Intercultural Understanding, 2013, volume 3, pages 49-56

FPL_Gen: A Computational Tool for Generating Flexible Plan Layouts

Belinda Torus[1] and Sinan Mert Şener[2]

[1]*Department of Architecture, Bahcesehir University, Istanbul, Turkey*
[2] *Department of Architecture, Istanbul Technical University, Istanbul, Turkey*

Corresponding author: Belinda Torus, Department of Architecture, Bahcesehir University, Ciragan Cad. 4-6, Istanbul, Turkey
E-mail: belindatorus@gmail.com

Keywords: Mass housing**.** Computational design."Open Building". Flexibility. Mass customization.

Abstract: In the field of housing construction the unique and tailor-made design and manufacturing has left its place to uniformity and repetition with mass housing. Mass manufacturing and individual design -the two positive aspects in design and production- come together in mass customization. Mass customized housing projects have great potential and it is easier now to design computer tools with promising features. Different approaches can be implemented in these tools and defined relationships and design decisions can be computerized in order to obtain various solutions. In this paper, a design method and a computational tool for generating mass customized housing plan layouts with "Open Building" approach is detailed in which design flexibility and mass customization have been taken into consideration for basic design decisions.

1. Introduction

Mass housing is a widely applied solution to create large number of dwellings in a single project. Even though the idea of building multiple houses as one project is quite ancient, especially after Second World War, rapid growth of urban population the new housing projects emerged all around the world. While in single house an individual habitant is consulted, in mass housing it is mostly designed for average habitant and therefore a generic design is usually implemented. One of the most criticized outcomes of mass housing is generalization and repetition which give the appearance of uniformity.

There are researches and studies in computational design. Especially in housing, mass customization and shape grammars are used in the analysis of different grammars and reproduction of the houses within the same grammar as well as new housing projects (Colakoglu (2001), Duarte (2001), etc.). Shape-grammars and rule-based design also offer a strong foundation for developing computational tools. Computational thinking allows a more flexible solution in terms of generating a rage of various plan types. With the help of precedent studies and applications, a tool is designed and developed while flexibility and mass customization emerges as the very solutions for the criticism of the mass produced uniform houses.

1.1. HOUSING IN TURKEY

Similar mass housing projects can be seen in many countries. In Turkey TOKI[1] (MHDA - Mass Housing Development Administration) is the biggest house supplier constructing more than 500.000 houses for different income groups since 1984 [1]. The rapid growth in urban population in Turkey accompanied with the need of construction for new housing for this population. TOKI tried to solve the housing problem by building systematic housing blocks (mostly medium and high-rise apartment buildings). These mass produced houses solved the basic needs for habitants and improved the life quality of them through solid infrastructure. These apartment blocks are mostly designed by the repetition of a certain house type because of the need of rapid and economic construction.

These houses could not respond efficiently the needs of the households both in the scale of housing block and single house. The reason for this deficiency is the same or similar plan layouts which have been repeated in every floor. These plan layouts do not have the opportunity for change and adaptation according to the needs of household because of the restrictions of the structural system as well as the difficulty and expensiveness of changing or alternating technical systems and infrastructure such as cabling, plumbing, etc.

Alternative households need social support, and the differing needs of households will require new housing and living environment (Unsal Gülmez, 2008). For example, size and number of rooms in the houses in Istanbul is not changed according to the number of household. In short, there isn't any relationship between these two values, which leads us to the discussion of; how much the existing building stock complies the way of life and satisfy the changing needs of today's families.

Construction firms and especially TOKI is criticized of the uniformity of the housing plans and repetition. Considering all these cases, a tool - FPL_Gen - is suggested for generating flexible housing plan layout alternatives which resolves uniformity and repetition in mass housing apartment buildings in Turkey. A computational tool requires definite decision making and defined rules and relationships. So in this tool architectural knowledge and decisions are made based on the demographic and housing studies in Turkey. Flexibility and mass customization emerges as the concepts for accurate solutions and "open building" approach is used for realistic and implementable layouts.

2. Methodology

"Open Building" is a multidisciplinary approach applied in building design that supports building adaptability according to different requirements: in built environment, in production and construction methods, in the market of products and product technology and in the user's demand for the suitable place (Nikolic, 2011).

The origin of "Open Building" approach is based on Habraken's studies and the idea can be summarized as *"... when considering housing of the future, we should try to forecast what will happen, but try to make provision for what cannot be foreseen. The uncertainty of the future itself must be the basis on which present decisions are taken."* (1972, p.42). Kendal and Teicher stated that *"The broadest environmental trend leading professionals toward "Open Building" practice is the reemergence of a changeable and user-responsive infill (fit-out) level. Infill represents a relatively mutable part of the building. The infill may be determined or altered for each individual household or tenant without affecting the Support or base building, which is the building's shared infrastructure of spaces and built form. Infill is more durable and stationary than furniture or finishes, but less durable than the base building."* (2000, p. 4).

The support or base building level is the stable part of the building consisting of structure system as well as the infrastructure system. In other words a support structure is quite different from skeleton structure, but *"...a framework for a living and complex organism"* (Habraken, 1972, p.69). Corbusier suggested Domino house as a prototype for flexible mass housing solutions which has an open floor plan with thin reinforced concrete structure and a stairway (fig 1).

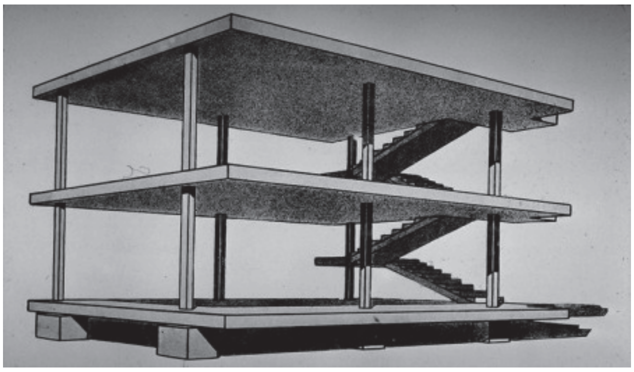

Fig 1. Corbusier's Domino House [2]

On the other hand "Open Building" approach suggests structure in relation with service spaces which is the basic permanent part of a building. *"Support is intended to accommodate and outlast infill changes, to persist largely independent of the individual occupants' choices, while accommodating changing life styles."* (Kendal & Teicher, 2000, p.33).

2.1. STRUCTURAL SYSTEM

In order to create a support, a structural system must be determined. Tunnel form construction system is selected because it is the most used construction method in housing projects in Turkey. TOKI and many other construction firms in Turkey used this construction system in apartment blocks because of its easy and rapid production. Also there are studies of its behavior under earthquakes (Balkaya & Kalkan, 2004).

Tunnel form is a construction technique where concrete is poured into two half-tunnel forms to shape load bearing walls (shear-walls) and floor slabs simultaneously on site. The process is repeated and generally in a 24-hour cycle per floor, apartment blocks can be rapidly built up. This industrialized modular construction and repetition make tunnel form construction system an attractive proposition for mass housing project usually medium to high-rise with repetitive elements or layouts.

As a modular system, tunnel form has construction limitations due to the size of the formworks and concrete. Even though special formworks can be designed, for cost and time efficiency, a certain degree of optimization is needed. Also in order to computerize the decision about construction method, basic decisions about sizes and size formulas must be clarified:

$Width_{min}$: 2.55 m.
$Width_{max}$: 5.85 m.
Width: 2.55+(0.30*n) (n_{max}:11) (1)

$Depth_{min}$: 5.00 m.
$Depth_{max}$: 12.50 m.
Depth: 5.00+(0.625*m) (m_{max}:12) (2)

$Height_{min}$: 2.30 m.
$Height_{max}$: 3.00 m. (3)

Number of floors may be between four, up to fifteen floors. The modular and repetitive use of tunnel formwork can be altered and in order to design various alternatives with different width and depth sizes.

2.2. SUPPORT

For support or base building, after selecting the structural method, some important main decisions is needed. In apartment blocks, the core consists of vertical circulation elements -staircases, elevators- and halls. Service spaces and especially plumbing and wet spaces are placed around the core. With this organization the durable frame -the support- will be the center part of the plan with the bearing walls which enables the infill to be planned freely and to be altered if needed (fig 2). Also with this organization, all the rooms will face outside.

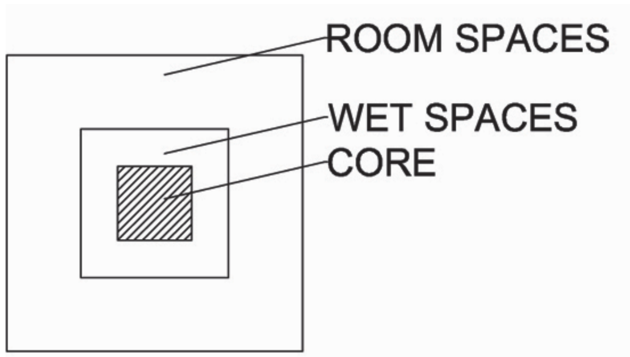

Fig 2. The spaces and interface of the prototype

2.3. CONCEPTS

The support idea as well as the "Open Building" approach welcomes two concepts in housing framework. Infill encourages flexibility and adaptability and it also promotes mass customization. It can be said that these concepts are strongly related with each other or at least some strong common points.

2.3.1. Flexibility and Adaptability

Yürekli (1983) divided flexibility which is emerged as a concept in architecture in two groups:

- design flexibility, depending on the stages of the production process of the building
- usage flexibility

In design flexibility, decisions about the planning and space organization (layout) are effective in the design and construction phase (Yürekli, 1983). In addition to Yürekli, Deniz (1999) suggested the notion of production flexibility -within the scope of the design flexibility- as another type of flexibility depending on the particular characteristics of the building and construction system. Designing flexible solutions for all users will increase the estimated cost therefore in flexible housing design, determination of the scope of flexibility will reduce the initial investment rates and enable future changes in the plan (Tatli, 2008).

Flexibility is promoted in this model by using a relatively flexible structural system or using a structural system in a more non-rigid way which can be classified under the topic of production flexibility. Tunnel-form systems, in this sense can be seen a rigid and modular system which are mostly selected to build repetitive spaces. The width and depth of the tunnel form can be altered based on the aforementioned formulas (1 and 2) and the spans and depths can be arranged by using different values of n and m consecutively. Although it will be a little bit less cost-efficient, the formworks can be altered and even a rigid modular structural system can be more flexible.

Adaptability on the other hand implies the ability to change if the need arises (Demchak, 2000). Re-partitioning a space or a partition means changing the spaces when fundamental living circumstances change.

2.3.2. Mass Customization

Mass housing attempts to satisfy the needs of the average household and tries to deal the problems of the users. Even for the average household, the number, income, background, education level, ambitions and living habits of the habitants may differ which are only some of the factors which affect the housing features. So a single type or some basic types cannot respond the need of an average household. Also in time the needs and circumstances may change which makes it even more difficult for mass housing to respond. At this point, instead of mass housing, a more individualized mass production is needed.

Customized mass housing can deal with the aforementioned problems better but even in mass customization the unpredictability of the future or change of needs must be taken into consideration. In addition a more flexible methodology can be used in order to be able to respond the unforeseen needs.

The mass production logic, which emerged with the development of the automotive industry at the beginning of 20th century, is based on rapid production for large quantities of same type of product for different users. Nowadays this logic is shifted to mass customization; a limited amount of mass production in order to fulfill specific consumer preferences for different types of users (Güngör, 2010). In the field of housing production and architecture, similar to many other areas, mass production took the place of unique and tailor-made design. In this sense, mass customization combines these two affirmative features and can be viewed as tailor-made mass production. Mass customization also promotes information technologies or vice versa; developing information technologies enables mass customized production.

With flexible structure and support design, the variations of each house or house type can be obtained even in the support level. The areas of the spaces, dimensions and spatial relations will have various possibilities and on infill level these possibilities and variations will be numerous.

3. Tool

With this tool (FPL-Gen), flexibility and mass-customization are sought and housing plan layouts are generated and projected with these concepts using tunnel-form structural system as constraint.

While developing the suggested tool, and generate plan layouts accordingly, the decisions are made, main elements and constraints are defined (for example, the size of the rooms, the size of the cores, the size of the bearing walls and their relations with each other etc. are all calculated) and embedded in the tool.

Apart from this knowledge and calculations, the main constraint of the prototype is the structural system. A hierarchical development of plan layouts are designed using the structural formulas as detailed above. There can be different forms for apartment blocks which can also be sought in the further phases of the study. But in order to focus on the generation of houses a rectangular block is selected as the main form.

3.1. PARAMETERS

The tool is designed to generate rectangular apartment blocks for different types of house units. One of the important features for the generation is the core which accommodates circulation areas, elevators and staircase. The sizes of the core as well as its relationships with the main rectangular form are both related to the size of the block and floor number.

The second step of the hierarchical generation is the house unit and the last step is the room itself. In order to generate this hierarchy; first, the core is placed and then structural system is projected. In these generations, the development of the spaces is processed as core, wet spaces and room spaces but only core and structural system is showed on the tool. Generated support is named as "base" which is the same on every floor of the block. With the dynamic use of the structural system, various numbers of bases can be produced with the same initial parameters.

There are also different types of house units according to the number of rooms and the type of kitchen. The bases with different sizes will give the opportunity to generate different types which can also be seen on each floor plan.

3.1.1 Basic Dimensions and Core

Basic dimensions for the apartment block and core is calculated for size limitations. The blocks are divided into four groups related with the number of floors. The core will consist of horizontal and vertical circulation elements and services and its size and position will depend on the size of the block and number of floors. It can be placed on the corner of the block, on the edge or near center (fig 3). In the blocks with more than 10 floors, it cannot be placed on the corner because it will cause instability for the mass.

The four groups based on number of floors and core positions are as below:

- 4 to 6 floors (corner, edge and center)
- 7 to 9 floors (corner, edge and center)
- 10 to 12 floors (edge and center)
- 13 to 15 floors (edge and center)

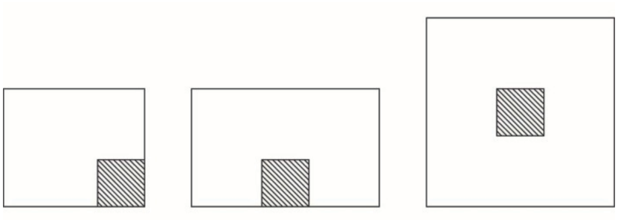

Fig 3. Places of the cores in main block form

The minimum and maximum values for the core and block are calculated in table 1 and-2. The size of the block is direct proportion to size of the core. When smaller block sizes are selected, sizes of the core will be closer to minimum values and when it is a larger block the core sizes will be larger.

Table 1. Core sizes (m.)

Floor Number	4…6			7…9			10…12		13…15	
	corner	edge	center	corner	edge	center	edge	center	edge	center
Min x	4,00	5,00	5,00	5,00	6,00	6,00	6,00	6,00	7,00	7,00
Max x	4,50	6,00	6,00	5,50	7,00	7,00	7,50	7,50	9,00	9,00
Min y	5,50	5,50	6,00	6,50	6,50	7,50	8,00	9,00	8,50	9,50
Max y	6,50	6,50	7,50	8,00	8,00	9,00	9,50	10,50	12,00	13,00

Table 2.Basic dimensions (m.)

Floor Number	4…6			7…9			10…12		13…15	
	corner	edge	center	corner	edge	center	edge	center	edge	center
Min x	11,50	15,00	15,00	12,50	16,00	16,00	21,00	21,00	22,00	22,00
Max x	17,00	31,00	31,00	18,00	32,00	32,00	32,50	32,50	34,00	34,00
Min y	13,00	13,00	16,00	14,00	14,00	17,50	14,00	24,00	16,00	24,50
Max y	19,00	19,00	32,50	20,50	20,50	34,00	22,00	35,50	23,00	38,00

3.1.2 Housing Units

There are four types of house units on the tool. These types are named based on the number of rooms (with one to four rooms) and the type of kitchen (open or separate kitchen).The new housing projects in Turkey mostly have one to four rooms and the inclination is towards to smaller houses. The house types are:

- 1+0 (with one room)
- 1+1 (with one living room and one room)
- 2+1 (with one living room and two rooms)
- 2+1+K (with one living room, two rooms and a kitchen)
- 3+1+K (with one living room, three rooms and a kitchen)

On smaller houses open kitchen is considered while for bigger houses a separate kitchen is taken into consideration. In (2+1) type both open kitchen and separate kitchen can be found. The areas of the spaces are calculated and minimum and maximum values are shown on table 3.

Table 3. Areas of the spaces and house types (m^2)

	1+0		1+1		2+1		2+1+K		3+1+K	
AREAS	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Sitting	13,5	32,5	13,5	18,5	16,0	23,0	16,0	23,0	18,5	27,5
Kitchen	5,0	10,0	5,0	6,3	5,5	7,5	6,5	10,0	6,5	12,0
Eating	4,0	10,0	4,0	6,3	4,5	7,5	4,5	7,5	5,0	8,8
Bathroom	4,0	8,3	4,0	8,3	4,0	8,3	4,0	8,3	4,0	8,3
Shower									2,5	3,5
WC					1,3	3,5	1,3	3,5	1,3	2,0
Room 1									6,5	12,6
Room 2					6,5	12,6	6,5	12,6	10,8	12,6
Master b.			12,5	15,0	12,5	15,0	12,5	15,0	12,5	15,0
TOTAL	26,5	60,8	39,0	54,3	50,3	77,4	51,3	79,9	67,6	102,2
CIRCULATION	6,6	18,2	9,8	16,3	12,6	23,2	12,8	24,0	16,9	35,8
TOTAL AREA	**33**	**79**	**49**	**71**	**63**	**101**	**64**	**104**	**84**	**138**

The problem at this point is not generating spaces within the limits but generating meaningful and useful spaces as flexible as possible. So not only the area but also the width and depth relationships of the spaces are also important and must be reviewed. In some cases the width and depth relationships of the spaces cannot be acceptable even though the area is in between acceptable values because these sizes are needed to be in direct proportion to each other. If the space is too narrow and the façade is limited, there will be basic planning problems and it will be less flexible. It will also have some basic planning problems when the span is too great and the depth is shorter. Also with partition walls these spaces can be divided and altered according to the relations.

After core, the structural walls will be calculated and assigned in the first place to generate the base. Partition walls will be assigned and housing units will be assigned separately for each floor.

3.1.3. Interface

The tool has four main panels. On the left part of the interface user decision panels can be seen (fig 4) which are block size and housing type panels. Block dimensions and number of floors can be set in the block size panel and house type panel which are explained in previous titles. The percentage of house type is assigned through sliding bars. If the total selection is below or above a hundred, the numbers are optimized. After the values are set, generation can be made. The core location and sizes are calculated and assigned while the structural system and new reviewed values for the sizes and spanning distances are displayed on the interface.

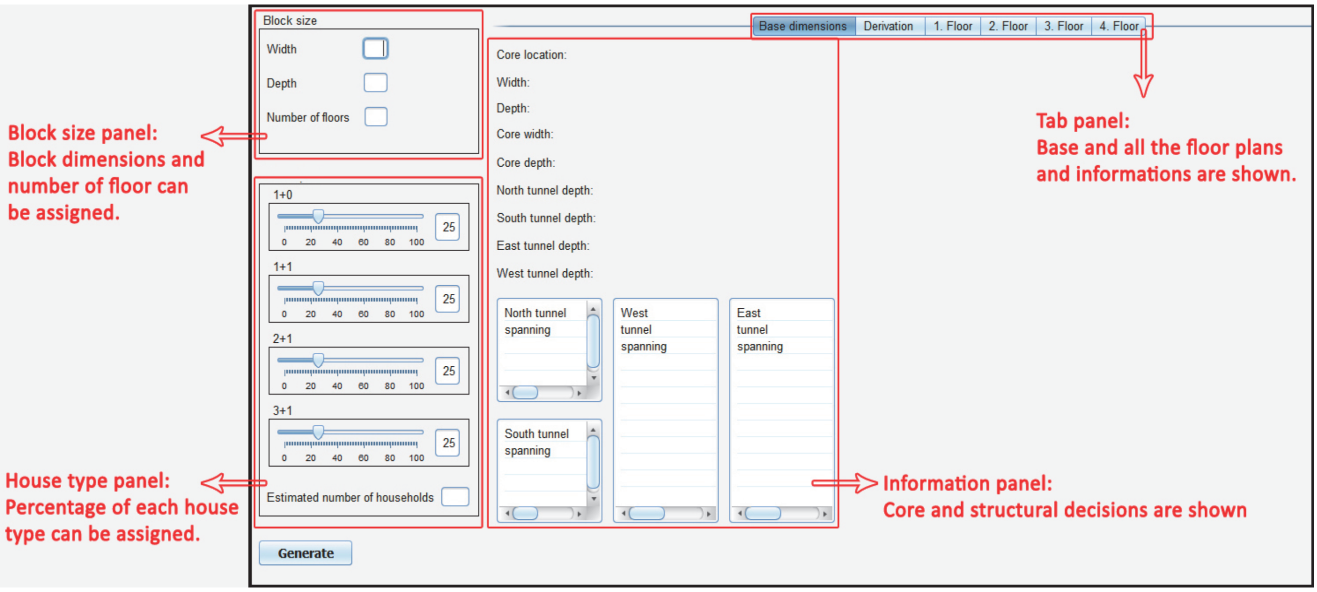

Fig 4. The interface of the prototype

3.2. GENERATION

After the initial values are entered, there can be different possibilities for the core position and size within the limitations which is a useful feature of this tool (fig 5). Also randomly selection is used in structural configuration too. Number of walls, n and m values is calculated and even in the smaller products there are various alternatives for structural configuration.

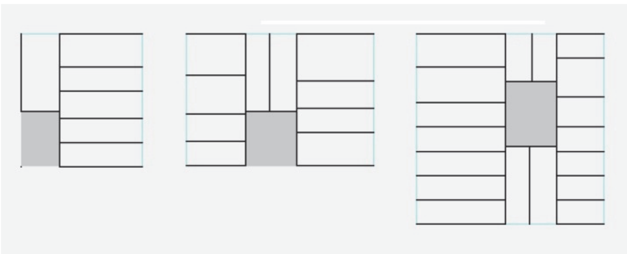

Fig 5. Different generations of the "base

The generation starts with core which accommodates circulation areas, elevators and staircase. The size and the position of the core are assigned. According to core position, the spanning lists and depth of required sides are calculated and assigned. Then core position and size is again reviewed based on these data. After the core and load bearing walls are calculated and printed on screen, the partition walls and housing units will be assigned and projected on the tool.

After the base is generated the house units are assigned again randomly selecting from the entered values. The housing assignments start from right lower corner and continue counter clockwise direction. So according to the house type, required number of rooms are assigned starting from the first floor.

3.2.1. Products

Two examples are shown with central core position with equal percentage of each house type to give an idea for the generation. In order to explain the generation and product first the basic dimensions are entered. After these values, which are the only values entered on the tool, calculations are made and base is generated. On the first tab base is projected while on the second tab derivation is made and the additional walls (partitions) and number of rooms are calculated. And finally floor plans are projected on each floor plan tab with required information.

First product:

The dimensions and selected values for first production are as below (fig 6):

- X: 20 m.
- Y: 20 m.
- Number of floors: 4
- The percentage of each house type is 25%

Reviewed and achieved values for base are as below (fig 6):

- Core location: center
- X: 19.92 m.
- Y: 19.95 m.
- Core width: 5.55 m.
- Core depth: 6.87 m.
- North tunnel depth: 6.88 m.
- South tunnel depth: 6.25 m.
- East tunnel depth: 6.88 m.
- West tunnel depth: 7.50 m.
- North tunnel spanning: 5.55 m.
- South tunnel spanning: 5.55 m.
- East tunnel spanning: 4.35-4.35-3.15-5.55-2.55 m.
- West tunnel spanning: 4.95-5.55-4.35-2.55-2.55 m.

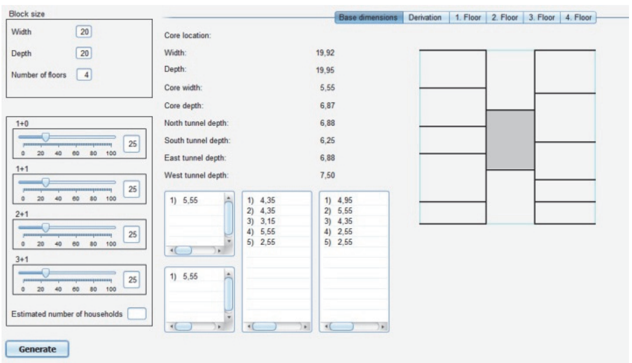

Fig 6. The base on the interface of the tool

Selected values on the second tab are as below (fig 7):

- Minimum number of rooms on a floor: 14
- Maximum number of rooms on a floor: 16
- Selected number of rooms on a floor: 16 (two additional walls)
- Total number of rooms on a floor: 64
- Minimum number of users: 39
- Maximum number of users: 78

On the second tab derivation is made and the additional walls (partitions) and number of house types is calculated and on the floor tabs plan layouts are projected as below (table 4 and fig 7).

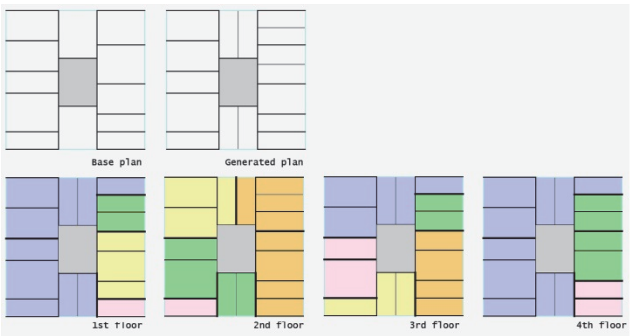

Fig 7.Base and floor plan layouts

Table 4.Number of house types in each floor

	1+0	1+1	2+1	2+1+K	3+1+K
1st floor	1	1	1	0	2
2nd floor	1	2	1	2	0
3rd floor	2	1	1	1	1
4th floor	2	2	0	0	2
TOTAL	6	6	6		5

First product - variation:

Another generation with the same initials and same room numbers in each floor is made. Number of house types is calculated and on the floor tabs plan layouts are projected as below (table 5 and fig 8).

Even though total numbers are the same, the number of different house types in each floor is different based on random distribution algorithm and the products are totally different.

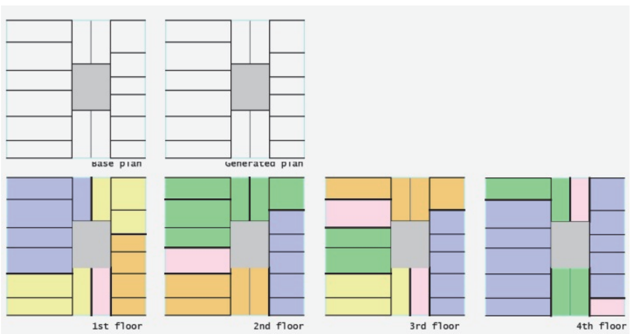

Fig 8.Variation of the first example

Table 5.Number of house types in each floor

	1+0	1+1	2+1	2+1+K	3+1+K
1st floor	1	0	2	1	1
2nd floor	1	3	0	1	1
3rd floor	2	1	1	1	1
4th floor	2	2	0	0	2
TOTAL	6	6	6		5

Second product:

The dimensions and selected values for second production are as below:

- X: 33 m.
- Y: 33 m.
- Number of floors: 15
- The percentage of each house type is 25%

Reviewed and achieved values for base are as below (fig 9):

- Core location: center
- X: 32.75 m.
- Y: 32.85 m.
- Core width: 9.00 m.
- Core depth: 11.74 m.
- North tunnel depth: 9.38 m.
- South tunnel depth: 11.88 m.
- East tunnel depth: 11.25 m.
- West tunnel depth: 12.50 m.
- North tunnel spanning: 5.85-3.15m.
- South tunnel spanning: 5.55-3.45 m.
- East tunnel spanning: 4.05-4.35-3.15-3.15-2.55-2.55-1.85-2.55-2.55-2.55-2.55 m.
- West tunnel spanning: 2.85-4.95-2.55-4.35-2.55-2.85-2.55-2.55-2.55-2.55-2.55 m.

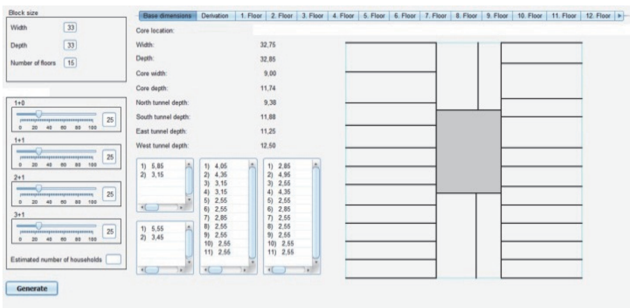

Fig 9. The interface of the prototype

The additional walls (partitions) and number of rooms are as below:

- Minimum number of rooms on a floor: 26
- Maximum number of rooms on a floor: 29
- Selected number of rooms on a floor: 28 (two additional walls)
- Total number of rooms on a floor: 420
- Minimum number of users: 255
- Maximum number of users: 510

On the floor tabs, number of house types in each floor and plan layouts are projected as below (table 6 and fig 10).

Fig 10.Base and floor plan layouts

If the initial values get larger, the number of structural configuration alternatives increase. In the second product with the same initial values, different number of rooms can be created in a floor varying between 16 and 32. So the overall number of rooms will also vary between 240 and 420. If different percentages of house types are added to the equation, there will be numerous generated bases and floor plan layout.

These abstract floor plan layouts can be selected for further infill design. Also the selected house types can be detailed and expanded.

Table 6.Number of house types in each floor

	1+0	1+1	2+1	2+1+K	3+1+K
1st floor	4	4	0	1	2
2nd floor	1	3	4	1	1
3rd floor	3	1	1	0	4
4th floor	1	2	1	0	4
5th floor	3	2	1	2	2
6th floor	4	3	0	2	2
7th floor	3	1	1	0	4
8th floor	4	5	0	1	2
9th floor	5	4	1	2	1
10th floor	1	2	0	2	3
11th floor	2	0	1	2	3
12th floor	3	4	4	0	1
13th floor	0	3	1	1	3
14th floor	1	2	0	2	3
15th floor	2	1	2	2	2
TOTAL	37	37	35		37

4. Concluding Remarks and Future Works

FPL-Gen generates flexible and mass customized plan layouts while it uses structural system as constraint. Especially repetitive projects like mass housing can benefit from these concepts. The scope of the tool and tool development is also important because the theoretical inputs are combined with computation theory and construction system which give realistic and rapid solution.

The "Open Building" approach and support is a promising approach and a generative algorithm with various controls encourages numerous meaningful base alternatives which can be dealt and detailed by architects and designers for future development.

This tool can also be developed, altered and detailed for further studies. Alternating theoretical background input and basic decisions can change the support and products. With adding or removing house types (4+1, 5+1, 3+2, etc.), variations can be obtained. On further studies infill variations can be defined and infill plans can be detailed too.

Acknowledgements

We would like to express our sincere thanks to Volkan Istek and Viki Handeli for their contributions to the program and ongoing study.

Endnotes

1. TOKI(MHDA - Mass Housing Development Administration) is a public corporation established in 1981 to solve the increasing housing problem. Since then TOKI have been providing social and affordable housing for the low and middle-income groups. In time with the changing laws and structure TOKI is now Turkey's biggest housing developer which provides house for every income group single-handedly or in collaboration with other construction firms.

References

Balkaya C., Kalkan E. (2004). Seismic Vulnerability, Behavior and Design of Tunnel Form Building Structures, *Engineering Structures 26*, 2081–2099.

Çolakoğlu B. (2001).*Design by grammar : algorithmic design in an architectural context,* Boston, USA: MIT, PhD Thesis.

Demchak G. L. (2000). *Towards a Post-Industrial Architecture: Design and Construction of Houses for the Information Age*, Boston, USA: MIT, Master's Thesis.

Deniz, Ö. S. (1999). *Çok Katlı Konut Tasarımında, Kullanıcıların Esneklik Taleplerini Karşılayacak Yapı Elemanlarının Seçimine Yönelik Bir Karar Verme Yaklaşımı (A Decision Making Approach to Meet the Flexibility Demands of Users for Selecting Construction Elements in Multi-Storey Residential Building Design),* Istanbul, Turkey: ITU, PhD Thesis.

Duarte, J. P. (2001).*Customizing mass housing : a discursive grammar for Siza's Malagueira houses,* Boston, USA: MIT, PhD Thesis.

Güngör, Ö (2010). *Genetik Algoritmaya Dayalı Kitlesel Bireyselleştirme Amaçlı Konut Tasarım Modeli (Mass Customization Aimed Housing Design Model Based on Genetic Algorithms),* Istanbul, Turkey: ITU, Master's Thesis.

Habraken N. J. (1972). *Supports: An Alternative to Mass Housing,* London, UK: The Architectural Press.

Kendal S.,&Teicher J. (2000). *Residential "Open Building"*, New York, USA: E & FN Spon.

Nicolic, J. (2011) *Multifamily Open Building:Application of "open building" approach in design and construction process of multifamily housing,* Barcelona, Spain. Politechnic University of Catalunya, Master's Thesis

Tatlı B. (2008). *Esneklik ve Değişebilirliğin Çelik İskeletli Çok Katlı Konut Yapılarında İrdelenmesi (Flexibility and Variability Analysis of Steel Frame Multi-Storey Residential Buildings),* Izmir, Turkey: Dokuz Eylül University, Master's Thesis.

Yürekli F. (1983). *Mimari Tasarımda Belirsizlik: Esneklik-Uyabilirlik İhtiyacının Kaynakları ve Çözümü Üzerine bir Araştırma (Uncertainness in Architectural Design: A research about the Sources and Solutions in Flexibility-Adaptability Need),* Istanbul, Turkey: ITU, Mimarlık Fakültesi Yayını

ÜnsalGülmez N. (2008). *Metropolde Çeşitlenen Hanehalkları ve Konut (Diversified Households in Metropolis and Housing)*, Istanbul, Turkey: ITU, PhD Thesis.

[1] http://www.toki.gov.tr
[2] http://archidialog.com