ROP: AN INTERACTIVE SPATIAL OPTIMIZATION AND GROUPING COMPUTER APPLICATION

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ABSTRACT. As a part of a research project at Eindhoven University of Technology, the computer application ROP for space-planning problems was tested in practice. The use of the application in a real-world project was evaluated. The decision-making process for the development of alternatives for a courthouse was observed to see how the computer application could support decision-making. The aim of this paper is to describe the performance of ROP in a real-world setting. ROP appears to be a useful instrument in decision-making for space-planning problems. Especially in the early stages of the design process, it enhances insight among all participants in a project team. It can also be used in situations where little information is available. To conclude, ROP appears to enhance communication between members of a design team.

1. Introduction

Computer applications are not new to space-planning problems. A new kind of approach for combinatorial problems has led to the development of the computer application ROP. This spatial layout planning application was developed by the Government Building Agency (GBA) and the Faculty of Architecture and Urban Planning, Eindhoven University of Technology. It consists of two modules: ROP-TRI and ROP-CAD. ROP-TRI shows a relationship matrix and a relationship graph, and ROP-CAD is a module connected to a commercial CAD application: MiniCad™ (1990).

The technique underlying ROP-TRI is defined as an interactive graphic heuristic procedure (Daru and Adams 1989). This technique is based on the work of Bertin (1981). It is argued that a person can recognize patterns of data easily when these are represented by symbols. This means that one can use ROP-TRI to organize the functional demands for space and physical proximity in a relationship matrix and graph by rearranging the symbols. The matrix and graph offer features to construct groups of functional units with strong relationships. What kind of alternative grouping is seen as optimal depends on the user. This is an important point, because other optimization criteria can be considered in addition to the criterion of physical proximity. For example, the number of floors in a building constitutes a criterion for the number of functional groups one wants to differentiate. In general, the human ability of recognizing patterns is used for operating ROP-TRI. It is argued that by manipulating matrix rows, a user can try to get what he or she considers the optimal functional 'clustering'. This means that the user can group functional units with strong relationships in the matrix. Visually, these groups appear as triangles.

The ROP-CAD part provides the user with features to construct and depict spatial grouping. It is the user of the program who decides what kind of optimization actions should be performed. ROP offers tools to do this in an easy and efficient way. At the same time, it is possible to see what alternative layouts mean in space use. One can also see how relationships are rewarded in the spatial layout. How this fits one's demands can be seen in the ROP-TRI matrix. For the GBA, ROP is especially useful as a support in the definition and design stages of building

H. Timmermans (ed.), Design and Decision Support Systems in Architecture, 201–212.

projects. It offers tools by which users can prepare and develop parts of their brief. Furthermore, it assists in matching the building to the organization. ROP performs best when there are several parties to the decision and when the criteria for optimization depending on the individual situation.

To elucidate the above advantages, this paper will explain how ROP can operate from two points of view. First, ROP is explained in terms of the internal tools that are offered. In fact, ROP is described as if a person is performing a task without concern for external influences. Secondly, the external environment in which ROP can act is illustrated in a project description, resembling reality for space-planning problems. Out of the two points of view, the discussion will deal with the benefits of ROP for space planning undertaken by the GBA. The next section deals with features of ROP to give the reader more insight in the program. The subsequent section describes a real-world case in which ROP was used. On the basis of the practical use of ROP, Section 4 discusses how ROP supports decision-making.

2. Space planning and ROP

ROP is an application for the Apple Macintosh computer (recommended level Macintosh II). As already mentioned, it consists of two modules: ROP-TRI and ROP-CAD. When using ROP, four general stages in a procedure can be distinguished. Figure 1 depicts these four general stages.

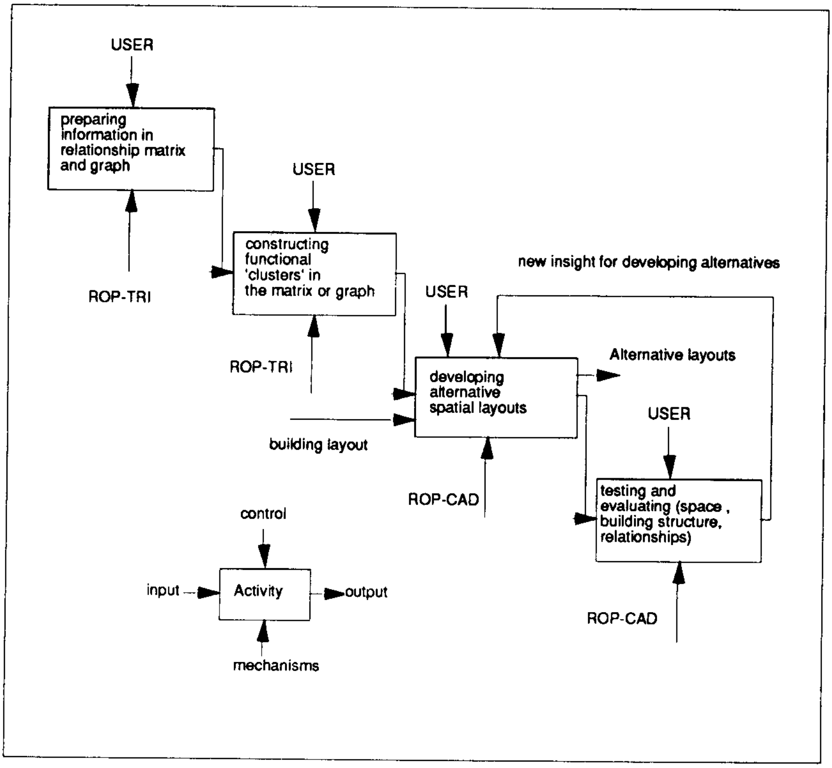


Figure 1. Process description of how ROP cab be used

First the data has to be prepared for ROP-TRI. In space-planning problems, this data is dependent on the request of the organization for which the new accommodation is going to be planned. Secondly, this data is transformed into new information for the planning procedure. The user of the program is the one who performs the task. These two stages concern the handling of the requirements ascribed to the functional units of an organization. In the next two stages, the building is also in the picture. This is where the actual allocation of functional units in a building takes place. Often there is no best solution at hand. Therefore, alternative spatial layouts are tested and evaluated to see which is best. This leads to new insights, and the spatial layouts will be changed accordingly. The rest of this section explains in more detail how ROP can be used.

2.1. ROP-TRI AND ITS FEATURES

In ROP-TRI, demands for space, reference names, and a reference number are shown in the left border of the matrix or along the perimeter of the graph. The matrix and the graph both represent the same data. In the top border of the matrix, the same reference numbers are shown. The relationships are defined as an expression of physical proximity. They should be rated as primary, secondary or unwanted, representing some degree of demand for proximity. What this actually means depends on the interpretation of the user. Mostly, primary relationships indicate a demand for rooms close to each other. Secondary relationships are less important than primary ones. Unwanted relationships indicate that the organizational units should be located separately in the building. Empty cells in the relationship matrix indicate that there is no demand for proximity among the organizational units. The relationships should be described by the members of the organization that will occupy the new accommodation. The scored relationships are represented by symbols in half of the matrix. On the left side of the diagonal, the primary and secondary relationships are depicted; on the right side, the unwanted relationships will be visible. The information can be imported in TEXT format. However, it is also possible to insert the information directly.

When the matrix is filled, it will probably reveal a scattering of dots (see Figure 2a). The user can then initiate the actions for clustering or diagonalization. He or she can do this by picking up rows with the mouse and move them to another position in the column. The functional units, with primary and secondary relationships, should be positioned near each other in the left column. The relationship dots will also shift positions when a functional unit is moved. This action can also be undertaken in the relationship graph. The matrix and graph are connected to each other. Changes in one are seen in the other. By performing the described actions, a user can construct clusters along the diagonal (see Figure 2b). This is optimizing on the criterion of physical proximity. The unwanted relationships should be located as far as possible from the diagonal. Other important criteria for a certain situation can inspire the user to undertake certain optimization actions. On the computer screen, something might seem not as optimal as possible, but it will appear to be more optimal when other aspects are taken in consideration. When a user considers a certain optimization as the 'optimum', then the information can be exported to the commercial CAD application MiniCad™.

2.2. ROP-CAD AND ITS FEATURES

In the MiniCad™ application, features of the ROP-CAD module are used. These support the spatial grouping process. The imported information from ROP-TRI appears in a spreadsheet in the order in which the optimization was made (see Figure 3a). With the features of the ROP-CAD module, one can manipulate the data. First, the functional units can be placed in an existing floorplan. It is also possible to construct a new floorplan. Secondly, physical units can be assigned to functional units in the spreadsheet (see Figure 2b). The difference between the quest for space and the actual assigned space is recorded in the spreadsheet.

These two actions can be performed by the user by manipulating the mouse and by choosing what he or she wants to do.

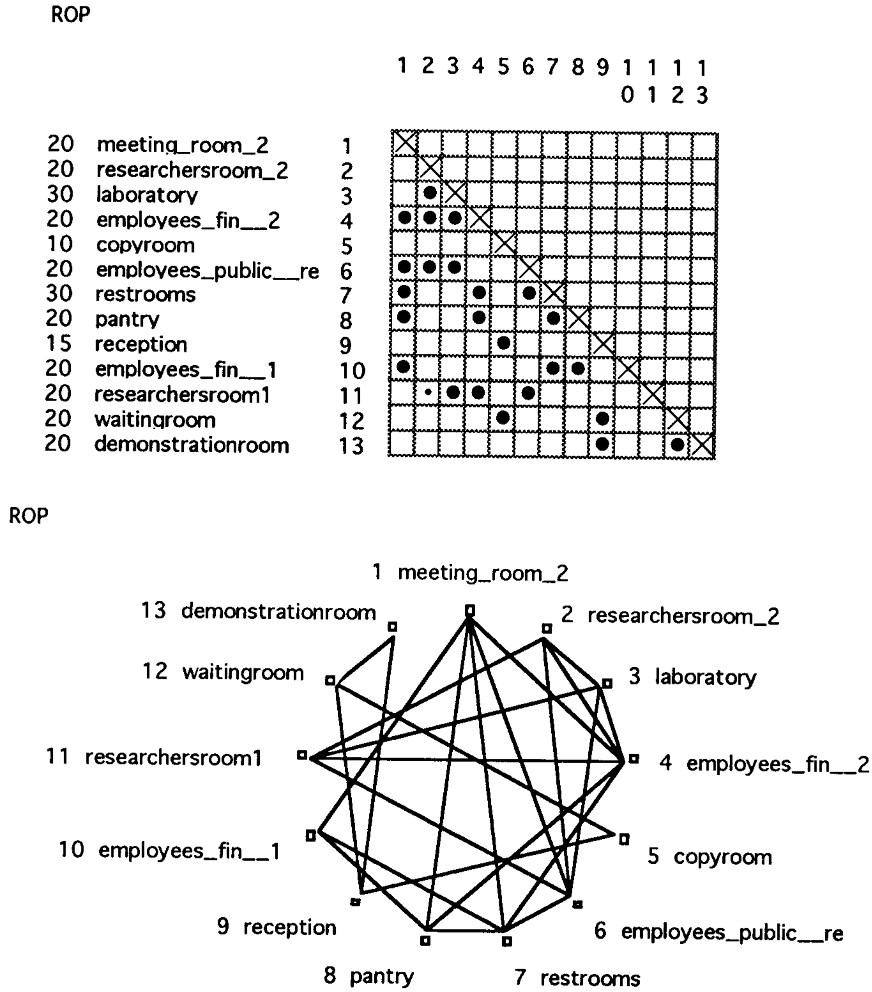


Figure 2a. Relationship TRI-graph and TRI-matrix

Whenever a unit is located, it is also possible to change that location by deleting the unit in that position and assigning it to another position. The spreadsheet will immediately record the actual situation. In this way the user can search for better space use in a very easy manner.

It is also possible to evaluate the relationships. That information can be sent back to the ROP-TRI module to compare the demand for relationships with the relationship achieved in a floorplan. The operations with the commands give the user the opportunity to construct, in an easy way, several alternative layouts. One can immediately see the consequences on the space budget or on the way requested relationships are realized. It is important to note that the variables of the spatial grouping process include functional units, requested and assigned floor area, and relationships. On the other hand, from his or her own experience as a space planner, the user can introduce all kinds of grouping criteria; e.g. structural restrictions of the floorplan or criteria that are dependent on the particular situation.

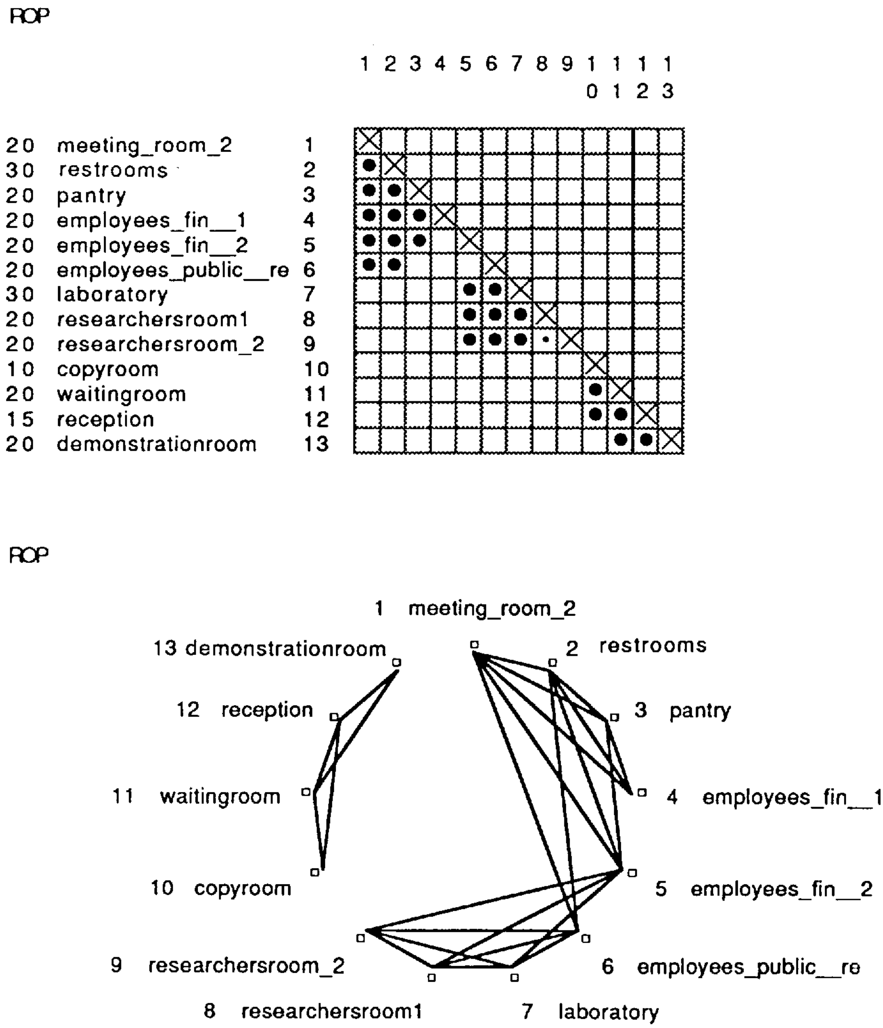


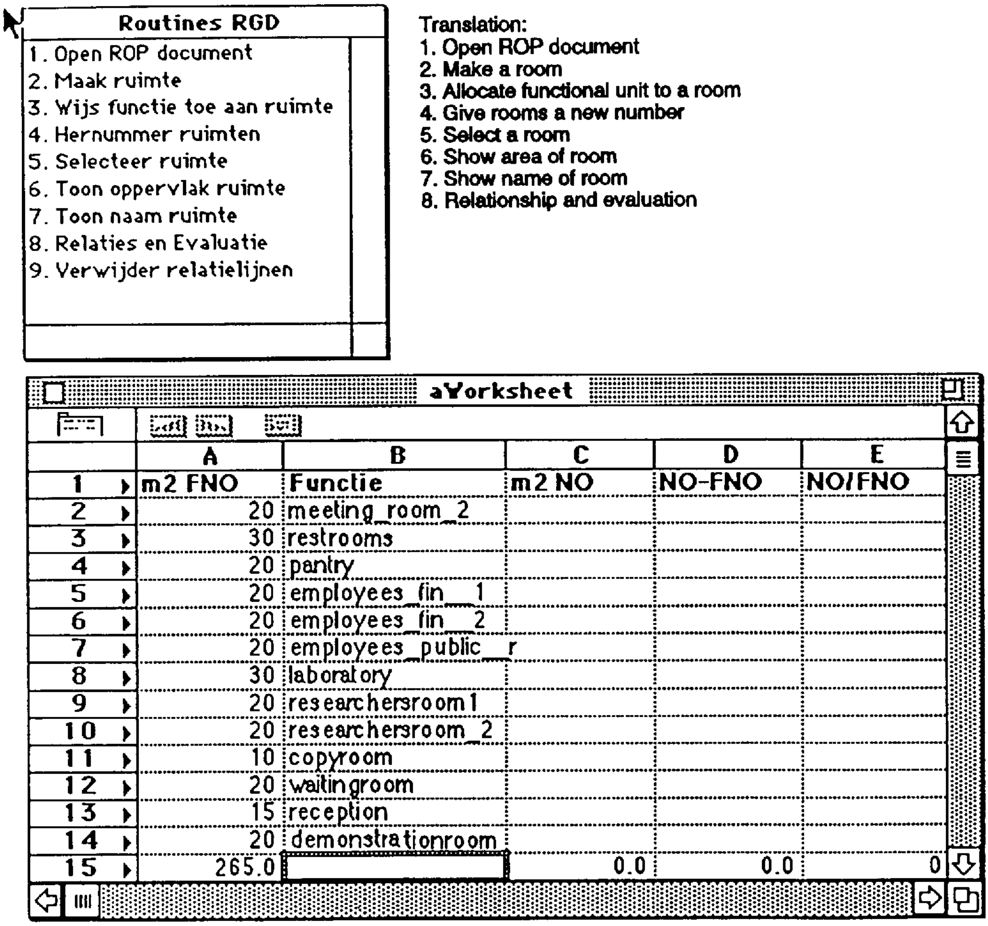
Figure 2b. A TRI-matrix and TRI-graph with functional clusters

In the ROP-CAD module, the 'optimum' is also what a user thinks it is. For difficult situations, an experienced space planner often has very creative solutions. The ROP applications allow these creative moves, since there are no restrictions. The features of MiniCad™ allow the planner to change the structure of the building if one thinks a better layout can be constructed.

FEATURES OF ROP-TRI

1. Possibility to import TEXT information, e.g. out of a spreadsheet
2. Inserting information directly in the matrix
3. "Clustering" by picking up the rows
4. Export possibility as TEXT or for MiniCad ™

Figure 2c. General features of ROP-TRI



	A	B	C	D	E
1	m2 FNO	Functie	m2 NO	NO-FNO	NO/FNO
2	20	meeting_room_2			
3	30	restrooms			
4	20	pantry			
5	20	employees_fin__1			
6	20	employees_fin__2			
7	20	employees_public__r			
8	30	laboratory			
9	20	researchersroom1			
10	20	researchersroom_2			
11	10	copyroom			
12	20	waitingroom			
13	15	reception			
14	20	demonstrationroom			
15	265.0		0.0	0.0	0

Figure 3a. ROP-CAD connection with routines and spreadsheet

3. ROP in Practice: A Real-World Case

A general overview of the actions supported by ROP is useful, but even more interesting is to see how such an application actually works. As a part of a post-graduate research project, projects were analyzed to see how ROP had been used in actual situations. In this paper the results of one case study will be discussed. The application ROP was used as an experiment in a real-world project for a design for a courthouse. It was possible to attend (as an observer) the meetings in which ROP was used. During observation and in interviews with members of project groups, activities were recorded, information input and output of every action was analyzed, and criteria used to control the activities were explored. This was done to make predictions about possible decision processes in which ROP could operate. On the other hand this benefits the development of ROP, because special demands coming out of the actual decision processes were revealed.

In the following, we will show how ROP can be used and what kind of external information influences the decision-making. An example of a decision process concerning space planning will be given in a description of a project. Some generalizations have been made which bring it close to reality. The information is based on the observations of a real-world project.

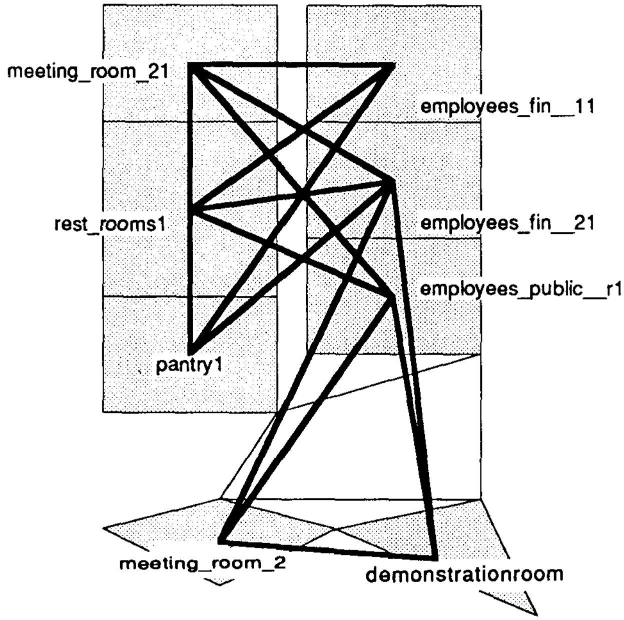


Figure 3b. Functional units are positioned in a floorplan

FEATURES OF ROP-CAD
1. Possibility to import ROP-TRI information
2. Assigning functional units to 'rooms' in a drawing
3. Construction new 'rooms' out of the spreadsheet
4. The spreadsheet shows space assigment: demanded space actually assigned space, and the difference between both
5. Evaluation features:
   - Presenting relationship lines in drawing
   - Exporting information back to ROP-TRI

Figure 3c. General features of ROP-CAD

3.1. DEVELOPING AND TESTING THE STRUCTURE OF A DESIGN FOR A COURTHOUSE

3.1.1. *Background information: the status of the project.* ROP was tested in a project for the design of a new building. Before ROP was actually used, some actions were already undertaken. A location had been chosen, and an architect had been selected. In the total procedure of the public building authority, the project can be situated partly in the definition stage and partly in the design stage. Participants in the project team included the architect, representatives of the GBA and the Department of Justice, future users, and a security expert. In this part of the design process the members of this project team were the decision-makers. In this project, decisions had to be made about the structure of the new building. The architect had already developed some structural sketches from a preliminary design.

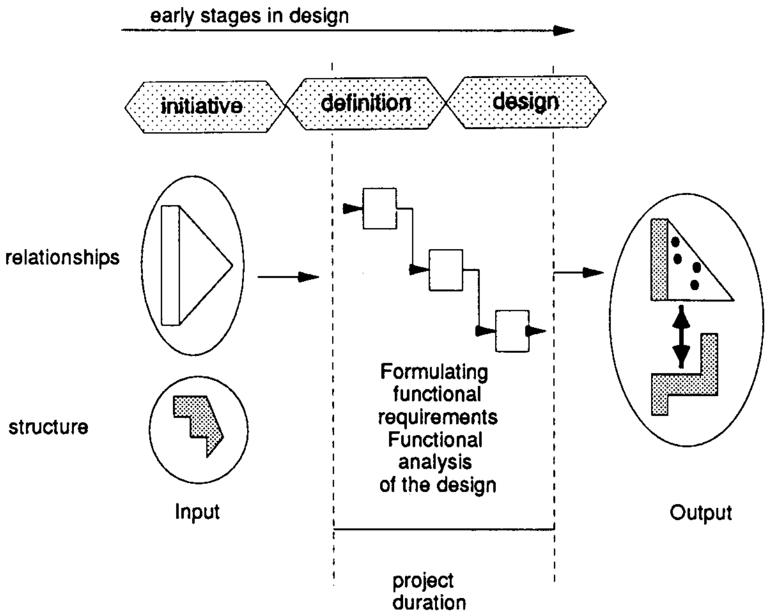


Figure 4. Situating the case

3.1.2. *The aim of this part of the design process.* In this part of the design process, a sketch design had to be developed. ROP was used in two kinds of actions. First, functional requirements had to be specified more precisely. There had been some changes in the organizational structure, so the relationships would have to be updated. Secondly, the developed structure of the design would have to be tested. As a result, more insight should be gained in the potential of the building structure for the functional units.

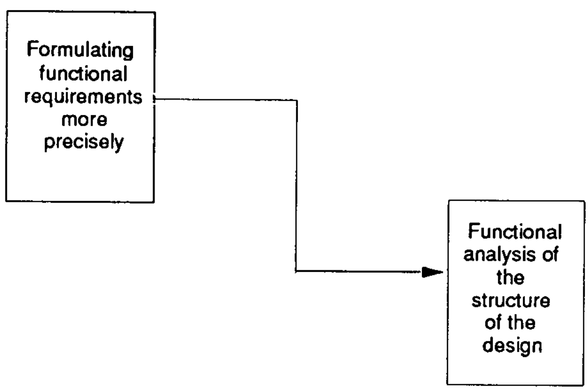


Figure 5. Two general stages in the project

3.1.3. *Stage 1: Formulating functional requirements.* In this stage of the project, three activities are identified. The building was planned to accommodate two organizations. There were thus two different briefs, describing on paper the functional units and the relationships between these units. This paper information had to be translated to be useful for ROP. The relationships that were mentioned in the briefs needed to be evaluated and updated to reflect the organizational change. During a meeting of the project team, a ROP-TRI relationship matrix was used to determine which relationships were still valid and which should be enhanced. The user group was able to identify the actual situation, and the security expert pointed out the unwanted ones.

After reaching agreement about the relationships, one could start to group the functional units. The designer took the ROP-TRI document back to his office. There he optimized the matrix from his point of view. He discovered some contradictions; he also found some situations that are difficult to realize when all relationships should be maximized. At this point, the relationships were reviewed again by the project team. The designer used the matrix to point out the expected problems. The clusters were also evaluated by the project team from their point of view. An important change was required by the decision that the two organizations should have an integrated accommodation. This led, for example, to the request that the conference rooms of the two organizations should be located near each other. New relations were identified and other clusters were formed. ROP-TRI was the tool that visualized the consequences of these decisions.

There also appeared to be some contradictions in demand. A secretary had a strong relationship with her boss, and an unwanted relationship with the main courtroom. Her boss also had a strong relationship with this courtroom. This situation is very difficult to deal with. Therefore the architect asked the members of the project team to think about how this unwanted relationship should be reflected in the accommodation. At the end of this activity, functional groups were constructed. These were represented in the relationship matrix and graph of ROP-TRI.

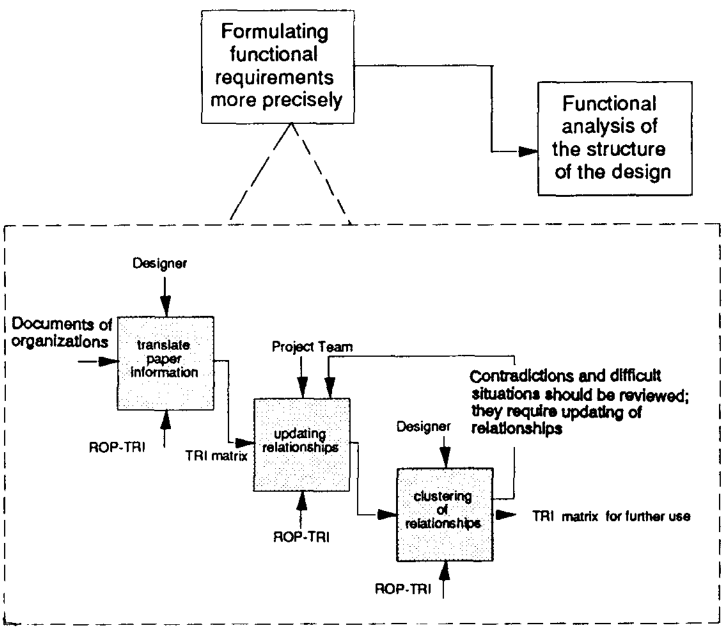


Figure 6. Activities to specify functional demands more precisely

3.1.4. *Functional analysis of the structure of the design.* In this stage two activities were identified. First, the functional units were positioned in the drawing. A computer drawing of the structure of the design was available. It was no problem to import the information into

MiniCad™. The ROP-CAD commands were activated, and the designer started to place the functional units in the drawing. He developed three alternative layouts. In doing this he also made minor changes in the structure to fit spatial requirements. The principal group also asked for an exercise whereby a certain part of the building could be tested for flexibility in regard to different kinds of functional units. Consequences for the space use that was actually assigned to a unit was recorded in the spreadsheet. In the second activity, the alternative layouts were discussed during a meeting of the project team. The designer had taken the ROP-CAD document, so that minor changes could be introduced on the spot. The consequences could be seen immediately and taken into account in the decisions that had to be made. In this process, external information was important to the decision-making. Personal opinions influenced the construction of the layout. In fact, one can say that this kind of decision-making is more or less intuitive.

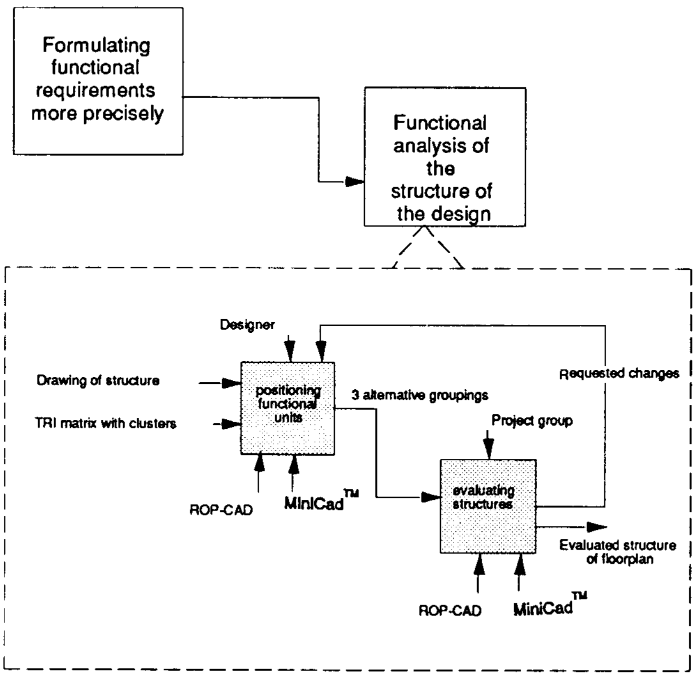


Figure 7. Activities to test and develop the structure

3.1.5. *Results of the project.* The proposed structure of the building was thoroughly evaluated in regard to the possibility of granting the requests for proximity of functional units. Also, the structure was tested on the space ratio. This means that the structure was looked at to see if it created lots of space that was not suitable for use or if the rooms for the individual functions were much too large. If this were the case, the building would be expensive. In this part of the design process, one can change such a structure very easily so that the space ratio will be better. The functional requirements toward the building were elaborated. But these requirements change over time. To be sure to adapt the accommodation according to the users' wishes, these changes should be monitored carefully. ROP can be used in subsequent stages, whenever the design is supposed to be tested in regard to its functional space use. However, this relationship matrix should also be updated according to expected changes in future functional use.

4. Discussion

Performance aspects derived from the internal functioning of ROP contribute to decision-making in real space-planning projects in an important way. Therefore it is important to distinguish these internal performance aspects. These include the following: (i) all the information that is imported in the two modules of the application is usually visible in the module for the user, (ii) the two modules follow a procedure that is common for space planning and can be followed easily, (iii) the user of the program keeps full control of the actions that are performed, (iv) both modules offer features to change the relationship matrix or a layout plan in regard to details, (v) several features are offered for evaluating the realized spatial layout. When these five performance aspects are translated to external conditions, decision-making in space-planning projects can be supported from two viewpoints. One can look at the kind of space-planning project where ROP performs best. Moreover, you can also look at managerial aspects of a space-planning procedure that are supported by ROP.

In regard to the kind of space-planning problem, ROP operates excellently where extraordinary organizations and buildings should be matched. ROP has no trouble assigning functional units to 'rooms' with strange shapes. There are also no restrictions on the kind of functional units that can be handled. ROP can assign office units to rooms, but it also performs well in a space-planning project for a hospital. One of the advantages of the application is that the user of the program remains in full control. So, in situations that are not common, unusual optimization actions can be performed.

As mentioned above, ROP supports decision-making from a managerial point of view. First, ROP can support decision-making in the early stages of a design process. At that point, the knowledge of the consequences of choices is limited. However, these choices may have an impact that is expensive or undesirable. This can also be said about the early stages in which decisions on space planning are made. ROP, on the other hand, needs little information about the building and potential users to determine whether a certain building layout will have a good ratio for space use. ROP allows parts of a design to be tested without putting much effort into gathering uncertain information; that information can change dramatically during the design stages. A principal can evaluate the first sketch alternatives on space budget without much effort.

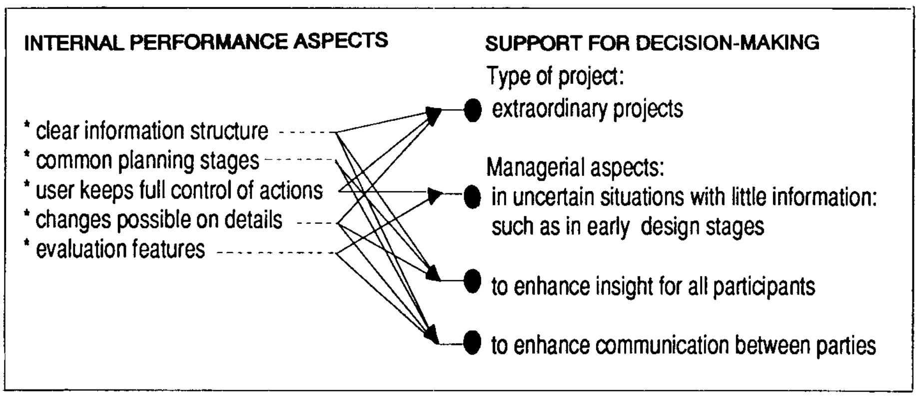


Figure 8. Internal performance aspects connected to decision-making

Furthermore, ROP offers tools to transform functional requirements into spatial layouts based on the criterion of physical proximity. People who formulate the functional relationships can see this transformation in stages through ROP-TRI and ROP-CAD. They can also intervene in the separate stages if they think the design is heading in the wrong direction. People involved in such a process who have no architectural background can more easily follow how their functional demands are transformed in an actual floorplan. It can be argued that ROP enhances insight. Thus, ROP can make an important contribution to the goal that principals and potential users are supposed to have more influence in the design of their accommodation. In this way, ROP can support quality, in the sense of better fit between primary processes and new accommodation. Last but not least, the process of developing a new accommodation for a governmental agency is a matter of communication and negotiation between all kinds of parties, e.g. working units of the GBA, members of governmental departments, designers, and users. ROP acts as communication medium between parties. In the stages where the functional demands should be defined, the ROP-TRI tool can be used to point out contradictions in the demands when possible options are considered. These contradictions can be easily illustrated in the relationship matrix. This is also true for the ROP-CAD module. A space planner can easily change a layout of a floorplan on small details, according to the wishes of others, and then show them the consequences immediately.

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