Complexity – A Dilemma for Planning

Research on complexity theory, complexity in planning practice, and emergent manifolds

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Abstract

This thesis draws the point of departure from the issues between planning and complexity. On the one hand, planning reduces complexity in order to organize cities, while on the other hand, complexity studies, a growing interest in urban planning discourse, suggest that increased complexity should be allowed to emerge in cities. Conceptual and practical tendencies between planning and complexity are investigated to explore the potentials for planning to deal with this issue. The main concern of the study is to contribute to improved responses to complexity in planning in order to realize the potentials of emergent complexity. Within this scope, the available theoretical information was compiled based on a literature review and then developed with syntheses and insights by means of a case study.

The case study provided this study with the opportunity to illustrate the potential for actual complexity emerging in new and large-scale urban planning practices, and also the ways in which planning can foster such a potential.

The results provide insight into different ways of thinking that can be brought to the development of cities and places, through planning that takes complexity into account theoretically and practically.

Keywords: urban planning, complexity, complexity theory, emergence, emergent manifolds, Brunnshög

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Alnarp, January 2023,
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1. Introduction

1.1 Problem Framing (Complexity & Planning)

Urbanization has been followed by the awareness of many social and ecological problems. Rapid urbanization has prompted the need to reconsider urban planning concepts and practices since the problems it brings threaten the liveability of spatial areas. In response, it was recognized that urban planning needed a deeper understanding of how cities grow and function. The complexity theory has been embraced by many researchers with the view that it can provide this deep understanding. Complexity theory, in its general sense, is the umbrella term of theories that examine the relationships between the elements of complex systems and the changes within the system (Portugali, 2006; Balmaceda & Fuentes, 2016). Several studies investigating the relationships between planning processes and complexity discourse have made a significant contribution to this understanding of how urban spaces grow and change as complex systems. Many of these studies also use complexity theory to identify new solutions to planning problems. At the same time, scholars have argued that new bridges must be built within the discourse of integrating complexity theory into planning practices. Gert De Roo, one of the pioneers of these studies, advocates going beyond the complexity theory of cities and exploring new applications and ways of applying these theories in order to measure the possible benefits (De Roo & Silva, 2010).

Introducing complexity term to the planning discussion in the theoretical sense has revealed new insights that contradict the ongoing planning practices of previous generations. These long-standing planning traditions asserted that planners had the authority, power, and ability to organize the spatial environment politically or socially according to their vision (de Roo & Rauws 2012). Consequently, cities were viewed as highly organized structures with components such as their land-use patterns and transportation systems (Batty, 2005). Complexity theorists reject this view of the high organization in its relevance to urban planning. Although the built environments of cities are rather resilient, complexity theorists embrace the idea that this manageable reality is prone to change quite easily (Batty 2005). Thus, it refocuses planners' attention on the need to deeply understand the nature of this change. The theory of complexity in cities deals with the factors that affect the

growth and change of urban and regional systems, namely the actual complexity of the system. The actual complexity is the emergence of activities, culture, transportation, natural capacities, and similar realities that actually exist in the spatial domain (Batty, 2009; Allen, et al., 2008). Throughout urban life, this actual complexity increases due to the diversity and adaptability of reality created by individuals, societies, and the natural chains-of events (Allen, et al., 2008). Many complexity researchers, notably J. Jacobs and C. Alexander, have argued that this emerging complexity is a key component of urban structure and even the success of urban planning, through increased diversity of nested, mixed-use, and overlapping frameworks (Jacobs, 1961; Alexander, 2013). According to them, in order to implement successful urban planning in the long term, it is necessary to understand how the complexity of the real city works and to use this actual complexity in a way that stimulates land uses, city activities, and functions. Similarly, P.M. Allen (1997) suggested that applying actual complexity to planning could be a new and explicit way of considering how society adapts to the diversity that arises as land use changes are influenced by factors such as environmental, cultural, social, and economic. Planning can be based on an evaluation of possible reactions involving incentives, such as local participation, invitations, or art projects, as an example of real complexity applied to planning. The result can be a basis for a new set of planning actions involving human systems based on these evaluations. Accordingly, Allen's view could be interpreted as, the investigation of actual complexity can provide a suitable basis for knowing how society perceives and reacts to these in urban reality when making actions, investments, and policy decisions within urban planning.

In planning practice, the focus is on planning ways to achieve, maintain and improve environmental and spatial quality and conditions. Problems faced by modern society such as demographic aging, climate change, and the transition to sustainable energy systems, as well as the available space threatened by urban population growth, make urban planning more challenging. This situation makes it necessary for planning practice to strategically organize elements such as the physical structures, buildings, streets, and transportation of the city in order to increase the liveability of the city. In this regard, the urban planning practice presents a great dilemma. That is, actual complexity, as the product of how the complex urban system emerges from human society, surrounds us, and increases as cities grow and change, stimulating society to adapt to new opportunities (Batty, 2009). However, cities and regions, if well organized, can limit the likelihood of successful adaptation by reducing the emergence of actual complexity (Allen, et al., 2008). The dilemma seen here is that planning, on the one hand, must be able to organize the city and reduce complexity, on the other hand, it should allow the emergence of actual complexity in order to support diversity and society. Exploring how planning can deal with this dilemma would be a useful goal to reveal the

benefits of considering the complexity in planning practice. Accordingly, complexity theory is an important resource because it can provide the tools needed to understand how planning practice deals with, relates to, and influences actual complexity (see figure 1). At the same time, complexity theory can facilitate a growing understanding of the increasing complexity and unforeseen factors, urban planning has to deal with.

Investigating the relationships between complexity theory, planning practice, and actual complexity in the context of real-world urban planning may be a possible method to illuminate the above-mentioned dilemma. Thus, in this thesis, the Brunnshög urban development projects in Lund, Sweden, set a case study in terms of planning practices and policies for managing emerging actual complexity. The case was chosen because of its opportunity to illustrate the potential for actual complexity emerging in new and large-scale urban planning practices, and also the ways in which planning can foster such a potential.

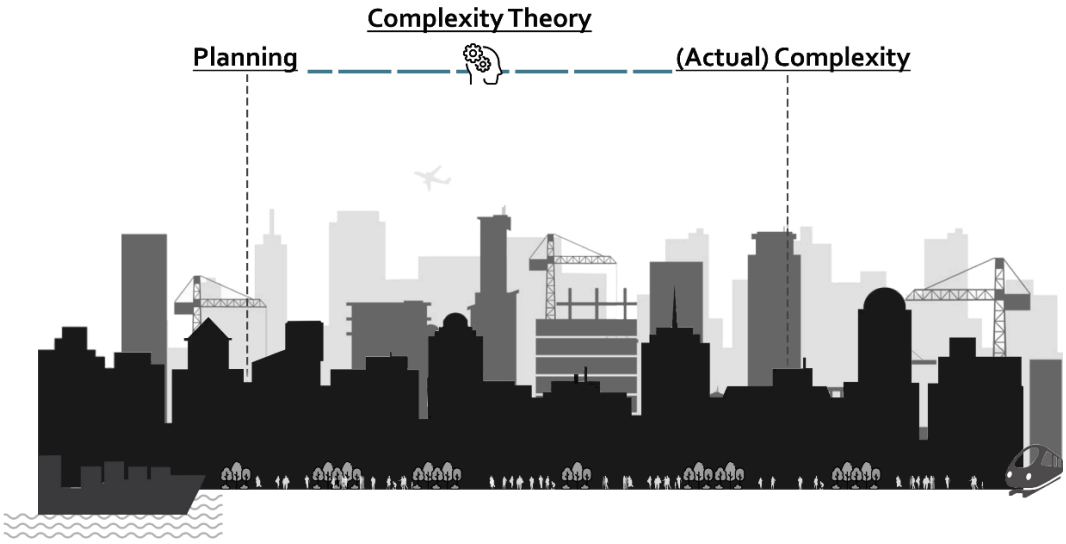

Figure 1. Illustration of planning, actual complexity, and complexity theory's relationship to the city. Complexity theory provides the thinking tools that planning needs to link planning and actual complexity on site. Image created by the author.

1.2 Concept Framing [1]

1.2.1 Complex Systems & Complexity Theory

Complexity theory is about the interactions and changes that take place within a system. The complexity in a system arises from many elements (inanimate or animate) in the system interacting naturally and continuously. The variation in the number, size, and effects of the contained elements results in the formation of multiple subsystems, intertwined within the same system. Compositions of dynamic and constantly interacting elements and subsystems is called *complex systems*. The main preoccupation of complexity theory is to explain the nature, behaviour, and rules of complex systems. Complexity theories apply to many fields such as science and sociology since complex systems can be found everywhere in life. However, in line with the argument of this paper, complexity theories are examined in terms of their particular relevance to urban planning.

The relevance of complexity theories to urban planning is understood from three main aspects in this paper. The first of these is the spatial aspect, urban spaces, which are the subject of urban planning. Urban spaces inherit complex system's characteristics from the human sphere and networks such as infrastructure, transportation, service, and remnants of history, which can be seen in many subsystems they contain.

The second relevance of complexity theories to urban planning is the temporal aspect. Complexity theory assumes that the interactions that take place in a system are continuous, dynamic, and synergistic, and therefore sensitive to temporal changes. The contribution of the complex theory to urban planning in terms of temporal change is that it suggests that nonlinear changes occur as a result of interactions in the system. Nonlinear changes are far from cause-and-effect relationship and therefore cannot be controlled and do not follow a predictable path. According to the complexity theory, non-linear changes, which are an inevitable feature of the world we live in, may have destructive or surprising effects. In terms of planning, nonlinear changes represent that elements may change, or new elements/systems may emerge as a result of interactions between system elements (i.e., within physical space). This means that unexpected outcomes may arise during or after the implementation of the intended actions in a planning process.

The third, complexity theories are also relevant to urban planning from an organizational aspect. The decision-making organization in planning includes a large number and variety of elements and interactions. Achieving this organization's planning purpose, also requires an understanding of many applicable methods, while dealing with many problems, such as technical, economic, and

[1] This chapter is mainly built on Batty, 2009; de Roo & Rauws, 2012; and Balmaceda & Fuentes, 2016.

social. In this case, it is necessary to create a decision-making mechanism by including the discussions of multiple different interests, experts, actors, and stakeholders in the planning. Complexity theories are concerned with the interconnected and multidimensional complex decision-making system that develops with the involvement of these multiple actors in the planning organization.

In essence, complexity theory can be used as a lens for urban planning in examining the connections and interactions between various spaces and human elements. However, this should not be seen as a way of simplifying complex systems, since the complexity theory is concerned with how the nature of a system can be characterized. Instead, this lens can be used to unfold the engagement between complexity theories, planning practice, and the actual surrounding. The planning practice has a direct connection to the reality in the actual surrounding, i.e., the increase or decrease in complexity, by influencing the space and the interactions between the elements. By relating the theory to the actual surrounding, complexity theories also have a connection with planning practice in terms of meaningful applications of their thinking tools. To this end, complexity theory seeks to bring a deeper understanding of how the system is formed and developed by examining the innate interactions between elements that are constantly changing in nonlinear ways. Urban planning could concern complexity theories in order to be able to maintain the complex dynamic essence of spatial and human processes and gain a deeper understanding of the possibilities of unpredictable outcomes.

1.2.2 Planning Practice & Complexity

Complexity theory is an increasing interest in urban planning. De Roo and Rauws explain why planning would benefit from an increased understanding of complexity as follows:

> "Complexity theory enables us not only to formulate an alternative perspective but also provides us with an enhanced understanding of complex spatial systems and possible opportunities to influence the impact of these system dynamics. The concepts....borrowed from complexity theory can help us to improve our understanding of spatial developments and how they unfold." (de Roo & Rauws, 2012, p. 8)

However, it is doubtful whether or in what ways the theoretical findings of complexity reach planning practice. Examining planning documents can be helpful to embody the ways in which the theoretical findings of complexity may be applied to planning practice.

1.2.3 Emergent Manifold

The ongoing processes of change in urban systems are not based on planning practice. These processes of change are based on life itself, in the actual site over time, apart from planning intentions. Namely, urban spaces are adaptive complex systems that can organize themselves. This adaptability of cities is related to self-

organization according to complexity theories. Within the actual site, self-organization takes place between the elements of the system, independent of external interference or guidance. In line with the argument of this thesis, the structures as a result of the process of self-organizational change without depending on the planning interventions in the site are expressed as the *emerging manifold*.

1.3 Critical perspectives on complexity theory

There are certainly many perspectives in planning not taking complexity theory into account. Being a relatively new branch in planning theory, and not much associated with planning practice, it is multidisciplinary and as said, with roots in natural science. While it is hard to find specific literature with "a critical perspective on complexity theory", it is also relevant to consider the literature on design-related planning literature (Dahl, 2020).

All urban planning practice is preliminary. Not only the scale but also the low detailing, the openness regarding the atmosphere, experienced surroundings, etc, makes it impossible to build a city relying only on planning documents. There are a lot of design decisions and outcomes between planning documents and the resulting built environment. Design is not based only on analyses and cannot rely on scientific evidence only. (Not least since all science is preliminary by nature – no scientist expects her findings to be lasting for long.) Instead, speculation, vision, and architectural culture play larger parts. Design can nevertheless be inspired by science, e. g. cybernetics and technical evolution (Lystra, 2014), also complexity theory.

Design literature and perspectives are far too wide a field to be comprehensively included in this literature review, but should nevertheless be mentioned since design perspectives would be present in this thesis, if only as a more or less "black box".

1.4 Case Study Area

The study object of the case study is the urban planning project for the development of Brunnshög district, located in the northeaster part of the city of Lund, province of Skåne in Sweden (see figure 2). The case study was conducted to empirically investigate real-life applications of urban planning and complexity considerations in the local context.

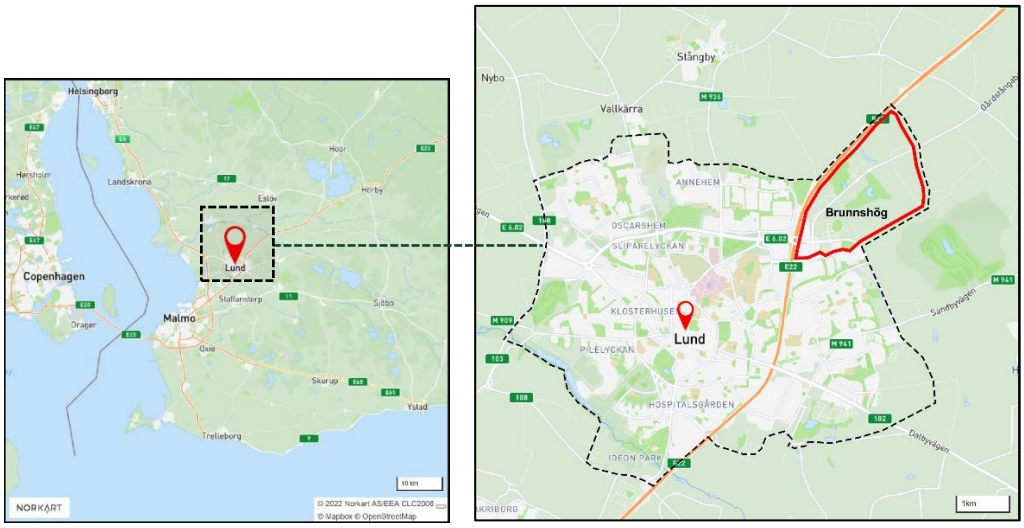

Figure 2. Map image of the city of Lund in the very South of Sweden (left) and the Brunnshög district in Lund (right). Maps are modified by the author and generated from ©Norkart AS/EEA CLC2006 © Mapbox © OpenStreetMap (2022).

The Brunnshög urban planning project is currently the largest in the municipality of Lund and one of the largest in the province of Skåne. Therefore, the project will have an impact at local and regional (and potentially more) levels. The Brunnshög project is originally a set of plans covering the development of five main project areas.

In addition to their local and national impacts, two of the project areas to be developed, ESS and Max IV, which are aimed to be the world's leading research facilities, attract the attention of many stakeholders and investors in planning as large international projects. While ESS (European Spallation Source) is funded by 17 countries with the aim of being a powerful neutron source and a centre for studies on the innermost structure and function of matter, MAX IV is the world's next-generation bright synchrotron radiation laboratory (Stadsutvecklingochtrafik, 2022). This sets Brunnshög apart from other examples of major development in Sweden. Other project areas to be developed will be a mix of residential and office spaces, and when all areas are completed, Brunnshög aims to host 40,000 people daily, working and living here (LundsKommun, 2021).

This project is noteworthy because it involves many stakeholders, investors, and private and public actors, along with the fact that one of the goals of the authorities and politicians in the municipality of Lund is to increase citizen participation in the planning process in a variety of ways.

Another point that makes the Brunnshög projects interesting is that the planned areas have a development period of more than 40 years. In Brunnshög, a district in the northeast of Lund city that connects just outside the city to the rural, the projects are in the early stages, all the detailed plans have not been concluded yet and the areas will be developed gradually. This situation highlights that there may be

changes in plans and practices over a period of more than 40 years. The areas have the outlines provided in the 2010 master plans (Brunnshögsprojektet, 2020).

The Brunnshög urban planning project provides many motivations for examining complexity in urban planning in a variety of ways. The first thing to note is that the project areas planned to be developed were motivated by many social and ecological innovations, and the adopted policies and strategies were presented in the management documents. However, the continuous interactions of actors and stakeholders involved in the projects during the planning and decision-making stages contribute to the complex system feature of the planning process. In addition, since it will be a long-term project, the fact that these policies and strategies have not yet been implemented in practice makes the plans and innovations prepared for multiple and simultaneous institutions in the field sensitive to many changes and possible outcomes. Many internal and external interventions may affect multiple and simultaneous projects in this large area and follow unpredictable paths.

On the other hand, substantial changes are occurring within the site itself in Brunnshög. Apart from the influence of the planning and implementation processes, these changes due to the nature of the existing site are many emergent manifolds. There are already people living and working in Brunnshög. The adaptations and self-organizations that inevitably occur as a result of these people's natural interactions with plan processes and physical elements in the field are the sources of these emerging manifolds. Therefore, emergent manifolds cause the creation of the unplanned and spontaneous order in Brunnshög due to self-organization.

1.5 Objectives & Research Question

In this paper, it is aimed to discover, investigate and sometimes speculate around the implications that complexity theory can provide insight into the possibilities for emergent manifolds in the site, following the relationships and tendencies between planning and complexity. While aiming to highlight the growing discourse on complexity theories in the planning literature, this study also seeks to shed light on the possible reasons for the lack of complexity understanding in planning practice.

The focus of the thesis is to explore how urban planning in the Brunnshög development project may be relevant to understand how complex systems can create opportunities for emergent manifolds.

To achieve this goal, the research content is structured around the following research question.

How can the Brunnshög planning project support the potential for emergent manifolds in order to involve complexity in planning?

2. Method & Materials

2.1 Method and Materials

In this thesis, the research question is approached around three main concepts, namely complexity theory, complexity management in planning practice, and emergent manifolds. The methodology used to answer the research question was carried out through a literature review and case study.

In the literature review, the selected concepts were examined under the general topic areas of complexity and urban planning. The compilation, which was obtained as a result of the findings including the specific and overlapping contexts of complexity and urban planning, presents the theoretical knowledge that will be covered by the thesis. The materials used in this literature review consist of academic articles containing the concept of "complexity" and academic articles and books containing the concepts of "urban planning". While examining these materials, the following questions were asked:

-"Relevance of complexity theories in planning literature",
-"How is complexity management addressed in planning practice?",
-"Benefits of complex systems approach in urban planning",
-"Impacts of emergent manifolds in complex systems on planning".

The case study was carried out through the document study of Brunnshög urban planning, and a field study in the Brunnshög area. Documentation for the Brunnshög project was studied through the materials of the governing documents, the website review of the municipality of Lund, and the overview plans. The following question were asked to these materials in light of the findings obtained from the literature review:

-" In what way do the planning documents for Brunnshög and Lund link or associate with the emergent manifoldness? ",

In the Brunnshög project, the field study is carried out on site samples selected from three different scales in the project area. It is aimed to examine the possibilities and potentials that the selected areas from small, local and large scales make room for the emergent manifolds. The potential of the emergent manifolds is discussed in view of literature findings in terms of single-use/mixed-use, flexibility, and capacity to adapt to diversity. As the Brunnshög project is a new and ongoing

project, many things have not yet been implemented in situ, which necessitated speculation and inference between the structures presented in the documents and currently available on the site. Speculations will be made in light of the results obtained in the literature review and Brunnshög project document study in order to be able to measure the potential of the emergent manifolds in the selected samples. The following questions were asked over the "what if" speculation in selected sample areas:

-"Could the emergent manifolds be increased or decreased?",

-" Are there any potentials that the emergent manifolds might bring to Brunnshög's planning?”

2.2 Synthesis

Using the literature study and the case study as inputs, possible links were sought between general approaches of complexity and urban planning, the planning process of the case, and components of the emergent manifolds in Brunnshög.

3. Literature Review

3.1 Complexity theories in planning literature

Complexity theories have been developed and conceptualized by scholars from many different fields. It was accepted in the natural sciences and then in the social sciences, bringing new scientific explanations in interdisciplinary fields. With the reflection of these developments in the way urban problems are dealt with, urbanism has been moving towards complexity theories. In light of the literature review, it can be seen that the special attention of complexity theories to time-space concepts is closely related to the nature of urban spaces, which are both the subject and product of urban planning. This relevance has been seen as the source of the relationship between today's planning discourse and complexity theories. The physical structures of different scales that make up the whole of a city express the space, and the constant evolution and change of this city express the time. The fact that urban planning is a method applied to both physical interventions in space and changes over time makes it related to the field of complexity theories.

The implications of urban planning literature's orientation to complexity theories, however, go back to the 1960s, when urbanists defined cities as complex systems (Crawford, 2016). In fact, from the 1960s to the present, theorists have proposed a wide range of theories and approaches, either explicitly or implicitly, to characterize cities as complex systems (e.g., Alexander, 1966 ; Batty & Marshall, 2012; Hillier, 2012; Portugali, et al., 2012). Complexity theories on the other hand show interdisciplinary development and combine them with an umbrella concept. In recent decades, complexity theories have been widely used to more comprehensively examine the growth and internal dynamics of urban elements (Balmaceda & Fuentes 2016). This has also encouraged the introduction of an understanding of complexity into the detailed elements of cities (Wachowicz & Owens, 2009).

Since the concept of complexity has been perceived as randomness for a long time, it has been relatively difficult to find a place in studies based on science and analytical models (Silva, 2016). Actually, complexity in urban space was not an uncommon concept. The hard-to-solve problems that Rittel and Webber put forward as wicked problems have already brought the increasing complexity of

cities into the planning discourse (Rittel & Webber, 1973). These wicked problems are complex because the urban problems that planners deal with produce a range of potential solutions and other interrelated problems with many variables working together (Rittel & Webber 1973). Therefore, the need to explore urban systems composed of many interrelated components such as population, transportation, ecological environment, land use, and real estate, and the difficult elements of these systems, has become a prominent effort in the planning literature. Complexity theories have also appealed to many urbanists in terms of their potential to respond to this need in urban planning. De Roo, one of the pioneering researchers of complexity theories in urban planning today, refers to complexity as unbalanced processes in the gray zone between order and chaos; defined as time-oriented, non-linear dynamic realities (De Roo, 2016). This understanding of complexity has highlighted pieces of information previously overlooked by analytical and deterministic models for urban systems.

The first examples based on complexity theories and methods are Prigogine's thermodynamically open systems or “dissipative cities” developed based on disintegrating structures and variability (Prigogine & Nicolis, 1985). Urban theorists and planners such as Batty (2005) and Portugali (2000; 2011), who conducted more comprehensive urban research based on complexity theory, were also influenced by thermodynamics and chaos theory in the natural sciences, and developed traditional quantitative urban models and adopted a new approach based on complexity as in other areas of social sciences. In this approach, cities are considered as self-organizing complex systems. Self-organization has become important in urban studies by representing complexity as the organic order created by the space itself as opposed to randomness (Silva, 2016). The studies of Balmaceda and Fuentes (2016) highlighted the non-linear changes in the development and urban dynamics of cities as a result of complex human interactions. The non-linearity of urban dynamics draws attention to multiple possibilities that lead to sudden changes and unpredictable consequences, making spatial development uncertain.

Complexity theories, which have increased their influence since the 21st century, have encouraged a change in the approach to cities. Despite the traditional approaches that argue that the system is in equilibrium with its organization, understanding cities as dynamic, non-linear, constantly changing, and self-adapting complex systems has been introduced to the planning discourse through complexity theories.

3.2 Complexity theory approach in urban planning

The urban system has a very complex structure (Batty, 2009). Cities have been recognized as complex systems as they are shaped by dynamic and nonlinear factors

such as physical, environmental, social, and economic. In order to understand the complex structure of the city system, it is necessary to reveal the characteristics of this structure.

The dictionary defines "complex" as "consisting of interconnected or interwoven parts" (Klein, et al., 2003). Cameron and Larsen-Freeman (2008) stated that if the parts are interrelated and therefore related to one another, it can be called a system. It is possible to see this when we consider urban spaces both as a whole and in certain categories. Infrastructures, buildings, neighbourhoods, streets, traffic roads, and similar countless parts are connected with each other and form the urban fabric. However, as Portugali (2006) argues, they interact with their environment— which includes every human and non-human element —and exchange matter, energy, and information. The mutual interaction of behaviors, forms, and contexts between people and space results from these interactions of complex systems. For example, a pedestrian crossing directs people to cross the road, but in the same way, that pedestrian crossing is planned and implemented to that area by people, while the drivers on the traffic road stop and give way while pedestrians pass from the other side. From this, we understand that complex systems do not originate only in physical parts. This means the formation of processes whose energy and information exchanges may not be obvious in the physical state of the city. Again, starting from the previous example, what would happen if the pedestrian did not choose to cross the pedestrian crossing, or what would happen if there was a bus stop instead of a pedestrian crossing? These questions can be answered with a multitude of possibilities that may arise. As can be seen, it is difficult to establish a clear relationship between the parts of complex systems. At this point, the contribution of complexity theories is to try to clarify the dynamic and variable nature of these relationships. In the discipline of urban space, complexity theory has been proposed as a tool that can provide an effective solution for understanding and planning urban spaces by responding to the dynamic nature of the city (de Roo & Rauws 2012). The complex system approach has been seen as an approach that can provide an opportunity for actors such as planners, local and central governments to make more effective policy decisions, assuming that it can be a feasible solution to complex, unpredictable problems related to planning within the scope of urban planning.

With a broad understanding, complex systems are multi-element systems in which a large number of elements interact with each other and there are non-linear relations between the elements, interacting with the environment (Wolfram, 1988). This understanding offers the potential to use complex, non-linear, self-organizing, and evolving mechanisms for spatial planning (Rauws, 2017)for the benefit of planning. Dynamics such as natural and social mechanisms in the urban structure, which are perceived as complex systems, are self-organizing and evolving dynamics. It has been suggested that the complex system understanding integrated

into planning can contribute to how these dynamics can adapt to new conditions, that is, to new interventions in the space. Self-organization in the system essentially comes from adaptation. The elements in the system take new forms by organizing themselves in the face of the crisis, while those who cannot do this disappear (Manson, 2001). Thus, an adaptation process that will increase the efficiency of the system is completed. Self-organization provides the skills and flexibility needed to survive in the face of changes in a complex and dynamic society.

Complex systems are systems that evolve. It adapts itself to the environment it is in and shows organizational behaviour while adapting. In complexity theory research, the organized and pattern-forming behaviors of systems with many components that interact with each other are called self-organization (Portugali, 2009). Self-organization is a set of entities, animate or inanimate elements, institutions, companies, etc., interacting with each other in complex systems. It results in the emergence of new formations as a result of the collective behaviour of objects in patterns, without a central controller (Crawford, 2016). There is no certainty about the direction of the formations that emerge with self-organization, due to the nature of complex systems that are constantly changing and developing (Portugali, 2006; de Roo & Rauws 2012). For this reason, it has been stated that these formations in complex systems are not linear. If a system is nonlinear, a small change in the system can cause huge changes and new situations (as in the 'butterfly effect') (Crawford, 2016). Nonlinear dynamics cause the formation of unexpected new situations in systems, which indicates uncertainties in spatial planning. These self-organization, non-linearity and evolution mechanisms of complex systems are developed concepts within the complexity theories and provide the thinking tools for urban planning (de Roo & Rauws 2012; Crawford 2016).

The complex systems approach began to take place in theoretical studies in urban and spatial planning in the 1970s. In the twenty-first century, it has become popular to approach problems that pose serious risks to the ecosystem, such as the conservation-use balance and climate change. With the complex system approach coming into contact with the planning of coastal areas in 2010's and later, the issues of ensuring, monitoring, and evaluating the governance efficiency of coastal areas and determining the authorities and roles of the actors, responsible for the management of these areas, have become more frequently discussed.

De Roo (2016) argued that complex systems thinking will introduce different kinds of spatial concepts that are better equipped to understand our complex environment and help us learn how to influence and regulate these environments, but this idea reveals realities not yet known to planners. It concerns processes such as planning, physical and functional changes, policies and actor behaviors in the complex systems of cities. These spatial, temporal and decision-making changes in planning provide an example of complex structure depending on the diversity such as social, economic, ecological and environmental. Attention to the dynamics of

complex systems, especially in the increasing urbanization conditions we are facing today, can guide planners in understanding these movements in planning and managing their possible potentials. With urbanization, environmental, ecological and social concerns are increasing. The speed and intensity of urbanization is effective in changing the land use pattern. It is important to investigate the factors that cause land use change in order to understand the change process, to estimate the speed, intensity and path of land change in the urban area. In particular, it is necessary to understand these factors in predicting and modelling the future trends of urban land use change and ecological impacts.

3.3 How is complexity management addressed in planning practice?

While complexity theory and understanding of complex systems continue to take their place in planning literature, it is rather contradictory to say the same for planning practices.

We can see urban planning practices as a strategic method that can be a solution to environmental problems and challenges. Planning is the activities made to respond to an existing issue or possible situations that may arise in the future with the most reliable solution (de Roo, 2016). In this case, planners should be able to predict the outcome and future of planning applications with logical management in the current situation (Balmaceda & Fuentes 2016). So, we can say that the more precise and accurate the predictions are, the more successful the planned solution is for the future. One can probably observe this inference by examining the widespread reliance on the planning of scientific method approaches such as rationalism and comprehensive planning, which date back to the beginning of the 20th century. From this perspective, traditional planning approaches see uncertainties as an obstacle to planning interventions and focus on reducing/preventing uncertainties as much as possible to ensure success. Because complexity actually brings uncertainty. A key principle underlying complexity theory is based on uncertainty, evolution, adaptation, and change. However, the era we live in is full of uncertainties of environmental, ecological, or social origin, such as climate change, epidemics, and environmental pollution. When one element of the system changes, the other elements it depends on tend to adapt in order to continue to exist. In this context, there is a need for applications where planning theories can explore dynamic relationships and urban systems can explore options that can survive even in unpredictable conditions.

The literature review indicates that planning approaches such as communicative planning and incremental planning give more potential to complexity/uncertainty than conventional planning. However, it is difficult to identify the complexity

approach in detail. This perhaps depends on the perspective from which planning practice looks at complexity. The idea of complexity offers another context for the world in change. Taking this approach and exploring what complexity can bring to planning in terms of practical feasibility may be overshadowed by technological methods and the visions presented in the blueprints.

Complexity theorists have also tried to introduce methods that can be applied practically in planning. Gert de Roo and Ward Rauws are among the pioneers in establishing theoretical explanations in order to build feasible bridges between complexity and planning practices. They have developed a spectrum that shows the degree of complexity for problems whose complexity is the target of planning. Ultimately, however, this theoretical explanation does not offer a practical methodology, since problems in urban reality are often in flux. Rather, their theoretical explanation emphasizes that the task of planners is an effort to continue to deal with the complex challenges they will encounter while continuing to seek predictability.

3.4 Emergent manifolds in planning

Another feature of complex systems is that they consist of emergences (Waldrop, 1993; Holland, 1998). Emergences are changes that occur in the structures and functions of the parts of a complex system through collective and independent actions.

Prigogine and Nicolis (1977) and Haken (1983), applying the complexity theory to cities, laid the foundations for the emergence of self-organizing behaviour in urban systems. Later, Allen (2012) developed the concept of evolution by further examining the work of Prigogine and Nicolis (1977) to understand dynamically complex systems. According to complexity theory, a city is constantly changing and evolving. Thus, Allen's concept of evolution has had a significant impact on our understanding of change in complex urban systems. The emergence arises from the self-organization of the elements and concerns the way in which qualitatively new and different structures emerge (Batty, 2009), which is the formation of permanent models quite different from the main element in this system. Emerging new structures bring new qualities, purposes, and functions to the space, leading to the evolution of the system (Allen, et al., 2008). It is not possible to predict the character of emerging new structures (Manson, 2001). In terms of planning, this means not being able to predict changes in space beyond the short term. In complex systems, the whole of the system is not the sum of its components or cannot be understood by dividing it into parts. In addition to the effect of the new character brought about by the emergence, other components of the system also adapt to this effect (Manson, 2001). Therefore, it is the interactions between the components, not the components, that should be considered when planning in complex systems.

Michael Batty stated that emergences are a way of restructuring urban spaces in surprising ways in the face of sudden interventions such as transportation or technological innovation in cities (Batty, 2009). Balmaceda and Fuentes (2016) also emphasized the nonlinear behaviour of emergences, and defined it as the multiplicity of different states that the system can achieve (see figure 3).

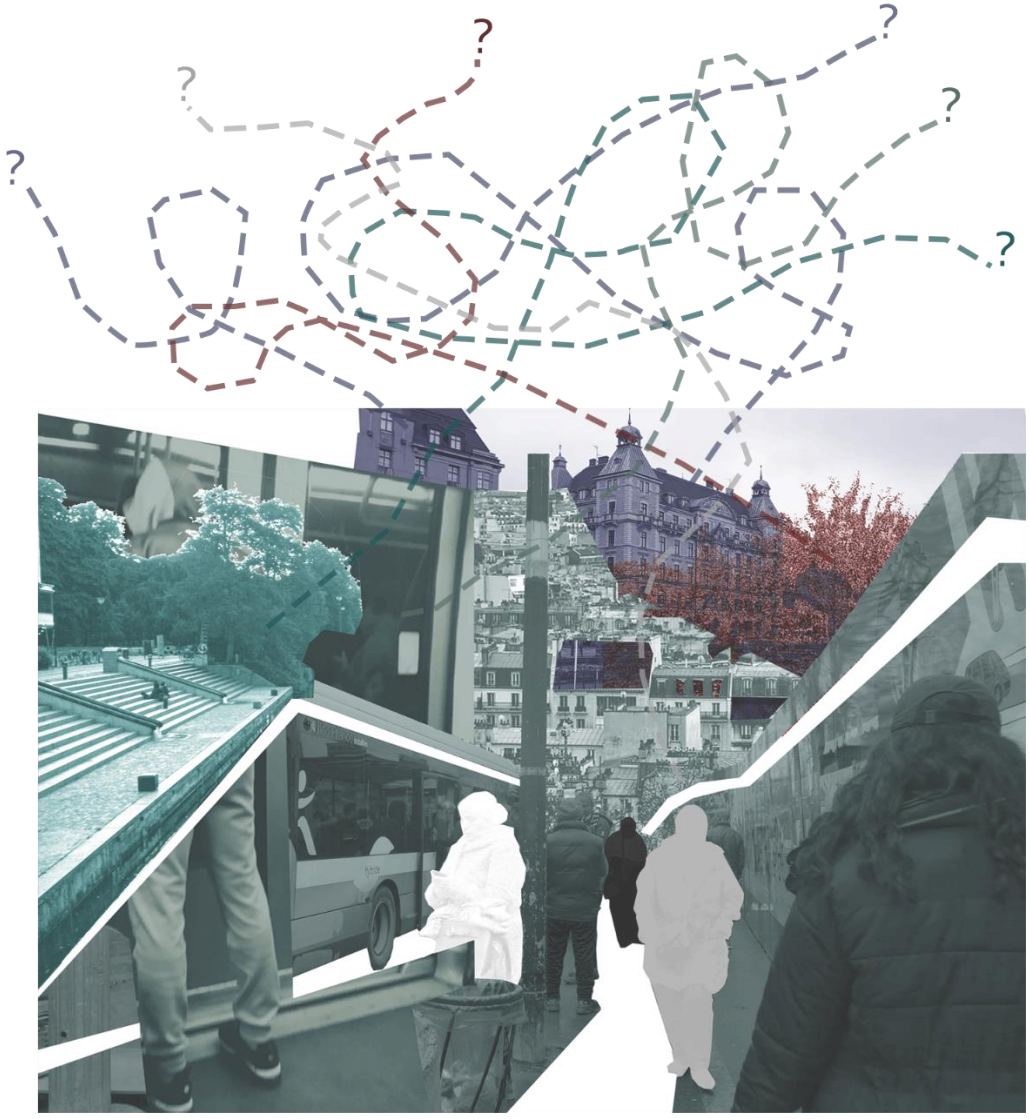

Figure 3. Image illustrating the formation of surprising and unpredictable structures in urban space. Image created by the author.

4. The Case Study

4.1 Document Study Results

The vision and targets for the development of Brunnshög are set out in the comprehensive plan that the municipality of Lund adopted in 2018. But the planning of Brunnshög began much earlier. After the OECD and the European Science Foundation predicted a threatening decline in neutron science in 1998, the decision was made to strengthen neutron sources to secure future research (Kopljar, 2020). After many years of national and international negotiations, the planning in Brunnshög was ignited with Lund winning the place of establishment of the ESS (European Spallation Source) in 2009 and taking the first steps for the MAX VI in parallel (Kopljar, 2020). The comprehensive plan covers the targeted developments until 2040 and beyond. As the document study shows, the main development objectives of the municipality of Lund until 2040 are planned around providing necessary housing to the growing population, creating space for growing job opportunities, building healthy and social living spaces for people, and integrating sustainability in all areas while achieving these objectives (Byggnadsnämnden, 2018a; 2018b). With the urban developments planned in seven main target areas, including the Brunnshög urban development project, Lund Municipality aims to expand by achieving their objectives. Within the scope of the expansion planning, these spatial implementations will have an impact on the existing complexity by causing major changes in systems such as transportation, housing, and trade. The impact of these spatial implementations on the complexity in Brunnshög and how they will be managed can be associated with the planning strategies followed for the practices in the space. According to the knowledge obtained from the literature review, the complexity in the spatial environment increases with the possibilities created for emergent manifolds. The facilitation of emergent manifolds, however, can be achieved through diversity in the interactions of elements in space and by allowing for change and evolution over time. The Municipality of Lund follows the densification strategy to realize the planned urban developments (Byggnadsnämnden, 2018a; 2018b), and it has been found that it is possible to trace the links between this densification strategy and the management and implementation of the emergent manifolds within the framework of planning.

According to the wishes of the municipality, the densification strategies for Brunnshög, primarily in locations close to public transport, are as follows.
-to expand the range of housing in the urban space,
-to strengthen public spaces and urban life,
-to make room for a multi-faceted business life (Byggnadsnämnden, 2018a). The impact to be created in Brunnshög by densifying housing, public space, and multifaceted business life has the potential to bring about diversity in interaction and change in the environment.

Within the scope of densification promoted by the comprehensive plan, there should be diversity in the neighbourhoods in Brunnshög. This diversity is valid to increase both the type of housing that will appeal to people from all types of backgrounds and the uses that will strengthen living opportunities such as proximity to nature, schools, and various activities around the housing (Byggnadsnämnden, 2018b). The densification of mixed housing types and usage diversity in its surroundings has been evaluated by the municipality as an opportunity to offer people to stay in the area even if their living situation changes (Byggnadsnämnden, 2018a).

Densification in public spaces is intended to encourage gatherings by offering mixed-use spaces by concentrating and combining housing types, workplaces, culture, and other social functions in the same space (Byggnadsnämnden, 2018a). Denser and mixed public spaces are seen as having a heightened impact on the manifolds that can arise in urban life, increasing the opportunities for various groups to meet and interact. Densified public spaces in Brunnshög can function as dynamic meeting areas, contributing to facilitating service, trade, and cultural interactions, and directing potentials that can emerge in the identity and attractiveness of the place (Byggnadsnämnden, 2018a). The planning of transportation infrastructure in Brunnshög in a way that reduces vehicle traffic and encourages walking and cycling has been suggested to strengthen meetups and one-on-one interaction with the physical space, as well as sustainability goals. Along with the infrastructure works to limit the use of vehicles to only one-third of the transport in the whole of Brunnshög, the effort is to make these roads attractive environments with the wealth of experience planned to be offered along the pedestrian and bicycle paths (Stadsbyggnadskontoret, 2014).

Focusing on densification also means efficient use of buildings. It was envisaged by the municipality of Lund that the ground floors of fixed buildings and residences should be designed to make room for multi-faceted business life (Byggnadsnämnden, 2018a; 2018b). In the thriving urban environment of Brunnshög, providing opportunities for future business interests to find a place can be seen as making room for unpredictable manifolds. Brunnshög's development is heavily stimulated by the ESS and MAX IV research facilities located here. These research facilities give Brunnshög both national and international appeal, while also

creating many job opportunities in the field of knowledge and research. On the other hand, due to its geographical location, Lund offers easy access to a wide labour market and to a large population base (Byggnadsnämnden, 2018a). Connecting Brunnshög to the center of Lund, the tram provides both the backbone for developments in this area and Brunnhög's access to this workforce and population base. The areas around the Knowledge Route (Kunskapsstråket), which connects Lund C to Brunnshög (see figure 4), were considered important for the formation of future environments (Byggnadsnämnden, 2018a; 2018b). These areas are seen as potential venues for the collaboration and infrastructure investments of the research and knowledge-oriented industry, also Lund University is expected to invest in these points in the future.

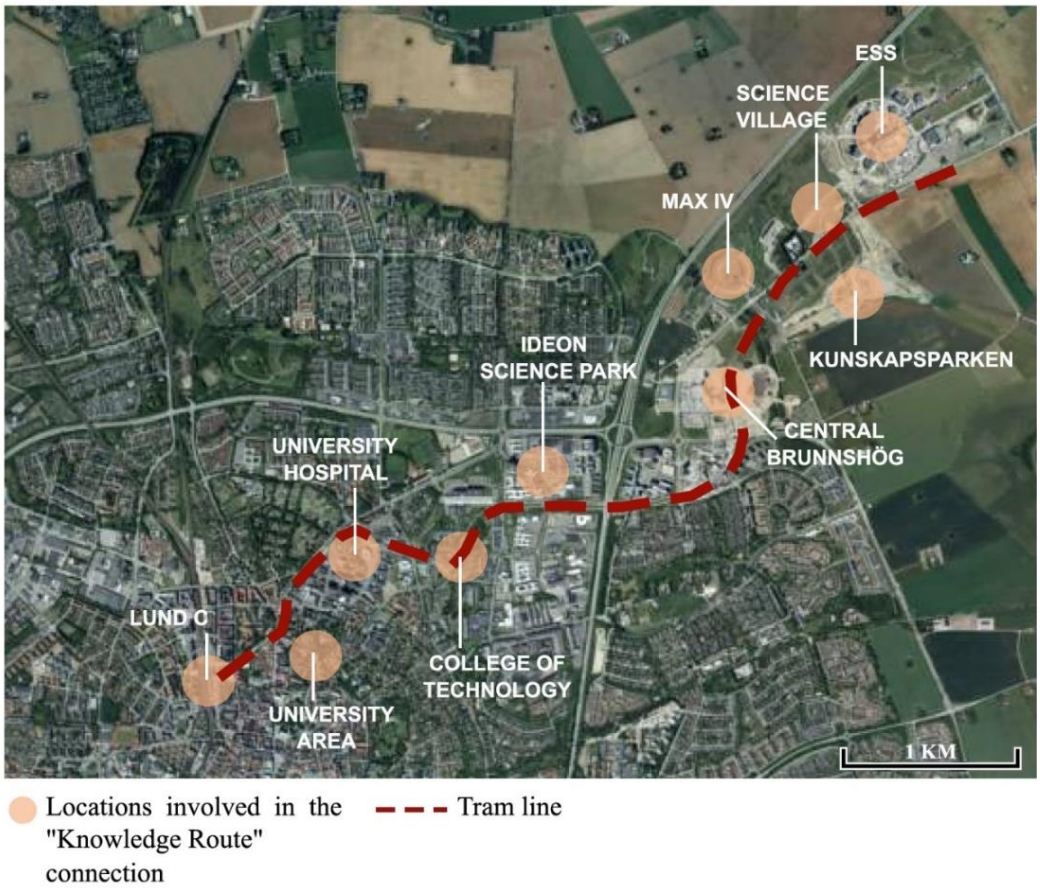

Figure 4. "Knowledge Route" is an urban connection between the central Lund and Brunnshög/ESS. The image is modified by the author and the background map is generated from ©Lantmäteriet (2023).

Although the comprehensive plan prepared in 2018 is a strategic document that guides planning in line with the intentions of the municipality, it faces certain difficulties. One of the difficulties is that this plan, which targets developments until 2040, cannot predict the changes that may occur in the face of factors that can change our lives very quickly, especially digital and global. For this reason, the

applications and investments planned to be made in the physical space should be able to provide room for new trends that may arise in daily life, fluctuations in the market, and new interests. In addition, since the densification strategies cause great changes in the existing environment and landscape, it is necessary to examine what possibilities do the comprehensive plan's framework allows in practice.

Detailed plans show that a completely new district will emerge in Brunnshög in the next 30-40 years. Several time-sharing applications planned for the completion of the district have started to be implemented by giving priority to the three areas near the tram stops. These are the 300-meter zones around the Solbjer stop in Southern Brunnshög, the Brunnshögstorget stop in Central Brunnshög, and the ESS stop in the Science Village area (see figure 5) (Stadsbyggnadskontoret, 2019). Although Southern Brunnshög currently represents a small part of this new area to emerge in Brunnshög, it is leading the way in the implementation of the planned and ongoing expansion work. The detailed plans for this area suggest the implementation of mixed urban development and expansion at points close to public transport and attractive walking and cycling paths in line with the objectives set by the municipality in the comprehensive plan. At the same time, Southern Brunnshög reinforces the character of urban expansion throughout Brunnshög, while providing connectivity to Lund's existing city districts. For Southern Brunnshög in the detailed plan, the large Solbjer block is proposed (Stadsbyggnadskontoret, 2014). The Solbjer block includes mixed buildings, parks, and public squares while realizing spaces where residences, offices, hotels, and commercial services can be accommodated together (Stadsbyggnadskontoret, 2014). The new public spaces, parks, and tram arrangement that will emerge in the area with the Solbjer block implementation have the potential to strengthen the relationship between the existing close areas of Solfångaren, Djingis Khan, and Ilion blocks, and Brunnshög (Stadsbyggnadskontoret, 2014).

A construction diversity of buildings, Solbjer consists of 8 blocks (see figure 6) designed with an irregular mix of 1-3 story small-scale and up to 6-story high buildings (Stadsbyggnadskontoret, 2014). Along the busy streets of Solbjersvägen and Sölvegatan, it has been proposed to include street houses as well as higher buildings with offices and an 11-12 story hotel building (Stadsbyggnadskontoret, 2014). In this way, in addition to the variety of uses, diversity is also included in the views through the height of the buildings. Housing is mixed-use in 8 main blocks in Solbjer, occasionally allocating shops, offices, two kindergartens, and underground parking lots on the ground floor (Stadsbyggnadskontoret, 2014). Two new kindergartens on blocks 7 and 8 within the planning area are proposed to be located on the ground floors of multiple residences and to be designed flexibly so that they can be converted into residential or central activities when the need for kindergarten is no longer present (Stadsbyggnadskontoret, 2014).

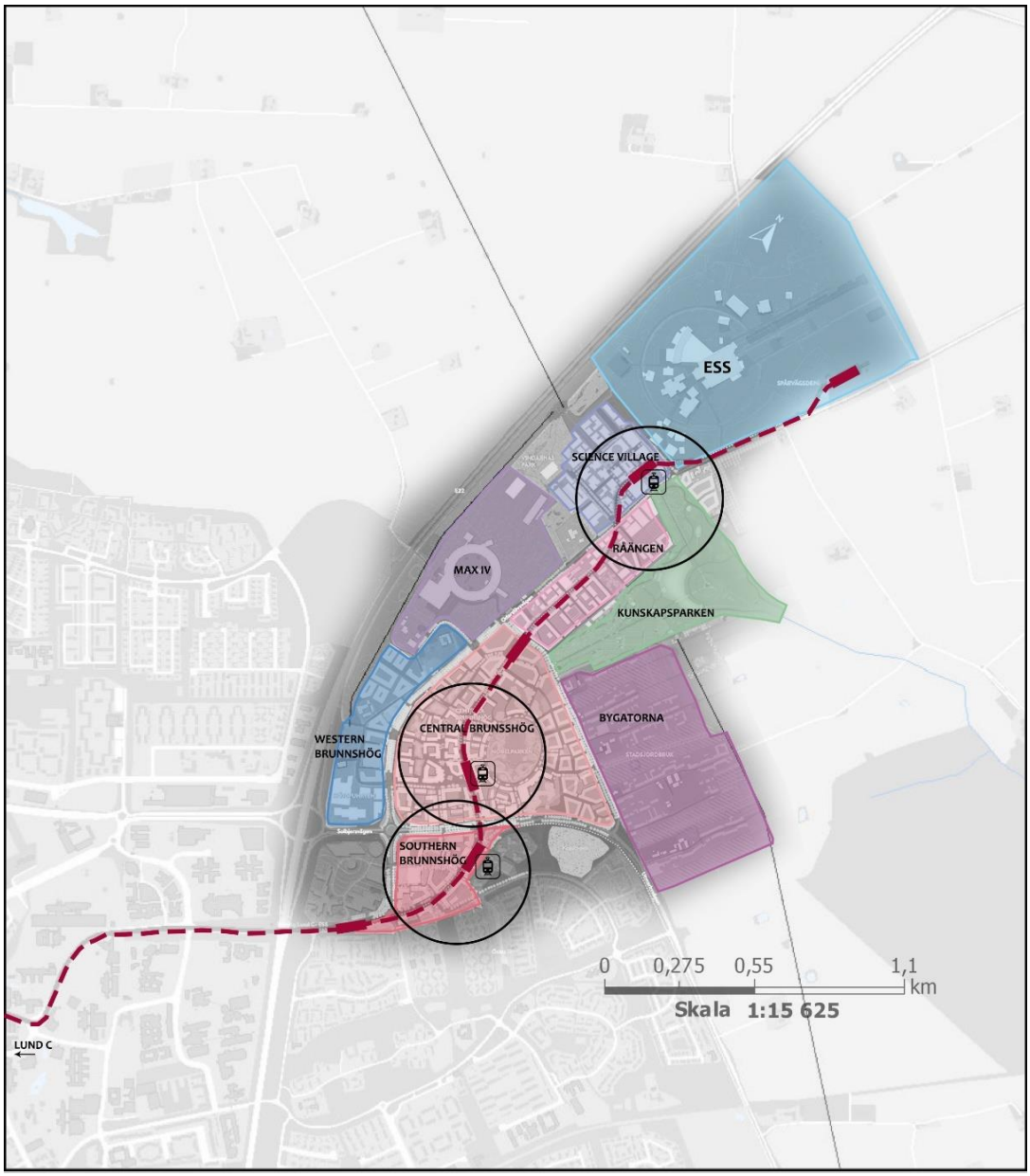

Figure 5. Map showing the planned physical layout for Brunnshög (Lundskommun, 2022). Different colors indicate project sub-areas that are expected to be completed within Brunnshög. The black circles indicate three different densification zones where construction is prioritized to start. Densification zones focus on the 300-meter area around tram stops. The image is modified by the author and the background map is generated from ©Lunds Stadsbyggnadskontor (2022).

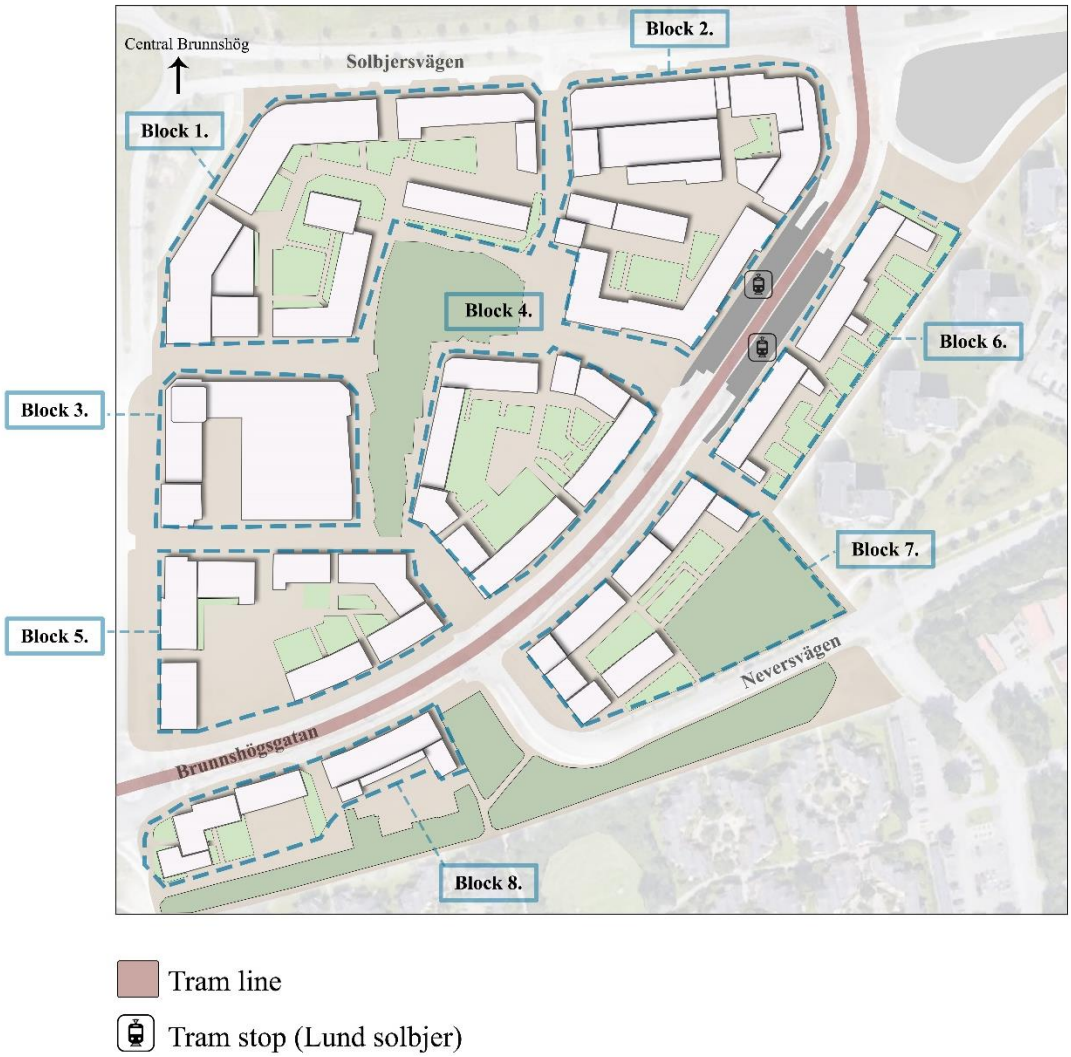

Figure 6. The physical layout of the Solbjer blocks planned for the densification zone in Southern Brunnshög (Stadsbyggnadskontoret, 2014). The area stretching on both sides of the Lund Solbjer tram stop consists of 8 blocks and green areas of different characters (light green indicates semi-public courtyard green areas, and dark green indicates public green spaces). The image is created by the author and the background map is generated from ©Lantmäteriet (2022).

In terms of activities and trade, it was considered important to increase commercial activities around Solbjer tram stop and square in Southern Brunnshög, but it is difficult to predict which type of trade will have high establishment interest in this area that will develop up to 30-40 years. Therefore, central activities such as hotels, restaurants, cafes, sports facilities, and gatherings are given priority, making these activities possible on the ground floors along Spårvägsgatan, Sölvegatan, and Solbjersvägen (Stadsbyggnadskontoret, 2014). The location of the operators on the ground floor is important in terms of increasing the ease of finding and accessibility by the users.

Another target area within the Brunnshög planning project is the Central Brunnshög area, located next to Southern Brunnshög. Two large areas are planned

in Central Brunnshög, a shopping quarter that will consist of two blocks and a park quarter. For the shopping area, located in the north of Solbjersvägen next to the Brunnshögstorget stop of the Lund C-ESS tram, two large blocks and a square are intended, combining commerce, residences, offices, and services (Stadsbyggnadskontoret, 2017). The newly formed character of Central Brunnshög, which consisted of agricultural land before the project and used as a flower field, will come to life with tram stops and attraction points concentrated around the square (Stadsbyggnadskontoret, 2017). Located at the heart of other main development areas in Brunnshög, this area is intended to form an important connecting point and destination for the future urban environment developing here. The detailed plans for Brunnshög center offer a shopping district, a mixed urban neighborhood condensed with activities and services (Stadsbyggnadskontoret, 2017). The diverse areas and streets throughout the neighborhood have various identities and themes and also complement the urban character of Southern Brunnshög.

The detailed plan represents two blocks for residential buildings, a rather large mixed city block to the north and a large residential compound block to the south (Stadsbyggnadskontoret, 2017). The north block encompassed townhouses, patios, greenhouses, and an arable raised courtyard (Stadsbyggnadskontoret, 2017). The arable courtyard has been designed with features that can create a playground for young children as well as a common recreation area for the residents (Stadsbyggnadskontoret, 2017). Services and activities in the north block are concentrated on the ground floors and space is provided for the grocery store, restaurants, and gym (Stadsbyggnadskontoret, 2017). The upper floor of the block is reserved for general services such as a health center, child care, library, and pharmacy (Stadsbyggnadskontoret, 2017).

In the south block, housing types ranging from 3-6 floors are planned with different heights and dimensions to provide a dense and diverse residential area (Stadsbyggnadskontoret, 2017). It is suggested that the ground floors of these residences should be made high in order to accommodate a change in use between the workplace and the residence in the future (Stadsbyggnadskontoret, 2017).

Brunnshögstorget, which will be an important connection and meeting center with its proximity to various services, different residences and the tram stop, is planned to be located in the northernmost part of the project area. However, within the scope of the Central Brunnshög project, which has a 10-year implementation period, the design of this square has not yet been finalized (Stadsbyggnadskontoret, 2017). Commercial and public services concentrated in this center are expected to increase the possibilities and population, so that some structures included in the area will become certain depending on the pace of development.

In Central Brunnshög, the planning of the park quarter has also developed in parallel with the future shopping quarter (see figure 7). This area is closely linked to the commercial blocks of the shopping district in the west, the grocery store, health center, pharmacy, and the Solbjer blocks to the south and is planned as a hub for the entire Brunnshög urban district. Therefore, high human mobility is expected in this specific area.

Figure 7. The physical layout of the two parallel projects carried out in the densification zone in Central Brunnshög. On the left is the shopping quarter consisting of two blocks on the north and south (Stadsbyggnadskontoret, 2017). On the right is the park quarter consisting of Nobel Park and surrounding buildings (Stadsbyggnadskontoret, 2019). The projects are located on both sides of the tram line passing through the middle. The image is created by the author and the background map is generated from ©Lantmäteriet(2022).

In the detailed plan, it has been seen that high-rise housing, human circulation, and recreation concentration have increased significantly for this project area (Stadsbyggnadskontoret, 2019). The oval-shaped Nobel Park in the middle of the project area has the potential to play an important role in the formation of the

character of the region with its natural green texture, walking and cycling paths around it, and the activity areas it provides (Stadsbyggnadskontoret, 2019). The planting areas, sitting and gathering points, sports facilities, different playgrounds, and the expanded school garden designed in the park bring many opportunities and uses for children and adults on a local scale. Among the seven city blocks planned around the park, the central block Pärlan, located next to the tram stop, stands out with its flexible use planning. The Pärlan block has been designed with the flexibility to allow various center activities, shops, offices, and residences to be built together (Stadsbyggnadskontoret, 2019).

Another long-term vision for Brunnshög is the Kunskapsparken. The planning area for the Kunskapsparken is aimed at creating a landscape that will feed the future Brunnshög district with ample recreation and green space. In the urban space of Brunnshög, which will develop over a period of 20 years, the Kunskapsparken is expected to create a large-scale event space not only locally but for the future on a regional scale, with the interesting uses and influences created by the surrounding ESS and MAX IV facilities and the Science Village (Stadsbyggnadskontoret, 2016). Covering an area of approximately 21 hectares, the park also forms an important volume in the expansion of Brunnshög (Stadsbyggnadskontoret, 2016).

On the Knowledge Route, which provides an urban connection from the center of Lund to Brunnshög, it is possible to enter the Kunskapsparken from the last two stops of the tram, MAX IV, and ESS (Stadsbyggnadskontoret, 2016). In this respect, the project area has been considered as an important nodal point and emphasis has been placed on strengthening its connections with different uses around its entrances. Between the Science Village, which will be located next to the ESS, and the park, green walkways are planned to strengthen connections and invite user interactions (Stadsbyggnadskontoret, 2016). In addition, a green pathway transition was provided between the Kunskapsparken and Nobel Park in order to strengthen the communication with the Central Brunnshög in the south-west of the park (Stadsbyggnadskontoret, 2016).

One effect of the Kunskapsparken's implementation in Brunnshög comes from its proximity to Kungsmarken, an important local recreational area for the city of Lund. While it has been determined that the stormwater flow paths to be realized within the scope of the plan proposal will affect the Natura 2000 area in Kungsmarken, the potential for the new recreation density to be added to the area with the Brunnshög projects implemented in the east of Kungsmarken will strengthen new connection roads between the two areas (Stadsbyggnadskontoret, 2016). The Kunskapsparken plan area has also been suggested as important in terms of its potential to become part of Lund's expansion area, with new ties being created in the future on the nation road E22 to its west (Stadsbyggnadskontoret, 2016).

The planning area of the Kunskapsparken differs from other densification focal points in Brunnshög by its land ownership conditions. Of the approximately 21

hectares of the planning area, about 14 hectares in the western part belong to the Lund Cathedral and the eastern part of about 7 hectares belongs to Ingemar Lindén, while a small part is owned by the municipality with a farm plot next to Odarslövsvägen (Stadsbyggnadskontoret, 2016). This situation has led to the implementation of the visions determined by the municipality, especially in the regions belonging to the Cathedral, to be more flexible. The land belonging to the Cathedral, between Odarslövsvägen and Kunskapsparken, and the land south of Kunskapsparken has been left for future use (see figure 8) (Stadsbyggnadskontoret, 2016).

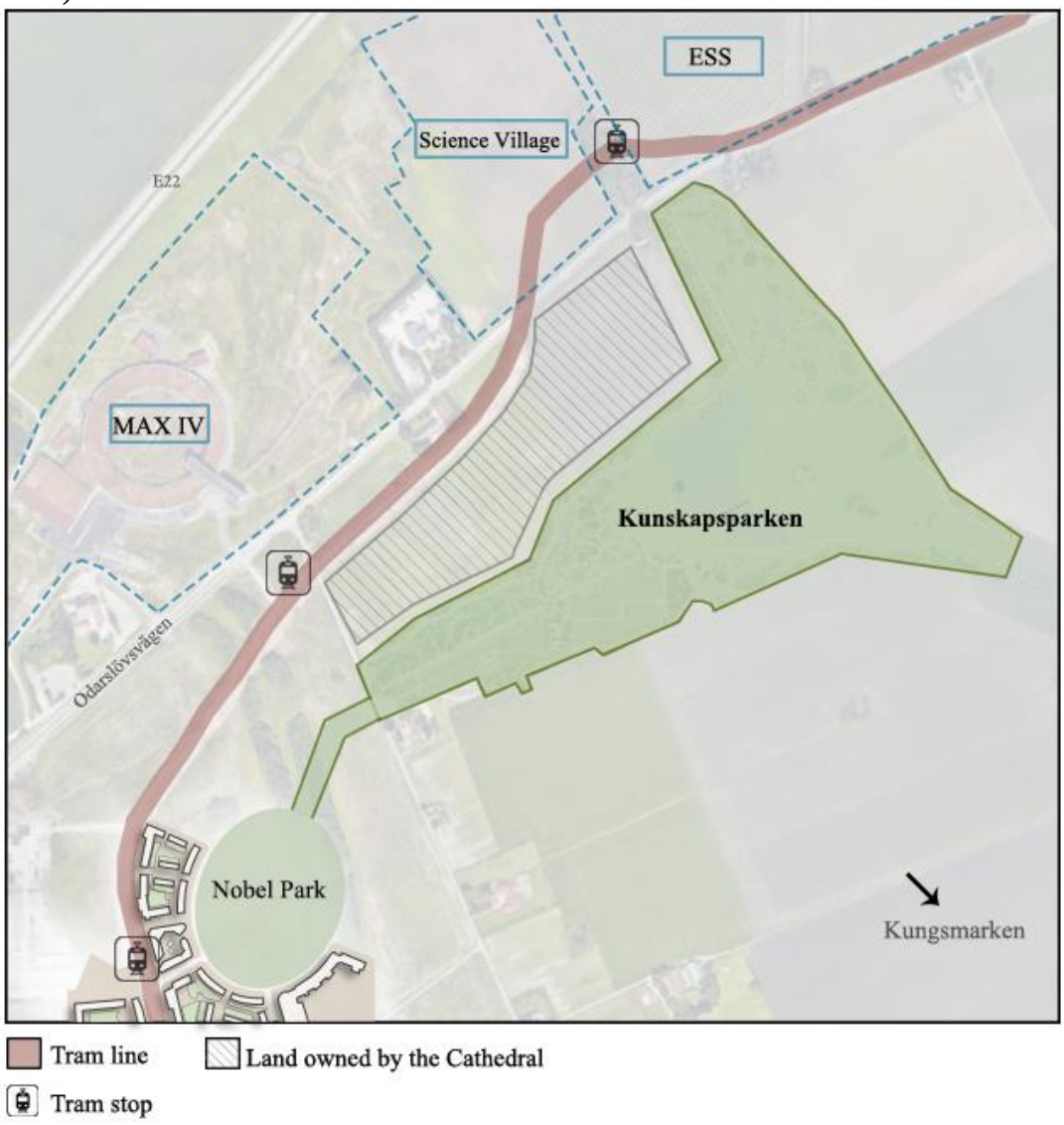

Figure 8. Map showing Kunskapsparken's location and relationship to its surroundings (Stadsbyggnadskontoret, 2016). The main entrances of the park are in close proximity to two separate tram stops. MAX IV, Science Village and ESS adjacent to tram stops are the main structures around Kunskapsparken. Kunskapsparken is also connected to Nobel Park and thus Central Brunnshög by a green pathway. There is a land owned by the Lund Cathedral between the tram line and Kunskapsparken. The image is created by the author and the background map is generated from ©Lantmäteriet(2022).

4.2 Field Study Results[2]

4.2.1 Small-Scale Field Sample

Field studies have shown that many of the actions described by the Brunnshög plans are still not implemented. Currently, there are empty areas whose implementation has not started and under construction lands in the field. In order to conduct detailed fieldwork, a neighbourhood park on Solbjer block in Southern Brunnshög surrounded by a street in a pedestrian zone is one of the selected areas (see figure 9). Around this park, most of the projects within the Solbjer blocks planning have been implemented in the area, and construction is currently underway within blocks 1 and 3. Southern Brunnshög has green areas of different characters (see figure 10,11,12). The selected neighbourhood park can be accessed by everyone as a public space, surrounded by semi-public smaller-scale courtyard green spaces between residential blocks. Functioning as a central neighbourhood park, the park consists of children's playgrounds, seating areas, and green open space (see figure 13,14). There are 2 to 8 floors of residences facing towards the park and the area is only accessible on foot. To the east of the park area are the tram stop, and shops and service locations along the tram street. Various cafes, restaurants, hairdressers, gyms, and grocery stores are currently operating along tram street. To the west, large facilities such as Ericsson and Sony Nordic are adjacent to the ending border of the Solbjer blocks. A high-rise hotel within block 3 has been completed and is now operating.

[2] Field studies include detailed studies of the sample areas at three different scales (small, local, large) selected in the case area Brunnshög, followed by speculation on each area (see chapter 2.1). The speculations are not intended to offer well-thought-out alternative proposals for the planning or design of the particular sample areas. Rather, speculations are used to consider different ways of emergent manifold potentials.

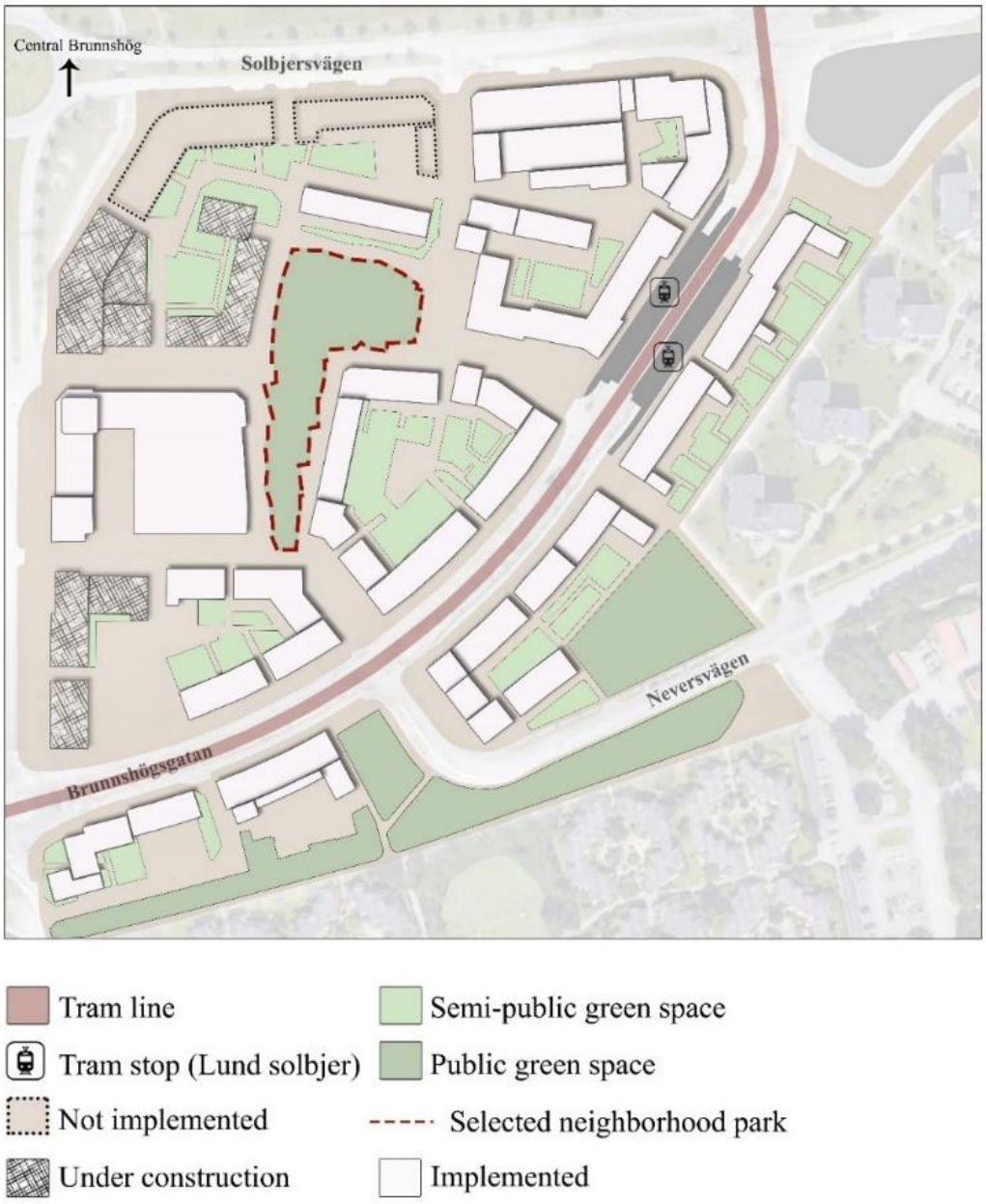

Figure 9. Map showing the completion status of the Solbjer blocks in Southern Brunnshög and small-scale area sample selected for detailed fieldwork. Currently, although most of the planned area has been implemented, there are still blocks whose implementation is in progress and has not started. As the selected sample area, the neighborhood park, is located at a central point surrounded by blocks. The image is created by the author and the background map is generated from ©Lantmäteriet (2022).

Figure 10. Examples of places with different characters in the area (a): A photograph of one of the courtyard green spaces in Solbjer blocks. The area offers many activities with its planting beds, picnic table, and green open space. The proximity to the apartments at the back of the area and the fact that it is easily accessible by the residents increases the possibility of use. (Photo: by author)

Figure 11. Examples of places with different characters in the area (b): Photograph of a courtyard found in Solbjer blocks. The area consists of a covered and outdoor bicycle park and green texture. More than half courtyard is occupied with a bicycle park, is not available for different activities. (Photo: by author)

Figure 12. Examples of places with different characters in the area (c): A photo from Brunnshögsgatan, where the tram passes. Here, the ground floors of the street buildings are planned for different uses such as offices and cafes. There are some cafes and restaurants currently operating (right). Buildings of different floors and textures, with easy access for walking. (Photo: by author)

Figure 13. Image from the neighborhood park chosen as the sample study area. There is a children's playground in the park and 2-story and 6-story residences with different characters at the back. (Photo: by author)

Figure 14. Image from the neighborhood park chosen as the sample study area. There are sitting areas and an open green area of the park at the front, and the buildings of the 1st blocks are under construction at the back. (Photo: by author)

The proximity of this neighbourhood park to all these services, facilities, and activities could make it the center of an important community node. In addition, the texture created by the residential blocks has dispersed building layouts and passages from the main street to the area, unlike the classic enclosed perimeter block model. This texture adds an inviting feature to the park and enhances potential to use it (see figure 15). While user groups such as residents, children, tram passengers, hotel visitors, and close facility employees provide the daily mobility of urban life around the park such as accommodation, work, shopping, and recreation, the park becomes an unintentional stop. Whether they want to use the park or use this area as a passage, users will create micro-interactions with this area. These interactions can trigger changes and create new temporary connections between people and the park. For example, trips to nearby restaurants or tram stop during busy lunchtime or after work hours may cause new organizations within the parking area during the day. In addition, there are no street elements such as benches on the tram street where the shops are located, thus this park also offers a resting point for user groups such as the elderly while going shopping or going to the tram. While the park area provides mixed-use opportunities for resting, playing, and meeting due to the physical elements it contains, an empty green area can support flexibility against possible emergences.

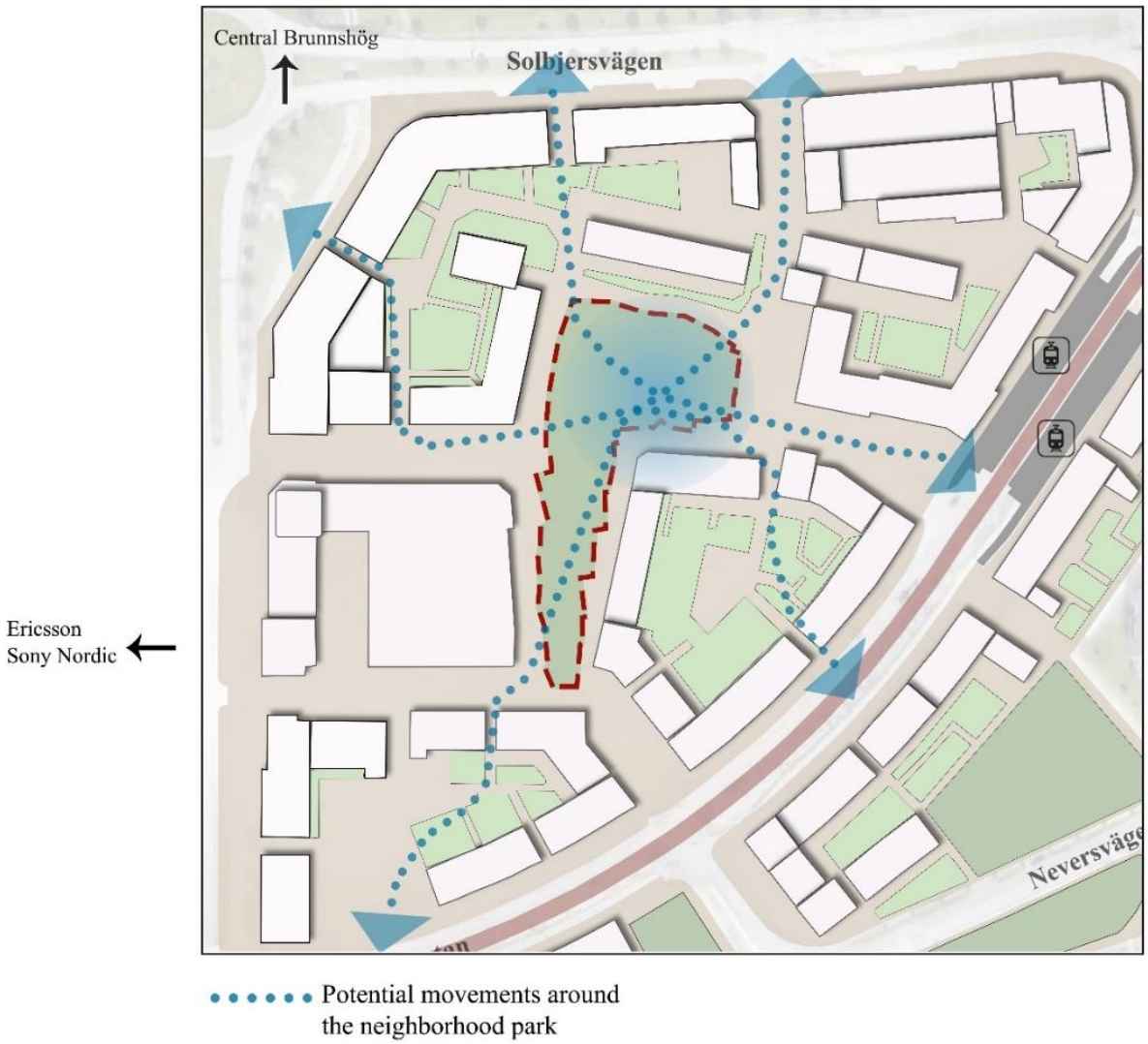

Figure 15. The dispersed building layouts of the blocks around the park and the passages it allows increase the accessibility of the park area. There is a high probability of coming across the park when crossing to reach the activities on the tram street, the facilities to the west, or Central Brunnshög. These situations were seen as opportunities that increase the possibility of meeting different groups and the possible use of the park. The image is created by the author and the background map is generated from ©Lantmäteriet (2022).

Speculations

What if a bicycle park was planned instead of the green park area in this area? Cycling is a means to increase transportation in Brunnshög, and bike parks should be concentrated in areas close to residences with the framing of the municipality (Byggnadsnämnden, 2018a; 2018b). The effects of this situation could have new implications, for example, on people's interaction with the site, the planning of houses surrounding the park, and stormwater strategy. The bike park that could be planned instead of the green area in this park would have added a more clearly defined but limited activity to the area, whereas the flexible use of the green area

of the park would have changed. In this way, passers-by and residents would be directed to other areas in the surrounding areas in order to meet, rest, etc. Also, the bike park, which would replace the green space, could encourage smaller-scale green stripes in the courtyards of the residences, which reduces the collective use of the park to a more individual scale. On the other hand, this green space is strategically located for rainwater harvesting, the change in this area can create conditions that require planning to cope with flood and stormwater management.

4.2.2 Local-Scale Field Sample

Central Brunnshög was used for the local scale fieldwork. The area consists of projects planned to the west and east of the tram street as a shopping quarter and park quarter. Currently, the shopping district has not been implemented in the area (see figure 16), while Nobel Park is open for use in the park area, most residences and planned school do not yet exist. Although the planning vision aimed to create an attractive and mixed-use urban character around the tram stop (Stadsbyggnadskontoret, 2017; 2019), the area is currently supported by Nobel Park as most of the planned projects have not been implemented yet. There are children's playgrounds, walking and cycling paths, wide green areas in Nobel Park, and a direct passage between it and Kunskapsparken. There are very different textures and landscapes between the almost completed Solbjer urban space in the south, the construction site for the shopping district, the MAX IV and ESS facilities opened for use in the north, and Central Brunnshög now. Therefore, it seems that the central area, which will reveal its main character as the center of the whole Brunnshög that will take shape here, will reach the desired goal in the future. However, in its current form, its open spaces and interesting interactions with its surroundings have already begun. The daily urban routines performed in Southern Brunnshög create effects that go as far as Nobel Park. The park currently caters to the nearby residents' exercise, children's play, and walking activities. The straightforward path leading to Kunskapsparken provides a transition from busy urban and construction activities to open spaces, creating a nodal point between different uses (see figure 17). When the buildings that will cover the oval-shaped perimeter of the park, the school, and the shopping area are completed, flexibility for many individual and collective activities can be facilitated by the large area provided by the park.

Figure 16. The shopping quarter, one of two parallel projects to be located in Central Brunnshög, is not yet completed. The construction of the area continues. The picture presents a view of the southern blocks of the shopping quarter under construction. (Photo: by author)

Figure 17. The picture shows the pathway from Kunskapsparken to Nobel Park. Although the implementation of all projects planned for Central Brunnshög to the site has not been completed, Nobel Park is already being used for a variety of activities. These activities have the increasing potential for emergent manifolds. (Photo: by author)

Speculations

What if in Central Brunnshög, Nobel Park and the planned mixed city block in the shopping quarter are replaced (see figure18)? This change would create many possibilities in terms of mobility and relations in the place. First, the fact that the park would be closer to the Solbjer area would have invited more people in South Brunnshög to this park area. This could have reduced connections and mobility flows between Nobel Park and Kunskapsparken in the current situation.

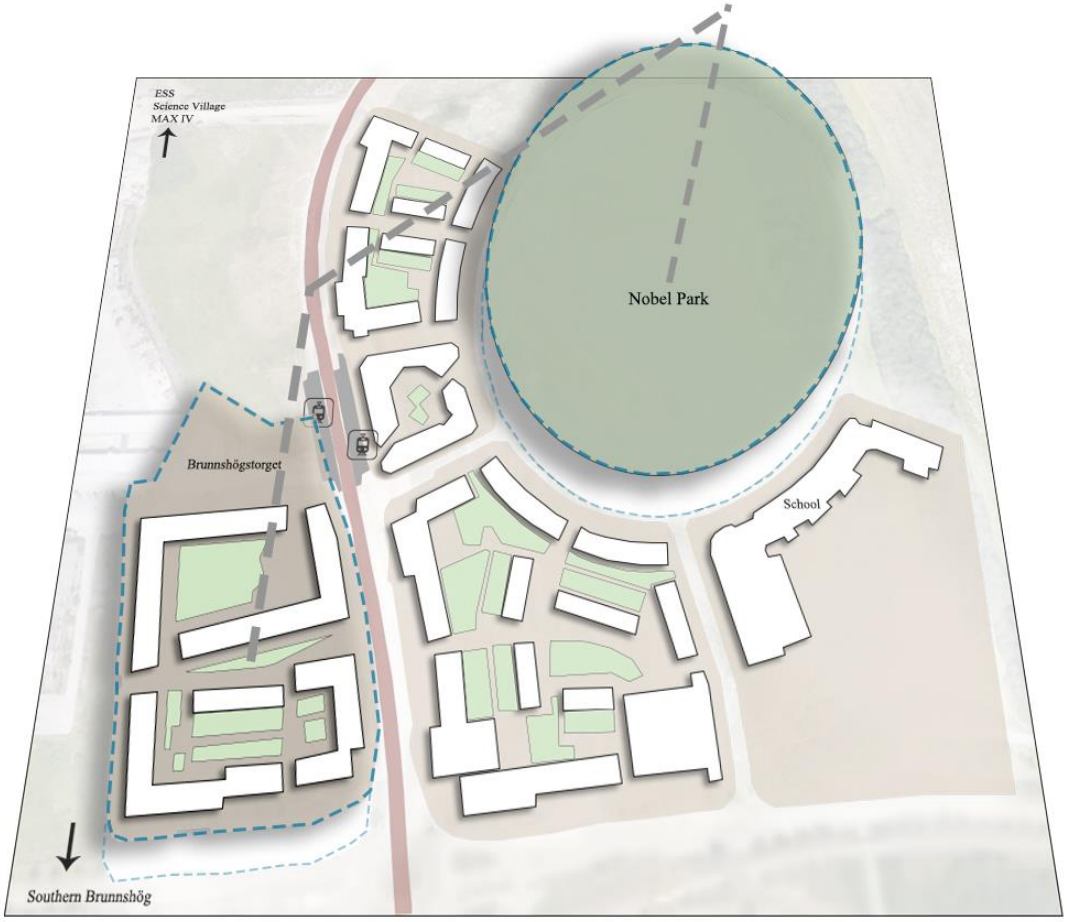

Figure 18. Speculated land use change between the shopping quarter and the park quarter in Central Brunnshög. The image is created by the author and the background map is generated from ©Lantmäteriet (2022).

On the other hand, the city block that would replace Nobel Park, by bringing shopping, health center, library, etc. activities near areas such as MAX IV and Science Village, may lead to the development of visits and interactions between areas in different directions. The new location of the city block and the amenities around it could result in faster development of this area compared to other areas of Brunnshög, with businesses and markets growing faster there. The rapid growth in the center of Brunnshög could have new outcomes that could also affect other areas, such as property prices.

4.2.3 Big-Scale Field Sample

The Lund C/ESS tram was chosen for the large-scale detailed field study. The city of Lund strives to grow in such a way that it can sustain an urban environment that is attractive to residents, innovative, and sustainable. The value of the tram's connection to Brunnshög in this strive cannot be overstated. For the planned developments in Brunnshög, the tramline plays a leading role in shaping the densification points, the layout of the different development areas, the communication between them, and the determination of future development projects. Tramways running from the center of Lund until Brunnshög along the Knowledge Route also have city-scale effects in strengthening connections for business and future investment opportunities, ensuring urban and cultural development.

Speculations

Lund Municipality also has urban development areas outside Brunnshög. The tram line stretching from the city center to Brunnshög not only allows Lund to expand in the northeast direction but also enables future links to be established with other urban development areas in the future. According to the comprehensive plans, one of the future links that can be established is the extension of the tram to Södra Sandby (see figure 19) (Byggnadsnämnden, 2018a). What if this extension plan was realized? The new tram line, which would run from the last tram stop ESS in Brunnshög to Södra Dansby, would create new contexts both between these two areas and at further regional scales (see figure 20). For example, the public transport that the tram would provide up to Södra Sandby would enable small-scale residential and business developments along the route. This way, new living conditions, and movements could be expected in these areas. In order to support these possible living conditions with capacities such as better accessibility and sustainability, it would be possible for different scales, diversity, and more typologies to emerge in building developments.

The new areas to be developed and the tram line will have effects on the existing landscape and climate, so they need to be supported with sustainable solutions. In this regard, another example would be that the need for large-scale road infrastructure and similar investments can be reduced, thanks to the low-energy public transport of the tram line. At the same time, the fact that business and residential buildings, which are likely to form along the tram line, deal on an individual scale for solutions such as sustainable energy and water supply, could lead to the emergence of various innovative building models and routines to complement them.

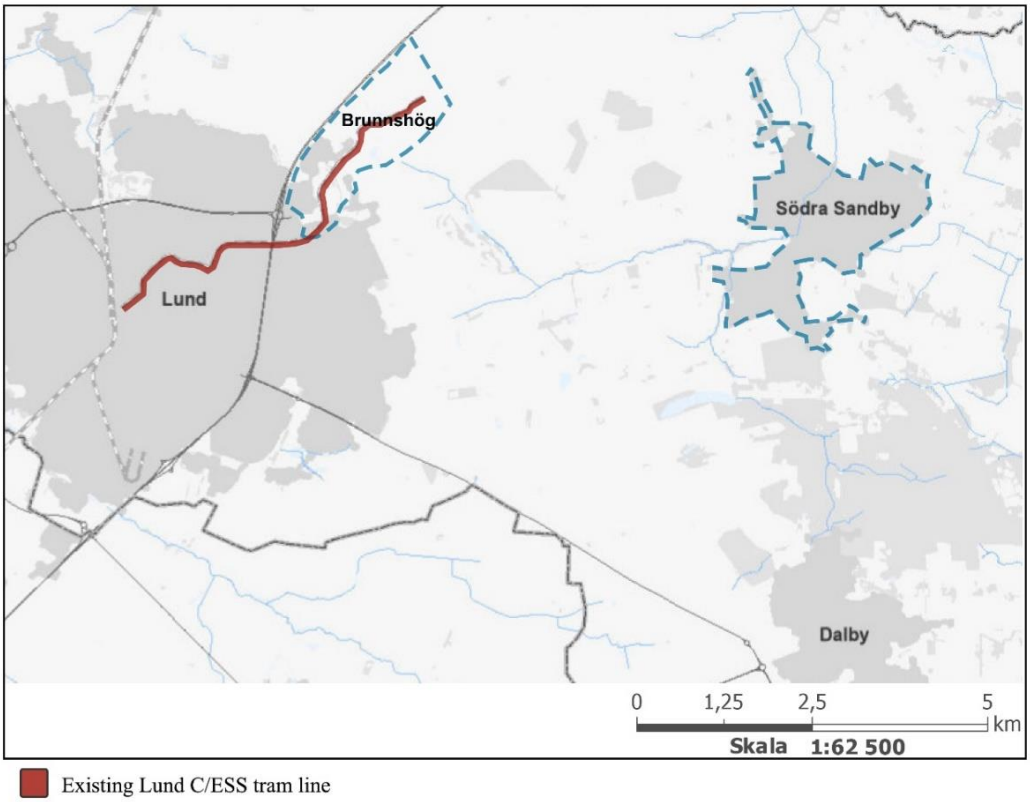

Figure 19. Map indicating the location of Lund city, Brunnshög district, and Södra Sandby to each other. . The image is modified by the author and the background map is generated from ©Lunds Stadsbyggnadskontor (2023).

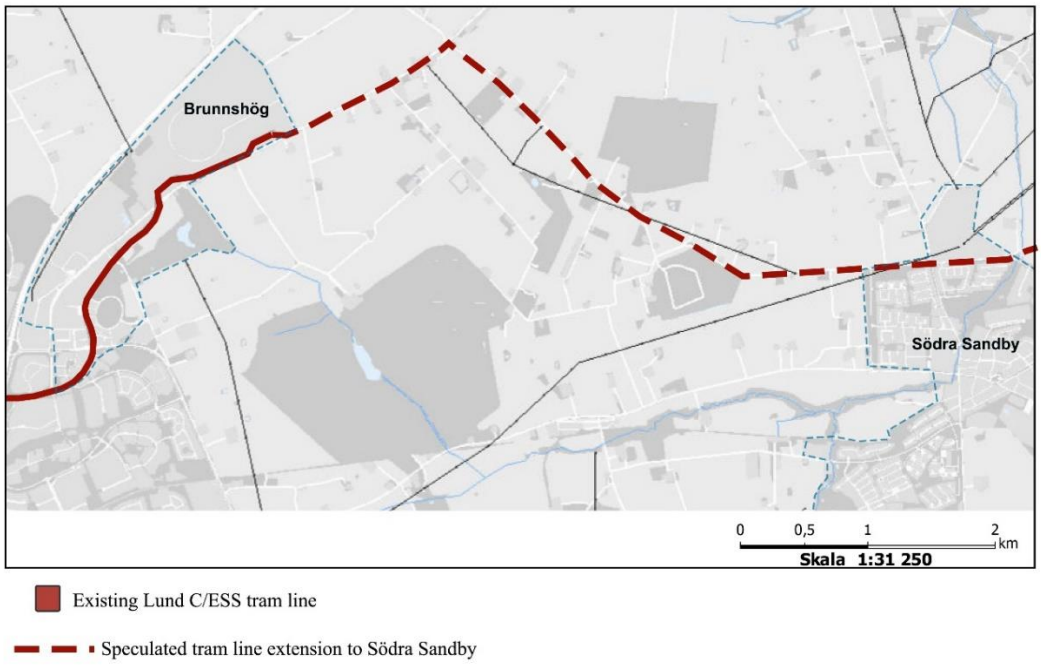

Figure 20. Map indicating the speculated extension of the Lund C/ESS tram line to Södra Sandby and its relationship to the potential area for new emergences to be observed. . The image is modified by the author and the background map is generated from ©Lunds Stadsbyggnadskontor (2023).

5. Discussion

Contemporary cities are complex places where countless units such as their physical structures, infrastructures, natural values, cultural and economic characteristics of the society, technological changes, experiences, and perceptions are housed together. At the same time, making contemporary urban spaces more livable is a constant pursuit of urban planning. While urban planning organizes the physical structures of the city in the name of this effort, it also plays a difficult role by having to deal with the relations, effects, and changes between the various units in the city and securing future scenarios. At the same time, the complexity arising from the organic and synergetic interactions in the city, which the planning sphere cannot control, increases its existence by giving fruit to the emergent manifolds. This thesis draws the point of departure from the dilemma between the strategic control of space that planning aims and envisions, and also the manifolds that emerged by complexity. The purpose of this research is to reveal the insights that can be derived through the theoretical and practical, relationships and engagement between complexity, planning, and emergent manifolds. To address this purpose, the link between complexity and planning is built around three main concepts: complexity theory, issues relating to complexity in planning practice, and emergent manifolds. The Brunnshög urban development project, providing a concrete and detailed investigation of the concepts, draws the framework of the research scope of the thesis as a case study. The research question within the framework of the Brunnshög project, a contemporary and extensive example of urban planning, is "*How can the Brunnshög planning project support the potential for emergent manifolds in order to involve complexity in planning?*" was formulated.

5.1 Discussion of literature study results

Complexity Theory & Planning Literature

One of the most important points highlighted by the introduction of complexity theories in the planning literature is the change in thinking about how complexity is perceived as a concept, as spatial representations and as a part of urban life. Complexity theorists express complexity in space as the number of elements a system contains and the interconnectedness of its parts. This new expression is in

stark contrast to the complexity that was previously perceived as randomness, which did not appeal to reason and analytics, as a problem that disrupts order and organization and needs to be corrected in space planning. The complexity that De Roo (2016) refers to as the gray zone can actually be interpreted more clearly in this way, that is, the complexity is neither an order nor problematic randomness, but rather what is in between the parts in space (i.e. in the system). The number of elements of the system and the interconnectedness of its parts have brought a new and dynamic approach to understanding the relationships between different elements in a space and seeing how they affect each other. This new concept of complexity has created opportunities to examine urban spaces in greater detail from the bottom-up. Thus, has probably contributed to the development of the scope of complexity used to characterize cities and urban structures.

Examining the complexity of urban spaces has become meaningful with the finding of complexity theories in the planning literature. The study of many complexity theories in urban planning, such as Portugali (2000;2011)'s work on self-organization, Balmaceda and Fuentes (2016)'s work on non-linearity, Allen (2012)'s work on evolution- were inspired by the natural and social sciences. Here, I see important contributions to the development of complexity theories by taking their foundations from multiple disciplines. It proves itself interdisciplinary with the concept of self-organization brought by complexity theories to planning infrastructure, especially in biology. Approaching urban spaces as systems displaying self-organizing behavior reveals that complexity in space takes shape in ways that planning cannot control. Looking at traditional planning approaches, it is geared towards achieving a specific purpose or goal and tends to focus on a linear path from start to finish. In contrast, complexity theory recognizes that the real world is constantly changing and non-linear, with many potential paths and actions along the way. Rather than trying to control events and remove uncertainty, it aims to understand the complex relationships between different elements in a system and see how they affect each other. We see that the effects of self-organized, non-linear and constantly changing urban space units on how physical, environmental, social, and economic conditions emerge and change are used in research within the scope of planning.

The literature review has shown that complexity theories have given the planning discourse a growing context, giving new ways of thinking about the meaning of complexity, urban spaces, and the world we live in. One implication from this review is that the discipline of urban planning can benefit from the insights complexity theories provide in understanding the interactions between the internal structure of an entity and its surrounding environment in spatial organizations.

Planning Practice & Complexity

The fact that the world we live in is becoming more and more complex, management of complexity in planning practice comes to the fore.

The complexity of urban systems and processes requires an approach that takes into account many aspects of the urban environment, including physical, social, and economic dimensions. Managing complexity should be perceived as requiring new strategies, methods, and approaches that consider the complexity and dynamic nature of the urban environment, not as correcting it. Understanding the complex ways in which the urban environment evolves and changes over time is crucial if we are to manage our cities more effectively and plan for a sustainable future. This is especially true in the field of urban planning, where the complexity of urban systems is rapidly increasing due to rapid urbanization and population growth. But there are certainly many perspectives in planning that do not take complexity theory into account. I think one of the main reasons for this has to do with the inability to measure complexity and ensure how different systems and organizations respond to complexity. The lack of precise answers to these questions results in a poor understanding of what complexity is in planning practice. In practice, urban planning mostly focuses on how the designed product will affect the environment, society and economy, that is, the final product. The complexity approach, on the other hand, deals with bidirectional dynamics, revealing a wide range of aspects that need to be taken into account.

Urban planning action often involves the design and arrangement of uses, within the framework of analytics based on cause-effect relationships, goal setting, data collection, analysis, forecasting, design, public consultation. Complexity theories and the planning of complex environments set certain limits on this action. This is because the innate behaviors that complexity theories put forward prevent plans from achieving their purpose. For example, self-organization and non-linearity behaviors create unpredictability and directly affect processes such as forecasting and implementing in planning.

Emergent Manifolds

Following the literature review, it was found that emergent manifolds are particularly relevant to the concept of evolution of the complex theories and unpredictability in planning. In space, emergent manifolds are formed by evolution as physical properties, as human behaviors, or as contexts. However, in complex spaces, many different aspects can occur even with a simple change, as well as the possibilities and directions of emergences are very high - which is why in this thesis these possibilities are called emergent manifolds. This means that the new feature to be created will be unpredictable, surprising, and possibly unplanned. The unpredictable and surprising nature of the emergent manifolds is due to the fact that there is no method to make them repeat as before or elsewhere, as Allen (2012)

emphasized with the concept of evolution. In addition, each site-specific features and contexts ensure that the emergent manifold is distinct to that area, in this respect, the emergent manifolds can be seen as a source that reveals the unique character of a space.

Michael Batty (2009) argued that emergent manifolds are the ability of urban space to restructure itself. This restructuring ability explains how the emergent manifolds adapt to new conditions in space as a result of self-organization and evolution in urban reality. In other words, from a different new perspective, it can be seen that the emergent manifolds provide opportunities that increase the adaptation capacity in space. But it can also mean that the manifolds that emerged are in tension with planning interventions. The self-organization and evolution that could occur against the interventions in the field may lead to emergent manifolds that would contradict the planning purpose.

Another relationship between the emergent manifolds and planning can also be addressed through the differences in the way the space is perceived. Space can be seen as an end-product that is processed for planning purposes and obtained by managing order. At the same time, when it comes to complexity, new manifolds are likely to be emerged constantly due to the continuous interactions in the space. Manifolds will also continue to interact with other parts in the space after emerged, meaning they will create their own order parameters. We can interpret this as the space never actually coming to an end-product.

5.2 Discussion of the case study results

The Brunnshög project has provided valuable insights into the relationships between the planning process and the emergent manifolds in the field, with the information obtained from the literature review. It may be seen that currently in Brunnshög, on the one hand, the rational motives of the actors, on the other hand, the emergent manifold, which is the irrational behaviour of the site, operates. The nexus of these two extremes is ever-increasing complexity. Brunnshög urban development projects may benefit from using complexity theory in order to understand what has been presented in the plans as well as the emergent manifolds in the site. Decisions made intentionally through the mind lead to concrete effects in physical space, which in planning is the reflection of the mind to the material world. On the other hand, there are structures born through purposeless means, which are manifolds that are emerged. For example, daily human activities can trigger social and technological currents. As a result, it has an impact on other interactions in the physical environment and even on other systems and their users.

In the planning documents, the whole Brunnshög district is represented as completed in line with the targeted/imagined development, which can reflect the

unity of the urban character of this new area. However, as can be seen in the field studies, there are plans in different processes that have been completed, are under construction, and have not yet started to be implemented. The links between the different land uses and different characters presented in the planning documents are not yet available in the area. Relations between the document and field study for the Brunnshög provide knowledge about differences between what has been imagined for the plans and what could actually emerge at the site.

Planning documents mention flexibility and measures for future situations that are currently uncertain. In this respect, it has links that can be associated with manifold potentials that may emerge. For example, the proposed building structure plans at Central Brunnshög are planned for transitions between residential and business purposes, providing the capacity to adapt to future changes, while also providing room for potential manifolds. At the moment, Brunnshög is highly complex which is in a constant state of flux and development. However, looking at the nature of the emergent manifolds and the reality in the area, it may be relevant to ask whether the planned land use in Brunnshög will evolve as the land use of the actors or the urban reality that will emerge here. It is not possible to see how they will be implemented until the projects planned for Brunnshög are realized. Until then, the undeveloped areas in Brunnshög, for now, leave room for temporary environments where potential future uses can be tested.

Detailed field studies have pointed out the results regarding the potentials of the emergent manifolds at Brunnshög and the roles of planning in this potential. Speculations made on the neighbourhood park, which is a sample of a small-scale area, draw attention to the potentials that may occur as a result of planning the area with different land uses such as a green area or a bicycle park. The change in the use of the planned area here is effective in the manifolds that may arise by causing changes in the relations between people and the place.

The sample area studied in Central Brunnshög points to the effects on manifolds that can arise through the difference in the organization of the two different planned spaces. The interactions of the two spaces, which are planned as a shopping area and a park area, with each other and with other systems around them vary depending on their organization. Speculation over the relocation of the park and shopping districts has shown patterns chains of interaction that may affect other surrounding areas such as South Brunnshög and Kunskapsparken, and the whole of Brunnshög in the future. This also indicates that spatial organization can be used strategically to support the different manifolds that may emerge.

Speculation on the possible extension of the tram line, on the other hand, points to the manifold potentials that can emerge through the growth and development of cities. The extension of the tram line from Brunnshög to Södra Sandby provides growth for the city of Lund, while increasing the potential for manifolds that can emerge through new land uses on the new connection. The potential manifolds here

lead to the development of methods that can affect large-scale infrastructure in different ways, while also pointing to the adaptability of space through emerging manifolds.

The case study also allowed more features to be explored about emergent manifolds. That is, manifolds can emerge over time, in the form of social actions (e.g., the use of green space for meetings in the example of a neighbourhood park) or in physical forms (e.g. infrastructure developments that may occur with the extension of the tram line), can be temporary or permanent, small or large scale, but the actual scale of the environment in which they are located is not decisive.

Another conclusion drawn from Brunnshög is that while the planning activity focuses on organization, regulation, and maintenance; complexity is that it expresses the reality in the field. However, it is difficult to determine what will happen in this reality due to behaviours such as non-linearity and self-organization. So, complexity may actually relate to the potential of what can emerge in reality in the field. When this is integrated with planning, planning plays an important role in promoting or reducing these potentials.

6. Conclusions & Future Research

This exploration indicates that it may be reasonable to think that the conceptual and practical problems between complexity and planning would benefit from the perspective of the way new complexities arise in the field. The Brunnshög case offers a context that it is conducive to investigations into the tendencies between complexity and planning both as to how increased complexity can be included in planning and what traces of increased complexity thinking might be in new planning practice. The study also presents one possible way to think that it would be beneficial to consider the complexity of the planning practice.

Planning has the ability to guide spatial processes to a great extent. But the spatial context is also part of a larger reality subject to constant change (e.g., climate change). On the one hand, there are comprehensively planned environments, on the other hand, there are emergences that are the product of change. The environment we live in is a complex structure in which the planned processes and the natural growth of the space coexist. One possible conclusion to be drawn from this thesis is that planning should support this coexistence, taking into account complexity while continuing to generate strategic solutions for spatial development. One way to move forward from this thesis might be to place an emphasis on how planning practice can be better equipped to adapt to the ever-changing, complex space. A possible effort for this may be by tracing the paths that follow-up studies included in planning can establish between practice and complexity. There may be an opportunity to discuss possible outcomes through follow-up plans for planning processes, mapping increasing and decreasing complexity.

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