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Assoc. Prof. Dr. Sertaç Güngör

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Chapter 1

THE EVOLUTION OF BIM USAGE FROM PAST TO PRESENT

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A Panorama and Preface

Nowadays, especially in large scale projects, work is progressing collectively through the sharing of data obtained from many stakeholders from different disciplines. While data is shared among stakeholders, errors and shortcomings can occur and errors that arise in the design stage can lead to different problems in the implementation stage. The resulting problems and emerging needs change the design, production and operation processes of the project and information technologies are being used throughout the lifecycle of the project. BIM can be defined as a methodology that includes the use of various technologies to improve collaboration, communication and documentation management between the AEC sectors. (Ahmad Latiffi, Brahim, & Fathi, 2014). BIM should not be considered as a design tool, but rather as a design-production process that advances with current and comprehensive information and technologies (Shourangiz et al., 2011).

The foundation of BIM technology is based on computer-aided design. With the technology, innovative tools and environments have developed in the graphic representations of design. The evolution and improvement of the tools has increased the productivity of the industry. Unlike these tools, BIM has brought a methodological innovation to the AEC sector (Daniotti, Pavan, Bolognesi, Mirarchi, & Signorini, 2022).

In the 1960s, Douglas C. Englebart made predictions aout the future of architecture in his article 'Augmenting Human Intellect' (Englebart, 1962). In the article, it was predicted that architecture would be done with interconnected information networks and parametric elements based on objects. The first software that Works with the logic of the BIM technology that we use today is the Building Description System (BDS) developed by Charles Eastman in 1975. In BDS, there is a continuously updated database consisting of subheadings such as material, library elements, supplier information (Bergin, 2011). In 1977, Eastman developed a second software with the same logic as BIM, which he named GLIDE. Both software are used in the design stage, but they differ from each other in terms of being evaluated at different stages of building life cycles (Eastman & Henrion, 1977). After this two software, ArchiCAD, GDS, EdCAAD, RUCAPS, Sonata, and Reflex were introduced to the market.

The term BIM was first introduced in the article "Modelling multiple views on buildings" published in the journal "Automation In Construction" in 1992 (VanNederveen & Tolman, 1992). The article suggested analyzing spatial and structural evaluations along with factors such as energy consumption and modeling data based on this information. During the 1990s, BIM tools were developed that allowed for the examination of parameters and data such as cost and energy in building models (Miettinen

& Paavola, 2014; VanNederveen & Tolman, 1992). One of these tools, the Building Design Advisor software, combined graphical analysis and simulations to enable users to evaluate the building's behavior in different scenarios and its structural, material, and geometric properties (Barnes & Davies, 2015). ProENGINEER, developed by Parametric Technology Corporation, was the first parametric modeling software. Any change in one of the objects linked to each other through parametric relationships automatically changes the other objects or entities to which it is connected.

Since 1995, BIM software has utilized the IFC (International Foundation Class) file format, which allows different disciplines to work together on a common platform by transferring data between different platforms. The International Alliance for Interoperability (IAI), established to create standards and rules for the use of the IFC format, has been known as buildingSMART since 2005. Software such as ArchiCAD Teamwork, Onuma, and Navisworks Jetstream enable multiple engineers and architects to work on the same model simultaneously (Aksamija, 2016). In 2000, Revit software was developed as the architectural version of ProENGINEER by Charles River Software. Today, Revit software, which is widely used as a popular BIM platform, was acquired by Autodesk in 2006.

The OpenBIM initiative has been proposed by various software vendors to improve collaboration (OpenBIM, 2014). OpenBIM is a data and modeling method that is not dependent on a specific software or format, and the IFC format is used for file sharing. In contrast, with ClosedBIM, the data is stored in a local format that is accessible only by the application in which it was created. For example, if a project is created and saved in the Revit program, it cannot be opened in another software. Therefore, the project design requires all relevant stakeholders involved in the implementation process to use the same software.

In 2011, an open-source solution (OpenBIM) to expand the functionality of Revit and Dynamo was introduced as a visual programming tool. Dynamo is used as a parametric design tool, allowing the creation of unique forms and the use of various analyses as design inputs (Karabay, 2017). Formit software, which started being used in 2012, also enables the use of BIM technology on mobile phones. With the adaptation of cloud computing technology in the form of BIM 360 software in 2019, project tracking and execution processes can be easily accessed from any location and time zone, resulting in a faster and more planned schedule.

All these changes and developments can be seen in the timeline given in Figure 1.

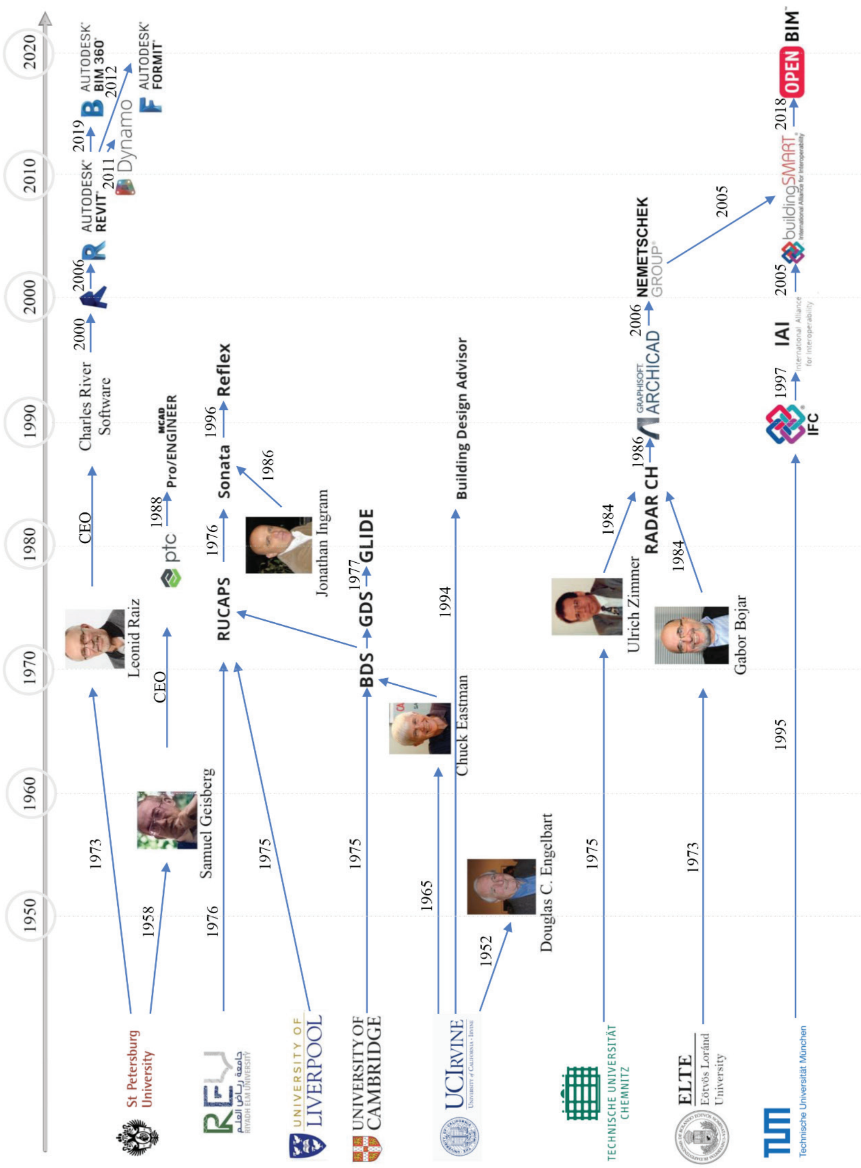

Figure 1. Historical Evolution of BIM Usage

Advantages, Disadvantages, and Limitations of BIM

BIM has become one of the current and important developments used in all stages of a project, with the new concepts and applications it has brought to the industry (Vanlande, Nicolle, & Cruz, 2008). Some of the concepts brought by BIM to the industry include object-based smart objects with parametric modeling, interoperability, conflict control, BIM dimensions, LOD model detail levels, and integrated project delivery (Akkoyunlu, 2015). Nonetheless, BIM has also brought various advantages to the AEC sectors. One of these is helping to improve coordination and collaboration among stakeholders (Sun, Jiang, Skibniewski, Man, & Shen, 2015). This enables design and construction plans to be synchronized and design errors to be identified (Rokooei, 2015). Other benefits include reducing total project time, enabling the tracking of the building lifecycle, increasing customer satisfaction and repeat business, reducing disputes in contracts, reducing errors in construction and re-construction processes, creating new business opportunities, cost optimization, reducing errors in documentation, reducing risks through conflict detection, optimizing design analysis and environmental and thermal performance. (Chi, Wang, & Jiao, 2015; Nguyen & Kim, 2011; Steel, Drogemuller, & Toth, 2012)

Although BIM brings many advantages to the AEC industry, it also faces many disadvantages and challenges. The AEC industry faces challenges in exchanging data seamlessly during collaboration and integration, which hinders cooperation and impacts the implementation of BIM. (Grilo & Jardim-Goncalves, 2010). In addition, stakeholders with limited knowledge of the subject and limited technical and training approaches can make the project process more difficult (Maçka Kalfa, 2018). One of the factors that restrict the adoption of BIM is the cost of software tools associated with it (Sun et al., 2015). However, even though there are various standards, contracts, and implementation plans for BIM use in countries such as England, Italy, and America, the absence of a standard, implementation plan currently in use in Turkey can make the project process more difficult (Salman, Khalfan, & Maqsood, 2012). In recent years, there has been dissatisfaction with Autodesk's primary BIM design software development and following user demands (Day, 2022a). The industry needs tools that can adapt more efficiently to continuously evolving digital workflows (Day, 2022b). This has led to various institutions and organizations communicating with Autodesk to express their demands and dissatisfaction.

In February 2020, the European Construction Industry Federation (FIEC) published a statement regarding the increasing costs faced by users and the lack of competition in the software industry (FIEC, 2020). In the same year, in July, a community of international architecture offices sent an open letter to Autodesk, expressing concerns about the lack of transparency regarding the future of software and the increasing costs from year to year regarding the lack of development of design software (AHMM et al., 2020). After two years, in September 2022, organizations representing professional architects in Denmark, Finland, Iceland and Norway sent a second open letter to Autodesk. The two open letters sent to Autodesk in 2020 and 2022 express the views of the organizations (AIN, ATL, SAMARK, & Firms, 2022).

A Future Projection

Just like CAD technology has gradually replaced drawing tools such as paper, pencil and ruler, BIM is starting to leave CAD behind. It is important to realize that the conventional processes that have been established in the industry no longer work in today's world and will not work in the future. Although existing technologies are used to a certain extent, they will not be as productive as they were before (Hardin & McCool, 2015). Technology is rapidly changing today and is contributing to established technologies that are in harmony with the industry. Therefore, it is believed that BIM can be integrated with new technologies to find solutions to current problems and respond to the needs of the era (Koutamanis, Dainty, Kvan, & Turk, 2021). It can be said that the existence of BIM will continue to evolve in the future and that organizations in the highly competitive AEC sector must be open to development and adapt to new processes in order to continue their work (Barison & Santos, 2012).

The graph showing the "Future BIM Maturity Projection" can be found in Figure 2 of the "Built Environment 2050: A Report on Our Digital Future" published by the Construction Industry Council established in England in 2012 (Mordue, 2019). The graph depicts how changing technology will impact the digital built environment. Key technologies are placed within the context of the BIM maturity levels they are associated with over a timeline. Level 2 highlights the use of standard exchange formats for file sharing, emphasizing the industry's digital means of communication. Level 3 supports digital formation through file sharing and collaboration in an online shared data environment. Radio frequency identification tags and building sensors feeding the new construction technology wave are planned in a 5-10 year target. Level 4 is related to adapting operational data to the digital environment through behavioral feedback. The future of construction includes self-assembly, robotics and computer systems, and automation of building controls. Level 5 is referred to as a paradigm shift. Here, the built environment is fully connected to digital data, allowing users to query and analyze the data, presenting the concept of smart cities. "Everything in Beta" for 2050 expresses future technological applications and the active management of construction. A 50% reduction in qualified workforce is expected by 2050 and this is associated with the end of Moore's Law[1]. The report also states that not

1 The law proposed by Gordon Moore in 1965 states that the number of electronic components will double every 18 months, leading to a decrease in the cost of each part (Moore, 1965).

all projections for the future are positive. The increase in digital data also increases security risks and threats, and it is necessary to work on how to manage risks arising from unauthorized access, manipulation, and sharing of data and systems (Mordue, 2019).

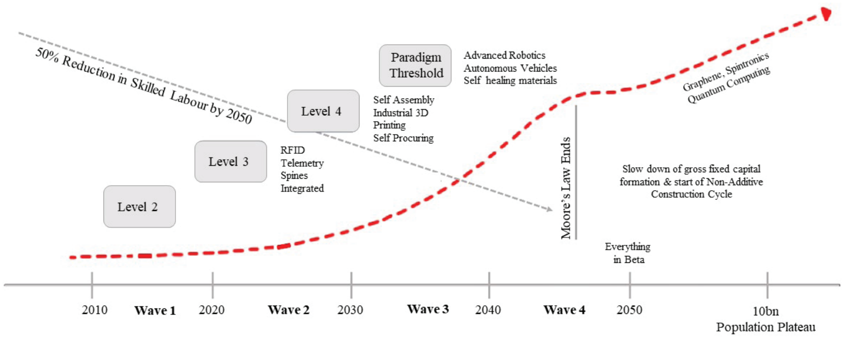

Figure 2. Future BIM Maturity Projection: BIM 2050 (Mordue, 2019)

Along with this, as a future projection in support of the scenario outlined in the report, it is possible to talk about a technological revolution that will transform the AEC industry in all aspects, affecting services, production and costs significantly, in order to respond to existing problems and needs in the coming years (Daniotti et al., 2022).

Integrating advanced technologies like artificial intelligence, cloud computing, ontology, blockchain, data analysis, IoT, laser scanning, digital twin, and machine learning with BIM in the construction sector can potentially address several challenges that limit the adoption of BIM in the AEC industry. (Khudhair, Li, Ren, & Liu, 2021). To effectively manage the information required in BIM, it is necessary to adopt new tools and technologies(Batty, 2018). Thus, it is crucial to stay up-to-date with the latest technologies that can aid in the digital transformation of the construction industry and assess them from a comprehensive viewpoint.

BIM plays a crucial role in digitalizing the construction industry by enabling efficient data management throughout the building's life cycle. However, BIM's potential can be limited if information integration and management are not approached adequately (Sun et al., 2015). Although several studies on dynamic BIM environments and various technologies have been conducted in the literature, a comprehensive approach to their integration has yet to be addressed (Khudhair et al., 2021). Figure 3 shows how different technologies can communicate with each other (Khudhair et al., 2021). The technologies expressed in the figure can be described in 7 subheadings:

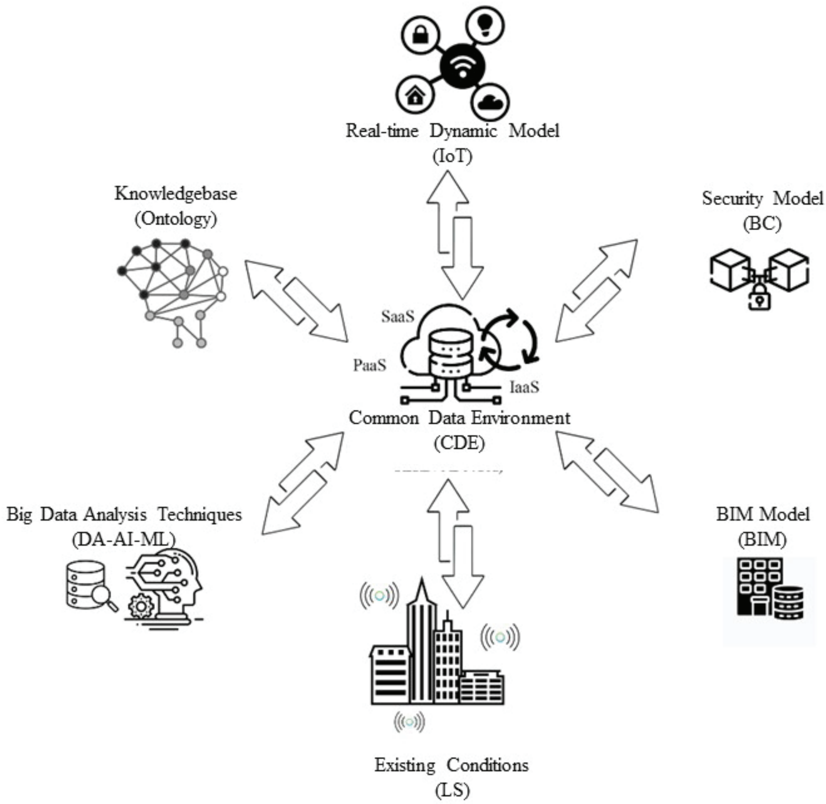

Figure 3. Technologies Supporting BIM Development (Khudhair et al., 2021)

Common Data Environment: It provides real-time collaboration, monitoring and data sharing among different users and different stages of the project life cycle. It is a virtual environment where all technologies communicate. With integrated cloud-based technology, users can access information remotely and there is a decrease in time and effort assigned to any task. The tracking of users involved in the project can be ensured and communication between project stakeholders is improved.

BIM Model: It is a model where data of the designed structures is located.

Security Model: To ensure data protection, security measures need to be increased as the size and complexity of data grow (Mordue, 2019). The use of blockchain technology in the BIM model can effectively handle security concerns.

Real-time Dynamic Model: IoT technology is utilized to supply data to BIM models, contributing significantly to creating a real-time digital model known as a digital twin. This technology relies on connecting devices like sensors, GPS, cameras, and barcodes to the internet and integrating them as tools (Chen et. al., 2014). Providing a rich data source, collecting real-time data from the environment and uploading it to the server enables real-time conditions and data to be converted and presented to the BIM model. Cloud computing technology enables real-time collaboration, and when combined with IoT, it can serve as a network integration tool (Arthur et. al., 2017). Data from IoT sensors can also be used in big data analysis techniques like artificial intelligence and machine learning to improve decision-making in present and future projects. However, utilizing IoT technology requires adhering to specific guidelines, standards, or rules that promote information exchange or sharing among different stakeholders (Dave et. al., 2018). Standards such as IFC assist in information exchange.

Knowledgebase: Ontology has the potential to enhance coordination among stakeholders and resolve compatibility issues in BIM models by incorporating field knowledge, which can enrich the semantic richness of BIM models. Additionally, ontology assists in converting field knowledge into a machine-understandable format. When combined with IoT technology, ontology can also facilitate real-time building monitoring.

Big Data Analysis Techniques: By utilizing data analysis techniques that incorporate input from IoT technology, BIM can be integrated with technologies like artificial intelligence and machine learning to enhance decision-making and management throughout a project (Khudhair et al., 2021). Machine learning can be applied to tasks such as security prediction, building material classification, and energy consumption calculation, among others. Moreover, machine learning can learn from past project errors, resulting in time and cost savings.

Existing Conditions: Laser scanning technology can improve the accuracy of data capturing from existing structures, enhance the details in the model, track the process, establish embedded models, and ensure accuracy in building material classification.

From this respect, a study has been conducted by authors to determine the direction in which current research trends related to BIM in the field of architecture have evolved in order to project the future use of BIM in architecture. In this study, information on 3326 publications published in the field of "Architecture" or "Construction Technology" containing the subject heading "Building Information Modelling" OR "BIM" was analyzed from the Web of Science database. According to the data analyzed in the VOSViewer program as shown in Figure 4, the key words of the most recent publications indicated in yellow are: internet of things, safety management, digital twin, linked data, deep learning, machine learning, scan-to-bim, terrestrial laser scanning, lidar, and blockchain.

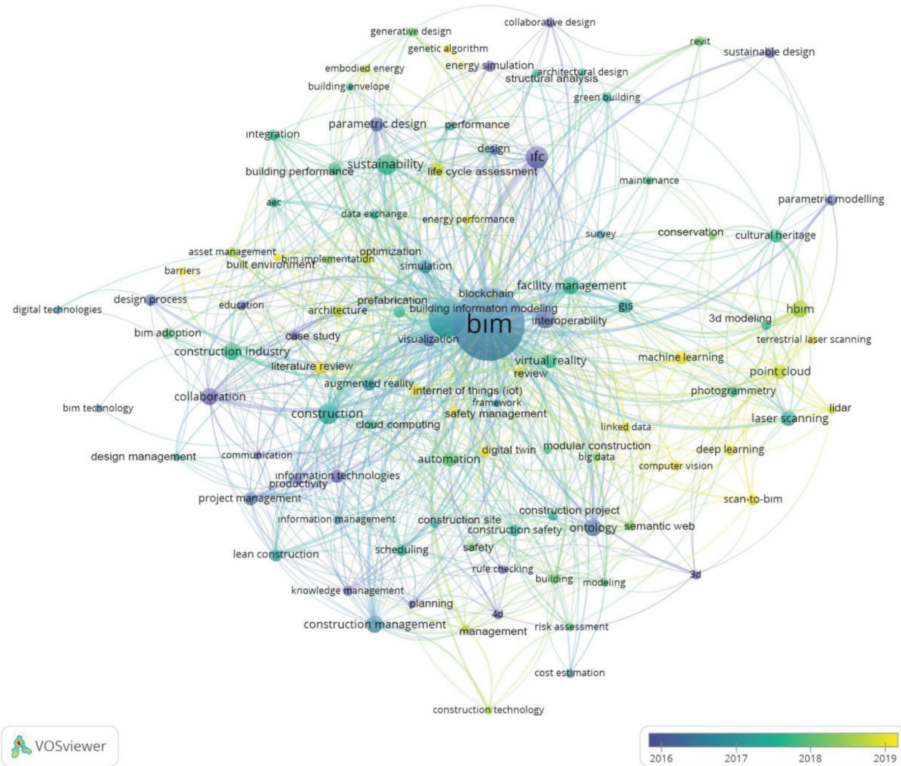

Figure 4. The change of key words in analyzed publications over the years.

Conclusion

BIM is conveyed as a methodology that involves the use of various technologies to improve collaboration, communication, and documentation management between the AEC industries. Although it offers many advantages to the sector, there are many disadvantages and challenges that BIM is facing in the AEC industry today. Technology is rapidly changing and contributing to the tools used by the sector. As a future projection, it is possible that BIM can respond to existing problems and meet the needs of the era by integrating with new technologies. However, it is not believed that a particular technology can solve existing problems. While several technologies can be utilized in conjunction with BIM to create a dynamic environment, a comprehensive approach to integrating these technologies has not been proposed yet. Nonetheless, the coexistence of multiple technologies working together with BIM represents a critical area of research. When key words from recent studies on the topic of BIM and architecture are analyzed in the literature, it is stated that the most current key words are the internet of things, security management, digital twin, connected data, deep learning, machine learning, scan-to-BIM, terrestrial laser scanning, lidar, and blockchain. This shows that there are potential areas for new technology to be integrated with BIM.

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Chapter 2

THE USE OF NATURE-BASED PATTERNS AS A TOOL IN THE INTERIOR ARCHITECTURE EDUCATION [1]

Sura Kılıç[2]

1 Derived from the PhD thesis titled “Pattern-based parametric workshop proposal for the basic design course in distance education”. Thesis advisor: Burçin Cem Arabacıoğlu, Mimar Sinan Fine Arts University, Institute of Science, Department of Interior Architecture, Interior Architecture, Istanbul.

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INTRODUCTION

Design education has a different characteristic than other theoretical and applied courses within the scope of interior architecture education due to its dynamic structure. Students cannot associate this new education system with themselves, and they experience a serious confusion, especially when they take design courses. They have difficulty in expressing themselves and cannot explain the processes of their randomly produced designs. A body of academic studies questioned and examined this process (Henriksen et al., 2017; Sawyer, 2017; Suastra & Ristiati, 2017; Küçükerbaş & Türel, 2011; Enhoş, 2008; Demirci & Aykurt, 2014). Due to these factors, interior architecture education gives a lot of weight to this subject.

At the very beginning of design education, students' concern of "how should I do?" prevents them from thinking critically, and it is reported in the studies that they create constraints for themselves (Boucharenc, 2006: 1-30; Çolakoğlu and Author, 2007:159-168; Uysal, 2015: 51-65). Instead, the question of "what am I doing?" brings the question of "what should I do?" afterwards. In order to introduce the design education to the student at an early stage and build the thinking skills, the basic design course should be the first step, and this brings the course to the fore. Moreover, the fact that the students study interior architecture and its inseparable part, 'design' in the basic design course for the first time increases the importance of this course even more. In this education, which is of such importance, there are experimental studies that have been developed and applied in different ways from the period of Bauhaus.

In interior architecture education, along with the use of 3D in the basic design course, studies were carried out on turning abstract problems into concrete and concrete ones into abstract, and gaining thinking skills (Boucharenc, 2006: 1-30; Çolakoğlu and Yazar, 2007:159-168; Uysal, 2015: 51-65). Developing a systematic pattern analysis flowchart in order to contribute to the literature is the main objective of this study. The aim of this study is not to bring a new approach to the basic design course, but to analyze the concrete model results obtained through the employment of flowchart in the course and to create a framework for the development of more effective learning environments. The proposed flowchart is regarded to have the ability to help students understand complex application studies, which is thought to be the study's contribution to the area. Students will be able to follow the process step by step by using a systematic flow diagram. This study aims to provide and encourage the participation of first year students in nature-based courses through understandable and uncomplicated flow diagrams, and to explore the possibility of its applicability.

When we look at the Interior Architecture Education in general, there is variation in the handling of design tools. In this framework, it is reasonable to carry out new studies to develop and support design education. In some of these studies, nature was considered as a tool. The first studies on nature and biology dates back to early 19th century. Written in 1917, the book “On Growth and Form”, examining the relationship between design and biology, has an important place in this context (Thompson, 1992: 645-934). Thompson shows how a series of geometric and topological transformations can explain and even predict morphological changes in animal species. From the 19th century to the present, biology has been studied by different disciplines and has been a source of inspiration in Thompson’s studies. In this context, biology has become inevitable to be examined in the field of interior architecture. As to the biology-design duality, many application studies were carried out in the field of interior architecture. In addition, biology-design duality has also taken its place in the field of education. In this context, our study is indirectly related to interior architecture education. Interior architecture students study subjects such as point, line, color, texture in the basic design course in the fall or spring semester of their first year. The literature review shows that studies were carried out on the development of these courses and pilot programs were implemented (Boucharenc, 2006: 1-30; Çolakoğlu and Yazar, 2007:159-168; Uysal, 2015: 51-65; Sarıoğlu and Erdoğdu, 2016:7-9). ; Dikmen, 2011: 1509-1520; Çetinkaya, 2014: 31-46). These studies were carried out second, third and fourth year students as short-term workshops. The studies carried out are studies aimed at developing and improving the subjects included in the basic design course. The subjects of the studies and workshops focused on the possibility that the relationship between nature and design can be established mainly through geometry and that students can solve every complex structure through algorithms. Accordingly, education models based on learning through nature were developed by organizing the trio of number, geometry and algorithm (Öztürk, 2013:83-101; Gedik and Özen Yavuz, 2018:135-159). This study aims to provide and encourage the participation of first year students in nature-based courses and workshops through understandable and uncomplicated flow diagrams, and to explore the possibility of its applicability. It is thought that the students will be able to understand design elements such as point, line, plane, volume and design principles such as balance, focus and symmetry more clearly in the pattern analysis through the workshop in the fall semester of the first year. Such studies and workshops started to be held more frequently in 2011-2019, and it is observed that they have become more intense in the last 5 years (Table 1).

2011	Istanbul Technical University	Digital Production: Contemporary Production Techniques from Design to Production
2013	Digital Design Symposium in Architecture Istanbul Technical University	ITU-Ç-Pattern
2013	Istanbul Technical University (ITU)	Epiworks: Intomotıon II
2013	Mimar Sinan Fine Arts University (MSGSU)	Parametric Surface Space And Play
2013	Yıldız Technical University	Gridal Infections
2014	Mimar Sinan Fine Arts University	Parametric Vertical Limits
2014	Istanbul Technical University	Epiworks: Intomotıon III Ve IV
2015	Mimar Sinan Fine Arts University Fatih Sultan Mehmet Vakif University	First Design Then Produce
2015	Bilgi University	Cellular Re-Visions
2015	Mimar Sinan Fine Arts University Ozyegin University	Sustainable Digital Ecologies
2016	Mimar Sinan Fine Arts University Bilgi University	Encounters, Criteria and Opportunities
2016	Bilgi University	Tectonic Sybiosis
2016	Kadir Has University	Dd Workshop-Digital Design Workshop Series
2016	Bilgi University	Parametric Modeling with Grasshopper
2017	Mimar Sinan Fine Arts University	Live in Form- Rhinoceros+Grasshopper Workshop
2017	Kadir Has University	Parametric Design Camp
2017	Ozyegin University	Metaphor in Design
2017	Istanbul Technical University –Izmir University of Economics	Mission Mars 2024 Workshop
2017	Bilgi University	Robotic Mediations
2017	Bilgi University	Non Planar Orthogonel Assemblied: Robotic Timber Fabrication
2017	MEF University	Freeform Brick Vaults
2017	MEF University	Stuffed Cast Workshop
2017	MEF University	Roboddraw
2018	Istanbul Technical University	Paradoxical Simulation
2018	MEF University	Kinetic Design Workshop
2018	MEF University	Lighting Element Design with 3D Production Techniques
2019	Kadir Has University	Global Summer School-Tutors
2019	Fatih Sultan Mehmet Vakif University	Parametric Design-Laser Cutting Technology

Table 1. *Workshops Held 2011-2019*

The proposed model differs from the above studies in terms of using an in-process systematic flow diagram. The model contributes to the students in terms of providing the opportunity to follow the stages in the study and to return to the stages. Table 1 is restricted to nature-inspired studies as numerical design - robotic fabrication - computational design - self-reproducing systems. The studies listed above contribute to the model development process in terms of pattern analysis and digitization. As can be seen in the table, the workshops with the main digital design or computational design content, having been held since 2011, have gradually increased, and their adaptation into the undergraduate course curriculum has still not been achieved (Kılıç, 2021: 49-50). The reason why this study is needed is due to;

Issue 1: intensive application of nature-based studies in 2nd, 3rd, and 4th years.

Issue 2: development of the applied studies within a certain systematic diagram. (Kılıç, 2021: 39-46)

Recommendations to the issues;

Recommendation 1: it is recommended that such a study be implemented in the curriculum for a week in the fall semester of the 1st academic year. The basis of the recommendation was established by the pilot study. In order to make the complexity of these studies more understandable, it has been evaluated through the pilot study that the application of the studies with the flow diagrams proposed in the theoretical framework support and facilitate the understanding of elements such as point, line, plane, and volume in the course.

Recommendation 2: it has been determined through the pilot study that the proposed diagram applied to the 2nd, 3rd and 4th year students help to produce more variations on the existing solution pattern. In this context, it increases the possibility of analyzing the invisible relations between the elements in a systematic framework through diagrams.

The proposed study model was applied to a total of 131 students in 4 universities through distance education. After the study, an online questionarrie was administered to theparticipants on Google forms. The effects of the variables were examined through "chi-square analysis".

Within the scope of this proposal, the possibility of creating certain algorithms by examining the developmental stages of organisms in nature is expected. The algorithms with this potential are to be obtained from the pattern on the object surface. After structural algorithm studies, parameter analyzes as to the process of change in the structural morphology will be performed. At this stage, students will be able to understand the expansion of the structure in algorithm and parameter analysis. In this context, students will be able to define not only the processes of concrete products, but also what the change in this process means as a concept and will be able to express them spatially. At this point, after the student determine the current situation thorugh evaluations, the student, before completing the process, should be given time to answer the question of what he has done so far, and asked to make sense of the process.

It is aimed to create an environment for testing morphological, non-linear and spiral paths that support the lesson plan with an open-ended model, which allows for the production of internal knowledge and the formation of new experiences. It is aimed to trigger the students to think about ways of knowing.

OBJECTIVE

Interior Architecture education is an educational discipline in which the experience-based learning that takes place in studios is at the center of the design concept. In this paper, it is planned to experience the basic design principles and elements that are required to be understood in the basic design course within the interior architecture education process, and to contribute to awakening and stimulating the minds of the students for various inventions thorugh raising awareness of nature-based learning. As a result of the pilot study designed for this purpose, an application-based flowchart is presented as a model for designing new patterns for basic design courses. In the creation of the model, the concept of pattern is researched in different disciplines within a broad framework in line with the principles of consistency and inclusiveness. The stages of creating the model include the stages of analyzing the pattern systematics based on abstraction in interior architecture basic education and reconstructing the systematic in a way that will increase the capacity to be used in the creation of new patterns. In line with these stages, it is aimed to define basic design elements such as point, line, plane, volume and basic design principles such as contrast, emphasis, repetition, balance, and rhythm in the formation principles of natural elements, and to systematize the same principles strategically to be used in the shaping of design patterns.

SCOPE

Within the scope of this study, an evaluation by interior architecture and architecture was made in the end of the the four-day workshop, and a model was proposed based on this evaluation. The usage purposes of the patterns are expected to be interpreted and improved by the participants. With the design method determined, the transformation of the principles existing in nature into rule-based systems is planned on a systematic flow diagram. This workshop dealt with relational modeling, bio-pattern and visual programming by associating computational design practices with natural phenomenon. The scope of pattern layout analysis is to emphasize and focus on design elements such as point, line, plane, volume, and design principles such as balance, focus, and symmetry. This study examines relations between elements in the pattern analysis process according to the basic design principles and elements, and employs an auxiliary model proposal within the scope of abstraction studies.

METHOD OF THE STUDY

The aim of the abstraction study, which is handled within the discipline of Interior Architecture, is to reveal the meanings in the elements and the relations between the elements and to create new meanings with new constructions. In addition, upon this act of thinking, participants are expected to develop unique stances for the compositions they have constructed by using the tools and materials they prefer with the suggestion of the faculty members. As a result of such an approach, the study is based on the systematic analysis of nature-based patterns through diagrams within the scope of abstraction studies. The study was conducted through an online workshop held at 4 universities. The study group consists a total of 131 first year students. At the end of the workshop, a set of two-choice survey questions was used to collect the quantitative data. The stages of the study were examined and evaluated in an orderly fashion. Flow chart was discussed as an auxiliary tool in systematization.

LIMITATIONS OF THE STUDY

In this study, the application of the proposed model was realized with distance education. Participation in the workshop is limited to the 1st year students. It is important that we explain the importance of the advantages and disadvantages of this workshop where the model presented through distant education. The reason for performing the workshop via distance education was that the study coincided with the 2020-2021 pandemics (Covid-19). With the persistence of the pandemic, the importance as well as the challanges of distance education has since become more apparent day by day. The number of students requesting to participate in online parametric workshop was much higher that those asking for face-to-face education, which is considered an advantage in terms of the implementation of the parametric workshop model. In addition, despite the limited access to computers by the first-year students for the 3D software to be used in the parametric workshop, it was no longer a problem for the students since computer acquisition became mandatory during the pandemic period and compulsory for distance education. In addition to the advantages, there were problems with internet access and network connection. Apart from the disconnection of the internet network, some students from four universities experienced hardware problems.

PROBLEM STATEMENT

The interior architecture education, which interacts with abstract concepts, has a wide-ranging, unclear, fuzzy and complex structure due to its structure and functioning. In this context, it was seen in the literature studies that the compositions/models made by the students in the abstraction study continued with a linear and rote understanding and had challanges in the process. Due to the development of the use of three dimensions in the basic design course during interior architecture education, studies have been carried out in the literature to turn abstract problems into concrete and concrete ones into abstract, and to gain thinking skills (Boucharenc, 2006: 1-30; Çolakoğlu and Yazar, 2007:159-168; Uysal , 2015: 51-65). Developing a systematic pattern analysis flowchart in order to contribute to the works achieved so far is the main objective of this study.

HYPOTHESES OF THE STUDY

Nature should not only be seen as a source of visual inspiration for designing organic forms or soft lines, but rather provides living and real examples to study and learn as a process and system that does not allow formal limitations.

In general, creating patterns is accepted as the main activity and main subject of the architectural creation process. The interior design process is not a one-way and straight process. Therefore, this proposed flowchart model only covers the definition of elements such as point, line, plane, volume and principles such as contrast, emphasis, repetition, balance, rhythm by solving and examining their existence in nature.

Based on the study problem, there are two assumptions on which this study bases.

Instead of observing and imitating nature, or nature being a source of inspiration for them, students need to develop new approaches based on understanding the element in objects and establishing meaningful relationships between the elements.

Based on the application example, it is believed that it would be beneficial to use flow charts in order to analyze and develop those with different pattern capacity production, instead of random analyzes. There is a need to develop productive-systematic methods and approaches that are alternative to the currently used traditional pattern analysis method.

THEORETICAL FRAMEWORK

Nature-based numerical thinking and pattern definitions

The etymology of "pattern" is from the Latin peter or patronus, meaning father, patron, god or master, meaning that the concept of pattern is derived as a pattern, matrix, template or layout. The current concept of model is defined as a sequence, distribution, structure or progression, a sequence or frequency of a repeating unit, a system or process of identical or similar elements (Garcia, 2009:8).

Despite their abstract appearance, even early neolithic models are considered to be symbolic and diagrammatic. The first important theoretical reference to spatial models in the Western tradition was in Plato's Timaeusi, where he described the world as full of tightly packed patterns with atom-like solids and geometric forms (Garcia, 2009:9).

The history of construction and space production has been covered in publications on pattern-based production methods written from the past (up to the 15th century in Europe) to the present. At the end of the 18th and 19th centuries, the rise of global capitalism, the industrial revolution, and the enlightenment and scientific projects led to an increase in aesthetic diversity. Additionally, the speed of using numerical data with the aid of pattern-based production systems increased with the pursuit of the "new". Theorists, architects, and designers, including Karl Friedrich Schinkel, Johann Joachim Winckelman, John Ruskin, Karl Gottlieb Wilhelm Bötticher, Gottfried Semper, Alöis Regl, Christopher Dresser, and Luis Sullivan composed works on pattern (Ruskin, 1849:134-140; Alexandre, 1977:797-804; Garcia, 2009:8-17; Sullivan, 1996:6-12; Dresser, 1996:25-73).

In an early period of significant taxonomic and morphological research and pattern theorizing, pattern theorists of the 18th and 19th centuries (influenced by Darwin and Linnaeus) sought to find ways to produce biological species, infinite and evolving, with the simplest elements from variable (nonperiodic) biological species (Garcia, 2009:9).

Creating patterns is considered as the main activity and main issue of the architectural creation process. Many methods are tried for the sake of this concept and it is seen that it is the subject of architectural research, especially with the models developed during the education process. Names such as Christoper, Achim Menges, Petruccioli present experimental studies on pattern modeling techniques in their own studios to enrich productive systematics.

Patterns are forms, shapes, structures that repeat themselves but contain tiny differences in each individual case, embodied in the basic working principles of nature (Ball, 1999: 8-24). Ball states that the patterns are the repetition of the unit, but these units do not have to be identical and the repetition can develop continuously in an irregular way. Mollison, in his book "Permaculture: a designer's manual", states that, as an example for irregularly developing patterns, sand ripples reveal a holistic structure and form a pattern even when they are not identical and properly arranged. According to Mollison, the emergence of patterns is never accidental, but the result of meeting the basic needs in our life and fulfilling certain functions (Mollison, 1996: 7-9). Detecting and examining patterns in natural formations provides us with a wide variety of clues about habits, permeability, cyclicity, speed, and relationships with other elements in the environment. Because natural events take on certain repetitive shapes and reveal certain cycles as a result of events and processes such as heat, contact, light, motion, pressure that they experience in their own cycles. In the analysis of the aforementioned pattern structures, it is also possible to notice that there are certain ratios, balance, tolerance and juxtaposition limits in the increase in measures such as size, volume, and length. These patterns include soap bubbles, Fibonacci series, hydrological and vascular systems, protein folds, cellular automata, attractors, force fields, Sierpinski triangles, coatings, Moiré patterns, fractals, networks, swarms, atoms and molecular structures, nodes, fluids, dynamics, gas/smoke/meteorological forms, viruses, microorganisms, bubbles, voronoi cells, L systems, light, fire, landscape/geology/geography, rhizomes and various hybrid renewable structures (Garcia, 2009:14). Waves (waves in the sea, undulations of dunes), fluid lines, nebula forms, spirals, rounded protrusions, branches (tree branches, river branches), nets, crystallization can be counted as the main forms in nature. The mathematical system is defined[4] through three main headings.

- Golden ratio: The golden ratio has been used until today as a tool to model a set of geometric forms (patterns) as a mathematical sequence of numbers, in order to explain some natural forms and structures and their growth processes. The simplest definition of the golden ratio, which we frequently encounter in nature, can be as follows; the ratio of the whole to the large part is equal to the ratio of the larger to the smaller part (Doczi, 1994:32-57). Earth, plants, people, trees, etc. therefore, everything created in the universe has a golden ratio. Since it has been determined that there is a harmony between the parts of all objects and beings that we can see in the universe and that it has not changed for thousands of years, the relationship known as the mathematical system of the creator is called the "golden ratio".

- Biomimetics: Biomimesis is defined as inspiring new generation designs by imitating/learning/experiencing the structuring/formation processes of natural organisms and their analytical solutions. This concept made its way into the literature as a product of the 20th century. Nature-based studies are also studied by different disciplines (Erdoğan and Gönenç Sorguç, 2011:273-278; Gedik and Özen Yavuz, 2018:142-143).

- Fractal geometry: Mandelbrot discovered fractal geometry in the 1980s and then continued his research. The concepts that form the basis of fractal geometry are disorder and uncertainty in chaos theory. One of the geometric concepts around us that we did not know to see until recently is fractals. Structure of fractals; No matter which point we take on the surface of the object in fractal order, when we enlarge it, we can still see the shape we saw at the beginning, no matter how long we continue this process, we can still encounter the same result, this phenomenon is called fractals (Mandelbrot, 1983: 18).

The evolution of pattern design from nature-based computational thinking

The development of pattern design in natural patterns creates its own world by repeating itself in the evolution process to create unexpected forms. The human mind will be perceived more easily when the findings obtained by observing natural events and phenomena are wrapped in simple formulas that will facilitate our understanding of their basic operating principles. Representing natural cycles and forms through geometric shapes is the field of study of many disciplines, but also falls within the field of interior architects. Digitizing the pattern required the use of mathematical language with trajectories forming algorithms. (Baş Yanarateş ve Kılıç Batmaz, 2013:30). As the mathematical equivalent of pattern orders, Mandelbrot's fractal is used to solve complex structures with simple connections divided into units. Thus, the form constructs in the design are largely based on the geometric system. In Sertsöz's work "The bright world of mathematics", the effect of mathematics on our design perception is expressed as follows "Nature is the same nature, only our power of perception enriched by mathematics changes" (Sertsöz, 2012:41-42). The change in our perception is also reflected in our design with fractals. Such current complex issues as data coding in design, algorithmic design and the basics of parametric design, analog-digital coexistence in design, sustainability and performance, digital production will be handled much simpler through the design education. In conclusion, the unit, which is repeated at all scales, leaves its place to the form structures that are transformed by renewing itself.

Criticisms of pattern design based on numerical thinking system

Today, architects, designers and interior designers use digital design platforms to generate form. These include parametric design, genetic algorithms, etc. It is possible to see examples developing in interaction with such technologies. The mentioned techniques and algorithm writing methods are based on a certain systematic thinking. Although the method affects the adaptation process of the students, it inevitably changes the direction of space that is effective in three-dimensional thinking. It can be said that the pattern-based parametric design also has many aspects that do not overlap with the basic design principles depending on the Gestalt theory within the scope of the design methods and processes of modernism. An exemplary study from the discussions for the parametric design formed with patterns is the study titled "The Inquiry of a Manifest: Parametrisism", where Oktan and Vural analyzed this process as acceptances and rejections (Figure 1) (Oktan and Vural, 2017:64-65)

Digital and technology are developing in accordance with our age. The methods and processes used in this developmental stage change and transform. When this process is evaluated within the scope of parametric design, it is seen that "*the period in which the computer was used as a 'tool' has come to an end and the computer will affect the design as a 'partner' in the next period*" (Schmitt, 1997:3-13)

ACCEPTANCES	REJECTIONS
Parametric Design	Euclidean Shapes
Curvature	
Form Differentiation	Relationality
Differentiated Repetition	
Association	Simple Repetition
Universality	

Figure 1. *Criticized acceptances and rejections on Digital Design (Oktan, Vural, 2017:64-65)*

There are also criticisms of digital design because it contains a formal necessity and is perceived as design-limiting. There are also criticisms of digital design because it contains a formal necessity and therefore the design is perceived as limiting. In this context, parametric design, differentiation of form, rejection of association and association come to the fore in terms of their application in parametric designs. On the other hand, curvature, differentiated repetition, rejection of Euclidean forms, rejection of simple repetition are not priortized (Oktan & Vural, 2017:67).

USING THE PATTERN AS A TOOL IN BASIC EDUCATION

Pattern recognition, exploration and selection methods

Awareness towards original creativity develops with the designer's ability to sense the basic idea behind the visible, perceive patterns and organize by establishing connections between elements. Self-organization, which exists in the creation process of nature, is 'evolutionary' and 'evolution' in design is realized by providing creativity that expands the capacity for diversification. Adaptable designs that have the ability to survive under changing conditions while preserving their originality, as in living organisms with systems that reproduce by repetition, are considered as future-oriented, innovative designs. In his work 'Patterns of Architecture', Mark Garcia defines the processes of discovering and organizing patterns (Garcia, 2009:8-16). Organizing activity occurs as a normal function of our brain, and new pattern arrangements can be created as a result of examining this mechanism and using the brain's processing systematic as a model. According to this explanation, pattern means the development of new thinking models from the organized brain to the organizing brain. Genetic codes that create complex structures that repeat themselves in nature are defined as algorithmic order in the form creation process of design. The algorithm creates numerical thinking systematics towards form production. The variable inputs of this systematic are also determined by the algorithm (Baş Yanarates and Kılıç Batmaz, 2013:30).

In this context, complex pattern structures that have common features and can be correlated can be defined or classified with certain features and characteristics within these structures. In this context, the purpose of pattern identification is to give the "complex unknown" a unique shape and to identify the pattern that belongs to a known class. Pattern recognition approaches are studied under three categories as follows;

1-Statistical pattern recognition (Jain et al., 2000:8-11).

2-Structural pattern recognition (Pavlidis, 1977:258-284).

3-Intelligent pattern recognition (Feez ve Hazem, 2013:57-76).

Within the scope of the research, the definition of structural pattern among three titles was emphasized. Structural pattern recognition is an active field that has been researched and studied because of its practical use. Structural pattern recognition is represented by a series of numbers that are the results of various measurements performed on the raw data, whatever the input object. These numbers can be interpreted as coordinates of points in a vector space, so the geometric term is often used to describe this approximation. If appropriate measurements are made, the points corresponding to the objects from the same pattern may be close to each other in terms of geometric distance, then the pattern recognition problem becomes the problem of finding regions in the space where the points from a single pattern are located (Pavlidis, 1977:3).

Based on the literature review, flow diagram was planned for the production of the shape. In this context, the analysis was made by reducing the morphological structure analyzed in the structural pattern approach to defining the basic characteristic. In general, the information extracted from the patterns is not only considered as the numerical values of the set of features. In addition, the interconnection structures of features, or the interrelationship between them, contain important structural relationship information that facilitates definition and classification. In other words, the definition takes place with the descriptive formal syntax obtained from the raw form of the pattern or the grammar obtained from their synthesis. For example, the number of vertices and edge angles of the pattern can be formulated with a hierarchical definition by reducing it to simple subcomponent patterns in general (Jain et al., 2000:4-6; Pavlidis, 1977:4). In the structural method, each pattern is treated as a composition of its components. In the pattern recognition method, the relationship between various units and the connections between the relationships are of great importance. For example, defining a leaf can be defined structurally as two equidistant pieces with bilateral symmetry (Hartvigsen, 2000:668).

Computing pattern recognition: New pattern capacity

All forms and ecosystems in nature emerge within the framework of a chaotic and hierarchical order consisting of defined rules. In the emergence of complexity and chaotic order in natural systems, the structural and environmental relations established by the components are as determinative as the components in the system. Self-organization takes place within the natural system. During this self-organization, while the structures have different forms and features on their own, they also perform as a whole when they interact with each other. In this context, it gains importance in the process that the structures created allow unlimited forms in their behavior and formation. In order to reach a form in the fields of design, architecture and interior architecture, it is necessary to reveal the existing chaotic order in complex systems and to adequately monitor and define the behavior of the systems and components in adapting these systems to the design.

In order to compute pattern capacity, pattern generalization should be possible. The order to be followed in making this generalization is given in Figure 1 and Figure 3.

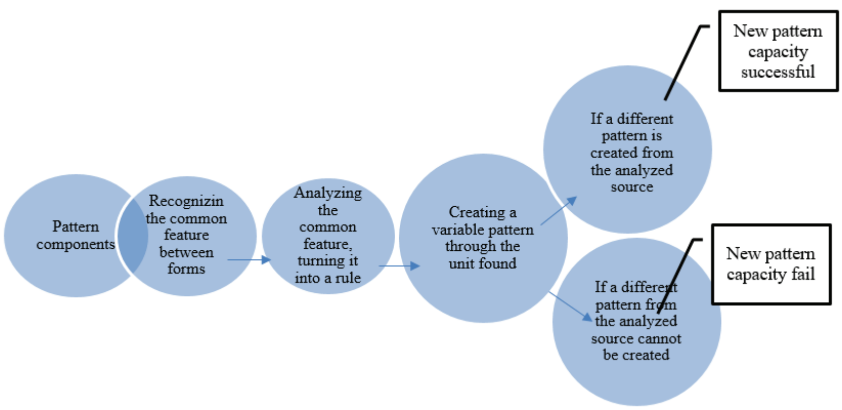

Figure 1. *Systematic pattern generalization diagram*

Conceptual parti generation from pattern recognition

Iconic method, metaphor method, analogy method, proportional method, inductive and deductive methods are used as architectural design methods (Kılıç, 2021). In order to create a conceptual parti on the pattern, inductive and deductive methods were used to generate a pattern recognition value. The inductive method is to reach general conclusions based on the observed facts one by one, in other words, induction is a type of reasoning that goes from specific to general. The deductive method, on the other hand, is to try to design its parts after determining the general rules about how a product will be remembered or how it will look, even after making the preliminary design. After the new pattern capacity analysis mentioned in the previous section, the parti studies are followed for the modular system design derived from the unit.

In the concept process, the vital functions of the living organism should be analyzed with the help of the discipline of biology and all data should be handled appropriately. For example, after the morphological shape analysis of an ambient insect, firefly, the shape structure of the source causing this light and glow should be analyzed geometrically, or the swelling of a pufferfish as a defense mechanism and the relationship and meaning between this swelling and morphology should be analyzed accordingly. As a result of this analysis, using deductive and inductive methods, parti studies are carried out with the unit in the pattern that we previously worked on at the beginning of the process. In doing this parti study, the reproduction or growth path should not be done randomly, but in accordance with the morphological structure of the organism. The conceptual parti diagram study is given in Figure 2.

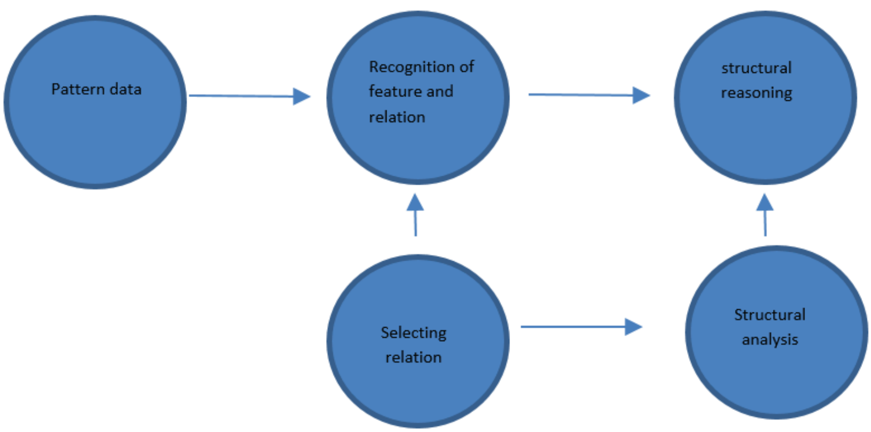

Figure 2. *Conceptual parti generation from pattern data*

Creating new pattern based on pattern

Pattern-based new pattern formations are obtaining and analyzing the existing pattern, obtaining a new pattern by abstracting the pattern with numerical data, deriving and reconstructing the new pattern by diversifying it. This is transformed into a physical model, then sequenced, and at each stage in the sequence, the student's spatial rotation and mental visualization skills, as well as abstraction skills, gain importance. Thanks to this method, which is used to reach the geometric form, form or object that the student envisions in his mind, it is also possible to make sense of the process and to question the process. In this method, since it is a process that can be followed in the form of an algorithm, it also allows for feedback. In Figure 3, there is a graphic explanation describing the steps to be followed for this process.

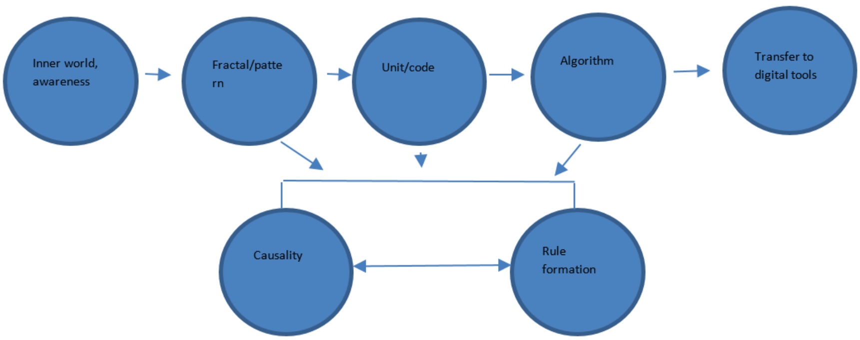

Figure 3. *Comparison of the constructs with the formation created by the algorithm, evaluation with causal connections.*

FINDINGS AND DISCUSSION

A total of 131 participantsconstituted the experimental group in the study. The gender variability of the participants is not analyzed. These figures show the number of participants to be analyzed (Table 2).

		Participant
University	AREL	24
	İSTİNYE	11
	MSGSU	38
	BEYKENT	58
		131

Table 2. *Number of participants*

The University Participants Afliated with				
		Frequency	Percentage	
	AREL	24	18,3	
	İSTİNYE	11	8,4	
	MSGSU	38	29	
	BEYKENT	58	44,3	
Gender				
	Female	116	88,5	
	Male	15	11,5	
Is the workshop length sufficient for you?				
	Yes	111	84,7	
	No	20	15,3	
How long do you think the workshop should be?				
	2	3	2,3	
	4	84	64,1	
	6	25	19,1	
	8	12	9,2	
	10	5	3,8	
	15	2	1,5	
Did your perspective on living things and objects in nature change after the workshop?				
	Yes	130	99,2	
	No	1	0,8	
Did the workshop contribute anything to you?				
		Yes	**131**	**100**
Did the workshop affect your 3D thinking?				
		Yes	125	95,4
		No	6	4,6
In choosing an object from nature, can you abstract and diagram it?				
		Yes	125	95,4
		No	6	4,6
Were you challenged to choose a biological inspiration?				
		Yes	27	20,6
		No	104	79,4
Would it be better if the instructor gave the biological inspiration source within the workshop?				
		Yes	26	19,8
		No	105	80,2

Did you find it difficult to extract concepts and keywords from the pattern that emerged from the biological inspiration?			
	Yes	31	23,7
	No	100	76,3
Were you able to load functions and role on the pattern created at the end of the workshop?			
	Yes	125	95,4
	No	6	4,6
Did you get more patterns than you had expected?			
74,8			**98Y**es
25,2			33No
Do you think this short-term workshop should be integrated into your basic design/ basic art/basic education courses?			
96,2			126Yes
3,8			5No
100			131Total

Table 3. *Frequency Distribution of Participants by Post-worjshop Questionnaire*

			Did you get more patterns than you had expected?					
			Yes	No	Total	X^2	sd	Fisher's Exact Test
The University Participants Afliated with	AREL	N	22a	2b	24	7,986	3	0,042
		%	91,70%	8,30%	100,00%			
	İSTİNYE	N	8a	3a	11			
		%	72,70%	27,30%	100,00%			
	MSGS	N	23a	15b	38			
		%	60,50%	39,50%	100,00%			
	BEYKENT	N	45a	13a	58			
		%	77,60%	22,40%	100,00%			
	Total	N	98	33	131			
		%	74,80%	25,20%	100,00%			

a 1 cells (12,5%) have expected count less than 5. The minimum expected count is 2,77.

Tablo 4. *Analysis Results of Students' Obtaining Patterns by University (Chi-square Analysis)*

According to the results of the chi-square test performed to determine the relationship between the university participants attend and the concept of pattern, there is a significant relationship ($X^2(3) = 7.986$, p=.004). According to the result of the Cremers V test, the relationship between the two variables is low (r=.247, p=.004). According to the frequency and percentage distributions, it was determined that the students studying at Arel and MSGSU Universities were able to obtain more patterns than they had expected.

			Do you think this short-term workshop should be integrated into your basic design/basic art/ basic education courses?					
			Yes	No	Total	X^2	sd	Fisher's Exact Test
Did the workshop affect your 3D thinking?	Yes	N	123a	2b	125	0,001	1	36,254
		%	98,40%	1,60%	100,00%			
	No	N	3a	3b	6			
		%	50,00%	50,00%	100,00%			
	Total	N	126	5	131			
		%	96,20%	3,80%	100,00%			
2 cells (50,0%) have expected count less than 5. The minimum expected count is ,23.								

Table 5. *Analysis Results of the Relationship between Understanding the Logic of Pattern and Basic Design Course (Chi-square Analysis)*

According to the results of the chi-square relationship test conducted to determine the relationship between students' understanding of the logic of the pattern and the basic design course, a significant relationship was found ($X^2(1) = 36.254$, p=.001). According to the result of the Cremers V test, the relationship between the two variables is low (r=.528, p=.001). According to the frequency and percentage distributions, it was determined that the participants who took the basic design course had a better understanding of the logic of the pattern.

Does the Systematic Flow Diagram have an effect on the development of 3D skills by explaining the abstract-concrete and 3-dimensional relationship to interior architecture students in a more understandable, practical and quick way?

There are uncertainties in the process because students do not know what they are doing in the design course. The proposed flow chart was applied to the students to make these uncertainties more understandable and to follow the process step step by step (Figure 1, Figure 1, and Figure 3). With the elimination of uncertainities, students can follow the developments created gradually with the use of systematic flow diagram, and they can follow the change and transformation in three dimensions. With these created diagrams, the student can expand or narrow down their work. The use of a systematic flow diagram also makes it easier for students to see the errors on the way, and to continue the process by re-evaluating the errors they notice. When returning to the previous stages due to the mistake made during the process or the need for reorganization, the student reinforces the three-dimensional thinking through repeating. The flow diagram that students can use together with mental regulation at the stage of turning the abstract into concrete facilitated the process. The graphical diagrams provided a better understanding into the process, which is complex due to the huge amount of data to be processssed and the continuous follow-up of the change and transformation of the data. It has been seen that the application of the systematic flow diagram provides convenience to the students in the subsequent editing stage or rearrangement of the multi-input data sets. It has been seen that using the pattern layout as a tool and experiencing this layout with a systematic flow diagram supports students' spatial thinking skills through repetition, returning to and following the previous stage, and it is quick and practical thanks to experiencing and following each stage in the process.

CONCLUSION AND RECOMMENDATIONS

The pattern is described in methods as a tool. By using the proposed flowchart (Figure 1, Figure 2, and Figure 3) in this study, it was aimed that the participants could improve their skills of analysis, and based on the results of the distance workshops, it is seen that the workshops made it more understandable, clearer and quicker for the participants to improve abstract-concrete thinking skills and build pattern-3D connection. At the end of the workshop, it was seen that the Systematic Flow Diagram and the abstract-concrete and 3-dimensional relationship can be explained to the students of the interior architecture department in a more understandable, practical and quicker way. Carrying out the studies on the planned days in the workshop through the systematic diagrams allowed the students to follow their own development by knowing and questioning what they were doing. At what stage the short-term parametric workshop proposal should be implemented in the four-year education period is a separate area of study and is an important research area outside the scope of this research. Regardless of the design method and approach, further studies should be conducted on short-term workshops applied in design studios in order to monitor the changes led by the use of 3D in design education, on how they can relate to each other in intermittent design studio processes, and how they differ through interpretation and practice. The proposed model can be implemented in and developed by universities, which can lead to creating new expansions.

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Chapter 3

DETERMINATION OF DISASTER EMERGENCY MEETING SPOTS FOR CITIES EXPOSED MULTIPLE DISASTERS[1]

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1. Introduction

Disasters refer to events (nature-, technology- or human-related) that interrupt or halt the normal life order and activities of whole or part of the society or destroy its self-sufficiency. Disaster is not considered as the event itself but its outcome (DEMA, 2014). In this respect, every settlement faces at least one disaster risk and measures must be taken to mitigate direct or indirect losses caused by disasters to maintain normal life order and activities (Becker, 2009; Das et al., 2013; Melgarejo and Lakes, 2014; Aka et al., 2017; Zhao et al., 2017; Güloğlu et al., 2021, Cesur and Bulut, 2022). It is not always possible for health, fire brigade, search and rescue units reach all disaster victims in the disaster area within the first 72 hours following a disaster, and in particular, everyone stands alone in the first minutes of the event (DEMA, 2019a). It is very important to strategically plan PDMS so that people can go to a safe place following a disaster, meet and contact with their relatives or other disaster victims, and first aid is done, and to eliminate the deficiencies of the areas (Mi et al., 2014; Çelik et al., 2017).

PDMS, which are mainly used for disasters such as earthquake, flood, landslide and fire, and that are part of the open and green area system, are areas where urgent needs of disaster victims are met, security is provided and life begins again (Kar and Hodgson, 2008; Li et al., 2012; Çavuş, 2013; Soltani et al., 2014; Wang et al., 2016; Xu et al., 2016). As is also understood from here, urban open and green areas as one of the spatial elements, play an important role in gaining resistance against disasters and reducing the effects of disasters. However, although studies were made on utilization of open and green areas to make urban areas resistant to disasters (Hossain, 2014), its importance has not been adequately understood yet and such areas are not as widespread as necessary. When it comes to the functions of open and green areas in cities, their recreational functions, ecological functions and social functions come to mind first before their functions of preventing and mitigating the effects of disaster in the event of a disaster (Jayakody et al., 2016; Belkayalı and Ayan, 2018; Belkayalı and Ayan, 2019).

While the open and green areas are of great importance in creating disaster-resistant cities, it is equally important to identify open and green areas that can be used as meeting spots during disasters. Use of any open and green area as a PDMS should be evaluated according to affection by disaster. At this point, previous studies stated that certain criteria should be considered in choosing the right place for meeting spots (Sugimoto et al. 2003; Hu et al., 2012; Chen et al., 2013; Masuya et al., 2015; Wang et al., 2016; Zhao et al., 2017; Özel, 2019). One of these criteria is to determine potential risk areas and position the meeting spots outside such risk areas in order to ensure area suitability and safety (Kar and Hodgson, 2008; Soltani et al., 2014; Güloğlu et al., 2017). Furthermore, some disasters such as earthquake may also cause secondary disasters such as fire. In this respect, while selecting the locations of meeting spots, it is necessary to ensure that areas will be at a safe distance to the gas stations, chemical depots, large slope areas, landslide points where the risk of secondary disaster can occur, as well as flood border where secondary disasters frequently occur (Fuentes and Tastes, 2015). Another criterion that should be considered is to ensure that the selected meeting spots is accessible and at a distance so that every individual can reach in a short time in the case of a disaster (McGuire et al., 2007; Soltani et al., 2014). Some studies in this subject also point out that the road network should also be considered and the area choices should be made in a way that access to the meeting spots will not be prevented due to getting trapped under debris or collapsed bridges during a disaster (Yazıcı and Özbay, 2007; Li et al., 2012; Ertugay et al., 2016; Belkayalı and Güloğlu, 2019). Moreover, people need support depending on their physical and psychological stress during a disaster. It should be ensured that people with special needs, such as the elderly, children or physically handicapped, have the same opportunities as other people in this process (McGuire et al., 2007).

The United Nations Office for Disaster Risk Reduction (UNISDR) states that strategic planning should be made and spatial elements should be designed to protect the city from disasters and reduce damage (UNISDR, 2012). Furthermore, each country establishes its own emergency management organizations, seeks ways to be prepared for disasters, respond in a short time and overcome disasters with minimum loss, and creates relevant planning guides and databases. In 1999, the Federal Emergency Management Agency (FEMA) created the Guide for All-Hazards Emergency Operations Planning, which emphasizes preparedness, response and short-term rescue planning elements (FEMA, 2019). This mission is performed by the Prime Ministry Disaster and Emergency Management Authority (DEMA) on a province basis in Turkey and it prepares disaster risk maps for each province, determine locations of the meeting spots and take necessary actions during and after a disaster (DEMA, 2013). DEMA attaches great importance to PDMS in the peparation stage of Provincial Disaster Response Plans in line with the decisions of the Disaster and Emergency High Board made in 2013 (DEMA, 2013).

Today, every settlement faces at least one disaster risk due to both natural events and human activities. In addition to the measures that can be taken to reduce and control the risk of disasters, the PDMS identified in settlements are of great importance in order to minimize the damage that may occur after the disaster, but it is a fact that not every area can be defined as a meeting spot. Especially in the face of the obligation of the authorities to determine the meeting spots, it is not enough for the settlements to designate the parks that form the open and green space system as the meeting spots. It is especially necessary to ensure that these areas are not affected by the disaster or are affected at a minimum level, especially in order to obtain the expected benefit from these areas. In addition, considering the fact that a disaster brings another disaster together, the most suitable place should be selected by considering more than one factor in determining a meeting spot in settlements. In this context, purpose of this study is to investigate the criteria to be considered in selection of the PDMS in a city involving multiple disaster risks by using GIS as well as appropriate areas. Central district of Kastamonu city was selected as the study area. In the city, which involve five different disaster risks, the location selection criteria for meeting spots for each type of disaster were determined and the locations of PDMS in the city were selected from the open and green areas listed in the zoning plan, and recommendations were made for meeting spots that are needed but not included in the zoning plan. The study focuses especially on open and green areas. The reason for this is to draw attention to the following problems:

- Although these areas are of great importance in the creation of disaster-resistant cities, disaster risk, in particular, is not considered in determining the places of these areas in the development plans.

- Although the open green area required per person (min 10 m^2) is determined in the development plans, there is no open green area that can be used as a meeting spot that every individual can access equally and easily in case of a disaster.

It is believed that this study will provide a reference for location selection for post-disaster meeting spots, especially for settlements that face multiple disaster risks, and contribute to develop disaster and emergency management plans to reduce the impact of hazards.

2. Study area

Study area is located in the Western Black Sea region at 41^0 21’ northern latitudes and 33^0 46’ eastern longitudes with a height above sea level of 775 m, and a total area of 13,108.1 km^2, and the total area of the district center is 1,829 km^2 (Figure 1) (Kastamonu Municipality, 2011; NADA, 2013).

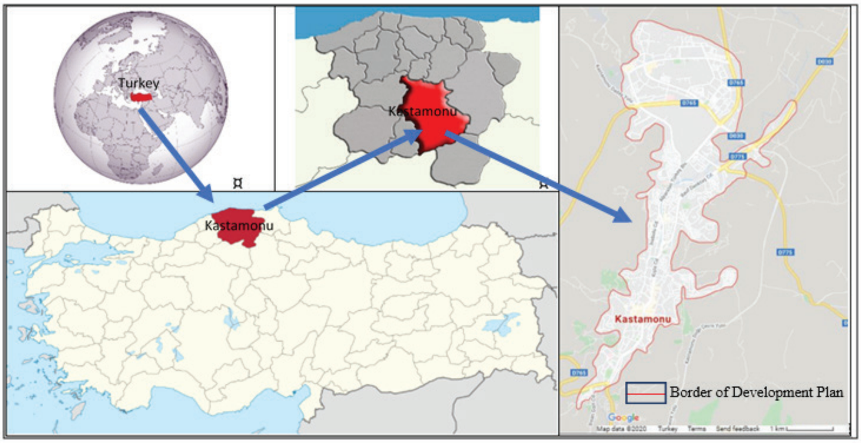


Figure 1. Study Area Location Map

Source: Mapdata 2020 Google(https://www.google.com/maps @41.3768053,33.7547558,14z).

Kastamonu city is located in the impact area of North Anatolian fault line and in the second-degree seismic zone and within the boundaries formed by topographic thresholds along the valley of Karaçomak Stream. Karaçomak stream, which enters the urban area after a distance of 6.48 km from Karaçomak Dam in a controlled manner, determined formation of the main transportation axis, allowing the density to increase in the plains it created around and the density decreases as it rises towards the slopes (Kovankaya et al., 2012).

3. Method

In previous studies on emergency meeting spot location, disaster-affected areas were determined for different types of disasters (Sanyal and Lu 2009; Masuya et al. 2015; Soliman et al. 2015). Liu et al. (2011) and Fan et al. (2017) also tried to estimate the risk of secondary disaster or technology accident, unlike other studies. Chou et al. (2013) pointed out that the meeting points should be of sufficient size for the population affected by the disaster. In addition, Tarabanis and Tsionas (1999) and JICA (2002) stated that the maximum walking distance that each individual can easily reach as the going distance from the building blocks to the meeting points should be 500 m/15 minutes or less.

In the study, primarily; disaster types were determined by taking into consideration the disasters that the city was exposed before. In the event of one or more disasters, the data obtained from the relevant institutions were used to map the possible areas of the city that could be damaged (Table 1).

The methods detailed below were used to determine each disaster risk. After determining the disaster risk areas, by the use of overlay analysis and suitability analysis, the open and green areas in the study area and the areas that are not exposed to or would be least exposed to disaster risk were designated as meeting spots. Afterwards, the designated meeting spots were evaluated in terms of size and service area, and suggestions were provided for the areas that could not meet the requirements.

Table 1. The base data used in the study

Parameter	Source	Description
Aspect	Digital Terrain Model (DTM)	Created from Digital Terrain Model
Drainage	Digital Terrain Model (DTM)	Created from Digital Terrain Model and Topography Map
Earthquake	Disaster and Emergency Management Authority (DEMA)	SHP. Format
Altitude	Digital Terrain Model (DTM)	Created from Digital Terrain Model
Immovable Assets	Regional Directorate of Land Registry	Vector data (NCZ.)
Land Use and Zoning Plan	Municipality of Kastamonu	Vector data (NCZ.)
Lithology	Municipality of Kastamonu and General Directorate of the Mineral Research & Exploration of Turkey	Digital Terrain Model (DTM)
Rainfall Distribution	Digital Terrain Model (DTM)	Schreiber Method
Slope	Digital Terrain Model (DTM)	Created from Digital Terrain Model
Transportation network	Municipality of Kastamonu	Vector data
Topography	Municipality of Kastamonu	Vector data (NCZ.) converted to Digital Terrain Model

A. Disaster Risk Analysis

For Disaster Risk Analysis, possible disaster types (earthquake, landslide, rockfall, flood, fire) in the area were primarily identified. The areas that may be exposed to earthquakes and floods were determined by digitizing the data obtained from the relevant institutions (DEMA and Kastamonu Municipality). In order to determine the areas that could be exposed to landslides and fires, the factors (slope, rainfall status, Geological status, etc.) that could lead to the occurrence of the related disaster risk were determined. Afterwards, the sub-factors of each factor were determined and scored between 0 and 5 (0: none, 1: very low, 2: low, 3: moderate, 4: high, 5: very high). In addition, the weight value of the factor included in each risk analysis according to another factor was determined. The weight assessment was made by 3 experts (urban planner, landscape architect, climate specialist) who had information about the study area, and the weight evaluations used in similar studies were also taken into consideration (Lee and Talib, 2005; Karabulut et al, 2013). The areas with the highest score were identified as the most risky areas in terms of the related disaster. The field of study was evaluated both according to the state of impact from each disaster risk and to the probability that all disasters occur at the same time. As a result of the analyses conducted on possible disaster risks, the areas with and without disaster risk were determined by scoring between 0 and 5.

Earthquake risk analysis

In order to estimate the damages and losses that may occur as a result of an earthquake disaster, the 'DEMA Earthquake Damage and Loss Forecast System (DEMA-RED)' was used with the permission of the DEMA. In the DEMA-RED system, structural damage (light, medium, heavy, and catastrophic), seismic intensity map, acceleration (PGA) and speed (PGV) maps are created on a neighborhood basis as an estimate of the damages and losses that may be caused by an earthquake with a magnitude of 7.3 and intensity of X, which will take place in the North Anatolian Fault Line within the Kastamonu Earthquake Scenario (DEMA, 2019b). In the Figure 2, the areas shaded in red show the areas involving earthquake risk.

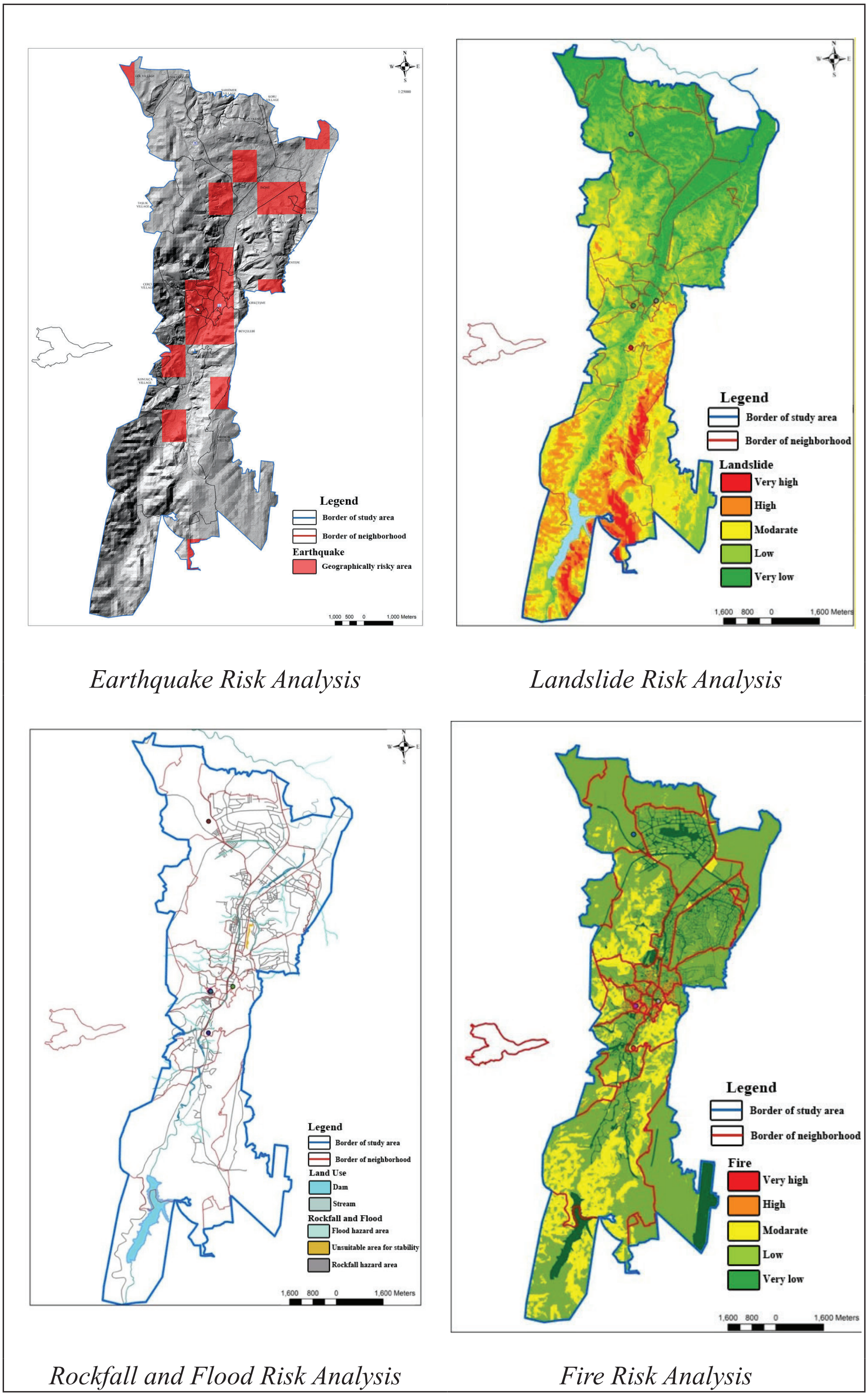


Figure 2. Risk maps of study area

Landslide and rockfall risk analysis

Landslide risk analysis and assessment for the study area (Figure 2) were made by following the Frequency Rate method proposed by Lee and Talib (2005) in the Landslide and rockfall basic guide of DEMA. Frequency Ratio (FR) is based on density analysis such as statistical index method. The data used in the landslide risk analysis was made using the databases classified in the Table 2.

Table 2. Risk Analysis Parameters

Risk	Parameter	Weight	Classification	Risk	Parameter	Weight	Classification
Landslide	Slope	1	0-10	Fire	Slope	3	40 >
			10-20				40-30
			20-30				30-20
			30-40				20-10
			40-50				10-0
			50-80		Construction types	7	Adjacent building
	Aspect	1	0				Separate building
			0-22.5, 337.5-360				Discrete building
			22.5-67.5		Building Feature	3	Wooden
			67.5-112.5				Prefabricated
			112.5-157.5				Half masonry
			157.5-202.5				Masonry
			202.5-247.5				Reinforced concrete
			247.5-292.5		Land use	7	Industry, Gas station, Forest (coniferous)
			292.5-337.5				Degraded Forest (coniferous), Landfill
	Lithology	1	Sandy limestone, Basaltande, Metabasic Rock				Grassland, Forest (deciduous)
			Limestone, Sandstone, Mudstone				Residential, Commercial, Military, Garden, Agriculture, Plat, Degraded forest (deciduous)
			Alluvium				Park, Religious, Administrative, Health, Education, Cemetery, Market, Sports, Terminal
			Pebble, Sandstone, Mudstone				Road, Stream, Bare rock, Dam, Airport
			Limestone	Total Disaster	Earthquake Sensitivity	1	Geographically Risk-Free Area
			Metabasic Rock, Metamelange				Geographically Risky Area
	Hillside	1	<-1.0		Landslide susceptibility	1	74-211,8
			-1.0-0.5				211,8-349,6
			-0.5-0				349,6-487,4
			0-0.5				487,4-625,2
			05-1				
			1->				625,2-763
	Distance to fault line	1	30 km				
			35 km		Rockfall	1	Area Without Rock Fall Hazard
			40 km				Rockfall Hazard Area
			45 km				
	Distribution of rainfall	1	45-72 mm		Flood	1	Area without Flood Hazard
			72-125 mm				
			125-173 mm				Flood Hazard Area
			173-207 mm				
	Land use	1	Urban Area		Fire	1	13-25
			Agriculture				
			Forest Area				25-50
			Degraded Forest Area				
			Plat				50-75
			Road				
			Landfill				75-100
			Bare rock				
			Open and green areas				100-123

The geological survey report based on zoning plan (Kastamonu Municipality, 2011) and the report due to rock falling within the borders of Hisarardı Neighborhood (DEMA, 1999) used to determine landslide and rockfall regions and transferred into GIS environment (Figure 2). Also, the study of Topal et al. (2011) examined the castle located in the city center for the rockfall hazard, and the rockfall danger area was exluded by using the statistical analysis method via RocFall v.4.0 software for the danger area around the castle. The map of the castle and its surrounding danger area obtained in this study was transferred into the GIS environment.

Flood risk analysis

In the making of flood-overflow hazard maps in the study area, the flood-overflow areas were transferred to the GIS environment as vector data prepared in the report commissioned by Kastamonu Municipality and approved on 18.07.2011 In addition, the Schreiber method was employed to find the distribution of precipitation per land for the study area. The method preferred to show the change of precipitation depending on the area assumes that the amount of precipitation is to increase by 54 mm every 100 m elevation.

Schreiber Formula (Hepbilgin and Koç, 2019):

$$Ph = Po \pm 54h$$

Ph = amount of precipitation to be found at a point in the area (mm);

Po = The amount of precipitation (mm) of a station in the area, the elevation and rainfall measurements of which are known;

54 = coefficient indicating that the annual rainfall increases by 54 mm at every 100 m elevation

h = difference in elevation between the station in the area and the point where the precipitation value is to be found

Fire risk analysis

Fire is among the secondary disasters that may occur as a result of an earthquake. In this context, a study was carried out to identify risk areas with fire spread potential and explosion potential in the city. For determining the fire risk analysis, fire risk areas in the city were tried to be determined considering the study of Karabulut et al. (2013). The study used the 1/1000-scale Digital Surface Model and the slope map obtained from the model, the 1/1000-scale Implementary Development Plan obtained from Kastamonu Municipality and the stand map of the city surrounding of Kastamonu (Table 2).

Considering that the spreading rate doubles as the slope increases in the slope parameter, the factor values increased in multiples. When examined the fire disasters that are accepted as effective on the general life throughout the province from the data available at Kastamonu DEMA, it was determined that the wooden and semi-masonry houses are predominant and the number of houses burning increases when the houses are adjacent or close to each other. A hazardous area zone of 30 m and a precautionary zone of 100 m were created by using Arcmap/ Geoprocessing/ Buffer command on a parcel basis in order to determine the impact area in the case of possible explosion by determining the gas stations and industrial areas within the study area (Figure 2).

Multi-hazard risk analysis

The risk analyzes prepared in the GIS environment were overlapped and classified in 5 stages according to the risk status, and a multi-hazard risk map (Figure 3) was created by giving a risk score (1: very low, 2: low, 3 moderate, 4: high, 5: very high) (Table 3).

B. Open and green area analysis

In the second step, it was tried to determine urban open and green areas that can functionally serve as PDMS based on the risk maps to prevent and mitigate the disaster losses of the city after a disaster. Also, their adequacy and qualification were examined according to the areas sizes pursuant to the population criteria and standards on the basis of neighborhood. Open and green areas specified in the Implementary Development Plan were evaluated in the scope of the study, including the children's playgrounds, neighborhood, district, city parks, squares, sports facilities, gardens of large public institutions, parking lots, refuges. Since the study centers particularly on open and green areas, open spaces (school gardens, market areas, etc.) that can be used as meeting spots were not included in the study.

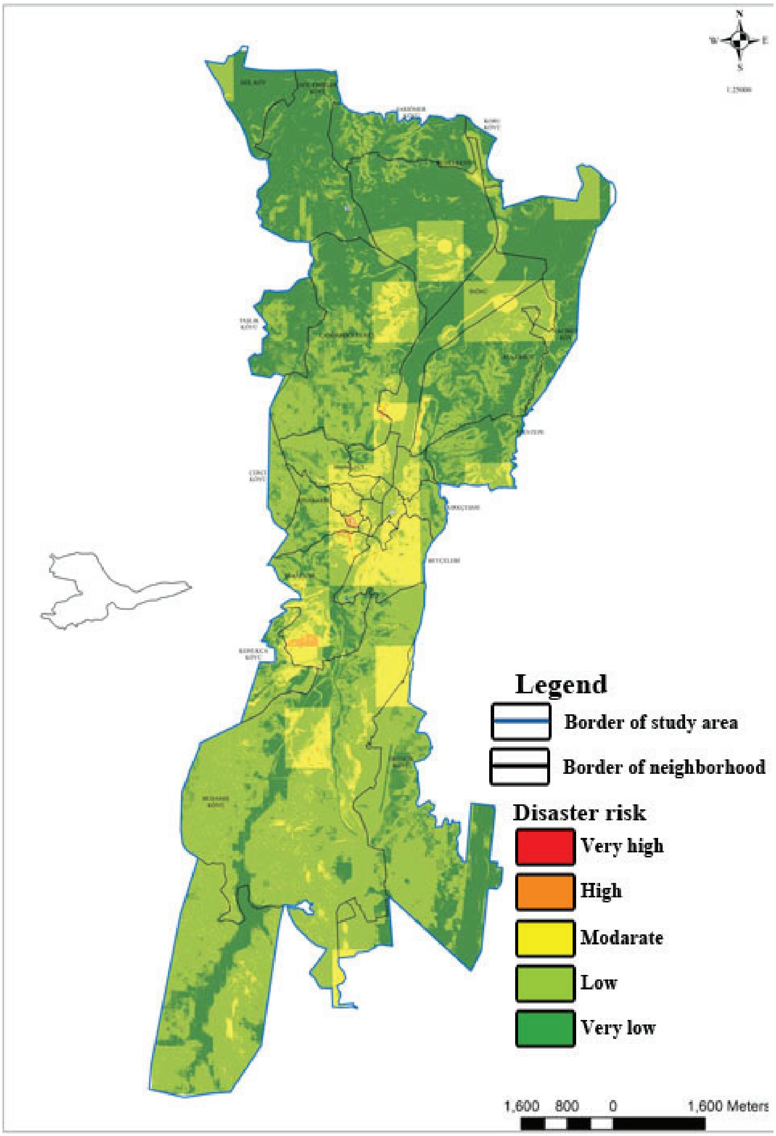


Figure 3. Multi-hazard risk map

Table 3. Multi-hazard Risk Analysis Parameters

Parameter	Classification	Risk Degree	Risk Score
Earthquake	Area Without Geographical Risk	Very Low	0
	Geographical Risky Area	Very High	5
Landslide	74-211,8	Very Low	1
	211,8-349,6	Low	2
	349,6-487,4	Medium	3
	487,4-625,2	High	4
	625,2-763	Very High	5
Rockfall	Area Without Rockfall Risk	Very Low	0
	Rockfall Risky Area	Very High	5
Flood	Area without Flood Risk	Very Low	0
	Flood Risky Area	Very High	5
Fire	13-25	Very Low	1
	25-50	Low	2
	50-75	Medium	3
	75-100	High	4
	100-123	Very High	5

C. **Assesments**

In the final step, assessments were presented. In order to identify the PDMS as determined by the Kastamonu DEMA and determine the areas that may be suitable for use as a meeting spot within the boundaries of the study area, the areas identified as open and green areas were evaluated in terms of both disaster risk and area size. For this purpose, according to JICA (Japan International Cooperation Agency) 2002, the gross minimum area of any meeting spot for the population in that region shall be 2 m^2/person and the service radius was taken as 250 m. Also, recomendations were developed on potential areas in the neighborhoods without meeting spots according to analysis.

4. **Results**

Suitable meeting spots were determined by overlapping the obtained risk map with the open and green areas listed in the zoning plan. The areas with the lowest and low risk levels are considered as post-disaster meeting spots. 28 urban open and green areas with the potential of meeting spot in the study area were not found acceptable since they cross risky areas. Furthermore, the areas at a distance of 250 m to the center of the area determined as a meeting spot were identified (Figure 4). Also, their impact areas were determined and graded according to their area size (1st degree: 10000+ m^2, 2^{nd} degree: 9999-5001 m^2, 3^{rd} degree: 5000-1001 m^2, 4^{th} degree: 1000-100 m^2).

Areas that are qualified as active green areas in the current zoning plan within the study area and actually used in accordance with the zoning plan were accepted as "Open and Green Area as Meeting Spots" and their area sizes were calculated. Total surface area of open and green areas as total meeting spots was determined as 1233288 m^2 (Table 4). According to disaster risk analyzes, sizes of suitable meeting spots were determined in each neighborhood (Table 4). Totally 994455 m^2 of open and green areas were determined as suitable meeting spots for Kastamonu. In other words, 81% of open and green areas comply with the meeting spots criteria.

The estimated number of people who can benefit from PDMS was tried to be found by multiplying the number of buildings on a parcel basis given in the 1/1000-scale implementary development plan, which was digitized in the GIS environment according to the population data of 2018, the number of floors, the number of flats in one floor and 3.01, which is the average household size of Kastamonu province. Table 4 shows that approximately 103,737 people in 19 neighborhoods have access to the urban open and green areas, which are determined as suitable meeting spots in the case of a disaster, only 88% of the population of 117,303 people can get service.

According this meeting spot criterion of 2 m^2 per capita as determined by JICA (2002), the required surface area was determined as 2.35 ha according to the population data for each neighborhood in the study area. The meeting spots determined under the coordination of Kastamonu DEMA can serve approximately 47,990 people, and this number constitutes 41% of the total population of the city center. Moreover, the meeting spots determined by DEMA cover only 48% of the amount of required areas (Table 4).

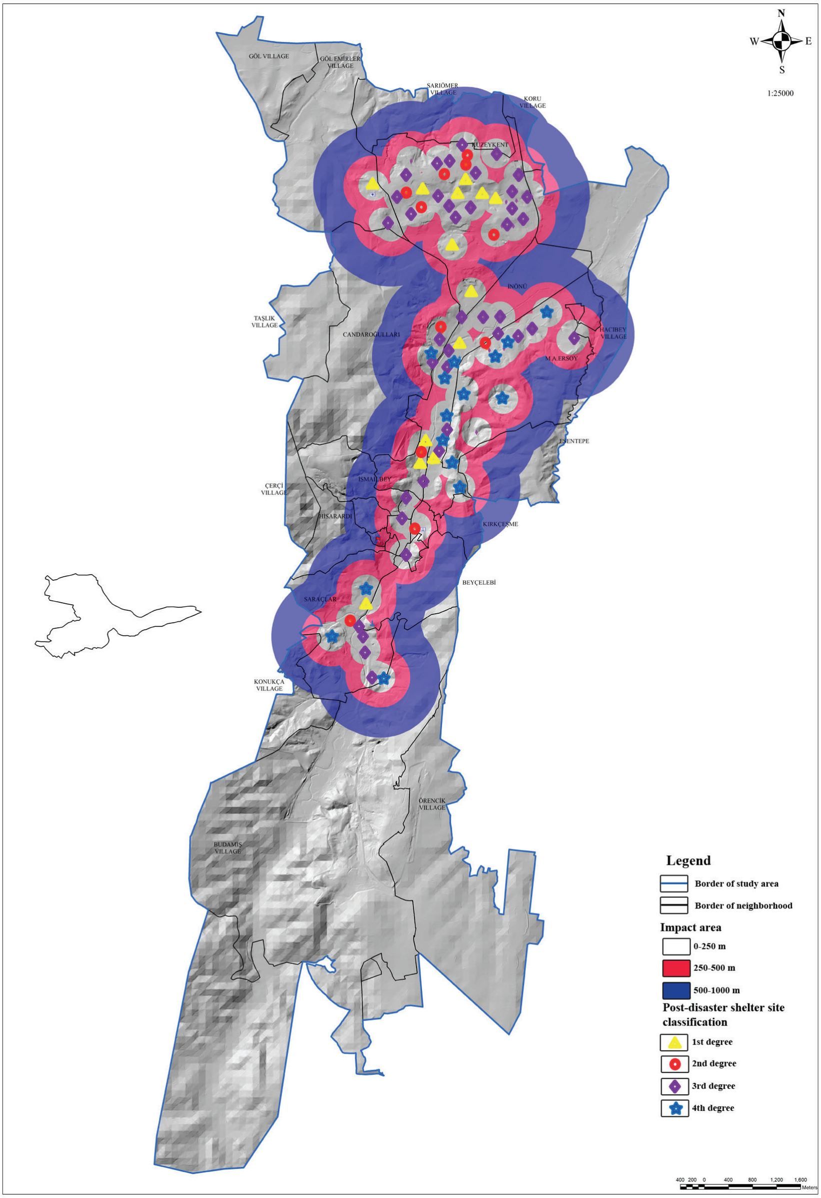


Figure 4. Post-disaster shelter sites map

Table 4. Post-disaster shelter site analysis

Neighborhood	The shelter sites determined by DEMA (m2)	Population	Green areas as shelter sites (m2)	Suitable shelter sites (m2)	Required shelter sites (m2)	Estimated population who can benefit from shelter sites	Capacity of suitable shelter sites (person)	Capacity of green areas (person)
Akmescit	-	1352	2431	-	2704	1167		1216
Aktekke	-	4994	46632	29002	9988	3852	14501	23312
Atabeygazi	-	395	2865	-	790	318		1433
Beyçelebi	-	2909	-	-	5818	2514		
Candaroğulları	7196	8148	12646	8864	16296	8619	4432	6323
Cebrail	5749	2624	11880	5749	5248	2259	2875	5940
Esentepe	-	3741	-	-	7482	1035		
Hepkebirler	-	1992	2742	2742	3984	2994	1371	1371
Hisarardı	-	988	279	-	1976	1092		140
Honsalar	4105	1552	4105	4105	3104	1368	2053	2053
İnönü	11939	21347	40848	39056	42694	20463	19528	20424
İsfendiyar	-	1451	3786	3786	2902	1542	1893	1893
İsmailbey	19757	3928	33195	32973	7856	3876	16487	16598
Kırkçeşme	-	1667	-	-	3334	270		
Kuzeykent	44040	26157	934728	777054	52314	22857	388527	467364
Mehmet Akif Ersoy	6623	18411	35280	32461	36822	16188	16230	17640
Saraçlar	13116	13813	101871	58663	27626	10311	29332	50936
Topçuoğlu	-	1259	-	-	2518	2550		
Yavuzselim	-	575	-	-	1150	462		
Total	112525	117303	1233288	994455	234606	103737	497229	616643

5. Discussion

It should be noted that disaster incidents and losses increase due to rapid urbanization, social and/or economic changes, planning practices that do not take into account the area characteristics or cannot adapt to rapid change, and PDMS are required within the open and green area system to mitigate such losses and prevent certain disaster (JICA, 2002; Fuentes and Tastes, 2015; Korgavuş and Ersoy, 2015; Jayakody et al., 2016; Çelik et al., 2017; Kırçın et al., 2018). Is a sufficient number of meeting spots being identified in order to have the effect of reducing expected losses and preventing certain disasters? Is the choice of location preferred from areas that are not exposed to disaster risk? Or, are the areas that are within the urban open green space system, and that meet such requirements as size, accessibility, etc. preferred?

In this study it was determined that the PDMS determined by DEMA meet only 48% of the required amount of meeting spots, and those who live in neighborhoods without a meeting spot are recommended to go to the nearest area during a disaster. Similar results are expressed in the study of Özcan et al. (2013), Korgavuş ve Ersoy (2015), Ocak (2017), Bahadori et al. (2017) and Çınar et al. (2018). However, great problems occur even after disasters since the meeting spots, which are of vital importance in mitigating the loss of life, are not sufficient or arranged according to the PDMS criteria after disasters experienced in the world and in Turkey. It should also be noted that, besides the necessity of post-disaster meeting spots, these areas should have the size and features to meet the need. It turned out that every open and green area identified in the city is not suitable for being a post-disaster meeting spot. Showing the irregular areas that are called ruler residues and areas that are not suitable for structuring in terms of soil and slope in the zoning plans creates problems in practice.

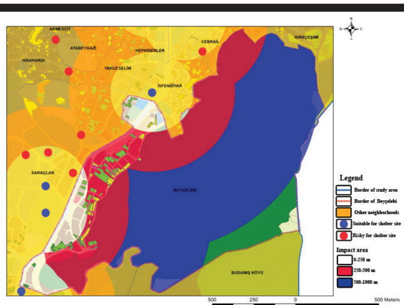
It should be considered that each settlement has different risk situations or degrees. One area may face multiple disaster risks as in Kastamonu city or one disaster may cause another disaster to occur. In this respect, it is thought that the meeting spots should be determined by considering each disaster risk. In this regard, a similar study was conducted by Chen et al. (2018) for Guangzhou province. In their study, Chen et al. underlines that different meeting spots should be established for different disaster types.

One of the mistakes in choosing the locations for PDMS is to think that every open and green area can be used as a meeting spot. For example, the study of Hadavi et al. (2014) on selection of meeting spots in the Zone 6 of Tehran after an earthquake disaster states that although there is no sufficient meeting spot in the study area, open and green areas can be used as meeting spot in the event of a disaster. However, studies suggest that every open and green area is not necessarily eligible for use as a post-disaster meeting spot. In fact, the results of the suitability analysis made using the geographic information systems in this study conducted for Kastamonu city show that 19% of open and green areas in the city could not be defined as suitable meeting spot. A similar result is expressed in the study of Kar and Hodgson (2008). In their study conducted for Florida, it was determined that 48% of the shelters are located in areas that are physically unsuitable.

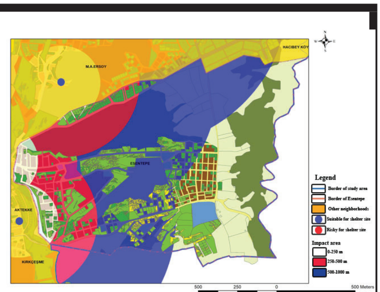
It should also be noted that risk analyzes could be made for possible disaster situations in order to locate the collection areas at the right points in the open and green area system, and having a database to simulate losses that may occur in the event of possible disasters will be a great advantage for the future studies. At this point, it can be stated that the city of Kastamonu is fortunate to have a database of losses against possible disaster risks. Within the framework of the Earthquake Pre-Damage and Loss Estimation System and Kastamonu Earthquake Scenario, structural damage (light, medium, heavy, and catastrophic), seismic intensity map, acceleration and speed maps were created on a neighborhood basis as an estimate of the damages and losses that may be caused by an earthquake with a magnitude of 7.3 and intensity of X, which will take place in the North Anatolian Fault Line, and it is believed that this enabled more accurate results to be achieved in the analysis performed. Chen et al. (2018) states that there is no such database in China, so it is difficult to estimate the losses in the event of a disaster.

6. **Recommendations**

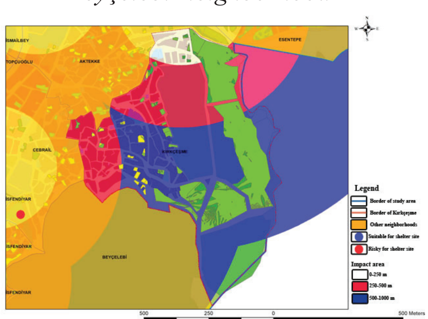
In order to determine proposed meeting spots for 5 neighborhoods (Beyçelebi, Esentepe, Kırkçeşme, Topçuoğlu and Yavuzselim) that do not have public open and green areas, the empty immovable properties under private ownership within the boundaries of the neighborhood were examined. In the risk analysis, the parcels that appear in the lowest-risk and low-risk areas were identified and it is considered to suggest them as meeting spot at the planning stage. As a result of the investigation, it was determined that the appropriate meeting spot determined within the boundaries of the neighborhood meet the required area sizes. The areas in Beyçelebi, Esentepe, Kırkçeşme, Topçuoğlu, Yavuzselim neighborhood that can be suitable and risky meeting spots are shown in the Figure 5.



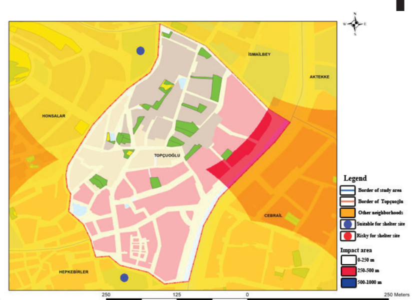
Beyçelebi Neighborhood



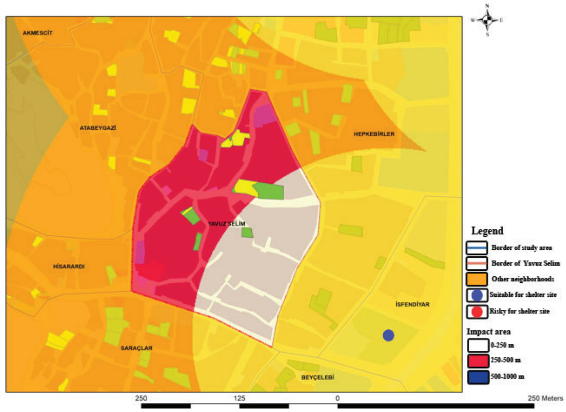
Esentepe Neighborhood



Kırkçeşme Neighborhood



Topçuoğlu Neighborhood



Yavuzselim Neighborhood

Figure 5. Proposed shelter sites for Beyçelebi, Esentepe, Kırkçeşme, Topçuoğlu and Yavuzselim Neighborhoods

• Open and green areas to be determined as meeting spots in the city center should be selected from areas that do not have risk in terms of disaster risk, and these areas should be planned in a way that will be homogeneously distributed throughout the city. As a matter of fact, choosing a place as a meeting spot is not enough in the case of a disaster. It is also important that everyone can access such areas as soon as possible, and that the area reached is large and adequate enough to meet the demand. In fact, it was seen that no location was selected a meeting spot for 8 of the 19 neighborhoods examined in this study, and no open and green area to be used as a meeting spot was determined for 5 neighborhoods.

• Open and green areas that will be determined as meeting spots in the city center must also be determined in a way that they can be sufficient for the population on the basis of neighborhood. If meeting spots that are not large enough to meet the needs on a population basis have been established, a certain proportion of the population will not be able to be protected from disaster risk. The study determined that the meeting spots that can be considered as suitable from the open and green areas identified in the zoning plan, can serve 88% of the population in the service areas of their respective neighborhoods. It was also found that the meeting spots determined by Kastamonu DEMA can only serve 41% of the total population of the province.

• While determining open and green area standards in urban plans, it is necessary to pay attention to criteria such as urban population, needs, urban character and density of usage. In determining the post-disaster meeting spots, which are part of urban open and green areas, the urban population and usage density should be evaluated first. Investigations for the study area showed that there are neighborhoods in the city that do not have an open and green area as a meeting spot. Moreover, even though they are identified as an open and green area in the zoning plan, the presence of areas that have not been constructed yet, or that are not used in accordance with the plan decisions is thought to pose a great threat to the people of the city. For this reason, the areas identified in the zoning plan and that may be suitable for meeting spot should be urgently implemented. Furthermore, it is considered necessary to meet the need by clearing method through expropriation for the benefit of society in areas identified as open and green area in the zoning plan but not sufficient for the population density.

• Structuring, which will cause more population density, should not be allowed, especially in the historical city center where wooden structures are concentrated. In these areas, the increase of fire risk due to the population increase may cause disappearance of the values that need to be protected. Moreover, the increase of the population at risk may lead to greater loss of life and property in the case of a disaster. The houses around the privately-owned open areas in historic city settlements with insufficient meeting spots and/or without a meeting spot should be renovated in a manner that will not pose a risk. Kastamonu city center is also quite old in terms of structuring and especially the buildings in the urban protected area are wooden, so it is a residential area with high risks of fire and related losses after a disaster in the city. The results of the study suggest that, if necessary, measures are not taken to protect the historic wooden buildings in the city center, the city center will face a great risk.

• Taking small industrial areas and gas stations out of the city will reduce the likelihood of secondary disasters after disasters. Unfortunately, the study determined that the city center of Kastamonu involves such applications. In this regard, the necessary revisions should be urgently made in the zoning plan and implemented.

• It is also important to inform the public about the areas designated as meeting spots in the city before a disaster occurs. In this sense, it is also important to inform the public and raise awareness through drills and information activities. Furthermore, it is necessary to determine the evacuation routes for the designated meeting spot in advance and put signposts for information and guiding the public to these areas. It was found that such a study has not been conducted for the study area.

In the light of the data obtained, it is thought that the decision makers should sensitively and quickly take action in the urban planning for Kastamonu city and consequently the review of the open and green area system considering the results. In addition, it is believed that the findings obtained from the study will also serve as guidance for regions and countries facing multiple disaster risks, and may find answers to the question of what criteria should be considered, especially when determining open green areas in urban plans. Considering the recommendations made for suitable open areas that appear to be safe on the risk map prepared in the GIS environment for the neighborhoods with insufficient meeting spots capacity as well as building islands that do not receive any service may help prevent loss of life in the case of a possible disaster. In order to avoid or minimize loss of life and property in the event of a disaster, disaster risk analysis must be made for the cities, and the locations must be selected accordingly, and the selected areas must be large enough and accessible to meet the needs.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, [Nur BELKAYALI], upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

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CHAPTER 4

STRUCTURAL APPLICATION OF GEOMETRIC PATTERNS: RECIPROCAL FRAME SYSTEMS

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1. INTRODUCTION

Building the spaces to be used in architecture and thinking about the top cover of these areas has been one of the important pursuits of all ages (Takva et al., 2023). At this point, structural systems from the simplest to large-span structures have formed the basic building block of a building. The tent frame in primitive times can be seen as the first spatial structure product applied by humans. This frame system, which is based on the principle that each structural element forms a solidarity by taking the load of the other, is a technique still used today and is developing. Another framing system that emerged in the logic of overlapping is the structure system called "reciprocal" and "nexorades" in the international literature (Geno et al., 2022; Baverel, 2000). The most basic principle of this structural system is that the short elements in the space to be covered provide strength by transferring loads to each other (Parigi and Pugnale, 2014). In this structure, which is generally used in the roof cover function, planes with different curvatures are formed. In fact, various geometric sequences are used to create these systems, which include a regular and symmetrical modular design, which is the result of knitting technique and geometry (Figure 1).

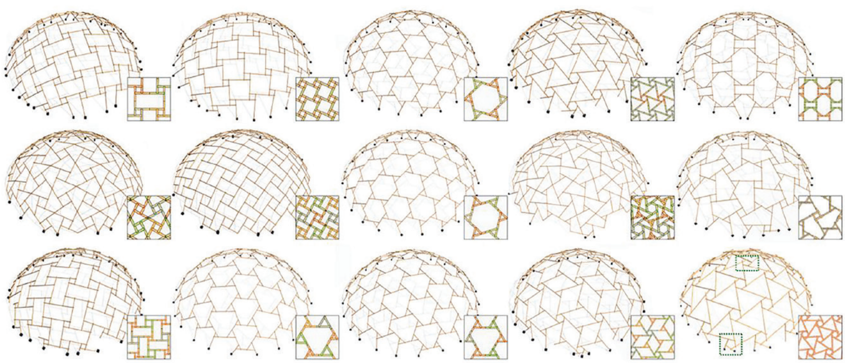


Figure 1. *Application of reciprocal structure systems on different geometric shapes (Parigi and Kirkegaard, 2013)*

The first example of systems found in the literature as reciprocal frame stuctures is based on the structure designed by Graham Brown in England (Chilton et al., 1995). The basic logic of reciprocal construction systems is the principle of large-span crossing with short beams. A regular pattern is formed with these short beams (Karakoç, 2017). The construction principle of reciprocal structures is that none of the load-bearing beams support each other from the end point and the load is transferred in a hierarchical order (Pugnale and Sassone, 2014). Reciprocal structures, which are formed by overlapping many structural elements, have several advantages over other structural systems used to pass large-spans (Başoğul, 2021).

The fact that these structures can be used in fast, cost-effective and simple design solutions shows that they can be handled on a wide scale. It can be produced with simple joint details as it is formed by overlapping the building elements. In addition to these, reciprocal structure systems are making progress with the use of technologies such as digital fabrication, robotic and CNC machines and production (Başoğul, 2021; Mesnil et al., 2018). Reciprocal structure systems continue from the past to the present and new production methods are emerging with the development of technology.

Indian tents consist of a structural system close to reciprocal systems in terms of construction method. Structures are produced with reciprocal or similar construction systems, dating back to ancient times (Karakoç, 2017). Reciprocal systems, which are suitable for regular polygonal and circular plan types, are also used in local architectural structures. For example, it is seen that the buildings called "Yurt" in Asia are applied with the overlapping technique on their roofs (Chilton et al., 1995). The roof of the "Yuva" project, which was built with sustainable materials in Alakır Valley in Turkey, and the reconstruction of "Agas İb" (Tree House) in the Khakasya National Museum named Kızlasov are examples of this (Karakoç, 2017). Roofs created with this system are also called "Mandala Roof" or "Swallow Roof Cover." There are many examples of the historical development of reciprocal systems from ancient times to the Middle Ages and from the Middle Ages to the present. In Leonardo da Vinci's (1452–1519) "Codex Atlanticus," there are sketches for clarity with regular and irregular geometric configurations (Pugnale and Sassone, 2014). In addition to these, thinkers such as Villard de Honnecourt and Sebastiano Serlio have studied the planar elements of these systems (Pizzigoni, 2010). Inspired by the drawings of Leonardo Da Vinci, a formation has emerged today called "Leonardome," consisting of prefabricated elements in an area of 4 meters in diameter and designing reciprocal structures by combining wooden elements without requiring any connection elements during the assembly phase. This formation creates domes by offering different reciprocal structure alternatives with wooden units (URL-1). In Figure 2, visuals that contribute to the development of reciprocal structures are given.

(a) (b) (c)

Figure 2. *(a) Reconstruction of "Agas İb" (Tree House) in the National Museum (Kutlu, 2020), (b) Bridge sketch by Leonardo da Vinci found in Codex Atlanticus (Sánchez and Escrig, 2011), (c) Dome alternatives with Leonardome formation (URL-1)*

It has been observed that reciprocal systems, which are the focus of the study, allow both various usage areas and different free designs owing to their easy and fast construction techniques, and especially serve the purpose of temporary structures such as pavilions and Expo structures. Therefore, in this study, reciprocal systems were evaluated over temporary structures. First all, the historical development and working principle of reciprocal systems with the information obtained from the literature are discussed. Then, in a reciprocal system, the morphology of the surface to be obtained, the material to be used, the type of unit element to be used, the primary geometry formed by the unit elements, the geometric sequence formed by these geometries, the distance ratio of the connection point on the unit element length, and the connection type are important and explanations were made. Finally, the characteristics of the construction technique, which is the focal point, were evaluated by analyzing the pavilion and Expo structures, which have different geometrical layouts, with the mentioned parameters.

2. FEATURES AND TYPES OF RECIPROCAL SYSTEMS

Reciprocal frame structures are derived from 3-dimensional grid structures based on mutually supporting beam structural members (Gherardini and Leali, 2017). Reciprocal systems are grid structures formed by adding and expanding a single beam element on top of each other (Larsen, 2007). Although reciprocal systems are structures that can only stand together with friction force without fixation, when looking at general examples, it is seen that a pattern is formed by fixation. Considering the load transfer principles, there is no hierarchical transfer. Each building element supports each other and acts as a supporter (Pugnale et al., 2011). In reciprocal systems, the structural elements are usually integrated with each other by friction, notching, nailing, or bonding techniques (Song et al., 2013). In large-span structures with complex construction systems, scaffolding swivel clamps are used (Sénéchal et al., 2011). There are certain rules that must be met for establishing reciprocal systems. At least 2 structural elements must provide load transfer. Integration should be made from any point along the length of the element except the corners of each supported element (Baverel and Pugnale, 2014). In Figure 3, the modulations of the reciprocal frames that provide the basic rules are given.

Figure 3. *Different reciprocal structure system modulations according to beam configurations (Geno et al., 2022)*

Different variations can be produced with different material alternatives by using reciprocal structures. While these structures are being designed, building materials such as wood, steel and reinforced concrete can be used. The use of nanotechnological and sustainable materials also affects the development of reciprocal systems (Ilerisoy and Takva, 2017; Güner et al., 2017). When we look at the examples of the buildings built, it is seen that the number of structures in which wooden construction material is applied is high because it is a light material, easy to manufacture, and the connection details are suitable for reciprocal systems. Reciprocal systems are divided into two as planar and curved surface systems. In a reciprocal system, the 3D view increases as the distance between the connection points decreases (Baverel and Pugnale, 2014). Additionally, features such as the geometry formed by the unit element used in reciprocal systems, the materials used, the distance between the support and the end points, the types of fasteners and the diversity of the unit elements create classification diversity in these systems. Geometric patterns created by the unit element can create different alternatives (Takva and İlerisoy, 2021). 11 different geometric patterns that can be created with reciprocal systems are given in Figure 4.

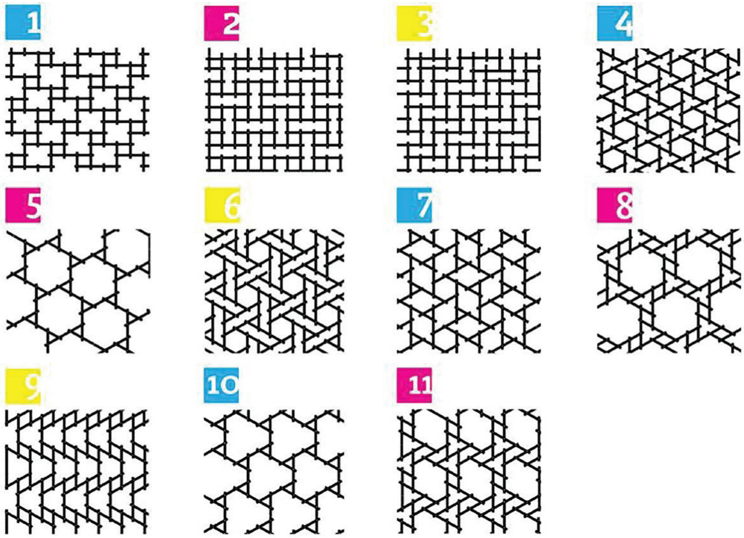


Figure 4. *Geometric variations used for reciprocal systems (URL-1)*

Some of the created geometric patterns are obtained by the repetition of the same unit, while others are obtained by combining different units to form a rhythm. These patterns are made 3D by reducing the distances between the connection points. In the systems created by this method, since the unit elements are designed as modules, it allows pre-production and it can be said that the production time is shortened. Additionally, design diversity is allowed as shorter beams and structural elements are used compared to a standard structural system. Starting from 11 types of patterns, it is seen that triangular, quadrilateral and hexagonal geometries and their derivatives, which are the basic geometric shapes, are used in these systems. The creation of reciprocal frames is established with the logic of load transfer of each unit element to each other. At least 2 elements are required in the formation of the system. It is important that each supported structural member never comes into contact with the corner points along the span (Pugnale and Sassone, 2014). In this system, which is created by transferring loads to each other and overlapping each other, interlocking systems can also be constructed by opening notches on the beams to create a planar pattern. In Figure 5, the transition from the production of the geometric module to the production of 2D patterns, and from the production of 2D patterns to the production of the 3D structure is shown.

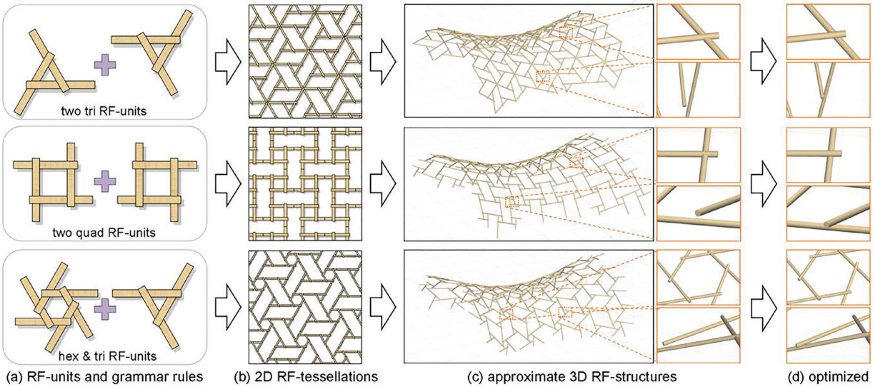


Figure 5. *The principle of creating geometric patterns and structures of reciprocal systems (Song et al., 2013)*

3. INVESTIGATION OF RECIPROCAL SYSTEMS THROUGH TEMPORARY STRUCTURES

Due to their easy and fast construction, reciprocal systems are encountered in temporary exhibition structures such as fairs, expo, and pavilions. When the main geometries of the reciprocal systems were examined, it was determined that three basic geometries such as triangle, quadrilateral and hexagon were used in the formation of the patterns and these geometries were also seen in the structural designs of the temporary structures. The common point of the structures consisting of triangular, rectangular and hexagonal geometries and selected from different climatic regions is that they are designed temporarily and obtained from reciprocal systems in their structure designs. By revealing the main structural patterns of the 5 determined buildings, the understanding of the design was examined and the similar and different features of the buildings were investigated.

3.1. The Serpentine Gallery 2005 Pavilion

Since 2000, the Serpentine Gallery team has been building a pavilion in London's Kensington Gardens every summer. With architectural experimental studies called "Summer Pavilions," research proposals with a formal and structural character are developed (Tunçbilek, 2013). The architectural attractiveness of the pavilion structure is highlighted in the research proposals (del Río-Calleja et al., 2022). Alvaro Siza, Eduardo Souto de Moura and Cecil Balmond designed the Serpentine Gallery Pavilion in 2005. The pavilion structure, consisting of a reciprocal timber structure, has brought a contemporary proposal to the history of construction (Melvin, 2005). In the pavilion, the construction method Zollinger called

"Lamellandach" was used (Karakoç, 2017). The main building material of the structure was wood. Besides wood, steel and polycarbonate building materials were also used. The construction is designed to construct the building holistically (Tunçbilek, 2013). The architectural structure, designed with an irrational approach, rises and falls from place to place and organizes the space in this way. In the structural wood material used, the planar unit elements are designed as interlocking. In the pavilion, the structure shapes both the roof surface and the façade. Unit elements are manufactured in Germany as fabrication and assembled and finalized in England (del Río-Calleja et al., 2022). The highest building point is 5.4 meters high in the building, which was built with the dimensions of 17*22 meters. (Tunçbilek, 2013). In Figure 6, the structural and formal views of the pavilion structure are given.

Figure 6. *Exterior and interior views of The Serpentine Gallery 2005 Pavilion (del Río-Calleja et al., 2022)*

3.2. Kreod Pavilion

The Kreod Pavilion was designed by Chun Qing Li (Pavilion Architecture) for the 2014 London Olympic Games. In the design phase, a plan consisting of non-costly, easily constructed, and disassembled structural elements was made. The pavilion, which was built as a temporary structure, turned into a complex system with multiple connections between the building elements. Spatial configurations can be provided with dismountable features (Popovic Larsen, 2014). The unit elements of the structure, which was constructed with triangular and hexagonal geometries because of the structural configuration, are planar elements and produced with wooden material. In the pavilion, an inclined surface was obtained owing to the combination of wooden unit elements. Assemblies were made quickly with the ease at the connection points of the structure, which reached the curved geometry. In the structure consisting of 3 parts, each piece is 20 square meters and the shell structure is spread over an area of 60 square meters. In the 3-meter-high pavilion, attention was paid to the parameters of sustainability, durability, environmental friendliness and aesthetics. The organic form has been created (URL-2). Figure 7 shows the appearance of the pavilion structure.

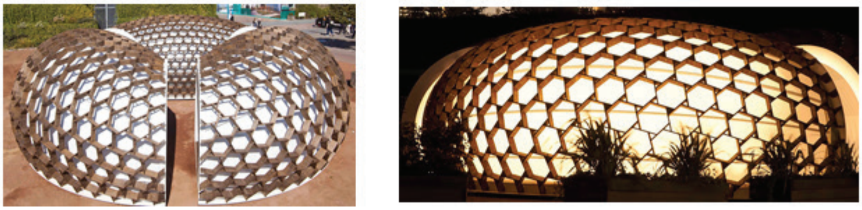


Figure 7. Views of the Kreod Pavilion (URL-2)

3.3. From Geometric Patterns to Load-Bearing Ribs Pavilion

The pavilion, designed for the Yeditepe Biennial in 2017, consists of four interlocking, repeating wooden arches. The span passed is 5.10 meters and the average length of the wooden elements used is around 50 centimeters. The total construction area is 23 square meters. A total of 618 wooden elements, 180 different from each other, were used to create the entire geometric weave. Wooden unit elements are prefabricated with CNC cutting and assembled on-site. The reciprocal structure project, From Geometric Patterns to the Bearing Ribs, was created by transferring a 14th-century geometric pattern to a load-bearing system. It was built in a regular barrel vault geometry. With the reciprocal mesh system created, a self-supporting structure that works against pressure and tensile forces has been obtained. In the design process of the project, the load-bearing system was created using the geometric patterns encountered on the pendants of the dome in front of the mihrab of the Selçuk Isa Bey Mosque, which was taken as an example for the exhibition concept. In this modularly produced pattern, a six-armed symmetry forms the rule of the rib system. The complex design of the project was modeled using Rhinoceros and Grasshopper software. The assembly time of the structural system took 3 days (URL-3). The visuals of the project are presented in Figure 8.

Figure 8. *Views of the From Geometric Patterns to Load-Bearing Ribs Pavilion (URL-3)*

3.4. The Princeton University Reciprocal Dome Pavilion

The building, designed by the AAU ANASTAS architectural office, which conducts experimental studies on reciprocal systems, was built for a book launch event held at Princeton University. Wooden modules were used as building material. The building has reached the shape of a dome with a combination of the patterns created. The final form was achieved by creating pattern algorithms through a computer program. In the process of reaching the final form, corner joints and angles were considered. Experiments were made on the structure with cell-based pattern algorithms from the design to the construction stage. With the developed parametric model, the relationships between the modules, the compatibility of the geometry and the pattern with the free-form surface were reviewed. The reciprocal structure, whose design has been completed, has been structurally analyzed and dimensioned using the finite element method. The prefabricated layers were combined with on-site assembly and the construction process was completed (URL-4). Figure 9 shows the visuals of the Princeton University Reciprocal Dome Pavilion.

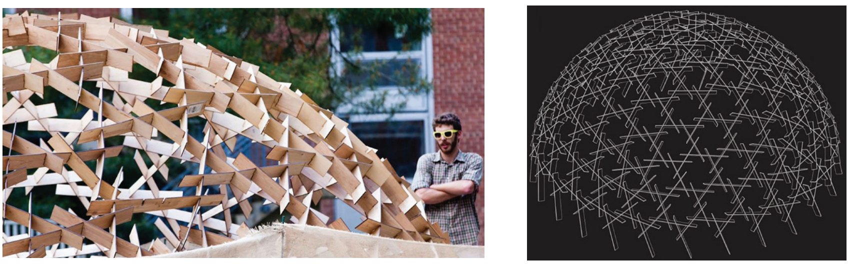


Figure 9. *Views of the Princeton University Reciprocal Dome Pavilion (URL-4)*

3.5. Stone Matters Pavilion

The prototype building, designed by the AAU ANASTAS architectural office in 2017, revealed the different uses of the local stone material used in Palestine. The interlocking stone making technique has been developed as an alternative to traditional stone making techniques. Patterns were created using a new computational simulation in the 7-meter-wide structure, spread over an area of 62 square meters, and stones were cut from this pattern. The structure was created by integrating the cut stone building materials each other. The integration of stones with a certain rule reveals an example of a reciprocal system. Generally, wood is used in temporary structures because it is light, easily shaped and can be cut to desired dimensions. The use of stone building material in this pavilion is one of the unique aspects of the pavilion structure. Stone materials were included in the structure by pushing the boundaries in the design. The entire structure was obtained from 300 interlocking stone building elements. Polystyrene stone blocks were roughly cut in one factory and transported to another factory for robotic engraving (URL-5). The views and perspectives of the pavilion are given in Figure 10.

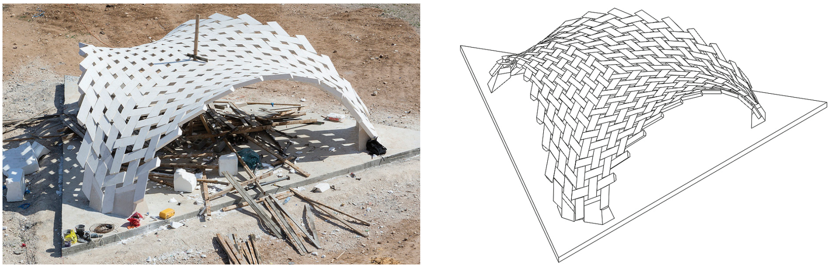
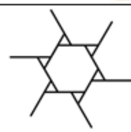


Figure 10. *Views from the Stone Matters Pavilion (URL-5)*

4. FINDINGS

When reciprocal systems are examined in general, it is seen that the basic design parameter is based on pattern creation. The basic geometries formed by these patterns, which are both regular and symmetrical in general, are triangle, quadrilateral and hexagon. Selected pavilions are grouped under these basic geometries. The design parameters are divided into basic headings as the morphology of the surface to be obtained, the material to be used, the type of unit element to be used, the primary geometry formed by the unit elements, the geometric sequence formed by these geometries, the distance ratio of the connection point on the unit element length, and the connection type. These titles were evaluated for each design. It can be seen that the materials used are generally wood. The distance ratios of the connection points differ on the unit element length. Notably curvilinear surfaces and free-form shapes are created in general in temporary structure designs. In addition to these, it is seen that experimental studies in reciprocal structures are at the forefront. The 5 temporary structures discussed are grouped in Table 1 according to their design and application features.

Table 1. *Comparative display of temporary structure designs (by the authors)*

Structure	The Serpentine Gallery 2005 Pavilion	Stone Matters Pavilion	Kreod Pavilion	From Geometric Patterns to Load-Bearing Ribs Pavilion	The Princeton University Reciprocal Dome Pavilion
Basic geometry					
Structure module					
Unit structural element type	Planar	Rod	Planar	Planar	Planar
Geometry formed by the unit structural element	Square	Parallelogram	Hexagon	Hexagon	Triangle
Geometric shapes in the structure	Square	Parallelogram	Hexagon and triangle	Hexagon, triangle and Parallelogram	Hexagon and triangle
The ratio of the connection point (x) to the length (L) of the unit structural element	x=L/2	x=L/2	x=L/3	x=L/3	x=3L/4
The main building material of the structure	Wood	Stone	Wood	Wood	Wood
The type of connection between building elements	Screw + interlocking	Mounting	Screw	Screw	Interlocking
The geometry of the structure	Planar	Vault	Paraboloid	Vault	Dome

5. CONCLUSION

Structural design, which plays a key role in building design, brings with it new searchesThese searches make the unit element, which is the basic building element of the structural design, questioned. With the developing technology and design programs, different design alternatives can be planned. Reciprocal systems are a application in which geometry and mathematics are integrated into architecture, providing design diversity. Reciprocal systems allow various designs to be made thanks to their advantages such as short beam lengths, material diversity, fast construction systems, and easy construction phase. These designs can also be found in many types of structures. It has been used since ancient times, especially in experimental studies and top cover designs with large-spans. Today, when technology has started to play an active role in design, complex structures can be built with these systems. Because of the development of technology and workforce, optimization of complex structures with algorithms and simulations has enabled reciprocal system details to be solved easily.

Building elements that can be produced as prefabricated can be added to architectural product stocks by on-site assembly. Temporary reciprocal structures, which are ready to be transported and used in a different function in a different region, are advantageous owing to their ability to be mounted and dismounted. Temporary reciprocal structures are mostly seen in fair structures, expos and pavilions. For this reason, examining reciprocal systems yields more efficient results for such structures. The researched reciprocal systems have been compiled and their properties have been evaluated. Because of the study, different architectural design parameters can be created through reciprocal systems, which have a deep-rooted history, and original designs emerge with the change in these parameters. It is thought that new reciprocal systems will be added to the architectural product stocks in the future with the diversity of designs and the increase in technological possibilities.

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