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Analysis of the Challenges in the Swedish Urban Planning Process: A Case Study about Digitalization

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Abstract: While the populations of cities continue to grow, institutions are demanding more sustainability in urban development, leading to a great increase in the complexity of urban planning. The need to consider social, legal, environmental, and economic parameters challenges the traditional urban planning processing in favor of an optimized and automated process. Generative design has the potential to optimize the design phase by automatically generating spatial design solutions and analyzing them in the design phase. The objective of the present study is to analyze the traditional urban planning process and to compare it with a digitalized driven process by using generative design. This study uses a mixed approach with four research methods: document analysis, survey, interviews, and a case study based in Sweden. The critical analysis of the Swedish urban planning process makes it possible to define the main barriers to a digitalized process. Results also show the benefits of using generative design for a more sustainable and faster design process. Two main conclusions can be made from this study: institutional and organizational changes are necessary to achieve digitalization, and generative design proves to be a useful tool that should be considered to support the digitalization of urban planning.

Keywords: urban planning process; digitalization; generative design

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Citation: Varela, E.N.; Öhrling, K.; Moscati, A. Analysis of the Challenges in the Swedish Urban Planning Process: A Case Study about Digitalization. *Sustainability* **2022**, *14*, 16333. https://doi.org/10.3390/su142416333

Academic Editor: Agnieszka Bieda

Received: 8 November 2022
Accepted: 2 December 2022
Published: 7 December 2022

1. Introduction

Cities have grown dramatically in recent years and are responsible for 75% of greenhouse gas emissions and house 55% of the world's population [1]. As a result, social, economic, and environmental sustainability have become priorities by numerous organizations, such as the United Nations with the Sustainable Development Goal 11: Sustainable Cities and Communities [2], the European Parliament [3], or the European Commission, which includes sustainability factors and digitalization among its priority topics in its Urban Agenda [4].

The increasing rate of population growth has led to increased demand for resources in cities, resulting in economic and social pressures [5,6]. Consequently, urban planning has become extremely complex due to issues, such as design, economic viability, decision-making theory, conflict resolution, advocacy, social equity, legal frame, and sustainability [7].

This complexity has put traditional design methods, analogue or document-based systems to the test [8]. Although traditional architectural design is widely used, it tends to focus on aspects, such as functionality and aesthetics, by integrating measurable criteria relatively late in the process [9,10]. As the initial design phase determines 75% of a product's life cycle cost [11], failure to account for other factors, such as daylight or energy consumption, can result in a significant increase in life cycle cost. In general, the main limitation of this method is that it is rigid and incapable of dealing with the complexities of modern urban planning.

The last decade has seen digitalization, information, and communication technologies perform a rapidly growing role in urban development. Researchers, the public sector, and software suppliers have developed a variety of frameworks, methodologies, and supporting tools to address this [8,12–15]. Digitalization has the potential to render decision-making in urban planning data-driven, responding to the increasing complexity of this process [5].

To achieve this digitalization, the architect, engineering, and construction (AEC) industry has started to implement tools, such as building information management (BIM) and the Internet of Things, to visualize, design, and manage the urban environment on large and small scales. These tools can manage large amounts of data, making it easier to address issues that occur in urban planning and in cities [16]. Decision support systems (DSS) and planning support systems (PSS) have also become widely used. These are tools based on geoinformation and modelling technologies, such as geographic information systems (GIS) or model-based tools such as Esri City Engine, used to provide support to planning stakeholders. According to Feizizadeh et al., these procedures are essential for data management in research, as they provide a wealth of resources, methodologies, and methods for assessment, analysis, and recommendations [17].

The development of urban data platforms has also gained great momentum and the use of reliable communication and network infrastructure, along with the handling of big data, can be considered fundamental to digitalization [14].

For decades, researchers have been trying to automate and optimize the spatial design and urban planning [18–20]. Generative design combines parametric design, simulation software, and optimization to explore large spaces and obtain optimal design solutions automatically. In recent years, this technology has been widely used to solve design problems in various fields, such as engineering, industrial design, and architecture [21]. However, in the AEC industry, generative design has been mainly limited to simple product generation [22]. There have been a number of case studies on the use of generative design in urban planning for the spatial distribution of buildings, [10,21–23], but none have compared this method with the traditional design method to assess its effectiveness and performance in urban planning. It is necessary to understand the urban planning process in order to understand the possible contribution of generative design in the digitalization of it. Although there have been some studies on the urban planning process in Sweden, they are based exclusively on the laws that regulate the process and not on the actual practice, nor on the point of view of digitization [24,25].

Therefore, the objective of this study is to analyze the traditional urban planning process and to compare it with a digitalized driven process by using generative design focusing on Sweden as a case study. For this purpose, the present paper answers the following proposed research questions:

What does the urban planning process in Sweden look like today?

What are the main barriers to the digitization of urban planning?

What are the advantages and limitations of using generative design in urban planning?

In the present study, document analysis, survey, interviews, and a case study were conducted. Given that the planning regulations, methods, and procedures differ between countries, and often among different districts/cities of the same country, we chose a case study; namely, a newly developed area in Jönköping, a medium-sized municipality in Sweden.

For the document analysis, a hierarchical procedure was adopted, from national laws and regulations to regional and municipal ones. The survey aims to determine the main problems in the urban planning process and the barriers to digitization. Interviews were conducted with those responsible for the development of the case study area, both from the municipality and from the developer company, to gain a better understanding of the process and to collect data for the case study. For the area that is the subject of the case study, both traditional and generative design methods are compared from an environmental and socio-economic perspective.

2. Materials and Methods

This study uses a mixed methodological approach, with both quantitative and qualitative data, and involves four research methods: document analysis, survey, interviews, and a case study.

2.1. Document Analysis

The document analysis was carried out to understand the legal framework, in effect in Sweden 2022, for the urban planning process. Ten documents were analyzed, including the Planning and Building Act (PBL) [26], Planning and Building Regulation (PBF) [27], National Board of Housing (BBR) [28,29], National Interests [30], Environmental Code (Miljöblaken) [31], and County Administrative Board [32], and some related literature and the Swedish digitalization plan for urban planning [24,25,33].

2.2. Survey

A survey was sent to all 290 Swedish municipalities through their public contact email address. The survey was completely anonymous, no personal information or email was recorded, nor the municipality to which the respondent works. Both the mailing and the survey header specified that the results would be used for research and for the writing of a paper. Of the 290 municipalities, 163 responded. The survey was originally written in Swedish and the results were translated into English. The survey included 14 questions: 12 multiple choices and two open questions. The questions were structured as follows: four questions about the respondents' background and the municipality size (large cities have at least 200,000 inhabitants; medium-sized towns have at least 50,000 inhabitants; small towns have between 15,000 and 40,000 inhabitants; rural municipalities have fewer than 15,000 inhabitants [34]); four questions regarding the urban planning process (process' steps, people, factors and tools); four questions concerning the exchange of information between municipalities and external participants, such as developers and consultants; and one question dealing with problems and obstacles in the urban planning process. A section for the respondents' comments closed the survey.

The survey was analyzed using the IBM SPSS Statistics 27 (Statistical Package for the Social Sciences) Statistics software to calculate frequencies and cross-tabulations between the type of municipality and the responses.

2.3. Interviews

Semi-structured interviews were conducted with one of the planning architects from the municipality and with the CEO of the developer company in charge of the design and construction of the case study. The interviews were conducted in Swedish and translated for the sake of this paper. In total, seven questions were asked during the interview with the developer company, while 11 were asked during the interview with the municipality. The questions were formed to clarify the planning process of the case study's area. The interview questions had two types: generic questions about the urban planning (aiming to obtain an overview of the planning and its barriers, and to understand how it can be digitalized); and questions about the case study planning process (to obtain the necessary data for the case study and determine if and how the design of this specific area differs from the usual process).

2.4. Case Study

The chosen case study is a newly developed area of around 5.5 ha in Jönköping, a medium-sized town (approximately 90,000 inhabitants) in Sweden. The area was redesigned using Spacemaker, an Autodesk web-based generative design software. Spacemaker uses artificial intelligence (AI) and generative design to analyze the data, parameters, and constraints of a project and propose alternative layouts and spatial configurations. It also offers analysis tools for these layouts.

This case study aims to establish whether generative design technology can improve urban planning. For this purpose, the scenarios proposed by the software and the one obtained from the original process were compared based on brute area (BTA), livable area within residential buildings (BOA), stories, volume, sun, daylight (VSC), noise (calculated with the method CNOSSOS-EU), and view distance (the distance in a 120° field of view from each façade), time, and cost (based on the license cost and an estimation of a planning architect salary [35]).

The case study part drew on the analysis of the interviews and documents available on the municipality's website. These data were used to draw the detail plan of the area in Spacemaker and define parameters, such as outdoor space or traffic density and speed limit. Once all the data, parameters, and constraints were introduced in the software, the new designs were obtained and compared with the original.

3. Results

3.1. Documents' Analysis: Urban Planning Regulations in Sweden

Urban planning is conditioned by rules, laws, and regulations. In Sweden, the PBL [26] and the PBF [27] form the legal basis for urban planning at national level. According to these documents, urban planning is the jurisdiction of municipalities [28]. Another relevant organization is the County Administrative Board, which coordinates planning documents prepared by various authorities to support municipal planning [32]. In addition to these laws, the environmental code [31] must also be taken into consideration, at national level.

In addition to the rules, PBL also includes a description of the planning process, which is divided into three parts: regional planning, general planning, and detailed planning. The process also weighs social interests in an open and democratic process. The PBF contains provisions on definitions, plans, and zoning regulations, requirements for construction works, permits, and notifications that are controlled by the government [27]. In addition, the BBR (National Board of Housing), contains general rules and recommendations on certain requirements of the PBL, and the PBF. The County Administrative Board aims to ensure that national and other state interests are taken into account in spatial planning [32]. Therefore, it is empowered to intervene in matters that may affect national interests, environmental quality standards, health, safety and the risk of accidents, floods, or erosion [28].

The planning process starts when municipalities intend to implement a master plan. Once the master plan has become law, the documents must be sent to the BRR. The interaction between the municipality and the County Administrative Board (Appendix A Figure A1) begins to clarify the demand planning basis, strategy, and environmental conditions that the master plan must fulfill. Planning documents and analysis are divided into public and governmental interests. For the general interests, it includes basic housekeeping, whom to promote, and localization. The state interests involve national interests [30], environmental codes, and PBL (Appendix A Table A1) [20].

As stated above, urban planning is a jurisdiction of the municipalities, so the process differs in different parts of the country. However, there are some steps that are usually followed. A brief guide published by BBR in 2020 [29], indicates the different steps that are normally included in the development of a detailed plan; see Figure 1.

All the municipalities need an updated comprehensive planning (MCP). This document includes the intention of land use and the national land use interest. The MCP documents should present the political vision and strategic choices based on a long-term perspective of the physical environment. In addition, the MCP also acts as a guide for other plans in the municipality. There is also a legal requirement that the MCP should coordinate with regional and national policies and programs [24,25]. In May of 2022 the government commissioned the BBR to develop a digitalization plan to adapt to a more data-driven approach to planning and building laws. This includes goals for a digital urban development process and digitalization strategy. The aim of this plan is to make Sweden a leader in digitalization in the planning and building process [33].

Figure 1. Guide for the planning process published by BBR in 2020.

3.2. The Survey

Table 1 shows the survey's answers: (1) the factors considered in the design of the detail, (2) plan the number of people involved in this phase, (3) the most time-consuming project phases, (4) the digital tools used in the design of the detailed plan, (5) how information is shared with external stakeholders, and (6) the main issues in the urban planning process.

Table 1. Survey results.

Q	Answers	N°	Frequency
1. Factors	Noise	143	87.70%
	Outdoor environment	142	87.10%
	Indoor environment	126	77.30%
	Daylight	122	74.80%
	Distance view	110	67.50%
	Wind	51	31.30%
	Traffic, infrastructure and mobility	27	16.60%
	don't know/not relevant	16	9.80%
	Geotechnical, water, environmental and cultural issues	8	4.90%
	Aesthetic/architectural values and landscape	5	3.10%
2. People	Between 5 and 10 people	65	59.10%
	Less than 5 people	21	19.10%
	Between 15 and 20 people	14	12.70%
	don't know/not relevant	8	7.30%
	More than 20 people	2	1.80%
3. Phases	Preparation of the draft plan	144	88.34%
	Comments from the Consultation	31	19.02%
	Others	10	6.13%
	Review of the draft plan	7	4.29%
	Adoption of the detailed plan	7	4.29%

Q	Answers	N°	Frequency
4. Digital Tools	CAD	113	72.90%
	GIS	128	82.58%
	3D modelling	15	9.68%
	Others	17	10.97%
	City modelling programs	18	11.61%
	Generative design	7	4.52%
5. Information Format	PDF document	141	92.80%
	2D document	137	90.10%
	GIS fileformat document	80	52.60%
	3D model	56	36.80%
	Don't Know	4	2.60%
	Script/database document	4	2.60%
6. Issues	Bureaucracy	54	35.10%
	Communication	51	33.10%
	Lack of knowledge about work strategies	42	27.30%
	Lack of knowledge about digital tools	35	22.70%
	None of the above	29	18.80%
	Administrative problem	22	14.30%
	Lack of non-digital	21	13.60%

The survey includes answers from rural municipalities (35 percent), small towns (42.9 percent), medium-sized cities (20.2 percent), and large cities (1.8 percent). Eighty-two percent of the respondents work in the planning department as planning architects or similar, 1.8 percent work as building permit engineers, 5.4 percent work as civil engineers or GIS engineers, and 10.8 percent work as project managers or in similar roles. According to the survey, the longest phase of the urban planning process is the preparation of the draft plan, with 88.3 percent consensus among the respondents and repeating this trend in all types of municipalities. The number of people involved in this process is between five and ten in 37%of the cases. This is the standard in small and medium-sized cities. In rural municipalities, 43.8% of the municipalities have between five and ten people and 37.5% have fewer than five. In the case of large cities, 100 percent of the respondents have between 15 and 20 people involved in the urban planning process. In general, the most considered factor when designing is noise (87.73%), closely followed by the outdoor environment, indoor environment, and daylight. These maintain the same trend in all types of municipalities, apart from traffic, infrastructure, and mobility, which are minor factors in all types of municipalities, except in large cities, where 33% of respondents consider it in their process

In general, the main problems within the process are bureaucracy (35.06%) and communication (33.12%), followed by lack of knowledge about working strategies among external stakeholders and lack of knowledge about digital tools within the municipality. Communication, both internally and with external stakeholders, such as developers, was rated between 3 and 4 on a scale from 1 to 5, for all types of municipalities. From the answers obtained in the survey on the exchange of information between the municipality and external actors, the main issues can be summarized and differentiated between organizational, like the ones caused by competing interest of gubernatorial organizations, and technical, like the format used to exchange information. Most of the municipalities mentioned the lack of resources and general knowledge regarding digital tools as the main reason for the issues within communication. Some municipalities, especially the smaller ones, explained that the main dialogue takes place via email, normally using PDF and 2D files, which limits the use of large files. It can also be observed that, as with digital tools, the use of 3D files increases with the size of the municipalities. In the case of the municipalities that uses the 3D models and city modelling software only 67% and 61%, respectively, of them exchange information in 3D formats. The same occurred with GIS, although 82.6% of the respondents use GIS, only 52.60% use this type of format to transmit information. Some municipalities also mention that the bad communication can cause delays in the projects as the data often arrive at a later stage.

3.3. Interviews

The first interview was conducted with the CEO of the developer company of the area of the case study, and the second interview was made with one of the planning architects of the municipality concerned. The project started in 2007 with the purchase of the land and the municipality became involved in 2009. The first sketches were made in the same year, but it took two more years to have a proposal ready for review. The draft plan, with the detail plans, elaborated in collaboration among the municipality, the developer company, the architect firm, and other consultants, was published in 2012.

The priorities and relevant factors of both parties for the design phase focused mainly on street network and topography. Noise and daylight investigation were necessary to create a comfortable living environment. Other factors, such as wind, were more complicated to analyze and not as necessary according to both municipality and the developer company. These parameters were chosen based on the laws and regulation during the planning process. The number of people involved from the municipality was estimated to be between 10 and 15. From the developer company, there were mainly two people involved. However, plenty of consultants were involved in different steps during the planning process. With all consultants involved, it is estimated that approximately

60 people were involved during the different steps to develop the case study area. The data and information flow were described as “old school” by the CEO of the developer company. Few platforms and collective databases were used, which led to data exchange problems in the planning process between the developer company and the municipality. Digital tools and methods were also described as “old school” by the developer company. The municipality mainly used Autodesk AutoCAD, Microsoft Office and Adobe while designing the area. In the recent years, they have started using Graphisoft ArchiCAD and Trible SketchUp 3D modelling tools. The municipality did not have an exact number of workhours or cost for this project, but the planning architect pointed out that a large amount of money and time were spent on most stages. According to the developer company’s CEO, the amount of time spent was an obstacle, primarily in the earlier stages when the land was purchased and in the current construction phase. The developer company explained how he would prefer to work with a clear time schedule that both parties follow to drive the project forward. The project area differs from other areas in the city. The planning architect from the municipality described it as very complex. The size of the area, the topography with slopes from two angles, and the location in the center of the city made it more challenging than most recent projects.

3.4. Case Study

There are 55 annexed and studied documents, including three draft maps for the community planning and construction work that is published by the municipality for the case study area. Although approximately half of these reports focus on environmental and geotechnical investigations, other reports, such as day-light analyses, noise investigations, and reports on culture and history, have also been published in collaboration with different consultants and stakeholders. By analyzing these documents, it was determined that seven could be produced directly with the use of the selected digital tool: the two detail plans, two outdoor environment analyses, a sun analysis, and two noise analyses. The rest of the documents cannot be automated, and several of them need in situ analyses; that is, environmental, underground water, or geotechnical studies. The data obtained from this documentation were used in the creation of the scenarios, providing, for example, with the buildable areas or the traffic density in the area. Three scenarios were studied: the original design of the detail plan and two scenarios designed with generative design. To create these two scenarios, parts of the detail plan were considered, including the buildable areas, outdoor areas, and, in one of them, the roads. The constraints introduced were varying building heights ranging from six to 15 stories high, with seven stories being the normal height. In this way, it follows the standards of the original detail plan. In the original design, the main factors considered were the topography, the road, and the aesthetic value. In this study, only roads and topography were taken into consideration since the aesthetic value is not a parameter in this tool. The roads were an important factor in the original design. For this reason, it was decided to create a scenario in which the original roads were considered and another one in which generative design generated the roads, with the constraint of a 12 m buffer from the road to the building. The topography is an automatic constraint in this software.

Figure 2 shows the three scenarios used in the case study: Scenario A, the original detail plan design; Scenario B, considering the roads; and Scenario C, without taking the original roads into account. Generative design was used in Scenarios B and C to obtain design proposals for the area, while Scenario A was used exclusively for comparison.

Daylight was one of the main factors according to the survey and it was also considered during the original design of the area, according to the interviews. For this reason, it was decided to use daylight as the optimization factor. During the redesign of the area, the software provided 99 proposals for Scenario B and 100 for Scenario C. The proposals with the larger livable area (BOA) were chosen for the case study (Figure 2). These proposals were compared with the original one using the same software, Autodesk Spacemaker. Scenario C’s BTA varies between 26,798 m^2 and 71,994 m^2, and the BOA varies between

21,597 m^2 and 57,779 m^2. In Scenario B, the BTA varies between 22,280 m^2 and 73,020 m^2, and the BOA between 17,729 m^2 and 58,581 m^2. The proposals with the largest BOA were selected for the scenarios and, as Table 2 shows, the original design makes greater use of buildable space.

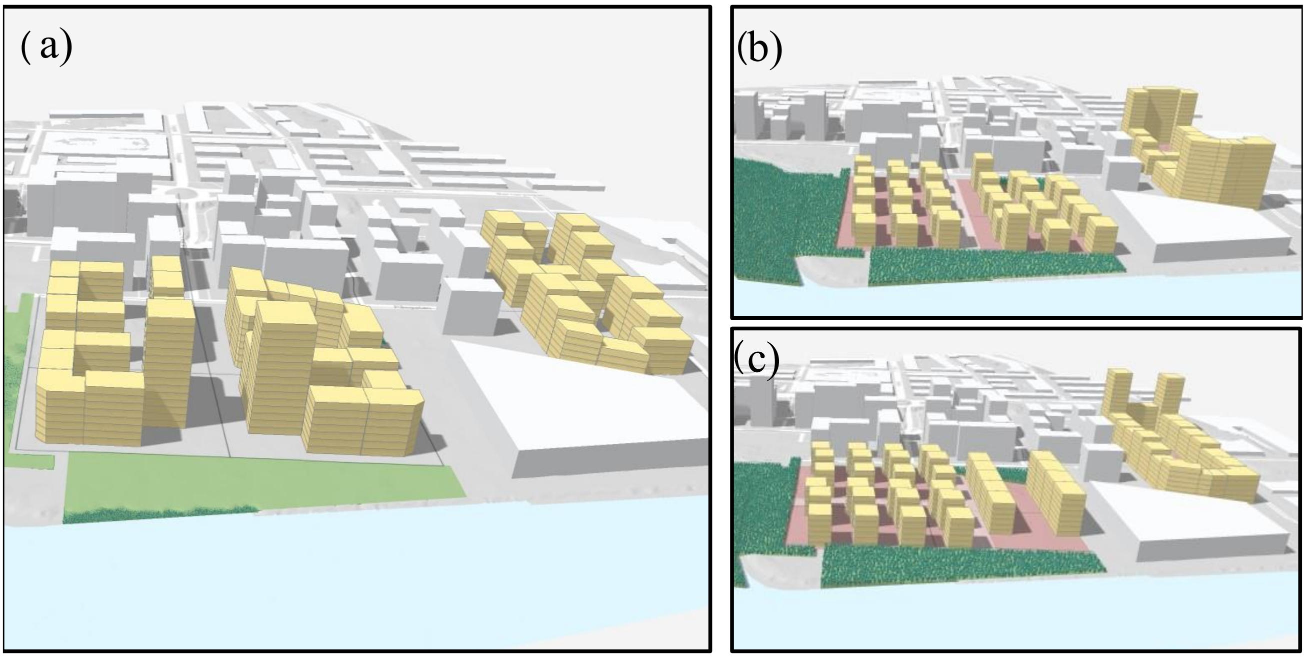

Figure 2. (**a**) Scenario A: original design of the area; (**b**) Scenario B: Generative design proposal considering the original roads; (**c**) Scenario C: Generative design proposal without considering the original roads.

Table 2. Volumetric analysis of Scenarios A, B, and C.

	Scenario A	**Scenario B**	**Scenario C**
BTA	82,622 m^2	73,020 m^2	71,994 m^2
BOA	66,366 m^2	58,581 m^2	57,779 m^2
Average number of stories	7.5	6.7	6.7
Total Volumen built	251,000 m^3	219,000 m^3	216,000 m^3

Regarding the noise analyses, the results of the three scenarios are similar, with 99% of the space below the 60 dB limit. Figure 3 represents the sun, daylight, and view distance analyses. The sun analyses were conducted for the date of June 21. These analyses show the percentage of façades receiving less than four hours of sun, between four and seven hours, and more than seven hours. The daylight analyses consisted of vertical sky component (VSC) analyses. This measures the amount of light reaching the façades, relative to the light available on an unobstructed horizontal surface, given as a percentage, with the maximum score being approximately 40%. Figure 3 shows the percentage of façades in the different scenarios: below 10%, between 10% and 20%, and those above 20%. Finally, the view analysis in Figure 3 represents the distance in a 120° field of view from each façade.

As Figure 3 shows, in the sun analyses, Scenario A gets less sun hours than Scenarios B and C, where more than 50% of the façades obtain more than 7 h of sun. In the daylight analyses the percentage of the façades that receive above 20% of daylight is also lower in Scenario A than in Scenarios B and C. In the view distance analysis, Scenario B has the higher percentage of the façade, with more than 700 m of view field distance. In this case study, the process of designing a new detail plan took four hours and an estimated €4781. This estimation comes from the calculation of four working hours of a planning architect in Sweden, at 23.80 €/h [35], plus the license fee of the Spacemaker software, €3830 per user and year. This process includes input of data, such as outdoor areas, surrounding buildings, traffic density, etc., the redesign of the area using generative design, and the analyses performed. However, a real economic comparison could not be made since the information on workhours and money spent by the municipality on the original detail plan design process was not available.

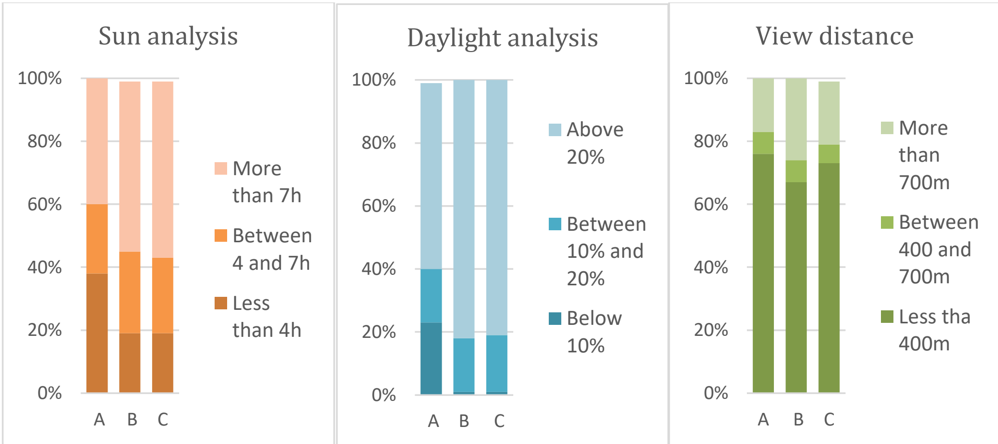

Figure 3. Analyses performed in Spacemaker for Scenarios A, B, and C.

4. Discussion

4.1. The Swedish Urban Planning Process

The urban planning process in Sweden is complex. It emerged from the document analysis that the legal framework of the process appears fragmented. Many documents are necessary to understand the urban planning process from a holistic point of view and the ambiguity of the policies has led to various legal disputes [13]. Municipalities are responsible for creating their own MCPs, which should include the relevant national rules and interests. However, several studies have shown that most of the MCPs are not updated [24,25]. Some respondents mentioned the lack of a clear legal framework as one of the main challenges:

"A common problem is the difficult trade-offs between competing public interests."

Forms of interaction can increase the complexity and tensions of planning and decision-making [6]. At present, the different actors—municipalities, landowners, county administrative boards, and different public agencies—work separately, contributing to the lack of coordination in the planning process [25]. The lack of coordination between different stakeholders, and the disagreements this causes, was one of the most prominent reasons that emerged from survey and interview answers for delays or failure to implement a project. "The longest delay is when different stakeholders disagree on fundamental issues that need to be resolved in the detailed planning process. For example, if there is a conflict between a municipal and a state interest".

Based on the survey and interviews, there is also incoherence in the process compared to the legal framework. In the legal framework the process is apparently linear, whereas in practice the process can stop, become delayed, or restart depending on political or social factors (Figure 2). For example, one of the respondents commented:

"Loss of political support during the planning process takes the most time."

4.2. Digitalization

In this paper, digitization is considered as the transition from decision making processes based on documents to a data-driven decision-making process [8]. Digitalization has the capacity to respond to the increasing complexity of the urban planning process and collaborate in the sustainable development of cities [12,23]. According to the survey, although every respondent uses at least one digital tool (mainly GIS and CAD tools), the most innovative technologies are used by a minority, and the communication still consists mostly in 2D and analog information. According to the interview, the use of new technology, starting in large cities, is increasing, but both the European [4] and Swedish [33] digitalization goals are still far from being achieved. For example, the European Directive 2014/24/EU [3] strongly encourages the use of BIM or similar tools for public projects. However, as the survey shows, 63.2% of the municipalities of Sweden do not use 3D formats in their communication with stakeholders, which presents a barrier for the use of BIM.

It can be concluded from the survey and interviews that the technology is available. Several examples of these technologies were brought up in the survey, such as generative design and even digital twin in a rural municipality, but only a minority of the municipalities use them. In this study, we have identified three barriers as the main reason for this: a political barrier, an organizational barrier, and a technical barrier. The following barriers are not only a barrier to digitization, but to the urban planning process itself.

The first barrier is the political one. The process is highly influenced by politics, which means that the timing of a project varies drastically depending on the municipality, the political support, or the "urgency" of the project. There is also lack of consensus, both within national agencies and with external factors.

> "So much is politically decided. It doesn't matter that I'm an expert in my field if the politics pulls the other way."

There is also an organizational barrier. The lack of a standard structure, frameworks, schedule, roles, and tools, or the excess of bureaucracy causes several issues in urban planning. In the survey, respondents mentioned the ambiguity in the process and in roles or lack of resources and staff, especially in the rural municipalities, as consequences of this barrier.

> "... It is an unclear division of roles within the municipality, where too many interests must come together, that makes it difficult to carry out the planning process."

The last barrier is the lack of a technical standard framework, processes, platforms, technical capabilities, and tools. Several survey respondents mentioned the lack of a common data platform. This causes a lack of digital and non-digital data and the loss of information during communication.

> "We are not able to buy all the tools and have staff with all the knowledge of the tools as they are used too rarely. Therefore, we have to buy consultancy services where it is needed instead. The result is then unfortunately a loss in the analysis. For example, when developing a 3D model, a lot of analysis occurs while the model is being developed. This analysis will not be the same of a 'dead' PDF image."

The new digitalization plan [33] presented by the Swedish government approaches some of the issues, such as the need to improve the information exchange, the need for a digital permit and construction process, and the need to analyze resources needed to digitalize the detailed plans [33]. However, this plan fails to provide specific solutions to these barriers.

As mentioned before, the urban planning process is complex and conditioned by many factors and rules [7]. As a result, this process cannot be fully automatized since several analyses need to be performed in situ, and some phases need to have specific waiting times. This study focused on the detail plan phase, but all phases of the process can benefit from digitalization. In the last decade, several researchers, the public sector, and software suppliers have developed a variety of frameworks, methodologies, and supporting tools [8,14,15]. All phases of the planning design process need different tools that provide a flexible environment to address various design and contextual issues and can help overcome these barriers [23]. To achieve any kind of digitalization it is necessary to first build a common data platform, to ensure a good communication within the national agencies and with external actors. An integrated urban data platform is the essential software infrastructure for a resilient and sustainable city planning [14].

Some examples of the digitalization of other phases in the urban process would be the digitization of administration data and procedures, or the use of social media for a more collaborative process. Digitization of administration data increases the efficiency of bureaucratic procedures and reduces inaccuracies, irregularities, and ambiguities, and it reduces the use of resources [8,13]. The use of social media enables the effective use of local knowledge and increases the acceptability of plans by building trust among participants [15].

4.3. Generative Design

The results of the case study show several advantages on the use of generative design tools in the detail plan phase. The environmental aspects and the time consumed in the process are the main advantages. The case study shows how the results obtained by the generative design scenarios, Scenarios B and C, in the analyses performed are a great improvement over the original scenario, Scenario A. Generative design enables the development of sustainable cities by iteratively testing and evaluating the design's performance as part of the design process [23]. The economic study has not been possible because the municipality does not have data on the time or money invested in this process. However, it is safe to assume that the use of these tools would lead to economic savings in municipalities that carry out few projects per year and provided it is accompanied by relevant training of the employees. This assumption is based on two facts: first, during the interview it was mentioned that a large amount of both was used and second, five of the analyses carried out by consultants can be perform directly with this tool: two outdoor environment analyses, a sun analysis, and two noise analyses.

The lack of flexibility of the chosen tool can be interpreted as a limitation or as an advantage depending on the user's expertise. Since the lack of knowledge in digital tools was defined as a barrier, a user-friendly generative design tool could be included into the urban planning process easier. Therefore, generative design tools must be simplified, or they risk the designer concentrating too much on the computational system and too little on the quality of the urban design outcome [23]. However, this lack of flexibility leads to a number of limitations, the main one being the limited number of factors available for the design optimization and for filtering the design proposals.

5. Conclusions

The document analysis, survey, and interviews produced a satisfactory critical analysis of the situation of the urban planning process in Swedish municipalities. The situation of the legal framework in urban planning is fragmented and not up to date in most of the municipalities. This greatly increases the complexity of the process and led to a lack of collaboration between stakeholders or even between different national agencies.

Digitalization is not the only solution for urban planning but can be a useful tool to make this process more efficient and sustainable. Three barriers were identified for the digitalization of urban planning: political, organization, and technical. Therefore, to digitalize the urban planning, political, organizational, and technical changes are necessary. Although the National Board of Housing, Building and Planning [33] is developing a plan to digitalize urban planning, it does not propose specific solutions to overcome the existing barriers. It seems necessary to develop frameworks and standardize departments and functions, redistribute, and standardize available resources and to create a common data environment for government institutions and external actors. The digitization of urban planning will not lead to an improvement if it does not include a proper framework on how to use the tools and platforms correctly and a common data environment to ensure optimal data exchange.

Generative design presents an interesting option to optimize the design phase. The usability of the tool used in this case study makes it a great option on how to implement generative design in the urban planning process. This tool offers great advantages in optimizing the design phase, making it faster and more sustainable by considering environmental aspects early in the design and by analyzing proposals during the design phase, thus designing more sustainable cities. The main limitation of this tool is the lack of aesthetics or logic in designing components like roads. Therefore, this tool, at its current state, should not be used to automate the design process, but rather to support it.

Author Contributions: Conceptualization, A.M., E.N.V. and K.Ö.; methodology, A.M., E.N.V. and K.Ö.; software, E.N.V.; validation, E.N.V. and K.Ö.; formal analysis, E.N.V. and K.Ö.; writing—original draft preparation, E.N.V. and K.Ö.; writing—review and editing, A.M.; visualization, E.N.V.; supervision, A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data available on request from the authors.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Document Analysis

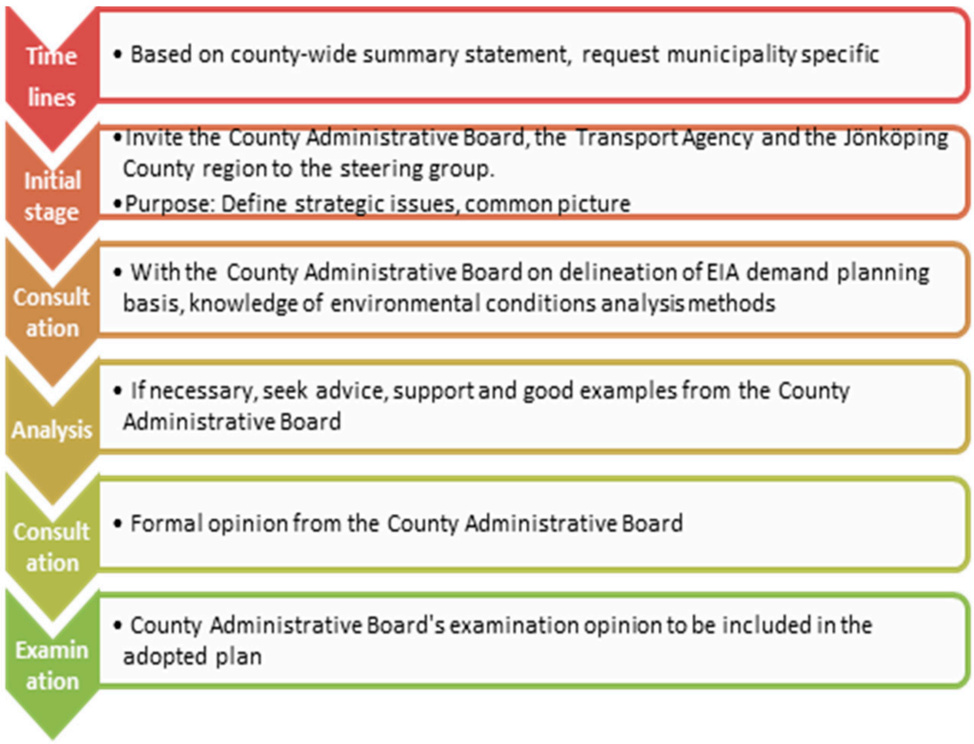

Figure A1. Interaction between the municipality and the Country Administrative Board.

Table A1. Masterplan's interests and contents [32].

Planning Documentation/Analysis		→ Plan Proposal
Public Interests	**Governmental Interests**	**Content**
Basic housekeeping Land and water areas are used for their most suitable intended purpose, considering nature, location and needs. **Promote** * Appropriate structure * Socially good living environment * Long-term good housekeeping * Good economic growth housing construction and development of housing stock **Location regarding** * Health and safety * Soil, rock, and water conditions, * Traffic, water supply, drainage, waste management, electronic communications, community services * Water, air pollution, and noise pollution * The risk of accidents, flooding, and erosion * Energy supply and energy management **Housing** * Large unaffected areas * Particularly sensitive ecological areas * Agriculture, forestry, and professional fishing * Natural, cultural, and, recreational values * Valuable substances or materials * Industrial installations production, energy production and distribution, communications, water supply, or waste management * Total defense	**National interests, chapter 3 MB** * Professional fishing * Natural environment * Cultural environment * Outdoor recreation * Valuable substances or material * Energy production—wind power * Communications * Water supply * Total defense **Named national interests (Chapter 4 MB)** * Vättern with islands and riparian areas * Emån * Natura 2000 **MKN (Chapter 5 MB)** Environmental quality standards for air, water, noise **LIS (Chapter 7 MB)** Areas for rural development in near the shore **Health and safety (PBL)** Human health and safety and the risk of accidents, flooding or erosion	**During the consultation, the municipality shall report (Chapter 3 § 8 PBL)** * The meaning of the proposal * The reasons for the proposal * The consequences of the proposal * The planning context that is relevant from a national, regional, inter-municipal, or other point of view **Must be stated in the Masterplan (Chapter 3, § 5 PBL)** * The basic features of the land and water use * How the built environment will be used, developed and conserved * How the municipality intends to meet the identified national interests and environmental quality standards * How to take account of national and regional objectives, plans, and programmers relevant to sustainable development. * How to meet the long-term need for housing, Rural development near the coast * The municipality's approach to the risk of damage to the built environment that may result from flooding, landslides, and erosion related to climate change, and how such risks can be reduced or eliminated

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