

Matchmaker : an instrument for matching demand for and supply of building

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Matchmaker

— An instrument for matching demand for and supply of buildings

Wim Adams and Roel Daru

Abstract :

To match supply and demand of buildings various approaches are possible. In this paper the well known, on SABA algorithm based, methods are assessed and compared to a graphic interactive approach. In a tool, developed by us, using this approach strongly developed power of human visual information processing and pattern formation, is used in collaboration with the computer power of fast and clear visualisations supporting for or giving feedback and consequences on decisions taken. To elucidate the working and idiosyncrasies of this tool a case concerning architectural heritage is discussed.

1. Vacancy of monumental buildings :

In Europe (in the EEC and in other countries, in particular middle European countries) a great number of monumental buildings, protected or not, will become vacant in the coming years. To avert the worst consequences of their obsolescence (be it technological, organisational, political, economic or cultural), it is necessary to shorten the time of vacancy as much as possible, and at best to eliminate vacancy altogether.

On the other side, there are a number of institutions or companies looking for premises in the cramped inner areas of European cities. Many of those are willing to move into existing building stock, if the building fabric can be adapted to their needs.

To match supply and demand while at the same time respecting the constraints imposed by cultural heritage, it is necessary to bring them together and to effectuate feasibility studies in the shortest possible time. This will sometimes occur in delicate circumstances, in particular when preservation depends on the proof that a building has an economical chance of survival. The feasibility study should be served by tools allowing the various partners to communicate on the level of the match between supply and demand, translated in terms of spatial organisation and building constraints.

2. Problems with matching :

The matching of a building and an organisation can be seen as a specific space planning problem in

which characteristics of a demanding party (an organisation with a housing problem looking for new or existing appropriate premises) are compared to the actual supply (spatial characteristics of existing or newly designed buildings in stock). In matching organisations with existing buildings (as compared to designing a new building) we are confronted with some specific problems. Spatial constructions of existing buildings are more or less rigid as compared to newly to design buildings. Each building has its own spatial structure and spatial characteristics with both fixed and more flexible parts which make this particular building more or less suited for a specific organisation.

In the process of matching supply and demand it is necessary to take correct decision regarding the match within a short space of time. Next to actual fitting organisational functions to spatial units of the building in a generated layout it is, in order to analyse and evaluate the proposed geography of the building, also necessary to easily retrieve the bottle necks or discrepancies given this specific arrangement of organisational functions over the spatial units of the building. To match supply and demand of buildings, various approaches are possible.

3. Approaches to the matching problem :

While interest in artificial intelligence approaches to the matching of buildings and organisations is growing and use of more conventional algorithmically based methods is most widely spread and therefore favoured by some, these methods, in general, have some significant drawbacks. The imperfections concern a severe restriction of available information on both building and organisation that is actually used by these programs, the transparency of the processing of this information as well as the quality, flexibility and format of the generated output, the proposed building layout. We think that a less "heavy" approach can be more cost and time efficient and solve some of the fundamental problems encountered by the two other types of methods. Although the tool we developed (ROP : the Dutch abbreviation of Space Optimisation Package) was originally developed for other problems, because of their likeness to the abovementioned matching problems we expect this

tool to be potentially suitable for these quandaries as well. We tested this by applying the tool in an actual case.

4. A graphic and interactive reordering tool : ROP

4.1 Background of ROP Development :

In the past years, our research unit at the Eindhoven University of Technology has developed and tested a graphic-based reordering tool and applied it to space planning problems of large governmental buildings, both existing and new.

This graphic-based reordering tool in fact is a generic tool, and therefore can be used for a large range of ordering problems for weighing, ranking and evaluating objectives, to have a synthetic view of the combined basic preferences and differences of the involved parties as for example in a jury wise evaluation and ranking of alternative proposals.

The proposed tool is the computer based, graphic and interactive version of the data and association matrices. The well-known paper version of particularly the association matrix (see figure 1) for a long time has been recommended for the inventory of existing relationships between functions or activities of an organisation in the preliminary phases of design. However, as long as these instruments could only draw static information on paper, they were much too ineffectual and found little real application in practical space planning problems.

4.2 Functioning of ROP :

The graphic based reordering tool consists of two components; one registering and displaying relationships between entities of a single set (in building design entities can be the activities or spaces of a building, in an organisation the functions or activities of employees), the second containing a record of relevant criteria for each of these entities (in building design a number of characteristics of the activities or spaces as e.g. constructive, climatological or layout properties; in an organisation the brief with its specific requirements of functions or employees). Scale of measurement of these criteria can range from nominal to ratio scales. In ROP there is no restriction as to the number of relevant criteria that can be inserted into the matrices. The registered data are translated into a graphical format and subsequently can be rearranged interactively.

The developed tool is connected by sub-routines to a computer aided design package, within which the grouped entities of the matrices are translated

into plans and attached data bases.

The experience gained by us in the past years corresponds for a large part with the needs outlined in the problem definition. However, the heavy constraints imposed by cultural heritage as addressed in this paper ask for a redesign and elaboration of these tools.

5. Case : Applying ROP to a monumental court house :

In this case the reordering tool was applied to matching some general facilities (as a restaurant with its employees, meeting room facilities and a post office) to a monumental court house.

5.1 Registration and optimisation of organisational and building information :

5.1.1 Registration :

The first phase is to describe the organisation (the demanding party) as functional units which can be made corresponding with spatial units. The prescription of spatial needs and additional requirements, also called the brief of an organisation, can take place in both quantitative and qualitative manners. In our tool the initial numerical or Boolean values expressing organisational requirements are translated into simple graphical symbols as dots or squares, whose sizes are in accordance with the original values they represent, and restored in the cells of respectively the triangular association matrix (revealing existing relationships between all distinct functions of the organisation) and the rectangular multi-criteria matrix (exposing all relevant

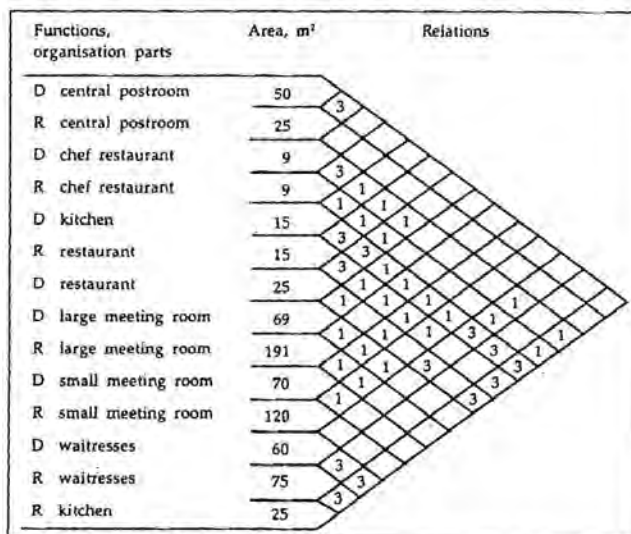


Fig. 1

Matrix of relationships between organisational functions. The values in the cells indicate the strength of the relationship with higher values representing strong relations.

requirements, wishes and preferences of the functions as to the offered space). In this case there were some fourteen entities with, next to the area requirements, a total of sixteen criteria considered to be of importance in generating a layout (see figure 2).

The above mentioned programs based on an algorithm are restricted as to the number of criteria involved. Mostly, only area requirements of the functions and the relationships between them are considered in the creation of a layout. With these programs it is not possible to include other information that has a possible or known consequential effect or is even decisive in the generated layout. Store-houses demanding a specific construction, while constructive characteristics cannot be incorporated or computer rooms that are not allowed to be placed in the southern (sunny) wing of a building while the program is not equipped to include information on required or preferred location of functions. While a number of relevant criteria is of a more general nature, other criteria are more specific to the present-day matching problem. Especially with matching of monumental buildings some constraints and characteristics will be unique for this situation. It is therefore essential that the program is flexible as to the number and type of criteria attended to.

A second major drawback of the algorithmic programs is that there is no feedback on quality and correctness of the input. In the generated layout the area of a room is, for instance, ten times as large as it should be because of a typing error. Not every mistake in the input has to be directly discernible in the resulting layout, although it did have effect. Because of the graphic format in which the information is presented in ROP, incorrect input is immediately noticed and can be easily corrected.

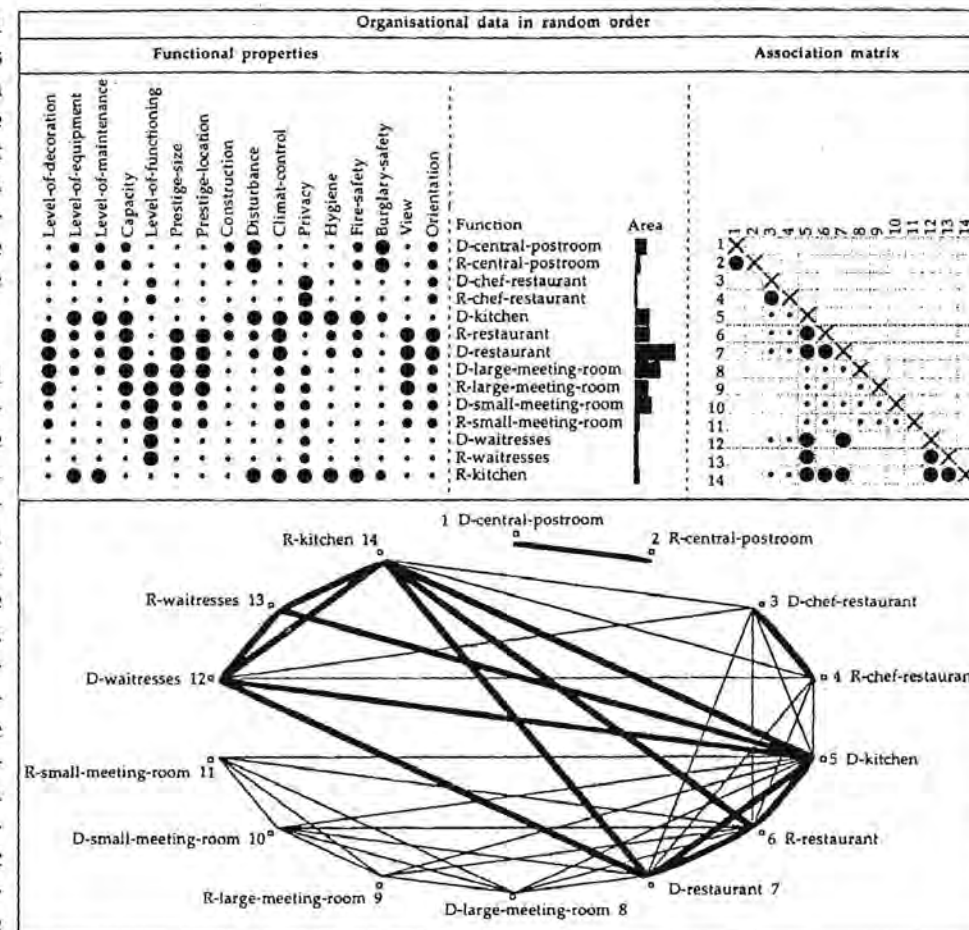


Fig. 2

Organisational data from the brief appear in random order. On the right in the topmost part of the figure, the association matrix shows the interrelationships of functional units. Larger dots express stronger relationships. On the left, the functional units are scored according to functional properties. The list of functional properties is accompanied to its right by a bar chart expressing required areas. In the lower part of this figure, an alternative view of the relationships is seen as 'walking lines'.

Parallel to describing the organisation in a triangular relationship matrix and a rectangular multi-criteria matrix, we also describe the monument in spatial units and distance relationships between these spatial units. The distance relationships between these spatial units can be generated directly within the matrix, but it is much easier, more realistic and self evident to generate this automatically from the draughted plan. The possibility to do this is part of the existing tool (see figures 3, 4, 5 appearing on next page).

Registration and typing in the constraints and relevant characteristics originating from heritage preservation objectives, expressed in levels of authorised intervention can also be done directly into the rectangular matrix of the reordering tool or retrieved from the draughted plan. In order to be able to match organisational constraints to authorised building interventions the databases of

Original plan of the monument

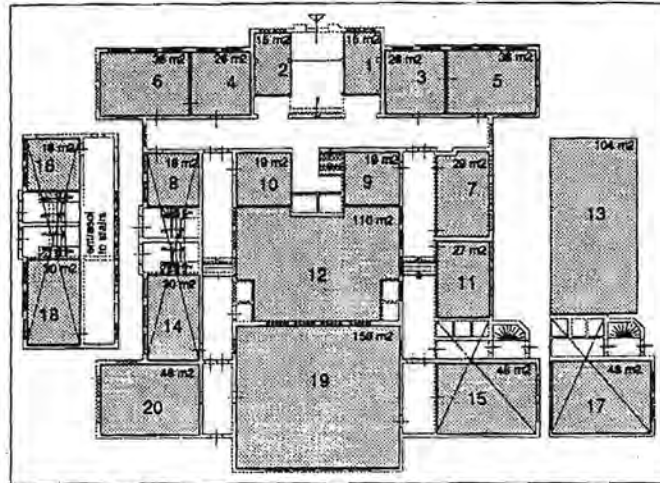


Fig. 3

Original plan of the monument drawn in a CAD program. The various spaces in the building that can be used for the spatial arrangement of functional units of the organisation are numbered. The courtyard, nr. 12 could, after roofing in, also be used to place one or more of the functional units. Spaces with numbers 16, 18 and 13 and 17 are actually located on an entresol floor above the spaces with respective numbers 8, 14 and 7, 11, 15.

both organisation and building have to be comparable; they have to comprise the same relevant criteria. When these building interventions can be expressed at the level of the spatial units we get two data-matrices of the building that are homogeneous with those of the organisation. The triangular matrix revealing relationships between spatial units of the monument, the rectangular matrix containing their properties and constraints regarding alteration in construction. Both matrices are also presented in a graphical format, with small graphical symbols in the matrix cells (see figure 5).

5.1.2 Analysis:

While analysing the data in ROP, the layout of the information can be rearranged by moving a selected part of the matrix, containing one or more of its rows and columns, to a new position. The matrix construction lends itself well

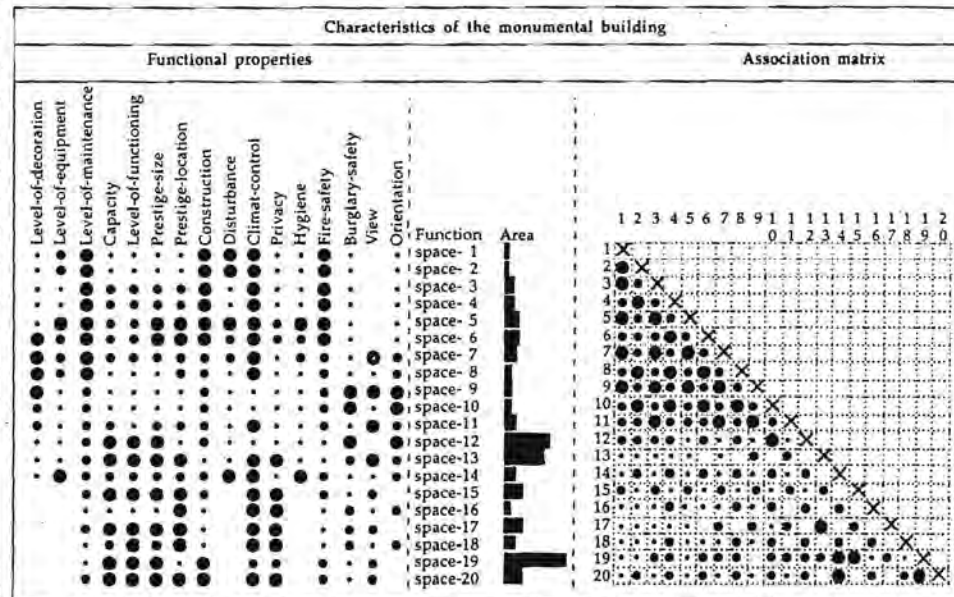


Fig. 5

The monumental building expressed in a matrix format. In lines 1 to 20 the different spaces of the monument are enumerated. On the left hand part some 16 functional properties of the diverse spaces are given (larger dots expressing higher scores on the properties). In the association matrix, on the right hand part, the size of the dots is an indication of the actual distance between spaces in the monument (see figure 4). The largest symbol corresponds to a 'walking distance' of less than 20 metres, the middlemost symbol with distances between 20 and 40 metres and the smallest dot expresses a distance of 40 up to 60 metres. Empty cells indicate that spaces are further apart than 60 metres.

Spatial connections through corridors

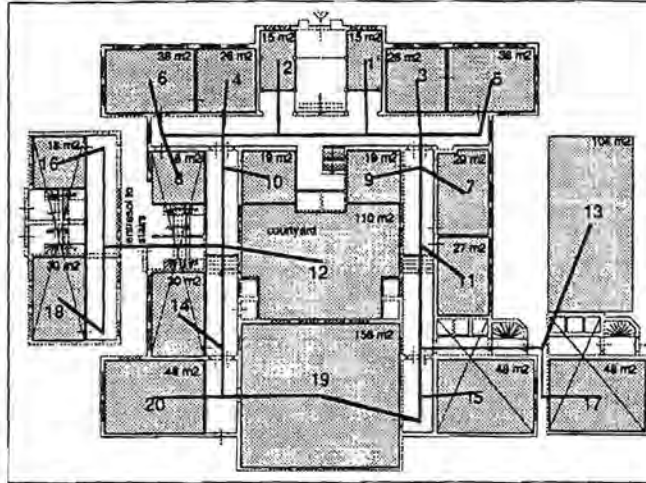


Fig. 4

Lines connecting the various spaces. The lines are channelled through the existing corridors of the building. The lengths of these lines therefore correspond to the actual 'walking' distances between spaces.

to such, mathematically correct, reconfigurations. As the matrix is re drawn on the computer screen after this movement, immediate visual feedback is given and the effectiveness of the manipulation can directly be assessed. In this method, complex cognitive processes in the analysis and interpretation of information are thus operationalised into tasks of

visual discrimination of the individual graphic elements, the recognition of graphic patterns and interactive pattern formation, that are highly developed in people (see figure 6).

The tool herewith offers the possibility of an interactive clustering of entities, with a cluster reflecting different entities of comparable spatial needs and/or additional requirements. As this rearrangement is done manually, the user determines or has to determine the importance of the different criteria involved. Deviations from obvious actions (actions generating a coherent pattern) not only provide information about the subjective importance of those criteria but also can or have to be elucidated in the discussion between the various partners involved. With algorithmic programs, the user has no or little insight on the weight or effect of the different criteria. Weights are fixed or have to be determined in advance and intermediate changes in weights are difficult to accomplish or not allowed.

When allowed the effect of changes in weights is not directly visible but only in the final layout plan. As matching a (large and complex) organisation with a (extensive and complex) building can be a prolonged process it is necessary to be able to examine and discuss intermediate results. Small, hardly noticeable, errors or slightly unfavourable allocations occurring in an early phase of the matchmaking process often can have far reaching, dramatic consequences on the final floor plan layout. As the layout is generated manually in ROP, corrections can be made immediately while the subroutines in the CAD program provide the user additional information as to adequate allocations for a specific function.

Thus, with the electronic version of this instru-

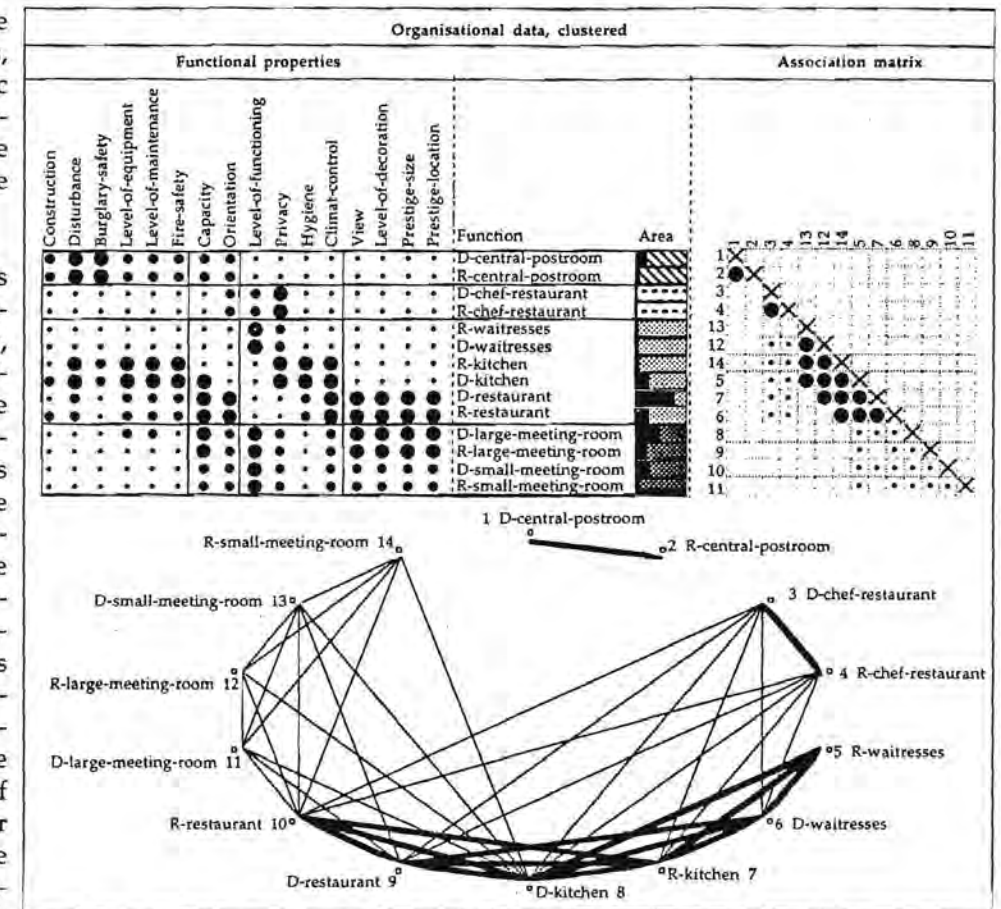


Fig. 6

The same data as in figure 2, but clustered. Items 13, 12, 14, 5, 7 and 6 now form a cluster of functional units with strong interrelations as expressed by large dots in the triangular matrix, as are items 1, 2, 3 and 4 respectively. The areas bar chart is supplemented by shadings expressing functional grouping (see also figures 7 and 8). The qualitative matrix is rearranged according to scores to obtain qualitative profiles. We can for example see that the units 1 and 2 have a similar profile and form a qualitative group, as do units 3 and 4. Within the larger group ranging from item 13 to item 6 we find a subgroup 'restaurant' with items 7 and 6 and a 'kitchen' group (14 and 5), each with its own requirements. By rearranging columns, we find groups of requirements with similar profiles concerning functional units. The graph expresses the obtained spatial concentration of functional groups.

ment visualisations can not only be used for presentation of summarising information at the end of the processing and analysis of data, but also to communicate, explore and support decision making throughout the analysis.

5.2 Matching:

In the next step, the actual matching takes place, where clusters of functions, or individual functions are assigned to the available spatial units (see Figures 7 and 8).

In this step the actual positions, properties and constraints of existing spaces in the monument are compared to the optimised and clustered spatial needs of the end user. This phase of the matchmaking process is, as the previous ones, done

Imported functional units, expressed as areas

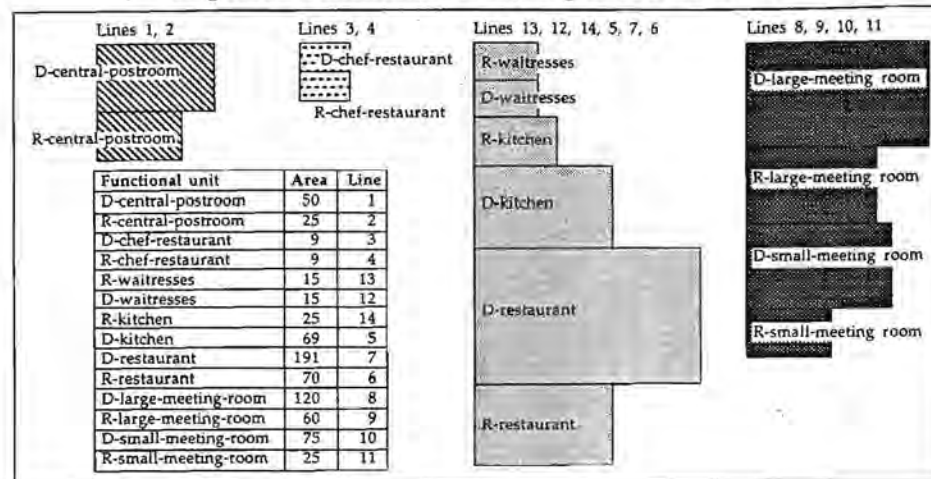


Fig. 7

Functional units as imported into the CAD program from the matrix program, diagrammatically expressed as areas from the brief, with corrections introduced by constraints of the monument (spatial grid, depth of building). The four groups (each with its own shading) correspond with the functional groups in figure 6.

manually. This offers the possibility to include other considerations than those directly deducible from the registered facts. Next to the intrinsic information, the registered information laid down in the matrices, the person in charge of the space planning can also take extrinsic information into account, information concerning building and organisation that is known by the planner although it is not comprised in the data matrices. The planner often already has a coarse layout in mind, partly based on previous experience and partly on his communication with persons being well known with both building and institution. This expertise he can neatly add to or fit into the present-day matching problem with its particulars and specific requirements.

There are various ways in which to view the consequences of the matching, one of the most interesting being the discrepancies' views, a display again based on the graphical matrices. This view obtained after evaluation of the generated layout, in a clearly structured way, reveals all deviations between demand and supply both regarding relationships as well as concerning additional spatial requirements (see figure 9). It therewith enables communication and stimulates negotiation between involved parties. This leads to rearrangements, possibly with some modifications of the original input from the

various parties, obtained by these negotiations.

With algorithmic programs the format of the output often is unclear, as e.g. when the resulting arrangement is presented in a numerical form; lists of spatial units with their functions or inhabitants. This format certainly is not suited to infer practical implications as distances and walking routes between related functions or to bring forth functions residing in adjacent spatial units. The output is also impractical and not realistic when functions are e.g. completely enclosed by other functions and not bordering the facade of a building, when

storehouses are not located in the basement of the building but on the main floor or when spaces are jagged or the length-width ratio is out of range. The generated layout is not flexible when changes in the configuration of spaces (exchanges) or small adaptations are difficult or impossible to attain.

In the last phase, the feasibility in terms of space, building fabric and costs can be appraised by

Plan of the monument with spatial arrangement of functional units

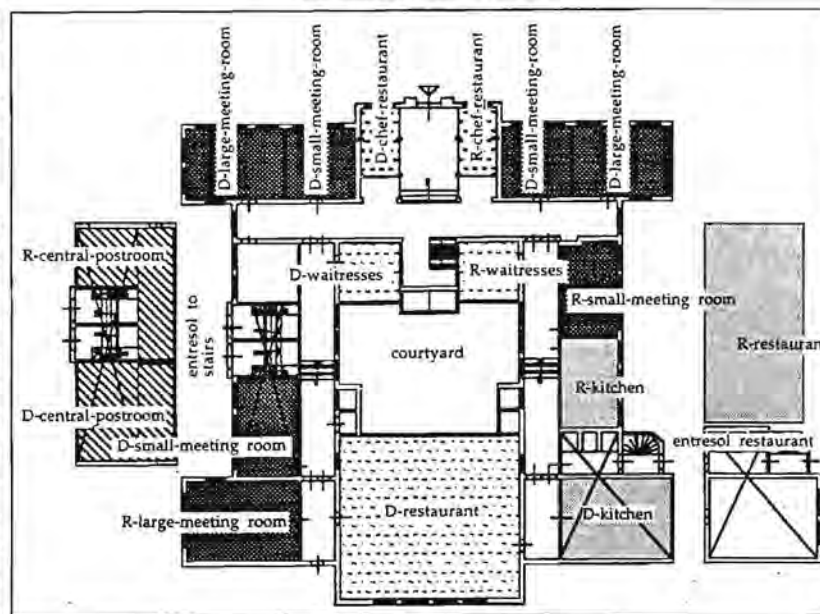


Fig. 8

Plan of the monument with a first spatial arrangement of functional units within the building. Some functional units had to be split to fit, while some existing spaces are unoccupied.

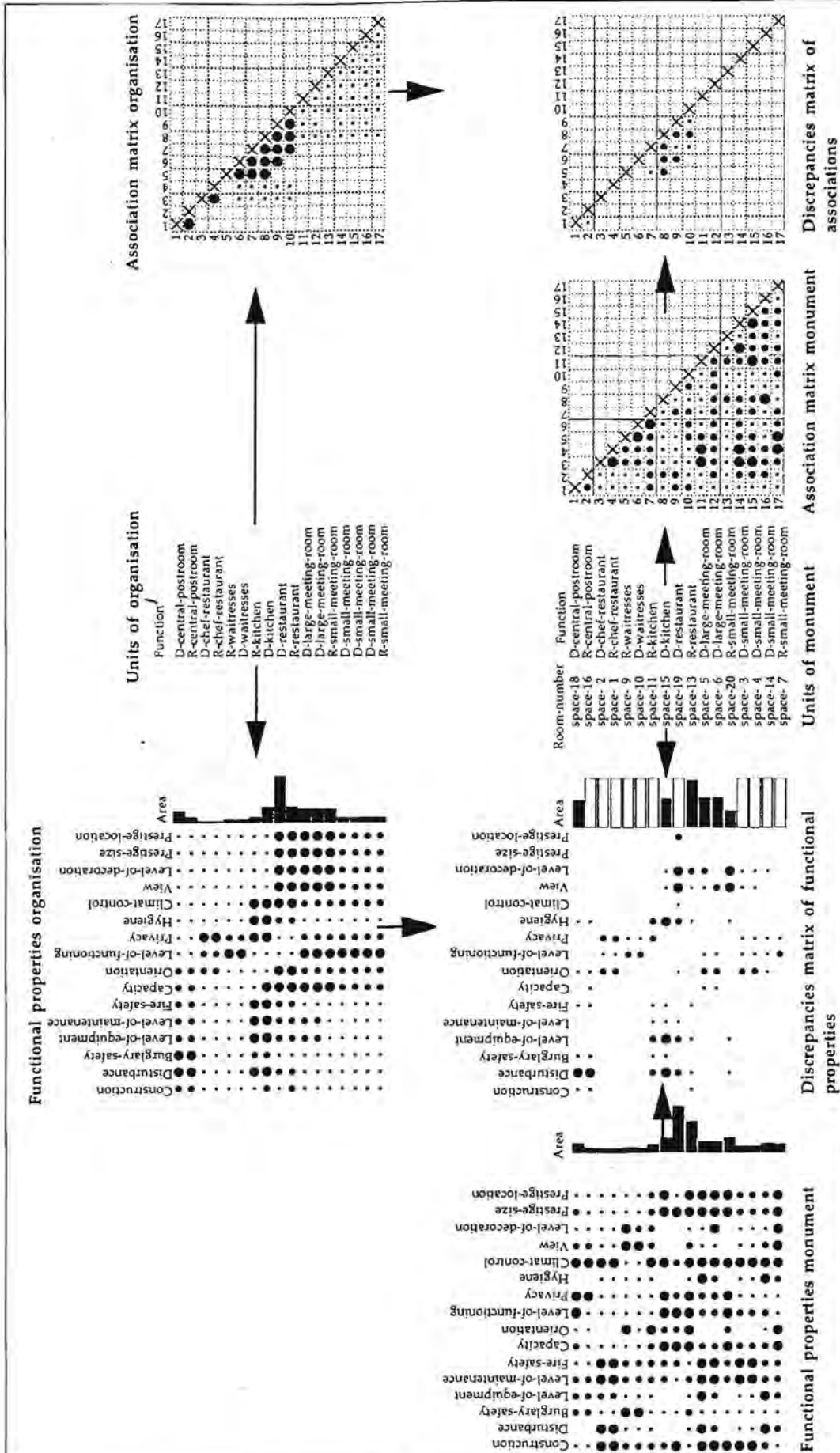


Fig. 9

In the middle we find a list of the spatial units. On the top is the description from the point of view of the organisation (units of organisation), on the bottom the description of the existing spatial units (units of monument). The spatial units are clustered according to the wishes of the organisation (top right), association matrix of organisation. The wished qualities of the spatial units are evaluated in the qualitative matrix of the organisation (top left, functional properties of organisation). The qualities of the spatial units in the monument are given in the qualitative matrix of the monument (bottom left, functional properties of the monument). They are combined in order to find the

discrepancies (qualitative discrepancies matrix of functional properties). We can for example see that the level of (visual and auditory) disruption for the postal employees is too high (second column, first two rows of qualitative discrepancy matrix of functional properties). In the same manner, the discrepancies between the wished functional associations and the possibilities offered by the existing building are shown in the discrepancies matrix of associations (bottom right). The discrepancies matrix of associations reveals that the rooms for canteen employees (items 5 and 6) are too far from the kitchens (items 7 and 8).

analysis of the type and importance of the discrepancies and the consequences of their pursued solutions. Once a compromise has been attained, preliminary proposals can be designed and laid down in terms of drawings. The spatial designs can then again be translated into matrix views and evaluated, including the comparison of renovation costs.

6. Summary of the comparison between ROP and algorithmic methods:

Some principal differences between our graphic interactive approach and methods that are based on algorithms can be summarised as follows:

Most of these methods use the so called SABA algorithm. Distinguishing a more coarse stacking and a more refined blocking phase in the generation of a layout these methods automatically generate a layout, while in contrast in ROP a layout is generated in a manual and interactive manner.

In ROP the user can base the decision he makes partly on extrinsic information, facts that are not recorded in the brief of an organisation or the description of the building but are nonetheless known by the user. Algorithmic approaches per definition only use the information that beforehand has been recorded into the program. In addition, the user often has no insight in the manner in which the algorithm weighs the different criteria.

Because of the manual generation of a layout, in ROP the user has control during the whole process and can correct or give preference to specific solutions. With the automatic generation of a layout, control of the process is mainly determined by the algorithm, with the user having no or only a very restricted possibility to interfere during the process. The planner normally can only make some manual changes in the stacking or zoning of functions after the stacking phase is finished.

In order to support the user in decision-making during the process, our method is centered on a graphic and clearly structured presentation of the information; other methods mainly present information in a numeric format.

Another supportive aspect of our approach is the immediate feedback of (the consequences of) actions taken by the user; algorithmic approaches on the other hand often only present the final results (layout) at the end of the process.

In a study by Li (1993) in two case studies (in

the first a design was made for a new kindergarten, in the second an organisation was matched to an existing twenty story building) the working and obtained results of ROP were compared to those of SPACE, a program in which the generation of a layout plan is based on the SABA algorithm. In the second, matching case, it was found that the obtained geography (both in stacking as well as in blocking) in ROP was significantly better than those obtained in SPACE, as based on distance between related functions. These results are in accordance with those found by Scriabin and Vergin (1975).

7. Additional options of the graphic interactive reordering tool:

The ROP package has a flexible design appearing from:

In the graphic reordering tool, information can be presented in different views, all having their own specific graphical format. Next to the triangular matrix of relationships, the connections between entities can e.g. also be presented in a bubble diagram or organogram. We found that different users prefer different formats while optimising the datasets. The program can easily be extended with additional formats wished for.

The tool saves all actions taken by the user. This creates the possibility to return to previous configurations of entities and to analyse the ordering process itself. In our project this ordering process of individual users in an experimental context indeed is studied for development of additional features and an increased potentiality and user-friendliness of the tool.

The matrix of relationships can be automatically searched for the non-planar graphs K3,3 and K5. Planarity is a prerequisite for the direct translation of a graphical matrix into a ground plan. A non-planar graph can be solved by bridging over or tunnelling under crossings, introducing intermediate nodes at crossing points (as e.g. a hallway) or changing the original pattern of relationships which caused non-planarity.

A genetic algorithm is going to be implemented which generates "intelligent" solutions of both rectangular as well as triangular matrix. These solutions in the near future can be presented as new steps in the process of the analysis. The user will keep the possibility to refrain from this supportive option or to make changes to the options presented by this genetic algorithm.

Once the organisation is described in the format of the graphical matrices it can be matched to numerous buildings. The same is true for the building, once described, all potentially interested organisations can be compared or matched to it.

Because of the modularity of the CAD component in the tool, with additional macro's, floor plan layouts can be evaluated for concurrent purposes as in determining "space syntax" axiality maps, determination of (shortest) routes between spaces, creation of duality graphs, analysing layout on possible problems concerning orientation, etc.

8. Disadvantages and deficiencies of ROP:

One of the major drawbacks to the program is that it requires attention and active involvement of the user throughout the complete process. It is not possible to insert the data, push one button and pick up the results after a little while.

A second drawback in the matching is the sometimes too large degrees of freedom a user has. Although feedback is given after allocating functions to spaces it would be helpful if the user would be given additional support in the creation of floor plan layouts, especially before making actual decisions regarding the best allocation for a specific function or the sequence in which to place the different functions. In a number of matching experiments we noticed that users often interchanged already placed functions or even reshuffled large parts of the settled configuration during the matching process. Advice on e.g. placing functions with heavier constraints first, as regarding the involved building, possibly would reduce retracing one's steps during the creation of a building layout. A possible future extension, helping to reduce reshuffling, could be to create a function which highlights best still available spatial units regarding specific criteria considered important (as e.g. which of the still empty rooms is at least twenty square meters, has power currency, and scores at least four on privacy).

9. Conclusion:

The graphic interactive approach to matching buildings and organisations has a number of advantages as compared to existing methods, such as more control of the user over the process, clearly structured views beneficial to communication between partners involved and revelation of subjective preferences. Case studies with ROP however have shown that because of an often too large degree of freedom of the user or planner in the decision making process, additional "guiding computer support" is to be recommended.

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