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A computational model for mass customized housing design bu using cellular automata

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Abstract:
Depending on population growth in major cities, in our country, the importance of the concept of mass housing has been increasing. Also the studies for solution of the problem haven't been both able to meet the needs of the users and to provide uniqueness, variety and flexibility in terms of the design. However, Cellular Automata (CA), one of rapidly evolving digital design approaches, has some potential (neighborhoods, simplicity-complexity, relations form-function and self-organizations etc.) for solution of this problem. In this study, with a protocol consisting of integration of Cellular Automata rules and the approach of "Reflection in Action", a model taking care of user participation for mass customized housing is presented with a digital approach. In this model developed by scripts of 3DS Max software, design of the site plan, organization of floor plans according to the user preferences and facade design is included. Besides, neighborhoods of the housing blocks in a site plan, relations of spatial units with each other's and cantilevers and setbacks in the facade design are organized by CA rules. This model proposal has been tested by using user scenarios in a site plan. Especially, the outcomes which offer rich alternatives for the floor plans and facade solutions of the generated blocks in a very short time have been obtained. Results of the study have been discussed from the point of view of innovative architecture.

Keywords: *Computational design, cellular automata, mass customization, mass housing.*

1. Introduction

In today's world called as "Information Age", where information technologies are constantly renewed and developed, it is seen that an approach called as "Computational Design" or "Digital Design" has emerged and significantly influenced all stages of design process in the architectural field as in the engineering fields.

Currently this approach is moving forward to an integrated architectural design process by the influence of developing technologies. The idea that design,

practice or materializing processes in architecture are complementary and are implemented interactively has come to light as a result of this approach. The concept of mass customization supported by digital production instead of mass production and standardization has also gained importance. In other words, a new paradigm based upon rich and creative possibilities of electronics instead of mechanics refuses simplification efforts of modernism. Also it has been put forwarded as a result of the idea that genuineness is as easy and economical as repetition (Kolarevic, 2003).

The problem of "housing demand" emerged as a consequence of rapid increase of population still maintains its importance in our country likewise in the world. Both private sector and the government (TOKİ-Housing development administration of Turkey) try to find different solutions and methods to this problem. However, most of those solutions are insufficient especially in terms of quality, user needs and variety. In addition negative impacts such as introducing economic prices, serial production and standardization still prevail. So it is obvious that innovative alternative solutions are ignored.

It is considered that integrated design processes in which digital designs and mass customization methods are evaluated together can be worthwhile. The aim of this study is to introduce the new developed digital design model. This new model in which cellular automata is used as a digital design tool because of its structural features has been introduced. The model generating options of floor planning considering users' preferences also produce alternative site plans and building blocks. The results which are obtained through the process of practice have been discussed.

2. Mass customization

Habraken (1972) points out that the housing makes sense when not only having a form which is determined by laws and provides the conditions and dimensions but also its users start to live in. According to Francescato (1993), the phenomenon which makes the concept of the housing being meaningful is its users and their opinions. Namely, he says that housing has a set of the meanings consisting of events and experiences which are important for its users. Also he explains that housing has a social quality due to the sharing of housing with a specific group. In other words, housing is a concept in which providing user preferences and their basic needs is priority. It represents the community of spaces which is combined with this aim. In this respect, user satisfaction and requirements are an important input for such buildings. User satisfaction has more critical position in mass housing where different users come together and both independent and collective relationships occur. This condition leads to use of the concept of mass customization, which has been popular recently and commonly evaluated in the other fields, for these works.

The mass customization which is often used in industrial design works defines a process which also enables the users to participate in designing processes and which supports user-designer-producer interaction (Crayton, 2001) This process requires modularity and construction. Modularity means that products can be divided into compounds which can be reorganized while configuration includes user preferences and method definition. In this way, the balance between freedom of selection for the user and standardization is also established.

Types of mass customization can be seen in different ways. They can be analyzed in three groups such as collaborative, adaptive and modular customization (Bardakçı, 2004). Collaborative and adaptive customizations come into prominence in architecture. Collaborative customization necessitates a dialog between the producer and consumer in order to determine the right demands of the user. The information obtained from this dialog is used in production. On the other hand in adaptive customization, the product is generally standardized; but can be modified by the user. The walls that can create various organizations in open spaces and constructions that can be divided into sections (wall, flooring etc.) as well as industrial, flexible and demountable constructions are included in this group.

Collaborative and adaptive customization methods are compatible with the approach of integrated design due to their features such as being interactive, combining different disciplines and applying design in the whole process. Currently the efficiency of the collaborative customization method supported by developing digital design tools is increasingly gaining importance. The roof form developed for the international terminal building in Waterloo Station in London, the Exhibition Pavilion which was designed by K. Oosterhuis and his team in Rotterdam, design of "World Trade Center" cockpit and voice barriers are the most common examples built by this method. In these examples, special parametrical models which require collaborative work among different disciplines were developed and the forms of buildings were shaped accordingly. Examples of adaptable customization methods are the support structures of Habraken (1972) and the project of İzmit New Settlements. The Habraken's study suggests a model which can expand horizontally and in which dismountable components can move easily as part of the flexible space and the structure can renew itself. Habraken's model which was used in Project of İzmit New Settlements has been partially applied to many plan schemas by direct participation of users in the process (Çavdar, 1978). At the end of the İzmit Project, the need for a digital tool in order to produce alternative plan schemas highlighting different user demands has been underlined.

3. Cellular automata and its applications in architecture

Computational architectural design approaches are realized through various generative design approaches (shape grammars, genetic algorithms, l-systems, cellular automata and multi-agents based on swarm intelligence). Among these approaches cellular automata differs from the others with its properties of both being presented graphically and developing innovative models besides managing complex structures with its neighborhoods from local to global.

Cellular automata comprise cells which represent specific number of the defined states and function as a set of rules with a specific grid order in a certain period of time (Terzidis, 2006). Cellular automata include basic components such as cellular spaces, local value space, neighborhood, limitation conditions, transition rules and repetitions (Hoekstra et al., 2010). Lack of external control (autonomous), heterogeneity, universal order (emergence from local relations), self-maintenance (repair and production metabolisms), harmony (functionality/ following external changes) and hierarchy (nested self-organizing processes) are the fundamental concepts of this tool. This tool which was originally developed to define self-organizing systems can also be used for interpreting problems of architecture and urban designing

which include a broad content from social interactions to spatial relations and behavior of material thanks to structural and behavioral features.

Conway's "Game of Life" is one of the most known examples of cellular automata and has become a prototype for complex systems with its simple and comprehensive properties (Hoekstra et al., 2010). It is a study which exemplifies a complex behavior as a consequence of very simple local rules. Basically it is operated by transition rules which comprise four different logical states and affect each cell separately (Figure 1). Rules of the Game of Life are based on set of logical and arithmetic processors using terms like "and", "or" and "not". These rules are applied to an initial configuration which includes living and dead cells within a lattice of NxM grids and new patterns start to emerge over time. In the proposed model, rules of Conway's "Game of Life" in Figure 1 have been interpreted logically and evaluated directly in architectural spatial relationships.

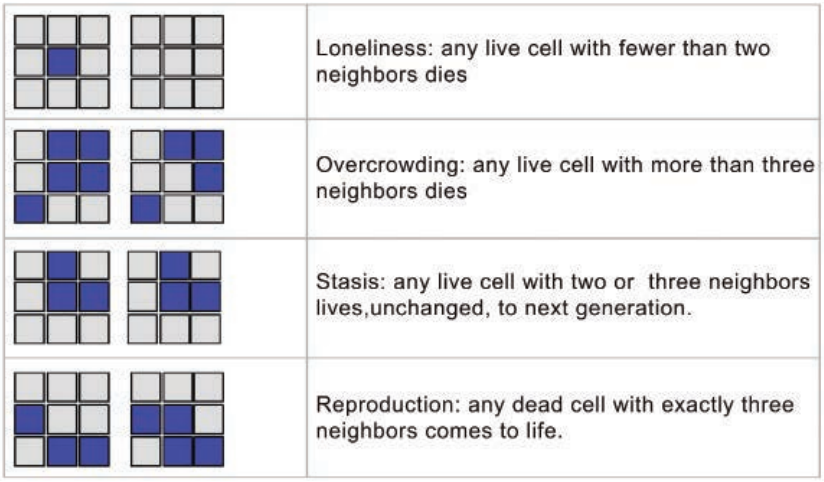

Figure 1. *Transition rules of the Game of Life (Devetakovic et. al, 2009).*

The Game of Life is evaluated directly or indirectly for many applications in diverse fields like ecology, game theory, sociology, urban design etc (Hoekstra et al., 2010). Also this model is commonly used in architectural implementations of cellular automata.

The first experiences about using cellular automata in architecture are Price's "Generator" and Frazer's "Universal Constructor" applications (Herr and Kvan, 2007). Price's study is the first architectural project combining a general understanding of useful space and elements of micro controller support structure. This study is based on the functionalist approach that spaces in structures are organized according to user needs rather than aesthetic. On the other hand, Frazer aimed at determining an architectural approach as logical cases both in time and space with his study "Universal Constructor". Then, Coates and his team (1996) carried out some studies in architectural design studio in order to develop a specialized cellular automata as a tool of decision-support having features such as shaping and extensive state variables in digital environment. This study inspired by Conway's "Game of Life" investigated three stages; firstly defining the rules and increasing neighborhood of cells and associating it with architecture; secondly behaviors of cells affected by environmental factors; thirdly potential shapes which can create three dimensional configurations affected by cellular relations. Krawczyk

(2002), in his studies, also addressed that cellular automata have the potential of cells to produce spaces and the development of their structural features. The generations include defining the growth space of cells and identifying their growth directions; determining the problems about establishing vertical and horizontal relations; carrying out processes such as combination or overlapping of cells and supporting these processes by structural elements; trying out varieties by changing shapes of cellular elements and eventually reaching to conceptual models.

Krawczyk (2003) explained the differences in generation processes in another work; hence he obtained new alternatives which may have regular and irregular architectural structures in each generation process by changing formal features of cells. Clark and Anzalone (2003) examined two and three dimensional cellular automata in terms of both their structural properties and potentials of creating architectural forms. They have investigated the potentials of forms consisting of appropriate geometrical and space-truss systems by matching rules of cellular automata with concepts such as discrete elements, algorithmic relations, patterns, scalability and external control. Every behavior of the new forms has been organized with certain rules (angle, location, distance, connection etc.) and they all engendered an integrated structure which can turn into different shapes with other elements.

Finally, Herr (2008) suggested in his dissertation that cellular automata can be used more effectively by adapting it to architecture instead of using classical cellular automata applications (such as Conway's Game of Life). It was proven by the approach of Schön's "Reflection in Action" that architectural problems can be solved by developing cellular automata which define special architectural relationships types and by giving feedbacks. Moreover, with the idea that the graphical elements representing cellular automata may limit architectural variety, some solution offers have been used as alternatives to the elements which are proven to be unproductive and are not restrictive to creativity.

4. The model for mass customized housing design by using cellular automata approach

Cellular automata cannot be used effectively because of its some negative features in spite of its contributions to the design process in architectural field. These negative features are the formation related to function, lack of ability to interfere in the process, redirecting to certain form patterns, lack of ability to manage spatial relationships as the content of the project expands. When cellular automata is assessed for well-defined design problem and interpreted in parallel with basic architectural approaches, its negative impacts can be reduced and, by the way, its contributions to design can be increased.

In other words, it is a suitable solution to adapt cellular automata to the conditions of the context without depending on the classical cellular automata and to evaluate it with designer's interventions in a problem context gathering different user types, containing different functions and requiring open ended opinions.

As an alternative solution, the similar approach to Herr's studies can be followed. However, in Herr's studies each of housing units were treated as a whole and they were usually positioned relative to the other housing units. In

our model which is presented in this study, each space of housing units are placed by establishing relationships with the other spaces.

There are very close similarities between CA and mass housing designs, which are gaining importance in big cities and which must appeal to different type of users, in terms of their contents and aims. Accordingly, as a decision-support tool, evaluating the model developed by CA can be useful for such design problems. For, the necessity to design these types of housing as innovative and unique examples meeting the demands is constantly gaining importance. Also, CA supports the process which is appropriate for the needs of renewal depending on the time and changing users as well as opening new opportunities for innovative formation, with its structural properties which operate as bottom-up and relate to the neighborhoods and in which function leads the form.

The proposed model developed within this problem context is actually a tool which searches for satisfactory solution alternatives in determining location of building blocks on a site and spatial configurations by additional required interventions and by using spaces and blocks including different neighborhood relations (Dincer et al., 2012).

4.1 Design protocol

The most important reason of not preferring cellular automata method in design process is that designer's interventions during the design processes are intensively needed in spite of the inability to intervene in solutions during implementation processes of cellular automata supported works. Hence, it is thought that using Schön's (1985) ''Reflection in action'' method which proposes an interactive process of dual conversation as a solution to the design problem will be useful.

Schön's "Reflection in action" method comprises of characteristics such *knowing-in-action, reflection-in-action, indeterminate zones of practice, reflective conversation with situation, framing-moving-reframing, practitioner's artistry.*

Schön suggests that reflection in action is not about the personal effort to solve a problem by means of instrumental talents acquired by professional education; but rather to negotiate with the problem by transforming it to the well-defined problem and using researched based methods.

Schön's designing approach has been combined with cellular automata method and used in the proposed model. The aim is to evaluate results of cellular automata included in design protocol through feedbacks and to develop an interactive process. In this way, it is intended to design a process in which the designer can participate actively and can control it entirely.

4.2 The model

The mass customized housing model using cellular automata approach has three phases: firstly deciding the locations of building blocks according to determined rules, which means producing a site plan; secondly spatial organizations considering user preferences and functional relationships on floor plans; thirdly, facade generations which generally come in sight as a result of spatial organization and due to requirements of some interventions in order to prevent monotony in buildings.

In the model “Reflection in Action” approach has been taken into consideration by dividing the selected design process into the defined design steps (designs of site plan, floor plan layouts and facade) for interval interventions and interpreting the alternatives which are generated with the specialized CA-supported digital design modules in these steps together with “Generate and Test” method. In each module which is belong to the steps, data entry and parameter changes determined by designer/user are allowed on the interface designs. Also the modules have renewable and developable features with new rules which may change according to feedbacks and evaluations. Thus, it is thought that the rules used in the study can be changed and enriched by different feedbacks. With this approach, it is expected that autonomous structure of classical CA can made to be suitable for user/ designer movements for indeterminate states of the design process and it can be customized (Figure 2).

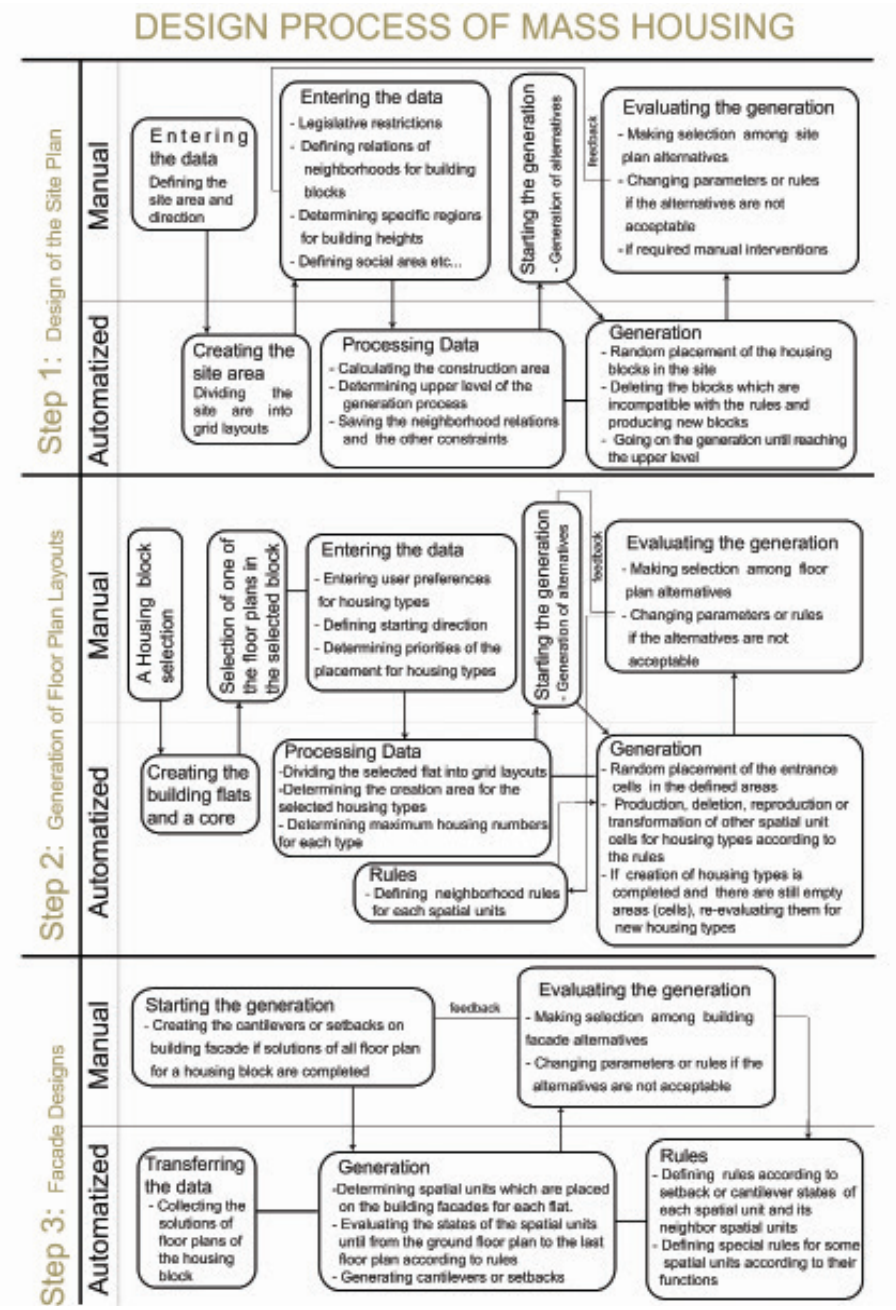

Figure 2. *Implementations of “Reflection in Action” method in the model.*

4.2.1 Design of the site plan

For mass housing implementations the basic decisions about the design of the site plan are important. These decisions provide to bring different building blocks together and to define common spaces (social spaces, green regions, transportation etc.). They greatly affect the urban aesthetic and common satisfaction of users in terms of form and function respectively. For the genuineness in these decisions, a variety pool where lots of alternatives can be experienced is necessary.

The content of the site plan decisions include various parameters such as land size, the ways around the land, natural conditions, buildings and open spaces, legal restrictions and decisions about the locations of buildings by using these parameters. In this process, support of cellular automata can contribute to determining the number of the buildings, their locations and size in the light of these parameters. In such configuration each building block represents a unit cell. Environmental conditions and legal restrictions define set of rules affecting generation, abolishment, continuation of these unit cells and their neighborhood relations. Furthermore, the site area represents a generation spaces (grid layouts).

The data about the site plan of the proposed model consist of parameters such as land size, legal restrictions and common spaces. The generation processes of site plan are carried out through some functions such as starting generation, repetition, retrieval and recording results. These parameters and functions are implemented by an interface facilitating access developed as part of the model and prepared by scripts of 3Ds Max software (Figure 3).

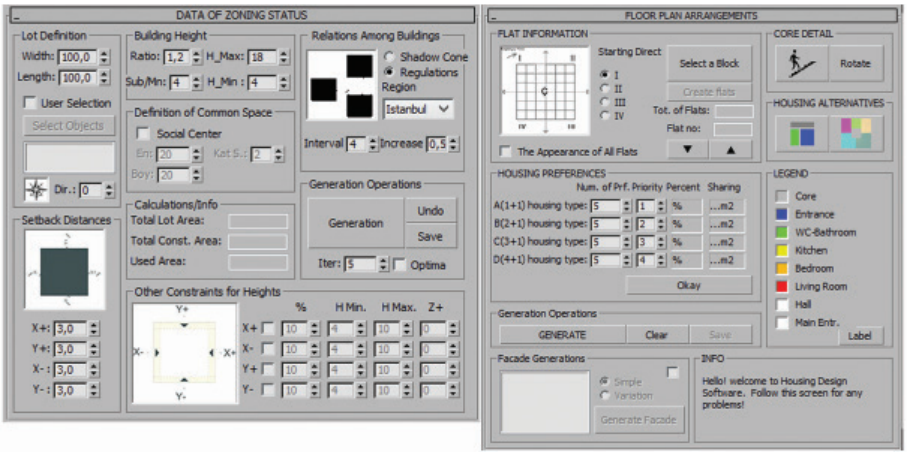

Figure 3. *The Interface of site plan (right) and floor plan layouts (left).*

Generation process of site plan starts with the random location of a building block which has a defined (fixed) floor area and whose height can be changeable, within boundaries of a site determined through the interface (Figure 4). The generation of these settlements continues until reaching the value of the total construction area for the blocks. In the generation, the neighborhood relations of buildings with the previous ones are evaluated after the first settlement. If there is no suitable situation in terms of the criteria, a selection between newly produced and existing building blocks can be made and one of them is removed. If total area of the building blocks is not reached to the total construction area during the generation process, the implementation of the model is carried out more than once and the generation process are

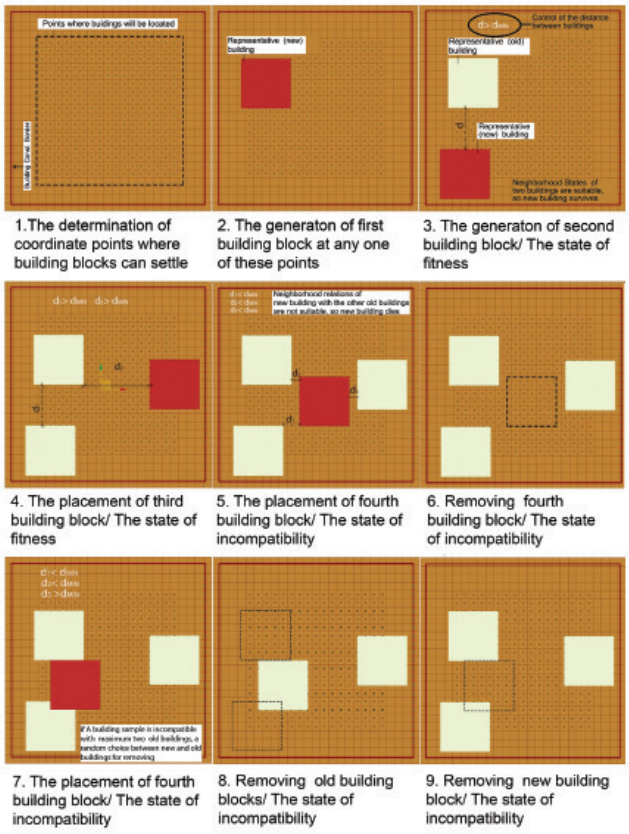

Figure 4. *Generation of site plan by locating the blocks.*

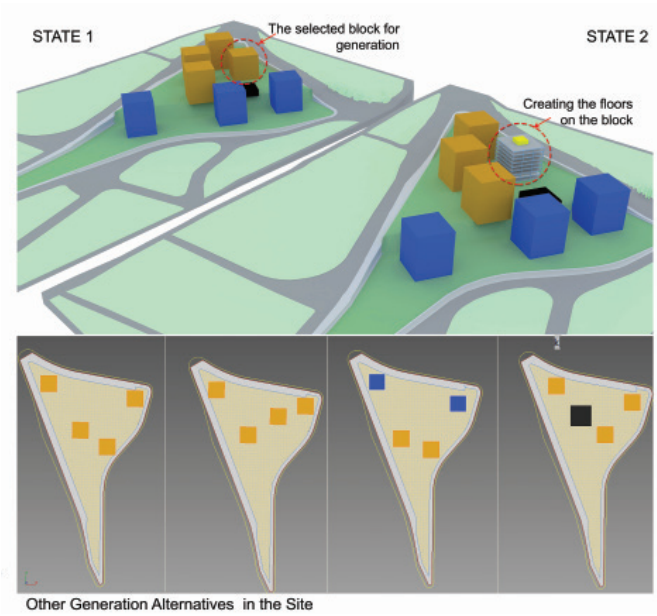

Figure 5. *Generation of site plans.*

continued until getting a satisfactory result and new building blocks are located on the remaining empty spaces of the land.

Site plan implementation was tested on a site chosen in Karabük-Yenişehir region. In this implementation the construction specifications about this region were used and user scenarios for a building block were prepared. Alternative settlement plans were generated by using certain parameters on the site plan (direction of the landscape, height values, social areas etc.) (Figure 5). After the generations, Each of the emerging plans was different from each other.

By the option of "user selection" on the interface, the model is applicable to other sites in different geometric forms and features as in the example of Karabuk-Yenişehir.

4.2.2 Generation of floor plan layouts

In today's approach of mass housing, floor plans of building blocks are composed by four or five different plan layouts, which are one living room and the other room/s (1+1, 2+1, 3+1, 4+1 or duplex houses), and these plan types are designed in the same way for each floor and finally presented to the users. The proposed model is a parametric computational model supporting the concepts of flexibility and variety besides producing alternatives by "generate and test" method. By turning user preferences made for each floor plan into a digital expression, this model defines a new formation possessing innovative features and in which each spatial unit triggers the generation of others according to this expression and they constitute different housing units together, thus variety is obtained.

The contribution of cellular automata to the design process of the mass customized housing would be to manage the vertical and horizontal relations of the spaces forming floor plans. These spaces are represented

by cells in the computational model. The cellular neighborhood relations are presented in cellular automata by the rules. Floor plan area is defined as borders of a generation space. This potential is also evaluated in the proposed model.

Each space of a house has its own requirements and relationships with other spaces to be established and they affect the locations of other spaces, too. This structure can be turned into a structure where each cell affects each other as a spatial unit likewise in cellular automata. This can only be realized by determining locations of spaces, changing functions, generating spaces and defining new spaces.

A central vertical circulation space for multistorey buildings has been proposed in this model: This vertical building core whose position is unchangeable in all floors is located in the center of the building whereas the other spaces are located around it. A structural system which enables flexibility and variety is preferred in this model. Firstly a skeleton model consisting of 8*8 m squares is drawn on grid order. The grids around the building core define potential housing spaces which can be divided into smaller units (4*4 m) and housing plans are formed by grouping according to the data about housing typology (Figure 6) on these grids.

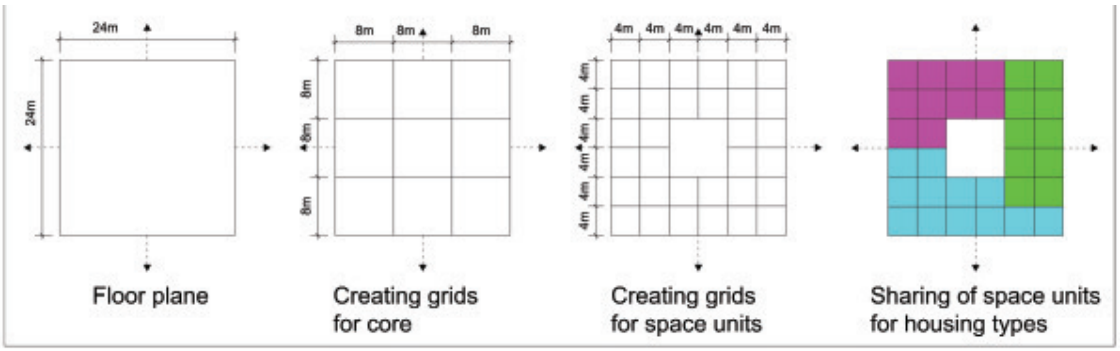

Figure 6. *Grid divisions of floor plans.*

The design of floor plan schemas for blocks developed in site plan implementation, occurs in stages such as determining order of precedence for types of housing, defining the direction, deciding A(1+1), B(2+1) and C(3+1) types of housing according to user preferences, generating of the floor plan schemas and evaluating the results. At first, a comparison between user preferences and conditions of types of housing is made in order to determine the patterns of types of housing that will be included in the chosen floor plan. According to user preferences sharing the area is made among types of housing described in the floor level. Areas of each types of housing are evaluated by considering limits of minimum and maximum area which were determined before. The types of housing which stay under the minimum values are eliminated and their areas may be shared with other types of housing according to preferences. If the value of maximum area is exceeded, types of housing are reviewed in terms of their space capacity to build more than one house. If the conditions are unsuitable, surplus of the maximum value is shared among other types of housing again.

Then interior space designs are initiated for chosen types of housing. In generation of the plans the operation process are implemented by placements

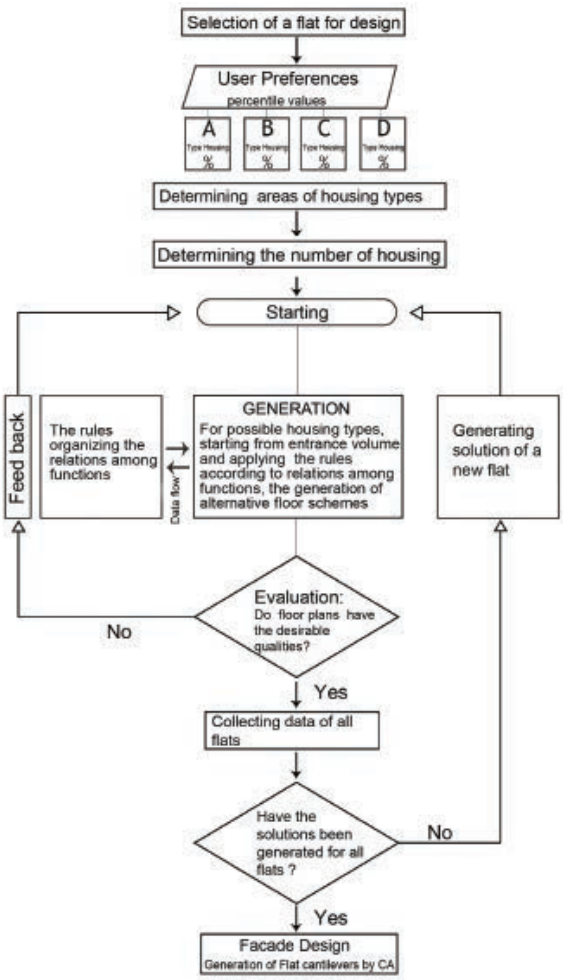

Figure 7. *Flow chart of space planning and facade designing.*

of the spatial units, which comprise entrance hall of the building, entrance hall of the house (G), bathroom (B), kitchen (M), living room (Y), bedrooms (YO) and balconies, in the shared areas of the floor plan in the context of certain neighborhood relations and rules of these spatial units (Figure 7).

Spatial units represented by cells generate types of housing in a floor plan according to certain set of rules of cellular automata such as birth, death and continuity as well as neighborhood relations in the bottom-up process. Actually the generation of types of housing starts when each entrance cell is located on the floor level simultaneously. Each entrance cell produced in the generation process also defines a housing unit. During the generation, the other spatial units affected by the created entrance or different spatial cells are also included in the defined house plans (units). In the model, each space cell includes specific rules based on its architectural topologic relations with the

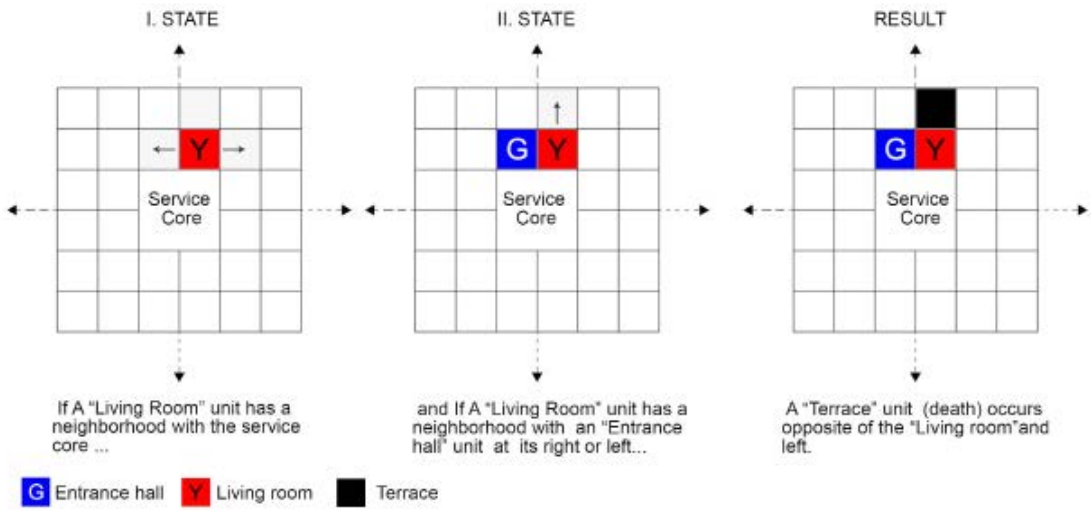

Figure 8. *A rule sample of a spatial unit on the floor plane.*

others separately. The interactions (creation, deletion or transformation of the cells) takes place with these rules (Figure 8).

After the spatial units are generated, the appropriateness of housing samples is tested. This testing operation is carried out by the value of minimum area specific to each housing type. If the area of a housing type is under the value which is necessary for the relevant housing type and if it cannot define any other types of housing, the generation of this housing unit is cancelled and existing cells are removed. The spaces which left empty are used for the generation of other selected types of housing according to the preferences (Figure 9).

The operations such as reviewing empty cells, adding new cells to housing units or changing functions of existing cells also affect the conditions of preference. The model can generate different types of housing (A, B and C types) in a floor plan (Figure 10).

4.2.3 Facade design

The facade design process of the building blocks is managed by additional rules which regulate vertical and horizontal relations between the spaces on the facade and according to the floor plans. Cantilevers and setbacks are formed in facade design of building envelope by the spatial units in floors on the exterior facade. The conditions of spatial units on the exterior of each floor on building blocks are taken into consideration in the generation of cantilevers and setbacks. Each unit, which is grouped by façade direction and their locations, forms a cantilever or a setback pursuant to the states of those vertical and horizontal neighboring spatial units (Figure 11). The rules concerning neighboring relations have been set for locating facade cantilevers.

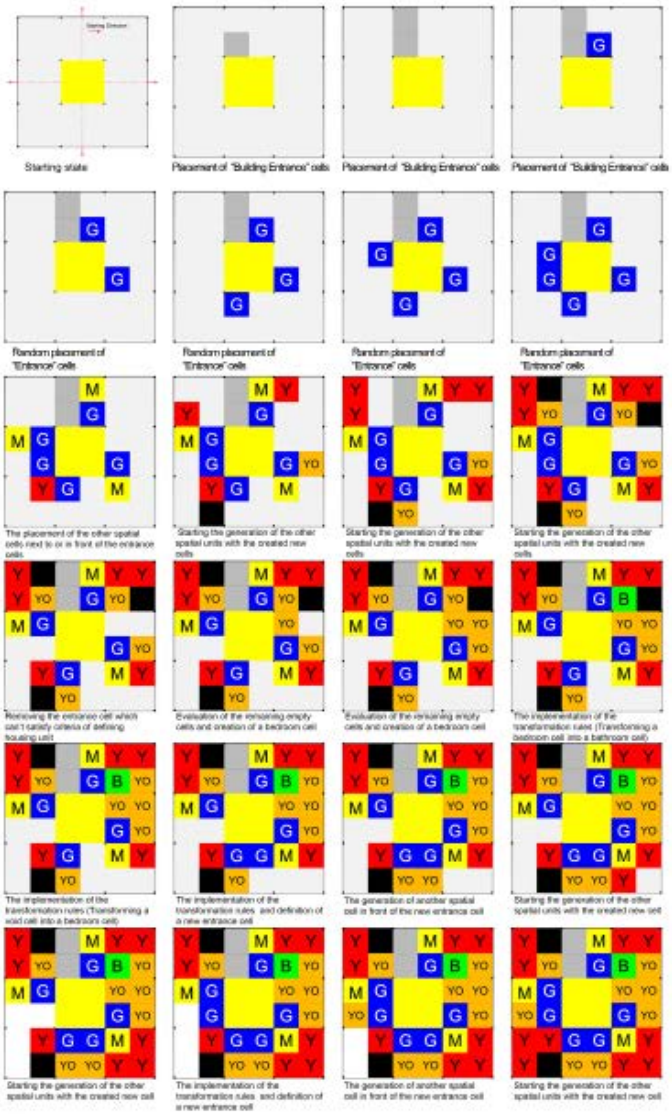

Figure 9. *The generation process of a floor plan.*

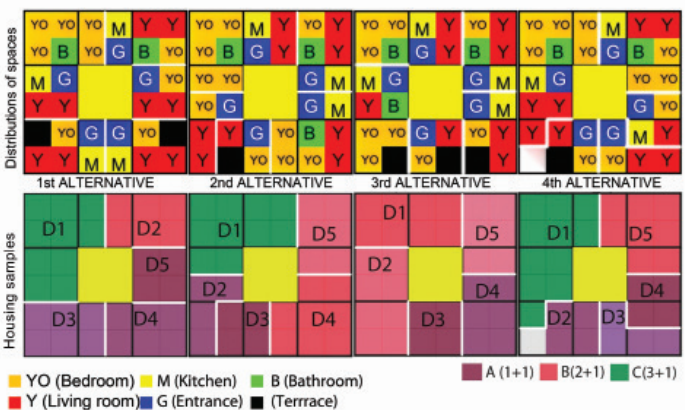

Figure 10. *Alternative solutions for a floor plan of the generated block in Karabuk-Yenişehir.*

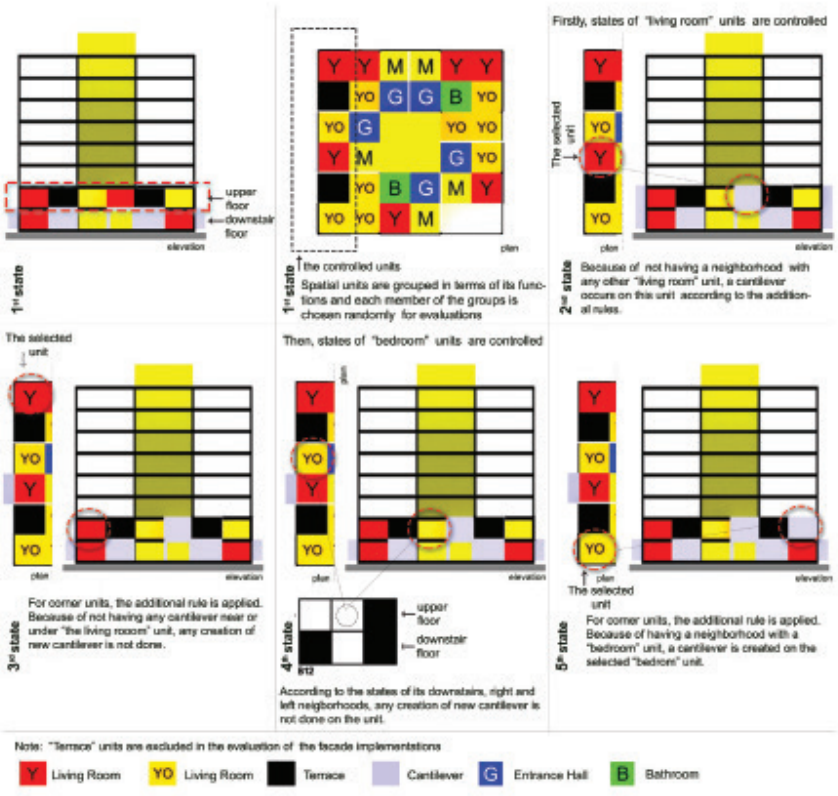

Figure 11. *The generation process of the facade by using cantilevers.*

The most important rule is to decide a cantilever generation by taking care of the neighborhood relations of every spatial unit chosen on floors excluded the ground floor with their downstairs and next-door neighbours (Figure 12). In this rule, the approach which is similar to rules two-dimensional is CA defined by numbers like “0” or “1” and colors like “white” and “black” is followed. Accordingly this rule is formed by a set of the sub-rules deciding the issue whether having a cantilever or not, which belong to each one of their downstairs and next-door neighbours of a spatial unit. According to the results of the table the new facade design of the chosen spatial unit is determined. The other rules on the other hand, are additional rules prepared for special facade conditions, types of housing and spatial units.

Some of these rules are as follows:

•As a general rule, the maximal three consecutive cantilevers are allowed vertically. If neighbor of the chosen cell and two consecutive cells having neighborhood with it have cantilevers together on the same vertical axis, creation of a cantilever for the chosen cell are canceled. By that, it is aimed at that generation of unchanging and monotonous facade compositions is prevented.

•A “Living space” unit in a housing sample can have more than one cell. In case all these cells have cantilevers, a column problem can occur in the middle of the interior spaces. So, only one of “Living space” cells in a housing sample can have a cantilever on the same facade.

•If a “Bedroom Cell” on the facade has a neighborhood with another “Bedroom

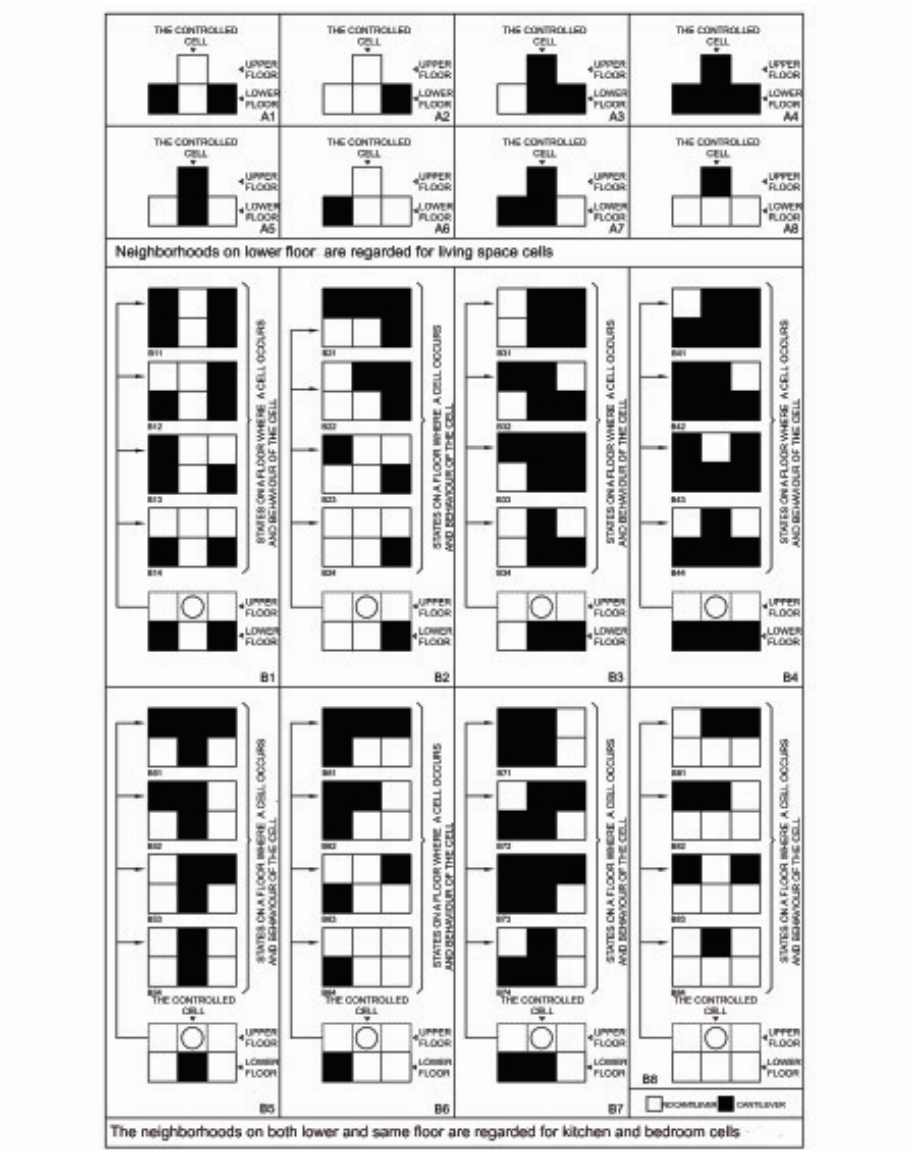

Figure 12. *The rules for facade designs.*

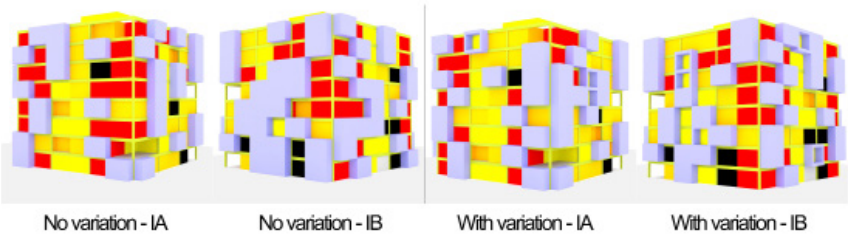

Figure 13. *Facade solutions.*

Cell" which is next to the core, these two cells define a room with a big volume together. Therefore, the cell can't have a cantilever, but the cell can create a setback in some cases.

•In implementations, a "kitchen" unit has a big area with 16 m². So these units can have a semi-open cantilevers or create a setback like "Bedroom" cells.

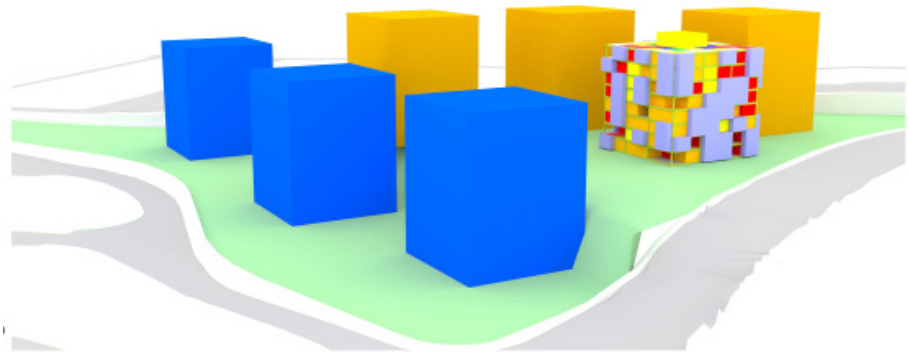

Figure 14. *Presentation of a building facade on a block.*

By the means of the developed interface, these rules were implemented on one of the blocks which were generated in the chosen site plan and floor solutions of which were completed. Thus different solutions were obtained at each time the model was run (Figure 13 and Figure 14).

5. Results

It has been tested that the cellular automata model is a computational design approach which can be used on different architectural scales such as site plans, floor plans of building blocks and facade designs of them for mass customized housing. The model can also be used in well-defined and modular spatial organizations which have complex functions (office buildings, dormitories, apart hotels etc…) during all stages of an integrated design process and it will make positive contributions to the decision making processes. It is anticipated that such models will be a useful support tool for the architectures and will provide occasion for producing alternative designs which promote variety rather than monotonous and repetitive solutions implemented by ignoring user preferences especially in mass housing designs. The model presented in this article is a parametric model which is capable of generating different alternative solutions by making use of the data concerning environmental conditions, user preferences and needs. The other results can be listed as follows:

•Using Cellular Automata unlike its classical approach is important in terms of providing the flexibility in design studies. This approach expands designer's solution space and generates alternative solutions for different design phases.
•The model suitable for design problem offers a designer to have opportunities of variety, which are difficult to obtain solutions with traditional ways. Designing the rules can be difficult and time consuming, but it is a fact that the processes of editing the rules with the feedbacks help a designer with more unique alternatives as a decision-support system. The results of the implementation have demonstrated it.
•Shapes of the building blocks are central square forms and layouts of the floors have been composed by squares. Accordingly, the rules and relationships among buildings and spaces have been organized. It is thought that these rules and relationships can be also described for different plan schemes (such as linear forms growing horizontally) in the future implementations by supporting additional specific rules to these forms and similar positive results can be obtained

•In all stages (site plan implementations, floor plan organizations and facade designs) of the model, a lot of alternative and developable solutions which requires rather long time to obtain with traditional ways are presented. These solutions can be transformed into the desired plan schemes with a designer's interventions in accordance with his/her design criteria. In this approach, numbers of existing alternatives increase further with user interventions which provide a designer to use his/her initiative. Thus concerns to reduction of a designer's efficiency in the process are removed

•The necessity of working with feedbacks has arisen during the definition of the problem and generating the alternatives in computational design. It has been concluded that integration of "Reflection in Action" approach to the CA which is one of the computational design approach have an important role in design process. The proposal approach in article supports Schon's "see-move-see" method with cyclical application of CA approach at each stage of developing design solutions

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Hücresel özdevinim yaklaşımı ile özelleştirilmiş kitlesel konut tasarımı için hesaplamalı bir model

Günümüzde kitlesel konut üretimi anlayışında kısmen değişimler olsa da, çeşitli uygulamalarda Modernizm'le birlikte gelen seri üretim tekniklerinin getirdiği kavramların (standartlaşma, tekrarlama, basitleştirme vb...) etkilerinin hâlâ devam ettiği görülmektedir. Özellikle büyük kentlerde, artan konut ihtiyacını ekonomik ve hızlı bir şekilde karşılamak amacıyla yapılan uygulamalarda, hem kullanıcı ihtiyaçlarına tam olarak cevap verilemediği hem de özgünlük ve çeşitliliğin göz ardı edildiği, birbirine benzeyen, kimliksiz yapı örneklerinin ortaya çıktığı görülmektedir. Bu nedenle, bu alanda kullanıcı tercih ve ihtiyaçlarına göre değişen farklı çözümler sunabilen yeni tasarım yaklaşımlarının geliştirilmesi önem kazanmaktadır. Bu bağlamda, farklı mekânsal ve topolojik ilişkilerden oluşan karmaşık yapıların çözümüne katkısı olan yenilikçi sayısal araçların olanaklarından ve kullanıcı-tasarımcı-ürün etkileşimini artıran uygulamalardan faydalanmanın çok daha olumlu sonuçlar verebileceği düşünülmektedir.

Bu çalışmada, önemi giderek artan özelleştirilmiş kitlesel konut üretimi, yenilikçi sayısal tasarım anlayışıyla ele alınarak bu tür yapılar için tasarımın başlangıç aşamalarında kullanılabilecek, kentsel ölçekte çevresel plan örnekleri; bina ölçeğinde ise, kat plan şeması alternatifleri ve cephe çözüm önerileri üreten bir sayısal model geliştirilmiştir. Bu amaçla modelde, yenilikçi sayısal tasarım araçlarından biri olan hücresel özdevinim yaklaşımı kullanılmıştır.

Makalede öncelikle, özelleştirilmiş kitlesel üretim yaklaşımı açıklanmıştır. Özelleştirilmiş kitlesel üretim yaklaşımı toplu konut uygulamalarındaki yeri, içeriği, çeşitleri ve kullanım alanları örnekleriyle birlikte incelenmiştir. Daha sonra kullanıcıya özgü bir tasarım ürünün geliştirilmesi için etkileşimli işbirliğine ve mekânsal komşuluk ilişkilerine dayalı birimlerin bütüncül bir yapıyı oluşturmasına olanak veren özelliğinden dolayı, konu bağlamında seçilen hücresel özdevinim yaklaşımının temel özellikleri, mimarideki uygulamaları ve kullanım olanakları irdelenmiştir.

Bu çalışma için geliştirilen model önerisinde, hücresel özdevinim (HÖ) yaklaşımıyla tasarlanacak özelleştirilmiş kitlesel türetim önerilerinin tasarım sürecinde, kullanıcı taleplerinin sürece dâhil edilebilmesi ve kullanıcı-tasarımcı-model etkileşiminin sağlanabilmesi için, geleneksel tasarım sürecinde mimarların çözüm geliştirme amacıyla, yaygın bir biçimde kullandıkları Schön'ün "Eylemde Yansıma" yaklaşımı uygulanmıştır. Makalede bu yaklaşımın genel yapısına da kısaca yer verilmiş ve modelle ilişkisi açıklanmıştır.

Model önerisinde, yukarıda açıklanan yaklaşımlar doğrultusunda hesaplamalı bir tasarım yöntemi geliştirilmiştir. Modelin kapsamı; önceden de belirtildiği gibi, kitlesel konut tasarımının en önemli aşamalarını oluşturan yapı adası ölçeğinde çevresel planlama, bina ölçeğinde kat planlaması ve cephe alternatiflerinin türetimi aşamalarından oluşmaktadır. Bu kapsamda başlangıçta, çevresel planlama alternatiflerini türetecek algoritma geliştirilmiştir. Bu algoritma ile tanımlı bir yapı adası üzerinde belirli bir taban alanına sahip konut bloklarının birbirleriyle olan

komşuluk ilişkilerini, yasal kısıtlamalar, tanımlanan ölçütler ve ilkeler doğrultusunda düzenleyen, farklı konumlarda ve yüksekliklerdeki kütleleri içeren yerleşim alternatifleri tasarlanmaktadır. Algoritmanın uygulaması, seçilen bir yapı adası üzerinde, ölçütlere dayalı kurallar dâhilinde ve kullanıcı taleplerini karşılayan verilerle çözüm önerilerinin üretimi şeklindedir.

Modelin ikinci adımını oluşturan kat planlaması uygulamasında, farklı katlar için, farklı kullanıcı tercihleriyle belirlenen konut tiplerine ait mekânsal kurgular türetilmektedir. Mekânsal birimlerin yerleşimi, belirli işlevsel ilişkilerle tanımlanmış ve kurallarla temsil edilmiştir. Bu aşama için geliştirilen algoritma, kurallara ve mekânların boyutsal özelliklerine göre farklı konut tiplerini içeren alternatif kat mekân organizasyonlarını türetmektedir.

Geleneksel tasarım sürecinde mekân planlaması ile birlikte tasarlanması gereken cephe çözümleri, modelde türetilen bina alternatifinin tüm kat planlarının çözümünün tamamlanmasının ardından, bu çözümlerdeki cepheye bakan mekânsal birimlerin düşey ve yataydaki komşuluk durumlarına göre birimlerin geri çekilme, çıkma oluşturma veya sabit kalmalarına karar verildiği bir süreçle türetilmektedir.

Modelde, her aşamada türetilen alternatiflerin değerlendirilmesi tasarımcıya/kullanıcıya bırakılmıştır. Bu alternatifler, 'üret ve dene' yöntemiyle değerlendirilerek uygun çözümler seçilmektedir. Bu değerlendirmelere göre, geri beslemelerle yeni türetimlerin gerçekleştirildiği bir işleyiş süreci, modelin de temelini oluşturmuş ve modelin "Eylemde Yansıma" yaklaşımıyla olan ilişkisini tanımlamıştır. Modelin her üç aşamada yer alan kurallar ve ilişki tipleri de Conway'in "Yaşam Oyunu" adlı HÖ kuralları ve Wolfram'ın iki boyutlu HÖ kurallarına göre düzenlenmiştir.

Modelde, 3Ds Max yazılımının betikleriyle hazırlanan, kullanıcının veri girişine olanak veren ve alternatif çözüm önerilerini grafik olarak temsil eden etkileşimli bir arayüz tasarlanmıştır.

Geliştirilen model, Karabük-Yenişehir bölgesinde seçilen bir arazi örneği üzerinde uygulanmıştır. Uygulamada çevresel planlama aşamasında, bölgeye ait çevresel ve yasal verilerin kullanımıyla konut bloklarının yerleşim alternatifleri geliştirilmiştir. Kat planlaması aşamasında ise türetilen bir binanın her bir katı için oluşturulan farklı kullanıcı tipi senaryolarıyla ve diğer parametrelerle türetimler yapılarak, birbirinden farklı mekânsal kurguları içeren kat planı şemaları oluşturulmuştur. Farklı konut tiplerini içeren ve tüm kat planı çözümlerinin tamamlandığı bir örnek üzerinden de cephe türetimleri gerçekleştirilmiştir. Model kapsamında geliştirilen ve cephenin kitle hareketlerini temsil eden kuralların uygulanmasıyla, cephelerde çok daha fazla çeşitliliğe ulaşılmıştır.

Sonuç bölümünde, sayısal tasarım yaklaşımlarının sunduğu olanaklar ve öneri modelin uygulanmasından elde edilen sonuçlar tartışılmış ve ileriye dönük uygulama alanları açıklanmıştır.