After completion of the GRP top skin, the object had to be turned over and the bottom skin had to be applied. This ship would sail to Tel Aviv and anchor at sea. From this location a giant freight helicopter would lift the roof wings individually from the vessel on a route to the shore, 5km inland during the night, to position the roof wings on the flat open building site. A mobile crane would then swing the roofs on top of the columns. The rest of the construction process would be rather conventional for Octatube. The building commission went into a separate meeting. After one hour of fierce discussions, the outcome was that the tender original with the GRP covering was practically on the average tender price level. On the other hand they noted that the alternative proposal was indeed very attractive from viewpoint of its extremely innovative design and construction, but was priced one million Euro over budget. Knowing the intellectual value of the alternative proposal, it would have been stupid to sell it at a lower price than the tender proposals. Usually technical alternatives are more efficient solutions for the contractors and tend to be lower in price than the original. A more expensive alternative is rare and hence extraordinary. Starting with the highest price and the best technology, may end with a contract at a compromised price. We also loose projects as our competitors can copy our technology after one completed project and execute this without the necessary research and without the higher Dutch labour costs of Octatube. But in the case of the wings, the alternative idea was to become a technical world novelty and Moshe Safdie understood this.

We spoke with Safdie about the Sydney opera House (built in the 1970-ies) and how lucky architect Jørn Utzon would have been if he could have used stiff GRP sandwich panels instead of the heavy concrete shells and ceramic tiles. Even though the realisation of the Opera House meant a major step in the history of structural engineering. My marketing concept had worked.
Safdie appraised his belief in stating that he thought that the idea was unbelievable and never done before to his knowledge. The response of the chairman of the building committee was to come up with different logistics for the GRP sandwich proposal in a manner that the price level could be lowered to 2,5 million Euro. He suggested that it might be possible to transfer the foam machining and the GRP production to Israel in order to reduce costs for shipment and labour at the same time.

8. Rethinking the alternative

Back in Delft we discussed the consequences with our engineers and the external team members. The plan was born in the airplane from Israel to the Netherlands. If we could build the GRP sandwich roofs, it would be a hit on the world market. We were prepared to transfer more labour to Israel in order to reduce costs and talk to new Israeli partners if our current partners would let us down in order to realize this proposal. First we could try to decompose the big wings into transportable components, which we could assemble on-site on a jig and finish the broken GRP layers and give the shells a final top-layer or top-coat. Complot could machine the polystyrene blocks and Polyproducts could set up an Israeli GRP plant in Tel Aviv on the building site. The most likely position to assemble a wing would be in a vertical position. Subsequently, the roof wing could be easily lifted by a mobile crane from between two 20m high scaffolds.

However, machining the polystyrene blocks in Israel seemed very expensive. The subcontractor was not experienced in estimating larger productions than mock-ups. The bottom price of Polyproducts in Israel did not give much hope either. At the same time the usual squeezing of tender prices came about, which forced us to land on another price level altogether. We decided upon a steel space frame with a locally made sandwich panel system on top, forgetting the world novelty of the stressed skin sandwich, just to stay in the race.

Based on this price and on our abilities Moshe Safdie was convinced that Octatube could do the best job. Therefore we received a pre-engineering contract to execute the design development and make material prototypes. We had to deliver further design development and prototypes of the construction of the Great Hall, assuming that the details of the Library would follow those of the Great Hall.

Figure 4. Three prototypes. Stressed membrane (left), GRP cladding to be locally produced (centre), prefab GRP sandwich (right)

9. Redesign & Pre-engineering Contract

In the course of the design development we could redesign the rough contours given to us in the tendering stage by Safdie as a Rhino scan from a material 3D model. We needed to convert this data, since it was unsuitable for engineering. Through analysis of different cross sections of the model and connecting these in fluent lines, a usable 3D model was developed. This software turned out to be an excellent medium for designing the different components. Also, the same software enabled constituent parts to be defined and combined into the total composition (sandwich roof wings, columns and glass façade panels). The design included the reinforced concrete walls, the support plates of the concrete tops for anchoring of the columns, both short and long columns, the façades, the roof wings and the intermediate glass strips.

At the same time a global analysis was made of the structural behaviour of the GRP wings and the steelwork. During this time we worked on two construction types: a steel structure of systemised CHS circular sections, covered with a thin GRP sandwich as the roof covering and the ‘golden’ option of the structural sandwich structure.

Negotiations with the client had resulted in a change of the subcontractor for the polyester work. The price level of Polyproducts remained too high and they were replaced by Holland Composite Industrials (based in Lelystad, NL). They had previously made hulls of motor yachts and sailing yachts in GRP up to 30m length with the vacuum injection method. At the same time, prototypes were made of both construction types: steel structure with local polyester covering and the integral sandwich. Both prototypes were shown to architect Moshe Safdie, together with the first results of the computer work in July 2003. The pre-engineering had indeed resulted in a dramatic reduction of the cost price as we were more and more familiar with the experimental aspects and how to resolve these. The original quotation was reduced to around the original average price level, thanks to the results of the pre-engineering contract. This pre-engineering contract was a wise decision, which we often advocate in the Netherlands (but which we almost never receive) for experimental projects.

10. Final design

The route from redesign and pre-engineering to final design took one year involving 5 to 6 engineers. The architect visited Delft twice in that time to check the progress on the design and the new prototypes that were made on his specific instructions. We had agreed that, in contrast with previous projects there would only be one party involved with computer work, in this case Octatube and the architect could only supervise and give instructions behind the monitor. Moreover, the impulses from the development of the prototypes, the production methods involving moulds and injection production plus the future assembly of the structural seams and the structural behaviour of the total wings, all had a deep impact on the final design and had to be fixed by the responsible contractor, in this case

Octatube. With these revolutionary developments: our 3 adages of “design and build in one hand”, ”the integration of architectonic, structural and industrial design” and “development of new products” are quite right. Respecting the wishes of the architect an intensive design and engineering route was followed, co-ordinating the two co-makers Holland Composites and Solico Engineering as indispensable. During the entire process the design methodology as development for special components, consisting of 3 mains phases: Design Concept, Prototype Development and Production, as published in [Eekhout 2006] were followed quite literally.

11. Final Engineering after Full Contract

The final contract was agreed on the basis of the adapted quotation and the approval of architect Safdie. The final engineering started on the basis of AutoCAD and Mechanical Desk Top and the final analysis incorporating the final production methods of the GRP wings, testing of the connections of the sandwich panels on de-lamination, assembly connections loading deformations, fire resistance and logistics in the Netherlands, the transport in special open containers, assembly on special moulds on the building site, jointing and finishing and hoisting into position. After the design phase of one year the engineering inclusive testing also took one full year.

Due to political change in government from the labor party of Rabin to the Likhoud party of Shamir, all proposals were reviewed by the local government bodies with extreme attention, were many unforeseen and sometimes un necessary problems were detected and had to be neutralized. Many people in Israel would like to see the project unfinished.

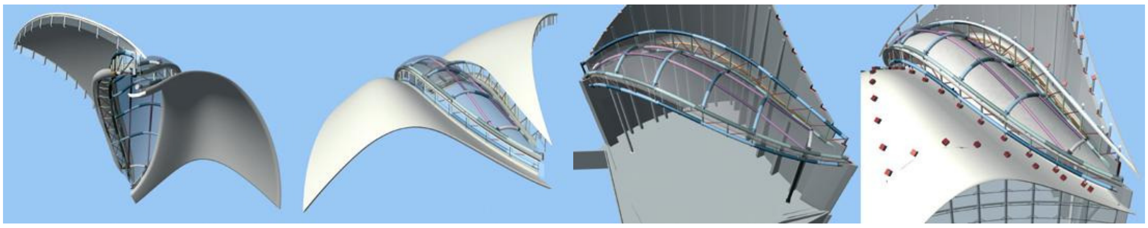

Figure 5. Three roofs of the Great Hall showing the *central body* and the position of steel *inserts* in order to connect the GRP to the *central body* and steel columns (right)

12. Production and Installation in 2005

From January 2005 onwards the production went into operation and the third year of experimental production and assembly started with experimental production of the components on the negative moulds. We started with the smaller roof of the Library. The production technique used in this case has been taken from standard production techniques of producing sailing ship hulls. Holland Composites had produced ships with hull lengths up to 30m. Experimental vacuum injected productions meant a clever step.

The production is very engineering intensive. The foam blocks of polystyrene have been milled accurately by Marin to negative moulds from CAD/CAM files. When the milled moulds arrive at Holland Composites, the surface is covered with a foil. Using vacuum-injection, the glass fibre is impregnated with polyester resin. Since the resulting layer of GRP describes the desired form in the best possible way, this will become the upper layer of the roof. After this layer is hardened, fire-resistant polyurethane blocks are sawn and applied to the roof layer. Between these blocks long glass fibre strips are placed, these will become the *stringers*. This are the structural ribs in the sandwich as a replacement of the original steel structure. The foam blocks are subsequently covered with more glass fibre mats and a foil for the next vacuum-injection. The polyester is also injected between the blocks, making the glass fibre strips GRP *stringers*, thus creating a structural connection between the upper- & lower layer. The foam block makes sure that a counter pressure is present if an unfavorable load was to occur on the roof. Local buckling of the GRP sandwich is prevented by this mean. After production of a roof, they are placed on a temporary structure in order to fit all the segments: the wing-shape becomes clearly visible now. In May 2005 the two wings of the ' Library' are shipped to Israel and arrived on the building site. In the mean time, in the production hall of Octatube , we are busy with the columns the roof rests on. Next to that, these columns also bear the load of the frameless glass façade. Making these columns is mainly a routine job for Octatube, the only difficulty being the connection between the columns and the roof. During the production at Holland composites steel *inserts* are placed within the sandwich. Specially developed ball-and socket-connections on top of the columns are bolted to the *inserts.* Therefore, deformation due to wind loads has no effects to the GRP sandwich. The largest challenge for Octatube proved to be the *central body*: the central part of the "Great Hall". Due to the large forces from the upper and the lower roof wings amongst others, this part of the roof has to cope with, unfortunately steel was the only solution to make this span possible. This resulted in a complex structure of tubular steel, later to be fitted with thin GRP panels. Because accurate 3D rolling is a rather complex procedure, the 2D rolled tubes possessed a greater accuracy. The 3D tubes, mainly situated in the length of the *central body,* at best approaching the desired shape, therefore had to be connected to the accurately shaped 2D tubes. At Holland Composites the entire *central body* was assembled in order to fit the panels. After every panel is fitted, the structure is disassembled en transported to Tel Aviv. In Israel it will be assembled in two parts, hoisted on its position and only later these two parts are connected

After the production of the roof parts of the lower wing of the Library, discrepancies between the theoretical drawings and the practical distortions and tolerances from shrinking of the polyester resin in the vacuum bags were measured. Tolerances because of warping of the negative moulds resulted in unforeseen deformations of the produced GRP components. These components together had to form the ruthless smooth surface of the complete wing in the end.All aspects were approached in an engineering manner: measuring, analysing problems and deducting solutions. Analytical engineering in the best traditions of the TU Delft made the initial amazing, improbable design solution finale a reality. The resulting design is a combination of structural design, with architectural flavour, incorporating the technologies from aeronautics, ship building, industrial design and geodetic surveying and poses an example of multiple innovation of technology, thanks to the involvement of co-makers Octatube International, Holland Composites Industries and Solico Engineering.

Figure 6. Test assembly of the *central body* and lower wing of the Library in Lelystad

13. Assembly & Tolerances

Due to the experimental character of the production process and the unfamiliarity with the consequences of vacuum deformation, we decided to perform a test-assembly or pre-assemblage on the premises of Holland Composites in Lelystad. The fitting took place on a positive steel frame, the shell would therefore be curved upward. One of the conclusions was that we would assemble the shell inversely, so the downward curve would face upward. When a technician would fall, he would not fall in the shell, instead of falling off the shell. Subsequently we would gently turn the shell over with a mobile crane, by means of three temporary hoisting fixtures in the shell. From the pre-assembly we could also draw conclusions regarding the theoretical versus the practical measurements of the individual segments. All the segments were produced on individual foam moulds and they all had their own shrinkage and shrink-direction. Yet together, these segments had to form the unforgiving smooth surface desired by the client and architect.

It was exciting to see if the total fitting of the individual deformed segments would still form a smooth surface when the entire shell would be assembled. In order to acquire this smooth surface we indeed needed the solid frame with clamps in order to force the segments in the desired position. When filling up the seams during assembly a bigger seam meant more fibre (due to the required ratio between fibre and resin) and thus causing a larger weight of the shell.
The connections between the individual segments can be divided in connections in the length and connections in the width of the segments. Both have a structural function. On the side of the segments a rabbet has been made of 220mm with and 15mm depth. In this rabbet a prefabricated reinforcement of 200mm with and 10mm depth (of high density glass fibre meshes that has been vacuum injected with resin) is placed. After the segments of the two wings in Lelystad were fitted on the steel frame, the frame was dismantled and shipped in special containers to Tel Aviv. The build-up in tel Aviv had to took place on the south side of a tall wall of the building. The segments were assembled inversely, measured, touched-up and finished with the structural reinforcement meshes and filler. Next, the shells were turned over and identically finished on the other side.

After the hoisting onto the Library, the shell is positioned on a steel sub-structure, which in its turn rests on a concrete wall with a much larger tolerance difference. Positioning directly from the crane onto the column heads, or *wing-connectors* with its adjustable shaft and connection plates, could only take place accurately by following the theoretical drawings. Until the end theoretical drawings remain the decisive factor. In all phases of engineering, production, assemblage up until the hoisting and positioning theoretical drawings are always present. Building parts are simultaneously produced in locations all over the world. In this project the steel was manufactured in Delft, the glass in Luxembourg and Belgium, the polyester segments in Lelystad and the concrete in Tel Aviv.

14. Conclusion

The resulting design of this contribution shows that building technical design, like architectural design and urban design leads to an integrated process. The result of this process have to be integrated into one technical artefact that satisfies all requirements and gives efficient answers or compromises in all of its life phases, be it conceptual design, material design, detail design, engineering, productions, assembly, installation, loading behaviour, functional use as a building, meaning of the artefact as a building, (even as Architecture) and in its context/surroundings, in its meaning as part of the Monument for the Yitzhak Rabin Museum. At the faculty of Architecture designs usually are wide, integrating many aspects, hopefully all related aspects that designers can think of. The discussion between designers from the 'designing' faculties of Architecture and Industrial design on the one hand and engineers from the 'constructing' faculties on the other hand stem from the integral versus the partial approach. Society expects from scientific designers that perfect solutions for society are developed. These solutions are not only the functional and technical solutions. It may be true that the well-known restrictions in the volume prices of the building industry, as posed by the clients in the building industry, lead to traditional and well known technologies, also the entrance thresholds in the building industry are low and competition is fierce. But sometimes experiments are driven through by persistent designers, willing to wander though the entire experimental development process, able to solve all foreseen and unforeseen problems.

The design, is the result of a combination of architectural design, building technical design, structural design, material design, with major influences from aeronautic and yacht design, from machine engineering (machining moulds) and industrial design, composite production design, assisted by the newest techniques of geodetic surveying to accurately measure the 3D forms in any stage of production, assembly and installation, all smeared by the standard computer design like Maya and Rhinoceros and static analysis programs, including Computational Fluid Dynamics. In all of the successive steps of the process many of the used technologies are applications of theoretical developments done in more fundamental design or science areas. The bold design proposals from this design process challenge the more fundamental partners in the design process to come up with new answers. This process was an illustration of the 'Delft Silicone valley-effect' that the TU Delft as a whole has, with its range of faculties, on the world novelty of the end result. The co-makers Octatube, Holland Composites and Solico joined forces and developed this very experimental project with high economic risks, but with great endeavour and the eternal optimism of designers envisaging a new future in the thrill of this experimental design & build process.

Figure 7-8. Montage of the GRP sandwich roofs in October 2005 (left) and the Great Hall in April 2006

Figure 9. The Yitzhak Rabin Center in April 2006

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A study of the development of IFD building systems by using the Technological Trajectories Mapping Methodology

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KEYWORDS

Industrialisation, Development of IFD building, Technological Trajectory

1 Introduction

The objective of this paper is to delineate the development trajectory of IFD technologies. The paper starts with introducing the main theoretical views regarding innovation and technological regimes (i.e. socio-economic factors as well as technological and scientific principles that jointly shape the direction in which technologies develop). Next the recently proposed quantitative methodology for technological trajectory mapping (TTM) will be introduced. This is followed by an overview of the development of IFD systems in historical perspective as decribed in literature. The results of the application of the TTM methodology to investigate the development trajectory of IFD building systems in the construction industry will be presented thereafter. The paper ends with concluding remarks on the development trajectory of IFD systems by combining the results of the explorative historical and descriptive analyses of the IFD systems development with those of the TTM exercise.

2. Technological Trajectory Mapping Methodology (TTMM)

Over time production processes evolved from home-based hand manufacturing via extensive changes of production characteristics from mechanization, rationalisation, systematization, standardization and automatization in a sequence of era towards large-scale factory production -bringing about a number of economic advantages- thanks to *technological innovations*. Innovations (problem-solving activities by firms) take place in a certain knowledge environment (*Technological Regime(TR):* which are socio-economic factors as well as technological and scientific principles that jointly shape the direction in which technologies develop socio-economic factors as well as technological and scientific principles that jointly shape the direction in which technologies develop. It sets the boundaries and form a constraint to what can be achieved in innovative activities associated with a given set of production activities, and the directions (natural trajectories) along which solutions are likely to be found [Marsili and Verspagen, 2001]. Sectoral asymmetries in industrial innovativeness can be interpreted on the grounds of *differences in TR* [Nelson and Winter (1982); Dosi 1982] Innovations follow a certain *development trajectory*, which is a stream of subsequent innovations as a result of continuous changes in paradigm and regimes.

To get a better understanding of the actual innovation trajectory Verspagen (2005) proposed -similar to Hummon and Doreian (1989)-. to use the *technological trajectory mapping methodology* (TTMM) to analyse the network of patent citations that are interconnected to identify the main stream of technological development. Patents are an indicator of a technological development and provide information on changes in the state of the art of a technology. The TTM methodology is a combination of patent citation analysis and literature study. The patent citation analysis technique is based on the idea that knowledge flows via patent citations and these form a certain network. If a younger patent cites an older patent the idea is that the knowledge of the older patent is utilized by the younger patent.Once the network structure is clear it will be possible to say something about the importance of various individual connections between two patents in the network. The patent citation analysis is a pure analytical method, and consists of three sections; (1) the creation of datasets, (2) the descriptive statistics and (3) the delineation of the patent citation network. A patent citation network is seen as a collection of vertices (patents/ pieces of knowledge) and edges (connections between patents). A patent citation network is represented as a matrix C. in which the element c_{ij} is equal to 1 if patent j cites I and zero otherwise [Verspagen 2005] The goal of the patent citation analysis is "to construct a 'main path' through the network that corresponds to the main flow of ideas in this field" [Hummon and Dorean 1989].A patent citation analysis does not give any further information on other factors that influence the development of a technology, such as the technological regime that either may stimulate or form a possible bottleneck. That is why the patent citation analysis is combined with a literature study on IFD building. The study described in this paper applied this methodology and investigated patent datasets in search for the main streams of technologies and knowledge regarding IFD building systems. Before describing the results of the patent citation analysis the results of a historic analysis of IFD building systems based on a literature study will be described.

3. Industrialised Flexible and demountable IFD building systems:

In the course of time building construction evolved from the application of simple mechanization on site via a further rationalisation and systematization of the construction process towards the prefabrication, standardisation, pre-assembly and modularisation of parts of the building, moving a large part of the building process from the site to the factory. Prefabrication reduces time-consuming on-site activities and increases on-site productivity; it has the possibility to contribute to a relatively low cost and standard quality of output and it eliminates some of the burdens of construction projects such as suboptimal site conditions. Prefabrication as such existed already in the ancient world (Egypt, Greece, Italy), where buildings were erected with prefabricated components made of stone [Warszawski 1990]. Industrialised building was pushed ahead after World War II by governments in Western Europe and Japan who acted as large clients faced with an extensive need for housing for millions of people in their countries.Industrialised building moved further forward through s*tandardisation* and m*odularisation. S*tandardized components -mass-produced in highly automated and strictly quality controlled production facilities to exacting physical properties and dimensions --fit together in a modular system of design, providing multiple preassembled units. A major problem arising from modularisation is in the connection of units of different modular dimensions. [Ricketts 2005]. The connection on site of the units is a distinct challenge. It is in this respect that efforts have been dedicated to develop innovative technological solutions such as specific joints and particular materials that allows the right fixation and connection of different prefabricated modular building elements. Prefabrication is often associated with mass production of buildings and thereby accused to neglect the clients' desire for individuality. Above that -in to today's ever-changing world, in which businesses and organizations understand the importance of being flexible, multifunctional and adaptable- clients of some types of buildings -such as office and health care buildings - expect that the buildings they occupy are flexible and adaptable too. Another aspect is that in general the life time of a building is expected to be approximately 60 years before the decrease of the functional, economical, sometimes socio-cultural value and in case maintenance is not up to standard also the technical value sets in. The life cycle of a building can be prolonged by thoughtful planning and design and engineering in such a way that a building can become highly versatile and adaptable to meet the client's needs for the present and the future. It all depends on the cost-effectiveness to maintain and up-grading the main structure and its infill whether the building is knocked down and disposed as waste material. An increased social pressure to improve the environmental sustainability of the generally rather poluting construction operations as well as government policies- legislation and subsidies- stimulated thinking about more sustainable building in a number of countries. It is in this perspective that the adaptability and sustainability aspect of buildings came into the picture. Solutions were sought in the development of *IFD building systems*. It should be noted however that these efforts are rather economically and practically driven than out of care for the environment.

From the above can be learned that the *Technological Regime* in which the construction industry is operating –the socio-economic environment with its rules, regulations, expectations and requirements- have changed, setting new boundaries for technological innovations. However IFD technologies are still waiting for a real breakthrough. The market demand for IFD buildings is most often limited to a demand for temporary buildings or modules. The client's perception of these buildings is that of a lower quality and inferior compared to traditionally built ones although the outside of the building may even look the same.[Hermans 1997]. The present legal instruments to implement policy also do not work in favor of IFD in many countries. The legislation for IFD building is the same as for traditional building but IFD buildings are classified as temporary [Gurchom 2002; Hermans et all 1997; http://www.ifd.nl 2006] National policies, although meant to stimulate IFD building, do not work out as desired in a number of cases –e.g. the Netherlands- due to a lack of communication between the construction professionals and policy makers.[Gurchom 2002] Design and building principles changed slowly. Moreover the introduction of prefabrication in the construction process tends to make the total process more complex. The requirements on dimensional tolerances are more severe. It requires more co-operation and co-ordination within the design and also construction processes should change including more transparent forms of planning cooperation and new forms of communication and/or exchange between planners and builders. [Koskela et all 2000]. A real move towards IFD building requires a regime shift in the construction industry. [Egmond 2005].

4 Empirical findings

The TTMM has been applied for the analysis of the technological "trajectories" of IFD systems'The US Patent and Trademark Office (USPTO) database (online full-text patents back to 1976) was used to search for a *set of patents* on IFD technologies by means of different queries with a number of keywords.The goal was to get between 1000 and 1500 valid patents, which are needed for the rest of the research. Two separate datasets were constructed. The first search with queries led to 1498 hits on the USPTO website which showed that the most patents belong to patent class 52/79.1 and its subclasses. Class 52/79 includes preassembled sub-enclosure or substructure section(s) of a unit or building [USPTO 2006]. Keywords used were prefab; prefabricated; pre-manufactured;temporary; modular; standardized; elements; modules; structures; building; wall; floor; roof. We refined this database by including other keywords such as industrial, window, joint, door, and excluding electrical. This led to 1150 hits. Next we searched for the citations that these patents make to other patents, by using the dataset of the National Bureau of Economic Research (NBER) with data between 1976 and 2002.

The 1150 patents of the refined query dataset appeared to be divided in 560 patent subclasses, which indicate that the IFD technology includes several types of technology. Most of these classes only contained 1 patent. There is a large distribution of the classes with more than 4 patents. The company analysis resulted in 605 different companies holding patents in the dataset. The company that holds the most patents only has 10 IFD technology patents. The conclusion is that no company is a real leading innovating company regarding IFD technologies and seemingly companies are not collaborating too. These findings reflect the fragmented character of the construction industry.

By using the Search Path Link Count (SPLC) method, the main paths of the development trajectory of a patented technology in the patent network was calculated. [Verspagen 2005]. The top main paths in the network are supposed to indicate the most important and interconnected patents and their development trajectory. To be able to distinguish which type of technology is mainly patented within the main development trajectory and which level of technological complexity is reflected in the patents, we have classified IFD technologies based on different levels of complexity. (1). *Construction components* -the parts used to create different elements, like joints or the frames in a wall-element; *(2) Elements* - the parts used to create a module or a building.(e.g. a panel, a partition wall, a roof or floor); *(3) Modules*, - a unit, a module or a building; (4) *A process* for making the components, elements or modules; (5) *Other or non-relevant* patents.

The *main paths of both datasets* represent only a rather low percentage of the total datasets (218 patents :15% in the 52-79 dataset and 64 patents :5% in the refined dataset). This means that there are no real strong interconnetions between the patents. The large fragmentation in the building sector could be due to that different producers of building products create their own technological trajectory

with their own technological innovations which are not compatible with other technologies of other producers and that these technologies are not based on older technologies from different companies. A closer look at the type of patented technology that is included in the first main path of the class 52-79 dataset shows that 54% of the patents in this 1st main path are those for building elements and 33% for modules. In the *2nd, 3rd* and *4th* main paths –all together 164 patents- most of the patents are for modules. With regard to the refined query dataset the 1st main path represented 5% of the patents of which the majority are patents for module technologies, 19% patents for building elements and 16% for process technologies. The 2nd and 3rd main path for this dataset however include for more than 50% patents for building elements.
The first top main path of the 52-79 dataset includes 20 patents for innovative modules and buildings. The innovative technologies developed from a general technology of modular and prefabricated building systems, towards more specified patents which explain a more detailed and specific version of the technology. The second top main path includes 13 patents. This trajectory of patents develops from basic patents – such as a method of building construction using synthetic foam material and a Prefabricated building module and modular construction method for the module - to more specific patents for modular building technologies such as a Standardized portable housing unit, Mobile home and a Portable refrigerated storage unit.
The *top main path of the refined query data set* consists of in total 11 patents representing mainly patents for building elements such as wall systems to separate spaces into different parts in several ways highly reflecting the flexibility issue of IFDbuilding. The patented technologies include those in the following sequence: a Wall system; Partitioning system; Office paneling system; Space divider system; Display wall formed of readily attachable and detachable panels; Work space management system; Free standing modular furniture and wall system; Wall panel system; Clean room wall system. Compared to top main paths in other sectors the top main paths for IFD technologies are relatively short.

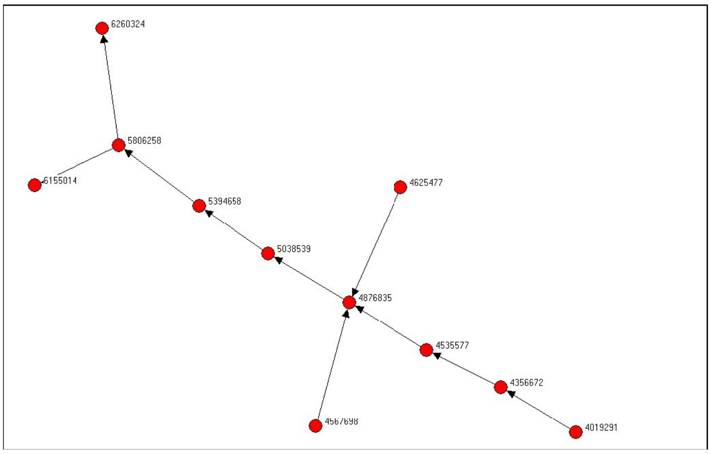

Figure 1. Top main path refined query dataset

The development trajectory of IFD building technologies over time appeared to proceed rather slowly. In contrast to developments in other sectors, such as the ICT sector for example only once a year and sometimes even only once every two years a new patent is added to the trajectory. Still one can notice a learning curve in the development trajectory of the patented technologies. A most significant aspect is that after 1998 the development trajectory shifts towards another dominant direction and even introduces a new top main path in the year 2002.

5. Conclusions

What could be learned from the study with the TTM methodology is that indeed patented technologies are based on knowledge and insights gained from foregoing innovations so there is a certain learning curve noticable also in construction. However this is in contrast to the trajectories in other sectors obviously rather limited. There certainly is no organized technological development of IFD technologies. The TTM analysis showed that there is an absence of one or even a set of

companies that can be seen as the leading innovating ones in the field of IFD technologies. There is only a relatively small number of top main paths, which on their turn are relatively short. This indicates the variety in different types of IFD technologies that are developed. If any, the focus in the innovative efforts can be seen in the development of different building elements inlcuding the materials to be used in IFD building systems as well as in the development of modular building systems. So there is no clear single direction in which the IFD technologies are developed. The characteristics of the technological trajectory confirm the rather diffuse character of the construction industry in which many different actors work on a diversity of innovations regarding IFD building systems. Despite the fact that IFD technologies have gained more interest among construction professionals being aware of the advantages of industrialised building and the social pressure to achieve more sustainable construction practices whilst meeting the customer's demand for higher quality at lower costs, the concept of IFD technologies is still rather young and waits for a real breakthrough. A number of bottlemecks to be found in the Technological Regime of the Construction Industry –as mentioned in section 3 of this paper- are due to this.
The technological trajectory methodology that is applied gives a useful though no comprehensive understanding of the mechanisms at work regarding the development and adoption of IFD building systems. A combination of historic and descriptive analyses by using the evoluationary network theories gives a better understanding and opportunity to utilize the potential offered by innovative IFD building systems to push the construction industry performance into the desired direction.

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Hybrid Systems in Light Steel and Modular Construction

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KEYWORDS

Light steel; housing; modular; acoustics

ABSTRACT

The use of light steel framing as a method of house construction has increased significantly throughout Europe in recent years. The steel industry has supported an intensive technical development, and housing systems are now available, which are highly adaptable in form and use. For example, in the UK, the market share for steel has reached approximately 5% of current house and apartment building. This paper describes the general forms of construction that have been adopted, and the levels of performance that are achieved. Recent developments associated with the use of light steel modules and steel frames in medium-rise residential buildings are also presented.

1. Introduction

Light steel framed housing comprises walls and floors fabricated from galvanised C, Sigma or similar cold formed sections of 1.2 to 3.2 mm thickness. In the UK, approximately 5000 houses and apartments have so far been constructed and some success is being experienced in France, Netherlands, Sweden and Finland. In housing, the most common form of light steel construction involves prefabricated wall panels and elemental floors (where joists are installed as individual elements). This is known as platform construction. Construction of the second floor begins using the floor as a working platform.

2. Panelised systems

At Oxford Brookes University, a demonstration building was designed using the Corus 'Surebuild' system of light steel framing, and gave an opportunity for long term monitoring of its performance. (The completed building is shown in Fig 1).

Figure 1. Oxford Brookes demonstration building

Figure 2. Testing of light steel frame

The demonstration building includes habitable open roof spaces, a high level of thermal insulation, relocatable internal walls, light versatile foundations, and is designed for rapid erection. The building has approximately 275m^2 of usable floor area and consists of a two-storey house attached to a three-storey studio apartment building. The three-storey portion of the building includes three studio bedrooms and shared kitchen, plus a self-contained two person flat in the open roof space. The semi-detached house is self-contained and is typical of modern house construction in the UK. It has three bedrooms plus a habitable roof space that may be used as an office, playroom or fourth bedroom.

The framework comprises prefabricated storey-high wall panels constructed using 75mm deep steel studs, and floors constructed using 150mm deep joists. The platform construction uses the walls and floors to form a stable box. The roof members comprise 'C' shaped sections in an attic truss configuration on the two-story side of the building and purlins spanning between flank walls on the three-storey side of the building.

Before construction, the structural performance of the light steel framing was verified by an extensive series of full-scale tests under vertical and horizontal loads carried out by Corus in South Wales. The light steel framework was tested under horizontal load firstly without, and then with its brickwork cladding. A test on the light steel framework is illustrated in Fig 2.

The measured U-value of the wall was 0.216 W/m^{2}K, which compares well with the theoretically calculated value of 0.2 W/m^{2}K. The U-value compares very favourably current recommended best practice in the UK. The acoustic insulation of the walls exceeds the requirements of the current UK Building Regulations- see Table 1.

Oxford Brookes University demonstration building (dB)	D_{nTw}	C_{tr}	$D_{nTw} + C_{tr}$
Airborne sound insulation of wall (D_{nTw})	65	-9	56
Airborne sound insulation of floor (D_{nTw})	57	-8	49
	L_{nTw}	$D_{nTw} + C_i$	
Impact sound transmission of floor (L_{nTw})	54	54	

Table 1: Summary of the acoustic performance of the demonstration building

3. Modular housing systems

The Murray Grove housing project in Hackney, London was designed by architects Cartwright Pickard for the Peabody Trust, a major housing association in the UK. The client wished to procure a building that was architecturally interesting, of a high and reliable quality, and which could be constructed quickly. A modular approach was therefore adopted and the design was developed together with manufacturers, Yorkon.

The building is 5 stories high and is located on a tight corner site. The majority of the accommodation was constructed using 3.2m wide modules. Two modules were used for one-bedroom flats and three modules for two bedroom flats. Other building elements including the cylindrical stair tower, external access balconies and monopitch roof, were all prefabricated. Stability to the access ways was provided by external bracing. The external façade to the street consists of terracotta tiles, whilst the façade to the courtyard behind the building incorporates steel balconies to all of the apartments.

Figure 3. Murray Grove module installation

Figure 4. Murray Grove courtyard elevation

Modular construction has also beginning to be used for refurbishment projects. A recent project for student accommodation in Plymouth carried out by a specialist key worker accommodation provider 'Unite', and has involved placing 28 modular bedrooms on the roof of a 4 storey former office building. The modules were fully fitted out and were fully serviced before delivery to site. They were constructed with open sides as in Fig 5. The extension was clad using a proprietary curtain walling system.

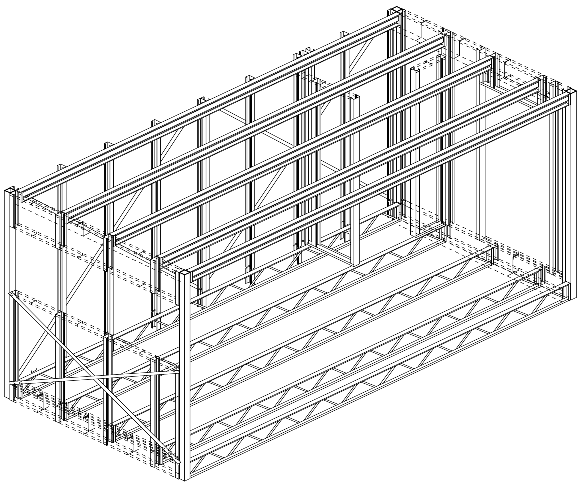

Figure 5. Open-sided module used in the roof-top extension

The modules comprised 75mm deep x 1.6 mm wall studs and 225mm deep lattice joists. Square hollow sections were introduced as corner posts on the front façade so that windows could extend over the module width. The open-sided modules were constructed so that adjacent modules could be placed together to minimise the internal wall thickness and meet tight internal planning requirements. Open-sided modules lead to flexible space use Installation of the modules took only 3 days.

4. Adaptable and sustainable construction

A recent ECSC demonstration project has resulted in 5 housing and residential buildings that are designed for rapid construction and excellent performance characteristics. In the UK project, a 'hybrid' panel and modular building was constructed in which the toilet-bedrooms, kitchens and stairs were all constructed as modules. The load bearing walls and floors were constructed as 2D-elements. The completed prototype building is illustrated in Fig 6.

Figure 6. 'Hybrid' modular and panel building

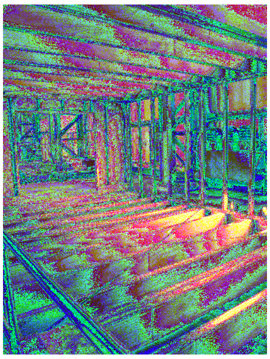

Figure 7. Plyweb beam

The floor system consists of a plyweb beam that comprises C section flanges and two plywood webs. These 320 mm deep beams span 5.25 m between load-bearing walls and internal walls could be positioned to suit user's requirements. These beams were subject to extreme testing which showed a load capacity in excess of 4 kN/m^2. They also possess excellent acoustic and thermal insulation properties, as established from on-site tests.

Similar demonstration projects have been completed in Finland, Sweden, Germany, France and Italy. In principle, this 'hybrid' technology could be used to create a new way of building for urban locations, as illustrated in Fig 8.

Figure 8. Urban street-scape created by mixed use of panels and modules (courtesy HTA Architects, London)

5. Medium-rise buildings

The market for steel in 4-8 storey residential buildings is also growing and has reached 20% of the apartment sector, which is itself close to 30% of current house building in the UK. Figure 9 shows a recent example of steel using *Slimdek*, which achieves the advantage of a flat floor of minimum depth which means that walls can be positioned without concern for beam positions. Often square hollow section (SHS) columns of not more than 200 mm are used, in order to fit within separating walls. Light steel infill walls and separating walls are used in all forms of construction, as they are lightweight and can be installed rapidly, and are re-locatable, leading to future adaptability.

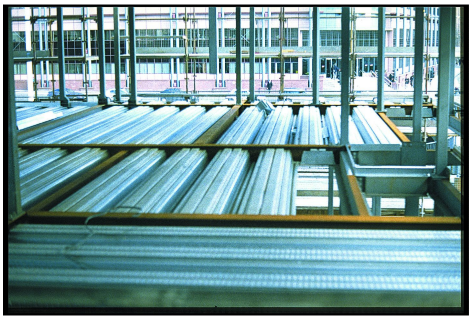

Figure 9. *Slimdek* construction in an apartment building (before concreting)

The world's largest modular building was constructed in Manchester in 2002 and consists of over 1000 modules, as shown in Fig 11. Stability is provided by braced steel cores located at the corner of the building. The modules have pre-attached cladding and can be relocated in the future.

Figure 10: 9-storey modular building in Manchester

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Industrialization processes in Swiss SMEs

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KEYWORDS

Industrialization, SME, standardization, systematization, process orientation.

1 Introduction

Since the 1990s, the construction industry has been undergoing fundamental structural change, which is perceived externally through bankruptcies and poor share prices of many companies [Hofmann 1999]. After many years of stagnating or declining demand, the symptoms of a perfect market with a large number of homorphous demands and virtually randomly interchangeable suppliers are impacting the Swiss structural engineering market, in spite of the fact that demand is meanwhile picking up again. Price competition is extremely fierce and involves bidding rounds that generate inadequate margins or insufficient profits to allow many companies to ensure their survival over the long term [Girmscheid 2005a].

The offering price is nowadays one of the principal criteria for awarding construction contracts. The less specialist expertise that is needed for the execution of the works, the more important the price becomes. In residential construction, where this holds particularly true, the price of a service is frequently the only criterion for selecting a supplier, given the lack of any other alternatives. In fact, the pricing structure generally bears very little resemblance to the actual cost structure. It is the market, and not internal cost calculations, that determines the price [Girmscheid 2006]. In order to win a construction contract, competitors underbid each other in the bidding process or bidding rounds although the financial scope within the industry is unbelievably narrow, with margins averaging between 2 % and 3 % [Girmscheid 2005a].

As illustrated by Boenert and Bloemeke [2003] and, in similar form, by Winch and Carr [2001], more than one third of all costs incurred across the entire construction process do not add value and are, for the most part, avoidable (Fig. 1). By introducing and optimizing planning, logistics and control processes, such calculation examples could soon become a thing of the past, if existing savings potential were to be rigorously exploited.

Corporate goals, such as customer satisfaction, low manufacturing costs, short construction times and high levels of quality, are irrespective of the size of a company. Success depends purely on selecting the right method of implementation, which must be tailored to each individual company. It is not just production requirements that need to be improved – it is important to establish a systematic interaction among planning and construction production that incorporates marketing considerations and marketing strategies [Girmscheid 2006].

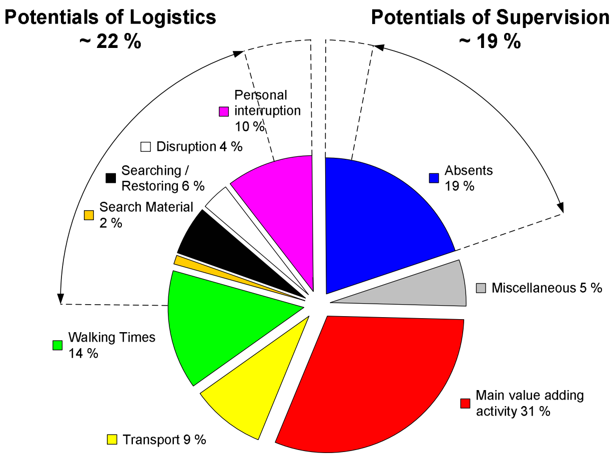

Figure 1. Potential means of reducing costs.

2 Research methodology

The hermeneutic spiral for this research project, which was developed within the framework of the theoretic-analytical constructivist research approach [Girmscheid 2004], is comprised of the following sources of findings:

- business management analysis of the individual processes
- qualitative data collation from problem-focused, semi-structured interviews
- evaluation of the interviews and findings from literature
- logical-deductive structuring of alternative actions arising from the evaluations
- organization of workshops to verify and structure operative solution clusters from the alternative actions

The interpretavistic constructivist research paradigm developed by von Glasersfeld [1987] is applied to constructing socio-technical systems for processes and alternative actions based on input-output relationships. The solution clusters and alternative actions or measures will be validated theory-driven logically [Girmscheid 2004] and empirically [Stier 1999] using sources of literature and interactive workshops with the companies involved, and tested for suitability. The concluding quality test will be performed by triangulating the results according to Yin [2003], on the basis of literature, qualitative surveys and practical realizability tests.

In order to achieve the resource oriented SME goals, conceptual operative industrialization concepts were analyzed, heuristically developed and validated for realizability in a research project conducted by SFIT Zurich in cooperation with the Swiss Association of Construction Entrepreneurs (SBV) [Bärthel 2002]. The project focused specifically on SME production, where the material generic characteristics are rationalization through standardization, systematization, flexibilization and mechanization / automation, according to Girmscheid [2005b].

3 Possible solutions for SMEs

To ensure their future, SMEs must focus on a resource oriented improvement of their profit situation, in addition to their strategic, market oriented positioning and target oriented marketing. Since a general increase in the price level is equally as unlikely as any release of the tension in the construction market, this improvement can and must be achieved by exploiting the following success potentials:

- by reducing costs against the background of price levels that are stagnating overall or even continuing to decline
- by expanding their product range towards system provision by including activities that extend beyond actual construction
- by improving the price structure with the aid of customer oriented services that are not exposed to direct price competition but which make the bid more attractive by increasing the customer benefit

Ultimately, it is the property developers as the construction industry's clients who decide whether a range of offered services is successful or not, which is why any attempts by a company to improve its position must focus on the market or customer interests. Irrespective of the optimal strategic positioning, it is above all the SMEs, which offer virtually interchangeable market services in construction production, which must strive to achieve maximum cost efficiency.

Girmscheid [2006] defines construction industrialization generally as the "rationalization of work processes to achieve cost efficiency, and improved productivity and quality". Transposed to SMEs in the construction industry, this means:

- Market orientation
  - Focus on specific market segments
  - Supra-regional specialization in specific work areas
- Resource orientation
  - Interaction among planning, work preparation and construction delivery
  - Optimized processes and an optimized organizational structure
  - The use of prefabricated components and variable construction modules
  - Standardization of construction processes and the building materials used
  - Mechanization and automatization of processes

Fig. 2 shows the structure of construction industrialization in different industrialization paradigms, together with the relevant marketing strategies and possible areas of application. Realization is dependent on cooperation among planners and specialist companies, which necessitates new project delivery and business models [Girmscheid 2006].

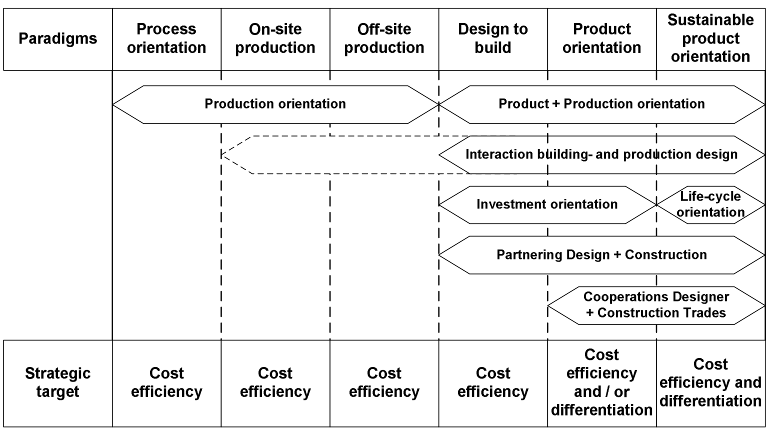

Figure 2. Industrialization paradigms and their relevant strategies.

3.1 Operative solutions

Since the combination of strategic and operative approaches is the only way to sustainably increase competitive ability over the long term, the following operative solution clusters were logically derived, in addition to the strategic solutions (Fig. 3):

- Standardization of materials, components and construction methods
- Systematization and rationalization of the integrative interactive delivery and production planning processes
- Rationalization of the deployment of equipment by using "all-round equipment" to increase the level of utilization
- Rationalization by using standardized information technologies for internal and external data exchange
- Rationalization and standardization through prefabricating components

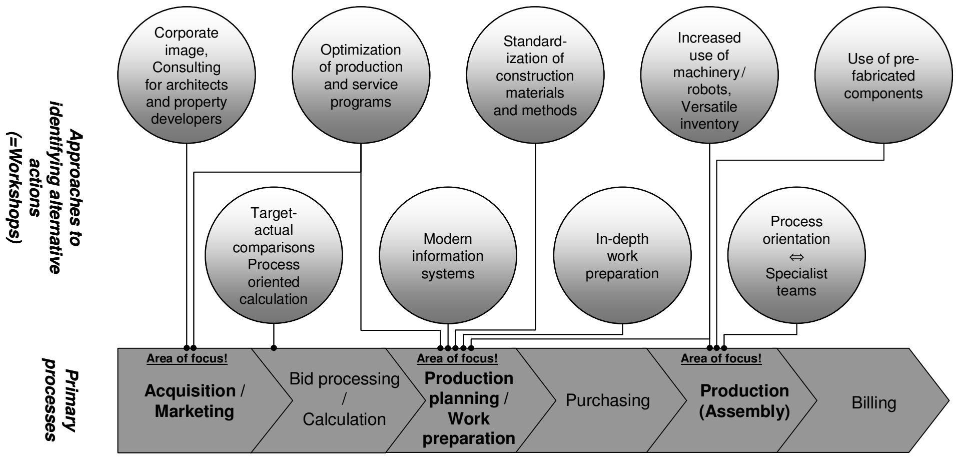

Figure 3. Possible alternative actions and their allocation to the primary processes in the value creation chain.

Various alternative actions were derived from workshops with industrial partners to develop a qualitative structure and implementation of the individual solution clusters. The logical approaches to possible solution clusters and alternative actions emerged, on the one hand, from analyses of small series and single order production in the field of mechanical and plant engineering that focus on the issues of diversity and the associated complexity costs. Further approached were based on an observation of the manufacturing and logistics processes (including the flow of information) in the construction industry [Schweizerischer Baumeisterverband (Hrsg.) 2002]. The approaches that were determined, together with their allocation to the primary processes of the value creation chain, are shown in Fig. 3.

3.2 Alternative actions for industrializing SMEs

Based on the potential solution clusters for industrializing SMEs (Fig. 3), which were derived empirically and logically, related alternative actions and measures based thereon were theoretic-analytically developed and qualitatively tested for realizability by industrial partners. The integrated approaches can be read in Bärthel [2002], this publication focuses on presenting the following solution clusters and alternative actions as examples:

- Rationalization through systematization and standardization of construction materials and prefabricated components
- Rationalization through flexibilization of inventory deployment using "all-round" equipment and construction aids

Building materials and prefabricated components:

Individually designed structures that are planned and built for the same purpose (e.g. homes) are often made from the same building materials and using similar construction processes. This offers a possibility of standardizing within the company those building materials that do not have an architectural impact. In the case of the shell, in particular, generally only technical functions need to be ensured, which gives SMEs certain freedom to decide which building materials to use, thus offering potential for standardization. The following practical examples highlight the approach to rationalization:

- Use of steel fibre reinforced concrete in floor slabs (Fig. 4) as an example of rationalization through the standardization and systematization of building materials. Possibilities of rationalization arise from the elimination of reinforcement works on the building site and a thinner slab, compared with conventional mesh reinforcement.

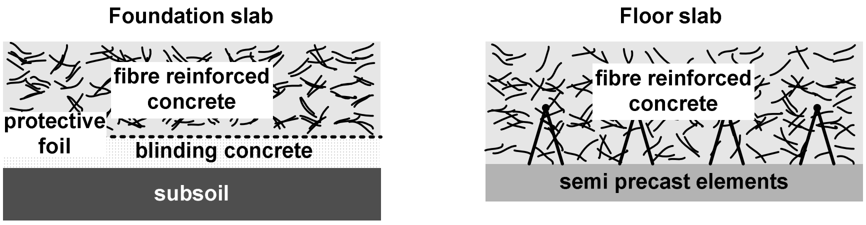

Figure 4. Rationalization through the use of standardized building materials (e.g. use of steel fibre reinforced concrete in foundation and floor slabs) and prefabricated components (e.g. semi precast floor slab elements)

- Use of hollow reinforced concrete walls in cellars as an example of rationalization through the use of prefabricated components (Fig. 5). Potential rationalization arises from the elimination of placing reinforcement on site and formworks.
- Use of semi precast construction systems with steel fibre reinforced top layers as an example for rationalization through combining standardized building materials with semi precast floor slab elements (Fig. 4 and Fig. 5), where the placing of reinforcement on site and formworks on the building site can also be eliminated.

Figure 5. Rationalization through the use of prefabricated components (e.g. hollow reinforced concrete walls and semi precast elements)

Equipment and construction aids:

Construction works can be performed using various construction methods and, in consequence, also using various construction aids and equipment. Generally speaking, the degree of specialization of the material and equipment relates analogously to the value adding potential, but is inversely proportionate to the degree of utilization. In order to ensure a high degree of utilization and, in consequence, a streamlined construction delivery across several projects, the existing construction aids and equipment must therefore be as flexible as possible. There are two basic ways of achieving this flexibility:

- Use of "all-round inventory", which generally does not offer optimal project-specific value added, given its high degree of flexibility, but which does guarantee a high degree of utilization and, as such, a rationalization of inventory deployment as a result of its extensive possibilities of application. One example would be the use of telescopic loaders that can be used both for loading and unloading, and for earthworks or transportation.
- Outsourcing construction aids and equipment and renting them on a project-specific basis. In this case, the system offering optimal value added is chosen and used for each project, whilst at the same time not tying up the SME's capital over the long term. One example for project-specific rental would be the use of rented formwork, which could be chosen for a specific project, adapted where necessary, and rented for the duration of construction.

Generally speaking, rationalization must be prepared using target oriented, systematic and standardized planning and work preparation.

The entirety of the individually developed measures was subsequently summarized in decision-making diagrams and check lists [Schweizerischer Baumeisterverband (Hrsg.) 2002], where the various statements relating to the measures and their implementation could be evaluated on a company-specific basis. An evaluation of the decision-making diagrams and check lists also enables statements to be made relating to cost saving potential arising for the individual business areas of a company from industrial construction.

4 Conclusion

Industrial construction offers optimal prerequisites for improving efficiency and strengthening earnings power, both in large and small companies. The main problems are primarily issues of planning, logistics and standardized processes, and less of a technical nature. Success depends, above all, on the attitude of the company's management, since customer orientation also means product orientation, and necessitates a willingness to change on the part of all players.

Any strategy aimed at industrializing construction must include approaches to overcoming the fragmentation of construction and planning works. The starting point for industrialization lies in a three-fold change

- of the sequential independent processes of preparing work drawings and production planning to form an interactive integrative planning approach aimed at "design to build"
- of construction production planning and logistics, which are scarcely or not at all systematized, to form a generally standardized systematic process to increase productivity (value adding)
- of improving planned construction production and logistics by introducing a continuous improvement process with a simple controlling mechanism to ensure systematic target management

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Two-dimensional cooperation network for system precast construction

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KEYWORDS

Industrialization, prefabrication, cooperation, network, system service provision

PAPER

1 Introduction

Due to the structural change and the globalization of the construction markets [Russig et al. 1996] in reaction to the tense earnings situation of the construction industry, at both German-speaking and international level, both construction engineering practice and research are striving to industrialize construction production processes ([Girmscheid 2005a], [Bärthel 2002]). In the field of building construction, these efforts at industrialization are causing a renaissance of precast reinforced concrete elements, modules and composite systems [Zürcher Hochschule Winterthur (Hrsg.) 2002], based, above all, on improved materials technology ([Jachmich 2001]) and efficient production processes ([Girmscheid 2000], [Ballard et al. 2003]). Although the method of construction with precast elements is used to focus primarily on the low-cost and rapid "serial production" of affordable housing ([Bongers 1998]), the potential for manufacturing individual buildings with individual shapes and functions and made from individual materials but using precast elements, modules and composite systems has meanwhile been recognized ([SwissBeton (Hrsg.) 2004]). Because of the lack of established and suitable market instruments, the industrialization potential of prefabrication has so far not been sufficiently exploited in practice.

The construction industry is increasingly seeing the opportunities offered by partnerships and cooperations as a means of synergetically exploiting not only tangible, but also intangible resources, in a competitive market [Girmscheid 2005b]. The principal architecture of such partnerships and cooperations for forming strategic networks [Sydow 1993], enhancing each company's own specific competencies [Friedli 2000] and the utilization of marketing and sales synergies ([Maier 2002]) are part of the research being conducted by neighboring disciplines, such as economics or business management.

Cooperative distribution systems as an instrument of growth for SMEs have scarcely been able to gain a foothold in neither the national nor international construction industry so far [Watson and Kirby 2000], since the idea of selling construction services right through to the client will only generally gain ground once customer orientation has been established. The ancillary construction trades are showing first signs of cooperative sales forms [Dornach 2004]. In this case the ambivalently structured construction market with its strongly local or in other cases supra-regional markets is used for cooperative networks to distribute products and services efficiently and profitably.

Embedded into the presented scientific environment, the following issues have been identified:

1. Outsourcing services that are not part of the construction company's core competencies is increasing in the construction industry. The research examines the reasons for the lack of a suitable form of cooperation that transfers the diametrical interests of the partners into a win-win situation.
2. In the construction industry, there is only a latent motivation to cooperate. The research takes the differing expectations of potential partners into consideration when developing suitable incentive systems that would allow them to perceive acting in cooperation as a win-win situation.
3. Based on the findings of the aforementioned issues, the two-dimensional cooperation structure with its associated, necessary system or cooperation partners will be developed, and the interactive, integrated process and organizational structures that are needed will be derived.

The cooperative business model with its two-dimensional cooperation network will substantially contribute towards achieving the economic goals of the cooperation partners:

- Increase in sales by increasing the market share of precast concrete elements in the considered market segment "individually designed single-family and multi-family homes"
- Increase in profits from offering customer-oriented system services with unique selling propositions that set them clearly apart from the services and products offered by the competition

2 Research methodology

The constructivist research paradigm and methods of qualitative and quantitative social research will be primarily used to reveal findings relating to the issues mentioned in the introduction. In addition, the logical models and empirical results will be validated and rehabilitated using a theoretical reference framework. The research methodology is based on [Yin 1994], [Mayring 1999], [Stier 1999] and [Girmscheid 2004].

The economic and organizational parameters required for the two-dimensional cooperation network will be identified by adopting the interpretavistic research approach using qualitative expert interviews and quantitative empirical studies. On the basis of this, the further research process will develop the logical-deductive business model by applying the constructivist research approach, give it a theory-based structure by applying the theory of structuration [Giddens 1985] and respectively the principle-agent theory and test its academic quality by means of triangulation.

3 System prefabrication business model

The fundamental structure of the system prefabrication business model comprises the two cooperation dimensions within which the players needed to successfully establish this method of prefabrication cooperate in the form of a strategic partnership. In the case of the business model outlined here, this cooperation focuses on the construction market segments for individually designed, integrated precast modules (e.g. prefabricated bathrooms and dormers) and precast systems for single-family and multi-family homes (SFH/MFH). The initiative to form strategic partnerships in the two cooperation dimensions, which will be described in more detail later, stems from a manufacturer of precast elements, whose strategic interest centers on the integration of the competencies needed for the system service. In return, the cooperation partners involved in the two cooperation dimensions benefit from the market-strategic potential of the cooperation networks, which only arises through the strategic cooperation and with the help of innovative precast technologies that enable the manufacturers of precast elements to prefabricate virtually any element independently of serial production.

At the initiative of a manufacturer of precast elements, the players from the prefabrication market (manufacturers of precast elements, planners, bonding technology companies, (partial) system suppliers, etc,) who are needed to produce a system service (e.g. SFH) cooperate within a supra-regionally operating, production oriented cooperation network (1st cooperation dimension). The system competency that is cooperatively integrated into such a cooperation structure is passed on to the locally and distribution oriented cooperation network (2nd cooperation dimension) (e.g. as a licensing).

The locally operating distibution and assembly oriented cooperation network, which involves the necessary players for construction site preparation, assembly and fitting (local architect, construction entrepreneur, electrical and HVAC companies), can use its proximity to the customers and the ensuing trust to efficiently market the system service. The organizational link to the first cooperation dimension is institutionalized by means of a focal company "Building construction system service". All the cooperation partners from the local sales and assembly oriented cooperation network and the planning experts from the superior production-oriented cooperation network are represented in this company. The client benefits from the advantages of prefabrication (defined manufacturing conditions/high level of finishing quality, efficient processes for building the structure/shorter delivery times, lower financing/investment costs) without having to relinquish his desire for an individual building, whilst at the same time receiving this system service from a single source. This approach enables the cooperation partners to achieve the customer-oriented strategic goals mentioned above.

3.1 Production and system oriented cooperation network

The production and system oriented cooperation network integrates the competencies needed to develop and produce an individual, customer-oriented system service (Fig. 1). It comprises a manufacturer of precast elements, who cooperates with the fastening technology company, (partial) system suppliers, architects for the conceptual system design and a planning expert to plan the prefabrication.

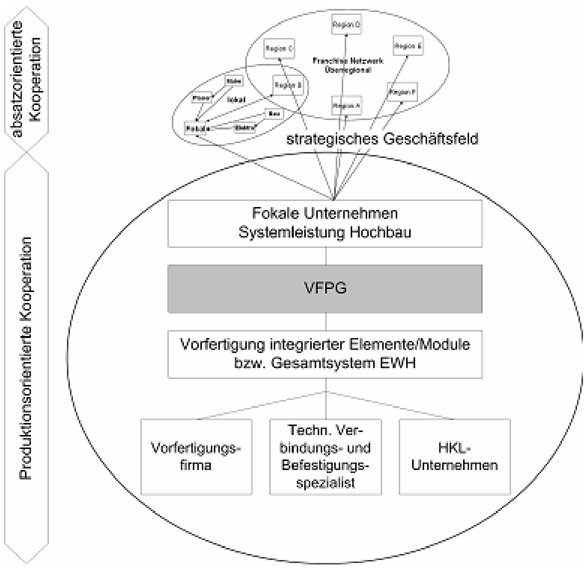

Figure 1. 1. Cooperation dimension – Production and system oriented cooperation network

The production oriented cooperation network provides the following output:

- the technical and creative design of the system concept
- a suitable supra-regional marketing concept to support the distribution of the system concept
- technological planning competency for the customer oriented individualization of the system concept in the form of precast planning consulting, check lists, and planning tools to support the use of precast systems, modules and elements

- a suitable incentive system to control the synergetic business interests and competencies of the involved partners in a target oriented fashion

3.2 Sales and assembly oriented cooperation network

The sales and assembly oriented cooperation network provides the expertise for distributing and assembling the system. It is comprised of a local architect, who is responsible for the individual, customer oriented design, a local construction company to prepare the building site, excavate, build the foundations and assemble the precast elements, and a local electrical and HVAC company to connect the installations (Fig. 2). Additional necessary services will be carried out by subcontractors. The sales and assembly oriented cooperation network provides the following contributions towards successfully establishing the business model in local markets:

- detailed knowledge of local market structures in the segment of SFHs and MFHs
- established informal local networks for acquiring suitable cooperation partners
- comfortable market access for acquiring potential clients
- operative tasks relating to preparation, assembly, commissioning and warranty works.

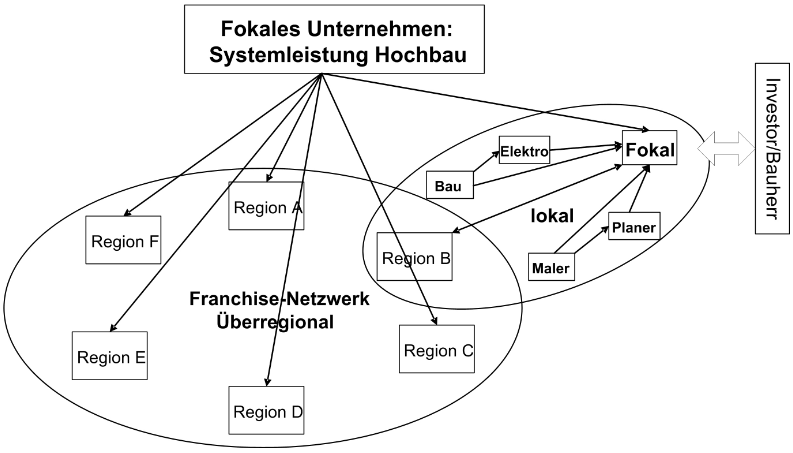

Figure 2. 2. Cooperation dimension – Sales and assembly oriented cooperation network

4 Conclusion and Outlook

The business model presented here comprises the production and sales oriented cooperation concept to develop and penetrate the precast market, the structure of the management concept to develop the virtually individualized service offering for customers, and the marketing of the overall product as a one-stop service and warranty. The construction management core of the business model is the two-dimensional cooperation network comprised of:

1. production and system oriented cooperation among key planners and companies to develop and produce an individualized, customer oriented system service
2. locally focused sales and assembly oriented cooperation among local/regionnal/supra-regional partners to ensure proximity to the customers and exploitation of local connections

The partners involved in the cooperation networks are given the unique opportunity of sustainably increasing their sales through the specific use of precast (partial) systems, modules and elements that are tailored to the needs of potential clients in the market segment of single-family and multi-family home construction, and of consequently improving the capacity utilization of their company resources. This results in a reduction of the specific overheads relating to a project, and companies have a better chance of obtaining an improved, positive project or operating profit. In addition, prefabrication allows the participating companies to reduce their non value adding work hours and, in doing so, to generate much higher contribution margins.

Clients obtain the commercial benefit of the business model from the efficient delivery of the construction within a considerably reduced construction time, since the building is then available for utilization much earlier, allowing, for example, a reduction in financing costs. In addition, clients benefit from the quality advantages in terms of less material and production variation and qualitatively optimized standard details and construction elements (learning system concept).

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Mass Customisation concepts and networks for the European market

a new challenge for the building sector

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1 Mass customisation, the solution for market saturation in Europe

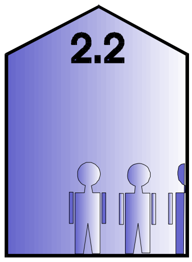

Fig. 1 Saturated market : *Housing occupancy Europe*

Many sectors of industry are faced with market saturation and businesses are struggling to survive. Customer behaviour has become unpredictable and major companies' classic marketing strategies seem increasingly incapable of reaching today's individual consumer. One of the sectors affected by this development is construction. The Dutch housing market is changing rapidly as a result of privatization and declining production. A downward trend in housing production started in many European Union Member States before it did in the Netherlands. Housing occupancy in Europe is falling to 2.2 people per housing unit and the ageing of the population is accelerating rapidly. Generally speaking turnover in the maintenance and refurbishment sector is higher than that of new build. The problem of selling products in saturated markets is found in many other industries. The same economic laws of decreasing consumer appreciation for standard products and subsequent pressure on product quality and differentiation apply in such market conditions in all industrial product sectors. In a free market the private actors - the customers - are in the driving seat. Sights also have to be set higher for value for money in this type of market in order to cope with the competition. There is a general tendency to use mass customization (MC) production technologies - the paradox of satisfying individual customer wishes and producing at a profit.

Europe	**Japan**
○ Decline of new build	○ Average age of dwellings 25 years
○ Rehabilitation/ maintenance sectors are growing	○ High prefabrication rate (200,000 dwellings)
○ Average age of dwellings > 50 year	○ Average new dwellings / 1000 inhabitants: 10
○ Average new dwellings / 1000 inhabitants: 5	○ Dwellings sold are predominantly new build (90%)

Table 1 Comparison of substitution of dwellings in Japan and Europe

In Japan customer driven industrialisation is the normal practice. The Japanese building industry demonstrates that a high degree of substitution is perfectly possible in a saturated market. The degree of substitution in the housing sector in Japan is at least twice as high as in Europe. This industry is highly customer driven, represents a large share of the GDP and is skilled at persuading consumers to replace their existing homes by new build. Japanese people do not buy existing dwellings and are proud of their new homes. They also don't like doing odd jobs in their homes, as do Europeans (often out of necessity). The European building industry, with its fragmented and competitive medium sized enterprises and its adherence to tradition, appears to be very different from the Japanese approach.

2 Building systems, the appropriate product level for mass customisation (MC) in Europe

The question is what MC techniques are suitable for Europe to reverse the downward trend. If we look at the current status of industrialization in the European building industry, we notice major differences within Europe between the northern and southern Member States. The emphasis in the southern Member States is on the traditional processing of building materials on the construction site like hollow bricks and concrete structures poured in situ. In the northern part of Europe there is rather a hybrid mix of industrialization and traditional building methods. In view with this hybrid mix of prefabrication and / or traditional building, dependant of the various building cultures in the European regions, large scaled centralized production of complete houses is not an option. Moreover, this kind of production has not been very successful in the past, due to its monotonous architecture and its association with cheap mass-produced housing built after the Second World War.

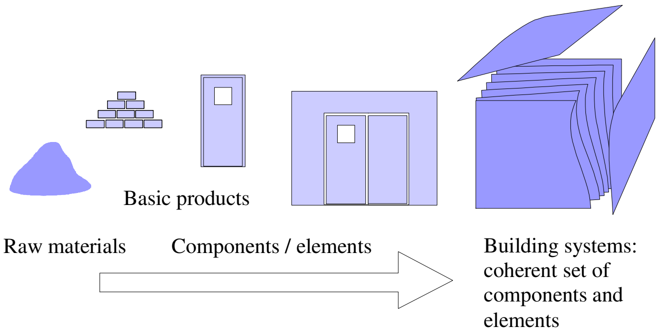

Fig. 2 Upgrading to customer driven industrialisation

Industrialization of the building industry is a broad concept. It can apply to both basic building products and building systems (see fig. 2). For example, the brick industry has seen dramatic labour substitution (90% approximately over a period of 50 years). However, basic building products delivered from stock - despite its high industrialisation degree in the factory- are not suitable to perform customer driven industrialisation.

Adaptation to customers wishes somewhere in the production process of the factory is simply not possible. Processing of basic products at the construction site still takes relatively large amounts of time. Each of these activities is always carried out by a different party, which results in poor logistics and a lot of inefficient intervals between the successive processing steps. Customer driven industrialisation should therefore preferably be focussed on the higher level of the product chain: the quick assembly at the construction site of transportable, flexible and tailor made building systems. Moreover, tailor made and just in time delivered systems create added value for the supplying industry, compared to the delivering of cheap basic products. The questions is how to market these systems all over Europe.

This is not an easy job, considering the different building cultures and regulations, which exist in the 25 Member States. The first condition to trade building systems without barriers is that they comply with the various building regulations on the European market. Complying with building regulations is not enough. The systems must be able to perform flexible buildings, tailored to customer's individual wishes and last but not least, gain a substantial market share to survive. The marketing of tailor made systems in a direct way to customers is being made increasingly feasible through the support provided by information technology (IT), contrary to supply on anonymous markets (which is the case for basic products). Networks of co-makers in the supplying industry are therefore necessary, to make arrangements on the junctions of building systems and the 'just in time' delivery of these systems.

- Stained glass windows gave way to prefab window frames;
- Larders gave way to refrigerators;
- Inbuilt store cupboards gave way to 'freestanding' cupboards;
- Earthenware sinks gave way to kitchen units;
- Thatched roofs gave way to roof tiles, chimneys to roof ducts, fireplaces to stoves and boilers, sculleries to washing machines etc.

Table 2 Industrialization by expanding markets (via supplying industry)

An important observation is next that the market exposure of building systems can be enhanced through the concept of disentanglement. This process started long time ago, fed by innovations in the supplying industry (see table 2). It is striking that these innovations became possible because the products developed from built-in elements into separate components. This stimulates substitution and increases exports. A higher degree of industrialization is made possible by expanding the market; a pantry cannot be exported,

whereas a refrigerator can be [i]. The root cause is that disentanglement is able to break down logistic complexity. Substitution of adaptable components and systems during the lifetime of buildings becomes thus an easy job. For new build it creates, trough the combination of adaptable systems, easy and manageable enhancement of variants, to suit customers wishes.
Last but not least, the concept of disentanglement can be applied to the building process itself. In this paper customer driven industrialisation in fragmented markets (like the European market) by working in networks is advocated.

3 The concept of the virtual kit as a basis for mass customisation (MC)

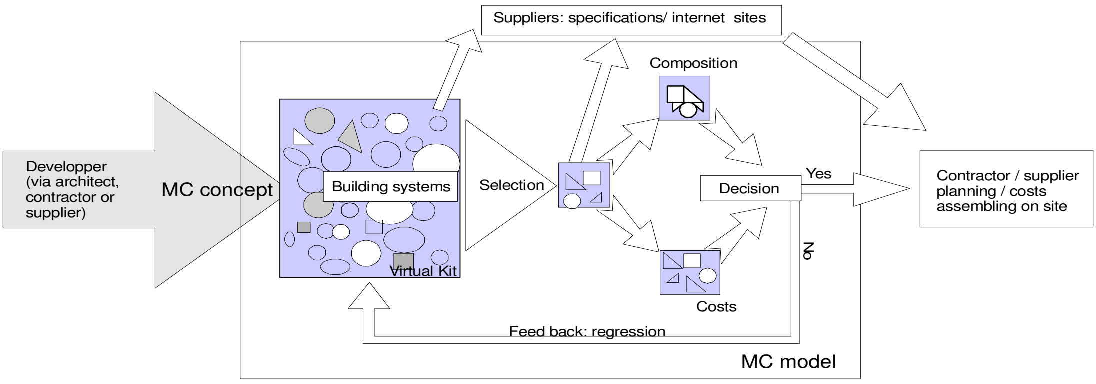

Fig. 3 MC model based on a virtual Kit

A first step to customer driven industrialisation on the European market is to market building systems, which comply to the different building regulations in the European regions. The usual European terminology for prefabricated multi-component products or building systems is 'kit'. A kit consists of a set of building components, which is marketed as one product. A kit is based on a harmonised European technical approval (ETA). Kits, based on ETA's bear the CE-marking to indicate that the product can be traded on the European market and can be used in buildings without any barriers. [Construction products Directive (89/106/EC) and Guidance paper C].

The European kit proves to be a perfect basis to elaborate MC concepts [van den Thillart 2004]. Kits are based on 'non physical' design systems. For MC purposes the notion of 'design system' is extended to 'design concept'. A design concept can be looked on as a flexible prototype that is considered by the market to represent a good opportunity. 'Flexible' means in this respect that the prototype can generate many variants.

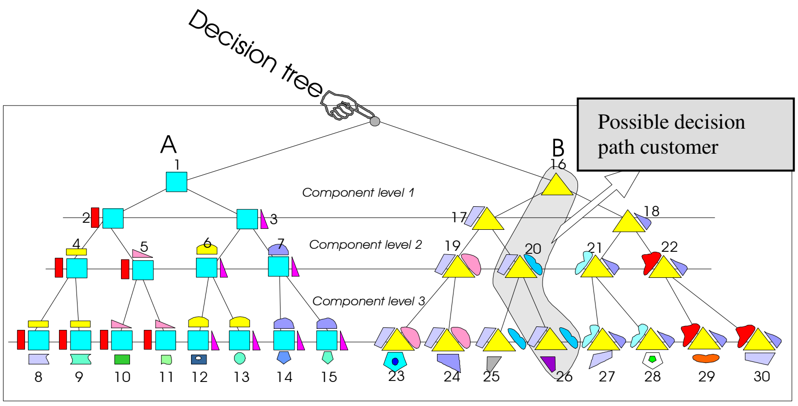

Fig. 4 Variation by disentanglement: shifting components to the other nods in a decision tree of a virtual kit

Imagine next that such design concepts form the virtual basis for kits. Those 'virtual kits' extend beyond individual projects and can be used at various different locations. A virtual kit encompasses all of the many candidate building systems that jointly, after selection by buyers, form a series of different dwellings. The building systems in the virtual box are ranked in layers. Every selection in a layer adds a building system to the building system selected earlier from the previous layer.

A virtual kit is turned into a MC model by organising building systems in decision levels on the basis of a particular marketing concept, supported by IT costing programs and programs for drawing component assemblies and three dimensional presentations (see fig. 3). The number of variants that consumers are free to choose from is a yardstick for how consumer-driven the plan is. Virtual kits can easily generate thousands of 'end variants' and even adapt completely different appearances. Creation of variants is not a goal in itself. The variants are manageable by the disentanglement of the different systems in the Kit. Disentanglement makes it possible to freely attach variant components to any branch of the decision tree (see fig 4). If 10 suppliers are each responsible for 10 variants this results in 10^{10} end variants. This many 'end variants' is feasible by spreading the logistic complexity over the participants. The customer only needs to take 10 decisions!. For the different techniques to create disentanglement, such as morphological transferability and techniques to postpone the order penetration point, see the publication 'Customised industrialisation in the Residential sector and its references to other authors' [van den Thillart 2004 *et al*.]

4 Aspects of chain integration, based on IT and virtual kits

IT has increasingly becoming an information carrier linking the different disciplines in the building industry. The ongoing advance of IT can stimulate collaboration between the many different parties involved. Co-operation in networks is important for the marketing of tailor made building systems, as we indicated above. The basis for co-operation is a flexible prototype, based on a virtual Kit. Its flexibility allows for location-independent pro-active marketing to customers. The direct marketing to the customer supposes chain integration.

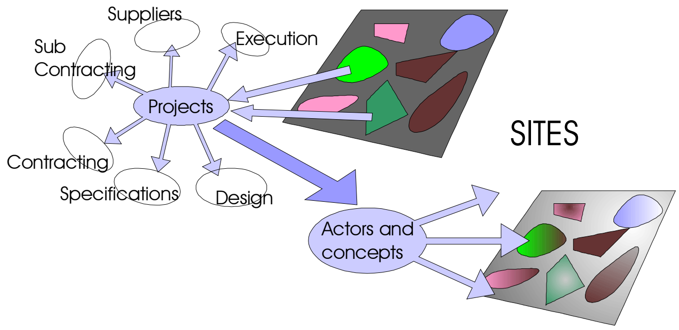

Fig. 5 From traditional tendering to proactive approach

The participants are not tied anymore by traditional tendering and constraints by the specifications of the contractor, but are able to offer their variant-options directly to the customer. For this to be achieved chain management is an important issue. The architect's new design challenge lies at the start; the development of a successful concept that can be used in several locations. This concept is based on the technical possibilities of the different suppliers in the kit. The contractor has the role of managing the whole process.

The suppliers play the role of co-makers. They make arrangements in advance, to guarantee that all the relevant components fit together and be delivered just in time at the building site. All supporting IT software programs, such as customer's choices, costs, virtual reality systems, E-commerce and technical specifications are interconnected in the MC model and designed to economize in a simple way the whole supply chain (chain shortening). This can be achieved in practice by means of a uniform electronic dossier that digitally stores documents such as design and drawing software packages, reports etc. that are identified by author, revision date etc, known as the back-office software. The IT software to market the products to the customer is the 'front office' software (see fig. 6). Individual customer wishes require careful monitoring of changes, which have to be horizontally transferred to all IT programs. The link between the front office and back office software is the last step in chain -shortening.

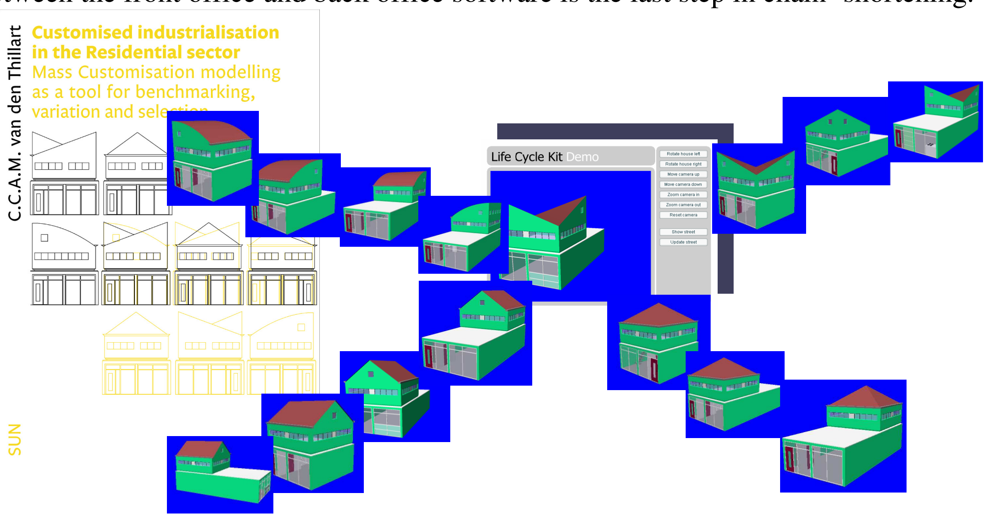

Fig. 6 An example of a front office program , the life cycle kit, elaborated for the TUD symposium in 2004 on mass customisation.

5 Practical application of MC pilot projects by the Esprit network

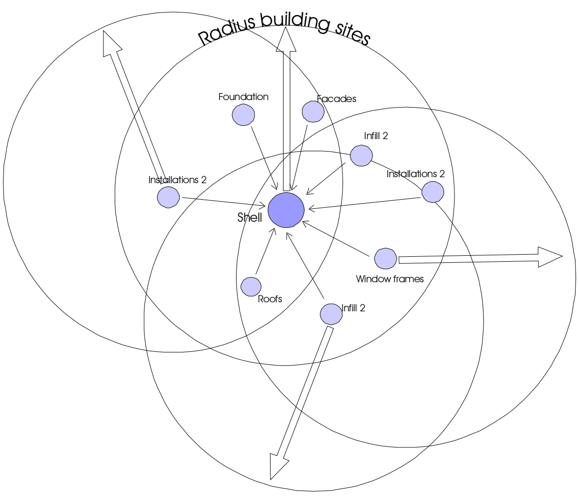

Fig. 7 Network model with different radius

As we indicated above, co-operation between the building parties and working in networks - even over long distances - is a condition 'sine qua non' to improve customer driven industrialisation in fragmented Europe. By IT, customers can be reached all over Europe, but marketing houses without co-operation of local authorities and industry is an illusion. The threat of possible elimination of the local industry is the main barrier to market completely industrialized houses. The network model permits foreign companies to join virtual Kits and vice versa. The advantage of the network model compared with centralized production is that it is suitable for all categories in the residential sector and the manufacturers do not need to be completely dependent on their production under this network model for their survival. The distribution of the logistical complexity makes participating in the network an easy job.

As all participants have an interest, there is therefore greater certainty of timely delivery than in the case of traditional public tendering. The MC concept, based on virtual kits has been adopted by Esprit, a network of companies in the Netherlands with special interest in customized industrialization. Esprit covers all professional building parties like developers, consultants, architects, contractors, and supplying companies in the construction sector. In the next years to come, three Dutch universities of building technology and architecture in Delft, Eindhoven and Twente are co-operating within the Esprit network to develop and monitor real MC projects, based on the virtual Kit concept

The Esprit supplying companies are able to market their variants direct to the customer, made possible by the disentangled building systems of the virtual Kit. The first pilot project deals with supply chain integration, comprising aspects like marketing, chain management and chain shortening (front office / back office), as discussed above. Other aspects of chain integration like quality chain control and sustainability will be exercised in following projects. Together these five aspects represent the Esprit method of supply chain integration. In the next three presentations companies, which are associated in the Esprit network present various aspects of MC techniques and marketing.

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Sun ISBN 90 5875 128 7 www.uitgeverijsun.nl
See for a broad survey of MC techniques the reference list in this publication

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[i] This process of disentanglement was the basis for the open building philosophy in the Netherlands. As far back as the nineteen-sixties a separation between two building systems – the support and the infill systems – was being advocated. This evolved into separating the different building elements and spaces in relevant decision levels, from the urban planning level to the infill level. During the nineteen-nineties the open building philosophy was extended to incorporate aspects of sustainable building. The 'demountability' of building systems also has significance for the primary reuse of these building systems, to be achieved by means of the dry installation of prefabricated building components. This last development is known by the name industrial, flexible and demountable (IFD) building.

Framework to facilitate process innovations

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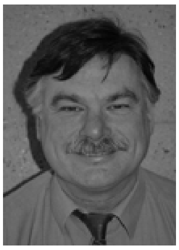

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KEYWORDS

Process innovation, innovative design process, change management

Summary

De construction sector experiences great difficulties in developing flexible buildings that are capable of meeting changing demands of tenants during its whole life cycle. The strive towards flexibility and adaptability of buildings is mostly based upon innovation of technologies applying traditional design strategies and organisation forms. The authors plead for innovation of the design process and organisation first in order to achieve successful innovation and implementation of new technologies that enhance flexibility. To escape the traditional construction sector's paradigm, research has been done in non-building industries on the role of process innovation. These results have been further examined in a case study. Together with an analysis of the construction sector the results from the non-building industries and the case study are combined into a framework to facilitate process innovations.

Introduction

The construction sector has difficulties in realising buildings that adapt to the changing user demands during the building's lifecycle. This leads to early obsolescence and partial rebuilding, high vacancy levels or even demolition of buildings that have not technically depreciated yet. This is on the one hand due to a lack of collaborative design in the early design phase [Rutten & Trum, 2000]. On the other hand a system approach to building design is missing which gives consideration to the differences in lifecycles of the various systems in a building [Brand, 1994] and stakeholder involvement [Habraken, 1961]. New design approaches introduced a more central role of the end-user and distinguished disconnected building layers with a support and infill (open building) [Habraken, 1961]. Later Rutten & Trum [2000] introduced a design approach with integrated functional levels and value domains that also supports the design team in a focussed attention to a dynamic future use of the building (strategic design).

Yet these design approaches are barely adopted in the building industry despite a wide promotion. The construction sector is dominated by a conservative culture, the market is fragmented and the continuous changing design and construction collaborations hamper technological innovation. The many specialised participants make coordination of complex buildings difficult and inefficient. Due to the fact that the building industry doesn't welcome and stimulate changes, pilot projects experience difficulties in implementing innovative design strategies or design partners continuously fall back into the traditional and safe working methods. It is obvious that there is a need for an implementation strategy of the above mentioned innovations in design processes. In this paper a framework is recommended to facilitate the succesfull introduction and implementation of innovative design processes.

Innovation research

Some industries are similar to the building industry, yet they are more innovative. A research was conducted to find the underlying reasons for their successes in an attempt to learn from their approach towards innovation (elegant stealing) [Van Loon, 2002]. According to the typology of Botter [1974] we have selected industries with similar characteristics as the building industry (see Fig. 1).

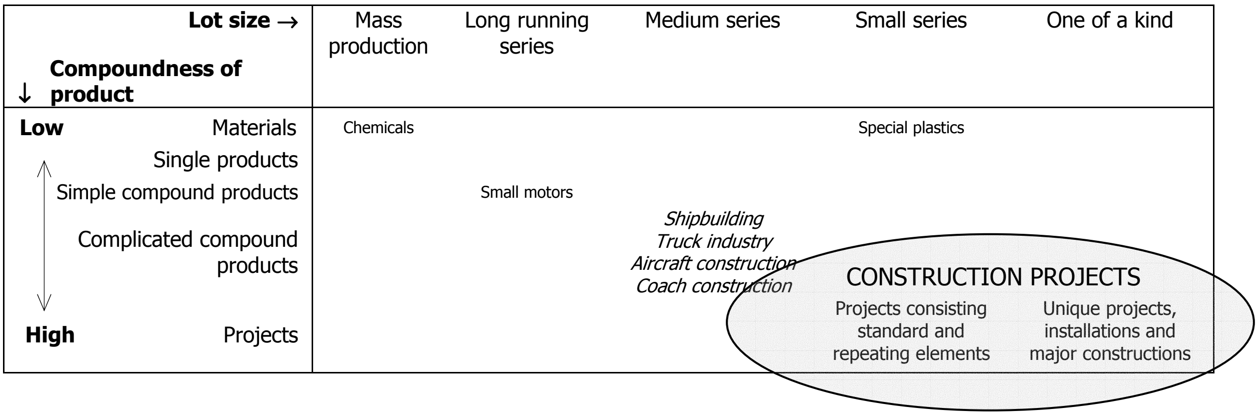

Figure 1: Botter´s typology [Source: Botter, 1974]

The following industries were part of the research; the shipbuilding, the truck industry, aircraft construction and the coach construction industry. In interviews with key representatives of companies in these industries insights were gained in key succes factors in innovation trajectories. These insights were subsequently tested in a case study that was conducted in a building project by a large health care organisation in The Netherlands. This project centered around the introduction of adaptable ICT-technologies in dwellings (ambient care). The main aim of the project was to further the quality of life through custom-made support services for care and well-being. As this project involved the need to introduce technological innovation in existing organsiations, it was a suitable test bed for the insights gained from the non building industries in terms of organising the innovation trajectory and defining desired interventions. Finally the construction sector has been analysed so that implementation of the key succes factors gained from research in the non-building industries and the case study will be more efficient.

Research results

Some generic lessons learned from the research, the case study and the analyses of the construction sector are:

1. When endeavouring change in a human system expect resistance. To overcome the resistance it is important to let people experience the advantages of the innovation and the opportunities it offers for them and-most importantly- to involve them in the process as early as possible so that the change comes from within themselves and is not being forced upon them by others.

2. To change the culture of a company or industry is extremely difficult. Often outsiders are conducive to bring the necessary change about. Consider therefore involvement of professionals from non-building industry or with a different educational background.
3. It is important that people are conscious of the need for innovation and its implementation. Communication to all layers of the organisation is an ongoing basic necessity.
4. One requires a framework that structures the various phases in the innovation process together with key success factors and desired interventions in each of these phases. The phases that non building industries distinguish are as follows:
    I. Initiative
    II. Trial phase
        a. Preparation
        b. Realisation
        c. Evaluation
    III. Consolidation
5. In the construction sector implementation of process innovation is most effective at cluster level, where all companies involved in design, construction and operation of the building decide to bring about innovation in the building industry. Realizing process innovation at company level is not very effective because of the equal basis of collaborations in construction projects and the need for an integrated approach. And initiatives at sector level often fail as a dominant player or coordinating organization is missing.

Below an explanation is given of each of the phases (mentioned under 4 above) in the innovation process together with specific key success factors and interventions.

I. Initiative

Organisations will initiate innovation processes when they become aware of the advantages and opportunities of alternative processes. External events such as technological innovations or changing societal demands can give extra impulses to change. By dissiminating the advantages and opportunities that alternative design approaches offer, organisations will become more conscious of the need for change and are more likely to participate or to start innovation processes. Knowledge centres and universities may play a role in this dissemination.

Intervention:

- Disseminate the advantages of innovative design strategies.

II. Trial phase

To experience the collaboration between the participants a trial phase is defined. In this phase one or more pilot projects will be executed. The sequence of the preparation sub phases is not strictly determined but may be carried out in parallel or overlapping time frames.

A) Preparation

Acquire a project

The initiator will search for a pilot project in which the cluster can deliver added value. By disseminating the opportunities of the alternative design strategy people will become enthusiastic for working with a cluster and implementing innovative design strategies.

Intervention:

- Disseminate the advantages of innovative design strategies.

Compose initial cluster

Starting innovation processes it is important to involve all knowledge domains from the beginning of the process. Part of the selection criteria for organisations is the willingness to participate for a longer period. During the selection process selection criteria should be used in order to create a balanced team as the participants should complement each other. An external, independent project manager can be involved to stimulate and guide the team according the principles of the innovation strategy.

Moreover, to guarantee and persuade the people to work as an integrated team, professionals from other industries or with a different educational background should be involved in the project. Besides the architect, technical specialist and project manager, the end-user has to be part of the cluster as well. If the initiator has not found a pilot project yet, delegates from formal user-organisations can participate in the cluster
Interventions:

- Create a multidisciplinary cluster,
- Involve end-users,
- Involve an extern, independent project manager,
- Involve professionals from non-building industries.

Anchor the organisation
In workshops the differences in expectations can be ventilated where awareness, insight and respect for each other can be reached and the barriers between specialists can be broken down and a common ground is built in terms of attitude, behaviour and practices and perspective. People get enthusiastic and get a drive to succeed as a team. Besides the creation of cohesion within the design team the organization structure is formalized in a project plan and consensus about the objectives is formalized in a gentlemen's agreement. Somebody is being held responsible for succeeding the process innovation's implementation. Experts can pass on the principles of innovative design strategies and adaptable technologies to create consciousness by the participants.
Interventions:

- Create shared attitudes, values and enthusiasm in workshops,
- Formalize organization structure and objectives in a gentlemen's agreement,
- Hold project manager responsible for implementation innovation,
- Education.

B) Realisation
The cluster will execute the project implementing the principles of innovative design strategies such as open building and strategic design in order to realize adjustable buildings which are flexible and adaptable to future changing demand dynamics.
Interventions:

- Apply innovative design strategies.

C) Evaluation
To close the learning cycle and continuously improve the cooperation within the cluster the innovation process and the project should be evaluated. Possible evaluation outcomes can be reassigning interventions or changes within the composition of the cluster.
Interventions:

- Apply evaluation tools.

III. Consolidation
The participating parties can decide to consolidate the collaboration. Through long-term collaboration ships and further formalisation the developed knowledge can be further improved for other interested owners. The cooperation has to adopt the principles of a learning organisation to be able to continuously react on future demands. Recommended methods are Kolb's learning cycle [1984] and the five disciplines of Senge [1995].
Interventions:

- Apply principles of a learning organisation.

Total process
Interventions, critical during all phases of the process, are open communication and applying intermissions. Communication is essential to create awareness over the project's goals and the method

of working. Intermissions are needed to control the project, to create a learning organisation, establish short term successes and to evaluate interventions.
Interventions:

- Communication,
- Apply intermissions.

Process innovation framework

The results of the research in industries, the case study and the analysis in the construction sector can be combined in a process innovation framework, see Fig. 2.

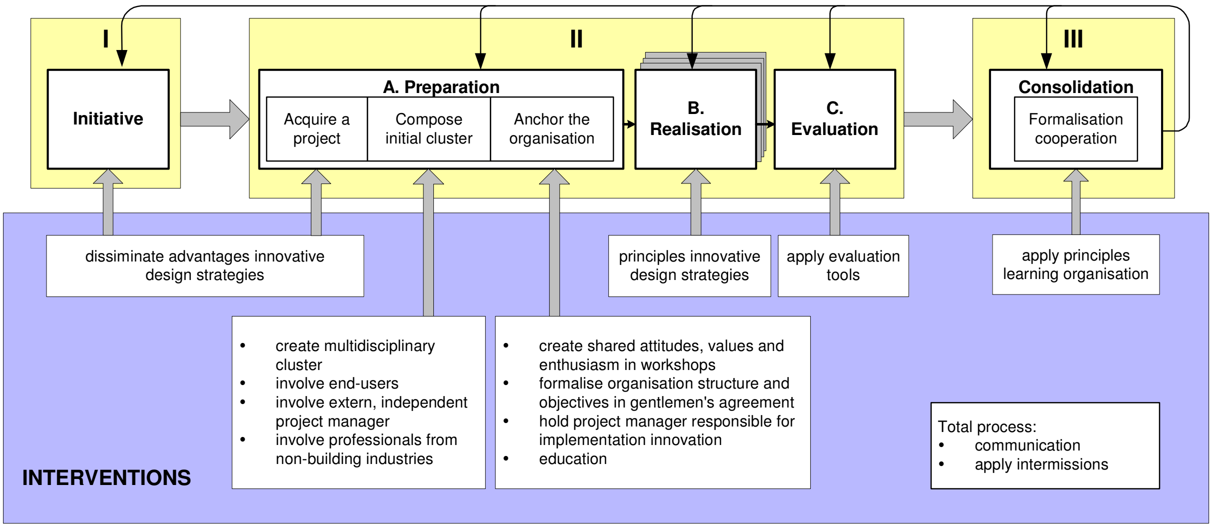

Figure 2: process innovation framework

Conclusions

In this paper a framework to facilitate process innovation has been introduced. The following conclusions can be drawn:

- The construction industry should become more conscious of the fact that innovation involves both process innovation and technological innovation.
- In the construction sector process innovations can only be reached by cooperating teams from the whole spectrum of the building industry. Creating clusters and long term collaborations is essential to bring about and successfully implement process innovations and continuously improve technologies. Every project offers besides a business opportunity, an opportunity to innovate together.
- The cluster should continuously consider external societal and technological dynamics. Creating a learning organisation and closing the learning cycle are essential elements.
- The construction sector can learn from other industries. We plead for more research in non-building industries or applying research done in other industries in the construction sector more often.

To start process innovation within the construction sector we recommend to adopt the proposed framework to facilitate innovation projects.

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Industrialisation of Construction, an investigation into the potential of upcoming technologies.

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Industrialisation, Construction, ICT technology for construction.

ABSTRACT

1 Industrialisation in historical perspective.

We often hear the complaint that construction is legging behind in the process of industrialisation. Is this claim true and if so, what is the reason why? To answer this question we should first define what industrialisation is. Industrialisation is a continiously ongoing process. It is the process of ever increasing efficiency and improving quality. Quality of product but also quality of occupational life. It started in the 18th century when manual power and horse power was replaced by steam engines. At the end of that century also combustion engines were invented. This new sources of energy caused a transfer of productive activities from households to factories. The big effects of this change on society are referred to as the "Industrial Revolution".

Construction was never a home industry. So initially this revolution did not change the construction industry. But also on construction sites manual work was gradually replaced by mechanical tools. Sawing machines, drills, stapelers, pneumatis hamers, mixers and pumps replaced most manual work. Later construction elevators were introduced and tower cranes became the landmarks of the industry.

But in the 20th century industrialisation became more then a switch from manual to mechanical work. The move to factories facilitatied the development of a completely new organizational approach. Modern management strategies like time management, logistics, just-in-time supply and lean production became the drivers for cost reduction and quality increase. Most industries benefitted from these new management tools. Unlike the construction sector. It met difficulties in the adaptation to this new stage of industrialisation.

2 Industrialisation in construction

The claim that construction is lagging behind is not fully true. The number of manhours needed to built a house or a square meter of office space is reduced by over 50% over the past decades. A majority of the building components are made in factories and assembled on site. Over 70 % of turn over in construction firms is purchased from third parties. The Just-in-time and Lean Production strategies are adopted by most mayor construction companies. Why is construction still said to be under industrialized?

There are two main reasons why constructuon is not industrialised like other industries. First buildings are made in the open air. Full production in factories is virtually impossible. Quality and efficiency suffer by bad weather conditions. Second, buildings are designed to be built only once. We may say that we only build prototypes. Construction seldomly gets the opportunity to built a series of identical buildings. The learning curve, typical for an industrial proces, is interrupted before a desirable level of productivity is achieved.

3 The search for most potential new technologies

In 2005 a research project was set up to identify the possibilities for further industrialisation in construction. Partners in this project were the Dutch research programming organisation SBR and the Universities of Technology in Eindhoven and Twente. The research methodology was first litterature search, followed by a web search. Where the literature mainly decribed research projects in universities and research institutes, the web was searched used to find research and development activities in the industry itself. Cpompanies with promising research delivrables were visited and interviewed to get a more indepth picture of the technologies. About 13 representatives of the construction industry contributed to the results with their industrial experience and practical insight. The report identified 10 potential business challenges catagorized in three strategies. [SBR 2005]

1. On-site strategies,
2. Off-site strategies,
3. Integrated concepts.

For off-site industrialisation the most potential was found in CAD/CAM systems. The technology is available and thoroughly tested. Acceptance by the industry is still limited.

For on site industrialisation the most potential was found for robotic technologies. Robotic systems to perform masonry work and floor tiling are close to market introduction. In Japan prototypes of robotic surfacing equipment were found. Mature robotic systems for positioning of elements were found in Japan as well.

Integrated concepts are concepts covering both the prefabrication off-site as well as the assembly on-site. Most potential was found in construction concepts based on prefabricated voluminous units and slab systems. The technology is not new, but the growing acceptance by clients and the introduction of the mass customization philosophy are enabling a soon expected break through. Japan and the USA are leading with a longstanding tradition in prefab housing. But also in Europe several recent initiatives were found.

4 Market penetration

For the Dutch market it was investigated how far these new options were already used. It was assesed by interviews that CAD/CAM systems were most accepted by the concrete products industry (83%) but only a meagre 12% in construction companies.

Industrial (fixed) robots were used in 50% of the prefab concrete factories and 17% used construction robots (mobile robots). For the steel industry these figures were twice 8%. In the wood industry no industrial robots were found, but 13% construction robots. The contracting companies scored two times 0%.

%	Contractors	Concrete Industry	Wood Industry	Steel industry
Construction Robots	0	17	13	8
CAD/CAM	12	83	13	42
Industrial robots	0	50	0	8
Automatic Transport	0	50	25	0
Automomatic Storage	0	33	0	0

Tabel 1, use of automated systems in the Dutch construction industry.

5 Constraints to investment in new technologies.

Also the constraints to investments in the new technologies was investigated. Of the respondents 78% mentioned high investment cost and 56% referred to the uncertainty about the short term profitability when asked for the mayor constraints. Also low reliability of new technologies scored with 36% significantly high.

Constraint	**percentage**
Investment too high	78
Return on investment too uncertain	56
Lack of flexibility	55
Uncertain economic situation	48
Risk of technical malfunction	42
Difficult to integrate in existing process	37
Lack of reliability	36
Maintenance cost	35
No innovation culture	32
No market information	31
Limited technical life cycle	30
No acceptance by employees	24

Tabel 2, Constraints to adoption of new technologies.

6. Importance of further introduction of ICT in Constructiomn.

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an investigation into the potential of upcomimg technologies.

Most of the found constraints originate from a discrepancy between supply and demand. The supply side of the market offers technologies that are not accepted by the demand side. Products are unreliable, requiring a lot of maintenance and not suitable to be integrated in existing production processes. These problems on the supply side got all high scores in the table above.

On the other hand the demand side is not really eager to adapt new ICT technologies. Though nmainly found in the lower scores above also these constraints are important enough to address. The company culture is not innovation focussed. Market information is not collected Employees do not accept change.

To understand better what the resons are behind this fisfit between supply and demand side a more indepth research was needed. The construction technology chair at the Eindhoven University of Tehnology together with Balance & Result, a Dutch consultancy firm, initiated a researchproject. First we wanted to know more about the gap between supply and demand. WE asked the mayor players how the construction industry and the related IT-industry see themselves. To investigate the industry a questionaire was sent to the members of a ICT-working commission of the Dutch Association of Contractors. ("Bouwend Nederland") So the interviewed parties were more than average interested in the subject. This group appeared of the opinion that their industry is under automated (78%)

The tabel below shows the replies to questions about the importance of ICT technologies, now and in future. Answers given by suppliers and buyers are listed separately. Both groups of respondants agree that the penetration of ICT in construction ishigh nor low. And both agree that increased use of ICT is of great importance for the construction industry. But parties disagree on the question how suitable the solutions offered by the suppliers are. Where supliers are conviced of a high suitability (75%) the buyers consider 94% as medium suitable. The table below confirms the findings from the research project mentioned above. Suppliers appear to be not aware of the inadequateness of the solutions they offer the construction industry.

Opinion of peer group.		**Supply side**			**Demand side**		
		high	**medium**	**low**	**high**	**medium**	**low**
To what extend are ICT-technologies already applied in construction companies ?		16	50	34	6	69	25
To what extend are ICT-systems applied in your (construction) company					22	23	55
How important is increased introduction of ICT technology for construction ?		75	25	0	75	25	
How important consider construction companies the increased use of ICT		75	25	0	62	25	12
Suitability of the actual supply of ICT tools for construction companies		75	25	0	0	94	6
To what extend should construction companies adapt ICT solutions in the near future		100			100		

Tabel 3, opinion of experts on status and potential of ICT in construction

7. State of ongoing introductions

Though the industry suffers of low unreliable and inadequate solutions they nevertheless continue the process of introduction and adaptation of new ICT-technologies. Therefor another subject of the investigation was to asses how far these ongoing introduction of new ICT technologies are under way. In the next table the 6 stages of introduction, from idea to optimalisation in process, are scored per technology.

Stages of implementation	**2D CAD**	**3D Model-ling**	**4D Model-ling**	**Mobile Data GPS)**	**Doc. Man. Systems**	**ERP**	**Project Web Site**	**E-com merce**
Idea			Buyers Suppiers	Buyers Suppiers				Buyers Suppiers
Investigation of possibilities		Suppiers					Suppiers	
Decision making		Buyers			Buyers Suppiers	Buyers	Buyers	
Introduction in process						Suppiers		
Daily practice	Buyers							
Optimalisation in process	Suppiers							

Tabel 4, Average stae of penetration of ICT in construction, buyers and suppiers view.

In the table above the 8 ICT-technologies with the best potential for construction were ranked in accordance with their state of average market penetration. The buyers opinion is marked with a "B". The suppliers opinion with an "S". The table visualises the opinion that only 2D-CAD is fully accepted in construction. The old fashioned drawings boards are virtually extinct. Quit a many systems is in – or close to - the decision making stage. Mobile data systems, 4D-modelling and E-commerce are still in the early stage of emerging awareness only.

In the study also the type of workers that could be benefitting most of the new technologies were identified. The expectations of the interviewd peer group are that cost estimators will use 3D models, Document Management Systems and Prtoject Websites. For planners much is expected from the use of 4D models. For purchasers it is no surprise that E-commerce will change their domain. For project managers and site agents it is expected that 3D models, but also Mobile data will be of importance. Here suppliers expect much use of 4D models where buyers think that 3D models will do. The expected development is the use of ERP systems and Document Mangement systems is both for buyers and suppliers limited.

8. Follow-up research

As an overall conclusion we can say that GPS based technologies are most promising for the construction industry. Therefor the research team will follow up the above project with an investigation into the possibilities and constraints of GSP based technologies for the construction sector.

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Optimization of Housing Production Industrialization, Efficiency, Sustainability

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KEYWORDS

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1. Background

Some of the most representative facts and figures relating to the present situation are:

- Housing is a primary necessity
- Housing accounts for a substantial portion of building construction (>80%), with production amounting to over 700,000 units yearly
- Today’s construction systems and procedures can be regarded to be obsolete and inefficient. They have remained essentially unchanged in the last 50 years, with a low level of “rationalization”
- Most “in situ” construction techniques deployed in housing are based on the use of an abundant supply of (generally low-skilled) labour to perform often repetitious tasks, for newly finished units of work have frequently to be demolished and rebuilt, with all that entails in terms of rubble, technological impoverishment of the industry, building pathology and the inevitable adverse impact on the cost of the final product. According to the latest figures, over 15% of construction costs is devoted to correcting on-site errors
- At present, nearly every block of flats is a prototype in which the initial design takes insufficient account of the construction system to be used, leading to work-site adaptations not necessarily suitable for the building whose implementation, moreover, detracts from overall efficiency. The result is that new production and control techniques in place in other industrial processes have not been instituted in construction, reducing the quality, efficiency and, in short, the sustainability of the process as a whole

In this vein, the specific issues that may be cited in support of the need for a change in the present approach include:

a. *High prices* that depend on a number of factors, including:

- *High construction costs*, due to the excessive use of “in situ” labour-intensive work resulting in relatively long turnaround times
- *Construction errors* that call for demolishing and rebuilding, as well as a substantial amount of correction work prior to the delivery of housing units
- *Pathological processes* in the first five years of use, and the concomitant additional cost

b. *Low quality* and concomitant high maintenance costs, normally due to:

- *Poorly suited designs from the standpoints of the,*
    - General approach (*preliminary design*) hampering process rationalization and sustainability both
    - Technical specifications (*final construction design*) leading to improvised worksite decisions and changes and hindering quality control of the various units of work.
- *Poor quality construction*, for several reasons:
    - *Poorly trained workers*
    - Excessive number of *units of work* erected "*in situ*"
    - *Insufficient emphasis on quality control*

c. *Scant functional and sustainable rationalization* of housing, with no particular emphasis on:
- *Energy savings*, for want of designs geared to bioclimatic and co-generation solutions
- *Home automation* systems for all building services as a whole, rendering the use of bioclimatic energy saving systems difficult

d. Obstacles to designing housing at least partially based on (industrialized) "*assembly*" techniques for greater overall efficiency in building production.

2. Objectives

In light of the foregoing, the project presented pursues two basic objectives:
- *To attain maximum sustainability in housing production and use.*
- *To optimize housing production.*

2.1. Maximum sustainability in housing production and use

A series of landmarks should be defined in this respect:
- ***Improve the efficiency of construction techniques and procedures*** (materials, components, workmanship), which entails *rationalization of the entire process*, to achieve:
    - *A high degree of industrialization*
    - *Shortened overall construction times*
    - *Lower total costs as a result of time savings*
- ***Improve the quality of the final product and durability of its components***, to lower building use and maintenance expenses
- ***Reduce maintenance needs***, in all respects:
    - *Lower energy consumption* through the use, among others, of:
        - Bioclimatic design
        - Natural energy collectors
        - Small power generators
    - *Reduced replacement and repair needs* thanks to higher quality and longer durability of materials and components
- ***Improve building operability*** with high comfort levels thanks, among others, to:
    - *Automatic control of functional use (home automation systems-Domotics)* covering all aspects of habitability
    - *Improved waste management,* with sanitation processing inside the building to prevent uncontrolled accumulation on the public thoroughfare

2.2. Optimization of housing production

This requires approaching housing construction as a global process covering everything from building design through final construction and service life maintenance, including material and component manufacture for civil construction and service installation and energy consumption in keeping with the intended use.

Such optimization may be achieved by reaching a series of intermediate targets:

- ***Design rationalization*** *(at the expense of its possible uniqueness)* which involves specific analysis in both stages:
  - *Preliminary design* to optimize operability and facilitate process industrialization, establishing the necessary design guidelines and producing what might be called a "*design to be built*" as well as a "*design for sustainable habitation*"
  - *Final construction design*, defining the technical specifications and conditions for such industrialization
- ***Coordination and classification of market products and techniques*** to attain:
  - Readily adapted mechanics and geometry for rationalized design (modularity and attachability)
  - Possible inclusion in a *housing construction industrialization process*, via one of the following two avenues:
    - *Closed systems*, involving the use of specific designs and components
    - *Open systems*, including interchangeable components and techniques for coordinated designs
- ***Design of an IT tool for:***
  - *Entry and updating of the various rationalized designs* obtained (first target)
  - *Entry and updating of the industrialization products and techniques* obtained (second target)
  - *Interactive use of the tool by the different actors participating in the process,* to seek industrialized solutions for real-life situations:
    - *Designers*, in particular, for their project designs
    - *Developers*, to optimize buildings
    - *Material manufacturers*, to specify product qualities and geometries
    - *Builders* to rationalize construction
    - *Users*, to optimize use and maintenance

The aim, in short, is to develop an **integrated computer-aided design system to facilitate interaction among the actors involved in the housing design and construction process** (designers, engineers, builders, suppliers, public authorities, users). This in turn entails the development of computer software that "improves" (automates and optimizes) normal design and construction tasks in the framework of existing practice, and the implementation of measures to begin to upgrade such practice through the consistent use of information and communication technologies. A second aim is to integrate the design and construction processes, as well as bioclimatic solutions.

All the foregoing should culminate in the erection of one or several "demo" buildings to verify both the feasibility of industrialization as a system for rationalizing housing construction - with lower costs and enhanced quality - and the utility of an IT tool to reach this aim. The building should also stand as an example of sustainable industrialized construction, in which particular attention is lent to aspects such as energy consumption during construction and resource consumption and waste generation once the building is in use.

3. R&D lines to be explored in the project.

3.1. Analysis of the status quo

The real needs of the various stakeholders will be analyzed: consumers, developers, designers, manufacturers and builders, along with the most representative rational design and housing industrialization computer software developed in recent years. In a nutshell, the analysis will cover any prior developments on which to base housing production rationalization and sustainability, and the integration of "ICTs" to improve housing design and construction.

3.2. *Study of rationalized housing solutions*
The typology of the many housing projects underway in both public and private developments in Spain should be analyzed to establish any corrections or variations required to rationalize preliminary design and, therefore, production procedures and sustainability. The result would be a series of "standard preliminary designs" from which to build a catalogue that could be entered into housing design software.

3.3. *Definition of sustainable housing solutions*
This activity, supplementary to the task discussed in the preceding item, would enlist the participation of all the actors involved and address the four basic components of sustainability, namely:

- ***Production process efficiency***, manufacturing materials and components in which raw material and energy *consumption*, as well as *pollution,* are *low;* and rendering construction techniques more *efficient* by using rational operations that require less labour.
- ***Low energy consumption in housing use and maintenance***, with low impact *bioclimatic solutions* and *co-generation* or CHP systems. A basic analysis of the life cycle of the solutions proposed should be included. Energy consumption will serve both as an indicator and as added value.
- ***Improvement of operability***, which entails the implementation of home automation systems for normal residential functions, as well as to ensure the most efficient use of energy savings systems; and automatic waste management techniques inside the building to enhance processing and protect the environment.
- ***Easier maintenance*** to ensure the *durability* of materials and components, convenient *replacement* and possible "*de-construction*".

3.4. *Analysis and definition of the optimum characteristics of construction products and techniques*
If the objectives are to be realistic, a system for integrating present and possible future systems and products on the domestic and European markets must be established. This will ensure the existence of elements and components usable with the computer-aided design software and that operation under open industrialization conditions with "buy and assemble" solutions is a real-world option. To this end, an exhaustive analysis will be conducted of products with some degree of prefabrication (standardized mass production) that can be incorporated into final housing units. This will involve studying schemes to ensure dimensional coordination under the design typologies defined in the preceding stage, along with an in-depth review of systems for joining and attaching the different construction components. All of the foregoing refers to both civil construction as well as building facility and service components and techniques. Moreover, an extensive study will be required to rationalize the deployment and improve the efficiency of traditional components and techniques widely used by designers and consumers.

All the above can be applied to define the most appropriate physical-chemical and geometric properties of construction products and techniques for a "*catalogue of industrializable parts and components*"; any such catalogue must be usable with the computer-aided design software intended to facilitate the task of manufacturers, designers, developers, builders and tenants in the development of sustainable and industrializable housing construction.

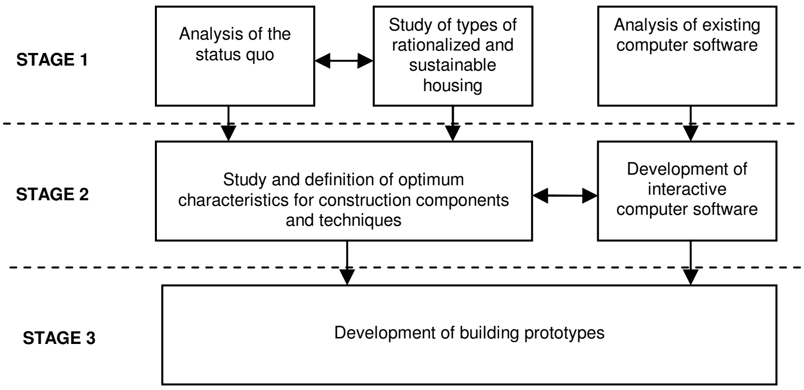
3.5. *Interactive software development*
The intention is to study and develop an IT system able to define and shape space into possible architectural solutions for housing within the limits determined by the project typology established in the preceding items. The system would be especially designed to accommodate industrialized market components or rationalized traditional techniques and sustainable solutions as well as home automation systems. Such software would constitute a help tool for *designers*, whose preliminary designs would be drafted from a series of iterations showing possible geometries and spatial relations that could be successively selected to develop the final solution. The end product should cover all the

various systems involved, from basic structure through HVAC, including facade and roof enclosures and interior finishes, as well as energy savings and home automation solutions.
It should also include the development of the *final construction design*, bearing in mind: compulsory European, domestic and regional legislation; the construction solutions accepted in the preceding item; structural engineering and interior design and comfort; construction drawings; job and technical specifications; and highly detailed bills of quantities for the solution put forward.
The program should likewise be a tool for all the other actors involved, including *developers* and *users* to define types and programmes of needs, material *manufacturers* to improve product design, and *builders* to rationalize and industrialize construction processes.

3.6. Building prototypes as demos

To complete the study and ensure its viability, prototypes must be developed to adjust preliminary and construction design procedures and guarantee the operability and sustainability of the construction solutions chosen. In addition to verifying the practical functionality of the software tool designed and its results, such prototypes must serve to analyze the actual viability of the industrialization processes involved in the assembly phase, including what might be termed the *partial industrialization of construction processes* to rationalize parts thereof. The foregoing would be performed in keeping with two possibly simultaneous options: the maximum use of *precast/prefabricated units* comprising certified components with quality finishes, and the rationalization of traditional techniques and systems to limit the amount of *on-site erection work* involving the enlistment of *unskilled labour*.
This should be supplemented with the establishment of *strict workmanship quality controls* and the possible institution of solutions to verify performance. At least two types of buildings should be erected for thorough verification, namely blocks of flats and single family, possibly semi-detached homes.

3.7. Project organizational chart showing key activities and proposed stages



4 Acknowledgments

Others Project participants:
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- DRAGADOS
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- Asociación Nacional de Derivados del Cemento - ANDECE
- Consejo Superior de los Colegios de Arquitectos de España - CSCAE
- Asociación de Promotores y Constructores de España - APCE

VBI FlexCasco, the skeleton for adaptabilities

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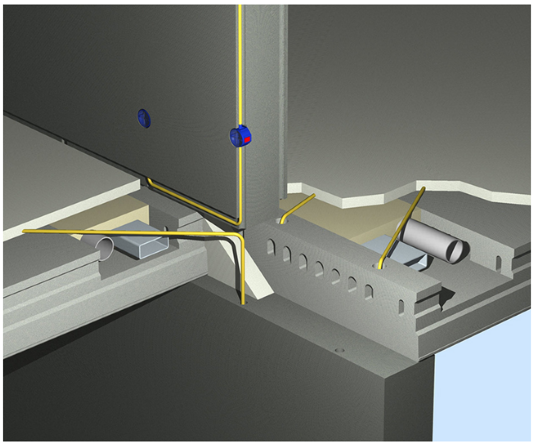
KEYWORDS

Each paper must have at least three, and no more than five, keywords. Followed by two blank lines.

Paper

VBI FLEXCASCO, THE SKELETON FOR ADAPTABILITIES



The goal of the VBI FlexCasco is to provide flexibility to all partners in the total building process and exploitation of the house or apartment, especially for the tenant or buyer. There are no obstructions to reach this goal. In the past many decisions had to be made in an early stage of the building process. Nowadays, many decisions can be made together with the client as soon as the skeleton has been built. The VBI FlexCasco offers space for all possible installations within the height of the floor and the thickness of the wall. The FlexCasco can create new possibilities for innovations of adaptable products in the finishing phase.

Building trends

The most important social trends in European countries that influence requirements of buildings, are:

- Quality:
  - demand for higher quality houses
  - better indoor climate
- Energy:
  - low energy-houses: more installations in the houses
  - more pipes because of balanced ventilation
- Flexibility
  - more individual influence to the buyer or the tenant
  - freedom of design of the floor plan

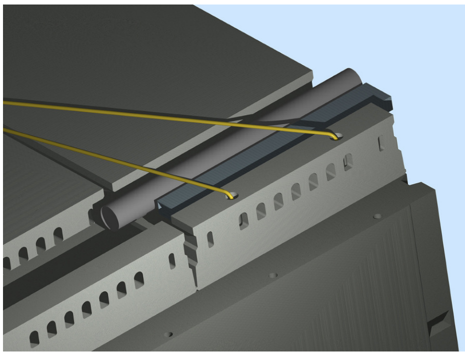
- Less labour on the building site
    - 3D: work on the building site is 3D:
      dirty, difficult and dangerous
    - more industrialised products

In the Netherlands we translated those trends to Industrial Flexible Demountable buildings. Changeable building is a keyword for the future. It concerns the development of the flexibility of building processes, the use of different building materials or building parts in order to achieve extreme flexibility and focus on guiding the customer/user/buyer. The building as far as layout and functionality are concerned, should be able to be adapted so easily and quickly at such low cost that the same or future inhabitants are still able to manage with the building.
Many building companies face the problem of how to interpret the wishes of future inhabitants. More space, more freedom of arranging the floor plan of the apartment and anticipating the individual buyers' wishes at the latest possible time in the building stage. That is the case, but how to organize flexibility?

Flexibility for everybody

Flexibility is a keyword for houses and apartments of the future. Where people used to, partly for financial reasons, settle for a limited quantity of square meters, nowadays the living room and kitchen can not be large enough. Luxury is increasingly within reach of a larger group of people. Besides, there is an obvious trend to adapt the wishes for housing to all stages of life. But also for dwellings with less m2 floor area in a normal standard situation flexibility can offer many advantages.

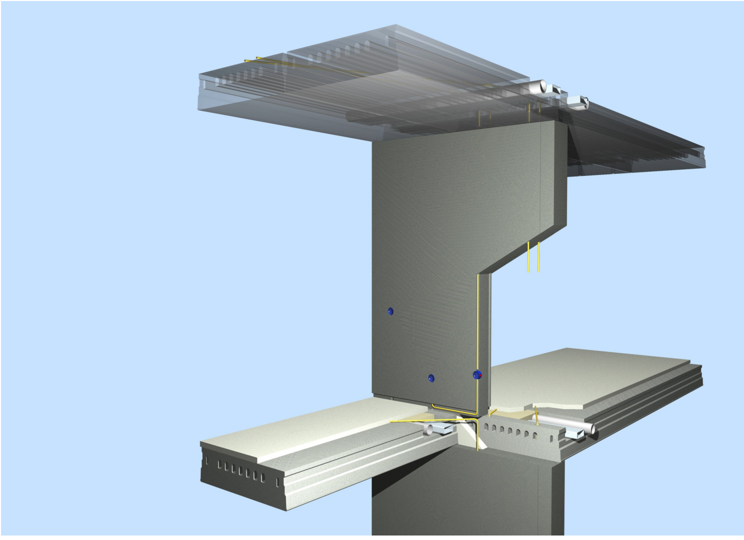
The answer: VBI FlexCasco



The VBI FlexCasco is the answer to the question about separation of rough structure (the skeleton with façades and roofs) and the finishing process. Separation of rough structure and finishing process is a real possibility. The VBI FlexCasco opens doors to flexibility in all stages of life of a building. Adjustments for care or conversions to offices or shops are easily made. This offers tremendous advantages to the architect, the contractor and the buyer, now and in the future. Every wish regarding arrangement of the floor plan can be fulfilled with the VBI FlexCasco because it offers flexible space with freedom of arrangement of the floor plan. Due to the complete separation of the skeleton and installation, the moment when buyer's influence stops is during the finishing process and not weeks before the work starts on site. And, the VBI FlexCasco offers a sustainable adaptability.

Separation of skeleton and installation

Due to the separation of skeleton and installation the building logistics change and fitters can delay their work until the finishing phase, with the result that buyers' wishes can be fulfilled until the last possible moment. Because of the option to re-open the pipe slots in a later stage, an easily adaptable building is obtained. Besides this the pre-stressed floors of the FlexCasco, the VBI Apartment Floors, enable large free spans up to 11 meters in length.
Because the load-bearing intermediate supports can be left out, large free spaces with full freedom in arrangement of the floor plan are obtained.



PRINCIPLES OF THE VBI FLEXCASCO

The VBI FlexCasco is a skeleton system that meets all quality and sound requirements and enables a complete open free space in each apartment of the building in which you can make all possible floor plans. Due to this buyers' or tenants' requirements can be met until in a very late stage in the building process, during the finishing phase and later at all times.

Dry-stack system

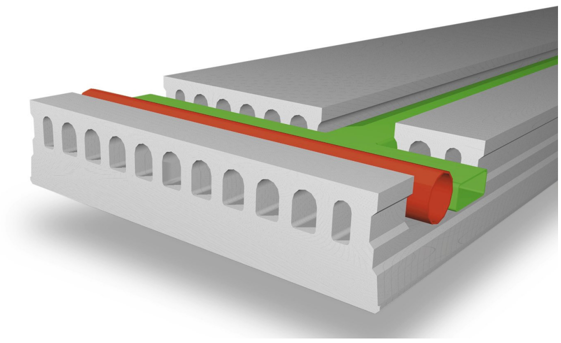
The VBI FlexCasco is a dry-stack system with hollow core floors and prefab walls. This contributes to a clean, dry and especially a fast way of building. This building logistic offers great advantages to all projects and especially inner-urban building projects.

No load-bearing intermediate support

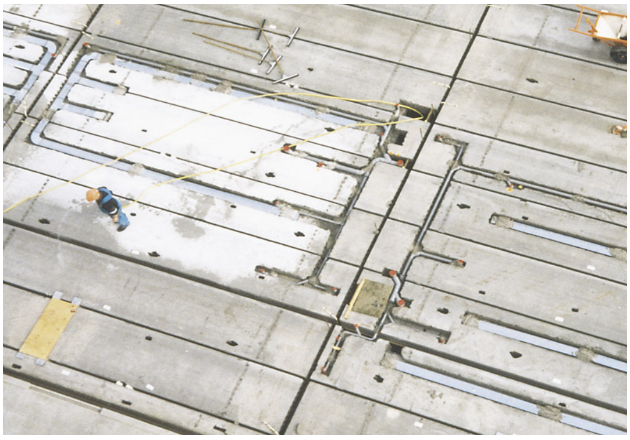
Until now large apartments were only feasible with a load-bearing intermediate support. With the VBI FlexCasco it is possible to design 11 meters wide apartments without any constructive interruption. The inner walls can therefore be situated at the buyers' discretion.

Pipe Floor/Apartment Floor

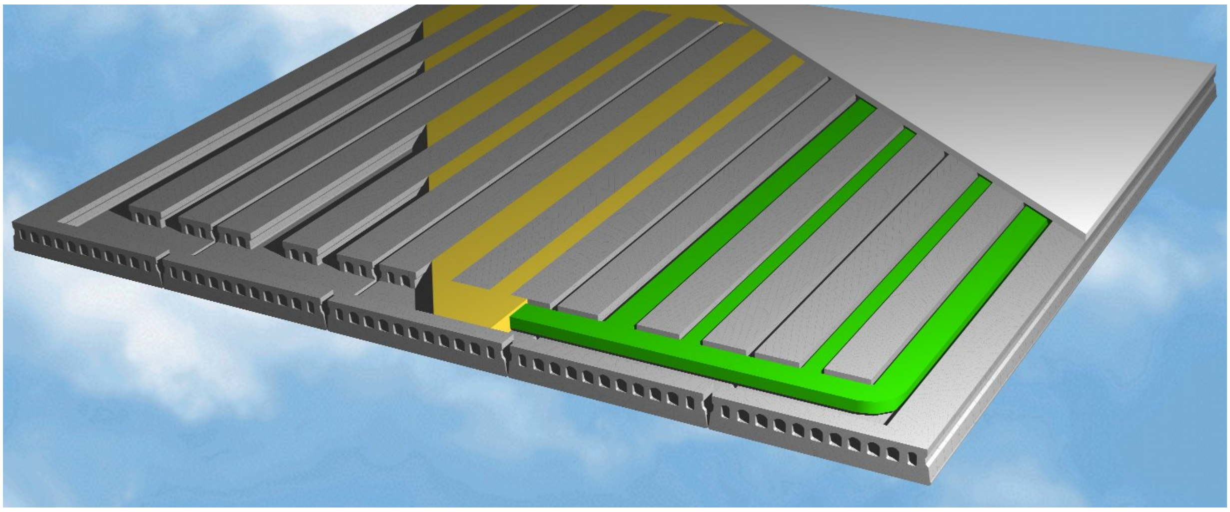
Inside the horizontal surface the flexibility of the installations in particular can be delivered by means of the slots in the VBI Pipe floor and Apartment floor. Slots can be delivered parallel to the support up to 700 mm wide. In the direction of



the span slots can be made in a width of 140, 240 and 340 mm. This way a pattern of slots develops, in which installations can be concealed in the constructive height of the floor. The slots do not need to be closed with a constructive concrete.

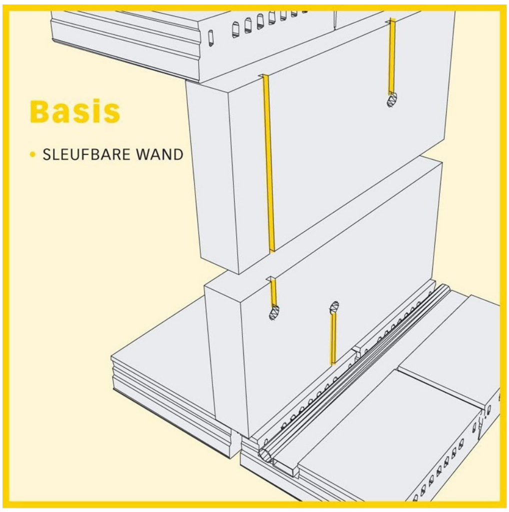


The standard pattern of slots in the floor guarantees the flexibility even after delivery of the apartment. The slots can easily be re-used by ways of filling them with stabilised sand. All varieties in arranging the floor plan require a different course of direction of slots and these also are simply fitted in. In the Apartment floor also predetermined extra slots can be made, so inhabitants' wishes can be incorporated until the last possible moment.



Walls combined with the Pipe Floor and Apartment Floor can be delivered in the following three varieties:

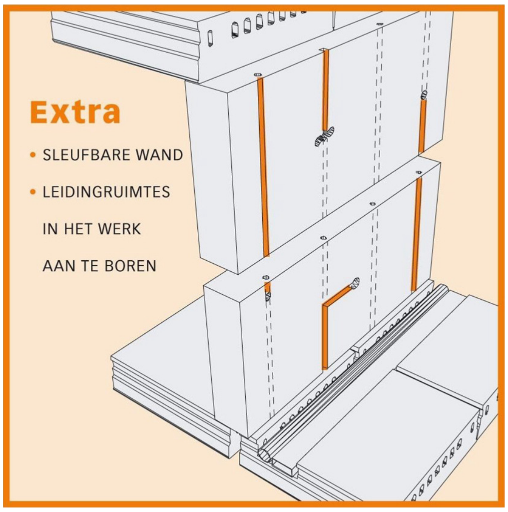
VBI FlexCasco-Basic



This variety links the advantages of the VBI Pipe Floor/Apartment Floor to slottable prefab walls. The walls are assembled in such a way that they comply with noise regulations. The walls permit easy slotting. Electric wiring, wall outlets, computer connection points, water pipes, etc. can be placed at any chosen location. This variety offers a provision in the floor for the linking wall / floor.

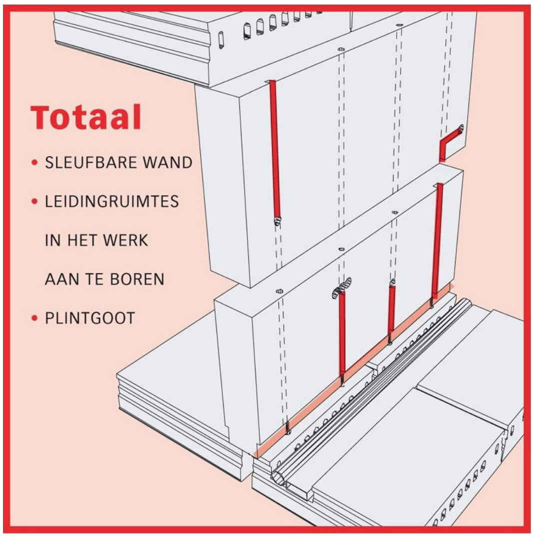
VBI FlexCasco-Extra

In the VBI FlexCasco-Extra the advantages of the basic solution are extended by providing the slottable walls with vertical ducts (centre-to-centre 600 mm). These ducts offer space to vertical division of electric wires and/or communication lines. Slotting is no longer necessary. It is sufficient to drill into the vertical ducts in the finishing phase in order to place the wall outlets at any wanted location. The fine grid also offers the possibility to realise future adjustments / additions more easily.



VBI FlexCasco-Total

The highest degree of flexibility is realised with the VBI FlexCasco-Total. The wall elements in this variety provide a 30 mm deep horizontal rebate on the bottom side in addition to the vertical ducts. This rebate offers space to neatly conceal all cables and wires for e-installations as well as antennas, wires for sound boxes, etc. behind a skirting in a skirting board system. This enables adjustments and additions in the finishing phase or in a later stage by simply drilling in the vertical ducts and wiring via the horizontal skirting board system.



Electrical provisions

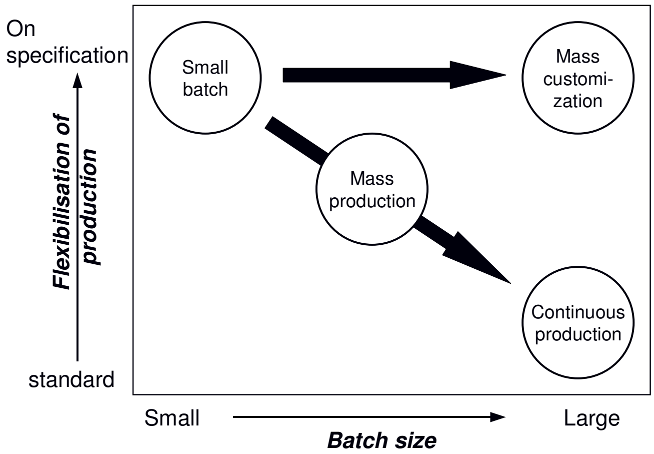
By installing the electric pipes beforehand in the rough structure phase, all varieties remain feasible. Just drilling in the finishing phase is sufficient in order to place the wall outlet at any desired location. It is even possible to make a connection from below via the skirting board as well as to fit in the television and sound system in a later phase. In the traditional way of building the installation of pipes needs to proceed the casting of the floors. Now, it can be planned as closely as possible before the moment of completion of the apartment.

Living - working - shopping

Even taking future developments into account the VBI Apartment Floor offers maximum freedom. Due to the large span it is possible to build parking garages underneath the apartments, or to give storeys a different purpose. This increases the yield of the building even in a later stage of the building's life span.

VBI FlexCasco offers opportunities for industrialisation of the building process

In real terms it comes down to it that consumer friendliness mainly manifests itself in a process or production-related approach. Historically there are three ways of production: by piece, series and continuous production (such as in the petrochemical industry). The serial size increases in this set of three, the product flexibility decreases. From the past, the production of hollow-core floors is usually a series product, like all prefab products. Because of recent ICT-developments and process control, more flexible production methods have become possible maintaining scale effects: flexible production (building in series with added flexibility).



Therefore, mass customisation (industrially clustered standards based on thorough market investigations) is not the same as piece production or serial production. In construction continuous production does not occur at this moment. Current house building is somewhere between piece production and serial production, the industrial production of prefab concrete products have all the characteristics of serial production. The latest development of the products for the VBI FlexCasco complies with mass customisation. The answer to flexibility and adaptability.

Building site becomes logistic workplace

A complete building can be designed based on prefab elements. And with larger spans infinite possibilities regarding the free arrangement of floor plans develop. This is what builders and architects can work with and what the building industry has been waiting for.

To choose and connect any façade (wood or ceramic/stone-like) to the VBI FlexCasco and to install heating and cooling installations as well as modern e-installations/provisions are easy and simple. This way building sites will grow more and more into logistic workplaces, with more efficiency and building speed and a decrease in cost of failure. These principals can offer their buyers and tenants a house or apartment with every freedom of arranging the floor plan and with a guaranteed adaptability.

SUMMARY

The VBI FlexCasco offers the possibility to:
- Build for every course of life
- Provide more flexibility by means of free arrangement of floor plans
- Easy to make free spans up to 11 meters
- Build more quickly
- Install the installation of pipes more efficiently in one labour cycle after finishing the skeleton
- Re-use skeletons for different purposes
- Achieve a higher yield
- Realise lower management costs

Slimbouwen®, adaptability on an economic basis

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KEYWORDS

Adaptability, Product development, Sustainability, Efficiency

1 Introduction

Slimbouwen might be translated as Smartbuilding. Slim in Dutch means smart but in the Netherlands we use the English meaning as well. Slim might therefore also be translated as lean and mean.
In the 20th century technological and market developments, have so to say surprised the building infrastructure. After many centuries of relative standstill the society and its needs developed quite rapidly, but at the same time we basically maintained our building methods. Fortunately the conscience is growing now that our building tradition causes severe societal damage. Taking this into account, the conclusion is that we cannot continue our traditional building approach.
On the other hand the question does rise to what extent the building industry is capable to react? The building industry is fragmented into many small parties and none of them plays a leading role. Everybody feels like being a follower. For this reason the obtained and existing innovation is carried out on a component level and is hardly of a conceptual nature. As a consequence the achievements are to be characterized as 'innovation by addition'.
In this contribution the author presents the history of traditional building with a special focus on ancient Roman architecture and the influence of casting iron techniques since they both have still mayor influence on the today's building technology.
The Slimbouwen concept will be presented and explained and elucidated with some examples of practical experiences. The presentation will also give an overview of the research field including some present research items. In other contributions at this conference some of these research items of the Slimbouwen Research Group are explained in more detail.

2 Structural building innovation up to 1900 AD

The traditional building process is also nowadays strongly based on ancient lines. Often it seems that certain phenomena in building are invented at a certain point, but in many cases they evolved slowly and remained through the ages. Sometimes they even were forgotten and had to be reinvented, not to speak about the never reinvented values which might even still be hidden for us in our era.
The ancient Romans applied the stacked construction method (building with stone or brick) on a large scale. Building with stone was already well known for centuries, but the techniques were revolutionary developed and exploited by the Romans.
In the Roman building technique the development of the masonry in particular is of great importance. The Romans already invented cement mortar and for efficiency reasons they contagiously developed a kind of poured concrete method. This method was named 'Opus Caementitium' 'fig 1'.

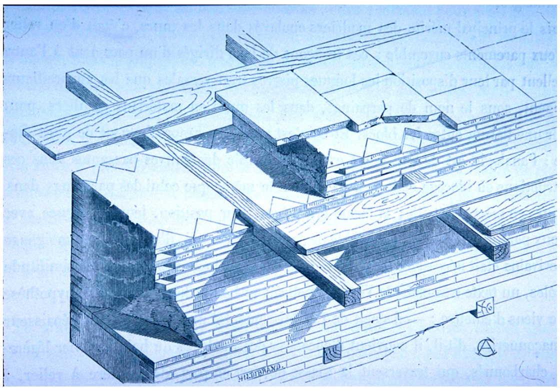

Figure 1. Opus Caementitium

On what remained from the Roman building technique is not representative for the reality. Also the ancient Romans constructed a lot with timber, but since wood did not stand the time of ages as well as stone does, a misrepresentative impression remains. Frame technology was also a regular technology.

In the 18e en19e century cast iron and steel was introduced as a new construction material. Cast iron already existed, but Abraham Darby discovered in 1709 in Coalbrooksdale that by using cokes as a fuel, higher temperatures could be achieved. This discovery facilitated the realization of larger foundries, larger casting-ladles and thus larger parts. His grandson Abraham Darby III produced and built in 1779 near Coalbrooksdale an iron bridge over the river Severn. Yet it lasted up to almost 20 years for this new technology concurred a broader basis. After that it became clear that a basis was created for the industrial approach of building and especially steel frame construction methods.

A famous example is Crystal Palace of architect Joseph Paxton, a world exhibitions building in short time erected in 1851 in Hydepark London and designed on the necessity of moving the building 'fig. 2'. It has been demounted and rebuilt in 1853 in Sydenham London where it functioned for many years. Unfortunately in 1936 it was destroyed by fire. Crystal Palace was an early example of building in glass and steel. One of the examples of disintegration of structure and fill in.

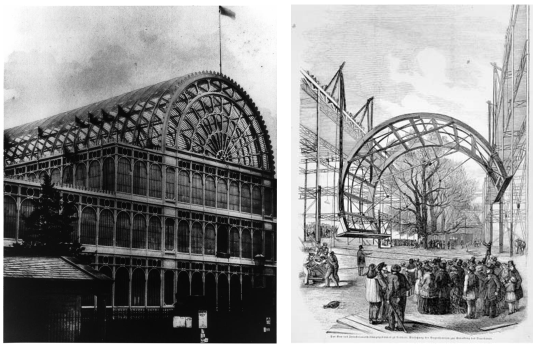

Figure 2. Crystal Palace (1851), an early example of industrial and demountable building.

3 Innovation by addition in the 20$^{\text{th}}$ century

Through the ages we maintained the existing stacking and frame techniques and we only added lots of technology on a component level. That is what is meant by 'Innovation by addition'.
Adding to the existing creates inefficiency at the end and that is exactly what happened in the construction industry.
The inefficiency mainly is caused by adding lots of installations and services during the last century. In 1900 the installation technique was limited to a sewerage system, water supply and a chimney.

Now, 100 years later, the installation technique is about 30-40% of the total building budget. Nowadays we use to hide them in walls in milled chases, being covered afterwards or we hide them into poured concrete constructions. We hang them under floors covering it with suspended ceilings. Through this way of stacked innovation the interweaving of services with the building parts has become very high.

This is an important conclusion since it has caused an inefficient building process. For one thing, the consequence is that the finishing process has become very complicated and is carried out by many disciplines with a high rate of mutual interdependency.
All in all it is remarkable that the building method as a whole never was rethought.

4 When is change to come?

A number of eye-openers show that the traditional way of building in the contemporary context is no longer tenable. The statements are based on the Dutch situation, however the effect is quite similar in other Western and industrialized countries.

1. For the realization of 1 m^2 net floor surface 1,000 up to 1,500 kg of building material is applied. To compare: A mobile home weighs 80-100 kg per m^2;
2. The building industry is responsible for 35% of the total waste production;
3. 25% of all road transport of goods is building related;
4. The production of building materials represent 8-10% of the total energy consumption;
5. 25% of a building volume is packaging. Customers rent or buy gross volume of which about 25% is taken in by building structures or hollow cores.
6. The price of houses is compared to consumer goods considerably risen;
7. Buildings are built with a technical life span of 100 year or more, but often they are demolished already within 35 year. The market and users are obviously significant more dynamic than the flexibility of buildings permit;
8. The traditional building process requires a lot of building site personnel and expertise that is not sufficiently available;
9. In an industrial environment profits are in the range of 10% of the turn over and falure costs in the range of 1-2%. In the building industry (contractors) it is the other way around;
10. The progress in the early stage of the building process (structure and shell) is experienced as rather fast The top of the building is generally realised quite soon after the foundation ceremony. After that it looks like there is no progress at all.

The eye-openers can be considered as symptoms that support the theorem that rethinking the building industry is unavoidable. The building industry, including technique, process as well as organization has, by the addition of many incremental innovations, evolved to the present mayor inefficiency and source for environmental damage.

5 Slimbouwen

Industrial and flexible building has been subject for analysis and developments for a long period. In 1914 Le Corbusier came up with the Dom-Ino concept. It was based on separation of structure and fill in. However in those days Le Corbusier hardly had to deal with services. In 1972 Professor John Habraken published his book “Supports, an alternative to mass housing” (already published in 1961 in the Dutch language). In that book he made statements about a separation of structure and infill and later he was also involved in developing technical solutions for the separation of services.
These developments were primary aiming on variation and/or the possibility of customizing houses. In addition Slimbouwen is strongly aiming on the efficiency of the process and the reduction of materials and volume. Through the economical advantages of this approach adaptability and sustainability, mostly considered as an additional performance, become feasible.

In the eighties and ninetieth, at Eindhoven university, experience with the separation of services was embodied in a research and development project, the so called ISB project (fig. 3) that has lead to two prototype houses and a broad discussion about how to build with breakthrough results.

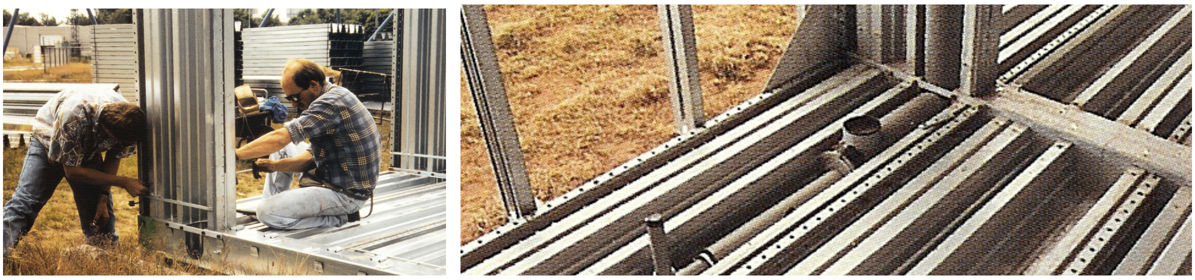

Figure 3. The ISB project

Slimbouwen is a strategy to obtain integral solutions. Important objectives are the reduction of fixed parts and the detachment of installation parts, both physically and from an organizational point of view. This detachment makes the building process transparent, makes buildings adaptable, does substantially improve the efficiency of the building process and also reduces the use of material, transport, energy, CO_2 emission, dust, etc.
Crucial is the detachment of services which enable to organize the building process in a sequential way with only a few subcontractors responsible for structure, skin, services and infill.

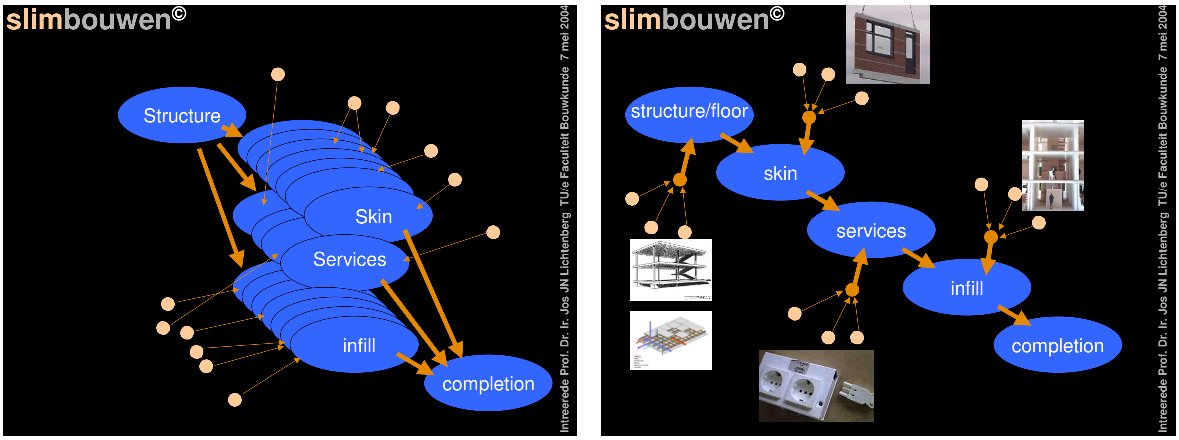

Figure 4. Traditional parallel process (l) vs. Slimbouwen sequential process scheme (r)

Figure 5. Examples of detachment of services

6 Research

Within the restrictions of available technology, Slimbouwen is already being practiced and applied in quite some projects in the Netherlands.
Apart from the direct benefits the Slimbouwen strategy also leads to and gives direction to scientific research and individual development efforts in business.
Recently a foundation was erected a.o. reasons to provide for structure for the benefit of the diffuse building market at one hand and to give financial support to research at the university at the other hand.

The author started up the research programme in 2004 and right now about almost 4 research employee equivalents are working in the programme, the most of them in the starting phase of their research.

To give an overview of the main present research items:
- Slimbouwen tools for design and organisation of the process (Jos Lichtenberg);
- Productdevelopment for Slimbouwen (Mark Cox);
- Flexible structures (Roel Gijsbers);
- Building for the elderly and the role of domotics (Masi Mohammadi);
- Energy saving in existing housing market (Michiel Ham);
- Free form technology (Arno Pronk);

Some current research topics from other cooperating research groups at the University in Eindhoven that are fitting in the Slimbouwen program are:
- Vibration in light weight structures (Sander Segers);
- Industrial foundations (Dr. Faas Moonen);
- Market adoption of Low cost housing (Zakari Mustapha);
- Prefab Housing (Maarten Willems);
- Polynorm (Guus Timmermans);

Some of them also contribute at this conference

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Lafarge roofproducts,
"THEY EVEN LINKED THE TUMBLE DRYER IN THE RIGHT PLACE"!

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Keywords

CHANGES

The dutch constructionmarket changes from a providermarket to a buyermarket, which means that at constructionpart pitched roof all concerned parties should give a suitable answer to the wishes of the consumer.

Hereby should be considered effectiveness, efficiency, flexibility, functionality, workability and aesthetics, during the whole buildingprocess from design until the realization of the building.

The focus on the dutch roofmarket will therefore be more and more developed from productlevel to constructionpartlevel. Premanufacture and combining different functions in systems should be a base with productdevelopments.

The fact that we have to deal with more severe regulations; the constructionregulation (Bouwbesluit) is based upon the performanceconcept, and, not to forget the more strict ARBO(Labour)-regulations(security), will lead to the rise of constructionpartspecialists. In the case of the constructionpart roof we speak about the roofer.

The question that we, as an important producer of rooftiles and all relevant roofsystems, asked ourselves a few years ago is: do we limit ourselves to providing materials and systems or should we go further.

LIFESTYLE

The pitched roof is by the consumer being considered more and more as a lifestyle; the pitched roof creates living space and the consumer wants to fill in this living space himself, wants to make his own choices for his roof, the shape of the roof, the materials and the roofsystems. The consumer wants a free choice in finishing the inside as well as the outside, a free choice in divisioning the space, a free choice in whether or not a sun-energy system, a skylight, a dormer for satellite-aerials and so on.
The consumer is prepared to pay for this freedom of choice.

The developer is strongly searching for the wishes of the consumer, he wants to be on the same wavelength with the consumers wishes, by delivering the additional value and by offering flexibility during the sale and the construction process.

The question is how to realize this promises in practice.

CONSTRUCTIONBUTTONS

The consequence of this developments to tune to the consumers wishes is that more parties are being involved by the design of the pitched roof. Next to the projectdeveloper are this for example the architect, the contracter, the roofer, the installer, the consumer et cetera.
By the increase of the amount of involved parties is the chance on constructionmistakes and communicationdisturbances higher.

A good example of where things can guaranteed go wrong is the eaves detail.

When you look at this, there are more then two hands full of disciplin involved: the designer, the tunnelcrew, the bricklayer the carpenter, the roofpanelsupplier, the rooftilesupplier, the roofer, the plumber etc.

The logistic process gets more complex also. If anything goes wrong, the costs of repair are sky-high.

THE CONSTRUCTIONPART ROOF

Most important is that parties are being involved in the design of the pitched roof in a far earlier stage.

To offer the complete constructionpart roof as a supplier of all roofsystems was only just a logical step for Lafarge. We developed the following formulas: Fixum as a formula for the new buildmarket and Fides for the renovationmarket. It is about a cooperation with certified roofers from the foundation Dakmeester.
The concept co-maker is particularly in its place with new building.

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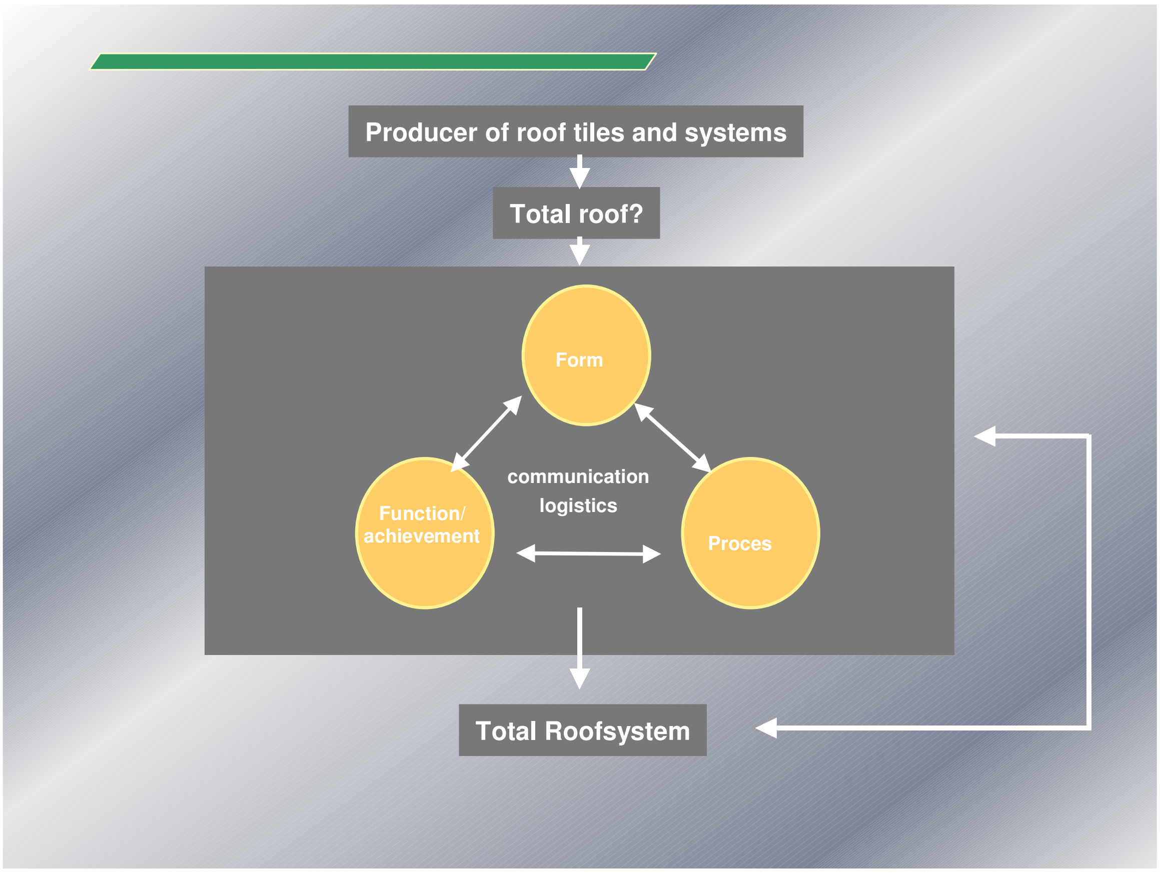


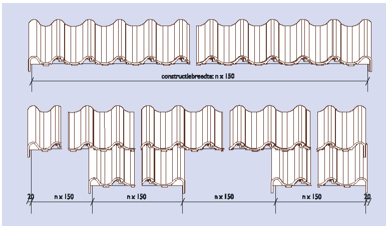
MODULARITY

When we want to create more flexibility, also during the building process, it would be a great step forward when the designer is developing with standardized systems, for example works with modular sizes.

Modular sizes can be easier understood, delivers a cost reduction where preparation time is concerned and gives the possibility to be flexible with adjustments, without the need for sawing and cutting. When developing roofsystems, manufacturers should take this into consideration.

A good example is the development of a new ceramic rooftilemodel by Lafarge dakproducten: the "Nieuwe Hollander".

Modular System



Measurements: n x 150 mm

Modularity: to be divided into equal parts, fixed measurements, allways right adjustments, perfect fit between different modules and building materials, higher efficiency, saves money and time, flexibility for future owners.

Our concrete tiles are all based on this modular system, ceramique tiles before the introduction of the Nieuwe Hollander did not yet use this quality.

INVOLVEMENT

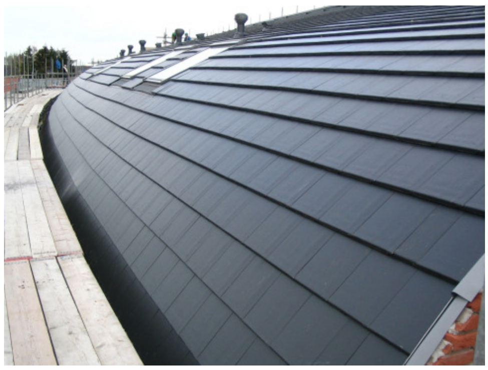
Involvement in a very early stage when designing is a prerequisite, most certainly when dealing with somewhat more complex concepts/design.

An example of good preparation:

Basic design was a metal roof, an alternative was being searched for reasons of building physics and environmental considerations.

Working method: consultation between designer, the roofspecialists for pitched roofs, Lafarge Dakproducten and the processor, a certified roofer from the Dakmeester foundation. Picking the most suitable tile model for this kind of job, in cooperation with the Dakmeester. The set up of an experimental roof to determine the horizontal as well as the vertical radius.

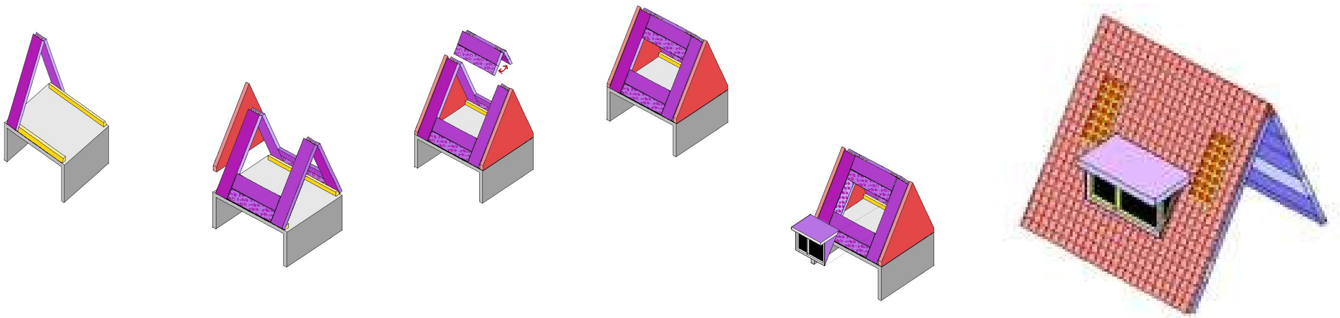
Approval of the experimental roof. Consultations with the roofpanel supplier on behalve of the correct segmentation of the roof.



ROOFPANEL, PREFABRICATED

Our vision concerning roofpanels is that they should be designed in such a way that a 100% flexibility is possible both during the building phase as in inhabited state.

Example of the systemconstruction:



The benefit of this systemconstruction is that sizes are standardized (modular sizes a multiple of 150 mm) it provides flexibility during the building phase, consumer: "*on second thought, we do want a dormer …*" and as an extra benefit the inhabitant can remove an element and order an element complete with sky light or a dormer without any need for sawing or cutting. Isn't it easy?

Benefits of this system:

The complete constructionpart roof, to be contracted by one party, certified processing by the Dakmeester, everything into one hand, simple logistics, industrial quality and expertise, expertless installation, limited coordination between different disciplines, reduction of material, weather independent, roof ready in one day, all roofdetails canalized to the roofspecialist.

Cost reduction by standardization, less preparatory work in planning/production by mainly standardized components, flexible last minute changes possible, quality improvement possible by repeating character, unrestricted rearrangement of the roof, modular system guarantees adaptation afterwards.

LIBERTY OF CHOICE

Last but not least: if we want to offer the consumer freedom of choice, we will have to show him/her something as far as the roof of a home is concerned. In that case we have to develop tools to do the job (they can be found at the website of Lafarge Roofproducts:
www.lafarge-dakproducten.nl, roofdesigner).

Mass Customisation concepts for the European market

a new challenge for the building sector

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1. Technology and freedom of choice.

More and more customers in Europe know their rights and want their individual wishes to be met as closely as possible.

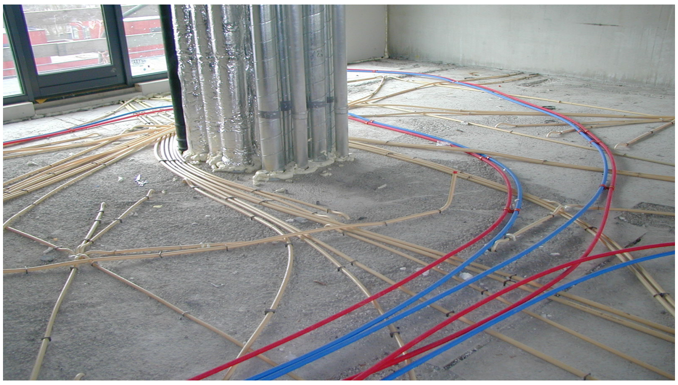
In a growing number of projects where integration of the electro technical installation, ICT requirements, domotica, multimedia, comfort, care and security functions is being discussed, it is crystal clear that these technology and applications are needed and necessary.

A look at the technological and social developments in buildings in the Netherlands, you can conclude that only lighting is obvious, while electrical engineering is self evident and almost everything is possible. In society freedom of choice is obvious, and technology has to be within range and operated with one press on the button.

People change, their circumstances change, their demands change and the capabilities in buildings need to keep up with those changing requirements. Every phase in life comes with different individual needs. One day we will be confronted, rather suddenly, with huge investments/ costs and tremendous adjustments in order to bring a building up to date.
Up until recently, the actual realisation of a system that combines all those requirements was only achievable for those who knew what they are doing now and in the future and are financially capable of doing so.

2. One integrated installation system standard in every building.

While discussing the individual requirements, on a customer base, to develop large scale building projects, a conflict, between those who are in favour of building industrialised and well-organized, and those who are in favour of improving the adaptability to personal needs and wishes, is eminent. The main reason for this conflict is that



every system is a stand-alone not inter- operable subsystem.

Without having a economic solution for the pasted 50 years, buildings (dwellings) are still build with the technology of 50 years ago. A basic AC power supply infrastructure and lighting only, is installed. Every other system and applications, with high costs, is additional added in the future.

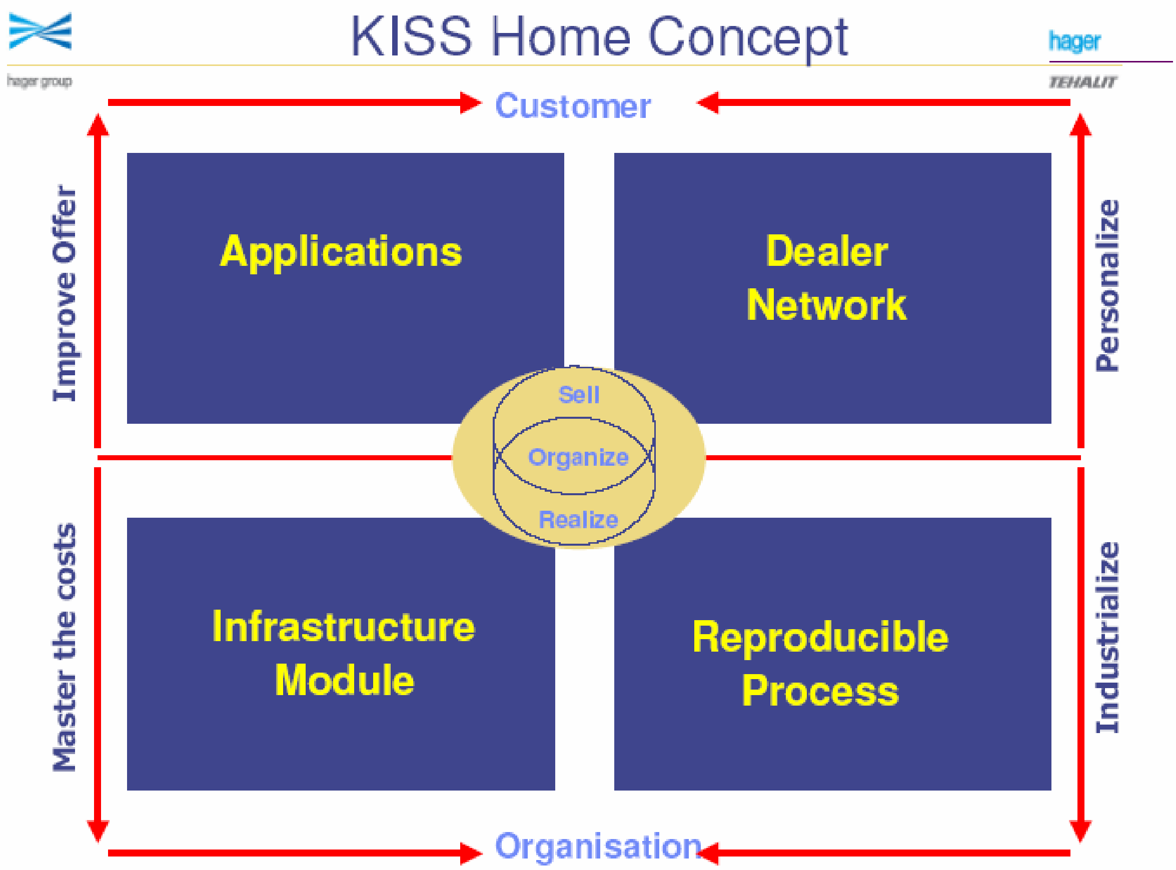
In, large scale, projects all participants face an additional challenge. Development should at least be market conform. The added value should therefore be affordable and at the same time fulfil as much individual wishes as possible, without actually knowing the specific individual requirements of the owner or tenant. The KISS Home concept is the integral solution to bring demand and offer together.

3. KISS Home vision.

In the KISS Home vision Hager Tehalit NL wants to give the customer a lifetime Freedom of Choice regarding the use of the building and personal needs, by creating flexibility, certainty and profit. Therefore you must personalize applications and functions to improve the offer and created customer value, and offer services within a dealer network.

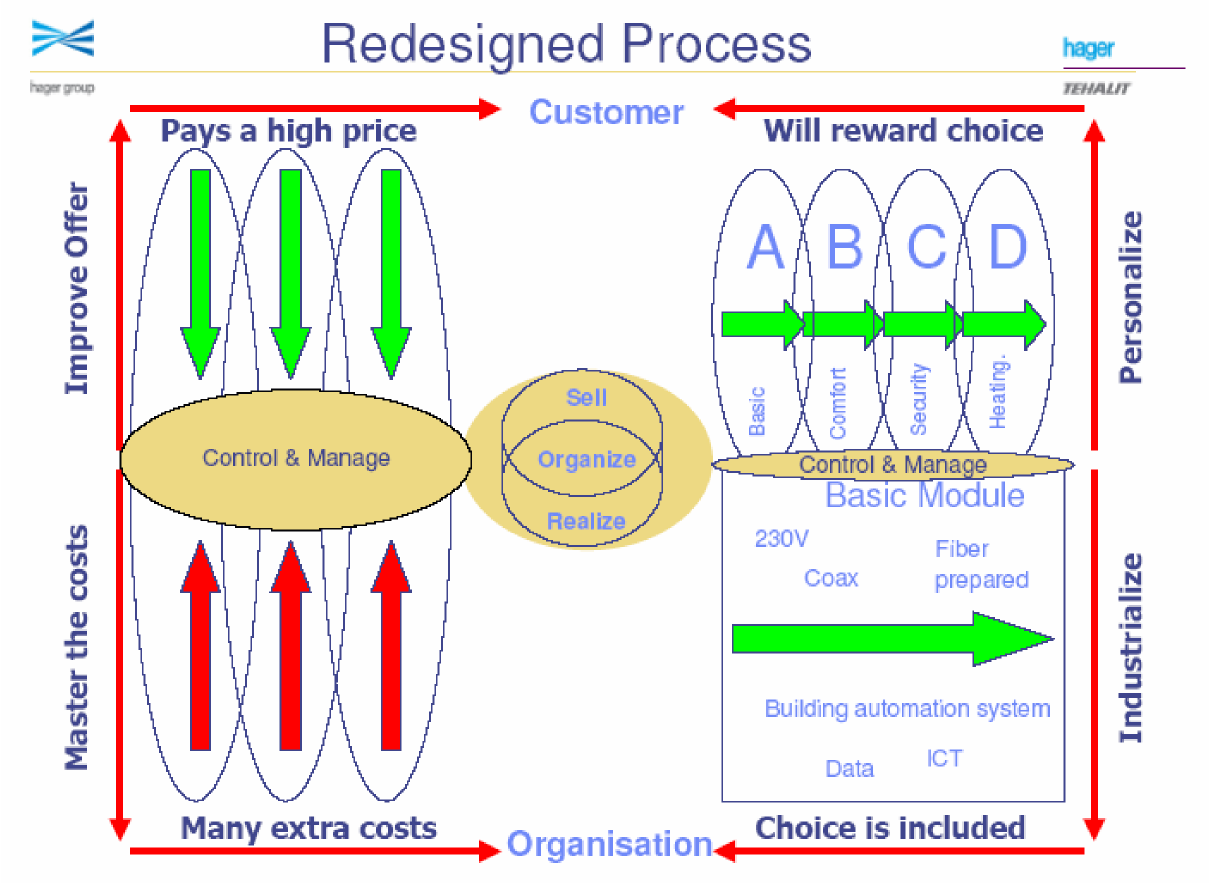
In the KISS Home vision Hager Tehalit NL wants to give organisations a platform to develop, design and build and control and manage the process. Therefore you must industrialize to master and decrease costs.

4. KISS Home Concept.



The model shows that the solution is to divide the customer processes from the building processes. For organisations that are focussed on the building process you have to create an basic infrastructure module. I f you can apply this module on a large scale, and you can reproduce it in all your projects, this will give you an industrial and economic advantage.
With the module you have a uniform basic installation system, an easy process and planning, you can share knowledge quickly, a flexibility system prepared for the long term and no additional high costs in the future. In the current traditional approach every project is unique, takes more time to prepare, is difficult to document, is difficult to change in the future, en therefore relative expensive today with high costs in the future.

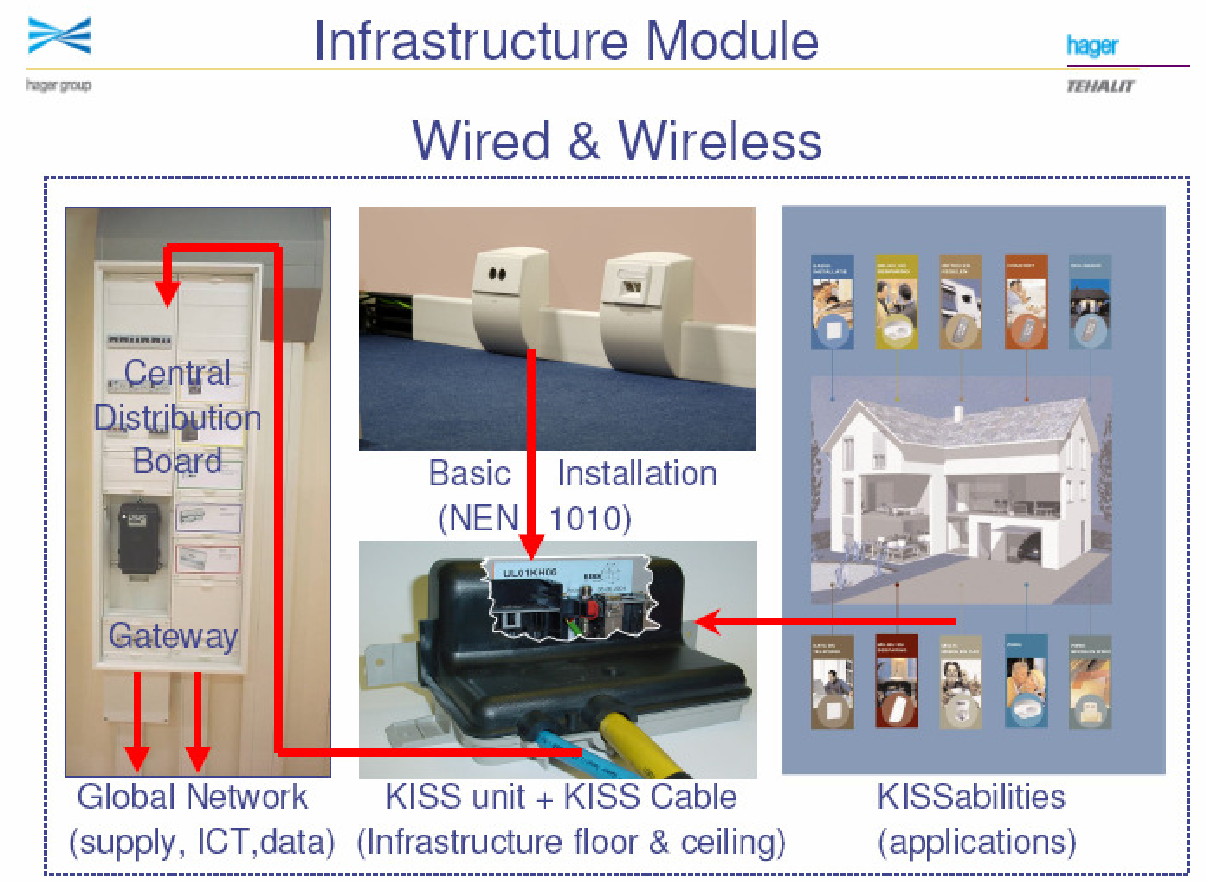
The separation of the costumer process from the actual building process by approaching usability and realisation as separate processes you can manage them both on a different organisational level. Fortunately this approach does not require a complete change of the current processes. Only the separation of the processes and accepting a new uniform standard will do the trick.



With the integral standard basic module every application can be added to the system as late as possible in the, even after, building process. Dwellings are pre-fitted with a basic electro technical infrastructure, a combination of a wired and wireless system, prepared for the future, giving the tenants and owners the possibility to adjust the installation to their specific needs right away or in the future.

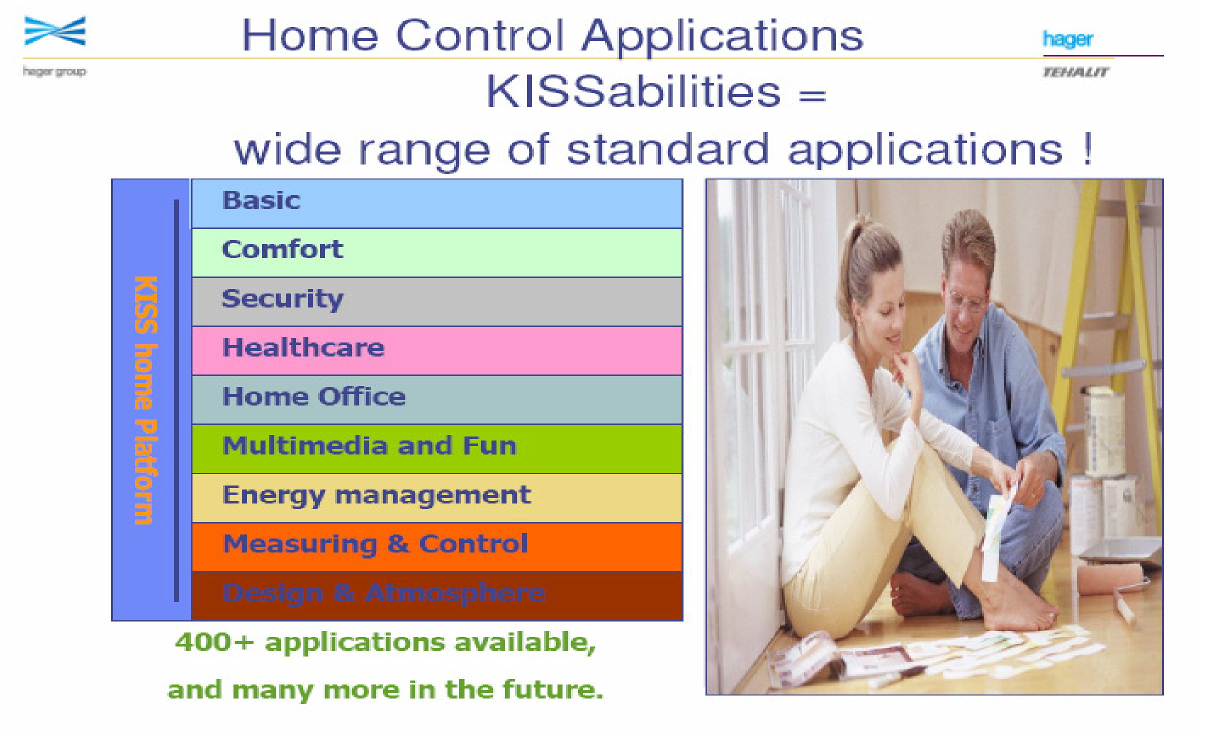
With only a minor additional investment, depending on efficiency levels even cost neutral, parties can actually offer individual freedom in large scale building projects and at affordable rates too.

5. Concept Infrastructure module & Home Control Applications.

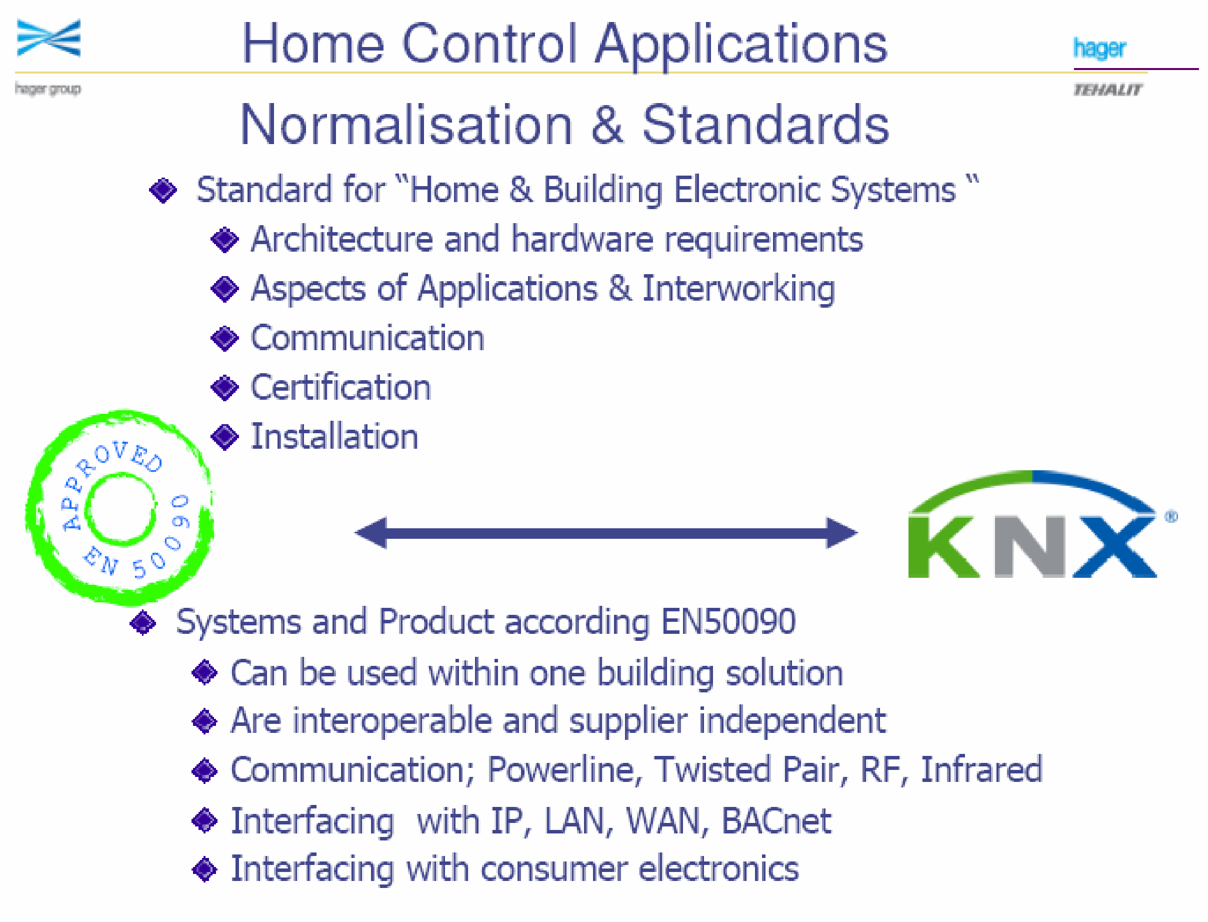


The infrastructure module contains the central distribution board as a gateway to local and global networks and a pre wired cable unit and skirting system.

A wide range of standard outlets and applications can be adapted to the system including building automation. hese applications or functions can be personal offered to the customers without discussing the contents of the technical installation.



Home Control applications are according to the EU standard EN50090 based on Konnex.



Conclusion;
As far as the electrical installation in a home is concerned, developing and building parties now can solve the problem between demand and offer once and for all with the KISS Home concept. They can consider current and future customer needs and current and future building technologies within one concept.

References;
The KISS Home concept is currently successfully used in projects in the Netherlands.
Project references and system information can be found on www.hager.nl and www.kisshome.nl .

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April 2006

Diffusion of Innovation in the Residential Building Industry

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Keywords

Innovation, residential building, diffusion;

Abstract

Housing has been one of the major problems in the developing countries because construction is not able to keep pace with rapid population growth. Standards in construction techniques differ from one country to another. Innovative sustainable construction materials and construction methods have been used in the design of low-income, flexible and comfortable family dwellings in the developed countries. This paper will outline the research programme for the adoption and diffusion of innovative building technologies. The research was designed to investigate the mechanisms that have an impact on the diffusion of innovative building technologies in the industrial practice of low-income residential buildings in the urban areas of developing countries: the case of Ghana. Majority of the individuals in Ghana are squeezed to variety of pressures, of which increasing urbanisation is another contributing factor to the low income individuals. The most vulnerable groups are urban workers in need of rental accommodations. The population of Ghana is about 21,000,000 million and a population growth rate of 1.25% (CIA fact book 2005, last updated July, 2005: * Estimates of 2005).The adoption and diffusion of innovative building technologies from the industrialised countries can help solve the housing problems in the developing countries.

Introduction

The focus of the research will be on the mechanism for the diffusion of sustainable innovative building technologies that have been developed elsewhere and could be adopted and applied in developing countries.Adoption and adaptation of the innovative solutions is assumed to enable the construction industry to improve its performance, the built environment as well as its contribution to the socio-economic situation in the country. This research intends to determine the actual mechanism that has an impact on a successful diffusion – i.e. adoption, adaptation and application- of sustainable innovative solutions for the construction of adequate houses for low-income households in the urban areas in a developing country like Ghana. Information about various sustainable innovative engineering solutions and conceptual drawings of residential building technologies will be collected and assessed on their potential for implementation in the construction industry. A critical requirement for these options is that the building technologies should be based as much as possible on the use of locally available (natural) resources.

A theoretical framework that is derived from an extensive literature study and that is in majority applied in the industrialised world will be used to investigate the particularities of the diffusion mechanism that might have an impact on a successful application of innovative solutions for the construction of adequate houses for low-income households in the urban areas in a developing country like Ghana. These theories state that technological advancement and diffusion are subject to the particular attributes of the socio-cultural, economic and technological environment in which they take place. It is also named the socio-economic landscape with its technological regime which has an impact on technological innovation (Nelson & Winter 1982; Patel & Pavitt 1994; Malherba & Orsenigo 1996; Kumaraswamy & van Egmond 2003).This, research contributes to (a) an improved understanding of actual mechanism at work in the adoption and application of innovative building technologies in the residential building industry in Ghana; (b) a possible improvement of the theoretic framework for the investigation of the particularities of such a mechanism in a developing country with an operational environment of the construction industry that differs to a large extent from that in the industrialised countries.

Introduction to diffusion of innovation (DoI) Theory

Diffusion is the process by which an innovation is communicated through certain channels over time among the members of social system (Rogers 1995).In the first stage, diffusion theories immerged from a sociological study applied by Ryan and Gross in 1943. Interviews were used with adopters of an innovation to examine a number of factors related to adoption. The interview-based methodology used in the Ryan and Gross study has remained the predominant diffusion research methodology ever since (Rogers 1995).Everett M. Rogers' book Diffusion of Innovations, first published in 1962, and now in its fifth edition (Rogers 2003) is the closest any researcher has come to presenting a unified theory of diffusion. It is understood in the meantime that diffusion of innovations is a multidimensional process and that a multitude of factors have an impact on this process as well. Rogers ‘work has attracted many scholars to the diffusion research and brought over 5000 published studies on the diffusion of innovation in various disciplines for the past six decades (Haider & Kreps 2004).Four of the theories discussed by Rogers are among the most widely-used theoretical approaches of diffusion: Innovation Decision Process; Individual Innovativeness; Rate of Adoption; and Perceived Attributes.

Innovation Decision Process

The stages in the Innovation Decision Process theory can be seen as having five distinct stages-Knowledge, Persuasion, Decision, Implementation, and Confirmation. According to this theory, potential adopters of an innovation must learn about the innovation, be persuaded as to the merits of the innovation, decide to adopt, implement the innovation, and confirm (reaffirm or reject) the decision to adopt the innovation (Rogers 2003).Many other important theories of innovation diffusion are overlooked, the Innovation Decision Process theory remains among the most useful and well known (Sachs1993).

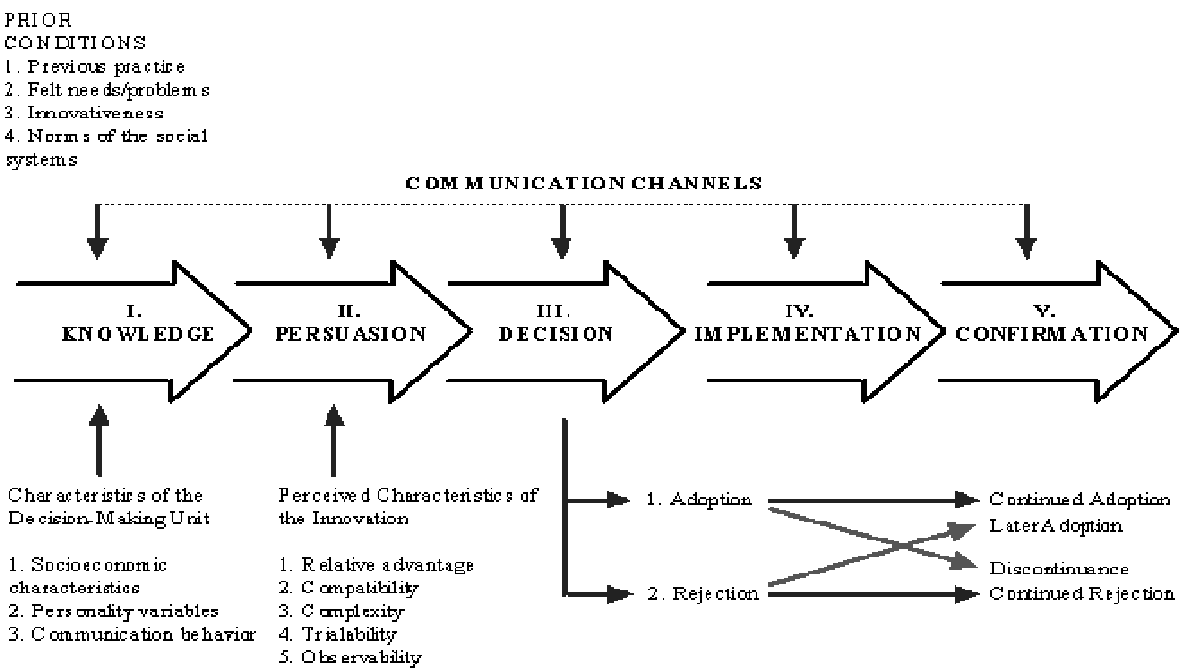

Figure showing the Stages in the Innovation Decision Process (adapted from Rogers, 2003).

Empirical evidence from literature in the application of diffusion theories

‘According to Koebel etal. (2004) diffusion of residential products and processes is still in its infancy and only a few empirical studies have been conducted’. It was also concluded that diffusion of innovation in residential construction is very complex, likely to vary between different classes of products, be subject to regional differences, and follow different patterns for early and subsequent adopters. A research conducted by the U.S. Department of Housing and Urban Development (HUD) and the Partnership for Advancing Technology in Housing (PATH) tilled: "The Diffusion of Innovation in the Residential Building Industry" looked at how and why innovations diffuse within the residential design and construction industry. The research was focused on "early adopters"- homebuilders who adopted particular products and materials at an early stage of market penetration. It was concluded that early adopters represented only a small percentage of all builders, they were critically important in demonstrating the benefits of these products and materials to other builders. It was also noted that middle-stage adopters deserved greater research attention, as they were the lynchpin to significant market penetration. They additionally noted that late-stage adopters were heavily influenced by the 'bandwagon' effect; when the pressure was on to adopt products, materials, and practices that were rapidly becoming industry standards. The research indicated that at the early stage of diffusion, national and regional firms, multi-family and modular builders, and custom builders were more likely to adopt innovations than the smaller volume single-family production builders. And while building product supplier representatives, subcontractors, and trade shows were important sources of information about new products and materials for all builders, early-stage adopters relied on technology transfer programmes and universities more than middle or late-stage adopters did. The research suggested that the perception among home-builders that home-buyers wanted the "tried and true" construction materials played an important role in the diffusion of residential construction technology. Further, the presence of "technology advocates" within the firm was also an important indicator in the diffusion of residential building technologies. More innovative firms were likely to stress the importance of being creative and innovative, and so were often among the first to use new products. Later adopters were more likely to be local firms and single-family production builders who emphasised marketability and profit, as well as those who associated the firm's success with land development (Koebel etal.2004).From literature studies could be learned that the theories of diffusion of innovation in the residential building industry have been applied only on limited scale and particularly in developed countries.

Innovation is “an idea, practice or object that is perceived to be new by an individual or other unit of adoption” (Rogers 1995).The type of innovation, or definition of innovation used will affect the shape of the network produced. Likewise, the shape and actors within the network will influence how the innovation is received. Different innovations will produce different communication networks within the same system. Rogers (1995) was of the view that organisation, and the projects within them provide a formal structure to communication and it may flow in numerous directions, based upon positions, title or role. Tichy etal. in Anumba (2003), view this network of communication as a prescribed, formal, or mechanistic structure. Rogers (1995) pointed out that the structure of a social system can facilitate or impede the diffusion of innovations in a system. In view of this last remark, the evolutionary socio-economic theories state that the particular environmental aspects of the country should be taken into account, whilst applying the generic diffusion theories.This research project is designed to carry out the investigations in the residential construction industry in a developing country with Ghana as a case in point. It will be carried out in line with the discussed diffusion theory.The generic diffusion theories will be merged with the evolutionary socio-economic theories in order that the particular environmental characteristics of a developing country like Ghana would be taken into account.

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Adaptables in the post-industrial society – a study of contemporary industrialized kitchen production in Denmark

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KEYWORDS

Architectural value, industrialization, module systems, complexity.

INTRODUCTION

There has always been a close link between means of production and architecture. Buildings need to be built; they reflect the technological potential of their time. Creating architecture can be seen as the fusion of contemporary ways of living and contemporary ways of production. The question then is whether the production systems are determined by the demands of the society? Or is the way we live determined by the way we produce artefacts, food supply etc.? The research presented in this paper seeks to answer these questions by introducing a theoretical model which focuses on the interaction between production and design. Architecture and the construction process are to be seen as a dynamic network in which technological potentials and the work of the architect inspire and enrich each other.

More than ever the contemporary Danish construction industry faces the challenging task of reorganizing its production systems. The industry is criticized for being to expensive and not efficiently organized. The industry needs to focus on a more industrial production to reduce costs and to obtain more rational production processes. The construction industry is to develop new models for industrial production which can meet the specific demands of the building process and the client. Inspiration may be drawn from other industries like the car- or aircraft production. These industries have developed adaptable production systems only using a few product platforms to create a large spread of individual solutions. However, instead of focusing on how industrialized production systems are developed in other business fields, this paper will be based on a study of a small part of the construction industry which has been industrialized thoroughly – the kitchen industry. In Denmark the contemporary production of kitchens forms an industrialized adaptable production based on module principles. A very large variety of solutions can be made using the same platform. A study of the production of kitchens provides the possibility of discussing how technology and architecture interact in an industrialized context. How do industrialized production systems meet the challenge of the architect who intends to create innovative solutions framing our modern society?

Method of approach

The case study forms a brief historical review of how the Danish kitchen production has developed during the last sixty years. Beginning with an analysis of an architectural competition from 1937 the visions presented in this competition and their impact on the development of the kitchen industry is discussed. Comparing this with a contemporary design competition allows the possibility of discussing the visions of the future way of designing kitchens and how these visions will challenge the industrial production systems. In order to understand the social and cultural changes in the society during the last sixty years I will introduce the theory of Anthony Giddens focusing on modernity and self-identity in a society beyond tradition. This will form the base for understanding the challenges architects face today.

THE VISION OF AN INDUSTRIALIZED ERA

In 1937 the Danish electronics company *Lauritz Knudsen A/S* arranged a competition called "The electric kitchen" (Pedersen 1937). The purpose of the competition was to generate new visions for the kitchen of the future, finding new ways of organizing the kitchen using all the new inventions of the time. A large number of the proposals introduced the idea of industrialized production and module systems. All the projects were based on very meticulous research into the function of the kitchen. Some of the projects even involved "experts" such as housewives in the discussion of how to organize and design the kitchen. This focus on function was also reflected in the criteria of the assessment made by the judging panel.

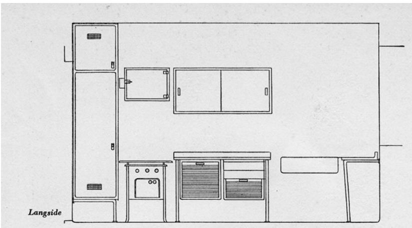

Figure 1. Typical proposal from "the electric kitchen"

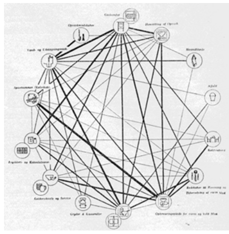

Figure 2. Diagram of the kitchen functions from 1930's.

The competition exposes discussions, which were characteristic for that specific time period. The design process was based on a scientific approach using methodologies from natural sciences and behavioural science, analysing the function very closely. In both Denmark and Sweden very large research programmes were devoted to the study of the routines of every day life (Heiberg 1948). Interviews were conducted together with close observations of people doing the chores of every day life. The research aimed at exposing the basic structure of the function to design the ultimate solution to the problem; a sort of an ideal configuration. The idea of developing standard units which would form the base of an industrialized production was part of an ideological vision. Providing the framework for the modern way of living to every member of the society was a political goal. The industrialization of the manufacturing process was seen as way of achieving this.

THE KITCHEN MODULE: 60 X 60 X 60

At the time the visions of industrialization were conceived most things were done using conventional craft based technologies. Kitchens were made by carpenters and every part of the kitchen was done by hand. In that way every kitchen was a unique custommade product. The focus on the function as the key to the design process gave birth to a new design tradition. From the 1930's and on this tradition came to hold the commanding position within the design process. This formed a paradoxical gap between the design process and the means of production. The kitchens were designed to reflect the way the kitchen was used. The design process was based on deep research into the function of the kitchen. This produced the focus on ideal solutions or standard solutions, which formed a contrast to the production based on custom-made solutions. As such, the industrialization played an important part in the design process long before the manufacturing process was industrialized. At the time the industrialization of the kitchen production took place during the late 1960's and early 1970's the module kitchen was already an integral part of the design process and the way kitchens were conceived by the costumers. All the insights into the development of the kitchen standard collected through more than three decades could now form the base of the conception of the kitchen module.

There is a clear link between the solutions presented in “The electric kitchen” competition and the module kitchen system, which has formed the base of the Danish kitchen production from the 1970’s until now. Many of the discussions introduced by the proposals in 1937 are reflected in the way the contemporary kitchen module is organized. The module is based on a simple principle: a basic cabinet 60 cm. wide, 60 cm. deep and 60 – 80 cm. high. The cabinet is an open frame in which different elements such as shelves, drawers and doors may be fitted, depending on the functional demands. On top of the cabinet a table top provides the working space needed. This way all the functional elements of the kitchen are united in one module.

The development of the kitchen module allowed an efficiency enhancement of the manufacturing process. Today the production is fully industrialized and the 60 x 60 x 60 module forms the base for the Danish kitchen production. This also has an impact on the design process. The kitchen unit forms a standard module, which both simplifies and constrains the work of the architect. The use of standard modules is a great help to the architect designing a kitchen, but it also reduces the number of possible solutions. The solution is limited by the very principle of the module system.

FROM FUNCTION TO IDENTITY

From the 1970’s to the present we have seen a major change in the architectural design process. In the 1970’s the focus was still on solving the problems concerning the function. Today the focus is on designing a framework of identity for the particular function or individual, a framework capable of distinguishing the function/the individual from one another and from the surrounding society. This change in the design process reflects the changes in the modern Western societies affected by globalization.

To understand the changes in the society by globalization and how this may affect the design process I will introduce the theories of the British sociologist Antony Giddens.

Giddens views the late-modern society as a consequence of the processes of globalization, which the development of new, dynamic digital communication technologies has brought about (Giddens 1990). Today, a tendency of separation of time and space is observed. In pre-modern society most of the daily activities took place within the same location and concept of time. Today, we are able to and in many cases forced to act across time and space. Time-space separation increases our possibilities of gathering information and knowledge. Today, the knowledge possessed is much more vast and complex than earlier. This is significant to and influences the way individuals and institutions organize themselves.

In Giddens’ description of the patterns of actions he differentiates between *practical consciousness* and *discursive consciousness* (Giddens 1984). Most of the daily actions are controlled by the practical consciousness, actions that are carried out without reflexion as a series of institutionalized routines. On the contrary, discursive consciousness is the reflexion on performed actions. The constantly growing access to knowledge, available as an increasingly integrated part of everyday life, challenges the daily routines (Giddens 1991). This challenge creates a potential for change, since reflexion may lead to a change of routines. A shift from practical consciousness to discursive consciousness happens. This leads to a new way of organizing society, the post-traditional society, a society in which we are no longer controlled by traditions but rather constantly faced with having to reflect on our choices. In this society, it becomes the task of the individual to create a self-identity through a continuous reflexive process in constant interaction with its surroundings.

Today the mission of architecture is to frame our everyday existence. As such, architecture is not only to frame a function, but is to add a special significance and identity to the function. Architecture becomes an important aspect in the process of creating a dynamic self-identity. A building creates an identity for the individuals or the organizations within it. The inhabitants communicate a series of values, shaping an identity, to the surroundings through architecture.

THE KITCHEN AS AN ADAPTABLE SYSTEM

Today's focus on the ability of architecture to create identity is mirrored in the production of kitchens. The kitchen module has become an adaptable system in which the individual module may be adapted to suit the wishes and needs of the user. The kitchen may be viewed as an open frame into which various elements may be fitted as desired. The surfaces and materials of the kitchen may be variegated so as to make the same module appear quite different as to the expression, thereby sending very different signals of identity. Since the system is based on a basic/standard module, it is quite simple for the user to make the different choices. It is possible to design one's own kitchen by adjusting a small number of parameters such as drawers, cabinets, doors and materials. A large number of possible solutions are contained within the same basic module.

In this way, the kitchen of today consists of a basic element, to which a number of layers that create an identity may be added. This is the strength as well as the weakness of an adaptable kitchen system. Changes to the surfaces of the kitchen module signal a number of values, but the configuration of the kitchen is limited through the logic of the kitchen module. The main elements of the kitchen, such as storage and place of work, remain static and previously defined. The identity is signalled by a series of isolated layers, not connected to the function as such or to new sort of needs or actions related to cooking. The individual is faced with a series of choices, all important to signals issued by the product, but not important to the use of the product as such.

Figure 3. Example of an adaptable kitchen system

Figure 4. proposal nr. 1589 from IMM Cologne 2005

THE VISION OF A POST-INDUSTRIALIZED ERA

Whereas the competition "The Electric Kitchen" of 1937 presented visions for the kitchen of the industrialized age, the competition "Kitchen is the Heart of the Home" presents the vision for the post-industrial age. The competition was arranged in connection with The International Furniture Fair of Cologne in 2005 (Imm Cologne 2005)) Almost 3000 designers from all over the world took part in the competition, and the forty-seven best proposals were exhibited at the Fair, afterwards to be printed in a publication. Browsing through the elected proposals, one proposal in particular sums up the problem of designing the individual kitchen for a person or a family of today. In the proposal "Take-away Kitchen" (fig. 4), Japanese designer Irit Katz-Feigi rejects the idea of the kitchen as a place of work. In stead, the kitchen is presented as a piece of furniture, couch, TV and microwave-oven in one foldable and transportable unit – designed for "the eternal urban nomads who do not like to cook". The proposal questions the traditional way of designing a kitchen: How to design a kitchen in a society, in which the kitchen is no longer a place of work, since it becomes increasingly common to live on ready-made foods?

In the development of the kitchen as an adaptable module system, the modern idea of function is not up for discussion. It is viewed as a static factor, constituting the backdrop for the basic module, thereby fixing the use of the kitchen, since storage, equipment and work zone is contained within or connected to the same unit. The possible changes are contained within a number of layers that may be fitted on to the basic module, as such primarily signalling value features. When these changes are contained within specific layers that are not linked to the function itself, it becomes difficult for the adaptable kitchen module system to challenge and innovate the everyday life.

The problem of the modular kitchen system is the static, fixing nature of the whole concept. One way of dealing with this problem would be the implementation of smaller elements rather than large cupboard units. Curiously, one of the winning proposals (fig. 5) of the 1937 competition explores this idea: Storage, technical equipment and work zone are designed as independent units, able to function individually yet capable of countless combinations. Since they are conceived as independent units, the possibility of creating individual solutions is improved. The solutions are able, not only to meet the demands of the users, but also to adapt to the physical context (the house) of which a kitchen will always be a part.

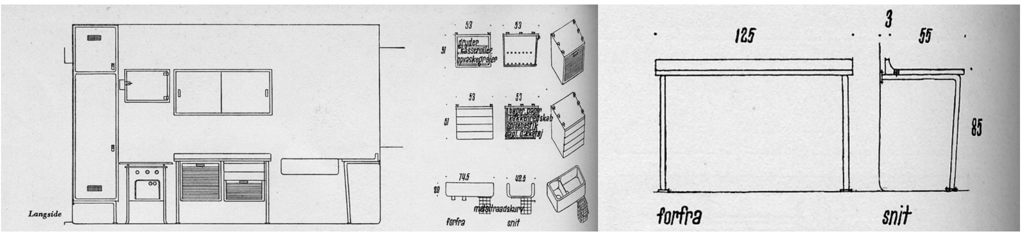

Figure 5. proposal with smaller elements from "The eletric kitchen"

CONCLUDING COMMENTS

When discussing adaptable systems in the building industry, comparisons with other businesses such as the car- or aviation industry have often been made. In these businesses the basic unit is used as a platform upon which a number of different solutions may be built. However, observing the industrialization of the Danish kitchen industry, a number of problems become obvious when trying to apply this model to the building industry. When manufacturing a car or an aeroplane, all the functions are given in advance. A series of parameters are fixed and well defined, able to be configured digitally or by other means onto a product platform. This is not possible in the same way in architecture. Not only does it have to meet the needs and desires of the individual person, it has to fit into a larger physical context, too (the site, the city and the infrastructure of society).

Creating architecture is a complex process. A building has to meet a series of varied needs that are constantly developed and changed. Through the architectural design process these numerous and often contradictory needs are united into a whole. Though architecture unites, it is not static. The way the building is used and the identity and meaning of the building changes with the development of society and culture.

In a society affected by globalization and a never-ending flow of information, the need for architecture to reinforce the identity of organizations and individuals is growing. Architectural identity should not be viewed upon as an independent factor that may be isolated in a particular layer of the building structure. Architectural identity arises as a link between function and significance in a complex network of constant change. This creates a need to develop new systems of production, able to meet the special demands of the building industry.

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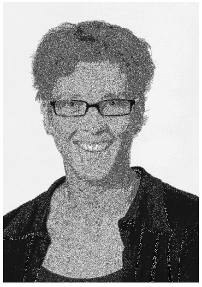
Activity Clustering in Briefing and Design.



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KEYWORDS

Brief, database, activity clustering, design.

1. Educational system in the Netherlands

Secondary education in the Netherlands, which begins at the age of 12 and is compulsory until the age of 16, is offered at several levels and can be devided into two main streams. The *vmbo* programmes (four years) combine general and vocational education, after which pupils can move on to senior secondary vocational education and training (*MBO*) lasting one to four years. The two programmes of general education that grant admission to higher education are *havo* (five years), the minimum requirement for acces to *HBO*, and *vwo* (six years), which prepares pupils for university.

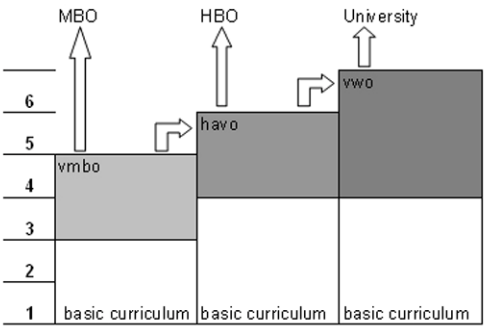

Figure 1. Educational system in the Netherlands.

In August 1999 a number of changes have taken place, among which the introduction of the vmbo level . Decreasing the level gap between secondary education and MBO and adjusting the education to the demands of the time were two of the main reasons. As a consequence all the subjects have been adjusted. The emphasis now lies more on acquiring skills which are necessary in general and specifically in certain professions. Information technology takes an important role; pupils use the computer to look for information, they learn the role of ICT in society and how ICT is used in specific professions. The way of learning has also changed. By creating a workplace structure for example pupils learn theory in businesslike surroundings. At this moment (2006) the government is investing 100 million euros in improving these practical training rooms. The main question is how to implement new spaces in traditional school buildings.

2. Case study

In the case we want to discuss in this paper there are two teams working at a school for secondary education; a vmbo (lowest level) and a havo/vwo team (higher levels). The dilemma in this case is that the vmbo team wants to implement a new didactic approach that focuses more on the individual students while the havo/vwo team wants to keep on teaching in a traditional, classical way like the school has done so far. Lets elaborate on both approaches.

The vmbo team wants to focus on 'inspiring learning' which means that pupils learn by experience, interaction and processing theories (Werkgroep zelfstandig leren, 1999). They want pupils to learn competences, skills and knowledge in their own individual way. The teacher incorporates the choices of the pupil in the learning process and by doing so, the responsibility for is lies not only by the teacher but also by the pupil himself. By asking the right reflective questions he teaches the pupil to make the right decisions (Stevens, 2002). In practice every student belongs to a main group (*stamgroep*) of a maximum of 80 pupils, depending on their age and level. Every main group is supervised by a core team of teachters and assistents. Within this main group, smaller groups will be formed depending on their interest, subjects and way of working. Pupils chose the way they want to work (individually or together in a small group) but instruction will be given in larger groups by the teacher.

Vmbo	*Havo/vwo*
Active pupils	Passive listening pupils
Teacher and pupil responsible for results	Teacher responsible for results
Working in a context	Working by subject
Working together	Working stand alone
Planning your own time	Prepared hourly schedule
Process orientated	Product orientated
Social control	Teacher corrects behavior
Skills and competences	Knowledge and results
Focus on your talent	Follow the curriculum
Main group spaces; *open-plan office*	Classrooms
Choice of workspace	Scheduled workspaces

Table 1. Vmbo vs havo/vwo.

Table 1 shows the main differences between the progressive vmbo team and the traditional havo/vwo team. On the other hand there is also a need for a laboratory for physics, biology and chemistry, as well as spaces for music, drawing, crafts and gymnastics which are needed by both teams and should be accessible for all pupils. In terms of scheduling the two teams have to plan together how and when these common spaces will be used.

3. Design brief

The main difference between the two didactic approaches that has an effect on the building is the difference of granularity. The vmbo team focuses on large amorphous spaces, like the open-plan office, where numerous activities can take place. Pupils will work here individually, in small groups or they will receive instruction. The main team of 80 pupils is the starting point of the organization as to where the class (a group of 32 pupils max) is the basis for the havo/vwo team. They mainly want the building to be built up of smaller spaces/ classrooms, which the class will visit one by one. Table 1 is an extract from an actual brief that illustrates these points.

Activity	*Cluster*	*Type activity*	*Group size*	*Nr. teachers*	*Type group*	*Field of learning*	*Time*
concentration	main team	Learning activity	1	0	individually		dependant
Laboratory	laboratory	Music	20	1	group	Art and culture	shift
Laboratory	laboratory	Physics	20	1	group	Human and nature	shift
Group work	main team	Learning activity	4-6	0-1	group		dependant
Project	main team		80		main team		shift
Study of sources	bibliotheek/ main team space	Learning activity	1	0	individually		dependant
Lecture	central		max. 80	4	main team		dependant/ max 1 hour
Instruction	main team	History	20	1	group	Human and society	dependant/ max 1 hour
Laboratory	laboratory	Laboratory	20		group	Linguistics	Shift
Test	main team		80		main team		Shift
Laboratory	laboratory	Drawing	20		group	Art and culture	Shift
Instruction	main team	English	20	1	group	Linguistics	dependant/ max 1 hour
Store belongings	main team		1		individually		-
Go to toilet	main team	-	-	-	-	-	-
Work individually without computer	main team	Learning activity	1	0	individually		Dependant
Work individually with computer	main team	Learning activity	1	0	individually		Dependant
Training	main team	Learning activity	20		main team		Shift
Presenting	main team		20		group		Shift
Preparing/developing teaching material	main team	Working individually	-	1-5	individually/group teachers		Shift
Progress talk	main team		1		1 to 1		15 min
Tutor group talk	main team	Starting and ending the day	20	1	Mentor group	-	30 min
Relaxation pupils	central	Drinking coffe, lunch, chatting	max. 80	4	main team		30 min

Table 2. Part of brief vmbo.

4. Brief database and representations

In conventional briefs the clustering of activities tends to follow either the organisational structure of the client/user or simple measures of proximity, usually on the basis of a single criterion such as pedestrian circulation distances between activities. Such clustering is insufficient in the case of complex buildings, especially with organizations that keep changing socially, demographically and structurally. Secondary education buildings are typical examples of this: new social and educational conditions not only bring regular changes but also require extensive but careful experimentation. The structure of a relational database can provide the required flexibility and adaptability. In this database each activity is described integrally by a single record. Each aspect, property and constraint is accommodated in a specific field (Deisinger and Breining, 2000). Consequently sorting the database by any combination of criteria (i.e. field values) returns a clustering of activities from a specific point of view, such as social cohesion within each group of users (pupils and teachers), interaction possibilities between different groups and activities, or the concentration of demanding services (Steijns and Koutamanis, 2004).

Clustering the activities results in a hierarchical structure which can be represented in a tree diagram (Steijns and Koutamanis, 2005). By keeping the structure flexible we can study different wishes and points of view, which means clustering criteria are exchangeable. In Fig. 2 the main criterium is the character of the activities and their proximity. This can easily be changed into a configuration where group size is the main criterium (Fig. 3). In both diagrams the activities and their relations are unchanged.

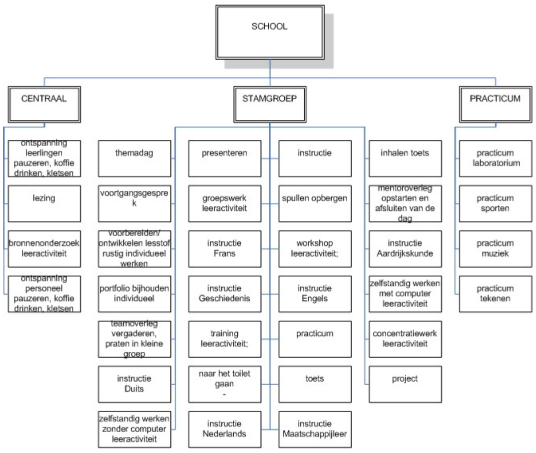

Figure 2. Clustering on the basis of proximity.

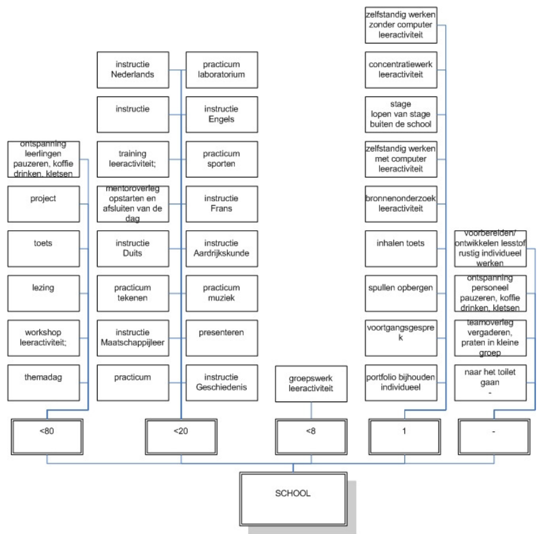

Figure 3. Clustering based on group size.

Figure 2 shows the tree structure of the clustering of activities based on where the activities take place. In this case there are three main groups of activities:

- *Central:* These activities are located centrally in the building so that they are available for all students, both vmbo and havo/vwo. Examples are activities that take place in an auditorium, lunch rooms and a library.
- *Main group:* The individual workplaces of vmbo students are located in the main group space. This part of the building is where they spent most of their time. It's where they get instruction, work individually or in small groups, store their belongings, go to the bathroom and give a presentation.
- *Laboratory:* The laboraty includes all activities that have to do with science, like physics, chemistry and biology, but also drawing, crafts and techniques. The laboratory is available to all students.

5. Design analysis

The tree structure is automatically and dynamically connected to the brief database. This means that information from the brief can be consulted from every part of the tree structure. Changes in the brief database are automatically passed on to the tree structure; the tree structure will be automatically rearranged based on new properties or structural changes.

The brief database can also be linked to representations of a building or design in a CAD program by connecting each activity with the space(s) where it is accommodated. Through this combination it is possible to study not only different clustering approaches but also their wider effects on a building. In the particular case of school buildings it makes possible the study of existing buildings with respect to new user requirements, the identification of possible building adaptations (including extensions), to compare alternatives, and to link different clustering options to the (dynamic) scheduling of learning activities.

By coupling the topological pattern with the geometry of a design (Fig. 4) the relationships between organizational clustering and spatial types becomes explicit.

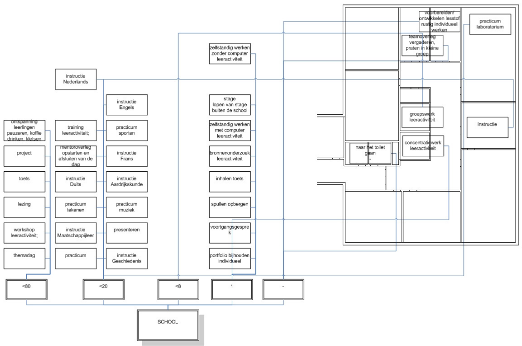

Figure 4. Connection between activity clustering and design

6. Discussion

The proposed approach allows both top-down and bottom-up approaches to the clustering of activities and users. In both cases the result is a number of clusters based on the individual activities with their particular spatial and functional requirements, as well as their belongingness to different, possibly overlapping groups and clusters. Cases were studied during the development and early application of the approach:

1. There is a differences in grain size between different school types and educational approaches; these are effectively neutralized by the coherence of the topological representations
2. The spatial dimension of topological representations anticipates design choices and makes typological assumptions explicit; this can also lead to determinism, especially when the existing building or a conventional type appear to satisfy all requirements
3. The connection between brief requirements in the topological representation and the geometry of the design is a welcome addition to the analysis and communication tools of designing

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Between past and future: daylight simulation and analysis for today

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KEYWORDS

simulation; building performance; daylight; integration

1 Introduction

In the past few decades, the building industry has been incorporating the efficiency delivered by the personal computer. Especially in the last decade, workflow in architectural and engineering firms has become digitized, leading to higher efficiency and transparent data management. However, other aspects of the electronic revolution have yet to live up to their promise (Koutamanis, 2000). These include issues relating to building performance that can be analysed in 3D virtual building prototypes.

Comprehensive 3D digital building models (collaborative or not) are generally considered as the Holy Grail in the field of collaborative prototyping (Yeomans et al., 2006). At the same time, however, the implementation of 3D digital building models is scarce, due to technical, operational and process limitations. We propose that existing technologies are generally sufficient for developing high-performance partial solutions, i.e. solutions focused on specific design aspects. This can support the simultaneous development of working methods for less traditional applications of CAAD (De Groot and Paule, 2002).

One such aspect is daylighting. Most building professionals will agree that the daylight performance of buildings is a relevant and crucial issue.(Leslie, 2003) At the same time, both building regulations and practice have not changed significantly during the last few decades. By using a recent case study, this paper investigates the possibilities of the combination of design computing and daylight performance analysis.

In general there are two main methods for the analysis of daylight performance: physical scale models and full-size digital models. However, with the advance of computational speed, the acceptance of digital design tools, the flexibility of geometric, surface and sky models and its potential reliability (estimated at ±10%) computer-based daylight simulation is the rising star (Mardaljevic, 2000). Research has shown that measurement in scale models, long considered to be accurate, can lead to large errors (60-200%) (Nair et al., 1997).

2 Simulating daylight

It is widely acknowledged that there are currently two tools (and underlying approaches) that qualify for daylight simulation: Radiance and Lightscape. Although a case can be made for using Lightscape within its particular strengths (Ng and Chan, 2003), we consider Radiance to be superior in daylight modelling and far superior in handling complex geometric models. Because of its extended backward raytracing calculation method, Radiance requires no specific modelling strategy, while Lightscape poses severe geometric restrictions originating in its radiosity calculation method. Furthermore, the reliability of Radiance simulation has been proved by several validation studies (Mardaljevic, 2000).

Nevertheless, the usability of Radiance suffers from serious drawbacks, especially in the geometric modelling, texturing and surface smoothing capabilities. To cope with this, we have used an in-house translator from the modelling/animation system 3ds Max to Radiance and additions to the Radiance core so as to provide a flexible, reliable and usable simulation environment. Aspects of geometry, surface reflectance and transmittance, and sky modelling need to be defined with great care (Lam et al., 1997). When handled with due care, Radiance provides the best of both worlds: visually compelling imagery and reliable lighting calculation (Ward and Shakespeare, 1998).

3 Case Study: Expansion of Royal Library, The Hague

In the spring of 2003 the board of directors of The Royal Library in The Hague was concerned with the combination of daylight and artificial light in a planned addition, which would accommodate a variety of functions, ranging from circulation spaces to an exposition area for delicate objects. The owner of the building (the Dutch Government Buildings Agency) commissioned the development a digital model for simulation. The main aspect of the simulation would be the visual quality of the spaces involved under varying lighting conditions.

Acquiring the required data for meaningful simulation was a task of varying difficulty. As is common in architectural design, no 3D digital model was available during the design process. Based on AutoCAD drawings from the architect’s office, the construction of the 3D model proved fairly straightforward (Figure 1).

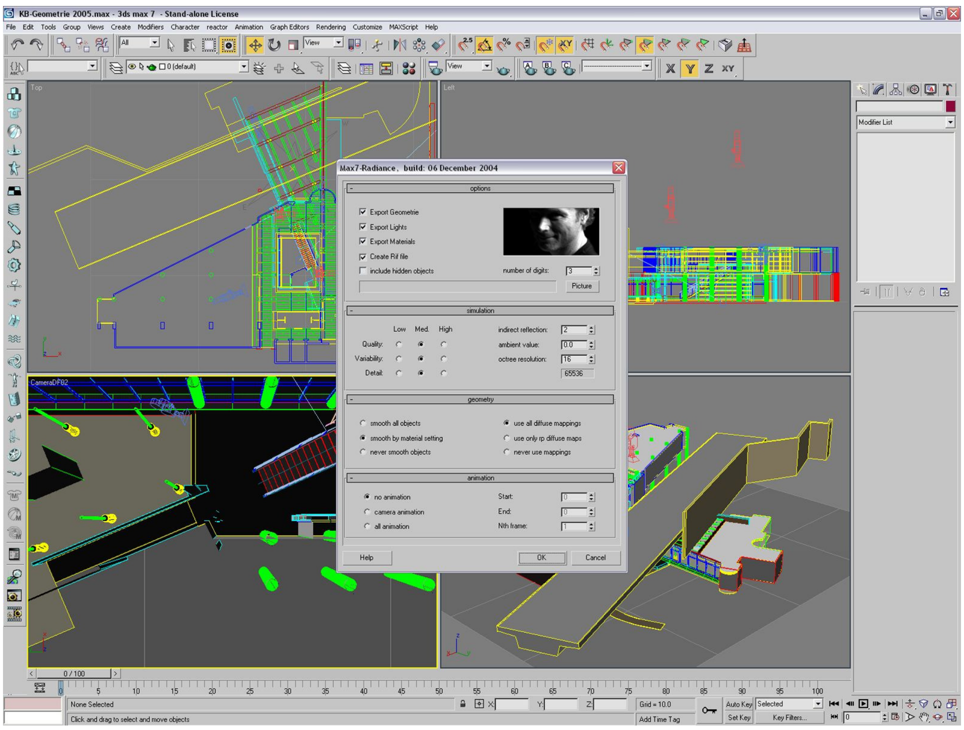

Figure 1. Exporting geometry, calculation setup and viewpoints from 3ds Max

Color and (diffuse) reflectance were based on colour description in the RAL-Digital 3.0 software from the ‘Deutsches Institut fur Gutesichering und Kennzeichnung E.V’. For a number of general lighting fixtures, the luminance data were available as photometric webs in the IES format. The remaining light sources, including a custom designed lightwall, were individually defined (Figure 2).

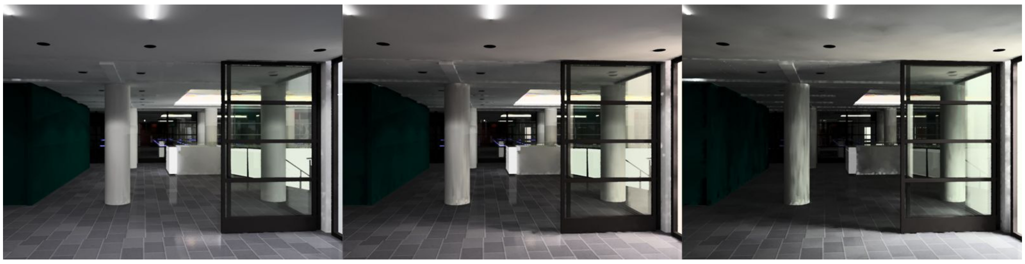

Figure 2. IES-defined lighting fixtures

A number of simulations were conducted with Radiance, resulting in series of images depicting the variation in visual experience during the day. To account for the non-linearity and accommodation functions of the eye, specific corrections were made to the datasets using pcond.exe, a utility that comes with Radiance (Figure 3).

Figure 3. Varying daylight conditions combined with artificial light (eye-corrected)

Other simulated design variations included the introduction of sun screens on several window glazing in the south and west facades (Figure 4).

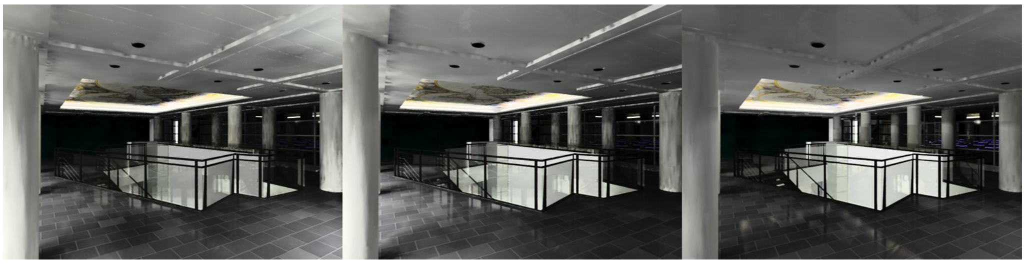

Figure 4. Sun blocking foils on first floor

Furthermore, the central colour-varying lightwall provided great changes in atmosphere, reflected in the colour-bleeding effects on nearby surfaces (Figure 5).

Figure 5. Custom lighting with changing colours

The process of 3D modelling, simulation and visualization were not performed in isolation but in conjunction with the ongoing design and decision-taking. The (intermediate) results of each stage were fed back to the key actors of these processes, allowing architects and consultants to make constructive use of the images produced (and their implied reliability) in designing and communication.

4 Evaluation of case

Following several discussions about the relevance of trying to predict the future, a common quantative subject emerged: the illuminance levels (in lux) to be expected under daylight conditions. Digital simulation was responsible for arriving at this, because it permitted the transparent combination of artistic and engineering elements, i.e. attractive photorealistic imagery and objective numerical data.

Analytical representations of the simulation results (Figure 6) are quite reliable in computational terms. However, the project definition did not include any description of the necessary geometric, reflection or lighting conditions for the evaluation of the analysis. With respect to the relevance of combining pictures with numbers, the project would have benefiteed from additional constraints, which would have allowed a higher level of performance.

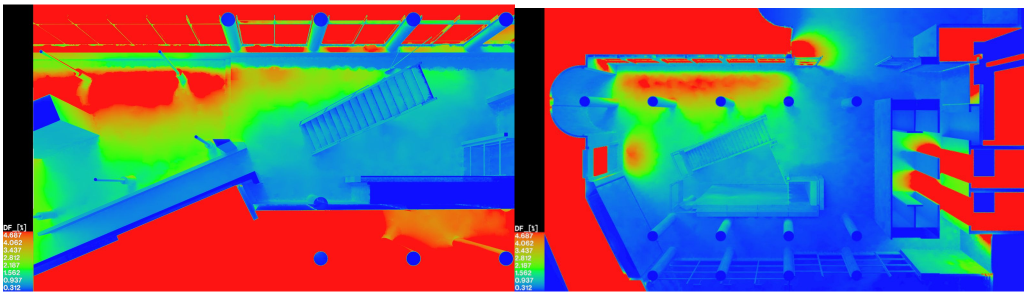

Figure 6. Daylight Factor distribution on floor levels of Royal Library

As in most cases, light simulation stimulates the formulation of relevant and interesting questions that can be answered in a practical and verifiable way. This does not imply revolutionary changes in the design process but a rationalization and optimization of design procedures. Architects do not necessarily need to be instructed in matters of light. Transparent feedback and the ability to create alternatives and variations in an efficient and reliable manner frequently suffice (Glaser et al., 2004).

5 Conclusions and recommendations

In the total lifecycle of a building, from project idea up to demolition, there are several questions concerning the flexibility of the process decision chain. In conjunction with providing solutions for worst case scenarios in the design stage, we should focus on development of structural methods for optimizing building performance throughout the building's entire lifecycle. We suggest a reconsideration of the processes that define the decision chain:

1. Development of a workable knowledge base of existing (daylight) design solutions in building practice

There are many buildings that demonstrate not only understanding and intelligent use of daylight with respect to building quality and performance but also truly innovative approaches and products. This perfromance can be measured and form the basis of future design choices.

2. Creation of specific, adaptable design brief criteria by means of intelligent best practice selection

In many run-of-the-mill projects (e.g. housing, office buildings) there is insufficient time and attention for finer points and designers exhibit the unfortunate tendency to revert to stereotypes that may perform poorly. Designs briefs can improve by using the accumulated knowledge of 5.1

3. Development of understandable design proposal analysis representation of design proposals

In order to be able to compare designs we need global measures of the quality of daylight performance. These include visual comfort issues like glare, functional zoning, light level variance and speed, and make use of general indices like the Daylight Factor and Daylight Autonomy ratings.

4. Construct (re)presentation policies that will provide combined access to knowledge base and design proposal analysis

Computer simulation, especially if coupled to extensive collections of well-documented cases and precedents, provides the means for effective, efficient and reliable specification, analysis and synthesis. Moreover, intelligent computer simulation can be an unobtrusive, supportive activity in the background of design activities that both identifies potential pitfalls and allows deferment of the solution on the basis of informed opinions (as opposed to unfounded guesses).

5. Reconsideration of building regulation possibilities

Good daylight design requires more accurate specifications, awareness of lifecycle aspects and attention to performance, as well as a closer interest in what research has to offer on the methodical and practical levels. Daylight requirements should be defined in terms of daylight performance, not in rules of thumb or general principles.

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The adaptability of landscape design in high-dense residential environment

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KEYWORDS

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Paper

1. High-dense living in Hong Kong

Hong Kong has one of the highest urban densities in the world. The total land use area is 1,070 square kilometers but only 22% of the total territory's area can be classified as built-up area and potential development area. Developments within these limited land resources have necessarily resulted in a compact urban form. At the same time, population growth in Hong Kong is in a high speed. Hong Kong has no alternative but to resort to high density development and large amount of the land are coming from reclamation (Chau, 1981). Under the high-dense living, outdoor landscaping thus plays an important role in buffering the density pressure. Currently, most of the outdoor landscapes in residential environment are hard landscape character with large area of paving. These places are also single function which only providing benches for sitting. There is a need to increase the adaptability of landscape design in high-dense residential environment. The purpose of this research is to identify the change potential of these spaces through a transformation study. It also will provide references for the future housing projects development.

2. Transformation study: Fuk Loi Estate, Tsuen Wan, Hong Kong

In 1960s, Tsuen Wan was already a center of light industry. Two resettlement estates, as well as two low-cost housing estates (including Fuk Loi), had been completed in this area. Fuk Loi estate was built in the 1963 (Table 1). Land sought for the low-cost housing estate was from land reclamation. The living environment at then was very poor which had no outdoor environment at all. The industrial area was only separated with the residential area (Fuk Loi Estate) by a nullah (Leung et al., 1999).

Gross Area (m^2)	Year of Intake	No. of households	Authorized Population	Block Numbers	Type of Blocks	Storey	Plot Ratio
38,200	1963	3,100	11,410	9	Old slab	7 & 16	2.33

Table 1 Basic information of Fuk Loi Estate

2.1 Form

From Figure 1 it can be found that the form of the landscape furniture in the estate has been changed a lot during these years. Although the major nine blocks did not change, some small buildings appeared in the estate. For example, the pump houses, electricity houses. Because of the improvement of living conditions, the requirement of the water supply and electricity supply raised accordingly. Within the fix territory of the whole estate boundary, the forms of landscape furniture varied from quantity, size as well locations. In 2000, a pedestrian canopy was added in the estate. It echoed with government regulation that required all the public housing estates to add pedestrian canopy in the estates in order to avoid rain and garbage throw from the higher building floors. This pedestrian canopy changed the entire outlook of the residential environment.

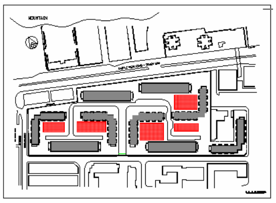
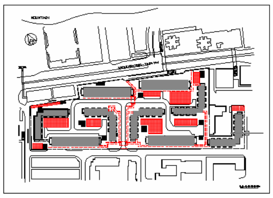
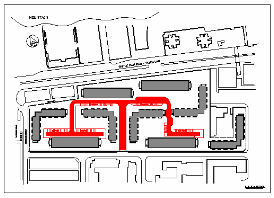
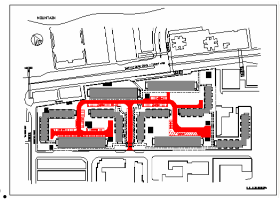
a.  b.  a.  b. 

Figure 1. Form change (landscape furniture) a. 1970s-80s b. 1990s-now

Figure 3. Territory comparison

The change of the trees also affects the form. In 1960s, there are no plants in the estate. In 1970s, because of the government's 'Ten Year Housing Program', many old housing estates began to plant trees. In Fuk Loi estate, plants species is highly limited at that time because of the reclamation soil condition. There are only 9 species of trees and most of them could not grow well. A built environment renovation was taken in 1990s, which replaced the previous residential landscape completely and turned into today's look. As living organisms, trees will grow up both vertically and horizontally. Through the comparison of tree coverage in Figure 2, it is found that the coverage of the landscape trees in the estate now is almost twice to the 1970s. The vacant space in the estate is less than before and therefore make it looks denser. In a high dense neighborhood, appropriate scale of the open space is very important which may let people feel relax. On the contrary, a dense outdoor landscaping in high dense neighborhood may bring more uncomfortable and unsafe feelings.

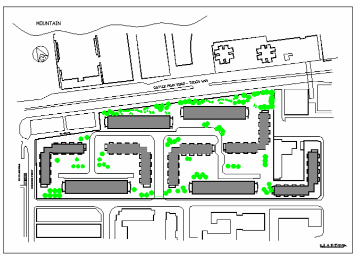
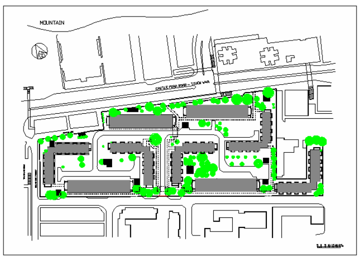
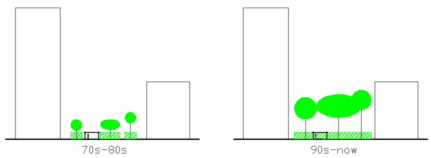
a.  b.  

Figure 2. Tree coverage form comparison: a. 1970s-80s b. 1990s-now c. Trees can divide sub spaces within fixed boundary. The shading spaces created by each small tree are isolated. After they grow up, their leaves and roofs connected and interweaved with each other thus created a bigger and wider shading space for the activity.

2.2 Place

Take the road width for example, because the percentage of owning a private car is increasing in the estate, there is a requirement to create more parking lots. Comparing the road width in 1970s and now, the current width of the road is only half of the original size (Fig. 3). Since there is no car parking consideration in the 1960s' estates practice, it now becomes a problem in most of the old public housing estates in Hong Kong. Now there are ten legally roadside parking plots in Fuk Loi estate compared with zero in 1960s and six in 1970s to 1080s.

The form of landscape furniture varied from quantity, size as well locations within the estate boundary while the function has some centralization tendency. In 1960s, there are only three simple children playgrounds in the estate. They are sandy ground with no pavement and no fixed territory. Until 1980s, the recreation places have been increased to five places, including table tennis, children skating area, basketball court, etc. Now there are eight places providing recreation and amenities facilities in the estate. The skating area now has been changed into a stage for the neighborhood public activities. The basket ball court disappeared and a badminton court is built up. More chairs and sitting areas are provided in the estates. Figure 4 shows the varying territory structure during different ages. From left to right, the place, which was non-thematic in the 1960s, was transformed and maximizing developed into a multi-function place in the 1970s. In 1990s, one more parking lot was divided on the north side and a small eclectic house was added here according to the increased electricity requirement in surrounding blocks. Thus the landscape place was decreased to half of the original size and the function is decreased accordingly. The place changed into a less attracting place in the estate.

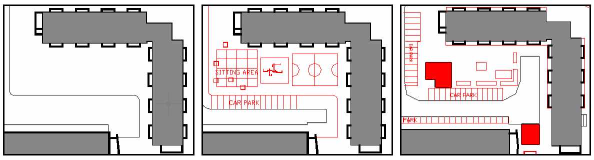


Figure 4. Varying territory structure

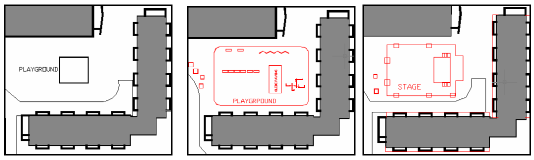


Figure 5. Varying form within fix territory

Form can also be varying within fixed territory. Figure 5 shows that in this block area, the landscape furniture form has been transformed three times in these 40 years. From left to right, in 1960s, there is only a simple playground here for the children in the estate. Later on, according to the increasing number of the children there is a need to increase the amenities facility in this place. Now this place is replaced with a stage referring to residents' proposal. They hope to have a place as neighborhood center where they can organize different community activities. People changed this place.

2.3 Understanding: Transformation in public housing project

To analyze the understanding of the landscape design in the residential environment, it should be first review the transformation of the public housing projects development conception. Studying the transformation of public housing development may help to have a better understanding of the transformation of the landscape design in each specific housing estate.

The concpetion of landscape design in public housing can be devided into three periods since public housing started in 1953. There is no out door environment in the housing estaes which were built from 1950 to early 1960s. Residents in these resettlement building had to face the problems of living in a new community, such as policy order and transportation (Leung et al., 1999). From mid 1960s, the industrial development flourished and 'Ten Years Housing Program' statred. Housing estates constructed under the ten-year housing program were generally of a higher building standard. More and more estates contained garden designs and had more recreation areas. Environment and facilities in the older estates were also improved under the program. In addition, the open spaces in the estates were more fully utilized by planting trees and setting more sitting areas. Fuk Loi estate was benefited too (Leung, 1999). In 1976, Home Ownership Scheme was formulated and later in 1978, the government began to cooperate with private developers by introducing the Private Sector Participation Scheme. From then on, the entire quality of the public housing estates' design had been upgraded to a new level.

Estate management is another achievement in the public housing development history. In the beginning of the 1970s, many public housing estates formed their own Mutual Aid Committees (MAC). They played the role of communicating residents' opinions to the estate management. In

1995, the further developed EMAC (Estate Management Advisory Committee) was established and experimented in eight public housing estates. Thus the residents participated more directly in estate management affairs.

Fuk Loi estate was intaken between 1963 and 1967. According to the interview to an old resident, Mr. Yiu (chair of the Mutual Aid Committee), it is known that the demographic in the estate at that time are mostly young couples with children around 20 to 30 years old. Now around 25% of the current people are immigrants during these years. The estate is become an old estate because over 30% of the residents are eld. They need more community facilities, recreation area as well as sitting areas in the estate. Because of the economic development of the whole society, the living standard of the people has been improved as well. In 1990s, the EMAC was formed in Fuk Loi estate. The structure of EMAC in Fuk Loi estate basically followed the criterion of the government, one housing manager acts as the chairperson, one or tow district councirs and residents' representatives from each block. Totally, there are 12 people in the EMAC of Fuk Loi estate. The housing manager is the chairperson. They have the general meeting every month and the content usually include the management of the housing estates, the implementation of the guidelines from Housing Authority, as well as reflect the residents' comments and enquiry to the Housing Authority. For example, improve the out door landscaping design, setting more recreation areas in the estate, set up an elder care center for Alzheimer disease and Parkinson disease in the estate, etc. The representative of each block is usually the Chair of the Mutual Aid Committee. Residents are more aware of the place they are living today. They take the chance and responsibility to influence and control their own residential environment.

3 Concluding discussion: Design for adaptability in residential landscaping

When the demographic populations as well as the residents' conception are changed in the residential neighborhood, there is a need to adjust the old designs and outdoor spaces according to the economic development. The history of the Hong Kong public housing development is also interweaved with the economic development in Hong Kong. Due to the land limitation and population pressure, the adaptable design becomes very important in Hong Kong's situation. Through the studying and analysis above, bellowing points can be reference of future adaptability design in residential landscaping.

- *Multi-function spaces: time fixed.* At a fixed time period, the space of the built environment should have multi-function. That means the function and purpose of the place may be changed due to different requirement.
- *Potential change: space fixed.* If the space fixed, landscape furniture should still have the potential possibilities to change according to the population structure change, conception change, requirement change, etc.
- *Plants species adaptability: location fixed.* Plants species selection in the residential landscaping should adaptable to the local soil condition as well as the microclimate. At the same time, different shape trees should be used at difference places in order to form a clear hierarchy of the landscaping.

In Hong Kong, the housing estates or projects are planned by the plot ratio. There is no clear classification of the residential levels and the residential environment usually only has one level, which at the neighborhood scale. Compared with Hong Kong, the residential neighbourhoods in urban China refer to housing estates usually having a clear territory, bounded by traffic road or natural divisions (mountain, river, etc.). According to *Code of Urban Residential District Planning & Design* [GB 50180-93], there are basically three scales as illustrated in Table 2.

	District (*Juzhuqu*)	Neighbourhood (*Juzhu Xiaoqu*)	Housing clusters (*Zutuan*)
Population	30,000 - 50,000	7,000 – 15,000	1,000 – 3,000

Table 2. Population Scale for Housing Estates in China

In these housing estates in China, landscaping design in the residential environment can be further divided into several sub levels according to the minimum scale requirement (China Department of Construction, 1993). For example, 1.0 ha for community park, 0.4 ha for public garden and 0.04 ha for courtyard greenery. The residential arteries usually outline these territories. From main district vehicle road to small pedestrian path in the clusters, different width of the road defines different level of the landscaping places. Residents in different level may have their influence on the above level landscape and control on the below level.

Based on this hierarchy, one more level is suggested to be added in understanding the landscaping in residential environment. Residents in each block may have the right to control the green land in or surround their building and at the same time influence the greenery of the clusters that they belong to. Figure 6 shows a general and entire hierarchy structure of the landscape design in residential environment which divided by different width of the road in the landspaing (the solid arrow line refer to the analysis in this study). Since most of the current residential projects in both Hong Kong and China are real estate projects, this structure may be seen as an idea model for the planners, designers and mangers to achieve. Residential project may vary due to the economic differences, but the hierarchy of control should be the same. Understanding the control from different level of the residents may help us to design for good adaptability in future practice. The transformation study in Fuk Loi estate is based on the neighborhood level which is also the only level in the estate. It is proved that landscaping space, as major component of residential environment, transforms faster and more complicated than built structure. It is possible to set up a landscaping hierarchy in the residential environment, which may help to create a more plentiful out door environment.

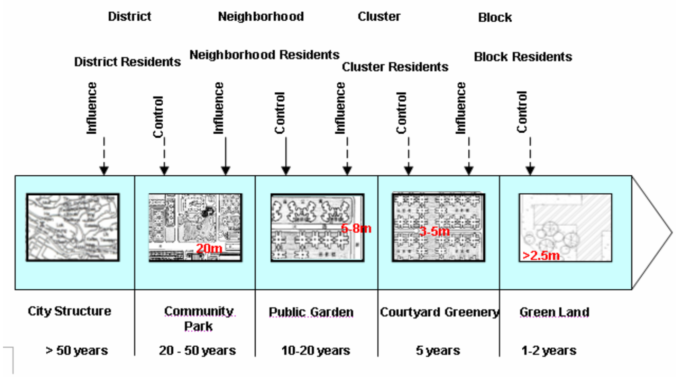


Figure 6. Reading landscape design in residential environment

4 Acknowledgement

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Adaptable Infrastructure

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Introduction

In the Netherlands, the available space for new housing projects is relatively limited. Solutions can be found by building (temporarily) in those areas, which are sensitive for construction. As it is on a temporary basis, (light town building) its construction might be allowed. A different option can be housing on water. Although the Netherlands has quite a vast open water area, we will not find many houses built on water. These two options require, both, an adaptable type of infrastructure. This paper is referring to two Msc theses of TU/e students who did extensive research in this field. It can be divided into a 'dry' and a 'wet' part, which is also symbolic for the Dutch countryside.

2. Infrastructure as a problem

Infrastructure is needed to facilitate transport of:
1. people and animals,
2. goods (products, water, waste, waste water),
3. energy (gas, electricity),
4. voice/data.

The fast changing requirements in urban areas, in both housing and office buildings, lead either to demolition and new construction, or to rehabilitation and re-use. Sometimes, this requires also a change of infrastructure, around these buildings. Often traditional infrastructure has a technical lifespan longer than the economic lifespan. After ending its period of economic use, most of the components are left obsolete and un-used as they are not designed and made for re-use.

3. Design for lifespan

The TU/e research unit for Architectural Design and Engineering developed the design for lifespan approach: "design and select the components and its connections in such a way that they function in accordance with the wanted lifespan".

Different types of lifespan can be distinghuised, which are also applicable for the infrastructure. With regards to economic life span and technical life span we adopted three life span scenarios, these are the basis for environmentally sound designs [Durmisevic]:

A. Economic life span < Technical life span.
The components of this infrastructure should be re-usable and/or recyclable.
B. Economic life span = Technical life span.
The components should be recoverable and than recyclable.
C. Economic life span > Technical life span.
The components of the infrastructure should be replaceable and recyclable.

The design efforts should be such, that the resulting products are sustainable. This requires thinking about environmental effects and should include options for re-use, replacement and recycling.

4. Infrastructure on land

When designing infrastructure, the first consideration should be the real demand for it. Through smart design, the need for infrastructure on land can be reduced:

1. Reduce the need for infrastructure by applying other options. Use techniques which are located close to the housing unit and think of autarchic options; but also,
2. Replace a provision by using a different one. For example cooking on electricity reduces the need for a gas pipe, if also heating is done differently.

In other papers [Erkelens 2004], we elaborated the options for light infrastructure on land. We just summarize them here:

- Rainwater: is filtered into the bottom around the building.
- Gravel chests are used to infiltrate the rainwater falling from the roof.
- Waste water; with the use of modern septic tanks (e.g. the IBA system) waste water is received, purified and drained into the bottom. Once a year the remainder has to be taken out of the tanks either to use as compost in the garden, or to use somewhere else.
- Telecommunication is wireless and by air.
- Roads can be provided with an aquaflow system, which does not require a storm water drainage.

During his MSc. thesis research Verkuijlen [2003] developed a simple infrastructure model for gas, water and power. He developed a duct system, in which those mains can be placed and can be coupled with others, for other directions. By doing so, the mains are concentrated at one location; easily, accessible and exchangeable. This prototypical design has further to be modeled in the nearby future.

5. Infrastructure on water

Building on water is getting increasingly attention. For the Netherlands this is obvious; lack of sufficient space in urban dense areas, the abundant availability of water and the seasonal floodings. So that it is better to 'join' the enemy (water) than to combat him. Already we see sites with floating green houses, residential houses.

Building on water requires special constructions. Commercial firms have developed different house types, and transport them over water to the required location. Special factories manufacture these units while these float from one production stage to the other. The construction of these houses doesn't raise much problems. However, field observations show us a number of problems, when looking at the connection between land and floating object. Figures 1 and 2 show lines for sewer, water and power, which are not well fixed and supported. It seems that during the design stage this hasn't been discerned and in the execution phase the contractor have to solve the problem, but not properly as it seems.

Figure 1. Mismatch of infrastructure (1)

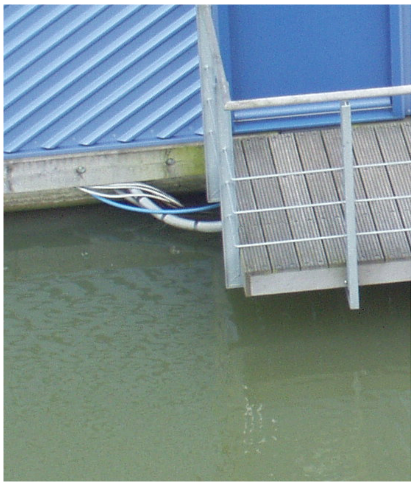

Figure 2. Mismatch of infrastructure (2)

At a greater scale we experienced similar problems with the single buoy moorings used for the transfer of crude oil from the seebottom to a tanker in full see. Rubber reinforced houses were used, but after a period of time the dynamic loads tore of the house and heavy spillage occurred.

In order to solve the signalled problem the following items will have to be reviewed:
A. floating systems,
B. mooring systems,
C. forces on the floating unit,
D. (infrastructural)connections between land and floating objects.

Ad A. The figures 3,4,5 and 6 below show the different floating systems which can be applied to create a floating bottom for the foundation of a housing unit. It is done similar to ships: a single or double lined steel hull, see fig. 3; a hollow concrete hull filled, see fig. 4; a reversed concrete hull but filled with foam, see fig. 5; or with a framework of hollow steel or synthetic tubes, see fig. 6.

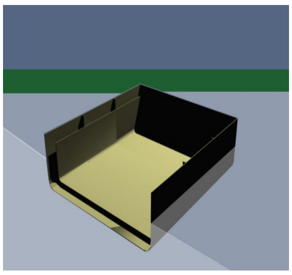

Fig. 3. Steel hull

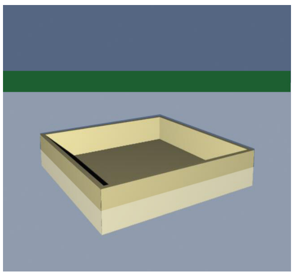

Fig. 4. Hollow hull

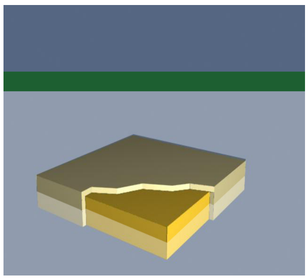

Figure 5. Reversed hull

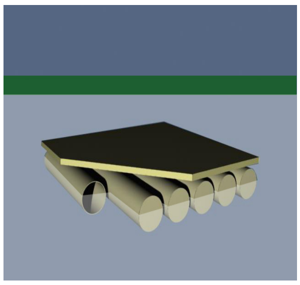

Fig. 6. Hollow tubes

Ad B. The systems can be positioned with a flexible connection to piles, which are driven into the bottom or with cables and anchors, although the latter does not fix the position in a stable way.
The connection with the land may be either via an also floating mooring system or directly to a fixed landing stage.

Figure 7. Mooring systems

Ad C. When looking at the connection between A (land) and B (floating object) there are vertical & horizontal forces and bending & torsion moments, Fig. 8. These forces (and moments) are caused by: the changing levels of the objects, the flexibility of the water, the tidal movements, the dead weight, the point of gravity and the loads due to the use. All these cause different movements. By applying special joint these forces and moments can be transmitted or changed into a different type of force.

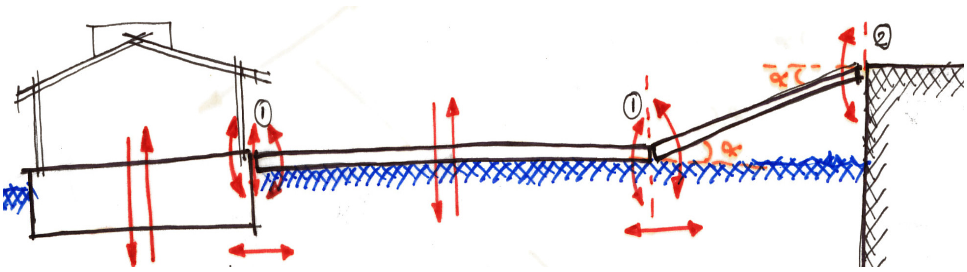

Figure 8. Impression of acting forces and moments on jetty, connection and floating house

Ad. D. The designed connections. The thesis has worked out a proper connection between the floating object and the mooring of which Fig. 9 shows more details. Whereby the following remarks can be made with respect to specific problems which had to be solved:

- (Flexible) lines for water, power, sewerage and data transmission were placed in a hollow insulated tube, between land and floating objects with special shivels.
- The real joints consist of hinges. At the land side we find a number of hinges consisting of vulcanized rubber and at the object side is a ball bearing hinge.
- A chain connection prevents the system from overloading in the event of a sudden break down of the hinges.

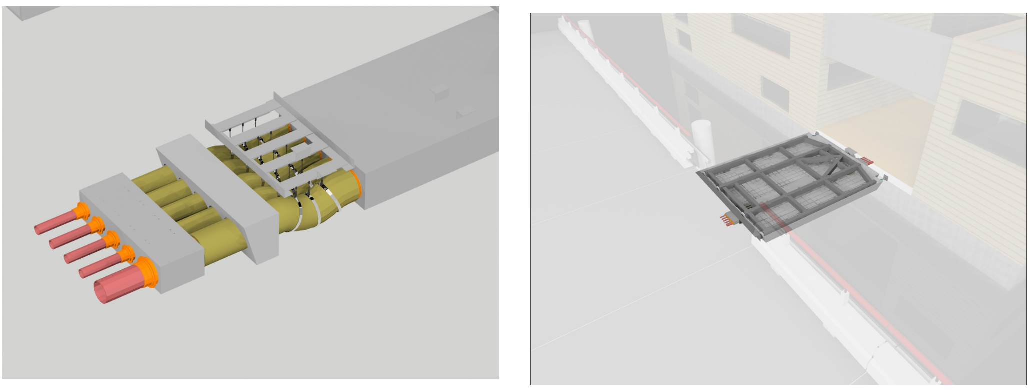

Figure 9. Model design of an adaptable connection between land and floating object

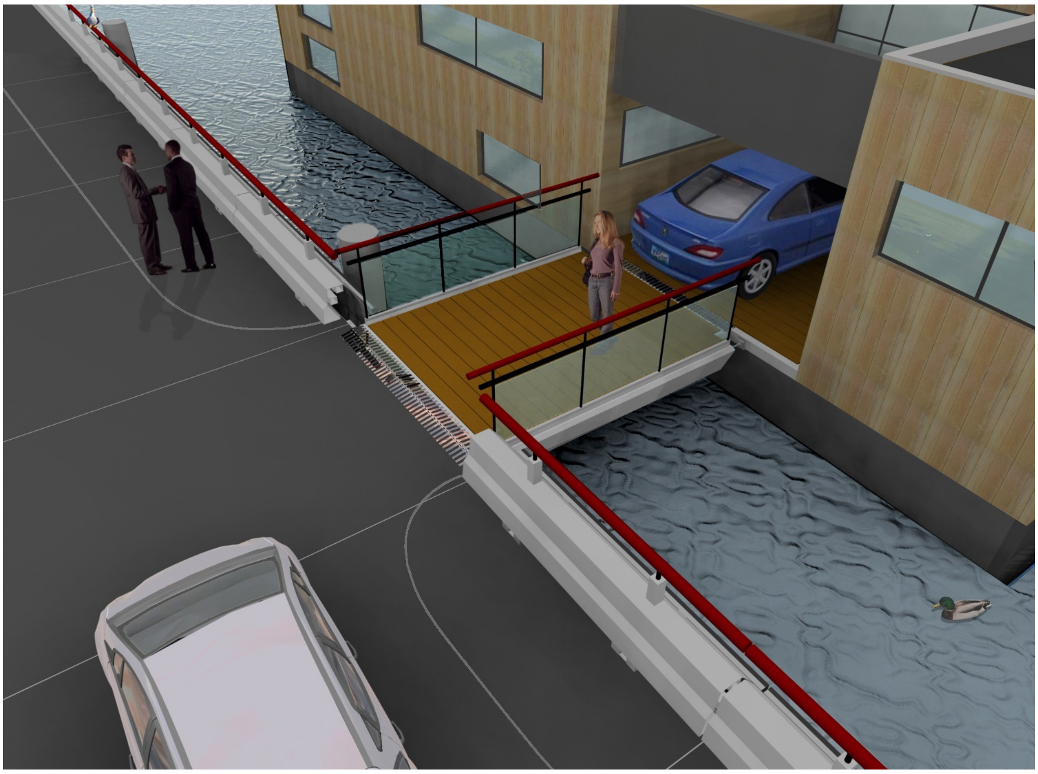

Fig. 10. An artist impression of the final design

6. Conclusions

1. Adaptable infrastructure is a promising answer to the fast changing requirements of a demanding society.
2. The design and production of an adaptable connection is challenging and feasible.

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Modular components for a generic small rail-linked transport interchange site – an exercise in designing for adaptability

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KEYWORDS

Modular Components, Rail Interchanges, Design by Research, Degrees of Adaptability

1 Introduction

Good architecture is usually based on the establishment of a harmonious relationship between the building and the site it is built on. When designing, architects study sites, and in-turn tailor buildings, forming relationships between the new and the pre-existent. However, when designing modular components to be used at various sites, this process is invalidated. The pre-existent is not specific but rather becomes a set of variables – a "generic site" – devoid of easily comprehensible visual information. Studying the generic site means pin-pointing the most important of these sets of variables, thus forming a range of scenarios that modules need to adapt to. Therefore, the development of generic architectural products becomes an exercise in designing for adaptability.

Funded by the Department for Transport and the Engineering and Physical Sciences Research Council UK, researchers from the departments of Architecture and Civil and Structural Engineering at the University of Sheffield liaised with industrial partners (Corus, SKM Anthony Hunt's, Derek Trowell Architects, and Davis Langdon and Everest) to undertake the development of generic architectural products for small rail-linked transport interchanges. The application of the envisaged components was to allow the rapid construction of small rail-linked passenger interchanges for the UK, avoiding disturbance during construction to the operation of the rail network, thus reducing possession costs (closures of lines). The research has recently been concluded and has culminated into designs for prototype modular components – platform substructure, platform and canopies.

The structure of this paper documents the identification of the generic requirements for adaptability of components following, in parallel, the evolution in the design of components. The presentation of the finalised designs and their spin-off applications is used as a vehicle to indicate the contribution that adaptable modular components could make towards the minimisation of initial and whole-life costs of buildings.

2 Adapting to a generic site

Bridging the gap between architecture and product design, the design process was influenced by several factors, each imposing requirements for varying degrees of adaptability [Table 1].

Conventional Architectural Design (site, building, client, architect)	**Building Systems Architecture (generic site, application, market, architect)**
Attempts the establishment of a harmonious relationship between the building and the site it is built on Fits the aspirations of people commissioning the work	Establishes infrastructural relationships with generic surroundings, governed by policy Needs to allow ease of transportation of components Needs to adapt to surroundings at different sites Has to respond to the varying needs of different stakeholders Becomes viable by ensuring market demand

Table 1. Comparison between the design requirements in conventional architectural practice and buinding-systems' design

Policy in the UK dictates minimum legal requirements for various design, maintenance and operational aspects of the railway environment. Dealing with small rail-linked interchanges, the railway tracks are the topological constant of the generic site. Their existence creates various permutations of the generic site depending on: the number of tracks, their position – either on an embankment on level ground or in a cutting, their shape – straight or curved, their inclination, whether they run through or terminate at the station, whether lines are electrified, the speed and type of passing rolling stock. In relation to these parameters, policy also dictates minimum dimensions of the trackside structures; for example, platform height is constant, 915cm above rails, while minimum allowable clear platform width varies from 2.5 to 3m (GI/RT7014 2004).

Transportability of the components was also a major issue for the design – considering access conditions to the possible sites while also taking into account transportation costs. As for the access conditions, consultations with the rail industry in the UK revealed that most situations will require delivering components to the site by road, as this would cause the least disturbance to the operation of the line and would be cheaper over short distances; on the other hand, transportation by rail is most economical over long distances.

Small rail-linked stations exist within varying settings; from urban, inner-city locations to remote rural locations – each setting diversifying the possible problems and challenges that can be faced. A constant parameter in all of them is again the railway itself. Dividing parts of the urban or rural fabric, the railway is a barrier that requires designers to think about bridging the gap. However, fitting into the fabric surrounding stations requires the modular components to be designed with enough adaptability so as to achieve some degree of site-specific individuality in terms of materials, volume, shape and scale. As the railway system in the UK is privatised, with different companies having responsibility over different parts of the network, the variability of the system can also serve to allow for branding of series of stations, thus appealing to the different stakeholders. A consultation with various stakeholders formed part of this research into identifying possible expectations.

However, the requirements for adaptability were not only derived through the process of studying the generic site but were also influenced by real market forces. Since prefabricated modular systems are economically viable when there is demand for high component production volume, which in turn minimises production costs, the design had to maximise the applicability of each component. Having identified a lack in station demand at the moment, the design focused on maximising the applicability of products so that they could be used in spin-off applications (tram or bus interchanges).

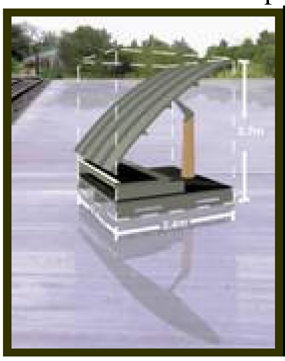
3 Designing for individuality

Based on the considerations for adaptability of components, the requirements for transportability over multiple means proved the starting point for design explorations. Having identified a swap body of 12x2.4x2.7m that can be transported over most railways and roads, the design team explored the possibilities of design within the confines of these dimensions. Figures 1, 2 and 3 depict, in sequence, the developed components loaded onto train and lorry and delivered to the site via rail.

Figures 1,2,3. Adaptability to different access conditions:
2.4x2.4x2.7m module dimensions allow transportation on road and rail

Working on the modular platform, the design sought to specify foundation options suiting varying ground conditions while allowing components to be positioned as far away from the rails as possible (1.3m to closest rail). The three solutions that evolved are concrete pad, concrete raft and steel screw-pile foundations. All require minimum site preparation, rapid installation and safe removal (deconstruction). Foundation options are coupled with two main beams and height adjustment mechanisms, forming the sub-platform module; this employs modularity in size, providing two options, 7.2m or 12m long –indefinitely extendable. The height adjustment mechanism and inbuilt flexibility in the interface of components allows the substructure to adapt to inconsistencies at installation and site peculiarities (cable troughs), as well as tram or light rail applications.

Developed to sit on top of the supblatfrom system is the platform and canopy module. This was developed working on a subdivision of the 12x2.4x2.7m swap body, measuring 2.4x2.4x2.7m. The module was designed so as to allow part of the platform and canopy solution to be delivered on-site and simply deploy from within the box. This contains: the platform's top layer, its extension, the column and the canopy. From within the minimum dimensions, the module can deploy to provide platform space offering 2.5m to 3m clearance to the nearest obstacle; column height providing clearance of 2,7m; and a canopy of almost 3m span. Figures 4 and 5 depict, in sequence, a single module and a module placed on the sub-platform structure mirrored by a deployed module.



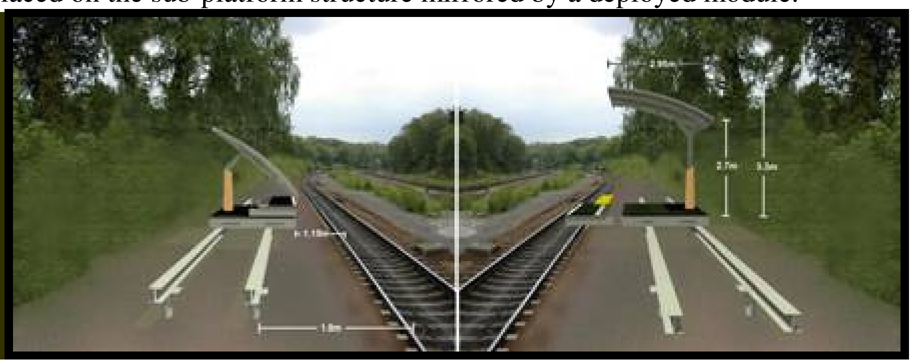


Figure 4. (left) The platform and canopy module
Figure 5. (right) A module placed on the sub-platform structure mirrored by a deployed module

Inbuilt within the components are further allowances for adaptability. The platform structure allows for employing different cladding options and its extension can be pre-engineered for each location to allow adaptability to curved lines. The column employs a tube-in-a-tube construction allowing for height adjustability, achieving varying clearances. Its connection to the canopy is designed offering two alternatives: a pin-joint and a ball-socket joint. The first allows the canopy to be packed within the containing dimensions and deployed to any inclination, offering adaptability to clearance requirements according to rolling stock and the presence of Overhead Line Equipment. Figures 6 and 7 show a single straight platfrom and an island platform respectively, created using the pin-jointed modules. The employment of the ball-socket column-canopy joint maximizes the adjustability to all dimensions, permitting canopies to tilt sideways and be positioned at any inclination and height, resulting in large architectural variations as depicted by the example shown in Figure 8. Furthermore, the canopy structure itself is designed so as to allow for lights and information screens to be hung or embedded from its exposed structure and is clad using the Kalzip system, which can be produced in large colour variations, is suitable for quick and easy site assembly and can also carry solar panels.

Figure 4. Single platfrom solution

Figure 5. Island platfrom solution

Figure 8: Wavy canopies achieved by using the ball-joint canopy-column connection

A spin-off of the platform module has already been designed for by Corus, using the subplatform module design coupled with the Quantum Floor Modular Unit - consisting of galvanised light gauge, cold rolled steel sections with a concrete infill. This design employs different dimensional modularity since the platform is larger and heavier but instantly creates much larger platforms – up to 12m long platfrom can be delivered in one piece. This spin-off product can be interfaced with the post and canopy components.

4 Does the systems-approach pay off?

Throughout the duration of the research project, the design partners undertook research actions parallel to the design. Davis Langdon and Everest (quantity surveyors) undertook research in identifying the key cost drivers for station construction. Through this research, it became apparent that possession costs during construction can amount to 8% of the total expenditure, which can be anything above £3m for a simple two-platform station. The system developed simplifies the construction process, reducing it to deployment and assembly of components, minimising possession times and therefore reducing costs. Estimations made by Davis Langdon and Everest for the application of the designed modules suggest that their price is competitive to conventional construction This estimation did not factor in the savings that can be made through high-volume industrial production of the components or through limited possession costs, thus proving that even one-off applications of the system can significantly reduce construction costs.

More than contributing towards rapid construction, the systems-approach generates benefits that are not always quantifiable in terms of cost. Having designed the sub-platform structure to incorporate foundations that require minimum site preparation and allow their easy removal, the system minimises disruption to the environment and simplifies construction processes where ground contamination is an issue (particularly at older railway sites). Removing the larger part of the construction process from the site allows greater predictability of the whole process – in terms of programming the work and increasing quality control while it also contributes towards increasing safety and reducing waste on site. The ease of transportability and the simple deployment of components allow future expansions and retraction of facilities. This creates a flexible, adaptable building envelope, essential for the railway sector - as stations receive altering patronage over large time periods requiring them to expand or retract their facilities. The overall impact of these benefits is the reduction in whole-life costs of the station.

5 Conclusions

This paper examined the application of modularity and prefabrication principles on the design and construction of small rail-linked transport interchanges. Having outlined the requirements for adaptability to the generic site, the paper progressed to the presentation of the designed components analysing how the requirements for adaptability were translated into structures. This lead to the presentation of variable solutions that can be achieved using the building system developed. The last section of the paper described the advantages of such a system-approach in terms of minimising initial and whole-life costs of stations and outlined the added benefits of this approach in relevance to the railway environment. The authors of this paper believe that this approach could transform the construction of small interchanges, influencing transport planning by providing more access points to public transport on minimum investment.

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SPACE BETWEEN PLAN AND MODEL

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1 Introduction

In our work we are busy with philosophy and the mathematics of Building Sciences. It is not relevant whether we are talking about new buildings or adaptation of buildings. The variables in both cases are Volume (V), Energy or Labour (E), and Time (t). By adaptation the variables will be $V_0+\Delta V$, $E_0+\Delta E$, and $t_0+\Delta t$, where V_0, E_0, and t_0 are already consumed variables. The variables ΔV, ΔE, and Δt are needed to make the adaptation possible. The ethical rules between those variables are valid for new and adaptable buildings that have to be adjusted. 'Theory of Building Models' [Krebbers and Stojanović 2006], 'Architecture and Ethos' [Stojanović and Krebbers 1997].

Our scientific goal is to make a mathematical model based on computation and ethics that will give us the answers to our wishes in structures, economics, and social expectation by adaptation. As we are dealing with these problems we are trying to communicate with Building Managers. The money approach and the technical structure have a very complicated mathematical relationship.

Synchronizing the request for an ***optimal solution*** within space (X, Y, Z), time (t), and money (M) means calculating in 5 dimensions (X, Y, Z, t, M). We believe that the mutual influence between us as theoreticians who exercise in Plato's principle space and the managers who intervene in Aristotle's pragmatic space are very important for the building reality and future.

In this paper we will define mutual characteristics of construction and adaptation. Ethos, quality, quantity, data, and information are common terms in the design, and building process. Ethics is a well-known word, but the question is, is it well understood? We shall illustrate some ethical problems with examples of Urban Planning.

2 Ethos

Baruch de Spinoza defined ethics as a science of 'good life'. Consequently 'ethos' can be translated as 'good life'. The question is: A good life for whom? The answer can be 'a good life for a character or a persona'. The words 'character' (Greek) or 'persona' (Etruscan) are one of the first possible translations of 'ethos'. Another translation of 'ethos' is the word 'custom':

1. Folklore custom (cloth, music, wedding, funeral, typical building style etc.),
2. Custom (money).

Ethos is the root of ethics which tends to objectify *values*, *choices*, and *senses*.

We can also use the words *usual* or *habit* to translate the word *ethos*. This means something we do as a group to keep society functioning. The rules in obeying customs are called: 'morals'. All social systems are under permanent observation of *morals* as a part of *ethos*. When this observation becomes repressive than we call it *censorship*.
We can approach *ethos* as an individual or as a group. There are many classifications of *ethos*. We have chosen to group it by number of persons (quantity) and by qualitative division. A group can vary from 1 person to all persons on this planet and for qualitative division we may use:

- **Metaphysics** (The science of the real as distinguished from the phenomenal being (*Onthos*). It can also been explained by calling it the backside of Physics. It sets the rules of science);
- **Naturalism** (A state of nature, or more popularly the ethical laws based on natural laws. Everything can be built, but we have to obey certain rules from nature. We are technologically capable of building so extensively that we can destroy the earth);
- **Hedonism** (Pertaining to pleasure. We can say that the motor of civilisation lies in hedonistic Ethics).

We think that *ethos* is crucial in building and that the context is so broad, that we cannot neglect the demands of *ethos*. In 'table 1' we show the relation between building constructions and the ethical grouping in a qualitative and quantitative way. We have attached two extra rows: 'money' and 'revenues'. 'Money' is the ethical and numerical evaluation of objects, subjects and their mutual relationships. 'Revenues' is the income generated by the construction. We are trained, with the help of economical feasibility models (money), to find the *price* of constructions, but in the table we can see that the *value*, shown in money, is not proportional to the qualitative substance of the constructions.

		QUALITATIVE		
		METAPHYSICS	**NATURALISM**	**HEDONISM**
QUANTITATIVE	**PERSONAL**	Home altar, icon	Place to live, educate and work. transport	Place for an addicted person, Coffee Shops
	REGIONAL	Religious buildings	Required regional buildings, Hospitals, Public buildings, Regional plans	Bingo and lottery halls, horserace accommodations, Luxurious residences.
	NATIONAL	Church, Synagogue, Mosque, Pagoda etc.	Required government buildings, Representative buildings, National plans	Gambling cities, Elite municipalities.
	CONTINENTAL	Shrine, Temple, Holy buildings etc.		Prestigious buildings for US, EU, Russia, China and India etc
	GLOBAL	Vatican, Mecca, Athos, Jerusalem	United Nations	Olympic games
	UNIVERSAL		Cape Canaveral, Baikonur, Koeroe, Hainan	Space exploration
	MONEY	*Less important*	*Important*	*Little important*
	REVENUES	*Slow, but sure*	*According to plan*	*Dangerously oscillating (high risks)*

Table 1. Ethical table of qualitative and quantitative division of buildings and constructions

Relative evaluation in *money* was illustrated by many people, but we have found the sentence of Oscar Wilde the most appropriate: ***A cynic is a man who knows the 'price' of everything and the 'value' of nothing.***
Value is a pure ethical definition. In daily life we evaluate static and dynamic phenomena in the form of money through the *price*. Most things in the naturalistic world have a *price*. *Price* has a quantitative (numerical) part and a qualitative (name) part (€ 1,000,000; '€' is the name, quality '1,000,000'; is the number, quantity). The quality, the name, has to do with *credibility*, *trust*, and *predictability*. The quantity, the number, means amount and is used for calculation.

Most people have problems in distinguishing the terms *value* and *price*. We shall try with two examples to emphasise the difference between them:

1. *Oxygen has almost no price, but the value cannot be measured. Will we pay for oxygen in the future?*
2. *We find it normal to pay for drinking water. Many people remember times when drinking water was free of charge. When society gets more complex we have to pay for these types of necessities.*

We have mentioned *ethics*, *quality*, *quantity*, *value*, and *price*. These are all characteristics with which we evaluate 'object', 'subject', and their mutual relationships. Before we start with the evaluation we have to analyse them. This analysis is a process that can be done in two ways: 'principally', and 'pragmatically'. The first way is to look scientifically at the *entire* object (subject or mutual relationships). The second way is, when an object is too big or complicated, to zoom into a part of our interest. The first way is called *principle* and the second *pragmatic*. The old Greek philosophers already pointed out at this problem. It was formulated by the Sophists: when you cannot see the whole, part of the information is lost (process of abstraction) 'Architecture and Ethos' [Stojanović and Krebbers 1997]. Solving a building problem in a pragmatic way will always lead to an 'error' (difference) at the end, but we are normally forced to solve building problems pragmatically. ***Urbanism can be stated as the science that tries to find solutions of building problems in a principle way***.
Every building structure has its good and bad prospects. Good prospects are: working, living, nursing, safekeeping, transporting etc. Bad prospects are that every structure takes space (often green areas are used) and most structures pollute the environment (destroys green areas). Some structures however, are necessary to be built: hospitals, schools, police stations, prisons, bridges etc.

3 Quality and quantity

Many people do not know that quality and quantity are bound. Information scientists define quality as a limited sum (integral) of quantities. The only way to make realistic calculations of qualities is with the help of quantities. Many scientists tried to objectify quality, but the results are questionable. Many solutions are part of voluntarism: Detergent 'A' is 3 times better than detergent 'B'. This type of evaluating is not scientific, as there is no scale and reference [Barzilai 2001]. Every read out is individually shaded and it is 'quasi scientific'.

Dealing with adaptation as well as with the original construction has other mutual characteristics and that is the modelling process. An adaptation model, for a difference of an 'original' construction model, has two different patterns. The 'original' design is always constrained by the building site. A construction that will be adapted is bounded by the building site and the remaining construction. It is obvious that within modern urban buildings we are using the existing infra-structure. These facts make the boundaries between original construction and the adaptation quite vague. By adaptation we want to change *quality* by adjusting *quantities*. In the previous sentence we mentioned *quality* and *quantity* and our conclusion is that there is a parallel with the words *data* and *information*. *Data* are meaningless numbers, characters and drawings, it has quality of quantity. By placing data in a certain order or pattern or relating it within a computer program, *data* can become meaningful; it gets quality and in that case we call it *information*. Another way to create 'information' from *data* is to filter *data* with a mask. The process of forming *information* from data is called aggregation. Aggregation is an element of synthesis and it is subject to individual interpretation. Lecture 'Architecture and Ethos' [Stojanović and Krebbers 1997]. Translating *data* into *information* leads to *duality*. Lecture 'Technical Models' [Stojanović and Krebbers 1997]

Every mathematical (formal) model has a very broad basis in text, drawings and calculations. When we want to make a mathematical model from such a broad base, we must aggregate groups of 'look alike' qualities. The second step in forming a mathematical model is to divide qualities into quantities of aggregated groups. This process causes abstraction. One part of our information gets lost (dissolves into data). Aggregation and abstraction, formulated in such a way, defines only the foundation of the mathematical (formal) model. The process of mathematical (formal) modelling uses a very small amount of 'information' from the verbal and conceptual part of the model. The process of abstraction induces dissolving of *information* into *data*. The definition of *information* can be stated as knowledge over minimal qualitative and quantitative characteristics of phenomena. Information theory says that information is defined with minimal two descriptors (mandatory qualitative and quantitative). *Data* however, is defined with only one descriptor.

Example: the number '100 kg'; 100 (data; quantity); kg (mass; quality)

The analysis of the example shows us that we have hundred kilograms mass of an unknown material. This type of *information* is called 'insufficient *information*' and in daily practise treated as *data*. That means that in the translation of the model we need a third *data* for full *information*. We can conclude that the verbal concept, due abstraction, was not complete.

4 Urban quantities and qualities

Urban Planners made lots of mistakes during the last two decades in materialising zoning and development plans. They failed to make good feasibility studies (technical and financial) and to present realistic alternatives. In many plans there was no public transport, no religious and cultural buildings, and there were for example not enough parking places. The analysis of these heavy mistakes shows that Urban Planners have a lack of calculations in their concepts. The static approach to 'time' (as the only independent variable at all) causes afterwards a vanishing of green areas in the process of urbanising the area. The costly utilities are badly calculated and they do not reflect the return on the investment. If we analyse dynamically the results of these mistakes we can conclude that we get: dissatisfied stakeholders, bad financial plans, no money for the exploitation, and a polluted environment. We believe that there is a direct correlation between these bad plans and the definition of quantity and quality characteristics. If we go through the past 10 years we can see that there was a fierce discussion, between Urban Planners and government, about the relationship between quality and quantity in plans. The general idea was that society demanded better products by Urban Planners and they should be more aware about the quality of their work. A big problem arose when Urban Planners tried to evaluate qualities. The scale of the qualities exists in verbal models, but disappears in the process of abstraction in conceptual and mathematical models. The real problem was generated when Urban Planners were ordered to make quality plans. This order was followed by a ban of using and keeping databases with urban quantities. That induces the sequential (pragmatic) calculation of time and eliminating of the variable 'time' as a continuum. Urban Planners and quality and quantity surveyors were forced to jump from a principle definition of their task, to a very pragmatic one. This type of approach delivers short term benefits by cutting costs, but in longer term it leads to collapse of practical solutions. On basis of this short analysis we emphasis at least three mistakes:

1. The market plays nowadays a prominent role in the planning process. Many municipalities allowed the market to make turnkey projects. A disadvantage is that local democracy lost control. Modern societies, as The Netherlands, are only partly a result of the market economy. Subsidies deform the effect of the market and it influences the buying capacity of money. Money gets 'soft'. The gap in reality between the outside world (macro) and the local market (micro) reflects disharmony. The municipalities thought that there is no financial risk, but the micro and macro financial calculations diverge. Many times extra money is asked or extra houses that have to be built to decrease the loss. The general cure used to close the financial deficit was shifting property from 'houses for rent' to 'owner-occupied houses'. In times of recession this manoeuvre gives boost, but it causes the collapse of the demand of the 'owner-occupied houses' in the future.

2. The lack of calculating abilities of Urban Planners and Politicians has caused the use of norms indiscriminately. Norms are needed to make good feasibility studies especially in conceptual models. Calculating with applied norms, in conceptual models, became normal practise in every new project. The problem with norms is that they are very seldom standardised. The designers

who used norms were very often not aware that norms have quantitative and qualitative aspects. The problem with applying a norm is that it can be misused for pragmatically political goals. Well defined norms are easy for calculations and visualisations. We only know one report [Werkgroep Ruimtebeslag 1979] in which norms are used as quantitative and qualitative phenomena. The elasticity of norms in this report shows that shrinking and broadening of applied norms including the mutual exchange of substance of norms and the flexibility between norms, made the creation of plans with a desired quality possible. Contemporary politics uses a static list of norms. The result of these types of norms is that we can only build 33.3 houses per hectare.

3. A third troublesome problem is the land development of plans. Plans are only judged as a sum of the costs of the various parts of the plan. There is no cohesion, there is no principality. The report from 1979 proposed a method of land development that was not only dealing with the plan, but also with the municipality as a whole and partnerships of the municipality with surrounding municipalities. In this method costs were redistributed between all existing expensive activities in the municipality. For example the costs of parcels were raised for the benefit of sporting facilities, recreation grounds, and allotments etc. A special category of this type of beneficial solidarity is the financial contribution to plans on a regional level, for example nature reserve. When the market got more and more involved in making plans, the natural bond between plan and municipality became weaker. Market parties are not interested in the problems of the municipality and absolutely not in partnerships between municipalities. Corporations and the corporate State have almost no feelings for the communities.

5 Conclusions

Because of the shift from community to market initiative, the land development and the typology of zoning and development plans have changed dramatically. The market is not the only one to blame, housing associations neglected their role in social housing and the government played 'hide and seek'. Some housing associations even built 'owner-occupied houses' and acted as commercial parties. The result is that some housing associations are overloaded with money.

At this moment there is tendency at the municipalities to make their own land development plans again. It is a pity that most scientific curriculum's have no specialisation in land development, because there is a big demand for specialist in this field.

Modern Western European societies show a trend to built excessively business buildings and much less residential buildings. (This problem is very interesting and we will analyse it in a new paper). This has caused the relative surplus in luxurious office buildings (In The Netherlands about 7.000.000 m^2). Some stakeholders (municipalities, market elements, housing associations) in the building process take a position as para-oligarch and that can have a fatal effect on society.
The controversy of contemporary global society is that it delivers working space which is more profitable than living space; however work is not a mandatory element of life.

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KEYWORDS

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1 Introduction

In a twelve year discussion about the problems in Building and in Architecture we realised that we needed an integral approach for technical problems. Both authors belong to different mathematical and philosophical schools, but we realised that many answers can be found in Linear Theory. In later research we developed a special approximation of mathematical derivative functions that originates in intersection approximation. This last research resulted in a book 'Open Construeren' [Stojanović and Krebbers 2001] and in a series of lectures and papers.

Applying mathematical techniques is for most architects a burden. They prefer to design, but they confuse drawing with designing. Designing is in our view a combination of descriptive, conceptual and mathematical tasks. Avoiding mathematics makes the design less reliable, incomprehensible, and more expensive. The complexity of architecture, urban planning, and building management problems are so broad that almost all mathematical techniques have to be used. On the other hand the level of knowledge of mathematics of Architects, Urban Planners, and Building Managers is so under-developed that we are forced to use mathematical techniques learned in secondary school. That is why we orient ourselves on linear analysis and mathematical modelling. Linear Programming has advantages, like easy adding or removing of new parameters and restrictions, but there are also disadvantages. For example the maker of the model has to change his way of thinking. Building a model structure with constraints, and without knowing the contents of variables, is opposite to our knowledge. We are all educated as 'bookkeepers' and the so-called 'matrix-simultaneous' way of thinking is quite strange to us, but practice proves us that we get accustomed very fast.

In the paper 'Theory of Building models' [Krebbers and Stojanović 2006] we have made a comparison between a formal physical building model and a formalised mathematical model. The conclusion was that with help of approximation of higher power functions we can adequately optimise many calculation problems. In this paper we will extend the possibilities of managing various building, structural, and urban managing calculation problems.

The subject of architectural sciences is the analysis of volume or surface. Volume is a function to the power three (cubic) and surface to the power two (square). In other words from the start we have a problem to transform a higher power function to a level applicable to linear theory. In the paper 'Curved Problems Straightened' [Stojanović and Krebbers 2006] we have proved that higher powers can be used in linear models. We are absolutely not the first researchers in this field. [Beale 1972] introduced quadratic programming, but the quadratic possibilities are limited to the objective function. The LP applications, we use nowadays, can handle quadratic variables and constraints. Both, Beale and software builders, make adaptations to the original algorithm. Beale's technique is a very difficult to understand and it is hard to find a daily live problem. The optimum in both techniques is always 'local' instead of 'global', as it should be in linear problems. As we know a 'local optimum' is suspected to be the highest peak in a foggy mountain area, but it is impossible to see if there is a higher peak around. In this paper we will suggest no adaptations to the original algorithm of Dantzig. In our approach we will therefore always find a 'global' answer. We merely build a shell around our model to automate the iterations of the differentiations outside the model. In this paper we will explain why we think that mathematics should be used more, how a model can be build, and we will show our technique in examples.

2 Mathematical models

Mathematical patterns are the main aim of mathematical modelling and can be used for multiple calculation purposes. Among mathematical modelling, linear models represent the simplest ones. The simplicity of linear modelling limits the possibilities of calculations. Linear models exclude higher power and trigonometric functions. Reality is not linear, trigonometric relations are present whenever we have angles in a problem. Consequently using linear models, in its literal meaning, will narrow the subject of our analysis. Computers are capable to repeat calculations endlessly. Dealing with higher powers in computers means that we order the computer to sum the known amount 'a' of a variable 'a'-times. The difference between linear and non linear functions is quite vague as we shall see in the following example:

$$f(x) = \sum A_i \cdot x_i \Rightarrow f(x) = x^n \Rightarrow \sum A_i \cdot x_i = x^n \qquad (1.)$$

We asked ourselves what shall happen in the particular solutions:

$$\sum A_i \cdot x_i = \left\{ x^{-(n-1)} \cdot x^1 ; \ldots\ldots x^0 \cdot x^o ; \ldots\ldots x^1 \cdot x^{n-1} \right\} \qquad (2.)$$

From the linear function `1.` we get a non-linear function `2.`. We are going to use this characteristic in solving non-linearity in our linear models:

$$x^n = \underbrace{\underbrace{x + x + x + \ldots\ldots + x}_{x} + \underbrace{x + x + x + \ldots + x}_{x} + \ldots + \underbrace{x + x + x + \ldots + x}_{x}}_{n} \qquad (3.)$$

The above statement connects linearity and non-linearity by way of a sum. The difficulty of linear transformations is that we can only operate with summing (adding) and subtractions. Multiplying and dividing are derivatives of adding and subtraction. In our papers [Stojanović and Krebbers 2006], [Krebbers and Stojanović 2006] we are dealing with the most sensitive problems of linear manipulations with models, but we are not sure if we will be able to solve every particular problem. This concerns particularly roots of arguments where there is no sufficient data about the connection between roots, adding, and subtracting.

Objective function

The objective function is the mathematical formulation of our optimisation (maximising, minimising, or a combination). Another name of this function is 'goal function'. In literature this function can be linear or non-linear. The function does not have to contain all off the arguments of the model. The innovation that we have introduced, speculates with the form of the goal function. We need a number of additional constraints to keep the goal function intact. The method enables a clear relationship of arguments within the goal function. The analysis of the objective function is an integral part of the model.

Constraints

Constraints give information about the relationship between arguments within the model. All arguments in the model are greater or equal to zero. The entire linear modelling process happens that's why in the first quadrant. With the constraints we can build linear and non-linear relationships between the arguments. Models built with this concept are clear ('glass boxes'). Every constraint is easy to understand and simple to correct. Another characteristic is that models can fit into a bigger model (like a procedure in a network or a brick in a wall). The goal of the model designer is to build an integral model, composed of different segments. Such a model needs one input and one output, but these types of models are rare. We use mostly models that consist of separate sub models that do not fit automatically in each other. The model can stay clear, but the result is not clear and will give a solution that can not be mathematically proven. In this case the model is solved in a 'black box'.

3 Algebraic transformations of the goal function

The form of the goal function is not always the most applicable one. We can rewrite the function to a form that is suitable for further calculation in the way we want it, but the contents will not be changed. It is difficult to understand our intention, but it will be clear with the help of examples.
The goal function can be of a linear or higher power nature. It can consist of one or more adjustable (endogenous) variables.
Example of a goal functions with only one variable:

$$x^n = Z \qquad (4.)$$

There could be also a problem of two or more variables (arguments) like:

$$\sum_1^n x_i^k + \sum_1^j \prod_1^{p,l} x_j^r \cdot x_k^t + \sum_1^s a_q = 0 \qquad (5.)$$

This kind of goal function has principally no solution, the solution can only be traced with the help of numeric calculation, but some of the cases can be solved in an analytical way. The lower the power of the argument, the better chances for an analytical solution. Most of the quadratic and some of the cubic goal functions have analytical solutions. In the following text we shall discuss some of these cases.
The solvability of the equation depends of the factors `n, i, k, j, p, l, j, r, t, s, and q`. If `n, i, k, j, p, l, j, r, t, s, and q` are equal to `m`, than the entire formula `5.` will get the form:

$$\sum_1^m x_i^k + \sum_1^m \prod_1^{m-1} x_i^k \cdot x_j^k + \sum_1^m x_j^k - \sum_1^m a_i^k = 0 \qquad (6.)$$

This formula can be written only under particular circumstances. It must satisfy the condition:

$$\sum_1^m x_i^k + \sum_1^m \prod_1^{m-1} x_i^k \cdot x_j^k + \sum_1^m x_j^k = \sum_1^m (x_i + x_j)^k \Rightarrow \sum_1^m (x_i + x_j)^k = \sum_1^m a_i^k \Rightarrow \sum_1^m (x_i + x_j) = \sum_1^m a_i \qquad (7.)$$

Such a particular solution is quite rare. We must rearrange the formula, but it normally does not get such a simple form. Most of the time we have to analyse the goal function in the form:

$$\sum_1^n x_i^k + \sum_1^j \prod_1^{p,l} x_j^r \cdot x_k^t + \sum_1^s a_q = 0 \qquad (8.)$$

$$\sum_1^s a_q = \sum_1^m a_i^k \qquad (9.)$$

$$\sum_1^n x_i^k + \sum_1^j \prod_1^{p,l} x_j^r \cdot x_k^t + \sum_1^s a_q + \Delta[x_i, x_j, x_k] - \Delta[x_i, x_j, x_k] = 0 \qquad (10.)$$

So that:

$$\sum_1^m (x_i + x_j)^k = \sum_1^m a_i^k + \Delta[x_i, x_j, x_k] \sum_1^m (x_i + x_j)^k - \sum_1^m a_i^k = \Delta[x_i, x_j, x_k] \qquad (11.)$$

We can rearrange the goal function in the following quadratic form:

$$(x+y)^2 = x^2 + 2x \cdot y + y^2 \Rightarrow \; x \cdot y = \frac{1}{2}\left[(x+y)^2 - x^2 - y^2\right] \qquad (12.)$$

Another premise for defining multiplying of two functions is:

$$(x+y)^2-(x-y)^2=4x\cdot y \Rightarrow \; x\cdot y=\frac{1}{4}\cdot\left[(x+y)^2-(x-y)^2\right] \qquad (13.)$$

The rearrangements of the goal function with two variables in cubic form:

$$(a+b)^3-\left(a^3+b^3\right)=(a+b)\cdot(a+b)\cdot(a+b)-(a+b)\cdot\left(a^2-a\cdot b+b^2\right) \qquad (14.)$$

$$(a+b)^3-(a^3+b^{3)}=(a+b)\cdot\left[a^2+2\cdot a\cdot b+b^2-a^2+a\cdot b-b^2\right]=(a+b)\cdot 3\cdot a\cdot b \qquad (15.)$$

$$(a-b)^3-\left(a^3-b^3\right)=(a-b)\cdot(a-b)\cdot(a-b)-(a-b)\cdot\left(a^2+a\cdot b+b^2\right)=-(a-b)\cdot 3\cdot a\cdot b \qquad (16.)$$

The above transformations are always possible. It is permitted to use all algebraic transactions in rewriting the goal function, but we have to take in account not to deform the boundaries of the essential function. In the following practical examples we have given an example of a calculation of higher power functions, with one and two variables.
In our paper 'Curved Problems Straightened' [Stojanović and Krebbers 2006] we introduced the ideas from Leibniz and Newton that the tangent is only one form of an intersecting line. The same is valid for the result line of the point of inflection. We approximated the curved line with a series of tangent points and points of inflection. When we join these points we get a polygonal line. The polygonal line permits optimisation with a Linear Programming application. [Stipanić 1971]

4 Three experiments

Interest

In this example we show how to calculate the interest for a loan of 55.000 Euro when we are able to pay 5000 Euro a year. The payback period is 15 years. In 15 years we will pay 75.000 Euros (15 times 5000 Euros).

Capital to borrow			**55,000**	**Euro**
Max annuity	**5000**	**15**	**75,000**	**Euro**
Max interest			**1.82**	**%**

Auxiliery equations

	0	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
Max. interest	6.000%	1.12	1.19	1.26	1.34	1.42	1.50	1.59	1.69	1.79	1.90	2.01	2.13	2.26	2.40
Min.interest	1.018%	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.10	1.11	1.12	1.13	1.14	1.15	1.16
tangent (f1, f2)		2.07	3.215	4.439	5.746	7.143	8.634	10.23	11.92	13.73	15.67	17.72	19.916	22.25158	24.7391
constant (c1, c2)		1.071	2.217	3.442	4.753	6.153	7.649	9.246	10.95	12.77	14.71	16.77	18.978	21.32578	23.8269

Find max interest

1.0368

		X	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	MAX.			
0	**Solution**	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.22	1.24	1.27	1.30	1.33	1.36	75000			
1	Min. X	1																1.01825	>=	1.01
2	X2	2.07	-1															1.07079	=	1.07
3	X3	3.215		-1														2.21674	=	2.22
4	X4	4.439			-1													3.44245	=	3.44
5	X5	5.746				-1												4.75284	=	4.75
6	X6	7.143					-1											6.15309	=	6.15
7	X7	8.634						-1										7.6487	=	7.65
8	X8	10.23							-1									9.24553	=	9.25
9	X9	11.92								-1								10.9497	=	10.95
10	X10	13.73									-1							12.7679	=	12.77
11	X11	15.67										-1						14.707	=	14.71
12	X12	17.72											-1					16.7744	=	16.77
13	X13	19.92												-1				18.9779	=	18.98
14	X14	22.25													-1			21.3258	=	21.33
15	X15	24.74														-1		23.8269	=	23.83
16	Max X	1																1.01825	<=	1.06
17	Capital to borrow															55000	-1	-2E-10	=	0
18	Max capital																1	75000	=<=	75000

Figure 1. Linear model for calculation of interest

The question is: how high can the interest be when the total sum can not exceed 75.000 Euros? The interesting characteristic of this example is the reverse oversight of the value of the function change as it roots every previous value. The example itself has no direct application, but it can be used in a bigger model for the calculation of final value.

Model without multiplying

The goal function is:

$$x+y-\frac{3}{2}\cdot x^2-\frac{5}{2}\cdot y^2-2x\cdot y \Rightarrow \; x+y-\frac{1}{2}\cdot x^2-\frac{3}{2}\cdot y^2-\left(x^2+2x\cdot y+y^2\right) \qquad (17.)$$

$$x-\frac{1}{2}\cdot x^2+y-\frac{3}{2}\cdot y^2+(x+y)^2 \Rightarrow \; (x+y)\cdot(1+x+y)-\frac{1}{2}\cdot x^2-\frac{3}{2}\cdot y^2 \qquad (18.)$$

Such a presentation of a goal function has four possible forms. We use these formulas to make the analysis and our practical problem and solution better understandable, in more comprehensible form, to the user. The changes in the form of this functions does not change the substance of the meaning, but merely the form in which the same function can be presented in various forms in algebra.
Our opinion is that such an approach to the analysis of the form of the function makes the solution of many applied mathematical problems easier to the daily practise.

	X	X^2	Y	Y^2	X+Y	$(X+Y)^2$	X-Y	$(X-Y)^2$
MIN!	100	10000	99	9801	199	39601	1	1
	100	10000	**2**	4	102	10404	98	9604
		200		101		301		99
		10000		198		20298		98

	X	X2	Y	Y2	X+Y	(X+Y)2	X-Y	(X-Y)2			
		10000					39601				
Solution	100.0	10000.0	99.0	9801.0	199.0	39601	1.0	1.0			
Goal	1	-0.5	1	-1.5		-1			**-59103.5**		
Xmin	1								100	=>=	100
X2	200	-1							10000	=	10000
Xmax	1								100	=<=	100
Ymin			1						99	>=	2
Y2			101	-1					198	=	198
Ymax			1						99	=<=	99
(X+Y)2					301	-1			20298	=	20298
(X-Y)2							99	-1	98	=	98
X+Y	1		1		-1				0	=	0
X-Y	1		-1				-1		0	=	0

Figure 2. Model without multiplying

Model with multiplying
To get a multiplying algebraic transformation we have to start from the formula:

$$(x+y)^2 = x^2 + y^2 + 2x \cdot y \Rightarrow x \cdot y = \frac{1}{2} \cdot \left[(x+y)^2 - x^2 - y^2\right] \qquad (19.)$$

With the help of this algebraic transformation we have solved the problem of multiplying with the help of linear transformations. This statement, however for the difference of the above, has to be placed with help of constrains in the model.

X	X^2	Y	Y^2	X+Y	$(X+Y)^2$	X-Y	$(X-Y)^2$
100	10000	99	9801	199	39601	1	1
0.22	0.0484	**0.1116**	0.012455	0	0.109959	0.1084	0.011751
	100.22		99.1116		199		1.1084
	22		11.0484		65.9884		0.1084

	X	X2	Y	Y2	X.Y	X+Y	(X+Y)2	X-Y	(X-Y)2			
		0					0					
Solution	0.220000	0.048400	0.111600	0.012475	0.024562	0.331600	0.110000	0.108400	0.011750			
Goal	1	-0.5	1	-1.5			-1			**0.178687**		
Xmin	1									0.22	=>=	0.22
X2	100.22	-1								22	=	22
Xmax	1									0.22	<=	100
Ymin			1							0.1116	=>=	0.112
Y2			99.1116	-1						11.0484	=	11.05
Ymax			1							0.1116	<=	99
X.Y		-0.5		-0.5	-1		0.5			-4.9E-17	=	0
(X+Y)2						199.3316	-1			65.9884	=	65.99
(X-Y)2								1.1084	-1	0.1084	=	0.108
X+Y	1		1			-1				0	=	0
X-Y	1		-1					-1		0	=	0
$X^2+2XY+Y^2=(X+Y)^2$		1		1	2		-1			9.71E-17	=	0
$X^2-2XY+Y^2=(X-Y)^2$		1		1	-2				-1	-9.7E-17	=	0
(X+Y)2-(X-Y)2						1	-4	1		0	=	0
(X+Y)2+(X-Y)2		2		2			-1		-1	0	=	0

Figure 3. Model with multiplying

5 References

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Creating Value through Break-Even Analysis in the Open Building


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Break-even, sensitivity analysis, modification cost, modification time, open building.

1. Introduction

According to the International Valuation Standards (IVS 2003) the market value of a piece of e real estate should be based on a valuation of both its highest and best use. The market value applied in accounting is based on how the property is utilized optimally. It must include an evaluation of the following questions: does the planned use suit the building, and is the building modifiable for the planned use i.e. how adaptable and flexible is the building. The principle of the open building involves investing in the hierarchical levels of the project in order to manage its complexity. Some solutions may in the short-term appear as additional costs compared to the traditional one-level solution, even though in the long-term they should be seen as value adding activities.

The open building is an example of sustainable value that is commonly accepted, especially from the theoretical point of view. However, even though this is taken as a self-evident fact, it is still not put into practice as widely as it should be. Sustainable design ideas, even though they are important for a project's organization, still tend not to be given top priority within the context of a given project [Emmit & Johnson 2004]. On the other hand, some project managers tend to focus on the short-term criteria i.e. successful accomplishment of the cost, time, and quality objectives, whereas the customers focus more on the log-term criteria [Kupakuwana & van der Berg]. Actually, the customers also tend to focus on minimizing short-term costs and underrating sustainable long-term values such as these of the open building due to reasons like an investor's will to maximize the rentable area at the expense of proper HVAC reservations i.e. sufficient structural capacity to accommodate future HVAC upgrades/changes.

The ongoing FinSUKE research project states that the solution for the overlapping problems of modern construction is open building [Kiiras et. al. 2005]. More or less successful open building cases have been presented in several articles. Nevertheless, a professional contractor may focus too heavily on maximizing his financial short-term profits or a one-time customer may simply fail to understand the open building as sustainable value. In this kind of situations translating the impact of the open building to hard figures may prove a useful tool. The aim of this paper is to demonstrate how financial figures can be applied to the task of illustrating the advantages achieved by the open building.

2. Project scope: open building vs. "non-open" building

The new International Financial Reporting Standards (IFRS) will have an effect on real valuation practices: changing the determination of real properties, a fair value method for real properties, and the handling of lease contracts. The fair value method will change essentially the practice of reporting write-downs only after they have become permanent. For instance, when a corporation had a piece of real property in its own use that had a greater market value than the book value, it could sell the property to an investor and lease it back with a long lease contract, and, at the same time, increase its earnings through the valuing difference. The new IFRS standards don't allow this, and on the contrary, will actually test the authenticity of the market valuations used in accounting. In the real estate investor sector, this change will obviously increase the demand for authorized real property valuations. These valuations will have more weight on the real vacancy rates and on the real profitability of a given piece of real estate. The IFRS change is expected to have an impact on real property strategies and to increase the volatility of the market. A logical consequence would be e.g. shorter lease contracts. In addition, filling an empty space by lowering its rent under the market rent is no longer rational because it influences directly the profits through the falling market value of the property [Hiltunen *et. al.*2005].

Hence, the proportional value of less modifiable buildings should decrease while the demand for the proportionally more valuable open building should increase. The financial approach presented in this paper evaluates a project's long-term cost structure and profitability when built as an open building in comparison to those built as a traditional "non-open" building.

3. Break-even point (sensitivity analysis)

In theory the total cost of a project should be the same for either an open or a "non-open" building; and only the cost allocation should differ. However, in the long-term the net present values of some cost units may differ because of the time aspect of the cost allocation. The result of the net present value (NPV) calculation depends on the discount rate. The NPV calculation of a project's future cash flow for determining its worth today is called the discounted cash flow (DCF) valuation. The discount rate that is implicit in an investment is called the rate of return on the investment. It is necessary to distinguish between nominal rates i.e. interest rates or rates of return that have not been adjusted for inflation, and real rates, which have been adjusted for inflation [Ross *et al.*2000]. In other words the real rate is the percentage change in one's buying power. Hence, compensation for inflation must be included in the analysis. In addition, as mentioned in the introduction, the decrease of rentable area due to HVAC reservations, the higher the cost of modifiable walls [Saari 2002], a necessary division to accommodate the HVAC equipment into both the base building and the infill (e.g. reservations, double inspections, and tuning) may increase the costs.

BREAK-EVEN ANALYSIS								
Rental Area m2		3 000	m2	Risk free	8	4,0 %		Debt excluded
Initial Investment Cost €		5 000 000	€	Inflation (i)				Site cost excluded
Additional OB Cost €	30 %	1 506 000	€	Discount Rate = (i+R)				
Rental Income Annual / m2		250	€/m2	OB Modif. T / Cost	1,2	months	250 000 €	
Maintenance Cost Annual / m		25	€/m2	Trad. Modif. T / Cos	6,0	months	750 000 €	

OPEN BUILDING					Modific.			Modific.			Modific.			Modific.	
Year		1	2	4	5	6	9	10	11	14	15	16	19	20	SUM
Inflation	INFL	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	
Total revenue (potential)		765 000	780 300	811 824	828 061	844 622	896 319	914 246	932 531	989 609	1 009 401	1 029 589	896 319	914 246	
Occupation rate		100 %	100 %	100 %	90 %	100 %	100 %	90 %	100 %	100 %	90 %	100 %	100 %	90 %	
Effective Gross Income		765 000	780 300	811 824	745 255	844 622	896 319	822 821	932 531	989 609	908 461	1 029 589	896 319	822 821	
Maintenance Cost		76 500	78 030	81 182	82 806	84 462	89 632	91 425	93 253	98 961	100 940	102 959	89 632	91 425	
Net Operating Income (NOI)		688 500	702 270	730 642	662 448	760 160	806 687	731 397	839 278	890 648	807 521	926 630	806 687	731 397	
Modification Cost					270 608			298 773			329 870			364 203	
Depreciation (25 years	0,04	260 240	260 240	260 240	260 240	260 240	260 240	260 240	260 240	260 240	260 240	260 240	260 240	260 240	
Tax rate	0,28	119 913	123 768	131 712	36 848	139 977	153 005	48 267	162 131	176 514	60 875	186 589	153 005	29 947	
Net Cash Flow		568 587	578 502	598 929	354 992	620 182	653 682	384 356	677 147	714 134	416 776	740 041	653 682	337 247	
Discount* (Rate: R + i)		1,00	0,94	0,84	0,79	0,75	0,63	0,59	0,56	0,47	0,44	0,42	0,63	0,33	
DCF		568 587	545 756	502 873	281 187	463 436	410 128	227 500	378 115	334 814	184 340	308 793	410 128	111 464	7 416 205
Investment (Total)		**6 506 000**													
Profit Index															**1,140**

												Prof. Index Differ.			**0,00 %**
TRADITIONAL (FIXED)															
Year		1	2	4	5	6	9	10	11	14	15	16	19	20	SUM
Inflation	INFL	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	
Total revenue (potential)		765 000	780 300	811 824	828 061	844 622	896 319	914 246	932 531	989 609	1 009 401	1 029 589	896 319	914 246	
Occupation rate		100 %	100 %	100 %	50 %	100 %	100 %	50 %	100 %	100 %	50 %	100 %	100 %	50 %	
Effective Gross Income		765 000	780 300	811 824	414 030	844 622	896 319	457 123	932 531	989 609	504 701	1 029 589	896 319	457 123	
Maintenance Cost		76 500	78 030	81 182	82 806	84 462	89 632	91 425	93 253	98 961	100 940	102 959	89 632	91 425	
Net Operating Income (NOI)		688 500	702 270	730 642	331 224	760 160	806 687	365 698	839 278	890 648	403 761	926 630	806 687	365 698	
Modification Cost					811 824			896 319			989 609			1 092 608	
Depreciation (25 years	0,04	200 000	200 000	200 000	200 000	200 000	200 000	200 000	200 000	200 000	200 000	200 000	200 000	200 000	
Tax rate	0,28	136 780	140 636	148 580	-190 568	156 845	169 872	-204 574	178 998	193 381	-220 038	203 456	169 872	-259 535	
Net Cash Flow		551 720	561 634	582 062	-290 032	603 315	636 815	-326 047	660 280	697 267	-365 811	723 174	636 815	-467 375	
Discount* (Rate: R + i)		1,00	0,94	0,84	0,79	0,75	0,63	0,59	0,56	0,47	0,44	0,42	0,63	0,33	
DCF		551 720	529 844	488 711	-229 732	450 832	399 546	-192 987	368 697	326 906	-161 799	301 755	399 546	-154 474	5 699 354
Investment (Total)		**5 000 000**													
Profit Index															**1,140**

Table 1. Break-even analysis of the open building strategy i.e. an example of a sensitivity analysis of the additional open building cost at a given inflation and discount rate variation. The time period evaluated is 20 years, and the respective modification interval five years.

In the case where the infill is considered an investment in stocks, from the investor's point of view the concept of an economic order quantity (EOQ) applied in cost accounting may prove a useful analogy for evaluating the open building. It deals with the equilibrium point of inventory holding costs, and set up costs or ordering costs [Drury 2000]. Even though Just-in-Time (JIT), as well the drive towards zero inventories, may have been emphasized in recent years, companies still have to deal with lot sizes. Holding costs are considered only as variable costs, but storage capacity decisions have also to be made. These decisions incorporate a fixed cost component to the holding costs. In this paper the storage capacity is the base building, and the given range of functions i.e. the different uses of the space is the product, in order to find an optimum proportion for the base building and the infill investments at a given modification time. However, the exact definitions of both the concepts and factors are preliminary from the point of view of the open building.

The analysis is a net present value simulation, in which the variables are the modification cost, the modification time, the discount rate based on the required return on investment, and the inflation (or the interest) rate. To keep it simple, the weighted average cost of capital (WACC) is not included in the model. The initial investment costs, the project size, the rental income, and the maintenance costs are considered constants.

Usually real property is a noncurrent tangible asset that generates revenues and cash flows for more than one period. The accounting items of a real property, like depreciation, extend over a long period of time, which increases uncertainty. The rate of depreciation depends on both the useful life and the allocation methods. The depreciation and the tax rates are also considered constants in the model. In reality the depreciation depends on how the investment is accounted on the balance sheet and on the income statement e.g. depending on how the projects are divided into development properties and investment properties. In the model the depreciation is calculated from the initial investment cost.

The influence of the variables is assessed in a comparison of an open building project to a "non-open" building project. As a simple sensitivity analysis, by changing the variables, the break-even point is sought for e.g. for an additional open building cost at a given discount and inflation level. The break-even point is found when the profit indexes, i.e. the ratios of the discounted the net cash flows to the total initial investment costs, are the same in both the open building and the "non-open" building cases. The model is made in Excel, but can be applied in any spreadsheet program suitable for NPV.

4. Conclusions

The case presented in table 2 shows that at a 2 % inflation rate with a 4 % return on investment (risk free) rate, assuming that in the open building case the modification time is roughly 1 month and the modification cost is 250 000 euros, and in the "non-open" building the modification time is 6 month and the modification cost is 750 000 euros. The break-even point is found when the additional open building cost is 30 % of the initial fixed cost, which could be considered exceptionally large. As shown in table 1, a more realistic estimation of the additional open building cost would be something like 3 %, ten times less. This example illustrates how effective an open building may be in the long run. In the example, it is assumed that the occupation rate is 100 %, and 0 % when the modification is ongoing (modification time in the open and "non-open" building is 1.2 months i.e. 10 % and 6 months i.e. 50 % respectively). In the example the time period evaluated was 20 years, and the respective modification interval five years (years 5, 10, 15 and 20).

The modification time seems to be the most critical variable, which implies that in open building it is rational to invest in systems that decrease modification time on a large scale even when these systems are expensive. Lower inflation decreases the difference, but the influence of inflation is minimal in practice. If the discount and inflation rates were assumed zero, the break-even point of the additional open building cost would be 20 % higher in the example. Also, a lower occupation rate shifts the break-even point of the additional open building cost higher. The result of an open building being more profitable in the long run than a "non-open" building is naturally not surprising, but the illustration shows that an approximate value adding impact of the open-building strategy can be quantified, which can be a useful tool as mentioned in the case in the introduction, when it is necessary to emphasize and quantify the sustainable value of a given open building project.

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Visualisation and Rapid Manufacturing
A survey of architecture practise in the UK

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KEYWORDS

3D CAD, Physical Modelling, Rapid Manufacturing

1 Introduction

Architecture, an art as well as a science existed for many centuries. The art of architecture is exhibited in the creative delineation of space and has composition of materials or the effective combination of both. In architectural history, design skills were focused on conceptualisation, representation and production; perhaps because the means and methods for communicating ideas were limited. Although through time, the limitations of two dimensional drawings progressed with the perspective (attributed to Brunelleschi) [Crum 1995] panorama and orthographic projection (Vitruvius) [Gaiani 1999].

The style, material and tools employed by architects continually evolves; design information is now communicated using various representation tools, including verbal comunications, texts, sketches, drawings and electronic data [Badke-Schaub and Frankenberger 2004]. The choice of representation has to suit the various design and construction requirements, although increasingly, design skill has become less visible and not automatically discernible in the final manufactured product [Woolley 2004].

In less than four decades, information technology - the use of electronic machines and programs for the processing, storage, transfer and presentation of information [Bjork 1999] has become widely prevalent in architecture. Today, practically all project information is entered into software tools or generated by computer programs and is represented in the many different formats used by the many disciplines involved in a project [Fischer & Kunz 2004].

Computer-aided design (CAD) is now the norm, permitting easy design representations in 2D, 3D and descriptive texts - flexible production technologies have freed architects and other designers from the straight-jacket of standardisation [Abel 2004]. Further progress has also been made with virtual reality applications where real environments can be simulated in a computer workstation. The designer can salubriously provide a high level of design detail by exploring various possibilities using technological tools. Detailing being the link, architects or designers are, as a result, no longer confined to just the art of design while other building professionals such as structural and mechanical engineers deal with the science and practicalities of structure and services.

The role of technology in architectural construction has also greatly advanced. Computer-aided manufacturing technology (CAM) may change the face of building construction. This flexible form of automation promises to provide designers with a more economic and expressive means to manufacture unique products, whose feasibility is less dependent upon their complexity or quantity

[Callicott 2001]. CAM will also further the inter-relationship between architects, engineers and building fabricators or manufacturers in the future.
Increasing design complexity requires advanced construction methods and more sophisticated tools are required to communicate building concepts to clients, planning authorities, component manufacturers and building contractors. Tools are required in some instances to meet core demands, such as; visualisation (what) and production (how).

Despite the extent of architectural computerisation, the automation of conceptual physical models is but a recent event. Prototypes are used to represent the proposed design and at best used to guage design factors such as scale and proportion. Rarely are physical models used to demonstrate how the building will be constructed. This transition from art to science might take place if the design was complicated e.g. Frei Otto's form finding techniques for complex lightweight or grid roof structures. And, these structures are now analysed successfully using computer programs [Lewis 2005].

Rapid manufacturing (RM) technology, defines the use of laser manufacturing technologies for the direct manufacture of solid 3D products to be used by the end user either as parts of assemblies or as stand-alone products [Hopkinson & Dickens 2001] and comprises systems such as selective laser sintering (SLS), Stereolithography (SLA) and 3D printing.

RM and other CAM systems, provides for the first time an opportunity for direct manufacture from computer generated information, creating an opportunity for the designer to be connected with the product. Rapid manufacturing systems were initially used for providing physical models of CAD (prototyping), although this is still not widespread, it has since progressed to the automated production of some final products directly from CAD files [Noorani 2006].

A current research project at Loughborough University (ArchiFORM*) is investigating architectural freeform construction as the utilisation of additive manufacturing technologies for design, renovation, production/construction and maintenance of building elements (small and large scale). With the aim to advance constructions processes and user experience. This is with the view that the technology will serve both the creative aspects of the design as well as the art of making or producing buildings. The technology in its current state, benefits building component design; either as a design exploration tool or for direct and indirect (tooling) manufacture.

This paper presents a summary of findings from a preliminary survey of architectural firms in the UK; exploring issues such as the objectives and purpose of CAD, physical modelling and rapid manufacturing technology in architectural practise as well as benefits of utilising these tools.

2 Architectural Practise Survey

The core aim of the survey exercise was to assess the current use and possible interaction between architectural visualisation tools and the benefits of rapid manufacturing technology as a foundation for future research. As Badke-Schaub and Frankenberger [2004] stated, the aim of a differentiated understanding of information representation in design practise implies dealing with a large number of dependent and independent variables from different fields. Therefore this investigation is limited to three main fields; 3D CAD, physical models, and rapid manufacturing with variables such as the level of use, skills, costs, obectives, and benefits.

The survey also tests the hypothesis that most architectural practises are familiar with rapid manufacturing technology and this knowledge will translate into immediate or future use, its also gauges the level of present and proposed future use of additive rapid manufacturing technology by architectural professionals.

*ArchiFORM, IMCRC EPSRC funded research project. Investigators: Christine Pasquire, Simon Austin, Dino Bouchlaghem, Alistair Gibb, Rupert Soar, Anthony Thorpe

2.1 Methodology

The terms used in the questionnaire and in this paper are defined as follows;

- 3D CAD: A three dimensional representation of a building generated using computer-aided design packages for a range of uses. Could also be defined as a digital representation of the objects making up a building or an engineering facility, capturing the form, behaviour and relations of the parts and assemblies within the building or the facility [Eastman, 1999]
- Physical models: Actual but scaled representation of an entire building or its elements, internal or external.
- Rapid Manufacturing: an additive or layering process of manufacturing physical objects directly from a solid CAD model.
- Architectural practise: any such organisation that is registered with the Royal Institute of British Architects and practises the art and science of designing buildings

In order to understand current use of visualisation tools by architectural practises in the UK, email and postal questionnaires were sent to 120 architectural practises in the UK; 63% by post and 38% by email. A 43.3% return rate was achieved.

A total of 48 variables were abstracted from the four part questionnaire and analysis was carried out using SPSS version 12.0. Standard desicriptive analytical testing was carried out on the data prior to abstractions. There were missing cases in each section but the majority of thesewere found in questions about rapid manufacturing technology where respondents were not aware of the technology.

2.2 Respondent background.

Geographically, the sample population were architectural practises in the UK (Greater london 39%, SouthWest 10%, East Midlands 12% and Northern Ireland 4%), respondents were selected using the following parameters; RIBA registration, service provided, size of practise and geographical region, although the actual responses received varied from the intended demographics.

74% of respondents were from architectural firms with less than 10 design staff and 2% with design staff of over a hundred. Position held by respondents ranged from architectural assistants to practise directors and partners and a range of services provided by the firms included architectural design, interior design, conservation, planning and computer visualisation.

3 Summary of Survey Findings

The questionnaire was divided into four main sections: 3D CAD, physical modelling, rapid manufacturing, and future use of rapid manufacturing. Recurring variables in each section were; frequency of use, purpose of use, project types and objectives, levels of satisfaction, costs and advantages.

3.1 3D CAD

Tests carried out on findings suggested that architectural firms comprising less that 10 design staff have higher percentage of CAD skills and are more likely to use 3D CAD during the design process. Figure 3 shows that firms with more than 50 design staff will have at least 25-50% 3D CAD proficiency. It was also found that visualisation tools are more likely to be used for conceptual design and planning applications for new builds than for other project types such as maintenance or conservation.

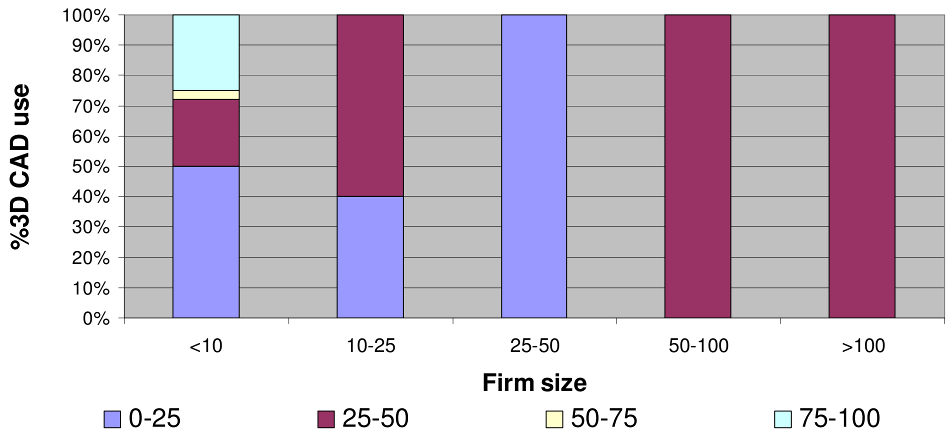

Figure 1. Percentage of practise design staff proficient in 3D CAD

Respondents identified the advantages of 3D CAD as follows:

- Immediate design visualisation and interrogation for; design clarity (form & shape), eliminating buildability problems at design stage, also for measuring design quality, control, communication, testing and exploration.
- Design understanding and satisfaction for clients and planning officers
- Co-ordination with other design disciplines
- For Rapid 3D Prototyping
- Easy to change, update and adapt
- Marketing advantage
- Good for public consultation

3.2 Physical models

It was found that 14% of respondents wouldl always produce physical models in-house while just 6% would outsource it. Cross referenced with the number of design staff, the time taken to produce physical models and levels of satisfaction based on available design staff is shown in Figure 4. For example, firms with 10-25 design staff produce more physical models in-house and are satisfied with how long it takes.

Figure 2. Level of satisfaction with time taken to produce physical models in-house and when outsourced.

Additional benefits highlighted for physical models include;

- Increased flexibility for analysis and design development
- Visible measurement of design progression
- Better design visualisation for problem solving
- Better design visualisation for communication
- Often needed for community understanding and funding body reassurance

3.3 Current use of rapid manufacturing technology

The majority of respondents (70%) have never heard of nor used rapid manufacturing technology. About 67% of those that have practically used the technology said it was considerably more expensive than other traditional methods especially as it had to be outsourced to service bureaux. 45% of users considered that despite the cost, it was worth it. (Figure 5 shows what rapid manufacturing was used for).

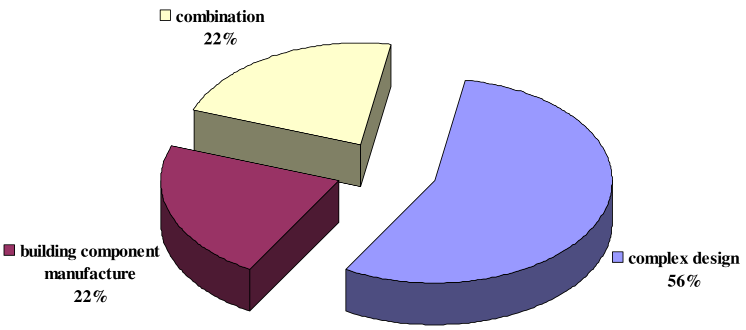

Figure 3. Purpose for rapid manufacturing technology according to respondents.

3.4 Future use of rapid manufacturing technology

Majority of respondents anticipate their future use of rapid manufacturing would be for big-budget complex (e.g. geometry and form) new projects . According to respondents, future use will also be based on cost and time saving benefits, easy access to technology, IT requirements and system usability, or based on client specification. [Fig 6]

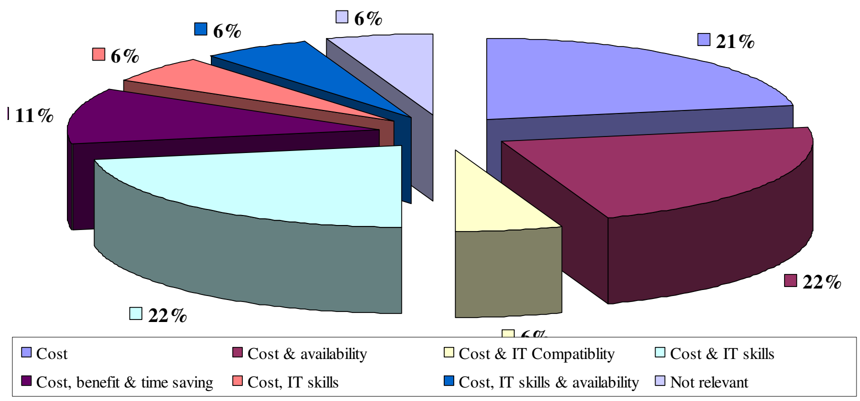

Figure 4. Factors influencing future use of Rapid Manufacturing technology

4 Conclusion

The entire preliminary survey explored additional issues such as the objectives and purpose of CAD, physical modelling and rapid manufacturing technology in architectural practise as well as benefits of utilising these tools e.g. cost, client satisfaction.

Most architectural firms use visualisation tools such as 3D CAD and physical modelling extensively. These two types of visualisation are easily inter-linkable with rapid manufacturing processes – providing an additional method for design representation and exploration.

The analysis also suggests that most firms agree there are benefits to rapid manufacturing within their current operations and in the construction industry as a whole. This is subject to the technology itself being readily available, fine-tuned to meet construction related demands , useable and affordable.

The conclusions derived from the gathered data provides the basis for further research on the interaction between existing design tools e.g. 3D virtual models and physical models with the potential for automation, geometric freedom, increased design understanding and efficient design actualisation proffered by rapid prototyping and manufacturing.

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Adaptable Buildings: Technological tools for hybrid settings

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KEYWORDS

Digital photogrammetry, Digital architecture, Mixed reality modelling, Hybrid buildings

1 Introduction

Buildings influence the general feeling of a place and the level of use and interaction within it, they contribute to the rejuvenation of urban areas and are judged within the context of the area as a whole. They do not only comprise physical objects but also define social spaces; tangible and intangible [Massey 2000] In addition to being a setting for social interaction, each building is the canvas for a combination of traditional and contemporary architectural philosophies and reflect the culture of the time during which it was built. This perhaps discounts the axiom that a building is well ahead of its time.

Design interventions should be gauged against traditional design parameters; scale, form, style, identity, cost, adaptability, usability etc. Style being a language of visual terms, grasping at and being particular to an historical period, making statements about history and circumstance, about erudition and social status, about origins and attitudes [Warren 1998] and form helps define context and belonging, Usability ensures that the building fulfils its purpose. Adaptability determines if the building will be useable in the long term.

For most architects, there are two types of projects; a new project more or less starting with a blank canvas or an hybrid project that requires adding to an existing building or setting with an established history. History not being a function of time but of cultural and social values that contributes to the identity of a place. But an architect in defining the 'historical setting' of the building forces a degree of reductionism in combining qualitative elements such as: time, significance or symbolism, function e.g. communal identity, (and interpretation of this) with modern technological tools to integrate form and materials.

Together with the need for better buildings within the context of its environment is the need for better methods of acquiring 'as built' information. The importance of up-to-date information cannot be in doubt but practitioners constrained by lack of time, money and human resources and perhaps unaware of their knowledge gaps, tend to rely on old familiar materials for solutions. Rarely, if at all, would a project be delayed while a search is undertaken for additional, but unknown information [Leslie & McKay 1995].

The research described in this paper explores the use of existing specialised techniques for the capture of as-built information and the integration into current CAD and VR tools to meet specific information needs in hybrid building design and construction. The outcome of this is visualised to be a quick and affordable solution for existing building information acquisition, storage/retrieval and use.

2 Hybrid: makes economic sense

Statisitics show that at least 2.5% of the building stock in the UK is subject to major refurbishment and renovation each year [Lee et al. 2005]. As figure 1 shows, increasing statistics of the number of buildings in the UK being retrofitted, renovated or modified suggests that there is a huge demand for either more space to satisfy simple or complex needs; demographic, functional, social, cultural or political, or that the existing building has failed and needs to be adapted to serve a new purpose; functional, economic, performance and aesthetic [Adam 1989]

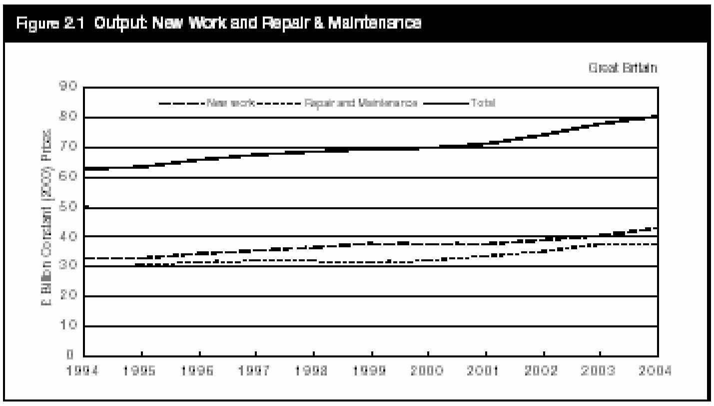

Figure 1. Construction output/year since 1994 (DTI, Annual Construction Statistics 2005)

It has been argued that plans to saturate both urban areas and the countryside with new developments will in the long term devalue the environment and adversely affect the economy and the building industry. This argument is based on the premise that a sustainable built environment is one that is recyclable and is capable of morphological changes in use and function thereby maintaining the socio-cultural balance required to maintain human culture and identity. In addition, the value of a building is often determined by its adaptability to multiple functions and use.

With regards to the economy, it is commonly agreed that the old is required to maintain the new. In his motor industry analogy, Adam [1989] explains that the used car business sustains the new car business, arguing that obsolescence in architecture will contravene user wishes. In addition, it may consequently lead to buildings e.g. housing no longer being affordable for the average citizen, the solution perhaps is in adaptable lifetime buildings capable of refurbishment to suit multiple needs over time. Refurbishment and regeneration schemes continually occur in most urban areas to convert existing structures for more timely uses either housing, corporate, academic or industrial and design professionals are increasingly required to either replace or balance past footprints with modern, forward- looking buildings.

3 Informed designs for efficient construction.

Innovation and context are among design issues highlighted at the preliminary stages of an hybrid project. Contextual design is becoming more favourable as a result of increasing interaction between construction professionals, user groups, planning authorities and other interest groups, together reassessing design successes and failures and balancing historical and contemporary needs.

In every hybrid project, information is required on various levels and at different stages of the design and construction procurement process. One of the primary causes of rework in constructionis the documentation on which the construction activity is based [O'Connor & Tucker, 1986]. Fundamentally, inaccurate, inadequate or misinterpreted data will lead to design errors and potentially rework during construction, which will lead to delays and increased project costs as a result of redesign, correction or re-construction.

The design team therefore needs to have an information management system in place to ensure that required information is sourced, made available when needed and interpreted appropriately. This information is consolidated on the architects request for them, or is commissioned as needed, depending on the complexity of the existing building and budget. Design decisions need to be based on cogent and precise data as clearly, a reduction in design errors will project a better professional image of the firm, lead to more effective design management, but more fundamentally it will improve profitability and competitiveness of a design firm. [Love et al 2000]

Factors that may determine the success of a design and the possibility of rework due to design error in hybrid buildings include the availability of detailed and relevant information, how information is presented and interpreted by the architect and how it is consequently communicated to construction professionals.[Fig 2]

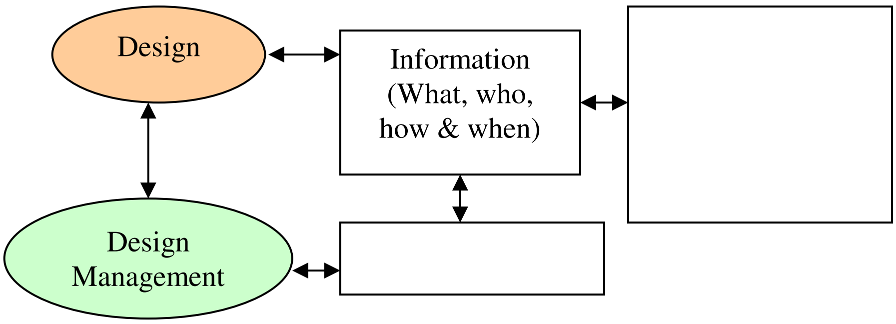

Figure 2. Information feed for design and construction processes (Simplified)

Building on an existing site often implies that there will be environmental, spatial, structural, service, planning and organisational limitations pertaining to the five key building considerations; site, building fabric, structure, services and components. These limitations consequently determine the location and positioning of the new building with respect to the existing one.

In most instances, as built documentations provided to the design team, at new project inception; e.g. design brief, drawings etc are dated and no longer valid because the existing building has evolved since initial construction.

Information required for design fall into two main categories; qualitative and quantitative [Fig 3] Qualitative information is often generic while quantitative information is usually project specific.

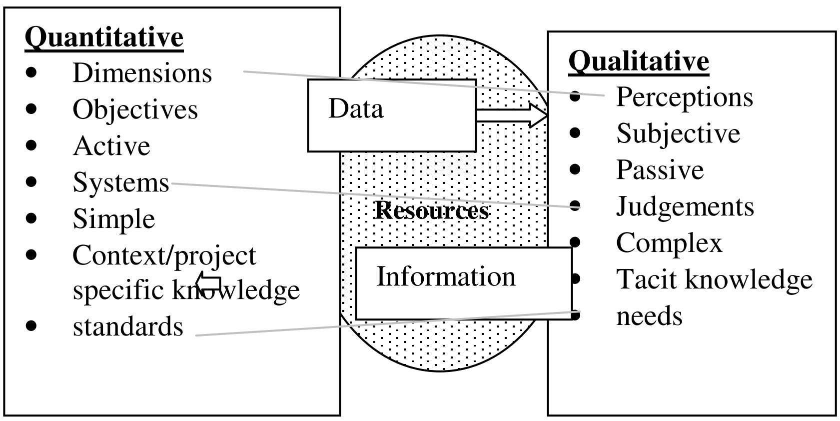

Figure 3. Generic and project based resources

At project inception; the following questions are pertinent:

1. What information is available
2. What information is needed
3. How will the needed information be acquired?
4. What is the significance of each information type: level of importance and impact on construction
5. What skill, techniques or tools are needed
6. When is the information needed? and
7. What is the consequence of not receiving the lack of preliminary information needed.

3 The problem

The main issue identified and addressed by this research is information deficiency: This is mainly 'real' geometric and symbolic descriptions of space [Steed et al 2004] based on the need to acquire information within minimal timescale, cost and human resources for remedial, rehabilitation or interrogation of existing buildings either for repair, maintenance purposes or to integrate a new element to an existing building. Generally, information is required for the design of the building or extension and for planned construction especially where space is limited, resources are tight and there is little margin for error. In many instances, mistakes due to insufficient or inaccurate 'as built' information could prove to be expensive for all parties: client, construction professionals and building contractor.

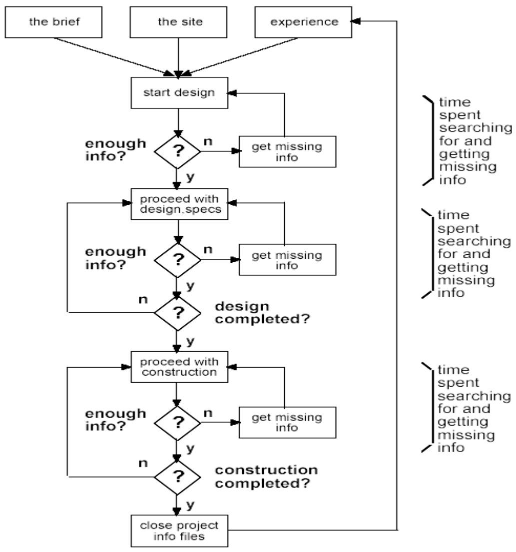

Figure 4. Getting missing information can take time [Davidson 2004]

Today, practically all project information is entered into software tools or generated by computer programs and is represented in many different formats used by the different disciplines involved in a project [Fischer & Kunz 2004]. There is therefore a need for a system that is easily operable: using skill sets that are already being utilised, homologous: providing two and three-dimensional information as well and pictorial or textural details of existing buildings and environments; visible, active and passive information such as form, geometry and material or user interaction and spatial relationships within the same process yet not time consuming. A system that is digital, comprehensive, scaleable with commensurate precision, easy to use and cost effective.

4 Proposed solution

A combination of photogrammetry and mixed reality modelling is being proposed for resolving information deficiency problems for the design team. Digital photogrammetry is a process used to derive accurate three-dimensional measurements of a real object from a two-dimensional image (photo) of the object. It is now possible to acquire high quality digital images for photogrametry using affordable digital cameras [Chandler 2005]

Mixed reality modelling joins or overlays physical and virtual environments to varying degrees, using a number of different approaches, technologies and interaction paradigms [Milgram and Kishino 1994] It is created when a real 3D image such as can be derived using photogrammetry is combined with a newly designed object in the same virtual environment.

It is being proposed that the combination of both techniques: photogrammetry to acquire, store and process 'as built' information will be a useful tool for the design team; the team could visit the site during preliminary stages to acquire image based information of the building. This information can then be kept for future use or selected images processed for immediate use.

On creating three-dimensional images of the existing building, several design iterations can be tried (within a virtual modelling environment) and communicated with the client and other interest groups until a suitable design is reached. The same set of photos can be scaled to acquire detailed information which can be used as instruction for construction at a later stage.

Digital photogrammetry offers the following benefits:

1. No physical contact required, image acquisition can be carried out at a safe distance.
2. There is automatic correlation between scale, distance and precision. The closer to the object the picture is taken, the more precise information can be acquired from it.
3. Images can be stored for future use to be recalled and processed when the information is required
4. Ability to capture and measure movement patterns such as waves and over time.
5. Efficient for measuring lots of objects at the same time.
6. For design and construction management, it contributes towards reducing down times and operational disruptions.

Mixed reality modelling proffer the following additional advantages:

1. Providing existing 'as built' spatial building information for preliminary design analysis (structure, services, components, fit)
2. Real and virtual three-dimensional data of both the old and newly designed building to analyse for structural, special and contextual fit
3. Real and virtual three-dimensional information for representation and visualisation and record keeping.
4. Real and virtual three-dimensional data for concurrent engineering, creating diorama and computer-aided manufacture.

Potential applications for buildings

1. Design and construction of hybrid buildings
2. Condition surveys- detecting defects and other problems
3. Building extensions, renovation or refurbishment
4. Building information for construction and component manufacture.
5. Meta' data for future projects.
6. Future performance needs: photogrammetry can be used to measure subjective user-spatial relationships to establish building use and future needs
7. Maintenance: planned prevention or urgent repairs
8. Restricted construction environment- For detailed construction planning for decanting occupants and phased refurbishments
9. Lifetime and adaptable designs: using preliminary three dimensional data acquired, a building can be planned, re-designed and constructed for future modification
10. Planning- data and modelling out can be used in 4D modelling and concurrent engineering.

5 Implications for design and construction

Applying proposed technological tool for the design, renovation and construction process for adaptable buildings will lead to better and efficient designs based on comparative yet detailed information. It will also provides a unified directory or framework for communication between design and construction teams and increased manufacturability: Construction and manufacturing information will increasingly be derived directly from CAD data

6 Conclusion

The construction industry comprises several fragmented processes. Aas a result, building documents and other related information are heterogeneous and communicated in multiple formats. Academic and industry practitioners are now investigating ways of unifying construction information working from a primary three-dimensional model throughout the entire construction process.

The combination of both digital photogrammetry and mixed reality modelling offers low specification and labour requirement, low technology, low cost solutions utilising techniques already familiar to most construction professionals and valuable applications in acquiring, recording, processing and utilising information for congruent hybrid design activity thereby resolving information and documentation problems that often lead to design errors.

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Nexorade: a structure for 'free form' architecture

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KEYWORDS

Mutualy supporting elements, nexorade, form finding

1. Introduction

The objective of this paper is to discuss the geometrical properties of different grids used for the creation of nexorades.
Consider the structure shown in Fig 1. This structure is made from elements using an 'interwoven pattern' as shown. This structure was designed and constructed by O. Baverel and exhibited at the University of Nottingham, UK, during the third Colloquium of the IASS Working Group on Structural Morphology in August 1997.

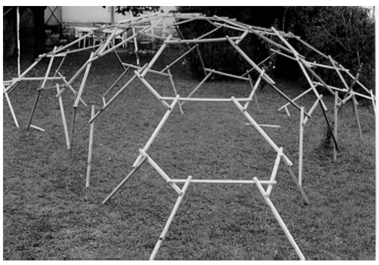

Figure 1. A nexorade, exhibited in 1997 at Nottingham, UK

The structure shown in Fig 1 is an example of what is referred to as a 'nexorade' or a 'multi-reciprocal grid' [baverel 00] [baverel 98]. Each one of the elements that constitute a nexorade is referred to as a 'nexor'. A nexor has four connection points, two of which are at the ends of the nexor and the other two are at two intermediate points along the nexor. The term 'nexor' is a Latin based word meaning a 'link' and the term 'nexorade' implies an 'assembly of nexors'. Historically, sketches from Leonardo Da Vinci showed that he understood the principle of nexorades, also an artist called Rinus Roelofs [Roelofs] did a lot on the subject but not much scientific work was done until now.

The formfinding of nexorade depends on 4 parameters that are the topology of the grid chosen, the diameter of the nexors, the engagement length and finally the length of the nexors. Nexorades have various advantages:

-They could be built with only on type of element
-They could be built with only one type of connection,
-It could be built with low technology components.
-Various shapes can be created with only one type of element and one type of connection

2. A method to find the forms of nexorades

A method using genetic algorithms was proposed to find the form of nexorades [baverel 2004]. The concept is to take an elementary configuration with no eccentricities and no engagement length (figure 2) and to transform it into a nexorade (figure 3). This robust and versatile method permit anyone to propose a configuration and to transform it into a nexorade. With this form finding method different grids were tried.

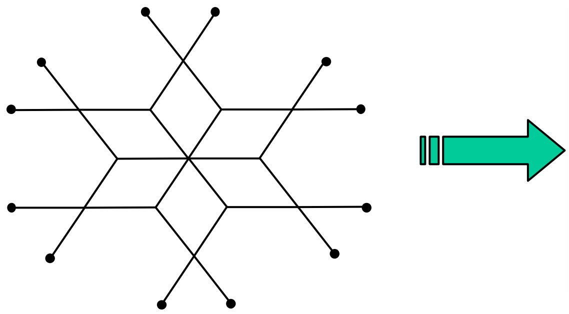

Figure 2: Elementary configuration

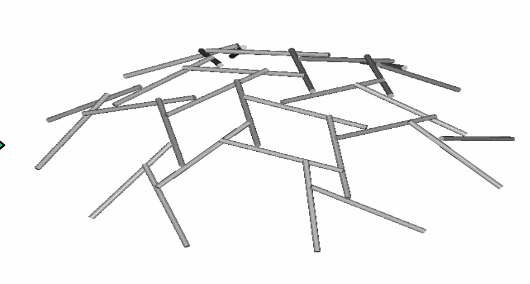

Figure 3: Resulting nexorade

3. Connection

Swrivel scaffolding couplers can be used as a connection for constructing nexorades as shown in figure 4. The corresponding idealised model (figure 5). In this model, the connector C between the beam A and the beam B is composed of three articulations. The first one is the rotation around the main axis of the beam A, its direction is that of the tangent of the deformed curve of beam A (the X-axis on figure 4). The second one is the rotation around the main axis of the beam B, its direction is again that of the tangent of the deformed curve of beam B (the Y-axis on figure 4). The third one is a rotation around the axis of the connector C, its direction is perpendicular to the beam A and B (the Z-axis on figure 4). With this system of three articulations, the orientation of the connector is free of constrain. This property is a key point for the construction of nexorades.

Figure 4: View of a connector

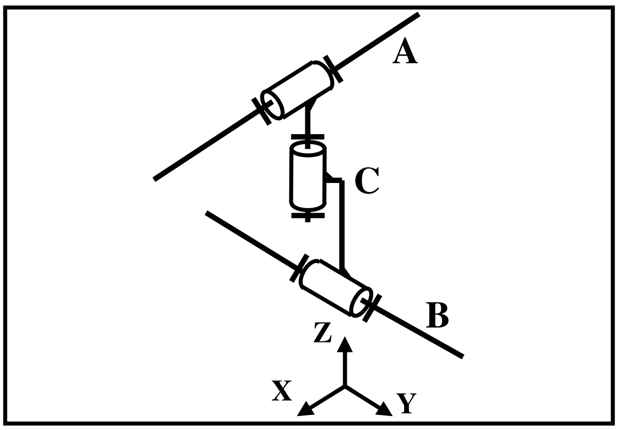

Figure 5: Kinematic scheme of a connector

4. Types of nexorades

The different tests (numerical and full scale model) have shown that we can distinguish three different families of nexorades that are :

-Fully adaptable nexorade
-Adaptable nexorade under constrains
-Rigid nexorade

4.1 Fully adaptable nexorades

A fully adaptable nexorade has at least four nexors connected to each vertex and each face has at least four nexors. We know from Euler formula that for any graph in the plane that

$$V + F - E = 2$$

Where V is the number of vertices , F the number of faces and E the number of edges. It can be demonstrated that only possible grid for a fully adaptable nexorade is a grid composed of squares (or rectangles or diamonds). The structure will adapt itself what ever the boundary conditions are. Another way to see the properties of this grid is to consider that; a nexorade is already built, for whatever reason someone wants to change the boundary condition or add new elements to the structure. By doing so, the nexorade will find itself a new geometry. Figures 6 and 7 show the in-plane degrees of freedom of an elementary node a nexorade. Figures 8 and 9 show the out of plane degrees of freedom of an elementary node of a nexorade. An example a complete nexorade is shown on figure 10. As there is no bracing along its surface, this type of structure is relatively soft in term of structural behaviour.

Figure 6: View of a fan

Figure 7: transformation into diamonds

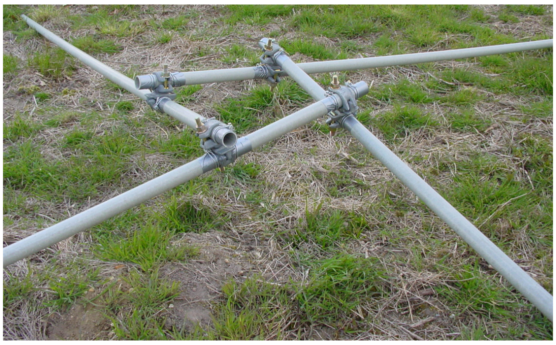

Figure 8: View of a fan

Figure 9: out of plane deformation of a fan

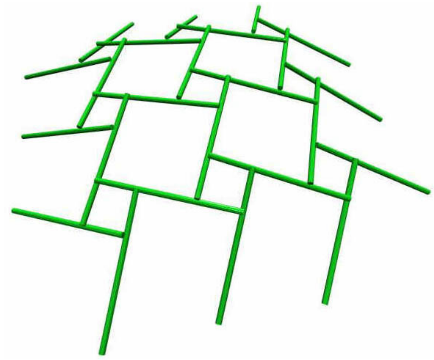

Figure 10: Fully adaptable nexorade

4 2 Adaptable nexorade under constrains

Adaptable nexorade under constrains are nexorades that will create shape with only one curvature. Therefore only conical and tunnel shape can be construct. These structures often use regular or semi regular tilling. For instance, when an hexagonal grid is used for a nexorade, certain geometrical properties are revealed. By assembling three element together a rigid node is created. As it is said in chapter 3, the rotation along the longitudinal axis of each of the three elements is allowed. By building an entire hexagonal grid these possible rotations either cancel each other or rotate in the same manner. Figure 11 shows the way the nexorade can be "folded", the arrow is parallel to the longitudinal axis of a cylinder with an hexagonal grid on its surface (figure 13). Figure 12 shows another way to "fold" an hexagonal grid. An example of nexorade using the symmetry shown in figure 12 is shown in figure 14. This figure represents three inclined arches jointed together. The intersection between the arches is made of diamonds that allow the geometrical deformation. The grid is a composition of hexagons and diamonds.

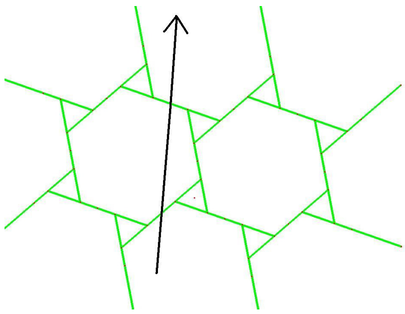

Figure 11: Symmetry A

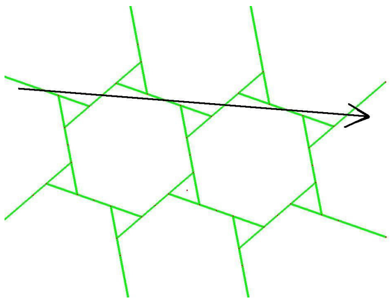

Figure 12: Symmetry B

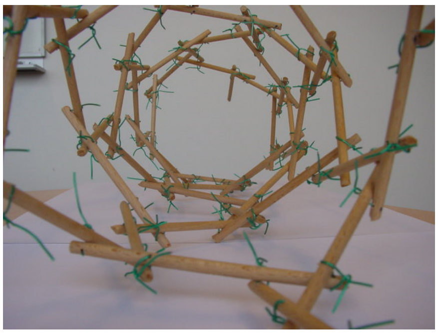

Figure 13: Nexorade with symmetry A

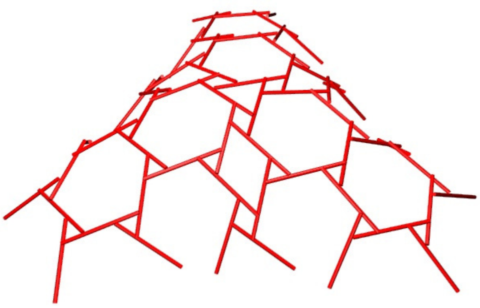

Figure 14: Nexorade with symmetry B

4 3 Rigid nexorade

The two previous families of nexorades had conditions on the connectivity between the nexors and on symmetry of the grid used. As they usually use two dimensional elementary configurations, the resulting nexorade are very different from the initial grid. If none of theses condition are satisfied the nexorade is either not buildable or the resulting nexorade will be very closed from the initial elementary configuration. An example of rigid nexorade is shown in figure 15, the resutlting nexorade is very close from the initial configuartion that is in our example a dodecahedron

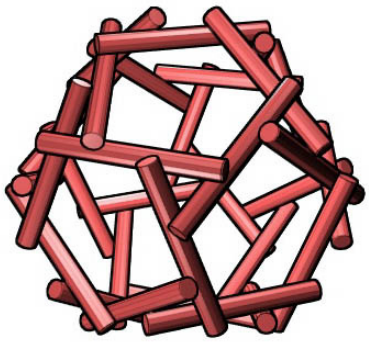

Figure 15: Rigid nexorade made from a dodecahedron

5 Cladding

The cladding of a structure that self-adapt is obviously something difficult to build. A solution of this problem is to use large soft tiles. This tiles could slide slightly beween one another in case of a modification of the boundary conditions.

6 Conclusions

The technology used for creation of nexorade was presented. A specific connection that allow an orientation free contrain between the elements was proposed. Three different type of nexorades have been presented. The fully adaptable grid shows the facinating properties of being able to self-adapt to a given boundary conditions. The adaptable nexorade under constrains has to use the symmetry of the elementary configuration to generate a nexorade. The last family concern all the other type of grids, the resulting nexorade is very close from the initial configuration.
Nexorades could be use as a structure for free form architecture either as a skeleton for a formwork or as a structure covered with a cladding composed of large soft tiles. In this case, the size and the shape could be easily adapted to the need and the wish of the architect.

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Assessment of Project Performance: Time for a Multidimensional Approach.

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KEY WORDS: Assessment, Project, Performance, Multidimensional

Abstract This paper seeks to highlight the emerging multidimensional concepts in performance measurement as opposed to the traditional system of measurement. It identifies the similarities between the approaches used by researchers in both the manufacturing and project management (and construction management) and suggests that the construction sector can establish a single unified framework that will be flexible and adaptable enough to be used on all construction projects in all socio-economic set-up.

Introduction

"When you can measure what you are speaking about and express it in numbers, you know something about it…(otherwise) your knowledge is a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in thought advanced to the stage of science(Lord Kelvin, 1824-1907)."

The subject of performance measurement has received much attention and has become a topic of increasing concern for both academics and practitioners (Neely, 1998). According to Neely, between 1994 and 1996 alone one new paper or article on the topic appeared every five hours of every working day! This development stems primarily from the problems identified with the existing traditional systems. The traditional performance measures, developed from costing and accounting systems, have been criticised for encouraging short termism(Banks and Wheelwright, 1979; Hayes and Garvin,1982), lacking focus (Skinner, 1974), encouraging local optimism (Hall, 1983; Fry and Cox, 1989), encouraging minimisation of variance rather than continuous improvement (Johnson and Kaplan, 1987; Lynch and Cross, 1991), not being externally focused (Kaplan and Norton, 1992). In project management, the above factors are real due to the over reliance on the "iron triangle" of time, cost and quality as the performance measure of project (Atikson, 1999). According to Atikson, this is a Type II error (something that is missing). Shenhar et al., (2002) opinned that evaluating an organisation's performance measures only in financial terms are insufficient indicators of an organisational success.

An attempt to move away from this led to the development of "balanced" or "multi-dimensional" performance measurement frameworks. Karplan and Norton (1992) developed the "Balanced Scorecard", arguably the most popular and widely used frameworks in the manufacturing sector as well as in organisations (Neely et al, 2005). Others include, the "Performance Pyramid" (also called the "SMART" system) by Lynch & Cross, (1991); The "Performance Measurement Questionnaire" (PMQ) by Dixons et al (1990); "The Performance Measurement Matrix (PMM), Keegan et al., (1989); "Result and Determinants Framework" by Fitzgerald et al., (1991) etc.

In the project management (also construction management), similar approach are being pursued under the umbrella of project success /failure measures. Notably, researchers are proposing a move away from the traditional technical and financial measures(the iron triangle) and proposing a multidimensional approach. Notable among the researchers are: Cooper and Kleinschmidt, 1987; Freeman and Beale, 1992; Shenhar et al, 1997; Vandevelde et al., 2002).

A change Propelled by the chages in the business environment

The change towards a balanced or multi-dimensional approach to performance measurement has been propelled by the rapid changes that has taken place in the business world in general. "Companies began to lose market share to overseas competitiors who were able to provide higher-quality products with lower cost and more variety" (Ghalayini and Noble, 1996). The emergence of new technologies and philosophies of production management (i.e computer integrated manufacturing (CIM), flexible manufacturing systems (FMS), just in time (JIT), Optimizes production technology (OPT) and total quality management (TQM), has shown that the traditional system has many limitations and that a development of a new performance measurement systems is required for success (Ghanayini and Noble, 1996). In the construction sector, the additional factor necessitating a move away from the traditional systems include the changing roles and tastes of the client (Latham, 1994, Yisa et al,1996; Bennet et al, 1988), the development of "mega structures"(***The Sears Tower of Chcago, the Twin Tower of Malaysia, The Akashi Kaikjo Bridge in Japan, The Palm Jebel Ali of Dubhai etc***) with all its complexities, the evolution of different procurement systemss and the quest for improvements in project execution.

A critical comparison between the traditional and the emerging measures (Table 1) reveals that the former in generally has no place in modern business environment.

Table 1

Traditional Performance Measures	**Non-Traditional Performance Measures**
Based on outdated traditional accounting system	Based on company strategy
Mainly financial measure	Mainly non-financial measures
Intended for middle and high managers	Intended for all employees
Lagging metrics (weekly or monthly)	On-time metrics (hourly, or daily)
Difficult, confusing and misleading	Simple, accurate and easy to use
Lead to employee frustration	Leads to employee satisfaction
Negleted at the shopfloor	Frequently used at the shopfloor
Have a fixed format	Have no fixed format (depends on needs)
Do not vary between locations	Vary between locations
Do not change over time	Change over time as need change
Intended mainly for monitoring performance	Intended to improve performance
Not applicable for JIT, TQM, CIM, FMS, RPR, OPT, etc	Applicable
Hinders continuous improvement	Help in achieving continuous improvement

Source Ghalayini and Noble, 1996

A key feature of the emerging performance measurment concept is that it lends itself to changes and innovation (Neely et al, 2005).

Common philosophy, similar approach, similar dimensions.
The decision to adopt a multi-dimensional approach for performance measuremnt was a necessary reaction to a prevailing environmental changes fuelled by globalisation (Rouse and Putterill, 2003). Despite the fact that individual authors have focused on different aspects of performance measuring systems in both the manufacturing and the construction systems similarities can be observed in the dimensions of performance being slected as measure. A summary of the major dimensions selected from the most cited literature are compared in table 2.

Table 2

Manufactury sector dimensions	**Project(Construction) management dimensions**
Customer	customer
Financial	Financial
Internal business	Internal business
Innovation and learning	Innovation and learning
Competition	Future business
Quality	Technical and quality
Time	Time
Cost	Cost
Employee, etc.	Prestige, etc.
Kaplan & Norton, 1992; Lynch & Cross, 19991; Keegan et al., 1989; Fitzgerald et al., 1991;	Hauschildt, 1991; Freeman & Baele, 1992; Griffin & Page, 1993; Shenhar, 1997; Vandevelde et al., 2002

The table illustrates that despite the obvious differences in the industrial set-ups and most importantly, the methods of operation, both industries admit to be operating in a business environment with all its competitiveness, dynamism and the struggle to survive in a changing global world. In addition, there is a clear orientation by companies in both the manufactury and project based industries to improve performance.

Framework for designing performance measurement system
One of the problems with the performance measurement literature is its diversity (Neely et al., 2005). Individual authors have tended to focus on different aspects of performance measurements. Also, the dimensions and perspectives appear to be an endless list. This diversity has meant that it is difficult to fashion the performance measurement as a system. Shenhar et al, (2000) comment that the various literature has not linked the identified success factors to their measures. A review of most of the performance measuring systems in literature by Neely et al., 2000 reveals that they do not provide enough integration of their various measures. The design of a performance measurement system thus requires that firstly, the system is well integrated where determinant (factors) are linked to results (measures/ indicators).

Neely et al, 2005 proposed a framework for designing a performance measuring system figure 1.
This takes into consideration

i. the individual measures (factors, measures) -A

ii. the performance measurement as a system -B
iii. the environment (internal & external) -C

This is applicable across industries and may be the necessary step pointing to a desirable end of unifying the various systems according their industry.

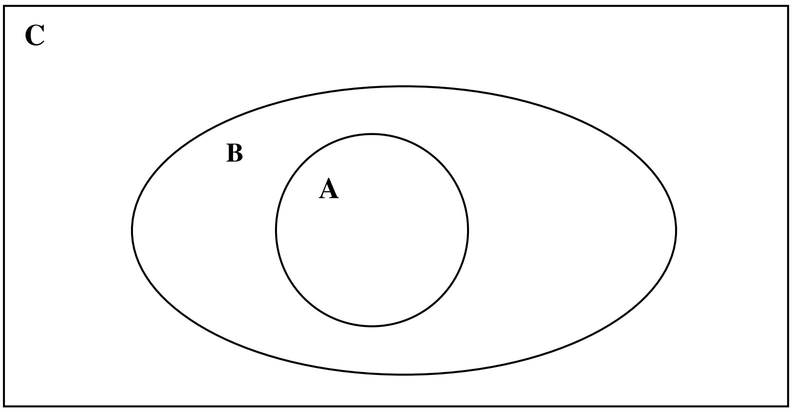

Fig. 1 Source: Neely et al., 2005

Conclusion: Towards a unified performance measurement system for construction projects
A study of delay factors by Zhang et al, 2003 (China); Faniran,O.O,2000 (Nigeria) and Makulsawatudom et al, 2003 (Thailand) reveal that depending on the socio-economic set up, level of development of the industry and other cultural dimensions prevailing in a country different factors may affect project execution and that, where there are similarities these factors may be of different import in different countries. This brings to the fore the challenge the construction industry face in its quest to design a project performance measurement or assessment system. Vandevelde et al, 2002, proposes that performance measures found should be tested in order countries and companies for their validity. They went ahead to stress that " it is useful to apply one single model in all future research on success determinants". The present author not only agrees with this but also believes that with detailed research across countries and establishment of a continuum of both performance factors and indicators, it should be possible to design a unified, flexible and hence adaptable system for measuring all construction projects everywhere.

Such a model should not satisfy the multidimensional philosophy as a fundamental requirement. In addition it should be able to meet the other relevant perspectives such as the Clients' perspective, the Practitioners' perspective, the socio-economic set-up(country), and the various procurement systems as shown in fig 2

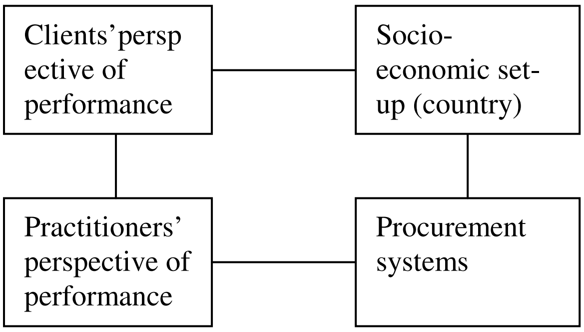

Fig.2

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