

A USER-CENTERED DATA FRAMEWORK FOR CUSTOMIZING MASS
PRODUCTION IN ARCHITECTURE



by
Doğ a  akmak

Submitted to Graduate School of Natural and Applied Sciences
in Partial Fulfillment of the Requirements
for the Degree of Master of Science in
Architecture

Yeditepe University
2023

A USER-CENTERED DATA FRAMEWORK FOR CUSTOMIZING MASS
PRODUCTION IN ARCHITECTURE

APPROVED BY:

Assist. Prof. Dr. Faruk Can Ünal
(Thesis Supervisor)
(Yeditepe University)

Assist. Prof. Dr. Aslan Nayeb
(Yeditepe University)

Assist. Prof. Dr. Can Boyacıoğlu
(Gebze Technical University)

DATE OF APPROVAL: / / 20...

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Name, Last name Doğa Çakmak

Signature

ACKNOWLEDGEMENTS

It is with immense gratitude that I acknowledge the support and help of my Professor Faruk Can Ünal. Pursuing my thesis under his supervision has been an experience that broadens the mind and presents an unlimited source of learning.

I thank my beloved friend Helin Yağmur Şahin, for her constant support.

Finally, I would like to thank my family for their endless love and support, making everything more beautiful.



ABSTRACT

A USER-CENTERED DATA FRAMEWORK FOR CUSTOMIZING MASS PRODUCTION IN ARCHITECTURE

The mass production approach, which aims to standardize living spaces by determining the basic spatial needs of the user, can serve more than one user at the same time in a short time at low cost. In mass production, the designer designs for an anonymous user group. This situation has prevented meeting the different needs and desires of various users over time. Unlike the fast, low-cost and low-quality products of mass production, the mass customization approach aims to provide fast, low-cost and high-quality products to the user. This approach emerged with the idea of solving the problems created by standardization by meeting the individual needs of the user that mass production eliminates. With its highly customizable products, mass customization allows the user to take part in the design, giving the user an identity. While the user is involved in providing the designer with user data to be used in the design, the designer will play a role in the making a creation using this data. Since it is not possible to process the data of each individual individually in a mass-scale design, information and communication technologies are used to collect, accumulate and process user data. With the help of technological devices used constantly in daily life, it is possible to obtain data that will enable customization in users' living spaces. In this study, a user-centered data framework is created for the customization of users' living spaces with the data obtained from the user's daily activities and spatial routines. Using this data framework, not only can customizable housing be designed for different users. At the same time, through continuous observation with the help of information and communication technologies, it is also possible to customize the user's existing house by identifying the changing needs and desires of users over time. Observation of the user's activities and spatial routines will support customization in housing by providing a user profile.

ÖZET

MİMARLIKTA SERİ ÜRETİMİ KİŞİSELLEŞTİRMEYE YÖNELİK KULLANICI MERKEZLİ BİR VERİ ÇERÇEVESİ

Kullanıcının temel mekânsal ihtiyaçlarını belirleyerek yaşam alanlarını standartlaştırmayı hedefleyen seri üretim yaklaşımı, aynı anda birden fazla kullanıcıya kısa sürede ve düşük maliyetle hizmet verebilmektedir. Seri üretimde tasarımcı anonim bir kullanıcı grubu için tasarım yapmaktadır. Bu durum zaman içinde çeşitli kullanıcıların farklı ihtiyaç ve isteklerinin karşılanmasını engellemiştir. Seri üretimin hızlı, düşük maliyetli ve düşük kaliteli ürünlerinin yerine kitlesel özelleştirme yaklaşımı kullanıcıya hızlı, düşük maliyetli ve yüksek kaliteli ürünler sunmayı amaçlamaktadır. Bu yaklaşım, seri üretimin ortadan kaldırdığı kullanıcının bireysel ihtiyaçlarını karşılayarak standartlaşmanın yarattığı sorunları çözme fikriyle ortaya çıkmıştır. Son derece kişiselleştirilebilir ürünleriyle kitlesel kişiselleştirme, kullanıcının tasarımda yer almasına olanak tanıyarak kullanıcıya bir kimlik kazandırır. Kullanıcı, tasarımda kullanılacak kullanıcı verilerinin tasarımcıya sağlanmasına dahil olurken, tasarımcı da bu verileri kullanarak bir tasarım gerçekleştirilmesinde rol oynayacaktır. Kitlesel ölçekli bir tasarımda her bireyin verilerinin tek tek işlenmesi mümkün olmadığından, kullanıcı verilerinin toplanması, biriktirilmesi ve işlenmesi için bilgi ve iletişim teknolojilerinden yararlanılır. Kullanıcıların günlük hayatlarında sürekli kullandıkları teknolojik cihazlar yardımıyla, kullanıcıların konutlarında kişiselleştirmeyi sağlayacak verilerin elde edilmesi mümkün olmaktadır. Bu çalışmada, kullanıcının günlük aktiviteleri ve mekânsal rutinlerinden elde edilen veriler ile kullanıcıların yaşam alanlarının özelleştirilmesi için kullanıcı merkezli bir veri çerçevesi oluşturulmaktadır. Bu veri çerçevesinin kullanılması ile farklı kullanıcılar için kişiselleştirilebilir konutlar tasarlanabilir. Aynı zamanda, enformasyon ve iletişim teknolojileri yardımıyla yapılan sürekli takip sayesinde, kullanıcıların zaman içinde değişen istek ve ihtiyaçlarının tespiti üzerinden kullanıcının mevcut konutunun kişiselleştirilmesi de sağlanabilir. Kullanıcının aktivitelerinin ve mekânsal rutinlerinin gözlemlenmesi, tanımlı bir çerçeve altında toplanmış bir kullanıcı profili sağlayarak konutta kişiselleştirmeyi destekleyecektir.

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LIST OF SYMBOLS/ABBREVIATIONS

AI	Artificial intelligence
AR	Augmented reality
CAD	Computer aided design
DGPS	Differential global positioning system
GPS	Global positioning system
HAR	Human activity recognition
HVAC	Heating, ventilation, air conditioning
ICT	Information and communication technologies
IoT	Internet of things
MC	Mass customization
MCS	Mobile crowdsourcing
ML	Machine learning
MP	Mass production
VPS	Visual positioning system

1. INTRODUCTION

With industrialization and the advancement of technology in parallel, the mass production approach has begun to be used in every field. As a result of mass production, standardized products can serve multiple users simultaneously with fast, low cost and less amount of labor work. Gropius's proposal to standardize spaces and produce them quickly with a system such as a mass production line [1], and Corbusier's proposal to standardize and produce housing elements like car parts [2], became the head of mass production debate in architecture. As Gropius and Corbusier suggested, the success of mass production depends on the standardization of the spatial counterparts of basic user needs.

While mass customization is being discussed in terms of qualifications, some architects and designers have experimented with customizing standard spaces by creating flexibility in spatial design [3]. Corbusier's Domino House is an example of this with its open-plan system. In terms of concept, the system proposed by Habraken as carrier (structure) and fillings(living spaces) is a massive-scale proposal [4]. The customization of standard living spaces by the users, as well as the ability to fit into the structure prepared by architects and engineers, paves the way for serving multiple users at the same time.

The most important movement based on mass customization as an approach is the metabolism movement that emerged in Japan. This movement, which argues that the building should develop as a living organism with the user [5], shows that mass customization can be applied over time not only on the basis of housing but also on the city scale. For example, the Nakagin Capsule Tower parallels Habraken's carrier and fillings system. It aims to change living spaces over time by interacting with standard living spaces with a standard and fixed carrier system and infrastructure systems. Although it is insufficient to serve its purpose, the point where mass customization can come for future studies is seen in the Metabolism movement.

In mass production houses, there is a structure in which only experts are in the role of designers and the user does not participate to design process. The user is assumed to be anonymous, as it takes time to meet the various requests and needs of different users in each separate design and production. In designs where the designer determines the user's needs under acceptance, fast and standard results are obtained with the decisions to be taken from

a single source. However, the fact that personal needs and wishes are not reflected in the design creates problems during use. Because the person who designs, implements, and uses the space on the basis of the approach is different. Therefore, these designs do not go beyond the standardization and implementation of basic needs. Because of housing is a product that should be shaped around personal data, the fact that the designer has more role than the user, negatively affects the usability of the final product and its sustainability.

The success of mass customization is possible if the user takes an active role in the design of the space together with the designer [6]. The real problem at this point is the way the user is involved in the process. The conventional user-designer relationship includes an approach where the users verbalize their wishes and needs while the designer puts them into practice. The users have no professional knowledge, and the designer may be inadequate about the user's spatial preferences [7]. Because the designer's access to user data is on the users' conscious needs and wishes. It is not possible for the user to obtain data about their unconscious needs coming from their routines created in time and space. Therefore, the need for a comprehensive analysis of the user's data on the use of space is obvious.

1.1. AIM OF THE THESIS

The aim of this thesis is to introduce a mass-scale customization data framework based on the spatial routines created by the daily activities of the users. The following research questions were determined to be answered within the scope of this study:

- What were the effects of the user representation when the general acceptance was evaluated over designs and user-participated designs?
- How are the provisions of the spatial routines created by the daily activities of the user in the design?
- How can a mass-scale application of user-centered data based on spatial routines be possible?

Considering the literature review, a study in which user representation in spatial design is examined through mass production and mass customization in housing has been revealed within the scope of the research question. In this study, it is aimed to discuss the relationship between the user and the designer in design through mass production housing where the user

is assumed to be without identity and mass customization housing based on user-participated design. As a result of this discussion, it is seen that the greatest deficiency in the relationship between the user and the designer is the difficulties experienced in the expression of the user's conscious and unconscious needs during communication. Because the conventional data sharing between them during the design includes the personal or stereotypical social preferences that the user expresses to the designer. Determining the needs coming from the unconscious choices of the users arising from their daily routines is difficult at this stage and emerges with the implementation of the project. Therefore, the determination of users' spatial routines is not a short-term task but should be studied within a certain time frame. Since it is not possible for a designer to live with the user and detect movement cycles, it has been considered that individual and collective use-specific technological tools that are collected over time will reveal the spatial reflections according to the time periods in which individual routines in living spaces show variability and stability. Therefore, it is aimed to create a time-based user-centered data framework by analyzing the daily activities and spatial routines of users in consideration of the examination.

1.2. SCOPE OF THE THESIS

Within the scope of this thesis, the ways of collecting user data required for customization and to produce a user-centered model for mass customization by discussing the role of the user in conventional housing design and the reflections of the spatial routines from daily activities in the design are determined. This study generally consists of five main chapters.

In the first chapter, information is given about the purpose, scope, and methodology of the study. In the second chapter, examples of mass production and mass customization in housing were presented. A literature review is presented in terms of the development and change of standardization and customization over time, the approaches of different countries in this context, usage differences, deficiencies, and benefits. Furthermore, the designer-user relationship is examined through mass production and mass customization in housing and the conflicts between the existing user-designer-product are criticized. The effects of the user and designer working together in the design and the fact that the user is assumed anonymous are discussed.

In the third chapter, the field of information and communication technologies is introduced and how technological developments can be used in user knowledge acquisition is discussed. In light of this information, tools that can play a role in obtaining user-centered data have been determined, and the effects of these data on spatial design have been evaluated.

In the fourth chapter, the daily activities of the users, their spatial routines, the relations of the users with the people with whom they share the house, and their spatial reflections are examined. Then, a user-centered data framework was proposed by analyzing activity-time-space relationships.

In the last section, we discuss the contributions and limitations of the proposed user-centered data framework and its place in future work.

1.3. METHOD OF THE THESIS

Within the scope of this study, an interdisciplinary literature review including primary and secondary sources was conducted. Within the scope of the study, prominent books, articles and websites on the subject were scanned and multiple sources were consulted. First, a literature review was conducted to determine the place of the user in mass production and mass customization approaches, and these two approaches were evaluated through the relationship between the user and the designer. Then, the negative and positive aspects of these two approaches to meet the needs and desires of the user are presented. Following the determination of the users' behaviors towards personalization in their living spaces, the user data generated by the user's needs and desires were determined. It was pointed out that information and communication technologies can be utilized in the way of obtaining user data through the inadequacy of the designer-user relationship established in conventional design techniques. Then, a literature review on information and communication technologies and personalization is conducted and an evaluation is made on the use of user data for personalization. In the next section, a literature study on the daily activities of users in space and the spatial routines that these activities create is presented. It is pointed out that the user data provided by spatial routines can be collected with the help of the ICT presented in the previous section. Then, a user-centered data framework is presented in order to use this data for personalization in spatial design.

2. PRODUCTION APPROACHES AND THEIR RELATIONSHIP WITH THE USER IN ARCHITECTURE

Throughout history, different approaches have been encountered in the design and production of space in architecture. While the relationship between the user and the designer is effective in spatial arrangements, the place of the user in the design process is shaped according to this relationship. The designers are at the main creators with their professional knowledge in spatial design and production. The user is in the background compared to the designer in the design process.

Within the scope of this study, mass production and mass customization approaches and the role of the user in the design phase were evaluated. In the mass production approach, the user is accepted as a user profile under general acceptance, while the user's participation in the design is ensured in the mass customization approach. In the spaces to be produced, two different directions are observed in terms of the representation of user-related data in the design.

2.1. MASS PRODUCTION AND BASIC USER PROFILE

Mass production in architecture is the production of standardized building or building elements with repetitive construction techniques with industrial production techniques. Prefabricated structures or structural elements are assembled on site after being produced at the factory. The adoption of standard designs and the use of industrial construction techniques enabled mass-produced housing to be produced quickly, cost-effectively, and of comparable quality. The main characteristic of mass production is standardization. Adoption of standard designs in mass-produced housing is possible if the designer decides on the basic user needs instead of the user. The designer is in the foreground, the user is anonymous. As a result of standardization, the quality of the product produced as a result of standardization is always constant. A product may consist of a single standardized component or it may be a combination of multiple standardized units. A space consisting of standardized building elements allows the replacement of the unit in case of a problem in any of its units. Therefore, one of the aims is to ensure the sustainability of the building. It is aimed to increase the

efficiency in production with the division of the labor force in production, low cost and fast production.

2.1.1. Standardization as a Modernist Dream

Standardization is the base of mass production housing. It is considered as the cornerstone of modernism as it initiated industrialization in architecture [8]. It is possible to achieve success in mass production by standardizing not only the design and building elements but also the process. The users of standard designs and products is also considered as anonymous. The standardized spatial provisions of the basic needs of the anonymous user appear in mass-produced houses.

After the World War II, the concept of "form follow function [9]" became popular as architects rejected ornamentation and emphasized the function of the building. Post-war architecture was shaped by the use of new production techniques and building materials. As industrialization progressed with technological developments, the idea of industrialization in housing came to the agenda with standardization. Henry Ford's reduction of the production process of a car to 93 minutes with the moving assembly line he established in 1913 is considered the beginning of mass production. This approach, which followed a parallel path with the modernism movement in architecture, also supported the architects' dream of responding to the needs of the public collectively. Modernist architects such as Le Corbusier, Walter Gropius, Frank Lloyd Wright, Mies van der Rohe and Jean Prouve worked to rebuild the cities destroyed after World War II in a new order [10].

Le Corbusier's La Ville Radieuse "City of Tomorrow (Fig. 2.1)" city plan proposal was designed for Paris and first presented in 1922. This design, which he thought could be utilized by millions of users, is a reflection of his dream of a "living machine" [11]. Le Corbusier, who also published a book with the same name, is proposed a modern urban planning with his project consisting of symmetrical, standard and multi-storey skyscrapers [12].



Figure 2.1. Radiant city by Le Corbusier [12].

One of the most important works on standardization is the redesign of the city center of Le Havre (Fig. 2.2), which was bombed in 1944, by architect August Perret. Perret, known as a pioneer in the use of reinforced concrete and prefabricated materials, built a new city with apartment blocks and government buildings designed with prefabricated concrete elements. The city he built was recognized as a UNESCO World Heritage Site in 2005 [13].



Figure 2.2. Le Havre by August Perret [14].

Following the example of Mies van der Rohe, Minoru Yamasaki saw the use of prefabricated building parts as an alternative to find a solution to the housing shortage in St. Louis (Missouri, USA) in the 1950s [15]. His Pruitt-Igoe public housing (Fig. 2.3), built in 1954, is a striking product of Yamasaki's modernist architectural approach. Over time, the housing, which began to house only residents of a certain race, was subjected to racism and

demolished by the St. Louis Housing Authority (PHA) in 1972 with the problems of uncanny, insecurity and lack of belonging it brought with it. The Pruitt-Igoe public housing project, called the collapse of modernism, failed to create livable spaces for low-income user groups with low cost and standardization [16].



Figure 2.3. Pruitt-Igoe social housing [17].

Therefore, mass production houses became widespread especially after the Second World War in order to meet the urgent housing shortage. In order for cities to recover quickly, the housing production process must be accelerated and the production cost must be low. Since the housing deficit was too large to be met with conventional construction methods, governments supported mass production as a new construction technique. In this direction, standardization was achieved by the designer's production of spatial equipment.

By using standardization, different cultures gave different examples. While these perspectives affected cultures differently, at the same time, they influenced the development process of the industrialization of housing. This study is limited by three main regions, namely the United Kingdom, Scandinavia and Japan. While UK is ahead of other cultures in terms of ideology, Scandinavian countries in terms of product, and Japan in terms of function [18].

2.1.2. Prefabrication and Different Perspectives

The UK has an older history of prefabrication compared to other countries. First, prefabricated housing construction started in the West with the efforts of global colonization. England does not dominate the local building materials of the settlements it colonized. For this reason, it transported the building materials produced in its own country to all over the world by ships (Fig. 2.4). Prefabricated structures from England were identified in Cape Anne (Massachusetts, USA) in 1624 and in New South Wales and Sydney (Australia) in the late 1700s and early 1800s. At the same time, Richard Walker's initiation of the export of corrugated iron in the early 1800's provided the first wood and iron structural system around the world. This building material, which is widely used today, has an important place in prefabricated architecture because it is portable and can be installed where it is transported [18].

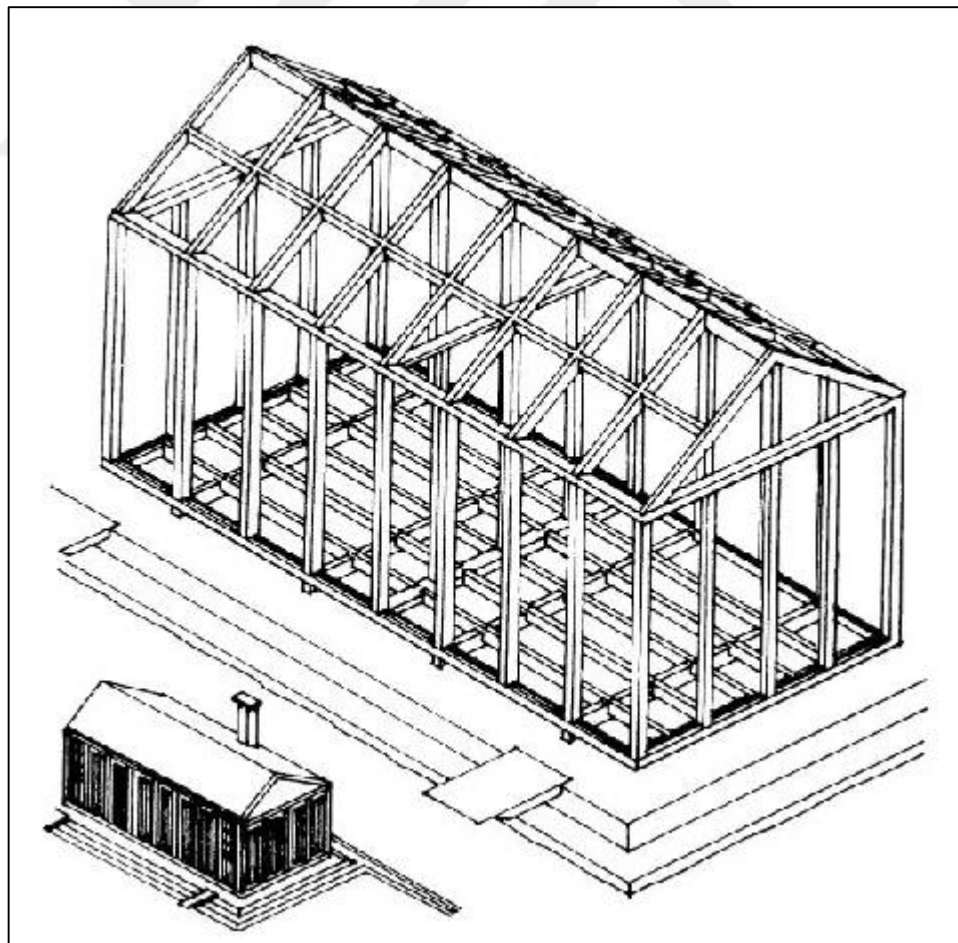


Figure 2.4. Portable colonial cottages [19].

England started to use mass production effectively in houses for the renovation of damaged houses after the Second World War. With the Winston Churchill government enacting the “Temporary Prefabricated Housing Program”, factories started to produce housing parts [20]. Within the scope of this program, a competition was opened and 1400 designs, most of which were rejected, participated in the competition. The most used designs are Arcon, Uni-Seco (Fig. 2.5), Tarran and Aluminum types [21].



Figure 2.5. Uni-Seco prefabricated houses, London [22].

However, low quality and short-lived houses could not adapt to changing times and users, and the number of prefabricated houses decreased over time. England has taken a leading position in prefabrication as a result of its colonial approach and its desire to expand its field of activity. By using technology more effectively, it has produced sustainable and dynamic structures and has had an impact on the spread of this practice to many cultures. As a result of adopting the policy of expansion as the main goal, England has developed various kinds of standards throughout history, but has not been interested in individualization.

The design of the first Scandinavian mass-produced residential elements began in the mid-1800s when architect and colonel Fredrik Blom was inspired by mobile structures such as barracks. At the same time, Blom offered his clients individual building elements, such as walls with doors or windows. These elements, which were originally handmade, were industrialized in a short time (Fig. 2.6).

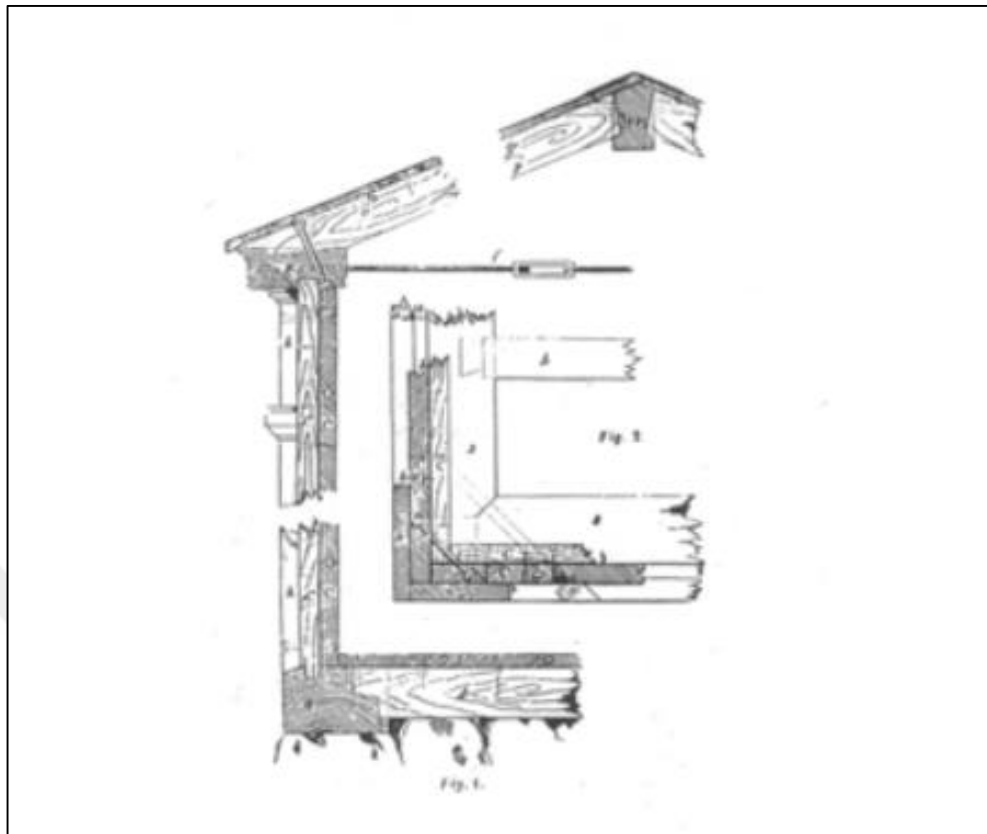


Figure 2.6. Fredrik Blom's prefabricated house drawing [23].

The large housing shortage that started in 1917 brought the production of prefabricated housing with mass production technique to the agenda in Sweden and Norway. In 1922, the National Social Welfare Board (Sossiaalihalitus) commissioned architects to design different farmhouses. With the "standard drawings for small houses" published for this purpose, the foundations of mass production began to be laid. In 1936, Alvar Aalto contributed to standard tiny houses with 3 different designs, which he called the AA system (Fig. 2.7). Then, in 1940, he designed Finland's first residential manufacturing plant focused on standardization. This allowed the use of mass production to spread throughout the country. After the the World War II, Finland not only used mass-produced housing to fill its housing shortage, but also paid its war debt to the Soviet Union with prefabricated housing parts [24]. Today, the Scandinavian government continues to use prefabrication production to build accessible housing and public buildings for all. 84% of single-family homes in Sweden have prefabricated elements, which greatly saves construction costs. This rate, which is 15% in Japan, is 5% in the USA, England and Australia [25]. When its historical development is examined, it can be seen that Scandinavian countries use mass production effectively in part production instead of mass housing production. In this method, which is

personalized according to the needs and wishes of the user, efficiency takes precedence over flexibility. Therefore, standards are specific and variations are limited [26].

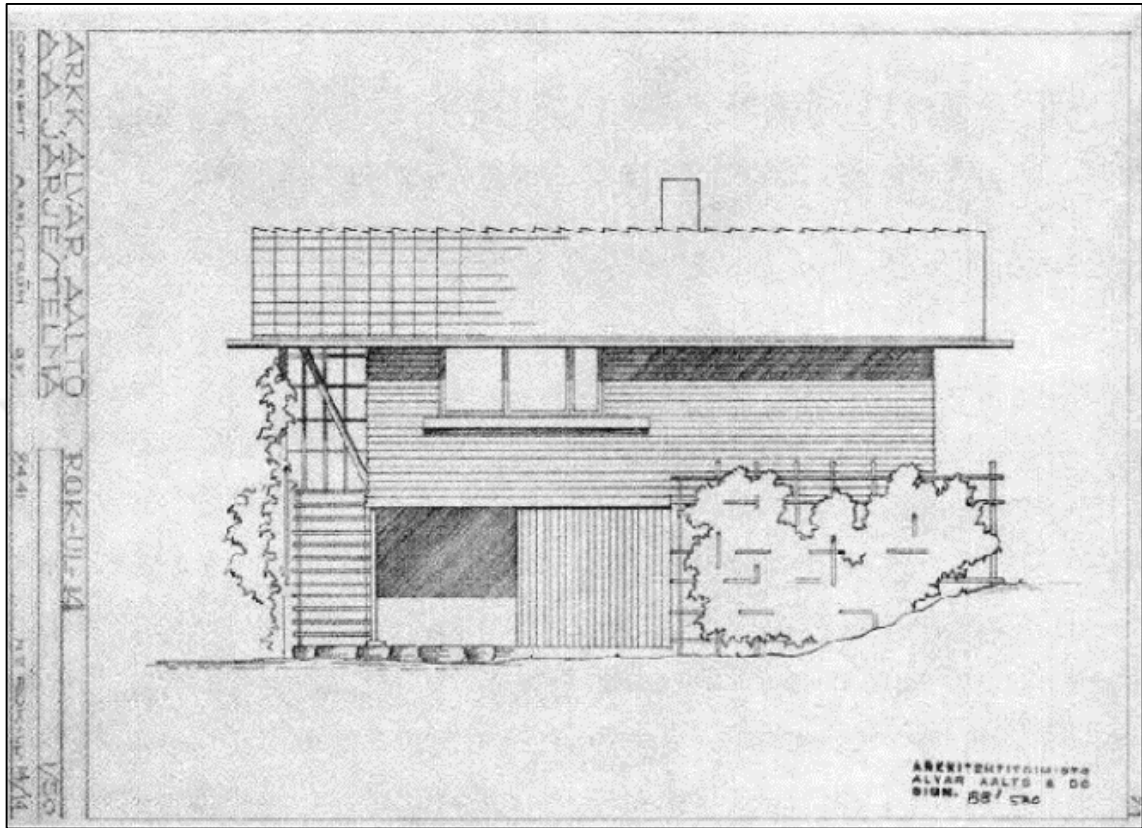


Figure 2.7. Alvar Aalto, AA-System houses type 14, 1939 [24].

Scandinavian countries mainly use wood as traditional building material, since most of their lands are covered with forests. Due to the fact that wood is a successful raw material in the production of prefabricated structures, mass production wooden structures have become widespread in its buildings. Thus, after filling the housing shortage, Scandinavian countries that adopted prefabricated wooden structures were more successful than the UK in developing the end product. Scandinavian countries, which have increased the preference of users by adapting mass production to their traditional houses, have worked on combining standardization with customization over time, thus producing higher quality houses.

The use of prefabricated housing in Japan dates back to more recent times compared to other cultures. Prefabricated houses, the first examples of which were seen in the 1960s, made their first rise between 1965-75 and the second rise between 1975-85 [27]. After World War II, almost 40% of industrial facilities and infrastructure were completely destroyed in Japan, and a housing shortage arose. With the effect of the current economic situation, the fear of

losing their national identity emerged with the system model proposed by the USA after the World War II. Additionally, with the massive migration of the working population to the cities, housing had to be provided for white-collar workers. As a result of these situations, the Japanese government proposed a plan to re-establish the cities [28]. Founded in 1955, The Japan Housing Corporation was tasked with producing mass-produced housing for middle-class families. As a result of several years of research, standardized 40 m² houses with standardized appliances (washing machine, TV set, rice cooker, bathtub, refrigerator, etc.) called “danchi” were designed and produced (Fig. 2.8).

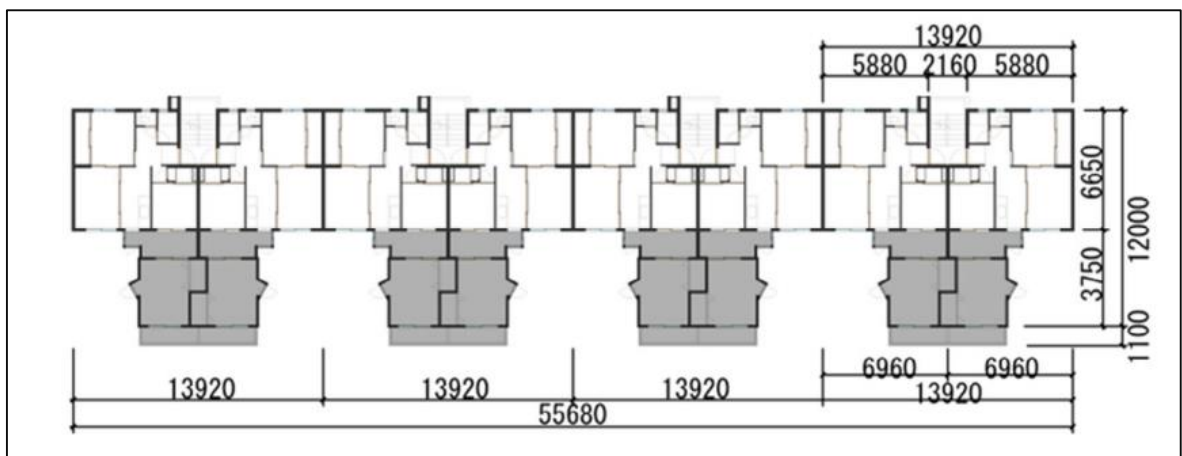


Figure 2.8. Floor plan of Kunitachi Fujimidai danchi [29].

At the same time, many Japanese intellectuals, including the architect Kisho Kurokawa, had similar socialist ideas [30]. The metabolism movement led by Kurokawa, which emerged within the scope of the re-establishment of cities, argued that the structures formed by standardized living units should be in an organic life cycle [31], (Fig. 2.9). Japanese prefabricated houses are named as “cross-cultural experiment” based on combining Western and Soviet housing typology with traditional Japanese elements in order to use mass production in housing production [32]. As of 1980, with the announcement of the Japanese government that it had solved the housing shortage, the mass production of the houses began to slow down, and instead, the manufacturers focused on the production of housing parts for product development [33].



Figure 2.9. Nakagin Capsule Tower, Tokyo [34].

Japan is culturally inclined to mass production, considering its social history. Since ancient times, the Japanese people's readiness for constant movement and displacement, stemming from the past of central authority, supports prefabricated production. Due to the lack of soil, the economic activity's orientation to industrial products obtained by using human brain and technology rather than agriculture after the World War II revealed the necessity of the construction of high-density buildings. As a result, land scarcity, population density and the adoption of wood as a traditional building material, the dependence of the economy on technology facilitated Japan's transition to mass production.

Therefore, in terms of ideology, England, Scandinavian countries as the final product, and Japan in terms of process have been more successful in mass-produced housing than other cultures. However, although they contributed to mass production houses in different aspects, they could not prevent the problems created by standardization. For this reason, mass production technique still lags behind in preference compared to traditional methods.

2.1.3. Homogeneity Becoming the Problem

Mass production houses, which became widespread in order to meet the post-war emergency housing deficit, aimed to meet only the basic needs of the users. Standardized spaces to meet basic needs have brought usage problems with interaction with multiple users. The main reason for the usage problems is that the house, which is defined as a social space [35], is

reviewed with an approach where the user is deemed to be anonymous. This approach is not compatible with the spatial movements of the users in their living spaces over time.

Spatial standardization aims at minimally satisfying the basic needs of an anonymous user. The houses standardized with mass production are low quality houses as a result of low cost and production in a short time. After the production phase, the place of the users in their daily lives is left in the background during the usage process of the house. As a result of this situation, the mass production houses of the period played an important role in eliminating the urgent housing shortage; however, with the increase in the quality of life of the users, they have been abandoned with the lack of belonging that the users feel towards their living spaces.

The fact that users feel a strong sense of belonging to a particular place or place that is similar to them or in which they feel unique [36], and does not prefer to live in similar living spaces is an important factor for the user to choose the place to live. With this assumption, it can be said that the uniform spatial designs offered to the users, apart from the personal belongings of the users and the experiences in them, will adversely affect the preferences of the users. The lack of identity and belonging, which developed as a result of homogeneity, over time, standard housing designs could not adapt to the spatial routines of different users [37], and remained insufficient to meet their wishes and needs [38]. Meeting the spatial needs of the users from the perspective of the designer has restricted the usage of the space and forced the users to act in a certain standard. But humans are social beings. Although user needs can be addressed under certain assumptions, it is not possible to conform user actions to a certain standard. The efforts of each user to transform their own home into a living space are directly related to the search for customization and belonging.

The fact that mass-produced houses are based on uniform spatial designs and do not allow for customization has made the anonymous user, who was assumed to be anonymous before the design, identical over time and de-identified [39]. This oppressive system perception has negatively affected the continuity of the houses by causing mass production spaces to lose their popularity rapidly. These houses, which are intended to appeal to users from all walks of life, have created neighborhoods that only users with insufficient financial situation have to choose during the process. Neighborhoods formed by mass-produced houses were characterized as uncanny, triggering class differences [40]. In the process, many of the mass production houses were abandoned and were not preferred in the future. The biggest example

of this can be seen in Pruitt-Igoe social housing (Fig. 2.3). Built with the aim of providing quick and low-cost housing for low-income users, this complex has been considered a failure of social housing. The fact that its users do not show any sign of belonging by watching its demolition is proof that this housing experience is no more than a shelter.

The only problem of today's mass housing is not to force the users into living spaces that meet the same and most basic needs. At the same time, mass production houses that allow growth and change to a limited extent will force their users to relocate when they are insufficient to meet the user's needs, or rather, when the production purpose is achieved. Although the modern society is a mobile society open to relocation, the evacuation of the houses that cannot meet the needs creates a great housing pollution. Since the remaining living spaces do not allow conversion and individualization, they are either demolished or transferred to the next owner. However, the fact that the housing stock is renewable and adaptable to life in a short time will be considered as a big step in terms of a sustainable society.

As a result, in mass production where the designer is at the forefront, the focus is on the basic needs of the user and the personal preferences of the user are ignored. An identity is not assigned to the user, as it takes time to meet the various requests and needs of different users in each separate design and production. However, in designs where the designer determines the user's needs under certain assumptions, although fast and standard results can be obtained with unilateral decisions, the fact that personal needs and wishes are not reflected in the design creates problems during use. This basic problem is that the user and the design cannot interact with each other as a result of the lack of communication that develops due to the fact that the person designing and using the space is different from each other. Therefore, an approach in which the designer does not act around the user's personal data negatively affects the usability of the final product and its sustainability as a result of this situation.

2.2. MASS CUSTOMIZATION AND USER PARTICIPATED DESIGN

Mass customization in architecture is the large-scale production of customizable building or building materials. This approach, which combines mass production and customization, aims to meet the various needs of different users at the same time. In mass customization, the process is standardized. Therefore, the wishes of the users can be met in the design. It

enables the rapid, low-cost and sustainable structure or building materials provided by mass production to gain flexibility through customization. The key to mass customization, which allows standardization and customization to work together, is communication between the user and the designer [41]. In spatial design, the user and the designer should work together [6]. The designer has professional competence but has no knowledge of the user's spatial preferences [7]. Therefore, with this approach, the designer transitions from the creative role to the controller and assistant role. The success of the mass customization approach is possible with the comprehensive decoding of the data on the user's use of space.

2.2.1. Creating Variations From Uniformity

The reason why mass production structures are not very successful in history is not only due to the process and technique. During the World War II, the mass production houses that had to meet the urgent housing need had to be produced in a short time due to economic inadequacies. In this context, the buildings of the period were of low quality, meeting only the most basic needs, and leaving the aesthetic and sense of belonging in the background [3]. In contrast to low-cost standard products of mass production; the reflection of low-cost, high-quality customized products on the architecture as flexible and adaptable houses highlights the idea of mass customization [3], [42]. This approach puts the users' wishes and needs at the forefront, ensuring that the final product is suited to their needs.

This idea, which came as a suggestion to the problems created by standardization, became popular after the book *Future Perfect* by Stanley Davis [43]. While mass customization in architecture represents a shift towards a more adaptable, sustainable, user-centered and technology-driven approach to design and construction, also allows for greater flexibility and customization to users in a more efficient way.

In this direction, the architects created flexibility in spatial designs, allowing the user to organize the space according to their own routines during the usage phase. The "support theory" developed by Habraken in the 1960s, on the other hand, is a proposal for the use of mass customization with customizable living spaces (infill) and infrastructure and carrier systems (support) (Fig. 2.10). This system, which contains functional spaces that designers can manipulate to produce different solutions, encourages diversity and customization [4], [44], [45]. This system, called Open Building (OB), allows flexibility and customization in

design by providing structural flexibility, modular and demountable elements, accessible infrastructure, service distribution and user involvement.

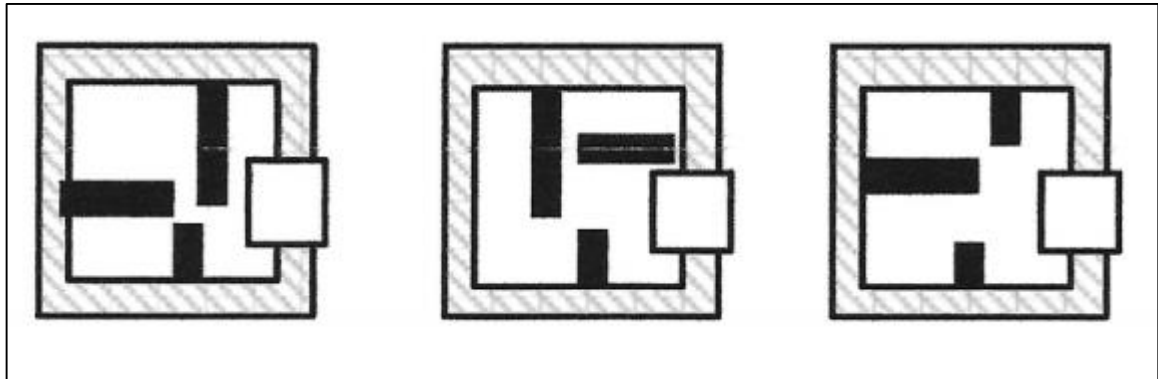


Figure 2.10. Habraken's support and infill variations [4].

The main point when creating a flexible space is changeability. Therefore, every solution offered for a variable purpose of use or a space that will adapt to the user can be changeable space definitions, space elements or location derived from this. In modern life, it is not easy to create spaces that can adapt to the user while designing the living space and transform according to the wishes and needs of the user, in structures produced with traditional methods whose common feature is stability. At this point, mass customization aims to respond quickly to flexibility [3]. Although at first glance, mass production is seen as a form of production that is the opposite of individualization, it is quite possible that it can provide a rapid transformation within the limits of today's technology. Customization allows users to create living spaces that align with their lifestyles, preferences and dynamics while creating a long-term satisfaction. Due to mass customization, it is possible to provide low cost and high quality buildings to more users at the same time (Table 2.1).

Table 2.1. The basics of mass production and mass customization.

<i>Mass Production</i>	<i>Mass Customization</i>
Rigid	Flexible
Standardization	Customization
Low-cost	Low-cost
Low quality products	High quality products
Anonymous user	User has an identity
User does not involved in design	Participatory design

Famous architects, who called mass production and standardization as the architecture of the new and modern world, also contributed to mass customization with the open plan application. Towards a New Architecture, in which Le Corbusier shares his housing proposals [2], consisting of floors rising on pilotis, can be defined as a handbook on transforming standardization from uniformity to flexible practice. The Dom-ino House (Fig. 2.11) he proposes in this direction is an example of a customizable open plan application that gives freedom to the users to implement their own spatial routine indoors [46].

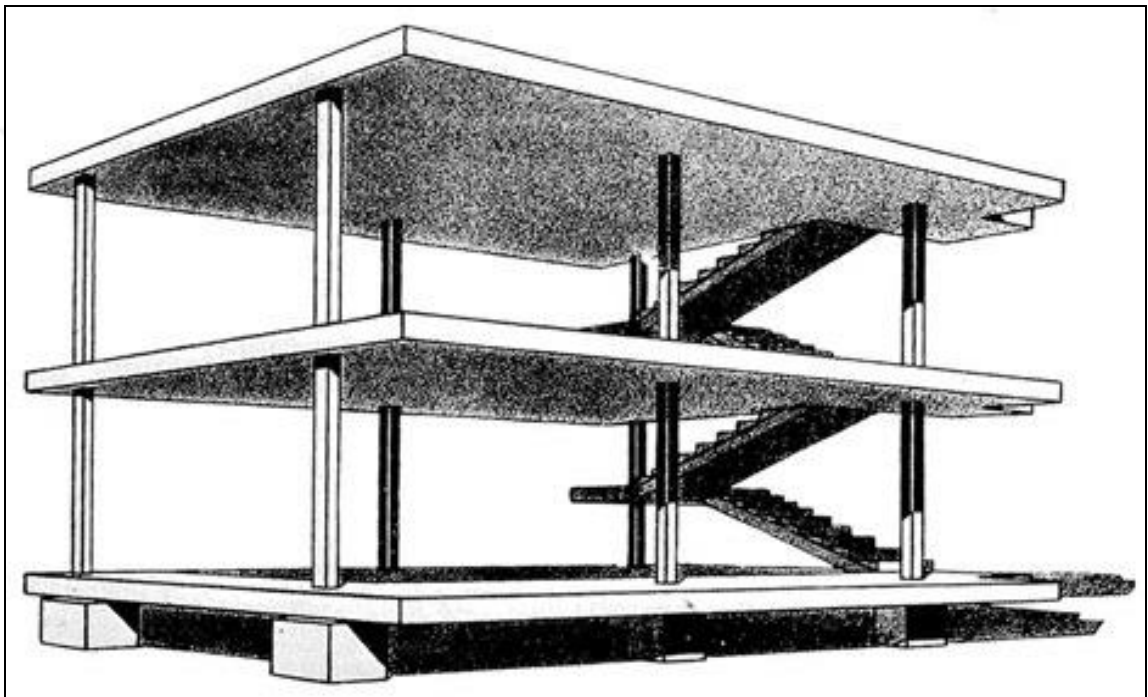


Figure 2.11. Domino House by Le Corbusier [47].

One of the architects working in the field of mass customization is Jean Prouve. Jean Prouve has worked with Le Corbusier on prefabricated houses in the early periods of the Second World War [48]. In the 1930s, Jean Prouve designed the Meudon House series (Fig. 2.12), which was formed with a prefabricated steel and aluminum carrier system, allowing planning in 25 different ways [3]. This housing design, which is offered with low-cost, prefabricated standard building elements, sets an example for mass customization with its fast and customizable features [49].

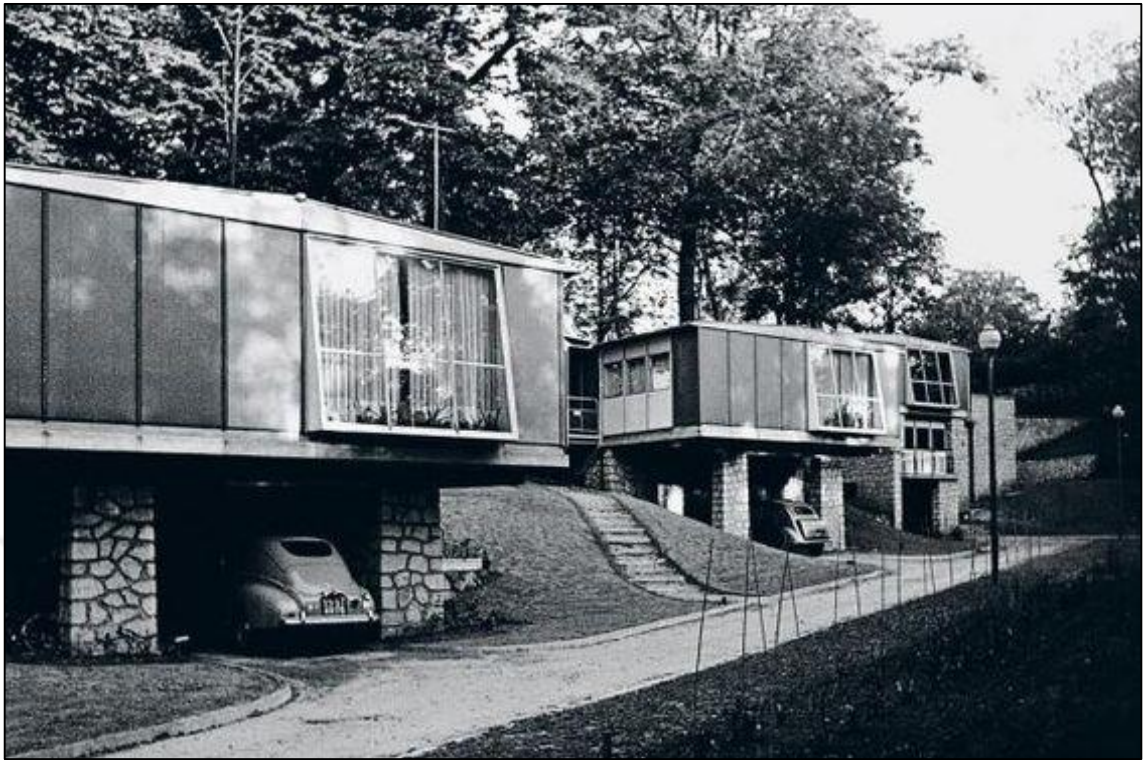


Figure 2.12. Meudon House by Jean Prouvé [50].

The main approach adopted in mass customization is to allow space for users to combine the designed building elements in different combinations [51]. Therefore, in these first examples, it is seen that the plans are presented openly to the user in order to customize the single houses for different users. Although they do not allow users to customize the exterior, open-plan single house designs give users the opportunity to create their own living space units in the interior.

While designers have introduced customizable open-plan single dwelling designs, experiments in a mass context have also begun to emerge. One of them, the Danish housing company Larsen-Nielsen, has created a mass housing design that is widely customizable. The LN-NYBO apartments (Fig. 2.13), with 14 different possible combinations ranging in net area from 33 m² to 113 m², were launched in 1968. The system was highly successful and by 1980 more than 9000 apartment blocks had been built in the country [52].

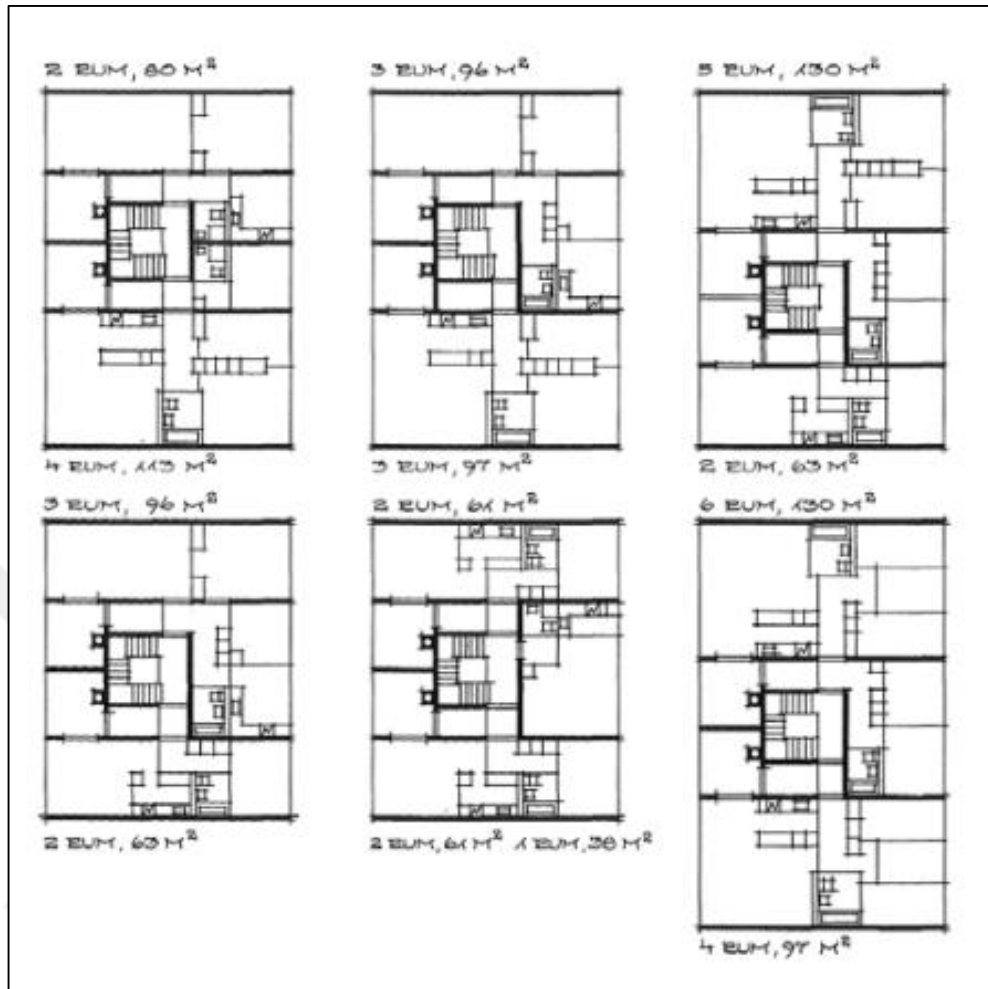


Figure 2.13. Larsen&Nielsen system [52].

Mass customization emerged especially after World War II to fill the housing shortage and to offer fast, low-cost and high-quality products instead of the fast, low-cost and low-quality products of mass production [53]. Therefore, countries that meet the urgent housing shortage with the production of standardized prefabricated buildings and structural elements have put into practice new forms of production that will serve their personalization and aesthetic concerns. While England, following an expansionist policy in mass production, returned to the traditional mode of production as the level of welfare increased; Scandinavian countries and Japan, which are historically, culturally and socially more prone to mass production, continue to expand their mass customization practices today.

2.2.2. Customization over Standardization

Following an expansionist policy in prefabricated housing production, England continued its industrialization efforts in housing production after the Second World War. The British government, which aimed to provide housing to low-income users with standard, pre-cast building elements, continued to produce housing until the mid-1960s. Contrary to social housing, which continued to be produced with industrial building materials until 1972, private houses continued to produce with traditional construction techniques. With the deaths as a result of gas leakage in a multi-storey housing estate in London in 1968, the confidence of the users in industrial structures was shaken, and the construction of low-rise traditional English houses was emphasized [54]. Industrialization in housing production in England has not developed much due to problems such as lack of specialist subcontractors, problems in the land acquisition process and planning regulations. Although a big step has been taken in the field of mass production building elements, it has lagged behind other countries in terms of industrial customizable housing diversity [55], [56].

The use of modular and prefabricated houses in Scandinavian countries has developed faster than in other countries, as they use ready-made wooden structures in 90% of their traditional structures [57]. Therefore, studies of Scandinavian countries on standardization in housing production are quite high. Having difficulty in meeting the housing deficit of growing cities over time, the Swedish government helped companies producing standardized housing until World War II. Sweden, which remained neutral throughout the World War II, suspended its industrialization efforts. Between 1865 and 1975, he produced million houses (Fig. 2.14) to meet the 50-year housing deficit [58], [59].



Figure 2.14. Prefabricated small houses in Sweden [58].

In this period, the production of prefabricated steel and wooden frame carrier system housing is quite high. However, after the housing shortage was filled, the government changed its standardization policy to mass customization by 1980, as users wanted to improve their quality of life and be seen as individuals [60].

Lindbäcks Bygg is one of the housing production companies that opened the standard mass-produced housing typology to user customization. Established in 1924 as a forest products company, Lindbäcks Bygg began production of detached houses in the mid-1960s and multi-unit houses in the mid-1990s [61]. The company developed an interface that allows customizable standard structures to be designed before they go into production, using pre-designed floor plans and diversifiable space modules [62]. Today, Lindbäcks Bygg continues to produce single family house and multi-storey houses that can be customized according to user preferences [63]. Another is BoKlok houses (Fig. 2.15), a joint product of Swedish furniture brand IKEA and international construction company Skanska. This partnership, which established a market extending to England with the first BoKlok house produced in late 1995, aimed to offer offsite houses to users with low cost and customizable options [64], [65].



Figure 2.15. BoKlok Modules [66].

In 1970s, the Japan government announced that the housing crisis has been solved [30]. As a result of the quantity has been reached the optimum, the need for work in quality has emerged [67]. So, the prefabrication housing companies turned their standardized products into standardized elements which allows customization [33]. In the mid-1980s and during the 1990s, mass customization was a viable strategy for the large national housebuilders [27]. Misawa House (1967), Sekisui House (1972), were the largest modular house

companies which evolved in this context. Even the Toyota, the Japanese car company has entered the housing sector in 1972. Although they use their users choices on the purpose of providing flexibility, their franchises had no specialists for housing sales. So, their housing plans were more standardized than Sekisui and Misawa Homes [67], [55]. Misawa Home's O model was received attention by its customizable plan at 1976 [33]. It has created competition between national housebuilders. The largest, Sekisui House has improved this customization by using steel frame units as an adjustable platform, customizable building components and allows changing in surface structures and painting [68], (Fig. 2.16).



Figure 2.16. The first Sekisui House model A, 1960 [69].

These companies did not just try to improve the quality of the new housing. They also began customizing existing abandoned houses. As an example, Sweden based IKEA and Japanese company MUJI started a collaboration to renew apartments all over Japan (Fig. 2.17) (Fig. 2.18). They aimed to attract users by renovating and customizing their danchi apartments [32].

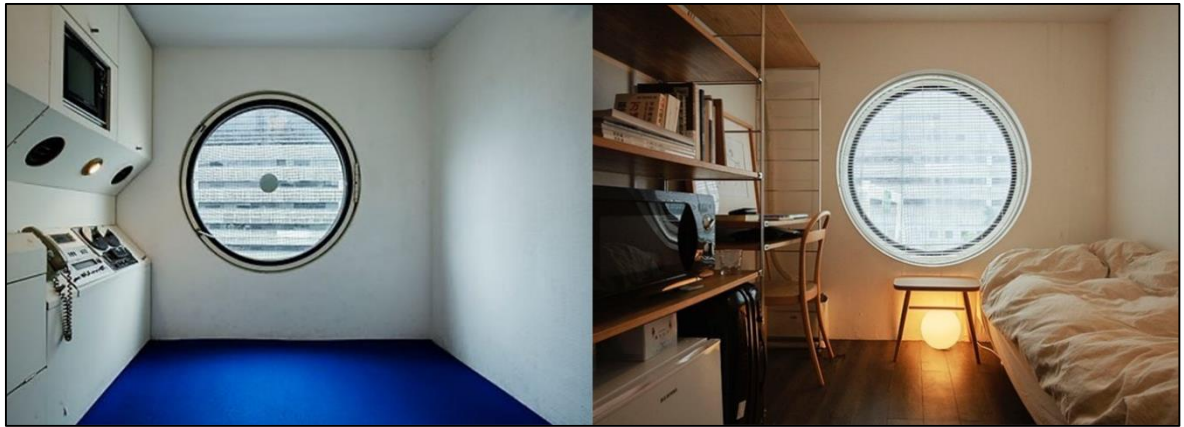


Figure 2.17. Nakagin Capsule Tower renovation before [70]/after [71].



Figure 2.18. A Danchi apartment renovation before/after [32].

Different governments pursued different policies to overcome the post-war housing deficit. The use of standardization and mass production in housing production took place in this direction. Mass-produced houses with an anonymous user group that is intended to appeal to users from all walks of life have created a building community with no identity. The mass customization approach emerged against the problem of anonymity brought about by homogeneity in housing.

The introduction of mass customization as an idea in architecture occurred at the same time as the elimination of the housing shortage and the improvement of the quality of life of the users. Therefore, countries that were pioneers in mass production also paralleled the initiatives of mass customization. However, as urgent needs were met and the quality of life

of users began to improve, countries' mass customization policies began to change according to their cultures.

The UK, which has successfully carried out a policy of mass production housing, has not been able to continue the same approach in parallel with the increase in the quality of life of the users. Although studies have been carried out on this subject, industrialization in architecture has not been preferred by users. This preference can be explained by the lack of specialized personnel and land speculation. At the same time, from a social perspective, users prefer private housing over social housing. The UK, whose housing market is characterized by private, low-rise housing, emphasizes the use of traditional building materials and traditional construction techniques.

In Scandinavian countries, on the other hand, mass production has been developed because traditional building materials are suitable for the production of prefabricated building elements, the inhabitants are mostly single-income earners (high divorce rates, individual living) and the government supports family-owned companies that produce small and standardized housing. Therefore, even when the quality of life of the users improved, they continued to prefer this type of housing. Users' preference for mass-produced housing led small housing companies to improve their products, and highly customizable mass-produced housing increased.

Similar to Scandinavian countries, Japan is prone to mass production in terms of culture, traditional building materials and social aspects. In contrast, Japan, which suffered from land scarcity, turned to technology rather than agriculture to improve its post-war economy, and industrial housing production developed accordingly. While users in Japan had a similar approach to mass-produced housing similar to social housing in the UK, they started to prefer these housing units as the buildings could be personalized with technological developments.

In conclusion, it is possible to say that the preference of users for industrialization in buildings is directly related to economy, culture and social structure. England, Scandinavian countries and Japan, which achieved similar results with different policies in mass production, it is seen that in the case of England, mass customization in buildings was not accepted by users. In Scandinavian countries and Japan, on the other hand, the fact that social housing production is a source of income for users and that it develops in accordance with their culture has affected its preferability.

In this respect, it is possible to say that user preferences are important in the housing market. Users who make housing choices based on their social structure, income, sources of income, technology and cultural background can change the housing policies of different governments. Therefore, user-centered design is a must when implementing a mass customization approach.

2.2.3. User-centered Design as a Solution

In mass customization, the user takes an active role in the design, working with the designer. This form of design, called participatory design, aims to increase product usability by involving the user in the design and production process. The user's involvement in the process creates the "I designed it myself" effect, reinforcing the sense of belonging in the users. An example of this is that users prefer customizable mass production products in their individual preferences [72].

Mass customization offers the user variety as well as the efficiency of mass-produced housing. Users can directly influence the design of their own living spaces with customizable solutions developed by designers. With this approach, which improves product quality, it is possible to respond quickly to the wishes and needs of users [53], (Fig. 2.19).

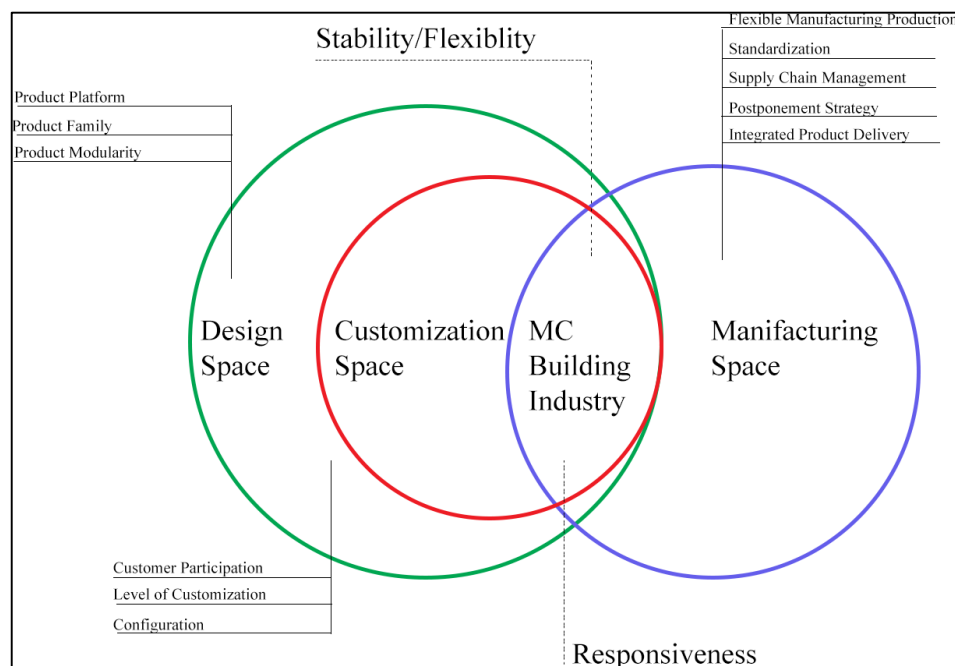


Figure 2.19. Mass customization in the housing industry [53].

Gilmore and Pine suggest four different approaches to customization: collaborative (customization according to user needs), adaptive (customization of standard products), cosmetic (presenting a standard product to different users in different ways) and transparent (customizing user needs and wishes for users by standardizing them) [73]. The ways in which the user is involved in the mass customization process can be summarized as co-design, co-production, co-construction and co-configuration [74], (Fig. 2.20). Co-production is a massive customization strategy in which the user takes part in the setup phase. Standard product elements produced by the designer are brought together by the user with certain instructions and involve the user in the process. Co-construction is the user's involvement in the development phase of product customization. The designer designs the standard product within his professional knowledge and develops it in terms of user personal preferences. In a design where the user is not involved, it is not possible for the designer to customize the product according to the user's wishes and needs. Co-design is a massive customization strategy that allows the user to control the design process. Due to this strategy, which also includes the user's point of view, it has been observed that it is more efficient to realize the user's needs by being understood by the designers. The final mass customization strategy is co-configuration. This approach allows the users to create the final product by making their own designs based on the standard elements determined by the designer [74], [75].

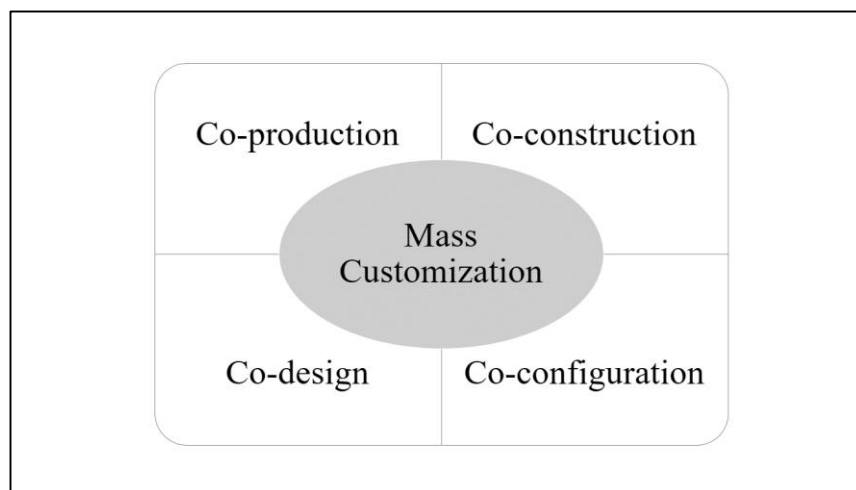


Figure 2.20. Mass customization process based on user participation [74].

The point to be considered in the participatory design method is to determine the approach to be used according to the discipline in which mass customization is carried out. The reason for this is that wrong or incomplete decisions that users without professional knowledge may take during the product design process may cause the end product to fail [76].

Considering mass customization in architecture, the co-configuration approach comes to the fore. Because, when mass customization and user participatory design method are examined in the discipline of architecture, it is not possible for users without professional knowledge to take part in the design, product development and construction process [7]. At this point, it is necessary for the user to participate in the design process in the transfer of personal data. In the manufacturer-customer relationship, the customer is the most important source of information for the manufacturer, since the person who uses the product and will continue to use it is the customer [77]. Likewise, in the architect-user relationship, the user is the architect's most important source of information. Because users are people who have knowledge about their spatial needs and usage patterns. It is not possible to design the spaces where personalization will be realized by determining the usage and purposes of the spaces by the architect and standardizing the basic needs. Therefore, user data transfer between architects and users gains importance. In order for customization to be successful, the user's personal data to be used in the housing design must be correctly determined and applied by the designer.

3. INFORMATION AND COMMUNICATION TECHNOLOGIES TO SUPPORT USER DATA ACQUISITION

Product customization is used to meet different needs and desires by take aim at different users at the same time, or to make the product interesting for different users. Although this method is to used as a sale an marketing technique, it is also an effective method for determining the needs of the user and meeting these needs. An example of this is that environmental psychologists who study the spatial behaviour of people by monitoring which routines the users perform in which spaces. One of the subjects studied during these observations is the improvement of environmental quality by planning a space as a residential and transit area at the same time [78]. Urban planners and architects defend that, in order to improve the quality of a place or environment, it is necessary to investigate what fuction the people who used give that place. Since users are dynamic living beings with different backgrounds, it is also necessary to understand that the space is not only design through function, but is shaped according to a usage routine [36].

Collecting user data for customizing a product is possible with conventional data collection techniques when analyzed on the basis of the examples above. However, in the current digital age, collecting and processing the data of millions of people at the same time is not possible with the conventional data collection techniques. Therefore, over time, the technique of continious monitoring of routine activities performed by individuals had to be developed. This is how the data pool called big data emerged. Every device works where electrical technology can be used in every field can routinely collect data from millions of users at the same time [79]. It has been determined that conventional data collection techniques are insufficient in defining spatial routines. It is not possible for the designer to be present as a direct observer while users perform their daily activities. Likewise, when looking at the data obtained through surveys and interviews, the user's lack of of awareness of which activity creates a spatial provision also affects the reliability of the data obtained in this way. To gather this data, a large data pool that collects the user's movements through electrical devices can be used. It is predicted that the internet of things (IoT), artificial intelligence (AI), location-based technologies and crowdsourcing apps which smart cities use to develop their infrastructure systems, can also be used to determine the user information.

3.1. DATA ACQUISITION IN INFORMATION AND COMMUNICATION TECHNOLOGIES

With the evolution of the internet, the change in the life conditions of the users goes in parallel. In the beginning, the internet, which only meant to provide information to the user, has expanded its service area over time and has become a system that works with the user. The internet, which has entered every aspect of users' lives in a period of about 30 years, from Web 1.0 to Web 4.0 (Fig. 3.1), is the most important resource used not only to provide information, but also to gather information [80]. While Web 1.0 only aims to provide information to the user, with Web 2.0, users have started to actively share information on the web. Later, with the emergence of AI and ML, the web 3.0 era started and the internet became a system where users and machines work together. The Web 4.0 era is the era of household appliances that can communicate with each other through the cloud system where personal data is stored and the internet of things [81].

WEB 1.0	COGNITION	machines provide information to the user
WEB 2.0	COMMUNICATION	the user is involved in the process of providing information
WEB 3.0	CO-OPERATION	user and machine work together
WEB 4.0	INTEGRATED	machines can also communicate with each other

Figure 3.1. Web eras and types of user-machine communication [80].

Internet of Things (IoT), which is among today's advanced technologies, is a general name given to identifiable objects (things) and their virtual representations in internet applications, enabling objects that can communicate with each other to be active elements in this process [82]. IoT not only connects the cloud, big data and artificial intelligence (AI), information and communication systems (ICT) but also connects the whole physical world to cyberspace,

providing continuous data transfer [83]. In general terms, user data is accumulated with the cloud to form big data. This big data uses artificial intelligence (AI) and machine learning (ML) to learn about users' preferences and show them future choices [84]. The preferences learned and expected to be made in the future are transferred back to the user's life as data. This cycle aims to provide the most appropriate service to the user by learning the user's character with the data obtained from the user.

Internet of things (IoT) and artificial intelligence (AI) are used in the smart city concept, which aims to collect the data provided by user behaviors and improve the life quality of the user. These systems can make user-specific data suitable for the users, even if the environment in which they are used changes [85]. For example, applications on smartphones serve two separate purposes as location data collected by GPS and applications based on user feedback. Space-centric data provides data on the use of space and frequency of use, while telco data provides monitoring of a device for a certain period of time [86]. In other words, smart cities integrate human-human, human-machine, machine-human and machine-machine communication via cellular network, Wi-Fi, bluetooth etc. It aims to provide development and welfare in cities by providing different platforms [87], [88], [89]. For this purpose, smart systems do not only provide continuous information about the current situation. It also stores this information so that it can improve the current situation. Considering AI and IoT technologies, transportation, security, energy, health, education, etc. it is possible to make improvements in many areas and to develop these systems according to user preferences with these improvements [90].

Another application for collecting user data is crowdsourcing. Crowdsourcing, which is used to develop products based on user preferences and feedback, provides fast feedback on products with low production time and complications. An example of this is search suggestions customized according to user searches on social media. In an area such as housing, which is difficult to improve once it is in use, crowdsourcing is rarely used today. However, crowdsourcing, which provides direct data on user preferences and patterns, offers a pool of data that can be utilized in housing design.

When examined as a usage area, a housing design is not made in accordance with these data. At this point, smart systems work in a way that the user can set and use after entering the house. An example of this situation is the examination of the annual usage distribution of the user for energy saving and the operation of the heating-cooling systems according to

these data. However, when we look at the design of the house, this data is specific to the heating-cooling systems and the design of the house is not designed to maintain the optimal temperature that the user will use in the first stage.

User data for personalization in house design can be classified as preferences, location and movement. The important thing here is to determine the ICT tools to be used to collect this data (Fig. 3.2). Within the scope of this study, crowdsourcing apps for user preferences, Wi-Fi technologies and navigation for location detection, and IoT devices for motion notification and user pattern determination are examined. While the data provided by the smart devices used in daily lives are used for customization, it is foreseen that AI and ML can be used to provide a framework for the user's possible preferences.

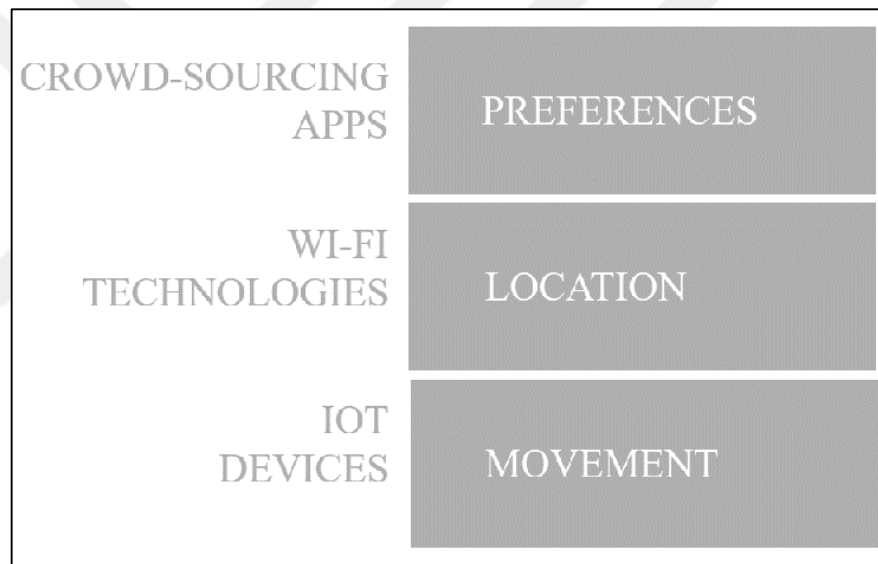


Figure 3.2. ICT tools for customization.

3.1.1. Crowdsourcing Apps and Lifestyle

Conducted by American sociologists and psychologists between the years 1920-1950, the closeness of the average answer to the correct answer, even when questions asked to a group were answered individually, is one of the first studies on crowdsourcing [91]. It has been argued that problems can be solved not from a single source, but with the participation of multiple users in a global context [92]. Internet sites such as Threadless, iStockphoto, InnoCentive [93], Wikipedia, Arcbazar are used as crowdsourcing today. The common features of these sites are to identify a problem and consult users to solve this problem.

Crowdsourcing, which is not supported by many experts, creates debate about the reliability of the data it provides. For example, Wikipedia is a virtual encyclopedia that can be modified by anonymous users. The competence information on the subject of the users who made this change cannot be accessed. Therefore, it cannot be said that the information obtained from Wikipedia is scientific. Likewise, Arcbazar, which is an architectural crowd-contest website, is a system where information and product exchange between users looking for architectural solutions and users providing this service. A design crowdsourced website called Arcbazar, a site described as "the worst thing to happen to architecture since the internet began," can produce questionable designs. On the other hand, it offers low-budget clients access to an international group of designers who have never been able to afford it [94].

Crowdsourcing is used not only in seeking scientific knowledge and a direct solution, but also in obtaining data to understand lifestyles in line with user choices. An example of this situation is the use of social media applications such as Facebook, LinkedIn or Twitter in recent years to understand the online personality patterns of users [95], [96], [97]. This data collection method, called mobile crowdsourcing (MCS) [98], is used actively or passively. In active data sharing, smartphone users share their data with each other over the internet. Passive data sharing, on the other hand, continues to work in the background with the permission of the user and continues to collect user data. MCS, which is used to increase user satisfaction and product usability, realizes its purpose by taking advantage of user feedback. Since each user using the applications is an active participant and the application used is a test environment, it also reduces participant and testing costs [99]. Therefore, it can be said that with this usage, crowdsourcing can collect data for future use by creating a pattern, not for instant solutions. It is thought that social media data of users can be used for housing design.

Social media applications used in daily lives provide direct data for customization. Active posts reveal a general framework of user preferences. Applications that record user preferences present the user with appropriate options over time. Used as a marketing strategy, this system also supports product development. The use of crowdsourcing applications in housing design can be realized in two ways. The first is to determine user preferences based on the frequency of use and sharing patterns of social media applications. The second is the development of a housing evaluation application that works on user-centered feedback. Pre-occupancy evaluation and post-occupancy evaluation (POE) are two

approaches used to examine the user-building relationship. Pre-occupancy evaluation methods analyze how future users will experience the building [100] while post-occupancy evaluation evaluates the occupancy performance, energy consumption, efficiency, user satisfaction, etc. [101]. An analysis system developed for this purpose can be used to understand the spatial preferences of users and to propose user-specific spatial experiences [102].

3.1.2. Navigation Technologies and Location

Users spend different amounts of time in different areas within living spaces. By determining the areas in which users spend their time, it is possible to prioritize space according to different users. With this data, the spatial priority of users using the same space can be determined, as well as the location data of different users in different spaces will be obtained. Therefore, it can be said that with the in-location data of users, it is possible to ensure that a space is included in the design in different ways according to its use.

By accumulating the user's location data in the space, information about which location the user uses at what times and how often can be obtained. This data can give the designer a space priority order during the design phase and show which space the user needs and at what times. For this purpose, the navigation systems that are actively used today examined and which system could be used in indoors was made are listed.

- **Global Positioning System (GPS):** It is a system consisting of space-based positioning, navigation and timing signals provided by users [103]. Today, devices and applications connected to the Internet can detect the user's location within seconds, by GPS. Using satellites to determine in a global context, GPS can accurately locate up to about 50 m. By 27 satellites around the world, GPS is generally used in outdoor navigation. The biggest problem in position determination is the deterioration of the signal in high-density regions [104]. Considering the location of the user in the house, 50 m margin of error is unacceptable. For this reason, the use of GPS indoors is not sufficient [105]. Phones, digital cameras, car navigation systems, many phone apps and smart watches all work with GPS.
- **Differential Global Positioning System (DGPS):** DGPS, which can accurately locate up to approximately 1 to 3 cm when applied correctly, can be used to determine when

the user is in which space in the house. This system, which has a limited area of use due to its high cost, is also, does not give accurate results when satellite signals are blocked [106].

- **Visual Positioning System (VPS):** VPS, which provides image-based location determination, differs from GPS in this respect. This system, which is found in smartphone cameras, is also used in the Google Maps application. It is powered by AI and ML [105]. In this respect, VPS can be used to determine the position of the user in the space with wearable technologies.
- **Augmented Reality (AR) Navigation Systems:** Augmented Reality provides data exchange between the virtual and real world by the gestures, body language and movements of the users [107]. Augmented Reality Navigation apps are AR solutions that can pinpoint precise locations [108].
- **Sensors:** Generally, sensors are used for local direction and direction determination. These sensors used in robots can map the environment by acting more independently than GPS [109]. Light Detection and Ranging (LiDAR) can be counted among the sensors used for this purpose by measuring the distance to an object with the help of light.
- **IoT and Cloud Networks:** IoT devices and cloud networks are also used to determine user location. These devices, which determine the location with the accelerometer, are actively used to determine the direction of the visually impaired individuals [107].
- **Wi-Fi Based Indoor Positioning System:** Another technology that determines the frequency of space usage based on user activities is Wi-Fi based indoor positioning technology [110]. Since GPS is generally used for outdoor navigation and has a high margin of error, Wi-Fi based indoor positioning technology is preferred for indoor location (Fig. 3.3), [111].

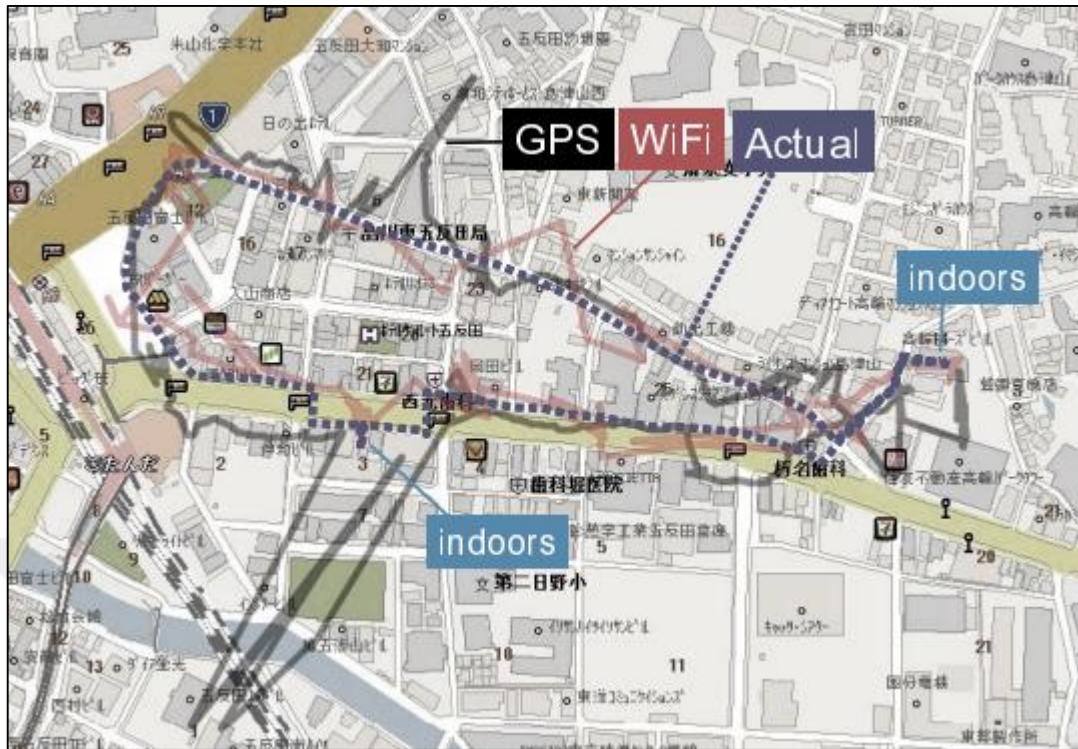


Figure 3.3. Wi-Fi location estimation comparison with GPS [110].

Determining the user's location within the house provides information about how often the user uses which space. At the same time, user location information can also be used to create a model of the user's movement between spaces. In this way, a framework of the user's spatial movement routine can be established. Among the listed geolocation technologies, IoT devices and Wi-fi were identified as the most commonly used in the daily lives of users without requiring installation. These technologies, especially found in wearable devices, serve as support in users' daily lives by sensing user movements.

Among the location detection technologies, Wi-Fi based location detection systems are particularly prominent. The most important feature of Wi-Fi technology is that it can determine the location of the user without getting stuck in obstacles such as walls, furniture, etc. inside the house [112]. Wi-Fi based indoor positioning technology is the most usable tool among location detection technologies with its low cost, easy applicability and widespread availability [111]. At the same time, it is also possible to obtain different location information of different users within the same space due to multiple datasets [113]. In this way, data from multiple users can be processed simultaneously. Therefore, Wi-Fi based geolocation technology will be a very useful tool for locating users in their living spaces on a mass scale.

Table 3.1. Different layers in IoT devices [119].

PERCEPTION	Camera, Robot, Sensors, Meter
TRANSPORT	Routing, Wi-Fi, Bluetooth
PROCESSING	Web Service, Data Center, Cloud
APPLICATION	Smart Health, Smart Home, Smart City, Smart Grid

IoT devices used in daily life can serve users in many areas because they work with the principle of determining user routines. The first of these is the human activity recognition (HAR) systems. HAR systems, which started to be researched for the first time in the 90s, started to be used actively in the lives of users with the adoption of wearable devices in the 21st century [120]. The sensors in wearable devices can collect and analyze the data of motion or stationary activities such as walking, writing, tooth brushing, climbing stairs with the help of accelerometers [121]. HAR systems, which are actively used in the field of health, can also be used in spatial design with the principle of creating user patterns by determining daily activities [122].

In addition, IoT devices can adjust energy consumption by controlling indoor geolocation, indoor lighting and HVAC (heating, ventilation and air conditioning) systems [123]. They can learn user preferences and control indoor systems according to these preferences over time. Therefore, IoT devices can be used to monitor user movements and preferences by simultaneously transferring user data collected via internet connection to other devices or cloud-based systems.

Another feature of IoT devices is facial recognition technology. This technology [124] which is used in open areas for user density and security studies, can detect different users within a house. Accordingly, it is thought that IoT devices can collect user data by person-oriented classification in case there are different users sharing a house. In this way, the spatial preferences of different users in the same house can be analyzed at the same time.

There are many ways in which IoT devices can be used to create personality analyses based on user daily activities. By these data, IoT devices serving users as personal assistants. It is anticipated that, IoT, which is used to run a smart home system by facilitating the user's life individually, can support mass customization in housing by collectively obtaining and analyzing user data.

3.2. SPACES AS DATA SOURCE

Information and communication technologies, which users actively use in their daily lives, collect and analyze user data and use them in product development. They are used in smart city applications for urban planning and infrastructure development purposes, are used by designers in computer-aided design and decision support systems in architecture. With this technology, which is also offered to the individual use of users with automation systems, smart home systems can be installed. As a result of that, it is possible to make improvements in the space according to the preferences of the users.

Every space where users spend time in their houses is a source of data on user routines. How long a user uses a space and for what purpose are important data to be used in design. Data on a user's sleeping hours, sleeping spaces, eating habits, cleaning routines, work patterns, hobbies, friends and family, and so on, constitute their spatial routines. ICT can make it possible to collect these data from spaces. IoT devices and Wi-Fi, especially with their activity recognition and localization capabilities, can be used to systematically collect and process user data.

By systematizing the user data collection process, the data collection and processing process will be shortened and can be used for mass customization. In this way, data on the spatial routines of multiple users can be collected and processed simultaneously.

It is thought that these systems, which work on collecting and processing user data, can create user spatial routines by collecting data on user daily activities for mass customization. Table 3.2 presents a scheme for the daily activities performed in the space, their spatial provisions, the data that can be used in the design and the method of data collection. Accordingly, user daily activities and the spaces assigned to these activities can be compared with the spaces where the user-specific activity is performed. The user data obtained can show the spatial routines of the users and form a pool of user data to be utilized in housing design in future studies.

Table 3.2. Daily activity, spatial provisions and user-centered data.

Activity	Spatial Provision	Data to be Used in the Design	Data Source
Sleep	Bedroom Living room ...	User's sleep time, sleep duration, spaces of sleep, end of day and start of day	Turning off lights and electronic devices, not using smartphones and clock activities, location information
Feed	Kitchen Dining room Living room Salon Balcony Garden ...	Whether the user orders ready-to-eat or prepares the food themselves, the space where the food is eaten, the time spent, the social activities accompanied and the social environment	Prepared food applications, shopping applications for grocery shopping, and use of electronic appliances such as stoves, refrigerators, etc.
Media use	Living room Salon Study room Bedroom Kitchen ...	User's leisure time, time and space of media use	TV on/off times, movie and series platforms used, location information of media source
Personal hygiene	Bathroom Toilet	Preference for bathtub or shower, time spent in the bathroom, use of the bathroom as a space of preparation	Location information, lights, sensors, music apps usage
House cleaning	Bedroom Living room ...	Frequency of space use	Vacuum cleaner (robot or vacuum cleaner), location and frequency of use, sensors
Doing laundry	Laundry room Balcony ...	User's storage needs, laundry and drying space needs	Washing machines and dryers
Work, study, read	Study room Living room ...	Items that the user needs for working time, working space, working space	Computers, telephones, electronic mail and spaces of use
Socializing	Salon Living room Kitchen ...	Social environment, space(s) used for socializing, frequency of meeting people, frequency of hosting guests	Social media accounts, electronic devices used and their frequency, location information
Hobbies	Study room Living room ...	Time allocated to leisure activities, interests, and spatial functions needed	Computer, television, phone and other smart device data, music and movie platforms, social media
Shopping	Study room Living room ...	Type of need, storage space according to type of need, lifestyle, social environment	Shopping apps

As can be seen in the table, the different activities that are shown in different spaces within the space in daily life are a continuous source of data for the personalization of users' houses. Even though the activities performed are in a certain class, the data provided by the activity varies from user to user.

The activities that users perform in their living spaces directly determine the function and needs of the spaces used. When designing a standard space, users are expected to indicate their wants and needs to the designer. In addition, the spaces within the house can give these needs directly to the designer according to the layout they create according to the wishes and needs of the users. With this data that can be obtained through ICT, the reliability of user data will increase and the quality of service to the needs of the user will increase with the resulting design.

The spaces where users' daily activities take place will provide data on user usage (Fig. 3.5). At the same time, it is possible to obtain information on the duration and movement between spaces with the help of information and communication technologies. This data pool will also provide data on the spatial needs of users. In this way, housing designs can be proposed according to the individual needs and wishes of the users. Considering ICT as a direct observer in the user's life, it will be possible to observe short-term and long-term changes in user preferences. In this way, the design of individual spaces that evolve and change with the user can be realized.

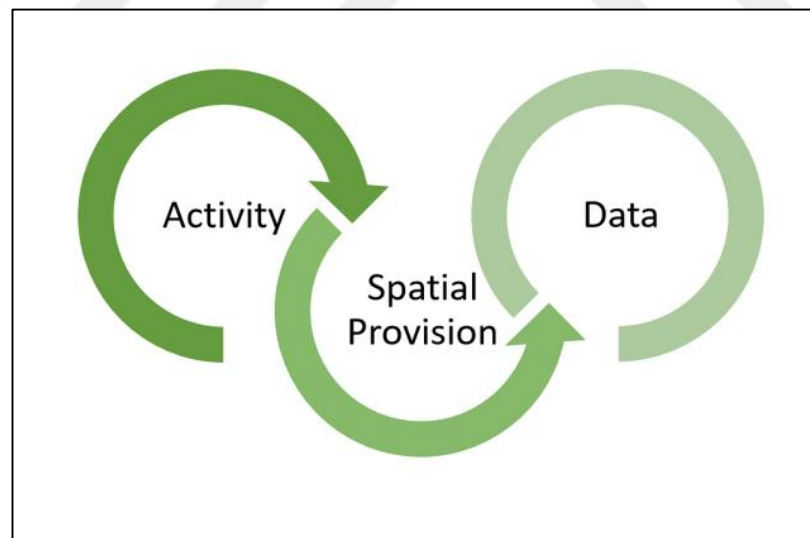


Figure 3.5. Activity, data and spatial provision cycle.

The activity receives a feedback with the data it reveals through the space where it is performed. While this feedback indicates the function and frequency of use of the space, it also prepares the ground for future activities. By identifying this data, the transformation and development of spaces can be ensured.

4. A USER-CENTERED DATA FRAMEWORK BASED ON DAILY ACTIVITIES AND SPATIAL ROUTINES

Users create their own layouts in their spaces over time. This layout created for use beyond the boundaries of space differs from user to user. It is the way the user uses his home that gives the most direct data about the user in the personalization of a space. The way the user uses the space evolves with the spatial routines of the user based on their daily activities.

Users enter into a cycle based on their daily activities in their living spaces. Daily activities that are carried out in different spaces, between spaces, at different time intervals and with certain frequencies within the space, form spatial routines by being constantly repeated over time. Activity cycles can be classified according to their repetition patterns and times. Daily activity cycles can provide information on basic spatial needs, while weekly and monthly cycles can provide data for space improvement. Although user activities show a certain continuity, behaviors that break the cycle may occur over time. When an analysis of the activity cycles is made, it is possible to see the continuity of the behaviors that break the cycle. Permanent changes in users' activity cycles yield changes in user spatial needs. It is possible to customize spaces by creating a user-centered data frame based on user daily activities and spatial routines.

Therefore, the spatial routines that provide direct information on the lifestyles of the users, the way they use the space and their purpose, and their spatial preferences are very important in the design of the space. However, although the user's daily activities determine the user's spatial routines, accessing this activity information is difficult for the designer. Users do not consciously perform the spatial routines of their daily activities. As a result, when contacting the designer, they cannot analyze their needs based on their spatial routines. Although it is possible for the designer to be a direct observer in individual housing designs, it is a waste of time and resources in the case of mass customization. For this reason, information and communication technologies that can accumulate the indoor activity cycles of users can be used to collect user data.

4.1. DAILY ACTIVITIES AND SPATIAL ROUTINES

Users and the space in which they live cannot be separated from each other. In addition, the situation of designing a space according to the user is not limited to the needs of the user specified by the designer. Users create certain routines in the spaces they live in time (Fig. 4.1). Therefore, a space should not only be physically functional, but should be designed with user routines emerging from experience. In architecture, the design of the space by limiting it only to function brings many problems in the usage phase. The space does not only serve the function directed to it from the time it interacts with the user. An example of this is the use of the kitchen, which is used as a cooking, eating and storage area, as a space to chat with the social environment during the usage phase. From this, it can be deduced that the daily activities of the users provide direct data on their personal space usage.

Tuan (1975) said that daily activities form the pivot of a house [125]. In daily life, users are in a continuous cycle of activity within the space. Getting up in the morning, having breakfast, going to work, returning home, eating with family members, bathing, sleeping and repeating the same activities the next day revolve around the same spaces. Users do not notice these repetitive activities unless they perform an activity that disrupts this cycle [126]. This is because these activities form a certain routine. When users perform their activities according to a certain routine, it transforms the space in which they perform them. The continuous use of a space for certain activities at certain times differs from user to user. Therefore, different spatial routines are formed over time according to the activities of different users.

These routines determine how a space is used and how it will be used in the future. Spatial behavior patterns are often used by environmental psychologists and behavioral scientists in the creation and development of social spaces. Data such as where users prefer as transit spaces, where they use as meeting spaces, where they rest or eat are important data sources in the organization of public spaces [127]. It is possible to say that users will show the similar spatial behaviors in their houses. The transitions between spaces, the activities they perform in which space and the times they perform them constitute the spatial behavior of the users within the house and thus their spatial routine.

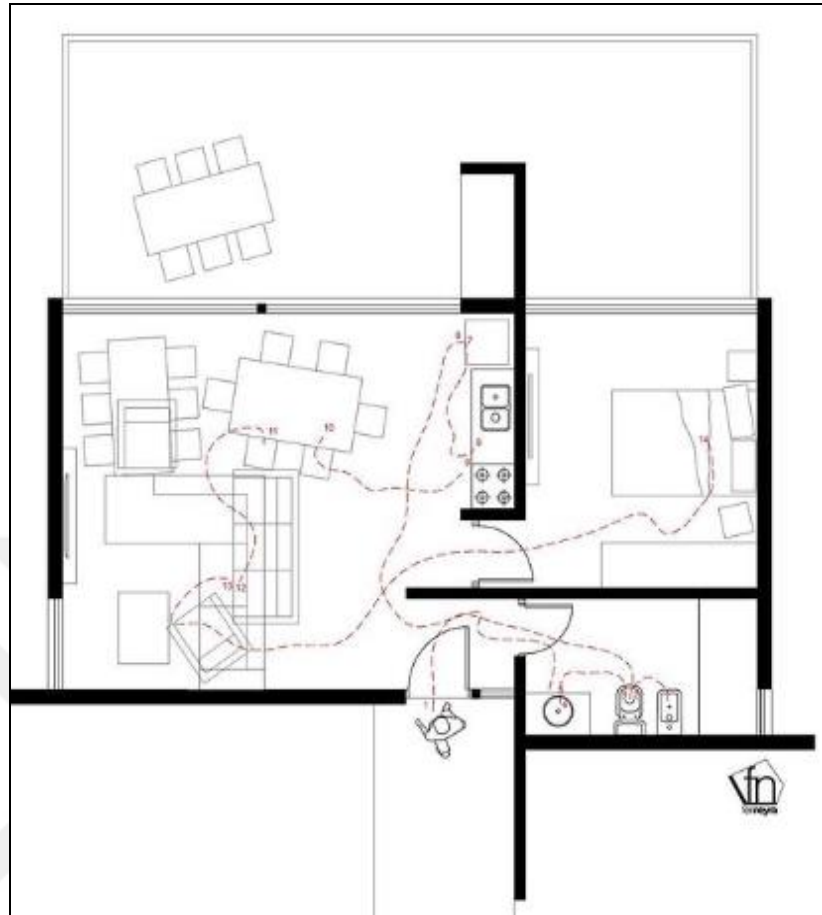


Figure 4.1. User movement in a space [128].

Daily activities cannot be limited to static function only. The user's movements within and between spaces also provide data about the use of space. Considering the continuity of individual activities, individual spatial routines are formed. Spatial routines show the unconscious needs of the user from their routines, beyond the need for standard spaces functioned in the house. According to Certau, a space should be designed experientially, not only with its functional physical aspects, but also with user routines. The inclusion of spatial routines in the design process also allows the development of the relationship between the living spaces in the house and ensures that the spaces work as a whole [129], [130]. A design made in line with the user's routine movements means that the unconscious needs of the user are met as well as their conscious needs. Determining user experiences is an issue that needs to be addressed in the communication between the user and the designer, and the activities of the user in the space should be examined. In this direction, the spatial routines produced by the activities should be used to create a user-centered data frame.

4.1.1. Passive and Active Choices

Users have conscious and unconscious preferences that they apply in their daily lives. Over time, these preferences become habits and thus routines by being repeated. Routines may consist of habits that cannot be expressed verbally, although they form a large part of the user's life. The biggest reason for this is that the user thinks that this routine will not have an effect on the spatial design. For example, drinking coffee can be a routine for the user. However, the user may not specify the coffee drinking routine during the design of the space, considering that it will not make sense. Likewise, brushing teeth is a routine. However, during the design, the user will not indicate that he brushes his teeth as soon as he wakes up in the morning. Therefore, the passive and active choices that will be important during the design must be recognized first.

The conscious preferences of the users are divided into two as the basic needs of life and the needs that develop over time from their lifestyles. The basic needs of life can be listed as sleep, nutrition, hygiene and excretion. After these needs comes the socialization need of the person. In a standard housing design, it is essential to serve the basic needs. The needs of the users, which come from their lifestyles and develop over time, are the needs of a user that change from user to user, which are effective in choosing a space to live. These needs, which can vary according to the user's working status, hobbies, storage needs, and how many people will use the house, appear as spaces that serve these purposes in the houses. These are the preferences that are known to be needed by the user and determine the spatial features that the user actively chooses in the housing design.

The unconscious preferences of the users, on the other hand, are the preferences that emerge after the user interacts with the space. The unconscious preferences that emerge as the daily activities performed in the house become routine by being repeated over time support the unique living spaces that the users create in their houses without realizing it. These living spaces are experiential spaces developed with behaviors, rather than spaces with certain boundaries created for the purpose of serving certain activities. Therefore, it is possible to determine these spaces not by user discourse but by their behavior. Unconscious preferences include the time the user spares for their daily activities in the house, the spaces they prefer, the order of activities, the order of use of the space and their movements in the space. These preferences, which develop with the constant repetition of familiar behaviors, are not noticed

by the user in most cases. What makes a standard spaces the home of the user is the living spaces created by the user's unconscious preferences, and therefore the experiential spaces. The familiar point in the space that feed the user's sense of belonging and feel most comfortable stem from their unconscious preferences.

4.1.2. Daily Activities Becoming Routines

Inside the space, each user sets his own routines. For example, if a family consisting of a mother, father, two children and a dog, it is seen that each individual has routines that they exhibit individually and together. Hours when working users are inside and outside the house operate according to a routine. It can be observed that users withdraw to their own rooms during sleep hours. The family can dine together at mealtimes, each user has a chair to choose and sit in. The user or users who cook the food, the user and users who collect the table are usually specific. Going out for the dog's toilet needs, feeding time and the user and users who provide it act according to a routine. By these activities, each user create their own spatial routines in their living spaces.

In *Living and Cooking* of Certau's *The Practice of Everyday Life*, the routines of the R. Family living in France are mentioned. In the book, Certau talks about the relationship between the chair in which Madame Marie, who cooks the food, sits, with her access to the refrigerator, stove and counter [131], (Fig. 4.2). This routine consists of the continuity of a behavior that the user shows unconsciously. For example, if Madame Marie was to be seated in the chair on the other side of the table, she would experience discomfort from having to get up and walk around the table for service.

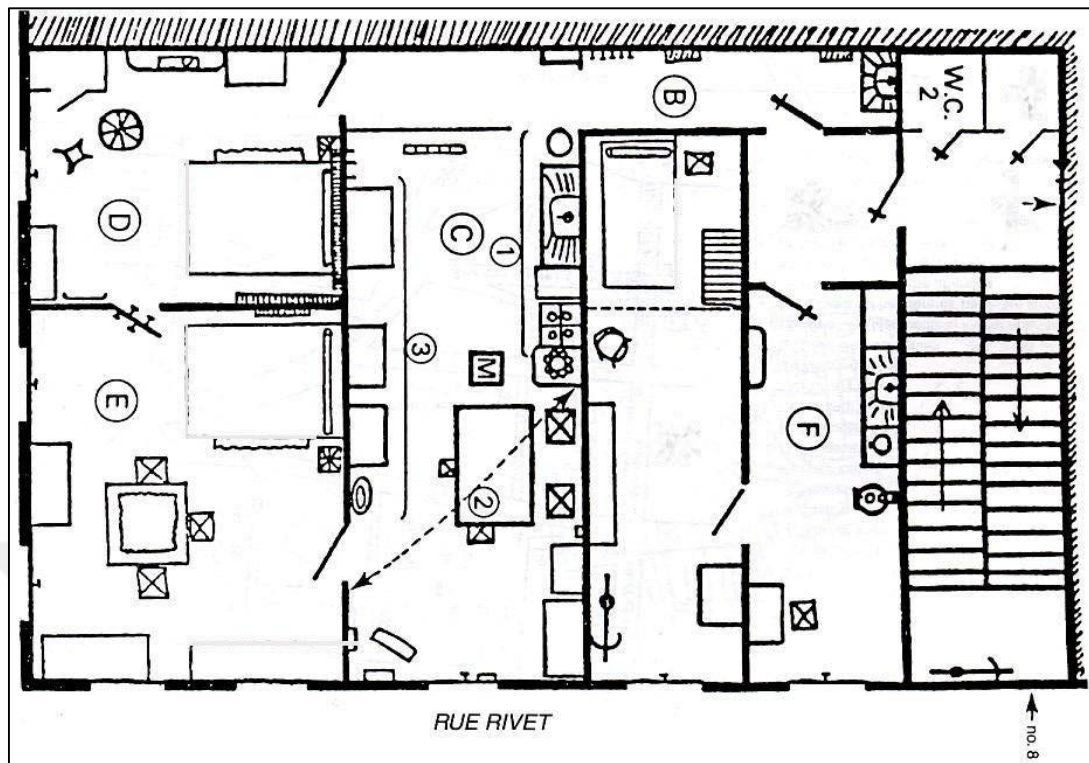


Figure 4.2. Madam Marie's house [131].

Certau mentioned that the same user had a stool in front of the window in the living room [131]. Because of her short stature, Madame Marie stands on this stool to watch out the window. In the case of Madame Marie, it is clear that the size of her windows, while appropriate for the rest of the family, is useless for Madame Marie. This section, where the routines of the R. family are observed and interpreted, summarizes the routines that the users exhibit at home in daily life. Although it may seem quite simple, it is necessary to consider the routines specific to each user when designing a living space.

4.1.2.1. *In-house duties*

Users who use a living space undertake a number of tasks that are not written or verbal among themselves. These duties may vary depending on many factors such as gender roles, users' incomes, social roles, capacity or socioeconomic status. In-house tasks will show which spatial design can be based on which user's routines in case of multiple users using a living space. One of the problems created by standardization is that the duties of the users in the space are not taken into account.

4.1.2.2. *Social activities of users*

The sociability of the users and the social activities they are a part of are clues for the spatial arrangements they need in their homes. A user who enjoys activities at home, and a user who spends time outside will have different expectations from the living space. Inferences about the use of living space can be made from the activities that users participate in and from the activities of their friends.

4.1.2.3. *The time periods that users spend in the space*

While the time spent at home before the pandemic was shaped according to the social life and working status of the users, this time had a great increase as they were forced to meet all their needs without leaving their home after the pandemic. In this process, living spaces have turned into a common space where both vital and social activities are carried out. With the addition of working from home, the expectations of the user from the living space have changed drastically. While it is expected that the way of use will return to the past with people starting to leave their homes again, the use of living spaces has diversified with the increase in the options offered to the person.

With the possibility of working from home, the time spent by the user in the living space has greatly increased. This new working order has not only revealed the necessity of a working environment, but also necessitated meeting the needs of the user in the working environment during working hours at home. Among these needs, the simplest is the need to eat within certain hours.

After determining the time interval that the users spend in their houses, which spaces they use and for how long, the unused spaces and the spaces that are used relatively more should be determined. Accordingly, it can be deduced that, for example, users who work from home, use the living room to work, do not cook at home, and order food from outside at the same times throughout the week, need a study room in their living spaces more than a kitchen. In the design of this user's living space, spatial arrangements should be made that can turn into a large working area or working area together with a kitchen designed in minimum dimensions.

In the cases examined above, time seems to be the common point. The routines created by the in-house tasks give the data of which user uses or does not use a spatial function more. It provides information about the frequency and need of use by showing the users' relations

with their social environment and social activities, how a space is used. When the duration of the stay of the users in the house and indoor spaces is examined, it shows which space in the house have more functionality than others. It also shows the difference in their functions and usages over time. Two important points emerge here. The first is the fact that user routines create unconscious needs. Routines from the user's experiences are not verbalized during design. On the other hand, it is physically time-consuming for the designer to observe the user routines one-on-one. Considering the masses, it is almost impossible to observe more than one user. For this reason, it is necessary to establish a system that continuously collects and accumulates user data over time in obtaining user data. The second point is the classification of these data. Since the frequency of application of user routines constitutes an important criterion for design, it should be examined accordingly. For example, it is a daily routine for the users to get up every morning and brush their teeth. However, general housekeeping occurs as a weekly routine. Family members of the users may be hosted as boarding guests once a month. A regular working users will use their vacations right annually. Considering its frequency alone, tooth brushing may seem like the most frequent activity, as it's a routine every day of the year. However, when viewed on an annual basis, routines that are not practiced every day will reveal a different framework. Therefore, it is considered appropriate to temporally evaluate the user data to be created from user routines.

4.1.3. Architectural Space Experiences

Users are constantly on the move in their daily lives. These movements occur in line with the daily activities they perform. The sequence of movements that the user prefers while performing an activity, the space or spaces, the path between the spaces, the sequence of activities, the other user or users with whom he/she performs the activity together turn into routines considering the continuity that develops over time. The repetitive behaviors of the users enable them to produce an unconscious attachment to the space [36]. These routines that users create in their environment occur unconsciously and are directly related to the users' spatial experiences [132].

Tuan (1975), argues that the user experiences that use that space outside the boundaries of the physical space constitute the space [125]. According to Benjamin (1999), a space carries the traces of its user by reflecting its usage and purpose [133]. Therefore, it is possible to say

that user spatial experiences reveal a personal behavioral framework specific to the user, considering the routine movements they create. Analyzing the user's perception of the space according to the user's experience of the space can give information about why the user uses a space and what can be done to choose the space.

Accordingly, user routines show how the user experiences the space. Space experiences that create a sense of belonging and familiarity towards the space do not only increase the efficiency of space use. It also determines the way the user behaves outside the familiar space. Thus, users' spatial experiences can provide a framework for how the user will act. Spatial designs that can be customized according to the user's spatial experience can change and evolve with the user, considering the adaptation shown to the user. This process will ensure the continuity of personalization by ensuring that the space has an organic order. By putting the customization approach into a system, it is possible to design spaces that adapt to the user according to the changing lifestyles and spatial needs of different users over time.

4.2. ANALYSIS OF ACTIVITY-TIME-SPACE RELATIONS AND A USER-CENTERED DATA FRAMEWORK PROPOSAL

There is a dependent relationship between daily activity cycles and spatial routines. The activity performed is based on the time period in which it is performed and the space where it is performed. An activity can be shown in multiple locations at different time intervals. Likewise, a space can be used for multiple activities. It is possible to define user-specific spatial routines by looking at the daily activities and frequency of use that a space serves. While defining user-specific spatial routines, daily activities are taken as the starting component. Daily activities form spatial routines depending on the space/spaces in which they are performed and the time they are performed. The activities are repeated in certain cycles over time, creating a user-specific movement routine. Therefore, it is possible to say that spatial routines show the movement patterns and frequencies of the users in their houses. Due to spatial routines that vary from user to user, users create their own spatial arrangements in a standard housing design. These spatial arrangements do not have sharp boundaries, unlike certain spaces created by the designer. The space, which interacts with the user, turns into a living space where multiple activities can be performed according to

user preferences. Therefore, it can be said that user spatial routines create the order that users unconsciously prefer while creating their personal living spaces.

4.2.1. Activity-Time-Space Relations

During a standard house design, different spaces are assigned to the daily activities that the user can perform. By standardizing spaces serving these activities, users and designers have a guide to follow. Since the users are individuals who have different needs and wishes from their living spaces, standardized spaces can be inadequate to meet the expectations. While basic daily activities need primary areas, users' activity-time-space relations need to be evaluated.

In order to understand the cycle of different users' use of a space, three basic questions should be asked about activity, time and space. These questions are which activity the user performs, how often and where (Fig. 4.3). With these three questions that determine the spatial routine of the user, it is possible to obtain information about the pattern and frequency of space use. Activity-time-space relations, together with the changes they may show from user to user, constitute spatial routines, which are the basis of customization. Spatial routines will create ease of use and a sense of familiarity for the user in the design.

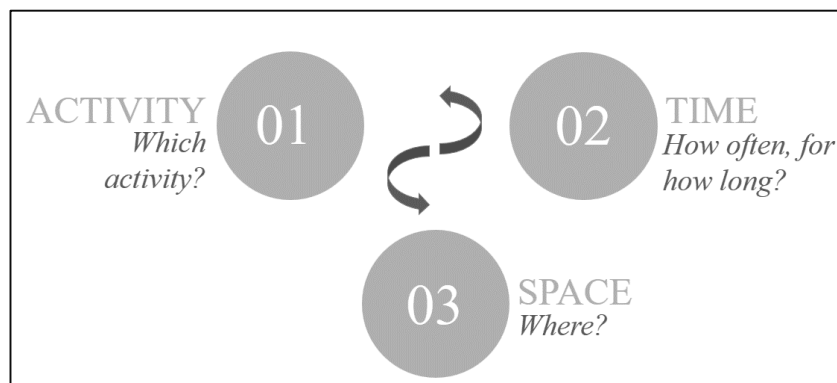


Figure 4.3. Activity-time-space cycle.

Basic daily activities are listed as sleeping, eating/drinking, hygiene and socializing. The primary spaces to be found in a standard housing design are designed as spaces that will serve these activities. The spaces designed as bedrooms for sleeping, kitchen for eating/drinking, bathroom/toilet for hygiene and living room for socializing are defined to meet the basic needs of the users in the house. Daily activities are not limited to activities

for basic needs. It is possible to expand these activities such as working, taking care of hobbies, dressing, storing, using media. Additional spaces such as study room, dressing room, warehouse/pantry have been started to be organized as the spatial counterparts of these activities. These spaces, which are encountered in the designs in order to facilitate the life of the user according to the usage needs, can be called secondary spaces since they are not encountered in every house. However, the spatial counterparts of daily activities do not only serve the needs assigned to them after interacting with the user. Regardless of the infrastructure of the spatial needs brought by certain activities, the time allocated to the activities and the spaces where these activities are carried out differ from user to user.

An example of this situation is that an activity can be performed in more than one space or that an activity is shown in a space other than the space to which it is assigned. Accordingly, it can be said that the daily activities of the user interact with the space within certain time intervals (Table 4.1). Therefore, in order to understand a user's lifestyle and spatial routines, it is important to know which space is used by which activities and at what time intervals. With the acquisition of these data, more comprehensive long-term analyzes can be obtained by providing data on the frequency of the user's use of space and the priority of which space is used for which activity.

Table 4.1. Activity-time-space relations.

<i>Activity ($a_{activity}$)</i>		<i>Time ($t_{start} - t_{end}$)</i>		<i>Space (s_{space})</i>	
a_{sleeping}	Sleeping	t_{sleeping}	Sleeping time	S_{bedroom}	Bedroom
a_{eating/drinking}	Eating/drinking	t_{eating/drinking}	Eating/drinking time	S_{kitchen}	Kitchen
a_{studying}	Studying	t_{studying}	Studying time	S_{studyroom}	Study room
a_{hygiene}	Maintaining hygiene	t_{hygiene}	Maintaining hygiene time	S_{bathroom}	Bathroom
a_{media}	Using media	t_{media}	Using media time	S_{livingroom}	Living room
a_{socializing}	Socializing	t_{socializing}	Socializing time	S_{salon}	Salon
a_{hobby}	Hobbies	t_{hobby}	Hobby time	S_{garage}	Garage
...	...	...	...	...	...

In Table 4.2, as an example, sleeping activity was examined and discussed under activity-time-space analysis. If the sleeping activity is analyzed in the exemplary situation, it is seen that it takes place 3 times at different time intervals and at different time intervals in different

spaces. While the activity under study is fixed, time intervals and locations are variable. This shows that there is not one spatial equivalent of sleeping activity. In a standard design approach, sleeping activity is reduced to the bedroom space, while the user's enjoyment of sleeping in different spaces is ignored.

Table 4.2. Activity-time-space analysis of sleeping activity.

<i>Activity Performed ($a_{activity}$)</i>	<i>Time Intervals of Activity Performed ($t_{start} - t_{end}$)</i>	<i>Activity Performed Space (s_{space})</i>
$a_{sleeping}$	$t_{sleeping1}$	Sbedroom
	$t_{sleeping2}$	Slivingroom
	$t_{sleeping3}$	Sstudyroom

In Table 4.3, the kitchen was chosen as the space and the activities performed in the kitchen were discussed under the activity-space-time analysis. In this table, the activities shown and the time intervals they are connected to are variable when the space is fixed. It is seen that activities such as socialization and media use are also shown in the kitchen space, which is designed as a counterpart to eating/drinking/meal preparation activities.

Table 4.3. Activity-time-space analysis of kitchen and performed activities.

<i>Activity Performed ($a_{activity}$)</i>	<i>Time Intervals of Activity Performed ($t_{start} - t_{end}$)</i>	<i>Activity Performed Space (s_{space})</i>
$a_{eating/drinking}$	$t_{eating/drinking}$	Skitchen
$a_{cooking}$	$t_{cooking}$	Skitchen
$a_{socializing}$	$t_{socializing}$	Skitchen
$a_{mediause}$	$t_{mediause}$	Skitchen

Therefore, it can be interpreted that the boundaries of spatial distinctions arranged according to in-house activities vary according to different users during the usage phase. The time intervals for the daily activities shown vary from user to user. The space/spaces where the activity is shown may differ. Likewise, a space can gain a new meaning where more than one activity is shown during the usage phase. Providing such data will support the customization of the space in relation to user activities.

4.2.2. Activity Cycles

It is seen that user activities cycle through time and space. The activity cycle, which is effective in the formation of spatial routines, varies according to the continuity and frequency of user movements. It is possible to say that the spatial routines of the users are also unique to them due to the time intervals in which the same activities are shown and the spaces vary according to the users. Routines can be repeated not only during the day, but also weekly, monthly and yearly (Figure 3.3). Routines are part of the cycle, which may vary within the time period in which they are examined. Since daily user activities can vary during the week and weekly activities within the month, it is necessary to consider user movements over a longer period of time when examining spatial routines. In this way, the days where the basic daily activities of the users vary in the space and time intervals will be obtained as data. An example of this situation is that the daily routines of the users during the week and the daily routines of the weekends are similar among themselves, but when they are examined together, they are different from each other. Likewise, when the monthly routines are examined, it can be observed that the user repeats a routine that he did not show in the previous weeks. It is possible to see this change by examining the daily, weekly, monthly and annual routines together. In this way, it can be determined whether the change in routines is short-term or long-term. Although short-term changes in user routines do not make a big difference in the use of space, long-term changes are necessary data to determine the change in the spatial needs of the user. Therefore, it can be said that activity cycles have an important place in spatial design.

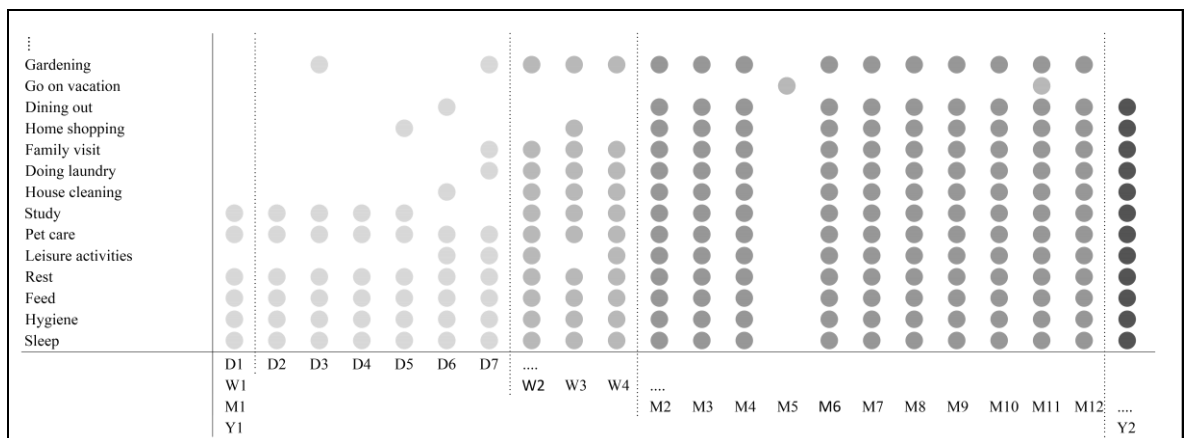


Figure 4.4. Users' daily, weekly, monthly and annual routines.

Activity cycles not only show the users' frequency of use, but also give the data of the their roaming frequency between spaces. The movement of the users between spaces creates a cycle in time, similar to the routines they show in the space. This routine, which is created according to users' ease of movement between spaces, can develop continuously or limitedly according to the housing design (Fig. 4.4). A space designed in accordance with the users' movement routine between spaces will allow users to move uninterruptedly, making the spaces where they perform their activities accessible (Fig. 4.5). Likewise, a design that is not suitable for users' movement routine will restrict their movement to the spaces, making it difficult for them to move fluidly in the space. A design that allows users' to move comfortably while performing their daily activities in the house will ensure efficient use of the space.

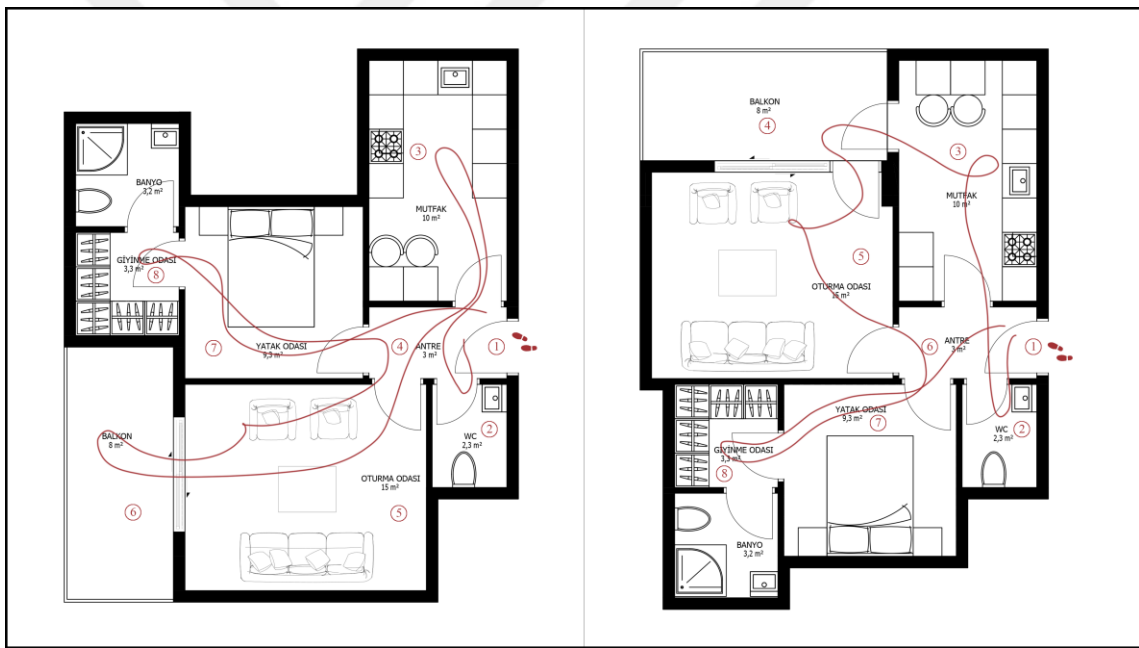


Figure 4.5. Users showing the same movement routine in different houses.

4.2.3. A User-Centered Data Framework Proposal

It is necessary to create a user-centered data framework for the daily activities and the spatial use and frequency of these activities and the spatial routines created by these activities. Analyzing the dependent relationship between daily activities, spaces used and usage intervals will reveal a customization plan for space usage based on users' spatial routines. In

this way, the time intervals in which the user's daily activities are carried out and the space/spaces used for these activities can be determined and activity cycles can be observed.

According to this framework, the activities represented under the abbreviation are listed according to the index number of the user in a way that covers all the activities. Activities take place at certain time intervals and in certain spaces. While the time intervals of the activities are handled depending on their beginning and ending, the spaces can also be classified under index numbers. There may be singular activities such as a_1 in Figure 4.6, activities that take place in the same space such as a_2 or activities that take place in different spaces such as a_3 . The open-ended data framework proposed in this study is suitable for data collection and analysis.

a_1	$t_1(t_{1a}-t_{1b})$	S_1
a_2	$t_2(t_{2a}-t_{2b})$	S_2
	$t_3(t_{3a}-t_{3b})$	S_2
a_3	$t_4(t_{4a}-t_{4b})$	S_3
	$t_5(t_{5a}-t_{5b})$	S_1
	$t_6(t_{6a}-t_{6b})$	S_2
...	...	...
a_n	$t_n(t_{na}-t_{nb})$	S_n

Figure 4.6. User-centered data framework.

According to this framework, it is possible to get an idea about which space used for which activity. The fact that the activity takes place only once in the time period when it is handled in a space and that it occurs more than once in the time period when the activity is handled in the same space shows the frequency of use of the space. This data will also be a valid way to see which venue serves which activity. In some spaces, multiple activities can be performed at different time intervals. This data, on the other hand, provides an understanding of the variety of purpose of use of the space and for which activity the space is primarily

used. Likewise, if there is more than one space where a single activity takes place, it is possible to see it considering this table. Again, this data will provide information about the spaces and infrastructure where the activity can take place. Therefore, according to this framework, a customization framework emerges regarding the activity, time and space dependence of the users.

If this relationship is to be shown as a formula, while the activity (a_n) performed in space (s_n) for a certain time (t_n) as frequency of space usage is F_{s_n} ,

$$F_{s_n} = \sum_{k=1}^n a_k t_k = a_1 t_1 + a_2 t_2 + \dots + a_n t_n$$

gives the frequency of use of the space (s_n). According to this formula, the sum of the activities performed in a space and their duration will show the frequency of space use. With the inference made here, it can be said that the total duration of the activities performed at different time intervals in different spaces gives the frequency of that activity. Likewise, for a space where different activities are carried out, it can be seen through this formula which activity uses the space first. With the acquisition of these data, it is possible to analyze the spatial routine of the user. By determining the spatial routine of the user, the spatial needs of the user can be determined and customizable housing production can be achieved.

5. CONCLUSION

Spatial design based on mass customization has been researched and developed since World War II. However, the use of user data provided by spatial routines in space design is not a common practice. Therefore, this study investigates the use of spatial routines, a social phenomenon, as a system for mass customization. In this study, mass production and mass customization approaches are evaluated through the role of the user. The consequences of the user being considered anonymous and taking an active role in the design of their own living spaces are discussed. To support this discussion, mass production and mass customization approaches are examined in the contexts of ideology, process and product. This study is limited to the UK, Scandinavia and Japan. The products and the development and changes in the process from mass production to mass customization in the UK in terms of ideology, Japan in terms of process and Scandinavia in terms of end product success are discussed.

The success of mass customization depends on the correct analysis of user wants and needs. Therefore, a user-centric customization data framework should be created. To identify and design user wants and needs on a mass scale, the definition of needs must be made correctly. It is a fact that users' wants and needs in housing have spatial equivalents in line with daily activities. These activities, which are standardized by designers and used in spatial design, are based on the basic needs of users. When it comes to customization, it is thought that the user's movements within the house should be evaluated rather than the standardization of the user's basic needs. A space exists as it is experienced by the user. Considering the differences in the spaces used in the daily activities, their movements within these spaces, their movements between spaces, and the time they allocate, this analysis is essential for the customization of users' living spaces. In this direction, it is possible to say that users' daily activities turn into spatial routines and that spatial routines are an important source of data on the spatial needs of users in housing.

When creating a user-centered framework, the relationship between daily activities, space, and time should first be analyzed. Spatial routines, how much time users allocate to which activity and which spaces they use for which activity should be determined. It is then possible to make a judgment about the user's spatial routine within the house. As a result of this analysis, it was determined that not every activity is performed in a single space. An activity

can take place in more than one space, or one space can be used for more than one activity. After interacting with the user, the spaces do not have sharp boundaries as determined during design. Accordingly, an activity-time-space classification enables the creation of a user-centered personalization framework. Although this framework is a suggestion for personalization, this data requires constant observation. On a mass scale, constant observation is a waste of time and resources.

In the traditional designer-user relationship, the expression of wants and needs is based on verbal communication, while there is not enough communication to define user-specific spatial routines. For this reason, it is thought that information and communication technologies can be used as an observer in the daily lives of users. IoT devices that provide services such as detection of daily activities, face recognition, localization, and lighting, HVAC, security in the house can be used to identify user routines. Wi-Fi-based indoor positioning technology can be used to collect data about the spaces where the user is located and the duration of their presence. Crowdsourcing applications can serve users' opinions and feedback on their lifestyles and living spaces. In this direction, AI and ML can learn user behavior by examining past user data and informing possible user spatial needs. By ICT, every space where users spend time in the house can turn into data sources that collect user data. User data that can be used for customization can be obtained in this way, from the user's sleeping habits, cooking habits, time and time spent on media use, and how many guests they host.

Establishing and systematizing the spatial behavior patterns of users also creates an assumption about their future preferences. Therefore, by accumulating data collected over time with ICT, it is possible to create multiple possibilities and new combinations for different user routines. This will not only enable faster and more efficient solutions for new users, but will also play a role in improving the living conditions of existing users. A housing design that can adapt to the changing living conditions of users will increase housing sustainability.

This study examines the relationship between user-time-space and emphasizes the importance of users taking part in the design of their houses. It is aimed to draw attention to the fact that housing production is a social and social phenomenon, as users have customized their living spaces throughout history and do not want to live in houses without identity. Considering today's technology, it is pointless to remain stuck in conventional housing

construction. However, it is not possible to think of a system that is completely independent of conventional housing construction. Therefore, it is thought that user space routines formed by user preferences wants and needs can be used in the design to facilitate users' adoption of their houses. This research, which is a preliminary study for future studies, and the user-centered data framework proposal can be used for customization purposes. This data framework, which can be applied with the help of information and communication technologies, can serve as a support for the mass customization approach in housing.



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