A design control structure for architectural firms in a highly complex and uncertain situation

Nr. P1110, A Design Control Structure for Architectural Firms in a highly Complex and Uncertain Situation[1]

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Abstract: A large architectural firm in a highly complex and uncertain production situation asked to improve its existing "production control" system for design projects. To that account a research and design project of nine months at the spot was defined. The production control in the organization was based on a mix of project management tools, resource allocation to whole projects, and regular updating of the project portfolio. The results of the research analyses showed that the situation of the firm's design projects cannot be controlled with only such tools, due to lack of coherence between the "production control" and the design situation. To improve the coherence, a basic "production control" structure is designed. The design of this structure is based on the match between the research findings and theoretical principles of how decisions should be made in multi-project situations that are highly complex and uncertain. The design consists of four hierarchical planning functions (strategic resource planning, rough cut capacity planning, resource constraint project scheduling and detailed planning). After finalizing and presenting the design, the design led to new insights into resource allocation for the client and has been approved by the client and office management. The implementation of the design is however still in design proposition due to other priorities.

Key words: Production Control, Resource allocation, Multi-Project Scheduling, Matrix structure, Engineer to Order, Design situation. Paper size, Font, and number of Pages

1. INTRODUCTION

Larger architectural organizations are mostly involved in many building projects in parallel. This involvement leads often to undesired human resource scheduling problems (HRSPs) (e.g. Emmitt; 2007, 2010). Solutions are important, because these problems lead to less efficiency in the architectural organization, and could cause project delays or lower project quality and therefore lead to less profit for both the organization and its clients.

Architectural management theory that considers design control mostly focuses on the complexity of information inputs and outputs and tasks in the iterative processes of single design projects (e.g. Austin et al., 2000; Gray et al. 2001, Carmichael 2006). Solutions for the HRSPs poorly get attention in the literature compared to production control theory (e.g. Hendriks 1996, 1998; Schönsleben, 1998; Leus, 2003; Bertrand et al., 1990, 2009). However, mostly the attention is not focussed on architectural organizations, but on Engineer-to-Order (EtO) production companies. Architectural organizations can be regarded as a category of EtO organizations.

Because architectural management theory mostly focus on the complexity of the design project scheduling, and production control theory does not focus on architectural organizations, we believe there is a gap that deserves more development in architectural management practice and theory. Especially, because on the one hand large architectural organizations cope with similar HRSPs, and on the other hand each design situation is different and specific. An understanding of existing design control structures in practice might lead to better theoretical principles for architectural offices, which could improve design control in practice (Romme & Endenburg, 2006). A large architectural firm with EtO characteristics in a German speaking country faced problems as described and explained and asked the authors to investigate and improve its existing "production control" system for multiple design projects to find out how the firm's efficiency level can be improved and be controlled.

To that account in the next chapter the research approach is described. In chapter 3 the situation of the firm's design projects (the design situation) and control structure are described and explained, and the weaknesses in the existing design control structure are revealed. In chapter 4 the starting points for the redesign are formulated. In chapter 5 the redesign and its theoretical principles are described. Finally the conclusions are given and recommendations for further research.

2. RESEARCH APPROACH

To find out how the existing "production control" system for design projects functions, the firm's resource allocation system was investigated in order to derive at causes that can explain the inefficiency. A case study has been designed (Yin, 2003) and conducted to that account. A qualitative method for the research was used focusing on management issues as Gummesson (1999) describes. The case study comprised a starting meeting with the whole group, a team workshop with the managers, interviews and participative observations to collect the necessary data. The interviews were performed with key persons in the management system using semi-structured interviews.

The focus of the research is on key concepts in production control literature to identify the weak points of the existing design control structure and to provide indications for resource allocation efficiency improvements. The research shows that the design control structure with only a mix of project management tools, resource allocation to whole projects, and regular updating of the project portfolio is too weak to keep effective control over the analyzed design situation. Therefore, a redesign with four hierarchical multi-project planning functions is proposed to improve the design control effectiveness. The mentioned theoretical framework, principles and methods can be useful in future design control research.

2.1 The formal resource allocation system

The resource allocation system as prescribed by the organization consists of three planning functions that are interconnected in a software program:

1. An aggregate planning function of assigning working hours to projects -responsibility of the aggregate manager- ,
2. A rough project planning function of assigning working hours to design unit parts of the project -responsibility of the Head Project Manager (HPM)- ,
3. A design unit planning function of assigning working hours to the design unit projects part and human resources - responsibility of the Design Unit Manager (DUM)-.

The aggregate planning was based on two 'efficiency rules': (a) all human resources have to be allocated to a project always, and (b) an amount of project working hours to projects has to be assigned. The fixation of hours had two goals. The first goal was to gain control over the project resources within the capacity as planned in the budget. The second was to make DUMs and HPMs co-responsible for the project profit.

At the start of a project the HPM estimated and assigned working hours for the design unit project parts in a rough project plan. The HPM's responsibility was to keep the working hours for a whole project within budget. The design unit planning made by the DUM was used to allocate human resources to the project working hours. The DUM was responsible for keeping the hours of the design unit within budget. The DUMs could fill in the worked hours in the information software system.

The formal information system for resource allocation had three main overviews:

1. The aggregate managers had an overview of the resource allocation in the whole office, and on the organization's profit;
2. The HPMs had an overview of the estimated Delta between the used and estimated hours for the project;
3. The DUMs had an overview of the resource allocation and on the Delta of projects' working hours the design units.

To gain insight in the coherency between the design situation and design control structure from a theoretical perspective the research and development approach for organization design of Romme and Endenburg (2006) (See Figure 2.1) was used.

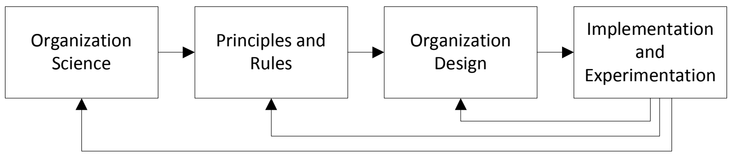

Figure 2.1: The research and development cycle in organizational design (Romme & Endenburg, 2006)

The cyclic approach was passed in the following order:

Step 1: Implementation and Experimentation; the implemented resource allocation system was analyzed; its usefulness and its weaknesses as perceived by the organization were obtained.

Step 2: Organization Science; the causes of the perceived problems were derived by analyzing and evaluating the existing control structure using key concepts of production control science.

*Step 3: Construction principles and rul*es; construction principles and design rules of EtO production control theory that fitted the practical conditions were collected.

Step 4: Organization design; the redesign was constructed by the theoretical principles and rules found in step 3, the encountered organizational situation, and the preferences of the people who were involved in the redesign.

Step 5: Implementation and experimentation; experiments should be done to evaluate the usefulness of the redesign in practice. Due to the limited time period the fifth step could not be completed. Instead the design proposition was evaluated with the managers and key concepts for coherency evaluation between design control structure and situation were used. Experiments should still adjust defaults in the practical usability of the redesign. Due to other management priorities the redesign is still in a design proposition.

The execution of the research and design project consisted of three phases: 1) an orientation phase, 2) an analysis phase and 3) a design phase. In the first two phases the first three steps of the cycle were completed. The design phase included the fourth step. In the orientation phase, the design situation and the problem area were explored. In this phase, data was collected by 22 semi-structured interviews. If managers aloud it, the interviews were recorded and partly transcribed, Minutes of all the interviews were made. The Questions were mostly how- and sometimes what- questions about the organization framed in a 7S-framework (Peters et al. 2004), the design control process, the used software system, and the strong and weak points in the process and the system. Additional data like formal documents, informal scheduling plans and interviews with control groups were used to triangulate the interview data to find causes for the perceived problems.

In the analysis phase, these causes were analyzed and evaluated. In this phase, 8 semi-structured interviews and a workshop were executed for data collection. Before an interview was executed information about project management approaches, complexity and uncertainty in design situations, together with how- and what-questions related to these subjects and the resource allocation in the organizations was distributed amongst the respondents. The purpose was to get a better understanding of the topics that were discussed during the interview. Interviews focused on questions related to the coherence between the design control and the design situation and on the relation between resource allocation and project scheduling. The interview data were again recorded and partly transcribed. Data about the relationship between the different hierarchical management activities with regard to project scheduling and resource allocation and possible solutions for perceived problems in this relation were collected in the management workshop that consisted of role playing games and reflection on these games.

The data of both phases were framed by theoretical production control principles as found in chapter 3. The orientation phase together with the analysis phase resulted in an evaluation of the coherency between the design control and the design situation. In the design phase a redesign was made by using the results of the practical analyses and theoretical principles found in production control and project management literature. The redesign was constantly adjusted after conversations with the concerned managers about the practical feasibility.

2.2 Sample and control groups

The architectural organization consists of several offices in various countries. Every office had its own separate resource allocation system. Due the limited research time of nine months in a big office in a German speaking country was taken as a sample for the research. The design control structure of this organization was investigated. The interviewees within the sample were chosen on the basis of their direct interaction with the resource allocation system. This implied that the aggregate managers, the HPMs, and the DUMs were interviewed. A minimal condition of one interviewee of each discipline and of hierarchical level was set.

To control if the sample's information was useful for the whole organization and if it was coherent with the efficiency perceived on operational level two control groups were used. The first group was used to control if the resource allocation system of the other offices worked similar and had similar deficits. The interviewees were chosen on the same basis as the interviewees of the sample. The resource allocation system did not work the same in small offices, although the similar tools were used, because informal communication in small offices was of more importance as in large offices.

The second group consisted of the staff that was managed. The people of this group were picked ad randomly. This control group was used to control if the perceived problems on all levels matched. The comparison showed that this was indeed the case.

3. KEY CONCEPTS FOR PRODUCTION CONTROL STRUCTURES

Because production control theory has more key concepts and theoretical principles about HRSPs as architectural management theory does, the existing control structure in the analyzed architectural organization is evaluated from a production control perspective. The focus is on architectural design projects. Therefore in this case we write about design control instead of production control. In general cases we keep using the term production control. The control of production processes can be defined as "the coordination of supply and production activities in manufacturing systems to achieve a specific delivery flexibility and reliability at minimum costs" (Bertrand et al.; 1990). The production control objective is the coordination of the primary process, aiming at (1) the delivery speed and delivery reliability, and (2) the resource allocation efficiency (Bertrand et al.; 1990). Design control is defined as the coordination of supply and design activities in architectural design systems to achieve a specific delivery flexibility and reliability at minimum costs.

The production control perspective leads to three units of analysis: A) the characteristics of the design situation B) the design control structure, and C) the coherency between the control structure and the design situation. The units can be framed by concepts and principles derived from Bertrand et al. (1990). The work of Bertrand et al. is used, because their concepts and principles are intended as tools for the analysis of production control problems in practice and the design of adequate production control systems that are adjusted to a specific situation. The units of analysis and the frameworks are explained shortly in this section.

A) characteristics of the design situation

The three important characteristics of the design situation that should be considered to select an adequate control structure (Bertrand et al. 1990). These are the following characteristics:

(1) The uncertainty and dynamics of the production situation: a) uncertainty creates b) dynamics, because it is hard to anticipate in an uncertain situation. A situation is more dynamic, if there are more changes, which should be controlled. The degree of uncertainty in a situation becomes higher if changes in the situation will be more unexpected. Uncertainty and dynamics can be situated at the demand side or the resource side of an organization.

(2) The flexibility in the production situation; Flexibility of resources is the pendant of uncertainty and dynamics. Flexibility has a quantitative aspect and a timely aspect. It is of no use if it does not serve any purpose. Flexibility makes it possible to reduce fluctuations in the primary process.

(3) The complexity of the production situation; the more interdependencies between separate elements are given, the more complex a situation is. A high degree of complexity needs more information and coordination than a low degree.

During the research, these concepts got less abstract, and can be described as follows:

(1) a) Uncertainty is the number of unknown requirements, methods, solutions and resource assignments in the process,
b) Dynamics are the number of changes in requirements, methods, solutions, and resource assignments during the process that occur due to the interdependencies and uncertainties,

(2) Flexibility is the ability to accommodate to uncertainty and dynamics by adaptation on the resource side.

(3) Complexity is the number of interdependencies between requirements, methods, solutions to requirements, and resource types needed to create the solutions.

The characteristics of the production situation can be depicted by mapping the relationship between the important aspects of the situation.

B) The control structure

A global control structure proposed by Bertrand et al. (1990) is used to frame different planning activities (See figure 2.1).

This structure can be decomposed vertically into aggregate planning and production unit planning, and horizontally into capacity planning and planning of inputs and outputs during the primary process. Aggregate planning gives on overall overview. Production unit planning gives a detailed overview over the resource allocation state in the unit. Capacity planning keeps track of the capacity to gain workload control. The primary process planning keeps control over the priorities in work order and task releases.

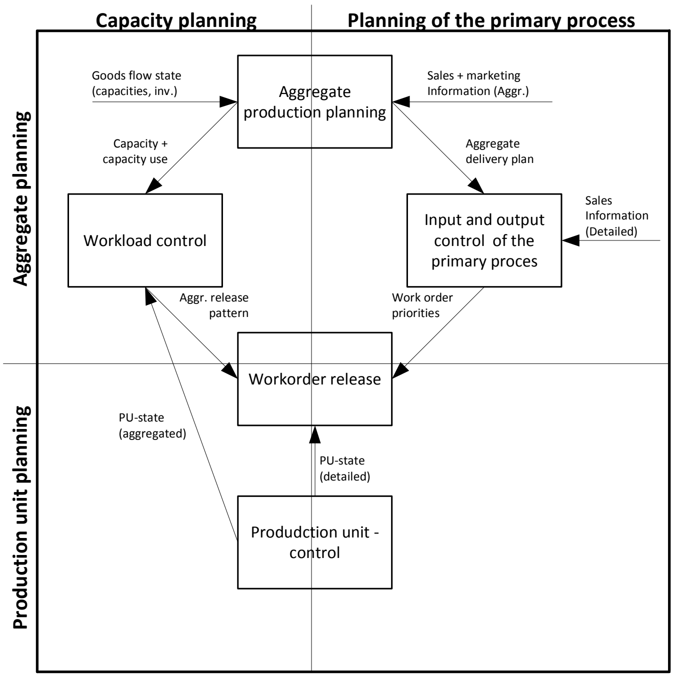

Figure 2.1: global control structure derived from Bertrand et al. (1990)

C) Coherency between the control structure and the design situation

The research model used in the analysis to evaluate the coherency between the design control structure and the design situation is also deduced from Bertrand et al. (1990). They express that an effective coherency between a control structure and a specific organizational situation should fulfill at least five basic rules:

a. The flexibility should be bigger than, or equal to the uncertainty, and dynamics;
b. The flexibility should be used functionally by means of a good information system and decision making process.
c. The flexibility itself, the authorization and the information for using the flexibility should ideally be available on organizational positions, where disturbances could appear.
d. The complexity should be reduced or clarified.
e. The complexity should be decomposed in such a way that rigidity and inefficiency will be avoided.

The coherence between the design control and the situation is evaluated by these five rules. The rules evaluate the effectiveness of the production control structure. If the structure is effective, there can be a reliable task scheduling and a good level of resource allocation efficiency.

These key concepts for production control structures were used to analyze the design situation and the design control structure and evaluate the coherence between these two. The findings of the analyzes and the evaluation are described and explained in the next chapter.

4. FINDINGS

4.1 Design Situation and Perceived Problem

The design situation in the investigated organization is depicted in figure 3.1.

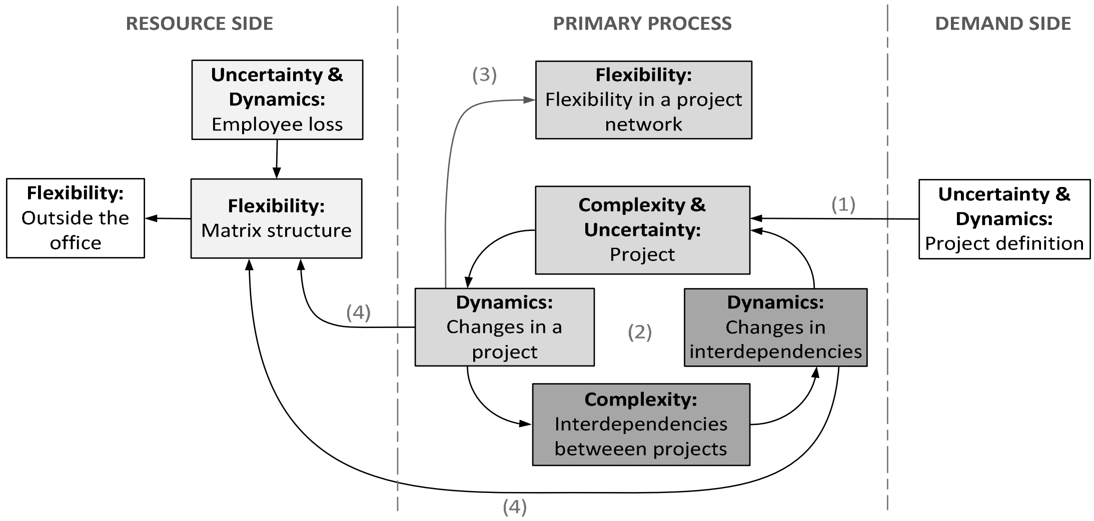

Figure 3.1: Design Situation at the investigated architectural firm

The findings of the interviews show that in the investigated architectural organization high uncertainty, and dynamics can be noticed on the demand side of the projects. The situation has similarities to an EtO situation as characterized by Wortman et al. (1997). The findings reveal that uncertainty and dynamics cause more dynamics in the high complexity in projects and between projects. The high uncertainty and complexity is typical for EtO environments with several complex projects in parallel (Leus et al.; 2003). Flexibility on the resource side can be used to stabilize changes in the planning of the primary process.

Only few design unit managers (with human resources working on all projects) perceived the interdependencies between multiple projects as resource scheduling problems. Most managers perceived the problems as “bad project management by others”, or as “relationship problems between design units”. Due to this perception, management blamed each other in a vicious circle.

4.2 The Design Control Structure

The formal organization used separate information systems for the resource allocation and project scheduling. The project schedules made by the HPMs contained the planned tasks and task outputs. The schedules could not be linked directly to the resource allocation information. This made the information of the resource allocation system almost useless. In order to have a neat overview of the project tasks in their design units, DUMs were forced to make separate informal information systems. The common formal information system was therefore not used regularly and information was not up-to-date. The information system was therefore also of less use for aggregate managers. It led to a situation that can best be described as an iceberg-metaphor (See figure 3.2). On top of the organizational iceberg the aggregate manager tries to control the iceberg by means of the formal information system. Under the water the iceberg is full of cracks between design units, because all design units use individual informal information systems.

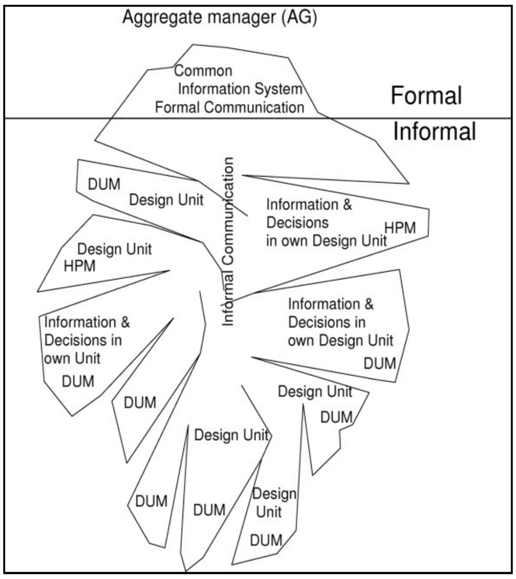

Figure 3.2: Iceberg-metaphor of the control structure in the analyzed organization

Only through informal communication it is possible to adjust pragmatically resource scheduling information with each other. A total common overview is lacking. This pragmatic design control structure also led to political and cultural issues. The goals within the individual information systems of managers became the dominant trigger for a behavior that focused on own management results. This resulted in defensive behavior, avoiding conflicts and decisions that could cause problems in individual planning. A political game between HPMs and DUMs could lead to role conflicts for the functional staff as mentioned during the workshop. According to Jones and Drecko (1991) such a situation can be recognized as one of the most commonly identified sources of conflict in matrix organizations. The issues also explain the perceived problem, which is described in section 3.1.

4.3 The coherence between the design situation and the existing design control structure

The coherence between the design situation as described in 3.1 and the design control structure as elaborated in 3.2 is evaluated in this section by using the five basic rules for effective coherency listed in section 2.4. In this section we conclude that the coherency rules do not match with the analyzed design control structure.

The first conflict is provoked by keeping everybody allocated to a project. By using the maximum capacity limit of the organization as basic principle, the need for more or at least equal amount of flexibility in comparison with the amount of uncertainty and dynamics is not considered.

The second conflict arises because the information system gives not enough information to functionally use the flexibility. In the formal information system, hours are assigned to whole projects and not assigned into detail to tasks. Therefore there is no insight into the project complexity and no clear Delta between the estimated time and the actual time needed to complete project tasks.

The third conflict with the coherency rules is the unavailability of authorization for using flexibility on all the right organizational positions, because the real flexibility is needed in projects, but only the DUMs have authorization to schedule tasks and resources of his design unit, HPMs only have influence (this also led to the political issues).

The fourth and fifth conflict results from the lack of clarity with regard to the complexity between projects. The aggregate planning level does not gain an insight in the interdependencies between projects. Due to a lack of overview, the complexity cannot be reduced and not be decomposed.

It can be concluded that the five basic rules are not fulfilled. This indicates that the control structure can be more effective.

5. REDESIGN TO THE CONTROL STRUCTURE TO THE DESIGN SITUATION

In the redesign a design project is viewed as a network of tasks, where each task generates output. Each output is the input for one or more interdependent tasks until the end result is reached. In the design process, these inputs and outputs are mainly design documents and requirements (e.g. functional requirements, client requirements). Another type of interdependency originates from the fact that tasks require human resources that are shared between orders (projects). Both types of interdependencies can lead to an inefficient situation, in which either tasks wait for resource availability causing loss of time, or human resources wait for tasks that cannot start because input is not yet available causing loss of resource capacity. Both interruptions cause loss of profit. As a basic principle planning should aim at sequencing tasks of multiple projects in time over human resources in order to minimize both types of waiting times. The redesign combines principles of production control theory with project management principles of the architecture and engineering (AE) industry.

The redesign is based on four hierarchical capacity planning functions derived from the hierarchical multi-project approach of Leus et al. (2003). They argue that a scheduling approach with four hierarchical resource capacity planning functions is needed in situations with a high degree of uncertainty and complexity: 1) a strategic resource planning (SRP); 2) a rough cut capacity planning (RCCP); 3) a resource constrained project scheduling (RCPS); and 4) a detailed scheduling. For the RCCP approaches they conclude that RCCP approaches as investigated in literature deal with uncertainty on the tactical level and are all *proactive* approaches. The approaches aim at anticipating uncertain events.

Due to research limitations, the SRP was not investigated and therefore not redesigned in detail. Basically the first hierarchical level, the strategic planning gives yearly (long term) goals for the human resource planning and incoming projects.

The second level, the RCCP, should take the interdependencies between projects and the project uncertainties into account. Understanding (1) pace of work intensities in creative design processes and (2) project uncertainties is key to a proactive solution for the control problems occurring at the aggregate planning level.

The increase of work intensity in design projects when a deadline approaches is inherently rooted in the design process (Beeftink, 2008). The interviews undertaken in our research confirm this. When deadlines of multiple projects take place at the same time, the office's resource capacity limit can be exceeded due to the increasing work intensity in more projects. By tuning deadlines with each other at the aggregate level high peaks can be avoided. (See figure 4.1).

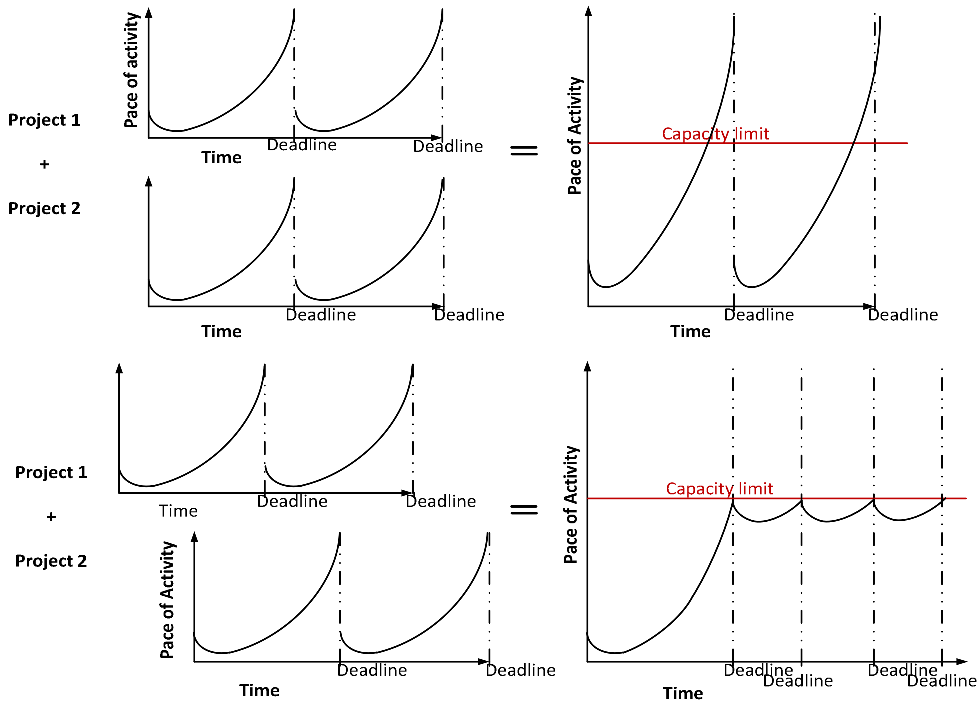

Figure 4.1: avoiding work overload peaks by tuning deadlines

On the aggregate level resource capacity buffers for "uncertain, dynamic projects" could be planned to avoid work overload problems caused by uncertainty and dynamics. By planning buffers the chance of a snowball effect due to interdependencies of shared human resources between projects can be reduced. In order to plan an uncertainty capacity buffer, an uncertainty estimation of a project should be made. The uncertainty can be estimated by using the goal-and-methods matrix of Turner and Cochrane (1993). The goal-and-methods matrix indicates parameters for the project's uncertainty: project goals and methods (See figure 4.2). The less these parameters are defined by the client, the higher the chance of a dynamic project situation. The research findings show that projects of the analyzed organization could be categorized in four uncertainty categories. This categorization could be used to estimate buffers at aggregate level. The buffer makes flexibility on the resource side possible (e.g. by outsourcing). By regulating project deadlines and creating uncertainty capacity buffers on the aggregate level the balance in the pace of projects can be controlled proactively.

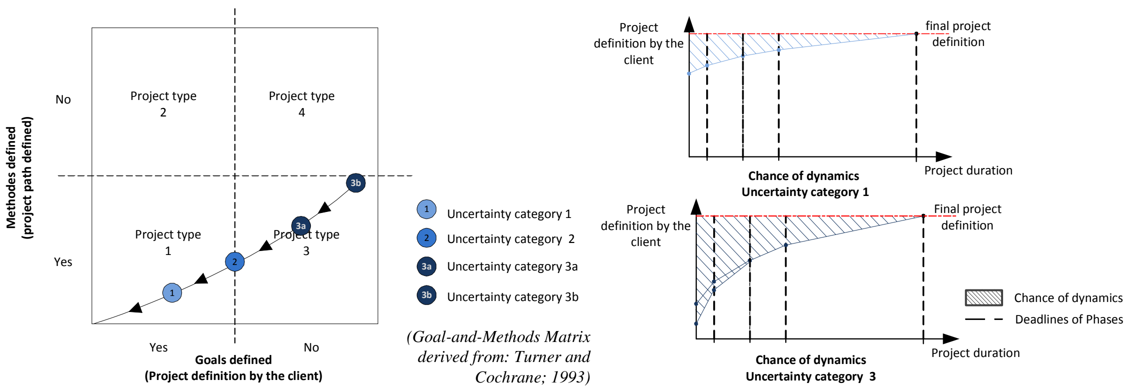

Figure 4.2: goal-and method matrix (Turner & Cochrane, 1993) used for categorization of project uncertainty

To allocate resources to projects productively at design unit level, the coordination of task inputs and outputs of the project should be planned and the duration of the tasks should be estimated before planning human resources on projects. This procedure has five advantages: the project progress can be measured in terms of time, the errors in the estimated task durations are visible, the relationship between inputs and outputs of tasks can be better established in time, the resources can be efficiently allocated and the project profit can be estimated better. The division in capacity planning and the coordination of inputs and outputs also elucidates the difference in responsibility between project managers and DUMs. The coordination and planning of inputs and outputs in a project is the responsibility of the project manager. He should define project goals and requirements. The estimation of the design unit tasks and the capacity planning is the responsibility of the DUM.

Because most design projects are uncertain, the planning approach on the operational design unit level consists of two hierarchical capacity planning functions: (1) a planning to find resource constrained project scheduling problems in the medium term, and (2) a detailed planning in the short term. The medium range planning should be based on deadlines, but also on the output that should be delivered on these deadlines (Leus et al, 2003). The interviews show that also the input description of technical specifications could help to optimize the task duration estimations. Due to the medium range planning based on deadlines, output and technical specifications resource constraint project schedules can be based on better estimations. Resource scheduling problems can be overseen and solved by allocating the capacity buffer that is set at the aggregate level. In the detailed planning, human resources are allocated to task priorities for the coming two weeks. By keeping the human resources flexible till the last moment, the organization can cope better with uncertainties and will work more efficient on projects.

Due to all hierarchical planning functions, it is possible to have a multi-project overview with a focus on single project goals and at the same time an efficient resource allocation. These functions have to get simultaneously tuned, e.g. by the communication principle by Hendriks et al. (1996, 1998). The set of hierarchical planning functions is in line with the coherency rules we found in the literature, the only constrain is a supporting information system for these planning functions.

6. CONCLUSIONS AND RECOMMENDATIONS

Especially for large AE offices with multiple projects in parallel, a design control structure is considered to be an essential tool to manage delivery reliability to the demand side and at the same time create efficiency at the resource side. This paper proposes a design control structure with four hierarchical planning functions and explores how these planning functions can function in a large architectural firm with EtO characteristics. According to the latest feedback from the organization the design control structure is still not tested or implemented. However managers at design unit level are now asking for the planning functions of the redesign, which shows a good support to implement the redesign at operational level. Although the proposed control structure has not yet been tested, the positive response from the management is a basis for confidence in the approach.

This research gives an example how production control theory concepts, principles and rules can be applied to control multiple projects in the AE industry. Project management as familiar to the AE industry focuses on creating less uncertainty and dynamics in projects (Laufer, 1996; Turner & Cochrane, 1993), but does not give any principles or tools how to handle resource allocation in large architectural organizations. The research shows that a control structure should take into account the familiar project management practices in the AE industry in order to get management support for the new control structure. Therefore theoretical concepts, principles and rules of a multi-project planning approach have been combined with project management principles that are familiar for the AE industry. This led to a redesign in which a multi-project planning approach is suggested with room for project management at the operational level.

In the literature as explored in this research, design control in architectural firms gets too little attention in architectural management practice and theory. It is plausible that more AE firms face similar problems in resource efficiency and delivery reliability, because most architectural firms have human resources working on multiple projects in parallel (e.g. Beeftink, 2008). In order to generalize the results from our research, more research and design projects should be done to create satisfying design principles and rules for the AE industry. Therefore the authors hope this paper contributes to attention for this topic in AE industry which is neglected by researchers, by sharing the redesign proposition and its theoretical principles and rules.

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