# Systems Thinking: A Methodological Approach for Understanding Urban Complexity

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ABSTRACT: The environmental, economic, and social changes in the last decades demand the readdressing of the city as an adaptable one defined through a network of interwoven relations rather than well-defined rigid structures. This intricacy forges the redefinition of accustomed design practices to manage the desired inclusive, adaptive, fluid, and responsive conditions of cities. However, incorporating these coexistences in defining urban conditions necessitates a multi-focal rendering of the associations and a speculative practice of a new methodological approach. Therefore, we need novel methodologies of research in the field of architecture. This paper will propose revisiting 'systems thinking' as a new methodology to research the pluralities, contradictions, degradations, and climatic challenges of contemporary cities. Rather than a top-down design approach, 'systems thinking' initiates a non-linear process by focusing on the relationships and interdependent variables. Therefore, embracing 'systems thinking' in the definition of contemporary cities can respond to the ever-changing conditions, which can alter the design practices and teaching-based research processes.

However, to envisage and structure a system that can respond to the pluralities, complexities, and contingencies of the ever-changing conditions, a deep reading of the city should be provided that can be produced, processed, or engaged in all phases of the design process. In this respect, experienced data avalanche and interaction with the large scale of bytes used for data-driven practices can be considered as a challenging transformation that proposes deep readings of cities and hence can be used in practicing a 'systems thinking' approach. This new method of engagement with data-driven practices cultivates an architectural transformation by sourcing, inspiring, and informing the architectural design processes for understanding the notion of resilient cities. The paper speculates on the potential of systems thinking initiated by data visualizations in producing deep readings and research on contemporary cities and its use as a methodological approach in architectural design education.

KEYWORDS: systems thinking, data visualization, architectural education

## INTRODUCTION

Over the past few decades, cities have experienced significant physical changes due to environmental degradation, ecological destruction, and human-induced climate change. These changes have significantly impacted urban conditions and their representations, necessitating a rethinking of the city as a more complex, saturated, and open system. The contemporary urban environment, characterized by diverse interactions and spatial dynamics, can be seen as an ecosystem encompassing socioeconomic, biological, geographical, ecological, and experiential elements. At the juncture of these social, economic, ecological, geographical, and experiential crises, architecture as a discipline is expected to define resilient approaches for unprecedented urbanization, climatic degradation, and ever-accelerating technological advances and challenge the norms and expectations with an interdisciplinary perspective. (Easterling 2014)

In order to understand these redefined urban conditions, it is essential to adopt a holistic perspective that examines the extensive associations and relationships within urban environments. This necessitates reevaluating assumptions, strategies, and tactics across urban design, architecture, engineering, and politics. Today's Architectural research must incorporate a multi-faceted approach to capture the complex interactions integral to the economic, political, and ecological dynamics of 21st-century cities. Since architectural research cannot be separated from the current state of cities, addressing the intricate, unpredictable, and dynamic nature of contemporary urban conditions requires a series of zoom-in and zoom-out analyses. The proposed research methodology has the potential to shift between different scales in understanding the broader dynamics of the city. We can only develop a complex matrix capable of accommodating new networks, connections, and phenomena through such a comprehensive approach, thereby providing insights into the emerging conditions shaped by various agents, including human, non-human, international, intergovernmental, and non-governmental entities.

## 2.0 SYSTEMS THINKING AS A METHODOLOGICAL APPROACH FOR COMPLEXITY

This conscious approach that requires working with multiple perspectives and acknowledging the emergent conditions defined in line with various diverse agencies in research is hard to achieve, especially in undergraduate education in architecture departments. It is a fact that architects need new tools and methodologies to develop this kind of deep research on cities. To execute an experimental research process in architecture design studios, a novel methodology called 'systems thinking' is instrumentalized for two consecutive years. Systems thinking is an approach that considers the overall system together with other related systems and its discrete parts. As Peter

Senge discussed in detail, it is a terminology that belongs to the management field as the fifth discipline. He defines systems thinking as a framework for creating a learning organization where parts interact with each other and build complex systems. According to Peter Senge, (Senge 2006) systems thinking is

> a framework for seeing interrelationships rather than things, for seeing patterns rather than static snapshots. It is a set of general principles spanning fields as diverse as physical and social sciences, engineering, and management.

For Senge, 'systems thinking' as a discipline is instrumental for seeing wholes through, focusing on inter-relationships rather than things and patterns rather than static 'snapshots.' (Senge 2006) It defines a cohesive system where different parts, in different scales and with different properties are interrelated with each other to define a complex whole. Having these potentials, systems thinking can be acknowledged as a research and even design methodology for studying complex structures and understanding the dynamics of a system from different perspectives. Adapting this methodology in architectural research, especially to study contemporary urban conditions, can be regarded as a meaningful strategy for understanding and engaging with the rapidly changing and evolving cities.

Providing an in-depth understanding of a comprehensive approach to studying complex conditions, systems thinking necessitates the ability to represent and assess dynamic complexity, acknowledge feedback processes, identify relationships rather than outputs, and recognize nonlinearity and irregularity. (Sweeney & Sterman 2000) The common concern in these necessities recognizes a dynamic 'behavior that arises from the interaction of a system's agents over time' that leads to various levels of complexity. (Sweeney & Sterman 2000) Welcoming collaboration and input, systems thinking as a methodological approach aims to increase the delivery of complexity and hence focuses on defining a complex whole. The concept of 'wholeness' considers that a system comprises various other sub-systems, which consider the definition of a system. For example, according to Russell Ackoff, a system is not the sum of the behavior of its parts; it is a product of their interactions. (Ackoff 2015) This definition of wholeness as a system enables understanding complex organizations operating in a dynamic and interconnected way and hence focuses not on the discrete elements but their interaction. Aiming to zoom in and out to see different relations and interactions, the concept of wholeness in the systems thinking approach prioritizes the dynamics of the system rather than the outputs. Therefore, acknowledging the systems thinking approach allows focusing on the whole system with a holistic view and requires us to consider each action in the context of the broader systems in which it is embedded. (Cavaleri and Sterman 1997)

Another specific concern of systems thinking is the dynamism of the organization, which demands a specific emphasis on feedback loops rather than the linearity of the process and cause-and-effect relationships. Considering the effects of action not only on the discrete condition isolated from its broader context but also its influences and effects on other systems alters the way the system is envisaged. (Senge 2006) The conceptualization of the system as a 'whole' composed of various complex systems in different scales and compositions allows the redefinition of each sub-system concerning a change defined in another system. This continuous feedback loop within the system also embraces the concept of emergence, where the system's behavior cannot be predicted only with individual components.

Since urban and architectural development strategies are expected to deal with diversity, manage technological challenges, encourage sustainable development, react to climate change, environmental degradation, and ecological destruction, etc., urban and architectural research and development strategies are expected to define a holistic approach that embraces tolerance and complexity. Embracing systems thinking in the reading, designing, and structuring of contemporary urban conditions may foster the architect in dealing with the pluralities, contradictions, degradations, complexities, and challenges of 21st-century cities. By adopting this methodology, architectural research can consider the broader and long-term implications, focus on interrelationships rather than cause-and-effect relationships, and provide a multi-focal rendering of relations, which defines a holistic approach to the design problem.

However, the structure and the concept of 'systems-thinking' necessitate an in-depth, interdisciplinary approach that recognizes the change as constant (Weisz 2018). To acquire, interpret, and use data about the city in constant transformation, the research may incorporate qualitative and quantitative data, which has become available with emerging technological developments. Especially data visualizations, which allow different and diverse information and data to be displayed simultaneously, can be used to associate with systems thinking methodology. When considered as a new challenge for the systems-thinking approach, these multilayered and multidimensional representations of complex data can map the ever-changing relations and ever-expanding data of the city with all its components and alter how we understand, define, and visualize the cities.

## 3.0 SYSTEMS THINKING IN ARCHITECTURAL DESIGN EDUCATION

This approach of producing a deeper analysis of the city in various scales and perspectives, where several systems interact to define a complex whole, provides advantages for embracing complexity in architectural research. With this framework, the paper presents a selection of student works produced in an undergraduate architectural design studio at TED University, Department of Architecture in Ankara, Turkey. The examples to be discussed aim to reveal how an approach of 'systems thinking' often associated with the management field has been adapted in architectural research as a method for reading and discussing the city. The article aims to uncover the potential of this methodology by sharing the outcomes of a survey conducted with the students who went through this experience, in addition to the discussion on examples produced in the design studio. As can be seen in the detailed

discussion of the examples, the systems thinking approach, which is usually operationalized in the first semester of the 4th grade, expects students to develop a series of readings and interpretations about the whole city based on the region they examine rather than focusing only on a particular site within the city. Therefore, the assigned areas for each semester require particular inquiry, which necessitates solutions and design approaches at an urban scale rather than an architectural scale and generally consists of problematic areas within the city.

Two major port cities in different geographies were studied in two years: Beirut in Lebanon and Samsun, another significant port city in Turkey. Even though the cities are different, the studio's main objective remained constant. It was explained as discovering the spatial, material, and experiential dispositions along the encounters of water with land/city and developing adaptive, solitary, and resilient strategies for the particular urban context. Most of the examples to be discussed here, which are named ‘operative mappings’ in the studio, benefited from the research conducted in the first 3-5 weeks of the design studio practices. All the student groups focus on a different aspect in structuring the basis of their research. However, the main aspect common in all examples lies in their attempt to develop distinct tactics for studying complex urban conditions and utilize systems thinking to cope with the discovered pluralities and network of relations. Incorporating systems thinking as an architectural research methodology and cooperating with data visualization strategies provided valuable inputs to the studio to discuss complex problems that cities face today, generate ideas about rapidly changing cities, and ensure resilient futures for the cities.

Two cities selected for research, Beirut and Samsun, provided very productive examples to study, as both cities face an urban collapse on many scales. For Beirut, problems related to the economy, urban management, transportation, lack of access to public and green spaces, and climatic risks are just a few examples of the problems that await solutions with larger-scale interventions and sets of integrated urban strategies. The Beirut Port explosion on August 4$^{th}$ can be regarded as a natural consequence of this downfall at many stages. The blast created a ground zero condition at the port area, literally hallowing the land and urbanscape of the waterfront urban edge. Any attempt to understand the particularities of this urban land of Beirut and the present conditions before and after the blast requires a deeper analysis of the many aspects of the city on a larger scale. The multicultural structure of the city, its historical significance, and its position within the region also play an important role in understanding and reclaiming the city's urban qualities and edge.

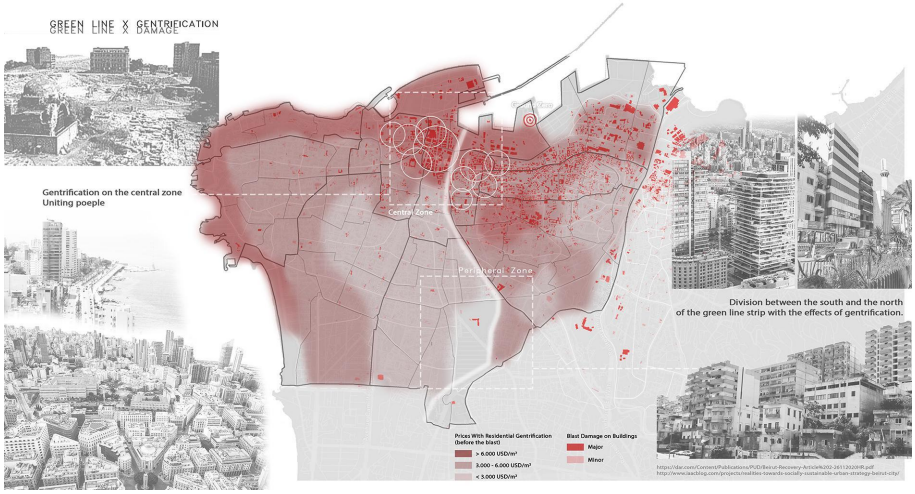


**Figure 1:** Demarcations of Green Line and other forces that affect the emergence of new urban zones. Source: (Emine Koç, Melisa Yılmaz, Nisa Gülin Özkan, Zeynep Köksoy 2022)

Perhaps Beirut's most important urban element, the *Green Line,* is an urban entity that triggers different relationships in every period of the city, regionally, sociologically, and historically. However, it is not an inactive urban formation or a single line that demarcates two distinct parts within the city, but an element of compromise and change, characteristic of which is unique to the city of Beirut. Regarding its different roles and pluralities, the visualization of the data tries to unfold the extent of associations and web of relations that can reveal the more significant dynamics of the city. As seen in Figure 1, the research collected and combined the data acquired from the Beirut Recovery Map (2024) to reveal the damaged buildings' information after the blast and the changes in the rental prices before and after the blast. The mapping of the information exposes demarcations of Green Line and other forces that affect the emergence of urban zones within the city, which are different from the accustomed typology of the city. These zones are divided into two parts, as displayed below. (Figure 1) The idea generated the zones of differentiation and how Beirut altered its morphology after experiencing a catastrophic event. Furthermore, it is a way to interpret different layers of the city and the impact of these layers on each other, all of which can be considered as design data that initiates the design processes.

*Redefining the water edge* in urban systems is another type of research where dynamic data, like the constant change in the edge conditions of the coastline in Beirut, were analyzed and visualized. The main idea in the research aspired from the intention to utilize variable and dynamic data such as climatic changes and tidal cycles as design input instead of more static geographic data. Non-human agencies, like the changes in the shoreline through the movements of the sea, when overlapped with more static geographic qualities or human interventions as the main subjects of research, initiated a holistic design approach to the definition of the coastal edge in a city, which is surrounded by sea on three sides as seen in Figure 2. The systems thinking approach in the case of this research

provided a ground for a holistic approach that is obtained from constantly changing data and turned into a problem-solving tool for the city's future scenarios related to the sea and the shore. The notion of boundary and its architectural interpretations were put under inspection to research interdependent variables.

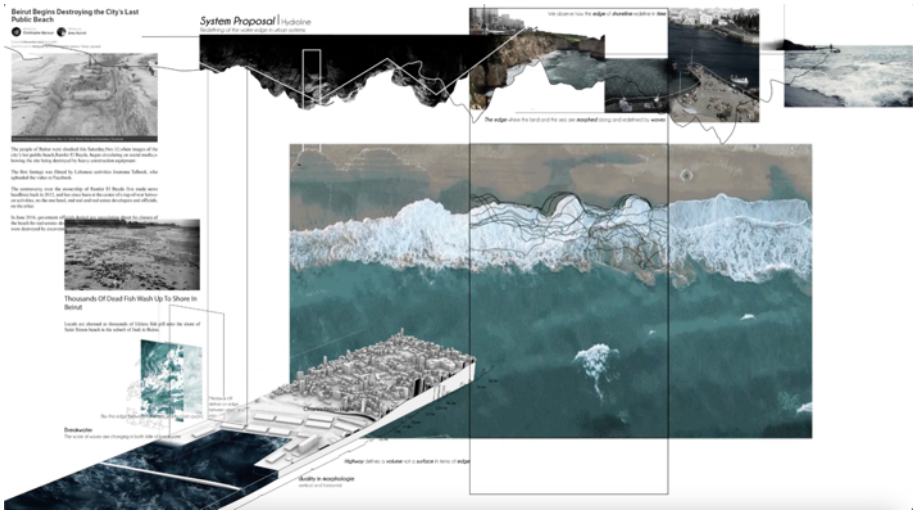


**Figure 2:** Redefining the water edge. Source: (Cansu Sivrikaya, Sema Akbacakoğlu, Gizem Simay Engin, Almina Yakut 2022)

In trying to map the relations between the coastline and the river in Beirut, another project recovered the data related to *drilling private wells* everywhere within the city. With these legal and illegal wells, the underground water fabric of the city of Beirut has been entirely changed by human hands, and the water network of the city has taken on a completely different character. These private wells are discovered to induce a marked rise in seawater infiltration, as the amount of extracted groundwater gradually exceeded the amount of natural recharge water. (Acra, Milki, Karahagopian, Raffoul 1997) Visualization of this data provides a layout that maps the unseen, unrecognized, yet vital aspects of urban life. The visualization of this relatively invisible data, just as conventional base maps that show geographic information, is utilized to lead to the emergence of different design systems related to future water uses of the city. (Figure 3) The data is visualized through overlapping different layers of information, the wells, the riverbeds, the morphology of streets, etc, as discrete but interactive systems working with and affecting one another.

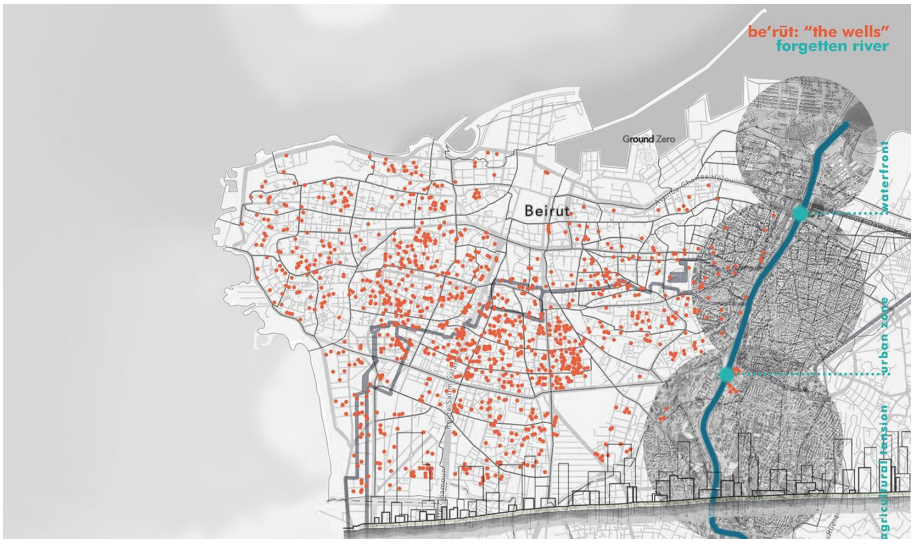


**Figure 3:** Drilling of private wells throughout the city. Source: (İlayda İlaslan, Mine Gülsün Kahveci, Seher Begüm Boztepe, Semiha Nur Korkmaz 2022)

In another example, pollution was mapped as an environmental and climatic problem in Beirut. Pollution is one of the most important problems in many cities today, and each city is expected to develop novel strategies to tackle it. Pollution threatens cities in many aspects, ranging from water to air pollution and other small-scale pollution like streets, rivers, etc. Beirut is no exception in its struggle with pollution at many scales that constantly interact. Research on pollution levels within the city should inevitably consider its causes and results and the reciprocity between different types of pollution. In the research displayed in Figure 4, the map integrates different information on pollution acquired from municipal documents and other resources. Different layers of information directly related to or affecting the general level of pollution in the city, like the pollution levels in the water, the intensity of NO2 by traffic, pollution caused by trash, distribution of pollution by wind, and the number of sea outfalls, creates a composite map, where different territories of pollution accumulation can be observed and studied. (Figure 4)

**Figure 4:** Layers of Pollution in Beirut. Source: (Doruk Özkoç, Ardacan Özvanlıgil, Emre Şimşek, Yıldız Cemaloğlu 2022)

Regardless of their subject of analysis, all the examples discussed here try to unfold how social, economic, and often political approaches transform the city and how these features, invisible or visible problems, and potentials are interrelated, thus making the unknown urban networks more comprehensible. This methodology can be argued to constitute one of the promising methods for architecture's relation to the unknown and imperceptible. In this methodology, data visualizations are argued to be one of the most indispensable tools for reading today's cities, and they work in an integrated manner with systems thinking, as they mutually support one another. In the following semester, the utilization of systems thinking allowed multiple issues to be considered simultaneously, similar to the examples discussed in the case of Beirut.

The city of Samsun, which is also an industrial harbor on the northern coast of Turkey, copes with the consequences of urban challenges outlined in the last decades, which alter its social, geopolitical, environmental, and architectural conditions. Considered a transfer and industrial node in the northern region, Samsun has a transportation network where Anatolia is connected to the black sea region through various means. Governing the national and international trade routes for years, the city has also been promoted as an industrial and agricultural hub, which augmented its geopolitical and geomorphological stance in the region. However, environmental degradation, urban destruction, and industrial policies have altered the definition of the urban conditions of the city and its definition noticeably in the last decades.

One particular example in this semester provided comprehensive research not limited to the city of Samsun but developed from an analysis on a much broader scale. Named as *Water Formation Library,* it can be regarded as a reading that defines the relationship of the city of Samsun with water through the analysis of the water textures of different cities and reveals the map of potential texture formations carried by the water movements. The project aims to retreat the Mert stream in Samsun, which has lost its quality as a wetland due to uncontrolled uses, and to restore its potential for irrigation as part of a larger-scale water network. To propose a system for this new network, mapping the existing water patterns throughout many cities and comparing them to one another enables the building of a comprehensive library, which can direct the design in achieving various tactics of water manageability. The acquired information and its collective mapping to be perceived together rather than separately inevitably pave the way for the formation of different associations of data that are not perceivable when analyzed independently. (Figure 5)

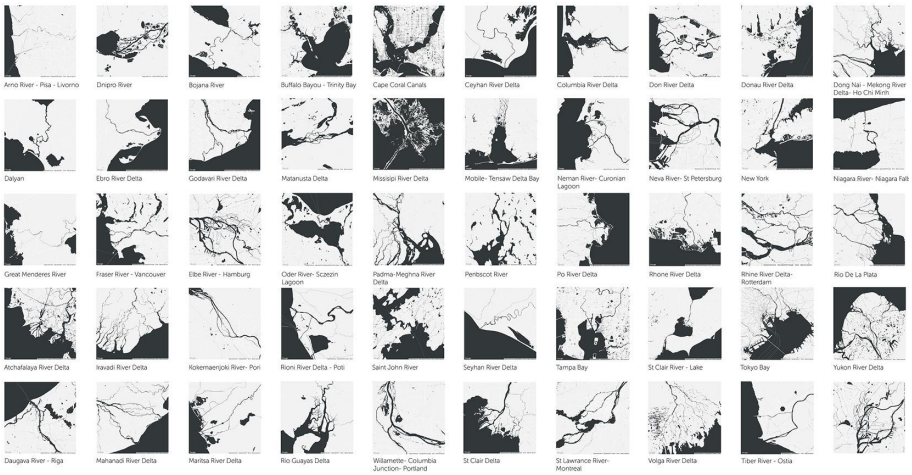


**Figure 5:** A library of water-land relations. Source: (Bartu Aydınlı, İlayda Ülgen, Zeynep Süner 2023)

On the other hand, the project called *The Night Drift* tries to map the life between the buildings in Samsun in an area that includes the port and the idle spaces surrounding the area. The port of Samsun stands out as an urban

element that affects the use of the city's coastal area and its relationship with the sea with an impact that covers a larger circle than its actual position within the city. Mapping out the human activity patterns approaching the port area night and day reveals a reading of the voids created by architectural structures rather than the structures that make up the city. It is the visual documentation of what is not visually evident or easily accessible at first glance. The project tried to establish a framework for discovering the interrelationships between urban entities, making visible the complex network of human flow together with connected and disparate zones of interaction (Gehl 2001). Its power in triggering a systems thinking lies in the way it overlaps different activity patterns to reveal the legibility of the relationships between uncanny spaces, crowded spaces, or spaces of attraction within the city that we do not perceive in our daily life, and most importantly the relationship patterns that bring these differentiations and contradictions into existence. The design process builds on this rather unconventional data set that can trigger new understandings for embracing complexity in understanding urban dynamics. Uncovering the patterns that lead to the emergence of certain urban conditions is regarded in the studio as a strategy for deep reading that can reveal a systematic approach to understanding the city. (Figure 5)

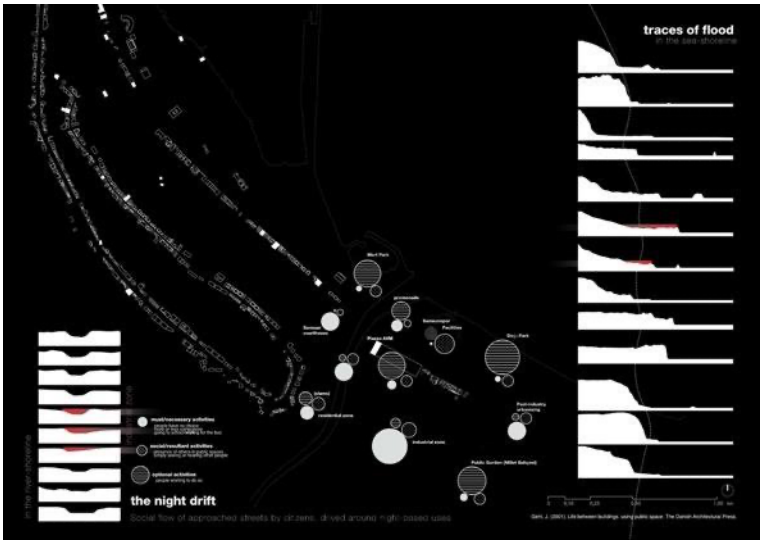


**Figure 6:** Data visualization displays the working hours of social spaces (café/restaurant, commercial facilities, social spaces etc.) and the related social flow of citizens in the city (Samsun). Source: (Başak Ünver, Betül İlayda Yılmaz, Zehra Dağıstan 2023)

The selected examples emphasize the interrelations in the city and discover the complex relations where various layers of data were overlapped and reinterpreted. In the studio process, the data visualizations produced also create another data set that contributes to the learning environment of the studio. Each visualization provides a different perspective on the city's urban conditions and initiates the reading of visible and invisible conditions. Although the paper includes selected examples from studio productions, the visual palette of data sets defines an explorative ground for architectural research and design. (Figure 7)

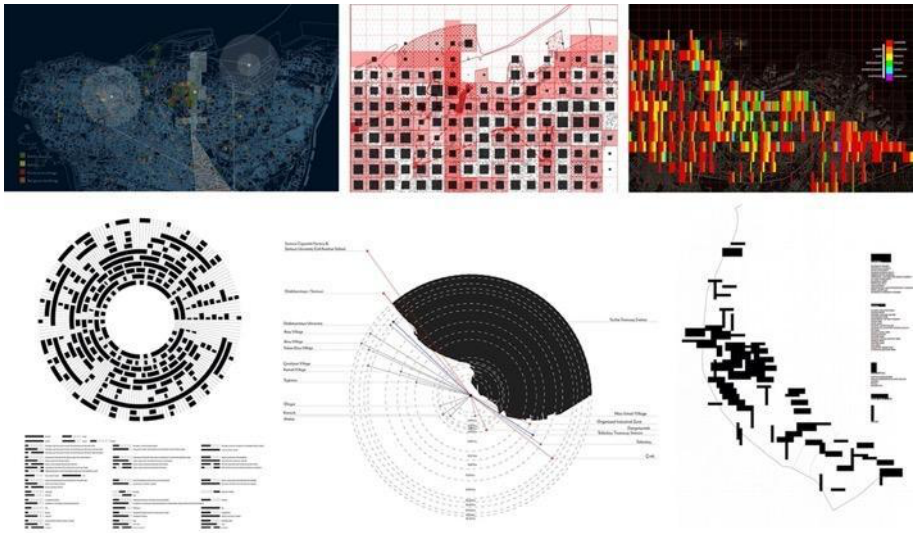

**Figure 7:** Data visualizations of the urban data were selected from two different studio processes. Source: (TED University 4th year studio works 2022-2023)

## 4.0 SURVEY ON SYSTEMS THINKING

The mentioned architectural research carried out by embracing systems thinking in architectural design education can be analyzed from various perspectives, specifically through data visualization. The increased exposure to continuous and massive data input from various sources alters the definition of a system and, hence, the consideration of systems thinking as a methodology. Therefore, an anonymous survey has been administered to a group of students to deepen the outputs and reflections of the aforementioned studies. The main concern of the survey was to understand the aftereffects of embracing systems thinking as a methodology in architectural design education and to reflect on the relationship between systems thinking, data visualization, and urban conditions. In this framework, the survey was applied to 25 students who have experienced the architectural design studio with systems thinking emphasis in the 4th grade. The questions can be categorized into five main groups, which are experiencing systems thinking as a design methodology, its advantages and disadvantages in the design process, integration of data visualization into the design process, using systems thinking in reading the information gathered in different scales (especially in urban scale) and the discrepancies between a systems thinking approach and the conventional architectural design approach. (Figure 8)

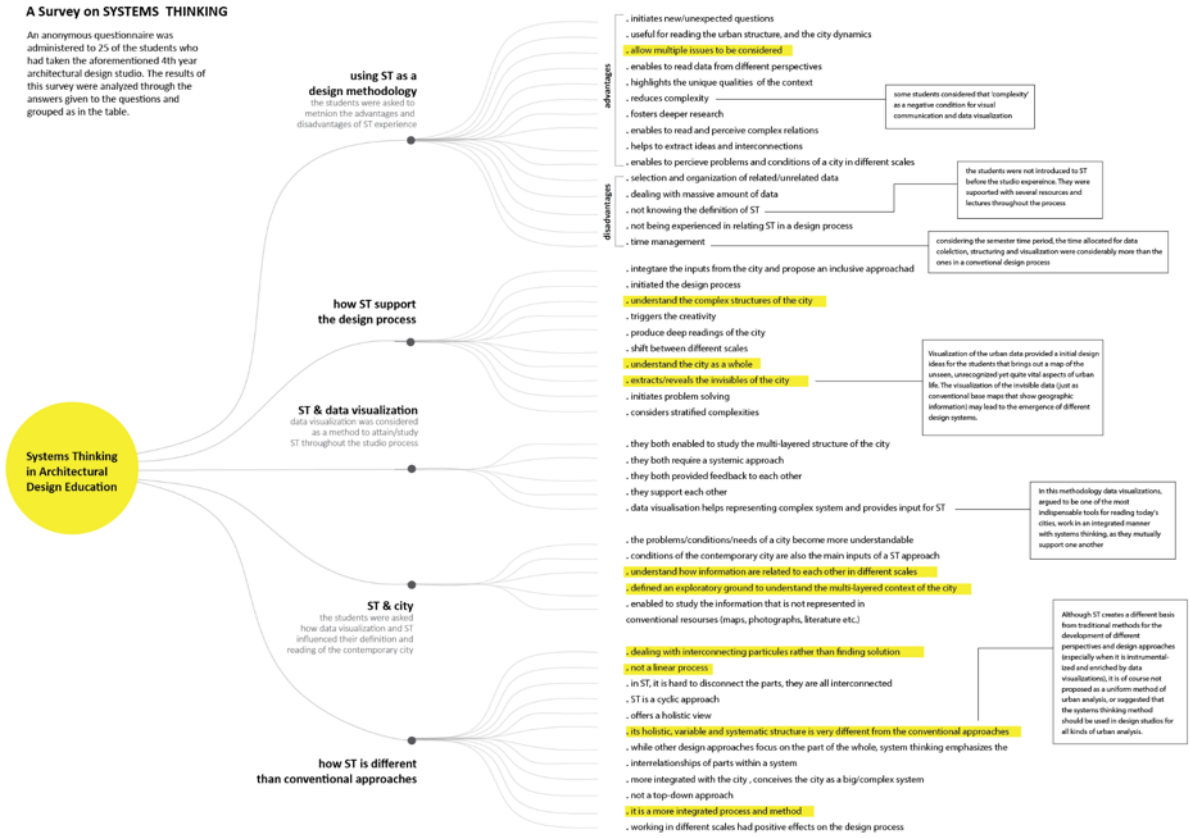


**Figure 8:** The outputs of the survey on systems thinking in architectural design education. Source: (Başak Uçar23)

According to the survey outputs, the students indicated that the definition of the design process through the systems thinking approach enabled them to have a holistic view of the design problem, including various perspectives/data/inputs from the urban scale. The ability to include multiple issues, organizations and data sets was considered a challenging design task since it initiated the consideration of '*unknown*' or '*invisible*' conditions of the city. Besides the conventional materials used for analyzing the city, such as maps, photographs, drawings, etc., systems thinking was also mentioned to have a positive impact as it revealed the unique qualities of the city and opened up new grounds for design exploration.

Another important output received from the survey was that the students were challenged by dealing with the complexity of the city and explored the potential of data visualization in defining systems thinking. They also noted the interactions between systems thinking and data visualization processes and underlined how they both supported each other. This can be considered a positive output of integrating data visualization methods into architectural research through integrating systems thinking in architectural design education. Compared to conventional architectural design education experiences, the students also indicated the positive implications of dealing with the complexity and massiveness of data inputs. This remark is a feedback of structuring systems thinking methodology through data visualization in large-scale architectural design problems.

Students also noted the difficulties of understanding the definition, potential, and requirements of systems thinking as a research and design methodology. Although systems thinking is studied in other disciplines and has deep literature, its acknowledgment in architecture -primarily through data visualization- can be considered a novel approach. Therefore, the students lack the necessary theoretical and technical background for systems thinking. The competence of the students in data visualization techniques and dealing with massive amounts of qualitative

and quantitative data can also be considered as a deficiency in the application of systems thinking since inadequacy of time management and data structuring were mentioned in the survey by the students as the disadvantages of the methodology.

With all these advantages and disadvantages, systems thinking in architectural design education and its research through data visualization tools can be considered a novel approach and, hence, be acknowledged as a methodology for studying complexity. Although the survey reveals the potential of this approach in the architectural education process and the need for competency in dealing with complexity, its capacity as a methodology in architectural research is also significant in producing deep readings of contemporary cities.

## CONCLUSION

The research process discussed aimed to test an experimental approach that challenges traditional urban research methodologies, as conventional tools and resources are inadequate for understanding the complexity of today's cities. These exercises aim not to propose a uniform methodology of urban analysis or to suggest that systems thinking should be universally applied in design studios for all types of urban research and design. Given that the examples analyzed and discussed come from undergraduate studies, they do not have a deeply developed research background. However, most of the research within the design studios benefited from the systems thinking approach as it provided a fertile ground for discussion on how research can benefit from working with multiple data sets and inputs. Although some research failed to respond to the complexity of systems thinking and data visualizations, they can still be considered preliminary attempts in adapting this method to the design studio. As the article argues, systems thinking provides architectural research with new ways to engage with urban complexities. It offers more open-ended, flexible research and design processes than conventional methods. In the words of Senge, (Senge 06)

> Systems thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively.

Therefore, it can also be regarded as a method suitable for responding to the shifting conditions of the city and its components, including human and non-human aspects, and understanding the network of relations that structure the very essence of the contemporary city, with all its *unknown* climatic, environmental, political and social problems. Looking ahead, ensuring the resilience of cities is likely a primary focus for architecture and architectural research. Expanding the scope of architectural research and integrating diverse data and inputs are essential for developing ecological approaches and fostering a more sustainable future. In this context, it is clear that systems thinking, enhanced by data visualizations, plays a crucial role in architectural education and research processes.

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