COMPUTATIONAL TOOL SUPPORT OF
OPEN-BUILDING DESIGN

A THESIS
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ABSTRACT

THESIS : Computational Tools in Support of Open Building Design

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The thesis explores the possible use of parametric object definitions during capacity analysis to support Open Building design processes.

The study proposes that design criteria regarding possible size, position and relation of design elements can be formulated and modeled parametrically. Then developed parametric data can be used as library objects during the exploration of dwelling unit layout alternatives. Parametric models, holding explicit design information can be shared, modified and re-used in different design cases.
The process and criteria used in the study are based on S.A.R. (Stichting Architecten Research) methods described in the study, “Variations - The Systematic Design of Supports” focused particularly on residential building types. Parallel to the S.A.R methods, the study focuses on the spatial capacity analysis between a floor plate and a number of alternative dwelling unit layout arrangements. Other capacity analyses such as structural, daylight or thermal performances can be formulated and studied in a similar way, but are not included in this study.

GDL (Geometric Description Language), a programming medium for ArchiCAD software, is used for the production of parametric models. The Keyenburg housing project designed by Dutch architect Frans Van Der Werf is taken as a base-building model to demonstrate the development and the use of parametric models.

Keywords: Open Building, capacity analysis, parametric objects, design constraints, GDL (Geometric Description Language)
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CHAPTER 1 - INTRODUCTION

Buildings integrate a number of ready to use products as sub-systems (partition walls, floors, piping, HVAC systems) developed by different parties. Compatibility, customization of products and coordination among participants are important design objectives. It is expected from the design of a building to provide a compatible and sufficiently adaptable environment that different users or user groups can select their preferred systems and arrange their spaces in their own way suiting their preferences and budgets.

Open Building is a design theory and method which leads to a number of research questions, particularly focused on the development of methods and practices aiming to provide variety in a built context through distribution of design control among design participants.
1.1 Open Building

Open Building is the term used to indicate a number of related ideas about the making of environment. These ideas are generally formed around an understanding of the built environment as the product of an continues design process in which decisions are made at various environmental levels such as city structure, tissue level, building and fit-out levels. Different parties operate and make decisions on different levels. (Habraken, 1998) (Figure 1.1)

Figure 1.1 - Different levels controlled by different parties. (based on the illustration, pg. 6 , Kendall, Teicher, 2000)
Open Building recognizes that, generally speaking, the need for change at lower levels occurs faster and more frequently than change at higher levels. Choices made at higher levels influence the decisions at lower levels. That is, a change in the street pattern will force a change to the buildings; a change of a building (e.g. relocation of the elevator) will force the interior layout to adjust accordingly. But the reverse is not the case. This kind of behavior describes an environmental “dependency hierarchy”.

Understanding these dependency relationships is important to those acting in the built environment because these dependencies among physical systems create dependency relations between the parties in control of the environmental systems at the different levels. That is, the urban designer sets the framework or stage to be followed or filled-in by the architect, and so on.

1.2 Base-Building / Fit-out

In an Open building design, it is conventional to distinguish between a “base-building” and the “fit-out”. The former is the more permanent parts of the building. By definition, the
base building is the part of the whole about which individual occupants cannot make autonomous decisions - it is the shared infrastructure. This consists usually of the building structure, the enclosure, the public circulation spaces and the main mechanical systems and installation pathways. Fit-out represents the more changeable parts, such as non-load bearing walls inside each tenant space and the mechanical systems specifically needed to support occupancy of each autonomous tenant space. (Figure 1.2)

Figure 1.2 - Base building and fit-out are recognized as two separate levels. Base building, a more permanent part of a building, is a context for a variety of fit-out units. (Habraken, 2001)
A dependency relation exists between these two configurations: Fit-out can change without forcing changes to the base building; but a change at the base building level forces the adjustment of the fit-out. This means that the base building is at a higher level.

Because of this dependency relation, the arrangement of base building elements (walls, floors, staircases) has a great deal to do with the variety of possible layout solutions at fit-out level. Capacity analysis is a method to study the relationship between two levels with such dependencies. It can be defined as a process to evaluate and determine a variety of reasonable fit-out level configurations that a base building can accommodate.

1.3 Systematic evaluation

A good base building is one that can accommodate a number of possible layout alternatives at the fit-out level according to agreed upon criteria for the evaluation of the fit-out arrangements. Through capacity analysis, alternative layout solutions are explored and compared to
evaluate the value of a base building design proposal. (Habraken, Boekholt, 1976)

"Zoning" is used as a tool to set a framework to place and relate spaces during the exploration of layout alternatives. Zones are classified into different types based on their location on the floor plan. Spaces are located on specific parts of a zone system based on set of conventions. (Figure 1.3)

Figure 1.3  α, αβ, β, αγ are zones on the floor plan. "Zoning" is a framework to place and relate design elements. (Habraken, Boekholt, 1976).
During capacity analysis, different sizes and positions of spaces are tested to explore alternative floor layouts. Based on the comparison of developed layouts with predefined criteria, design elements (parts of base-building, zones, spaces and fit-out components) are modified. The process of exploration and evaluation of the layout alternatives continues until a satisfactory number of layout variations are realized; that is, until agreement is reached among the parties involved.

Spaces are positioned relative to zones based on a set of conventions. Conventions represent standards, preferences or requirements about location, dimension and the relation of spaces. Examples are location relative to the facade (natural light or access to balconies or the ground; adjacency to base building mechanical installations, etc. Type and number of alternative layouts are influenced by the decisions on standards about spaces. To evaluate the capacity of a base building design proposal, base-building and fit-out level elements are distinguished. All types of design elements and their standards (parts of a base building, spaces, and fit-out components) are described.
In order to be able to use described data in a systematic process, the data needs to be explicit. One example is the knowledge that a space with a certain function is located on a specific part of a zone system. Since information about design elements is well-defined and explicit, it should be possible to formulate it in a computational form. It is on this latter possibility that this thesis is focused.

1.4 Thesis organization

The thesis is organized in five chapters. The first chapter introduces Open Building and the idea of capacity analysis as a method to evaluate base-building design proposals. In the second chapter, the idea that standards about size, position and the relation of design elements can be modeled in a parametric object form is introduced and related to Open Building design methods. The third chapter demonstrates the development of parametric components. Parts of a base-building, spaces and fit-out components are described and modeled in a parametric object form. The fourth chapter exercises the use of predefined parametric objects to develop
and compare alternative floor layouts during capacity analysis. The last chapter summarizes the study.
A variety of CAD systems are being used in different stages of both architectural design and construction. A great deal of important digital information is processed and shared among design participants. The way to describe design knowledge in a computational form is important to provide an effective medium for different purposes.

Typically, in an earlier generation of CAD systems library objects were represented with geometric information and used mostly for drafting and visualization purposes. There has been a direction in current CAD systems that digital data contains a number of kinds of design information in addition to its geometrical representation. In this way, computational data with design knowledge can be used in the organization and generation of a design.
2.1 Parametric library objects

Most CAD systems use object libraries to construct a virtual model. Library objects can be basic geometric elements such as lines, arcs, rectangles or they can be building components such as stairs, slabs, walls in both 2d and 3d representations. Typically, users select predefined library objects from a toolbar and assemble them to construct a design. (Gross, 1990) Library objects are usually represented in a parametric form. Parameters are lists of properties used to represent objects’ characteristics. Both numerical (length, height, volume) and non-numerical (type, material, color) can be set as parameters. Each parameter has a value, that is, a variable to set. (e.g. color parameter can have blue, white and red parameter values) During layout stage, library object is modified by changing parameter’s values.

In most of CAD systems, a certain type of object is represented with a specific list of predetermined parameters. For example, a cube object can represented with its length, width, height, material parameters. Different
CAD systems represent library objects with different list of parameters. Parameters are fixed for each system and objects can be modified by changing parameters values. This fixation limits the ways to describe and use a parametric object. Several CAD systems (ArchiCAD, Autodesk Revit) provide an associated programming environment allowing the user to construct custom parametric components. Different from conventional use of library objects with fixed list of attributes, parameters can be described and controlled through coding by the user during the design process.

2.2 Representing sets of alternatives

In modeling a custom parametric object, a model is identified with its number of features such as size, material, color etc. Identified features are represented with a list of parameters. Design decisions on parameters and parameter values are described by constraint definitions. Basically, in a parametric model, constraints are the statements specify acceptable values for parameters. At Figure 2.1 sizes of a
Figure 2.1 - Number of constraint conditions on length and width variables of a room (Mitchell, 1977)
room are represented with two parameters: length and width. Numbers of constraint conditions (maximum, minimum values equality, inequality relationships) are described on width and length parameters of a room. (Mitchell, 1977) As different constraints allow different values for width and length values, each condition describes a different region of alternative room sizes. Additional parameters such as height, color or volume can be added and new constraints can be described on added parameters. In this way, explicit design knowledge (preferences, requirements, specifications etc.) about a modeled object can be represented as sets of constraints on a described list of object’s features. (Gross, 1986) Developed parametric object with sets of constraints on parameters values allows user to select within a controlled range of choices.

2.3 Formulating explicit criteria

Capacity analysis evaluates base-building potential to accommodate alternative floor layouts. In order to explore and evaluate layout alternatives in a systematic process, design data (type, position, size, relation) about all kinds of elements (parts of a base building, spaces, fit-
out components) used in the analysis need to be described and documented explicitly.

It is possible to model explicit design knowledge in a parametric object form. Described design information, standards, requirements and preferences about the OB design elements can be formulated in a form of parameters and constraint definitions. Modeled objects with explicit design information can be used during capacity analysis to explore of alternative floor layouts. This is explained in the next chapters in more detail.
Chapter Three demonstrates the development of design elements in a parametric object form. The study uses GDL (Geometric Description Language) for the construction of parametric objects. GDL is ArchiCAD’s associated programming medium developed for the production of customized library objects. GDL uses a scripting language to model objects. In GDL, properties of modeled objects are represented as a list of numerical and non-numerical parameters. Objects’ geometry, relations on parameters and parameters values are described through coding.

The study and development of standards about spaces and fit-out components and their use in a capacity analysis are based on S.A.R.¹ (Stichting Architecten Research) methods. The Keyenburg project, built in Rotterdam in 1984 and designed by Dutch architect Frans Van Der Werf, is taken as a base-building model. (Kendall, Teicher, 2000)
3.1 Keyenburg project

The Keyenburg project is one of the early pilot projects designed and constructed based on SAR methods. (Figure 3.1) During the design of the project, base-building and fit-out are recognized as two separate levels. The base building is designed according to a design process considering potential variety of floor layouts at the fit-out level.

![Keyenburg housing project, view of an inner courtyard](image)

Figure 3.1 - Keyenburg housing project, view of an inner courtyard (Bosma, 2001)

After the completion of base-building construction, individual dwelling unit sizes were determined, based on different user requirements. Then, each unit was designed in detail, with the participation of both architect and the future resident.
3.2 Zones and grids

In an open building design process, the position, size and relation of spaces are described in relation to zones as described earlier. In the Keyenburg project, five different zones are recognized: alpha zone, beta zone, alpha-beta margin, gamma zone and delta zone. (Figure 3.2)

The zone adjacent to a facade is an alpha zone. A beta zone is an inner zone has no direct relationship with a facade. Gamma and delta are external zones. Spaces are placed in a zoning according to certain conventions. For example space with a bedroom function locates on the alpha zone next to facade to get daylight. Bathroom function requires no
direct connection to outside and usually locate on beta zones. Alpha-beta margin is the area between alpha and beta zones. Design elements which are located on either alpha or beta zones can overlap on alpha-beta margin.

In a GDL model, edges separating each zone are formulated as parallel lines. zalp, zbet, zmar² parameters are set for depth of each zone. (Figure 3.3) The relative distance between each horizontal line represents depth of an associated zone. Dimensions zalp = 300cm (10ft), zbet = 120cm (4ft) and zmar = 180cm (6ft) are assigned as default values for each depth parameter. Depths of δ and γ zones are taken as a fixed values as 150cm (5ft).

! 3d script
! Zone system

lin_ 0,0,0,thor,0,0
ADDy zalp
lin_ 0,0,0,thor,0,0
ADDy zmar
lin_ 0,0,0,thor,0,0
ADDy zbet
lin_ 0,0,0,thor,0,0
ADDy zmar
lin_ 0,0,0,thor,0,0
ADDy zalp
lin_ 0,0,0,thor,0,0

Figure 3.3 - Depth of each zone and margin is represented with a separate parameter.
Similar to zones, grids represent a guideline system where design elements (such as bedrooms, kitchens...) can be locates based on a set of rules. Grids are described as lines in both horizontal and vertical directions on the plan. Dimensions of a grid system are represented with two parameters $bn_1$, $bn_2$. 10cm (4 inches) and 20cm (8 inches); grid size used in the original design are assigned as default values. (Figure 3.4)

![Diagram of a grid system with parameters $bn_1$ and $bn_2$.]

(Figure 3.4) - 20cm (8 inches) x 30cm (12 inches) band grid.

This zone-grid model allows the user to control the depth of alpha, beta and alpha-beta margins and alternative band grids can be arranged through modifying $bn_1$, $bn_2$ parameter values.
3.3 Base-building

The idea is to model the base building in a parametric object form considering its repeating pattern. The base building consists of divisions with the same bay size of 450cm. (15ft) Load bearing walls with openings, vertical mechanical system stacks, slab, beams occurs in each division and are recognized as parts of a base building model. (Figure 3.5) Primary parameters proposed to be modified during capacity analysis are width of a single bay, number of bays and position of a vertical mechanical systems stack. They are represented with nbay, wbay and shor/sver parameters. Default values 450cm (15ft) for width of a bay, 2 for number of bays and 300cm (10ft)/510cm (17ft) are assigned for each parameter.

By changing the number of bays (nbay), a user is allowed to work on a number of divisions at the same time to explore different unit subdivisions and compare the resulting layout alternatives on the same plan interactively. The size of a bay and position of vertical stack can be changed to any dimension at increments of 30cm (1ft), the size of the band grid used in the original design.
Figure 3.5 – axonometric view of parts of a base building
3.4 Spaces and Functions

Spaces for functions associated with dwelling (bathroom, kitchen, bedroom, etc) are used to explore alternative layout arrangements on the dwelling unit floor plan. Spaces are described with a number of its features: type, kind of function it accommodates, its position relative to the “zoning” and its relation to other spaces.

In the CAD model, the geometry of a space is represented as a 2d rectangle.

! 2d script
! Space

RECT2 0, 0, width, length

Based on the type of activity a space is expected to accommodate, the SAR method classifies spaces into three groups: special purpose spaces, general-purpose spaces and service spaces. The “type” parameter is created with its parameter values: special purpose space, general-purpose space and service space. Each type of space can accommodate certain functions. There are six different functions selected for this study. They are living room, bedroom, kitchen,
storage, bathroom and entrance. Functions are also sub-categorized according to their size and usage.

<table>
<thead>
<tr>
<th>L</th>
<th>living room</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>L without dining function</td>
</tr>
<tr>
<td>L2</td>
<td>L with dining function</td>
</tr>
<tr>
<td>B</td>
<td>bedroom</td>
</tr>
<tr>
<td>B1</td>
<td>one person bedroom</td>
</tr>
<tr>
<td>B2</td>
<td>two person bedroom</td>
</tr>
<tr>
<td>B3</td>
<td>master bedroom</td>
</tr>
<tr>
<td>K</td>
<td>kitchen</td>
</tr>
<tr>
<td>K1</td>
<td>kitchen for cooking only</td>
</tr>
<tr>
<td>K2</td>
<td>eat-in kitchen</td>
</tr>
<tr>
<td>b</td>
<td>bathroom</td>
</tr>
<tr>
<td>E</td>
<td>entrance</td>
</tr>
</tbody>
</table>

A “function” parameter is created. The variables of a function parameter are dependent on a choice of a type of space. Special purpose space accommodates bedroom and kitchen functions. (B1, B2, B3, K1, K2) Living room (L1, L2) is housed by a general purpose space and bathroom, entrance functions (b, E) are accommodated by service spaces. If a special purpose space is selected as a type of space from the type parameter, variables for function parameter becomes automatically B1, B2, B3, K1 and K2.

IF type = 'special purpose' THEN
VALUES ‘fnct’ ‘B1’,’B2’,’K1’,’K2’
It is possible to analyze maximum and minimum dimensions of a space with a specified function. (Figure 3.6) Layout components can be placed and manipulated on each function and critical sizes of a function and alternative layout configurations can be explored. For example, minimum width size for two person bedroom function is documented as 240cm (8ft).

Maximum and minimum dimension of a space is determined by the constraints $w_{max}$, $w_{min}$ and $l_{max}$, $l_{min}$. They describe the ranges of allowable values for the sizes of a space. Unit is the parameter representing the amount increment between minimum and maximum values while changing size of a space during layout stage.

\[
\text{Unit} = 30 \\
\text{VALUES "width" RANGE } [w_{min}, w_{max}] \text{ STEP unit, unit} \\
\text{VALUES "legth" RANGE } [l_{min}, l_{max}] \text{ STEP unit, unit}
\]

Dimensions provided by the analysis are assigned to the width and length parameters of each function as default values. Depending on the selected type of function, a parametric object recognizes related max and minimum values.
Figure 3.6 – The analysis provides information about different sizes and possible layout arrangements for special purpose spaces. (Habraken, Boekholt, 1976)
IF funt = 'K1' THEN wmax = 330  
wmin = 150

For the location information of a space, a “position” parameter is created. It is text information that notifies a user about the placement of functions during a layout stage of a design. Two types of position information are entered for each type of function. First is the function’s relative position to the zone system; second is the function’s relative position to other types of functions or design elements. For example;

<table>
<thead>
<tr>
<th>type</th>
<th>service space</th>
</tr>
</thead>
<tbody>
<tr>
<td>function</td>
<td>Bathroom function</td>
</tr>
<tr>
<td>position 1</td>
<td>located in the beta zone and alpha / beta margin</td>
</tr>
<tr>
<td>position 2</td>
<td>needs a direct relation to the vertical mechanical system stack</td>
</tr>
</tbody>
</table>

As a result, the developed parametric objects hold design knowledge about all types of spaces, functions, their acceptable sizes and position information. Parametric objects are stretchable; that is, the size of each space with a specified function can be modified within a range of their allowable maximum and minimum values.
3.5 Fit-out components

Fit-out components are elements (furniture, partition walls, facade components) used to determine a space’s standards. To understand the standards about spaces (maximum, minimum sizes, layout alternatives), fit-out components are placed and reconfigured for each function to understand capacity of different sizes of functions and alternative layout arrangement. Thus, decisions about size, position and relation of fit-out components influence conventions about spaces to be used in a capacity analysis. In a GDL model, fit-out elements are modeled in three dimension. (Figure 3.7) Similar to spaces, each component has position, size (width, length height) and position attributes.

Figure 3.7 -- fit-out components
! Partition wall

width : 10cm (4 inches)
length : stretchable (increments of 10cm)
height : hwal
position : located on a 10cm band of a tartan grid
CHAPTER 4 – USE OF LIBRARY OBJECTS

Parts of a base building and a fit-out level’s elements have been distinguished. Standards related to type, size and position of space and fit-out level elements have been formulated in a parametric form. Parametric objects with design information are the library parts used by a designer to explore alternative layouts. Sets of standards built-in to parametric objects represent preferences, requirements about spaces and fit-out components and influences set the stage for the next phase in capacity analysis - the exploration of alternative layouts.

This following part of this chapter demonstrates the use of the developed parametric models in a capacity analysis.
4.1 Dwelling units

In Keyenburg’s base-building plan, two openings between each division allow variation in unit sizes. Divisions separating dwellings can be positioned in number of different ways. In this study, unit C is selected to explore alternative floor layouts. (Figure 4.1)

![Diagram showing floor plans A, B, C, and D.]

Figure 4.1 – Openings between each division allows variety in unit sizes.

In this part of the analysis, the floor plate is considered as a whole to explore alternative floor layouts for a specific program of a dwelling. The study requires that a standard dwelling requires functions: an entrance, a living room, a kitchen, 2 bedrooms (one of which is master bedroom) and a bathroom.
4.2 Analyzing a floor plate

The objective in the analysis is to explore possible locations of spaces with specified functions on the floor plan considering described program of spaces and their location information entered in their position parameters.

Developed parametric objects (spaces) are selected from ArchiCAD's toolbar and placed on each sector. Each function parametric object has the knowledge of its maximum and minimum sizes, its position information (relative to the zoning and relative to the other spaces). Built-in design data can be modified through coding. Library objects can be dragged, moved or resized on the ArchiCAD's layout window. Different alternative combinations of functions are tested by changing locations and dimensions of specified functions.
Initially, other than the base building structural elements the only element on the plan is a vertical mechanical systems stack. The default width of a bay is (wbay) 450cm (15ft). The location of this stack is represented with two parameters shor (horizontal coordinate) and sver (vertical coordinate). (Figure 4.2) The position of the stack can be changed through parameter values, and advantages and disadvantages of and various locations can be explored.

Figure 4.2 - selected unit plan.

In this study, the stack’s original location is taken for the further exploration.
In the first analysis step, α1 and α2 zones are analyzed. Searching for alternative layouts starts with placing L and E functions on α2 zone with their minimum widths (Figure 4.3). Living room is the largest single space in the dwelling and it can be located (facade) on the zone system in two locations, either in the α1 zone or α2 zone. Their minimum and maximum depths are recognized by stretching on each function on the plan.

![Diagram of dwelling layout](image)

**Figure 4.3** - E and L1 functions are placed on α2 zone.

Objects can be stretched on the plan within the maximum and a minimum constraint values coded in object before. After the placement L1 and E functions, the remaining space -
with 210cm (7ft) width can only accommodate either K2 or B1 functions.

In the next step (Figure 4.4), K2 is selected first and placed on α2 zone next to the entrance. Both required bedrooms are expected to be located at α1 zone. Since it is the required function, B3 is placed on the α1 zone. Minimum width for B1 function is 180cm (6ft). B2 requires 240cm (8ft) minimum width. The only possible combination of bedroom functions is B1+B3 at α1 zone.

![Diagram](image)

**Figure 4.4** - K2 is placed at α2 and B1+B3 is the only possible combination at α1 zone.
If we place B1 function at α2, it means the unit has two bedrooms already. The left room at α1 zone can be possible space to accommodate K2 function. K2 function, different from K1, has a dining unit and it requires to be located on the facade. Since minimum width size for K2 function is 210cm (7ft), the left room at α1 zone is not wide enough. Since the possibility to place K2 function on α1 zone is important to achieve variety of floor layouts, we decided to increases the size of a bay from 450 cm (15ft) to 480cm (16ft) by changing wbay parameters. (Figure 4.5)

Figure 4.5 - Bay size is increased to 480cm (16ft) to able to locate K2 function at α1 zone.
After changing bay size to 480cm (16ft), K2/B3 and B1/B3 function combinations are possible at α1 zone.

As a second phase, all functions are removed from layout window and L1 is placed at α1 zone. (Figure 4.6) Since two bedrooms are required in the program, B3 function, which requires the largest minimum width size of 270cm (9ft), can only be located at α2 zone next to the entrance. Similar to the previous test, K2 and B1 functions can be placed at the left room on the α2 zone.

Figure 4.6 - L1 is placed on α1, only location for B3 function is α2 zone.
B3 function is placed in its only possible location next to entrance and then K2 is placed on the left space at α2 zone. (Figure 4.7) Since the size of the bay has been increased earlier, it is possible to locate B1 function next to L1 function on α1 zone.

![Figure 4.7](image)

**Figure 4.7** - Increased bay size allow B1+L1 combination at α1 zone.

In the next step, locations of functions (K1,b) on beta zone are tested. (Figure 4.8) Technical constraints are important while locating bathroom and both kitchen functions (K1, K2) on the plan. The position of bathrooms and kitchens depend on the location of the vertical stack.
Bathrooms should be located next to vertical stack or along a wall close to it. The Kitchen function can locate almost anyplace on the zoning as long as there is a continuous wall to connect the kitchen piping to the vertical stack without a doorway interruption.

Figure 4.8 - possible locations of functions (b, K1) and their allowable sizes on β zone.

4.3 Alternative layouts

The process of developing alternative layouts is described in the following section. First, a described program of functions is placed and arranged in the “zoning”, in
consideration of their dimensional and positional standards. Possible locations of spaces and their allowable sizes are explored and the results documented in drawings. Since possible locations of functions in the zoning and their size ranges are known, layout alternatives can be developed by adjusting different sizes of functions in the zones and margins.

Four alternative layouts and configuration of functions are represented below in Figure 4.9 and 4.10. Based on the evaluation of proposed alternative floor layouts, the standards of design elements (parts of base-building, zones, standards about spaces and fit-out components) can be modified. For example, the depth (facade to facade dimension) or the position and size of parts of a base-building (e.g. pipe shafts, location of openings in structural walls, etc) can be modified, new parameters and constraint definitions can be added or existing ones can be modified on the standards of spaces and fit-out components. After preferred modifications are made, capacity analysis is repeated and exploration of layout alternatives continues until an optimal numbers of layouts are developed.
Figure 4.9 – Alternative floor layouts 1
Figure 4.10 - Alternative floor layouts 2
CHAPTER 5 – CONCLUSION

The study has two parts. In the first part, design elements (base building, spaces and fit-out components) have been described and formulated in a parametric object form. In the second stage, developed parametric objects have been used to explore alternative floor layouts. In doing this analysis, it was then shown how and why changes to the initial “test space” (base building) can be made.

Parametric objects holding design information about elements (size, position and relation) allows exploration of alternative floor layouts in an interactive way. Built-in design standards can be modified at any phase of the capacity analysis through coding. Based on the design objective, various other parameters can be described to develop model OB elements used in the capacity analysis.
In the decision making process, instead of starting from the beginning, a base building described with a list of parameters including design information can be taken as a starting point, to modify in successive stages and to then use again later, in a new project. This allows sharing and re-use of previous design experience. Parameters and sets of constraints as conventions can be shared and understood by different parties and can help the coordination and communication.

In an ArchiCAD environment, the link between layout operations and the set of conventions (size, position and relation) built into parametric objects are limited to snapping, stretching and text data. Future research can be the development of independent design tools handling specific OB design operations such as knowledge of dependency relations among levels or disturbed design control.
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NOTES

S.A.R. (Stichting Architecten Research) is a Dutch Research institution focused on the development of methods to analyze the capacity of a design considering variation in lower levels.

! variables

base building model

hbea  (height of a beam)
hsto  (story height)
hwal  (height of a wall)
lsta  (length of a vertical stack)
llb1  (length of load bearing wall 1)
llb2  (length of load bearing wall 2)
nbay  (number of bays)
thor  (total horizontal length of the model)
tver  (total vertical length of the model)
shor  (horizontal coordinate of a vertical stack)
sver  (vertical coordinate of a vertical stack)
wbay  (width of a bay)
wlbw  (width of a load bearing wall)
wsta  (length of a vertical stack)
zalp  (depth of an alpha zone)
zbet  (depth of a beta zone)
zmar  (depth of a alpha-beta margin)
Spaces

**type** (type of a space)

special purpose space
general purpose space
service space

**fnct** (function of a space)

K1,K2,B1,B2
L1,L2,E,b

**post** (position information)

relative to zone/grid system
relative to other spaces

lmax (maximum length)
lmin (minimum length)
unit (increment amount)
wmax (maximum width)
wmin (minimum width)

Fit-out components

**post** (position information)

relative to zone/grid system
relative to other components

! Band Grid
! 3d script

! Vertical lines

FOR m=1 TO nbay
FOR k=1 TO wbay/30
ADDx G1
LIN_ 0,0,0,0,tver,0
ADDx G2
LIN_ 0,0,0,0,tver,0
NEXT k
NEXT m

! Horizontal lines

FOR k=1 TO tver/30
ADDy G1
LIN_ 0,0,0,thor,0,0
ADDy G2
LIN_ 0,0,0,thor,0,0
NEXT k

! Base-building
! 3d script

! Load bearing elements
! Slab
! Vertical stack

!------------------------
!load bearing elements

! Walls

FOR k=1 TO nbay+1 ! first row
ADDx (wbay+30)*(k-1)
BLOCK wlbw,zalp,hwal
DEL 1
NEXT k
ADDy zalp+zmar ! second row

FOR k=1 TO nbay+1
ADDx (wbay+ wlbw)*(k-1)
BLOCK wlbw,zbet,hwal
DEL 1
NEXT k
ADDy zmar+zbet                                  ! third row

FOR k=1 TO nbay+1
ADDx (wbay+ wlbw)*(k-1)
BLOCK 30,zalp,hwal
DEL 1
NEXT k

DEL TOP

! beams

ADDz hwal
FOR k=1 TO nbay+1
ADDx (wbay+ wlbw)*(k-1)
BLOCK wlbw,tver,hbea
DEL 1
NEXT k

!------------------------

! Slab

ADDz -15
BLOCK thor,tver,15
DEL 1
ADDz hwal+hbea
DEL top

!------------------------

! vertical stack

ADDx 30
ADDy sver

FOR k=1 TO nbay/2
ADDx shor

CUTPOLY 4,
10,10,
10,lsta-10,
wsta-10,lsta-10,
wsta-10,10
BLOCK wsta,lsta,hwal+hbea
CUTEND

ADDx 2*(wbay-shor-60)+wlbw+wsta
CUTPOLY 4,
  10,10,
  10,lsta-10,
  wsta-10,lsta-10,
  wsta-10,10

BLOCK wsta,lsta,hwal+hbea
CUTEND

ADDx shor+wsta+wlbw

NEXT k
DEL top

Master script

tver = 2*zalp+zbet+2*zmar
thor = (wbay*nbay)+30*(nbay+1)

2d script

project2 3,270,2

Parameter script

VALUES "nbay" 2,4,6,8
VALUES "wsta" 60,90,120
VALUES "wsta" 60,90,120

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! Spaces
! 3d script

BLOCK A,B,0

! 2D Script
parameter script
VALUES 'type' "special purpose", "general purpose", "service"

IF type = 'special purpose' THEN
VALUES 'fnct' 'B1', 'B2', 'K1', 'K2'

IF type = 'general purpose' THEN
VALUES 'fnct' 'L1', 'L2'

IF type = 'service' THEN
VALUES 'fnct' 'E', 'b'

master script
Unit = 30
VALUES "width" RANGE [wmin, wmax] STEP unit, unit
VALUES "length" RANGE [lmin, lmax] STEP unit, unit
! Cabinet
! 3d script

CUTPOLY 4,
57,43,
57,47,
60,47,
60,43

BLOCK 60,90,200
CUTEND

! 2d script

project2 3,270,2

HOTSPOT2 0,90
HOTSPOT2 60,90

! Wall
! 3d script

PRISM 7,hsto,
0,0,
0,B,
A,B,
A,B-10,
10,B-10,
10,0,
0,0

! 2d script

project2 3,270,2

HOTSPOT2 0,0
HOTSPOT2 A,0
HOTSPOT2 A,B
HOTSPOT2 0,B
HOTSPOT2 0,B
! Bed component
! 3d script

    BLOCK A,B,45
    IF A > 90 THEN
    GOSUB 30
    ELSE
    GOSUB 20
    ENDIF

END!-----------

    20:! 
    ADDz 45
    ADDy 50
    LIN_ 0,0,0,A,0,0
    RETURN

    30:! 
    ADDz 45
    ADDy 50
    LIN_ 0,0,0,A,0,0
    ADDx A/2
    LIN_ 0,0,0,0,-50,0
    RETURN

! 2d script

    project2 3,270,2

    RECT2 0,0,A,B
    HOTSPOT2 0,0
    HOTSPOT2 A,0
    HOTSPOT2 A,B
    HOTSPOT2 0,B

Master script

    VALUES "A" 90,150
    VALUES "B" 210