MANAGEMENT OF PRODUCT DEVELOPMENT

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URBAN PRODUCTION

EXPLORING URBAN MANUFACTURING SCENARIOS FOR FUTURE URBAN RESILIENT CITIES

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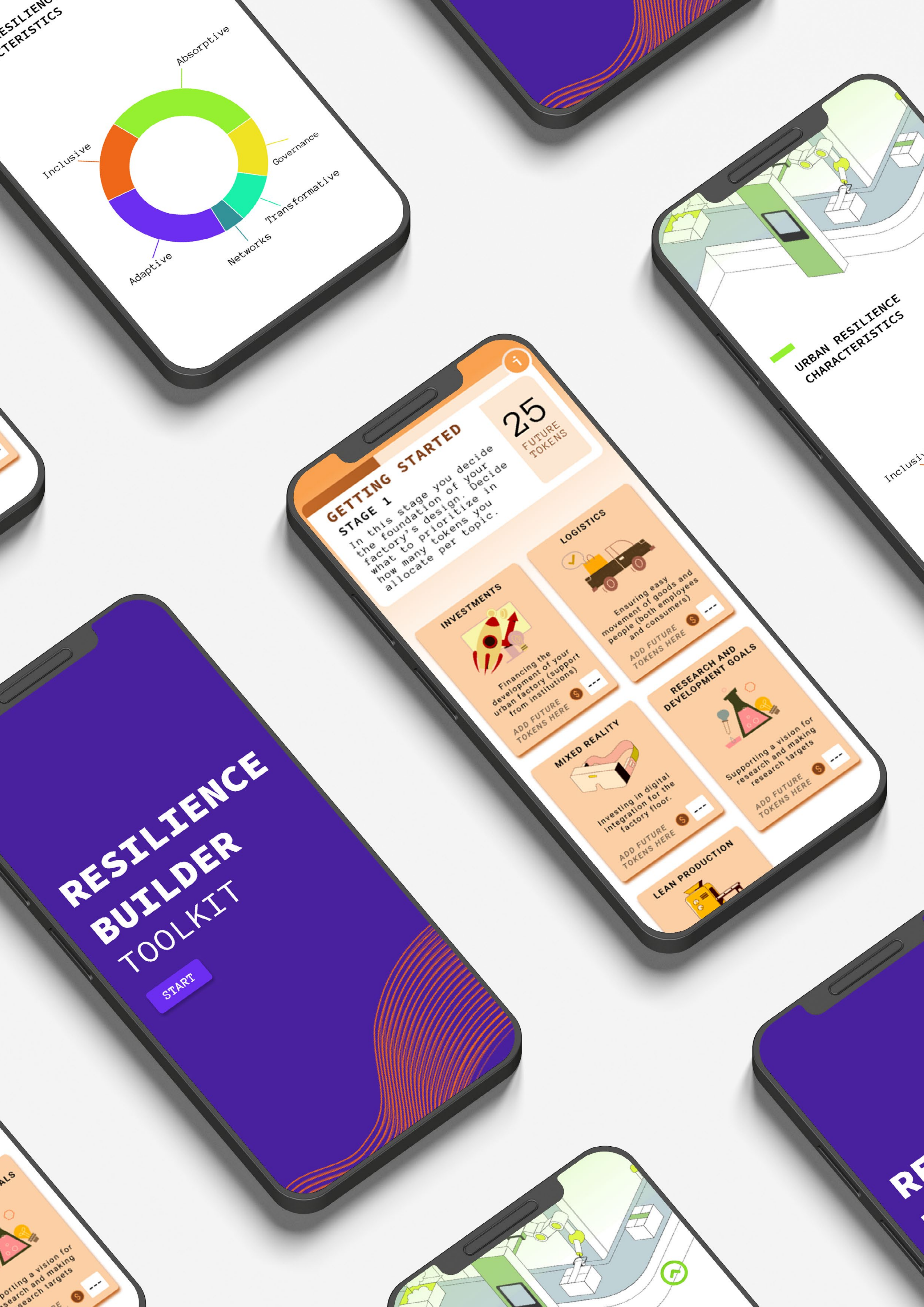
Also thank you reader for going through my report as there are many many many pages. Enjoy!

SUMMARY

This report's purpose is to answer the research question "How can a city-factory-product interface be simulated such that configurations supporting urban resilience are explored?" The research centres around urban production's impact on urban resilience and sustainability. A frustrating issue with urban factory implementation is that factory design and urban planning goals are on different levels and not easily compared. There is a need to align the city's perspective with that of the factory so that dialogue about responsible design choices can be made together. The responsible design can be achieved using urban resilience and sustainability measures. This is done by exploring the relationships that exist between a city, factory, and the designed product of the factory.

The main deliverable of this research was a resilient urban manufacturing toolkit. This is an interactive application that guides the user along their journey to making a resilient and sustainable future city, factory, or product. The city-factory-product interface was expressed using a future scenario. In which the characteristics of the city nexus could be weighed for importance by the user. It is because the scenario allows for both reflection on the current state of the user and the desired future outcome that they can interpret urban resilience responses. Finally, this toolkit developed from this research would be suitable in the project development phase to test different business concepts against each other. It is recommended to use this toolkit in combination with other literature on the topic of urban manufacturing and urban resilience. This can be the starting point for SMEs to gain knowledge on the possibilities of moving production back to cities



Absorptive
Governance
Transformative
Networks
Adaptive
Inclusive
URBAN RESILIENCE CHARACTERISTICS
GETTING STARTED
STAGE 1
In this stage you decide the foundation of your factory's design. Decide what to prioritize in how many tokens you allocate per topic.
25
FUTURE TOKENS
LOGISTICS
Ensuring easy movement of goods and people (both employees and consumers)
ADD FUTURE TOKENS HERE
INVESTMENTS
Financing the development of your urban factory (support from institutions)
ADD FUTURE TOKENS HERE
RESEARCH AND DEVELOPMENT GOALS
Supporting a vision for research and making research targets
ADD FUTURE TOKENS HERE
MIXED REALITY
Investing in digital integration for the factory floor.
ADD FUTURE TOKENS HERE
LEAN PRODUCTION
RESILIENCE BUILDER TOOLKIT
START

CONTENTS


FACTORY'S
URBAN RESILIENCE FOCUS
The following information relates to the urban resilience impact of your factory design:
TOTAL URBAN RESILIENCE FOCUS
0
50
100
Your city design scores a 55 out of 100 for its focus on urban resilience.
This means that your design accommodates inclusivity of the city, community in the city, can be adaptive, absorb shocks, has strong networks, is transformative and has a governance focus.
MORE DETAILS

INTRODUCTION

The last 3 years during the COVID 19 pandemic and Ukrainian war, has shown the world that a centralization of manufacturing in one country can lead to very unstable supply chains for cities globaly. There has also been a growing concern about the increase in shipping goods leading to higher pollution outputs. Simultaneously, the consumer's desire for personalized goods arriving in a timely fashion is not decreasing. And urbanization is increasing as a higher percentage of populations are relocating to urban spaces. There is a need to reframe the way we manufacture today. To address sustainability and accommodate the changes in our society. Cities need to be proactive to not only protect themselves from shocks (such as natural disasters or man-made disasters) but also to enhance the social, environmental, and economic sustainability of the area. This proactive and flexible adaptation to disturbances is called urban resilience.

Urban Factory (UF) is one theoretical solution that offers a way to address logistical and sustainability issues[1]. There are signs that it could also address the urban resilience needs of cities. But more research is needed to see that relationship. The promise of UF is to integrate factories into urban spaces and use local human and material resources. This would theoretically decrease pollution due to transportation. It would also increase economic possibilities for community members. Like all new technologies, there are potential frictions that can come from the production of noise and air pollution, the values of citizens in a community and other unforeseen challenges. This report investigates the relationship of the potential impact of urban factories on a city's urban resilience.

Urban factories and production is a topic that is still mostly discussed in the academic world and not yet known by businesses. It becomes very difficult to implement urban factories because of its interconnectedness to cities. Stakeholders in the manufacturing goods sector have very different metrics used to measure progress than stakeholders in urban planning and governance. There is a need to align the city's perspective with that of the factory so that dialogue about responsible design choices can be made together. The purpose of this report is to make this topic more accessible by identifying how a city-factory-product interface can be simulated such that configurations supporting urban resilience are explored.

In the report, the relationships between a city, factory, and product are investigated to create an effective toolkit for simulating a city-factory-product interface. The first chapter explains the research scope and design challenge. The purpose of this chapter was to introduce the reader to important concepts used in the project. It also lays a baseline for the next steps in the project's development. The second chapter details the concepts of city, factory, and product in relation to the research question. It details the methodology and outcomes of the cross-impact matrix as well. Here the relationships between each dimension were shown as influence flows. Through this description, one can begin to understand how impacts made in one dimension can influence another and vice versa. Chapter 3 explores the problem space of the research. This was done using insights from experts and defining the most important stakeholders. The conceptual framework for the research was defined with objectives for the deliverable to achieve. Requirements and a system structure were also detailed. The next chapter focuses on the user, their motivations, struggles, and interactions with a potential toolkit. By understanding this some user experience concepts were developed. These concepts also aligned with the various subsystems found in Chapter 3. Chapter 5 discusses the proof of concept of the designed toolkit. It details the functionality of user interactions and their relation to the system. The final chapter evaluation and discussion reflect on the validity of the toolkit. This was done through user testing. This chapter also discusses the overall choice of toolkit type, the degree to which the central research questions were answered in the research, and what forces are motivating the adoption or avoidance of developing urban factories with the purpose of enhancing the urban resilience of cities.

This research was done over the course of one academic year and has empirical studies made by individuals from the Twente region of the Netherlands. The impact and application of urban factories are focused on the European region.

RESEARCH QUESTION

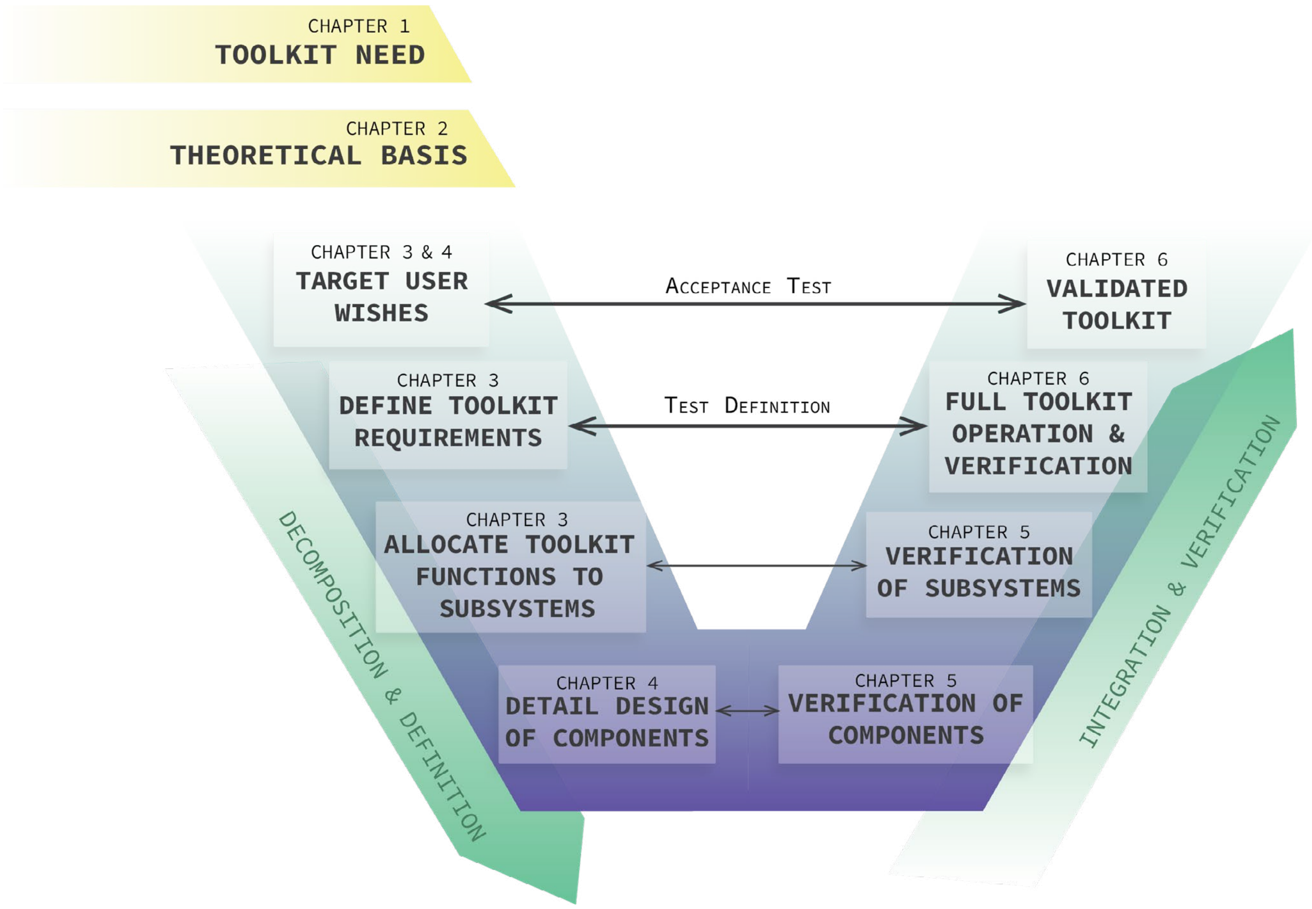
HOW CAN A CITY-FACTORY-PRODUCT INTERFACE BE SIMULATED SUCH THAT CONFIGURA-TIONS SUPPORTING URBAN RESILIENCE ARE EXPLORED?

RESILIENCE FOCUSED

URBAN PRODUCTION

READING GUIDE

The following diagram is based on the extended vee model, it shows the break-down of each chapter ofthe report in relation to how the research process went. The connection between chapters is also shown using arrows.



CHAPTER 1

DESIGN CHALLENGE AND SCOPE

Figure.1. Photo credit: Simon Gougha Athens,Greece

BACKGROUND

Urbanization in Europe is expected to increase to 83.7% in 2050. The total population of European functional urban areas (FUAs) is expected to increase on average by 4% by 2050. The spread of which is uneven and almost half of them will lose population [2]. This means that manufacturers must consider where their production will happen and where their workforce is located. Mercer [3] found that employers rank career and job opportunities as twice as important as employees found them. And in actuality, overall life satisfaction was rated the most important by employees. This was twice as important to workers than employers thought. Therefore, quality of life in a city is paramount for the manufacturing industry as it is the most important factor for their employees.

Growing cities means higher GHG emissions for municipalities, increased air pollution, road congestion, and a lack of affordable housing in Europe [4]. Urbanization also impacts industries such as manufacturing, as it can lead to higher land costs and zoning policies that preference neighborhoods [4]. This reality shows a future where urban sprawl is an unavoidable issue [2]. On a macro level globalization is often seen as a driver for urban sprawl. One proposed response to globalization for the manufacturing industry is urban manufacturing. Urban factories make use of local materials and shorter transportation routes to produce goods. These goods are then specialized to a local region. Thus moving factories from the fringes of cities into the city. To then become part of the urban space itself.

Urban factories then have to consider the challenges that come with the interconnectedness of being in an urban space such as a city. Hermann et al. [5] describe this interconnectedness as the city-factory interface. It is the exchange flows at the border of a city's system and a factory system. These exchange flows are then translated into the corresponding systems as either negative or positive impacts. An example of this could be energy usage. The degree to which the city and factory are interconnected varies based on the choice of factory design. In the case of urban factories, where the resources are obtained locally, and the product is produced and sold locally, that connection becomes even more intricate.

It is also important to consider how urban systems can address future growth and the decline of cities. Municipalities have to be more conscious of the sustainable flow of resources, energy, goods, and technologies coming from other regions in likely post-growth scenarios [6]. To stay resilient municipalities, have to consider how to keep cities growing in a sustainable manner. Therefore, social, environmental, and economic needs are met while also maintaining the ability to bounce back from sudden shocks. Cities face both manmade and natural hazards such as climate change, economic crises, and natural disasters. How they manage to cope with these stressors is a measure of their urban resilience. Urban resilience and sustainability are very closely linked but remain two separate topics. Sustainability is more of a societal goal focusing on environmental social and economic aspects and resilience is expressed as a feature of an urban system[7] [8]. Zhang and Li [9] state that rational urban development can only be achieved when it is both resilient and sustainable. Cities are not the only systems to suffer from these stressors, manufacturing industries also need to ensure that urban resilience is supported. The recent crisis caused by the COVID-19 pandemic highlighted structural weaknesses in the globalization of manufacturing. In this case, many countries ran out of important health supplies as they lacked the ability to produce them locally. There is no other option but to seriously consider how to make manufacturing that is suitable in urban environments. There is an opportunity to investigate configurations supporting urban resilience by simulating a city-factory interface.

The ability to define the relationships of cities and factories in a hypothetical scenario can save both time and resources (as opposed to directly investing huge sums into a physical factory). A city-factory interface simulates the needs, trade-offs and impacts of placing an urban factory in a given city environment. There is the potential to understand the relationships of each system as it relates to urban resilience using the concept of that interface. The potential impact of a product manufactured in an urban factory is not limited to the factory system or to the city system in which it is used. A product's lifecycle can also greatly impact the urban resilience of a city. The city factory product nexus shows that a product does have an influencing factor on both a city and a factory. It is important then to also consider the exchange flows involved with a product's lifecycle. Therefore, the city-factory-interface is limited in describing configurations which could support urban resilience. This research will build upon Hermann et al.'s work by simulating a city-factory-product interface, thereby including more details of the product lifecycle.

There is literature about the potential sustainability impacts of urban factories on cities, this research will build upon that by adding an urban resilience perspective.

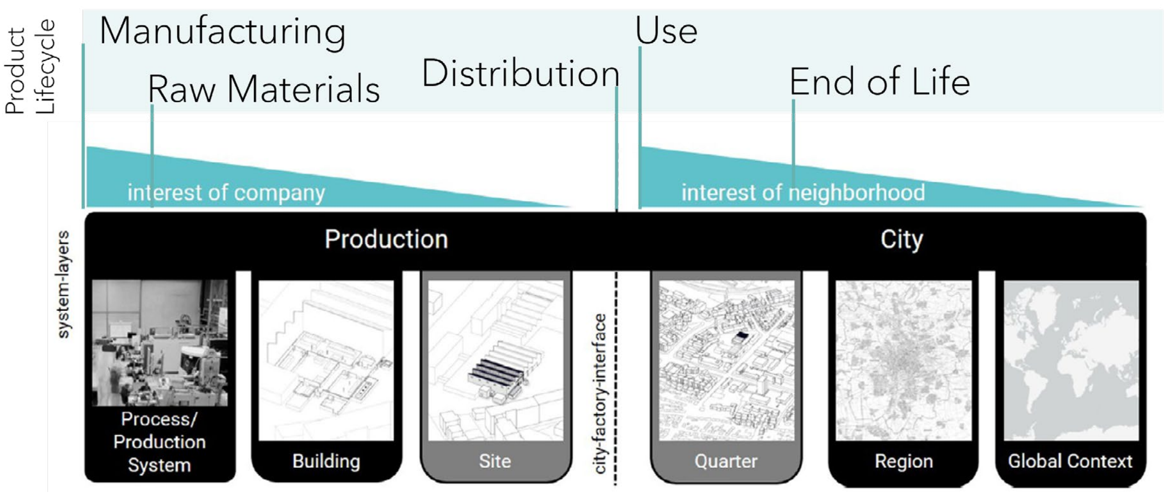


Figure.2. Adapted diagram of City factory interface. [9, fig.3]

PROJECT AIM AND SCOPE

The aim of this research is to promote sustainable design of urban factories by focusing on the way they shape (support/constrain) urban resilience. By focusing on simulating a city-factory-product interface one can make the often-ambiguous relationships in urban production more tangible for future industrial designers and companies. The designed toolkit is not a case study for one possible urban factory in a particular city. It is instead meant to replicate the conditions of an urban context (with changeable inputs) so that various configurations of urban factories and products can be explored. Through this thesis assignment the question, "how can a city factory product interface be simulated such that configurations supporting urban resilience are explored" will be answered.

Ultimately the designed toolkit should:

- Promote the design of responsible urban factories by focusing on the way they shape (support/constrain) urban resilience. Thereby highlighting non-economic standards such that participants can use different valuations to appreciate design choices.
- Be flexible and dynamic. Thereby replicating the conditions of an urban context (with changeable inputs) so that various configurations of urban factories and products can be explored.
- The toolkit should also align interests of stakeholders. So that the often-ambiguous relationships in urban production systems and cities are made more tangible.
- Offer a starting point for multiple stakeholders to discuss future scenarios involving urban resilience and sustainability, considering each other's perspective.

DESIGN CHALLENGE

This report explores the topic of urban factories with the focus on learning factory environments. In terms of the product lifecycle, the production in the city and the use of products are explored in more detail than the extraction of raw materials and the end of life. The research centres around urban production's impact on urban resilience and sustainability. This is done by exploring the relationships that exist between a city, factory, and the designed product of the factory.

A frustrating issue with urban factory implementation is that factory design and urban planning goals are on different levels and not easily compared. There is a need to align the city's perspective with that of the factory so that dialogue about responsible design choices can be made together. An integration of the city and factory, a city-factory interface would be able to resolve this. The responsible design can be achieved through the use of urban resilience and sustainability measures.

An interface showing this interconnectedness could offer companies, designers, and municipalities a way to test possible urban factory configurations in various urban contexts. Thus, giving them the agency to design production responsibly.

The goal of this research can be summarized by the main research question and the sub questions.

"THERE IS A NEED TO ALIGN THE CITY'S PERSPECTIVE WITH THAT OF THE FACTORY SO THAT DIALOGUE ABOUT RESPONSIBLE DESIGN CHOICES CAN BE MADE TOGETHER."

Research Question:
How can a city factory interface be simulated such that configurations supporting urban resilience are explored?

Sub questions:

- In what ways does a city's design, influence a factory design, and their offered products?
- How can urban resilience goals be translated into metrics that apply to a factory set in an urban context and products for a local market?
- How can relevant future scenarios be explored in an urban resilience context such that the desires/needs of stakeholders are also considered?
- What can be done in the design of the interface to make the simulations results scalable so that it can give a good impression on impacts to its urban environment?

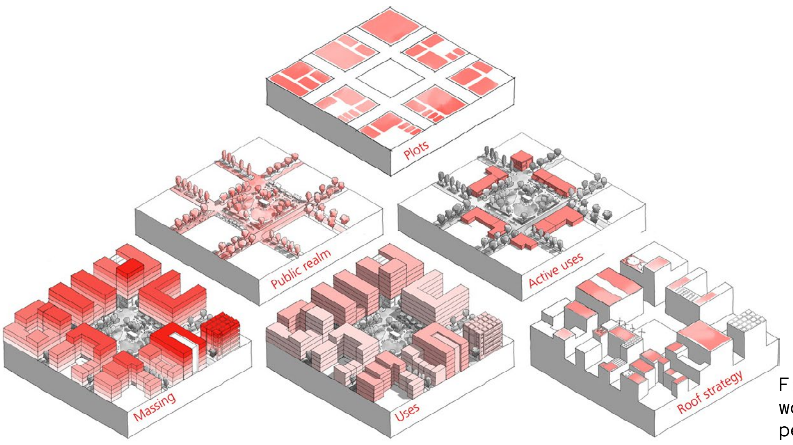


Figure.3. Urban design works over a long time period. [10,fig 6]

CHAPTER ROUND UP

URBAN RESILIENCE

Is defined as the capacity of a city and its urban systems: to absorb the first damage, to reduce the impacts (changes, tensions, destruction, or uncertainty) from a disturbance (shock, natural disaster, changing weather, disasters, crises, or disruptive events), to adapt to change, and to rapidly transform systems that limit current or future adaptive capacity.

URBAN DESIGN

Is described as, the study of the physical distribution of an area, as well as its social and temporal characteristics and the collective interpretation of a space with shared human activity and history.

CITY-FACTORY INTERFACE

Describes the city-factory-interface as the exchange flows at the border of a city's system and a factory system.

In this chapter the background, research question and project aim and scope -as well as the design challenge,were discussed.

The purpose of this chapter was to introduce the reader to important concepts used in the project and also lay a baseline for the next steps in the project's development.

In the next chapter city-factory-product relationships, the theoretical underpinning of the project is described. Here an extensive literature review is used to make clear the interconnections of a city, factory and product in the contexts of urban manufacturing, urban resilience and sustainability.

CHAPTER 2

CITY-FACTORY-PRODUCT RELATIONSHIPS

THE CITY FACTORY PRODUCT NEXUS

The city-factory-product nexus as described by Juraschek et al. [10] shows the interconnections of factories, products, and urban systems. An urban factory provides value to a city by being a source of jobs for the community as well as making use of local and regional suppliers. Conversely, the factory makes use of the infrastructure existing in the city. The product fulfils the purpose of the factory by being made. At the same time the factory produces the product with technology suited to its manufacturing needs. Finally, the city has its demands fulfilled by receiving the offered product. Likewise, the product can exist because of the available market within the city and is used by the citizens. [5]

Figure.4. Characteristics of city, factory and product

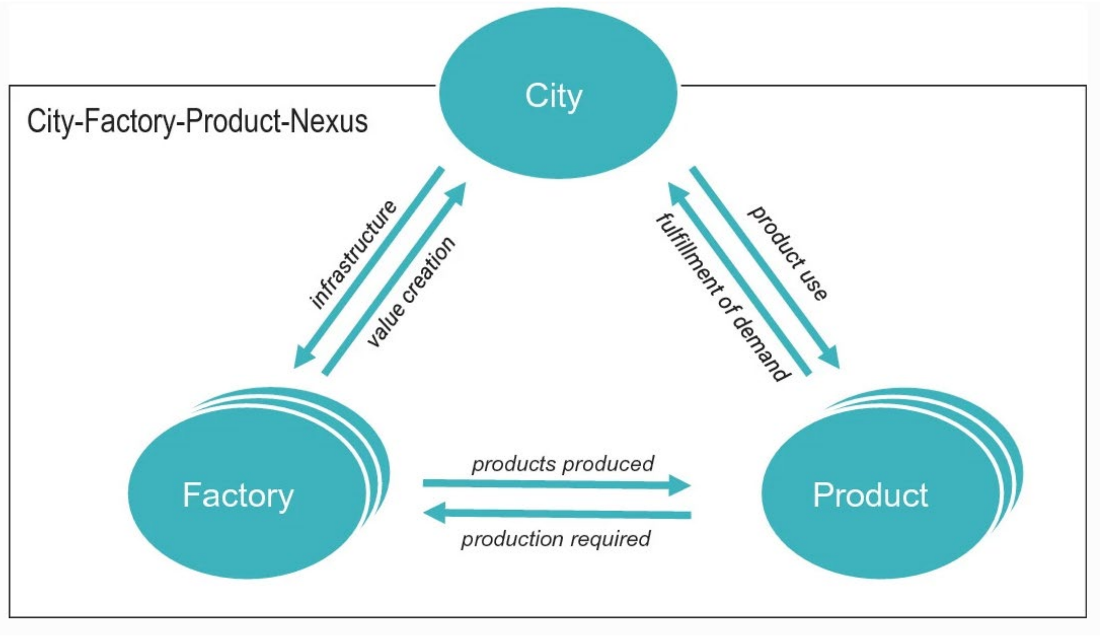


Figure.5. City Factory Product Nexus [9, fig 2]

DEFINING CITY

Following from the definition Hermann et al.[5], a city can be described as an urban space. Urban space, in the sense of urban production systems, is a spatially concentrated, significantly populated settlement structure with multifunctional utilizations. It requires an identifiable place, human population, a built structure, an identity, and a sufficient temporal continuity. Following from this description elements relating to the characterization of a city and its relation to the research question were explored. The three main categories of a city are as follows: urban design, urban resilience, and city sustainability.

URBAN DESIGN

There is not a current consensus of the definition of urban design, and it is often left as an ambiguous subsection of architecture [11]. In this thesis the meaning of urban design more closely follows the definition of Cozzolino et al. and Carmona et al. Carmona et al. describes urban design as a fluid term dependent on the structure of a space with shared history and human activity, a physical environment, both physical and social resources, objectives for social communication and interaction and, behaviour (as it relates to the dynamics of urban land markets)[12]. Cozzolino et al. described urban design as a profession that focuses on public concerns. Their definition follows; "urban design as a creative and purposeful activity with collective and public concerns that deals with the production and adaptation of the built environment at scales larger than a single plot or building" [13]. For the purposes of this study as urban design is described as, the study of the physical distribution of an area, as well as its social and temporal characteristics and the collective interpretation of a space with shared human activity and history.

Urban Design is delineated into six main categories: morphology, visual, perception, functional, social, and temporal [12].

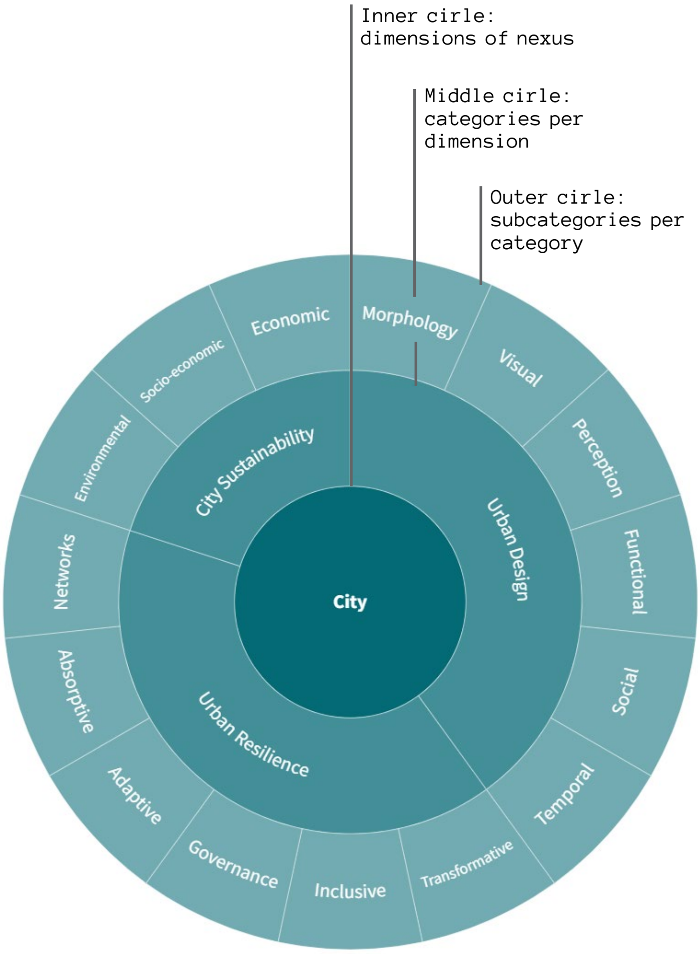


Figure.6. Detailed view of city characteristics

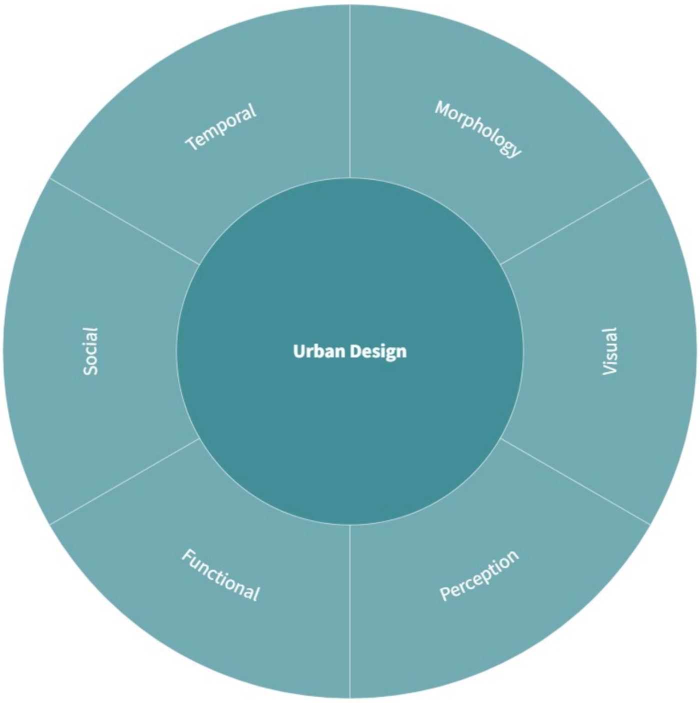


Figure.7. Detailed view of urban design characteristics

Morphology is the configuration of urban form and space, and the spatial patterns of infrastructure that support it. It focuses on land uses, building structures, and street/ plot patterns. [12].

The visual category pertains to the way visible physical elements (such as buildings, lampposts, bus stops etc.) are arranged and integrated in a space. Specifically, it looks at the aesthetic order and patterns of how the urban space is organized, the level of integration of building structures with existing visuals, as well as the visual space qualities of negative and positive space. Negative space describes the empty space defined by intentional building structures, and the building structures, conversely, describe the positive space[12].

The perception category is about the experiences and meaning associated with a place. It deals with the emotional response (affective), the organization of information in the environment (cognitive), the meaning associated with the environment (interpretive), values and preferences (evaluative) and the distinctiveness of a city (imageability)[12].

The functional category is about the intentional and unintentional interactions of citizens with a city. Comfort and relaxation are functional elements of a spaces designed to bring peace to citizens, an example of such a structure is a natural park. Engagement is another important function of a space. This can either be passively like through the use of statues and art or actively as with a playground space. A space can also function as a point of discovery, e.g., with a cultural fair hosted in a space. Also, an important function of a space is to allow fluid movement through it. All the functionalities can intersect with one another, this can be easily seen in the influence of movement on the functionality of activities in a space. Lastly, a functionality of a space can also ensure privacy[12].

The social category deals with the aspects of a city that might influence the socialization of its citizens. Such aspects include accessibility, public space distribution, neighbourhood proximity to urban production, neighbourhood type, safety and which members are included/excluded from a space. [14]

Lastly, the temporal category deals with the ways in which a city adapts and changes with the movement of time. This is often over a timescale of months and years. Specific aspects related to the temporal category are the long- or short-term use of a space, the sharing of a space over time and the ability to change over time.[14]

URBAN RESILIENCE

Dependent upon the field in which resilience is discussed, its definition can vary towards themes such as adapting to environmental disasters or to preservation during economic shocks. Wardekker et al. [15] talks of resilience as a system that is tolerant to disturbances and reduces the impact of such events by adapting quickly. Wagner and Breil, Asian Development Bank and Bruzzone et al. consider resilience from the perspective of the citizens first and their ability to withstand stress, adapt and develop such that the community can function and move on from a traumatic event[16]-[18]. Urban Resilience is described by Ribeiro and Pena Jardim Gonçalves as the capacity of a city and its urban systems (social, economic, natural, human, technical, physical) to absorb the first damage, to reduce the impacts (changes, tensions, destruction, or uncertainty) from a disturbance (shock, natural disaster, changing weather, disasters, crises, or disruptive events), to adapt to change and to rapidly transform systems that limit current or future adaptive capacity[19]. For this thesis, the definition of Ribeiro and Pena Jardim Gonçalves will be used.

Following from Zeng et al. and Irani & Rahnamayiezekavat urban resilience can be described in the following categories: transformative, inclusive, governance, adaptive and networks [8], [20].

The transformative category as described by Zeng et al. is “the ability to implement changes to stop or reduce the causes of risk and vulnerability and ensure an equitable risk-sharing condition”[8]. It involves self-organization, risk management and institutional efficiency/integration.

Following that is the inclusive category. This category pertains to the active involvement of all represented social groups in a city, not only that they are physically represented but that these members also have agency in matters pertaining to the development of their city. The inclusive category then is determined by the degree of collective ownership experienced by citizens and the participation of the community in city affairs [8].

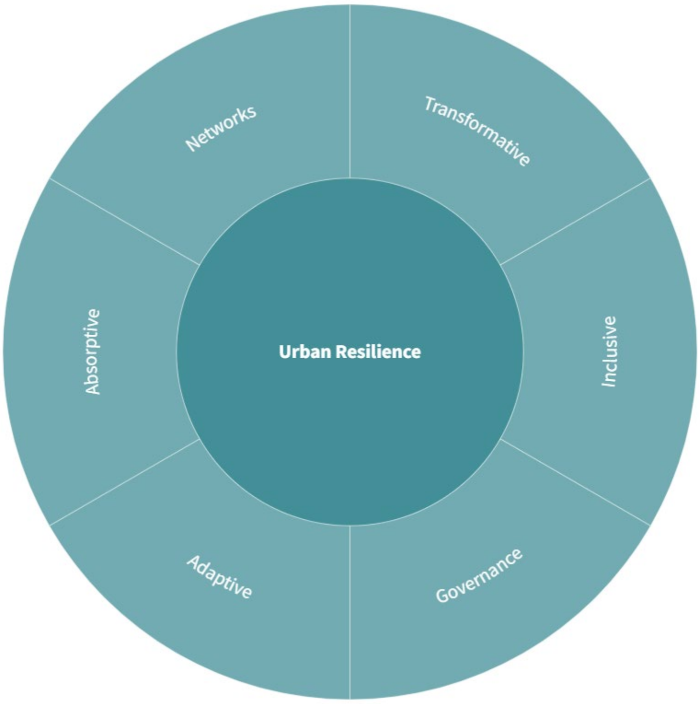


Figure.8. Detailed view of urban resilience characteristics

The category of governance, relates to bureaucratic structures that organize, legislate, and protect a city and its citizens. It is important for there to be accountability, interpersonal and interorganizational trust for governance structures to operate. Other aspects that can help maintain equity of how risk is absorbed by citizens is with tools such as tax policies, safety net programs and strategies for green development [8], [20]. The adaptive category is about a city’s ability to adjust to threatening disruptions. Robustness to severe weather, allowing for reflective moments such as analysing new data and updating old standards and innovation. [8]

Absorptive category is defined by the flexibility and redundancy measures in an urban system.[8]

The category of networks relates to the channels for the transfer of resources and the transportation infrastructure itself. More specifically networks relate to material and energy flows, and the transportation of goods.

CITY SUSTAINABILITY

Sustainability has been classically described as a combination of social, environmental, and economic needs. It is the development that meets the needs of the present needs without compromising the ability of future generations to satisfy their own needs [21]. When looking specifically at sustainability in an urban context, terms relating to life quality, social and culture are emphasized [22]- [24]. City sustainability in this report is described by three main parts, environmental, socio-economic, and economic factors.

The environmental category is defined by the ecological footprint of the city, waste management, access to green space, freshwater availability, fresh air availability and renewable energy[8], [20]. The ecological footprint is about the number of natural resources as defined by the area of land and water used by humans to sustain a population[25]. The ecological footprint is directly related to the amount of energy consumed and how the waste produced is managed. Outside of that factors that influence the daily lives of inhabitants of the city are their access to fresh air and water as well as to green spaces.

The socio-economic category relates to measures of the population such as population age, gender distribution, urban growth and physical capital. It also concerns access to schooling, health services and citizen participation and inclusion in decision making regarding the shared urban space[20]. It is important to differentiate the factors influencing economics due to that of the citizens themselves vs an average of the city. As an average of the city would include measures of wealth based on that of the industries inside the city.

Lastly, the economic category as it relates to a city's sustainability is defined by characteristics such as: employment rate, variety of occupations, economic growth and integration with regional economies[8], [20].

Figure.9. Characteristics of city sustainability

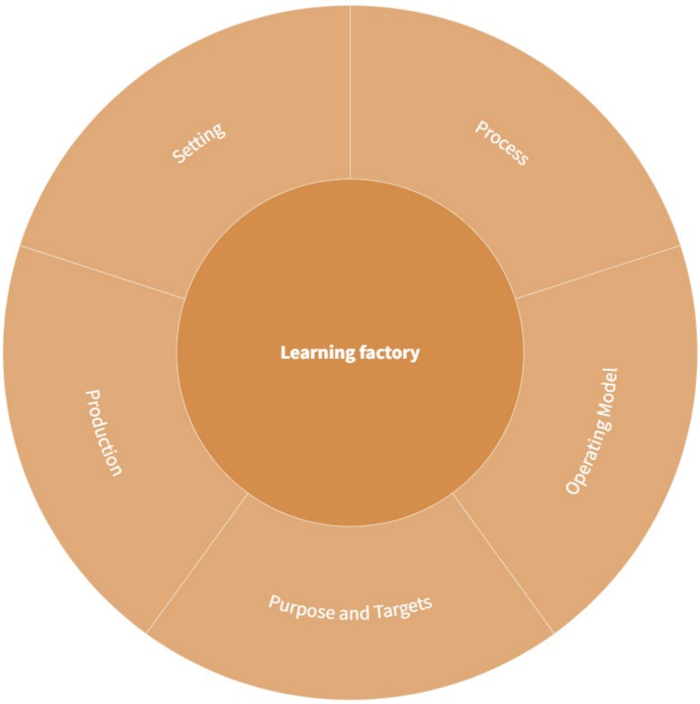


Figure.10. Characteristics of learning factory

DEFINING FACTORY

A factory is a place of value creation in a broad sense. A factory can be seen as a local grouping of production factors for the realization of the entire or a part of the value chain of real goods[26]. The common impressions of factories are that they are a site for manufacturing goods however they offer much more. Factories can for example offer services like education, training, and personalization of goods. Factories can come in a wide variety of sizes and types. In this research e focus is on factories in urban spaces. As such the term factory is divided into two subcategories a learning factory and an urban factory.

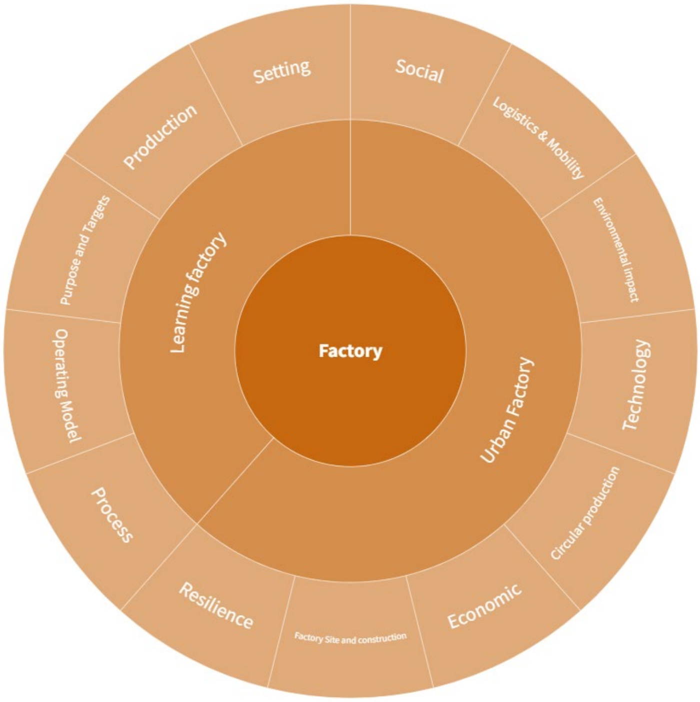


Figure.11. Detailed view of factory characteristics

LEARNING FACTORY

A learning factory is a place where individuals can experience the environment and technologies associated with production in a controlled environment targeted towards educational/training goals. Learning factories are one type of urban factory configuration. A learning factory offers the opportunity for knowledge sharing between industry experts and citizens. This could be interesting for increasing the urban resilience of a city. Through entrepreneurship, diversification of skills and greater community participation and ownership. Some characteristics of learning factories relevant to the scope of this research include the operational model, purpose and targets, process, setting and production. Characteristics relating to the development of educational didactics were seen as outside the scope of the research and therefore omitted.

The operational model of a learning factory describes how the factory is financed, personnel and who is responsible for its development. As such this category is defined by the development (own development, external assisted, external), the operator (academic institution, non-academic institution, profit oriented) and the trainer.[27]

The purpose and targets of a learning factory detail both the role of the learning factory and the group constellation. The role can be either as a research object or a research enabler. The group constellation can either be homogeneous or heterogeneous. [27]

The process category relates to various cycles and flows involved with manufacturing. More specifically it includes: the product life cycle, factory lifecycle, order lifecycle, material flow and process type.[27] The setting category is about the learning environment, the work system levels and the enablers for changeability. The learning environment is on a spectrum from purely physical to purely virtual. With the possibility for mixed reality in between as well. Work level systems can range from a workplace to work system and network. Enablers for changeability refers to the mobility modularity, compatibility, scalability, and universality of the setting.[27]

Lastly, the production category relates to the product complexity, product portfolio and product variants. The product complexity relates to the number of parts. The product variants relate to the number of variations of a product part and the product portfolio refers to the number of different products produced.[27]

URBAN FACTORY

An urban factory is a sustainable factory designed for and located in a local urban setting. Urban factories can be described using the following categories: logistics & mobility, technology, social, circular production, environmental impact, economic, factory & site construction and resilience. The first category of logistics and mobility describes the movement of goods, resources and people related to the factory. More specifically it details the internal and external logistics of the urban factory as well as the mobility of workers and commuters nearby the factory.

Technology describes the advanced technology more suitable to an urban environment because of their low environmental and noise pollution. Types of technology used in this category are internet of things (IOT), mixed reality, 3D printing, Industrial AI, cyber physical systems, sensors and digital twins. The social category describes aspects related to the consumers of the product, the community in which the urban factory is located as well as the employees of the factory. This includes: customer involvement in production, employee wellbeing, community collaboration, urban factory image, workplace quality and educational demand for employees.

The circular production category relates to the environmentally sustainable integration of the urban factory into the urban systems. This specifically relates to green transportation, renewable technology, waste management and if the product is a 'green product'.

The environmental impact category relates to how the factory influences the urban environment from an environmentally sustainable perspective. This includes effects on the ecosystem, resource consumption, radiation, noise production, photochemical oxidant formation, acidification, human toxicity, emissions and ecotoxicity.

The category factory site & construction relates to the type of manufacturing equipment used, quality requirements for production and the factory building itself.

The economic category relates to the business side of the urban factory. This includes the funding, business model, land cost, infrastructure, labour costs, logistics costs and customer benefit by personalization.

Lastly the final category of the urban factory is the factory's resilience. Resilience relates to internal and the external resilience of the factory. The internal resilience is about issues such as the adversity to wrong decision making, equipment failure and worker strikes. External resilience involves the response of a factory to issues outside itself such as the adversity to political issues or natural disasters.

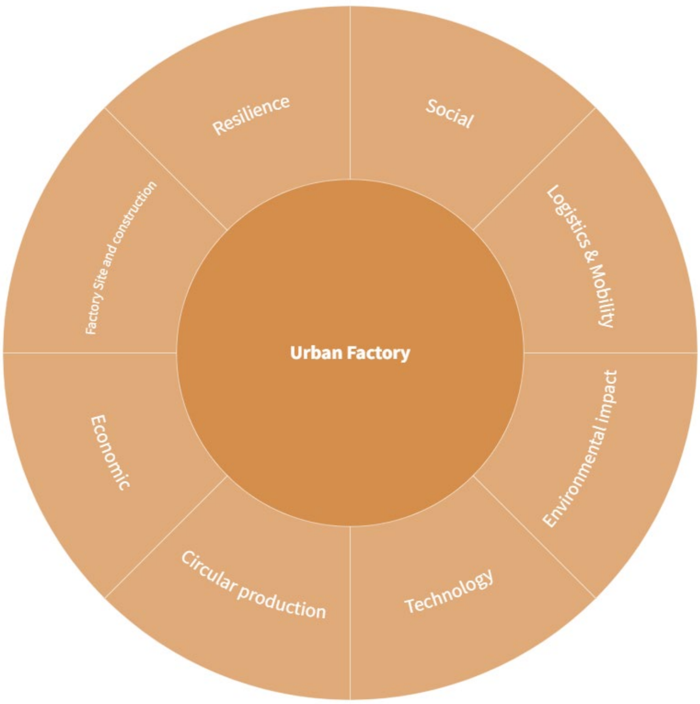


Figure.12. Characteristics of urban factory

DEFINING PRODUCT

Products are made to satisfy consumer needs, whether that be business to business or business to consumer, physical, service or a combination of the two. Factories are designed to make products in cost effective and time efficient manner. Products therefore can dictate a lot about the design of an urban factory and its requirements. In this research a product is defined by the dimensions of physical product, service, and product service system.

PHYSICAL PRODUCT

A physical product is defined by its materiality, its main functionalities, and the way it is intended to be used. Therefore, the three categories describing physical product are material components, use design & life cycles and function.

The material components category relates to what physical aspects are considered in the production of a physical product. This includes: the product dimensions, weight, surface treatment and the materials it is composed of.

The use design and lifecycles address physical ergonomics and cognitive ergonomics as well as the product and customer lifecycle. The physical and cognitive ergonomics relates the use design.

The function category relates to aspects that address the functional requirements of the physical product. This includes: the lifetime of the product, consumption in use and the functional complexity of the product.

Figure.13. Detailed view of product characteristics

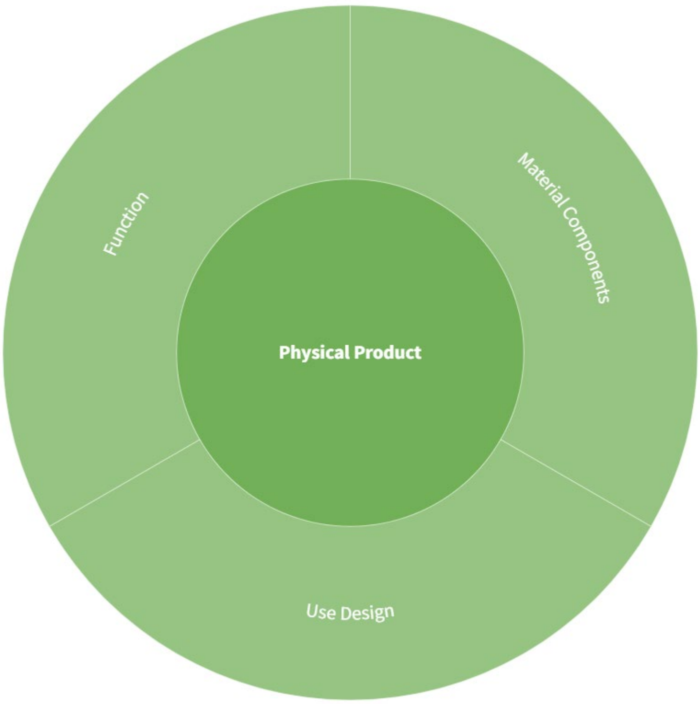


Figure.14. Characteristics of a physical product

SERVICE

The service aspect of the product relates to additional services an urban factory can offer to support the product offering for customers. In this case the categories of maintenance and customer integration were highlighted in the context of an urban factory.

Maintenance relates to the functional upkeep of a product during its lifetime. More specifically maintenance is defined by the products' design for maintenance and any legislation and safety requirements that influence the product design.

Customer integration is about the extent to which customers are involved with the production of the product and support after purchasing the product. It involves aspects such as personalization, service support, know-how transfer, cultural relevance, and perceived quality.

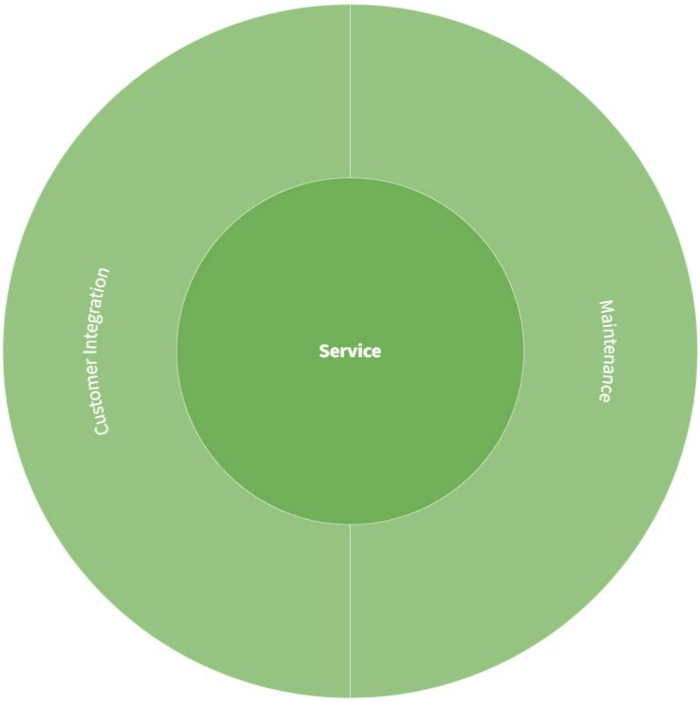


Figure.15. Characteristics of service

PRODUCT SERVICE SYSTEM (PSS)

A product service system is the combination of elements relating to a product and service as well as supporting infrastructure and networks. In this case it relates to the secondary elements of the system as the product and service specifications have been described earlier. These elements are the end of life of the product, resource consumption and cost properties.

The end of life is about how the product is handled once it can no longer carry out its original functionality. This refers to whether the product is reused, recycled, or disposed.

Resource consumption relates to the resource needs to produce the product and its offered services. It specifically addresses human resource needs and the extraction from the local ecosystem.

The cost properties category relates to the value creation of the product, the production and services cost, revenue of the product and services and the market for the offered product.

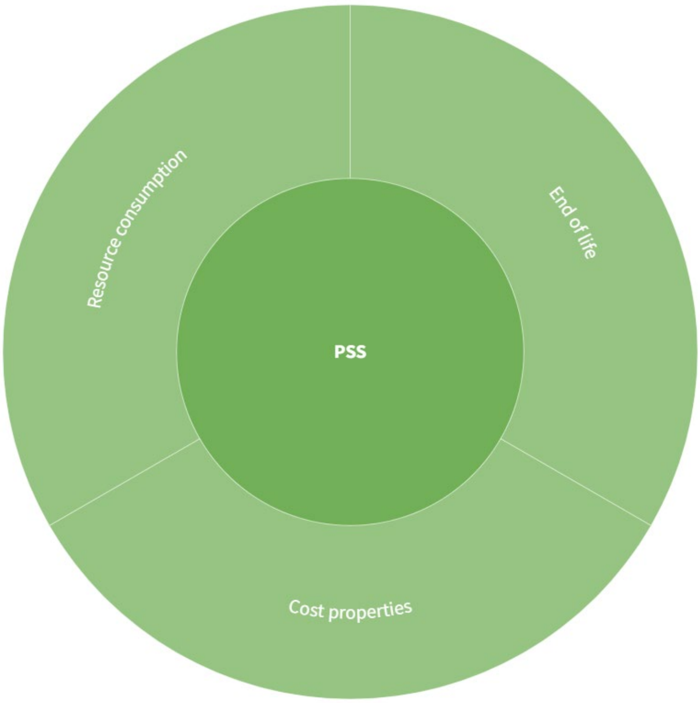


Figure.16. Characteristic of product-service system (PSS)

CONCEPTUAL-FRAMEWORK

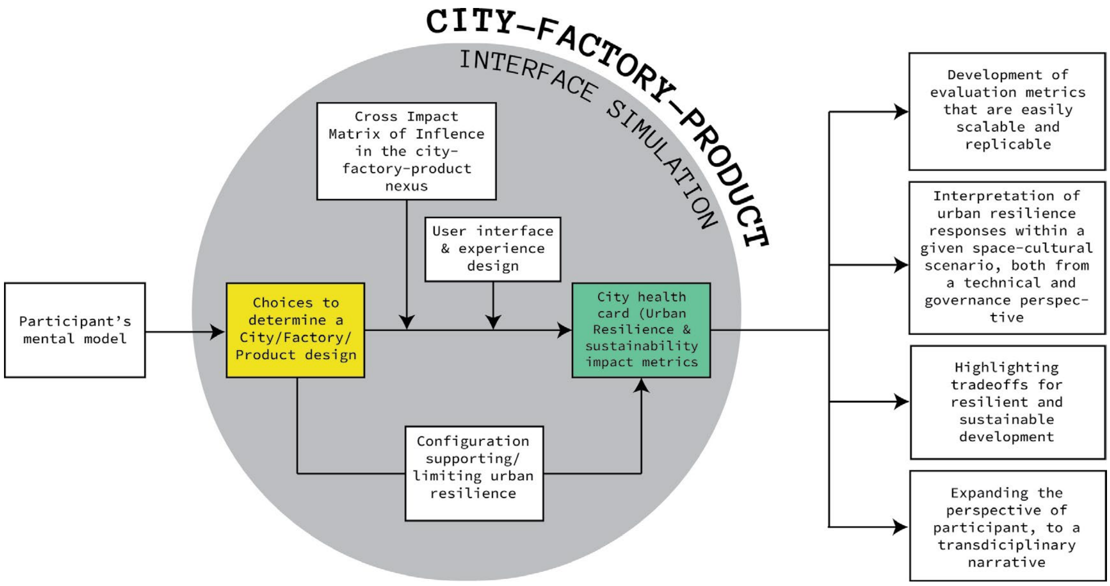


Figure.17. Conceptual framework diagram

In figure 17 the research process is described, highlighting the relationships of each expected variable from the research question and desirable outcomes. To begin to decompose the question "How can a city factory interface be simulated such that configurations supporting urban resilience are explored?" one must start with the user perspective. A participant's mental model describes their own interpretation of information given their life experiences and knowledge base. In this case it specifically addresses the user's perspective and what would influence them to choosing the role of urban planner, factory planner or product designer. It also addresses the way in which the participant interprets the framing of questions in the toolkit. To understand the user's perspective experts were consulted (see more in chapter 3, toolkit framework and logic)

After this the participant interacts with the city-factory-product interface simulation. The first step is the independent variable of 'choices to determine a city/ factory/product design'. This describes the input of the participant during the interactions with the city-factory-product interface simulation. This variable leads to the dependent variable of 'city health card (Urban resilience & sustainability impact metrics)'. This relates to the impacts of the future scenario on urban resilience and sustainability of a city. It can be any output visual or textual that correlates to the user input such that the outcomes on the furthest right of the diagram are achieved.

To get to the dependent variable the input from 'choices to determine a city/factory/ product design' are moderated by variables 'cross-impact matrix of Influence in the city-factory- product nexus' (see further in this chapter) and 'user interface & experience design' (see chapter 4, conceptualization). The 'cross-impact matrix of the influence city-factory-product nexus' variable relates to the relationships derived between those entities and the way that inputs from the user are analysed based upon it. The 'user interface & experience design' relates to the design choices in the prototype of the "city-factory-product

interface simulation".
The choices of the participant in the designed city/factory/product are also mediated by the variable "configuration supporting/limiting urban resilience and sustainability". The degree to which the choices made by the participant match to an ideal future scenario impacts the way in which results are delivered by the dependent variable.

The last part of the conceptual framework are the expected outcomes of answering the research question. There is the potential to develop evaluation metrics for urban resilience that are easily scalable and replicable. This has not yet been applied to the topic of urban factories. There is also the opportunity to interpret urban resilience responses within a given space-cultural scenario, from both a technical and governance perspective. As this toolkit would combine the needs of a city with that of a factory and product[19]. This toolkit can also offer the participant the agency to highlight trade-offs for resilient and sustainable development in cities. And lastly the participant can expand their perspective to a transdisciplinary narrative[28].

DIMENSION	KEYWORD
City	Urban design, urban resilience, urban sustainability, dimensions of urban design, dimensions of urban resilience, sustainable urban design, sustainability, and urban resilience
Factory	Learning factory, urban factory, urban production, smart factory, dimensions of learning factory, dimensions of urban factory, sustainable manufacturing, urban resilient factory design
Product	Product service system, dimension of product design, product characteristics, dimension of PSS, dimensions of product service system, sustainable product design, urban resilient product design

Table.1. Keywords for searching on google scholar and Scopus

METHODOLOGY

To best encapsulate the unspoken but highly influential roles a city has on a factory design and how that impacts the kind of product made; a cross impact matrix of a city-factory-product was created. The goal of the cross-impact matrix was to highlight interesting relationships and form a basis for the working logic of the designed toolkit. This matrix was defined in the following stages: a literature review, defining dimensions, categories, and subcategories, removing redundancies, and scoring the relationship influence of each element.

Using a literature review the morphology of an urban environment (city), an urban production site (factory) and a product-service system (product) was described. For the literature review key terms were detailed for search on Google scholar and Scopus (as seen in table 1). After finding relevant scientific articles, mentions of types of characteristics or dimensions were noted. From this a scope of relevant topics could be detailed to keep within the bounds of answering the sub-research question; “In what ways does a city’s design influence a factory design and their offered products?”.

Once the scope was defined, topics were grouped into dimensions, categories and subcategories. Each subcategory was a then attributed either, minimize, maximize, or achieve positive impact of resulting in a more resilient and sustainable outcome. This is in line with a similar method by Hermann et al.[10].

These categories and subcategories were then mapped onto a cross impact matrix in which their relationships to each other and themselves were evaluated. Because elements of cities, factories and products have an innate influence on each other; some elements were repeated in the morphology of each dimension. Any redundancies that didn’t serve to create any unique or relevant findings were removed from the matrix.

A relationship between two subcategories could have a neutral (or insignificant), mild, or strong influence. These were donated by scores: neutral = 0, mild = 2, and strong = 5. The relationship score for a category, was calculated by using the average of all the subcategories of that category. This means that each subcategory had equal weighing factor. This was done to simplify the matching process and allow for the user to identify of potential elements that would need weighing in the framework of the tool (see chapter 4). After matching all the subcategories in the cross-impact matrix, those with little to no overall influence were removed from the matrix.

$$\begin{matrix} \textit{Event } 1 \\ \textit{Event } 2 \\ \textit{Event } 3 \end{matrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

Figure.18. Example of matrix [27,fig 1]

CROSS-IMPACT MATRIX

The cross-impact matrix was developed by Theodore Gordon and Olaf Helmer in 1965 to A cross-impact matrix is a n x n matrix [aij]. Each cell or entry of the matrix, aij, represents the impact on (or conditional probability of event i given the occurrence of event j [29] .With this tool different events could be compared in a matrix and evaluated based on their influence on one another. The use of the cross-impact matrix follows the type 2 definition by Chao [29]. Here the trend value is measured. This could be the magnitude of impact, for example, on a scale of 1 to 5.

In this case the values assigned to each intersection of subcategories (i.e., events) were assumed based on literature reviews rather than empirical evidence. There is more space for further research into the specific relationships that exist. Also, the influence scores assigned to each intersection had no indication of a positive or negative attribute. This means that an influence can be noted but not in a specific direction. While each sub-category defined does have some indication of minimizing, maximizing, or achieving a positive impact (that being the increased urban resilience of a city-factory-product scenario), this was not included in the matrix due to the qualitative nature of some sub-categories. It would not be possible to be consistent with either a negative or positive attribution to scores as some sub-categories are defined by achieving a specific target.

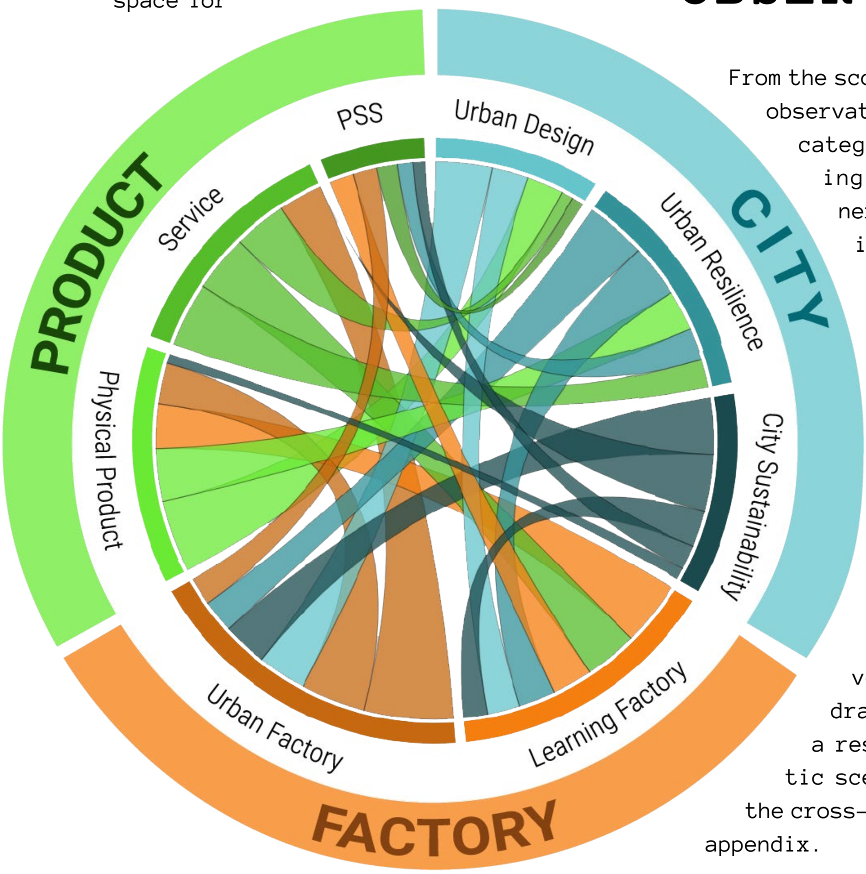


Figure.19. Chord diagram of the inter-connected relationships found in the cross-impact matrix

OBSERVATIONS

From the scores given to subcategories, observations could be made about the categories and dimensions within the city-factory-product nexus. These scores are called influence scores. With this there can be drawn specific conclusions about the influence of one category of a dimension vs another. Thereby allowing for the prioritization of certain aspects and showing the previously difficult to define connection between the city, factory, and product systems. This information can then be used in the development of the toolkit to draw upon user inputs to give a result reflective of a realistic scenario. For more details on the cross-impact matrix please see the appendix.

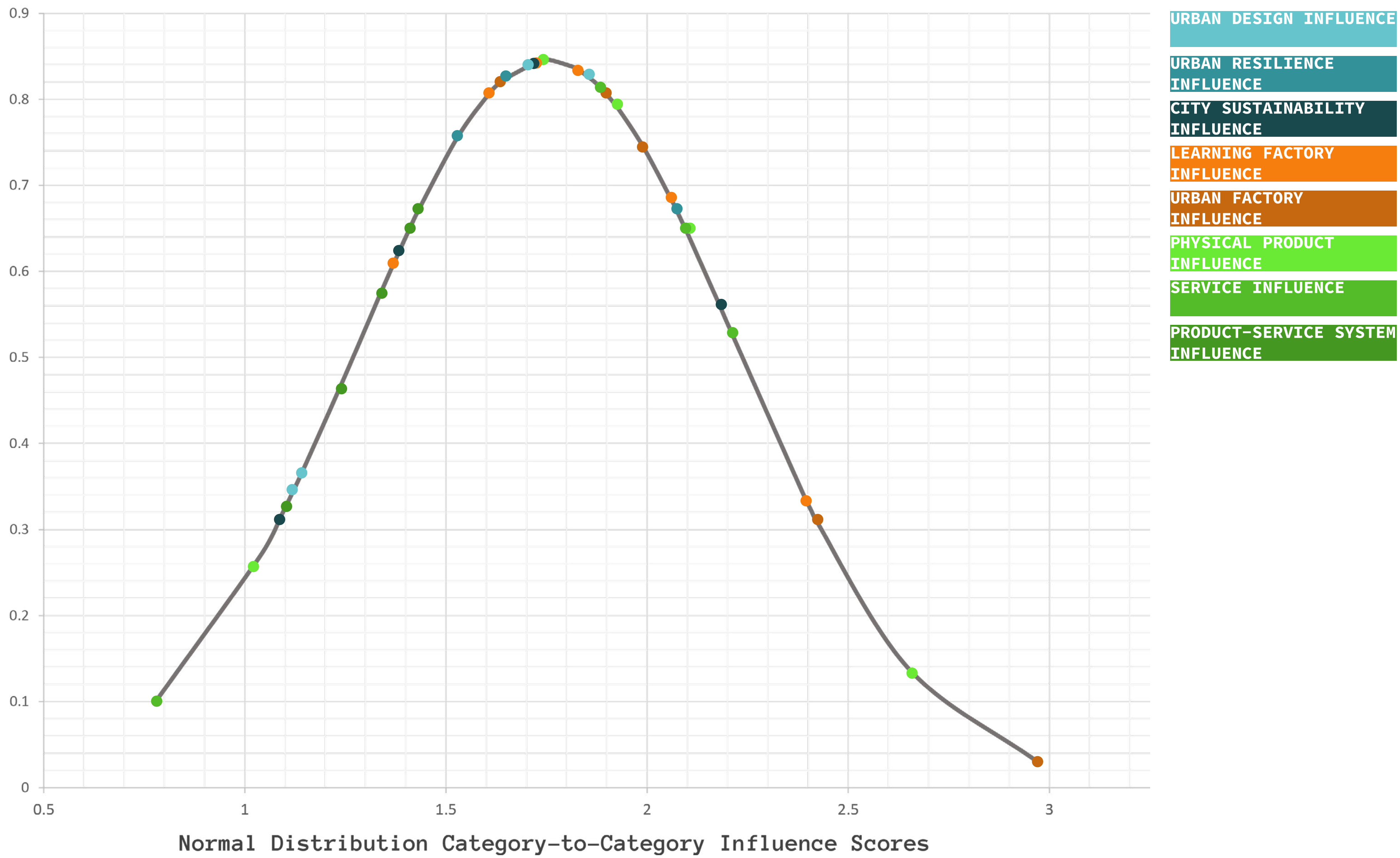


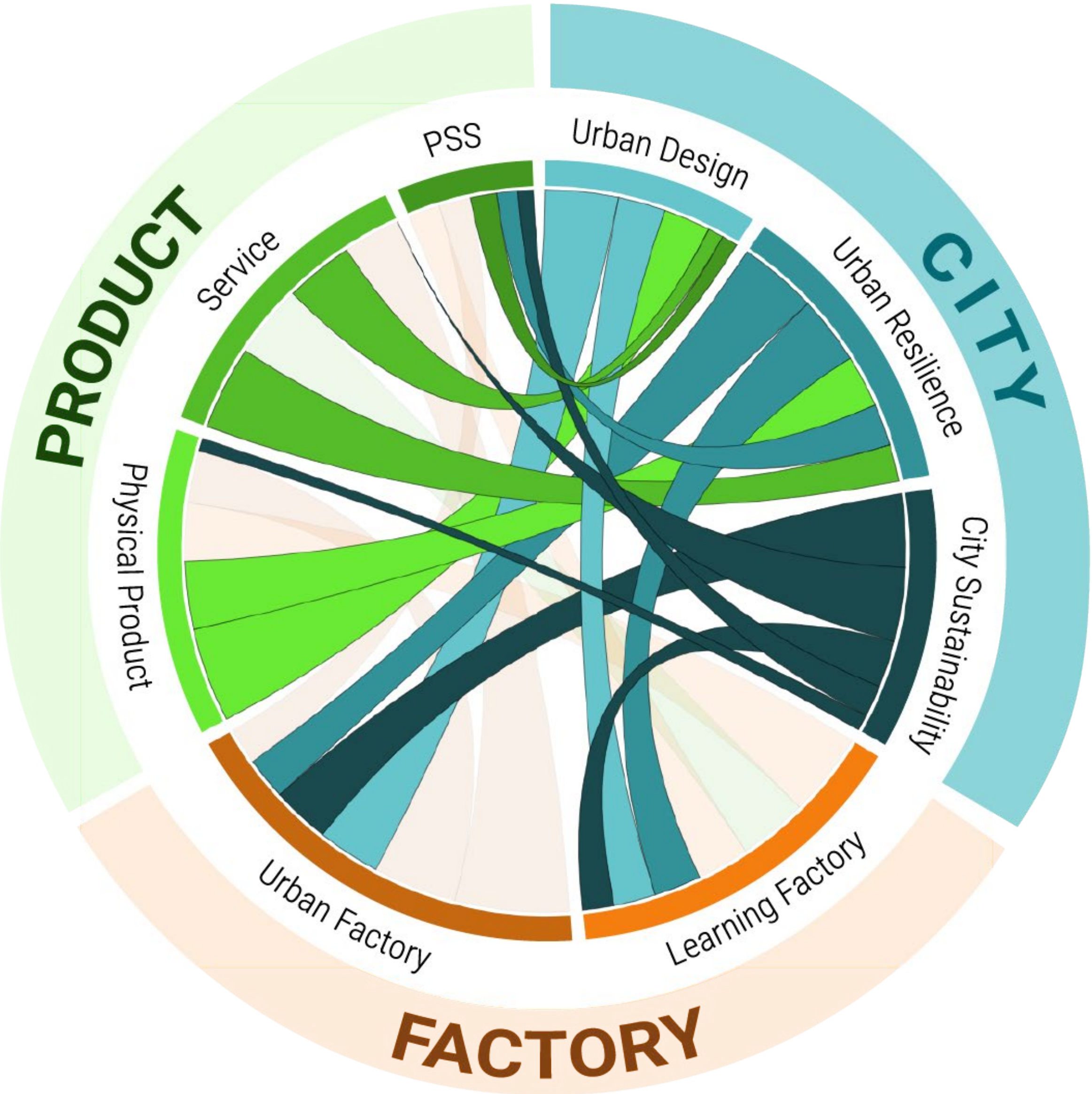
Figure.20. Normal distribution spread of influence scores of each category of a city, factory and product on one another

Two types of charts are used to describe the observations, a chord diagram, and a table. The chord diagram shows the interconnection of entities in a matrix. The size of the chords between entities (also called nodes) shows the relative importance of that connection. The larger the chord thickness the higher the influence score. The colour of the chord relates to the stronger influence flow (that being which category had a positive influence score weight). The values for the diagram were emphasized by taking the difference from the highest and lowest influence scores then adding them to every score value. Influence scores were calculated by taking the average rating of each intersection on the matrix that correlated to the category A acting upon a category B. For example, the urban design category's influence on a physical product category. See the appendix for more details.

Tables show the dimension and categories, influence on another dimension/category. The weight shows which category has a positive or negative influence on the other. This is calculated by the difference of influencing category A minus the influenced category B. The negative score indicates the flow of influence would be coming from the influenced category rather than the influencing category. The positive score would indicate the opposite. These tables can be found in the appendix.

While influence flows are quantified, they are meaningless as a stand-alone number. Context allows for a better understanding of the observations. These scores show trends when they are compared to each other as seen in figure 19. This method allows for the ability to judge and infer meaning to how qualities of abstract and qualitative variables relate to one another. These results of this method should not be interpreted as a summation of all aspects relating to a city, factory and product designed for an urban context. Instead, it should be used to interpret the way the city, factory and product are described and understand the relationships between those entities given the parameters set for them.

Figure.21. Chord diagram describing the influence flows attributed to the city dimension



CITY INFLUENCE

The dimension of city has been described by the flows of influence of the nodes urban design, urban resilience, and city sustainability in figure 21. Of the three nodes urban resilience shows the greatest influence score values as it has the largest arc in the inner circle comprised of all the nodes. After which is city sustainability then urban design.

In the diagram the design of the city greatly influences the factory designed whether it be an urban or learning factory. Urban resilience also has a stronger influence flow than the urban factory and learning factory. Interestingly the product dimension also influences the urban design and urban resilience. With the urban design having very little influence on the service and product service system (PSS) nodes. While the city sustainability does not have the highest influence scores of the city nodes it does have the strongest influence flows. When compared to every other node in the product and factory dimensions, the city sustainability had the stronger influence flow.

CITY INFLUENCE ON PRODUCT.
Table 2 details the values of the specific influence scores of the city dimension on the product dimension, including all the city's categories. The city has an overall influence score of 1.44 on the dimension of product. This score relative to other scores

calculated give it meaning outside of being just a number. This dimension-to-dimension influence score is the lowest of all measured scores. These scores range from 1.44 to 2.10. The higher the score value the more influence that dimension has on another dimension. The urban design score is 1.36. Values for category-to-category influence scores range from 0.18 to 2.97. This means that this value was on the lower end of that spectrum. The subcategory of urban design with the highest influence score is the temporal subcategory. The subcategory with the lowest influence score was the visual category by a wide margin. The category of Urban resilience had a low score of 1.56 with the subcategory of the highest score being the adaptive subcategory and that of the lowest being governance. Lastly, the city sustainability subcategory had a score of 11.29. The highest subcategory value being that of the environmental subcategory by a large 1.1 difference with that of the lowest value of the socio-economic subcategory.

CITY INFLUENCE ON FACTORY.

The overall score of the dimension of city on the dimension of factory is 2.01 as can be seen in table 3. A score on the high range as compared to the other dimension-on-dimension influence scores. The category of urban design had an influence score of 1.93. With the higher influence scores of subcategories ranging between 2.2-2.6, the highest of which was the temporal subcategory. And the much lower values of visual and functional subcategories having 1.1 and 1.6 respectively. The urban resilience category had an influence score of 2.13. Two of its highest scored values were the adaptive and networks subcategory with each scoring a 2.6 value. The lowest subcategory influence score was the inclusive subcategory at 1.9. Lastly the city sustainability subcategory had an influence score of 1.99. The highest subcategory, environmental, had a value of 2.2 while the lowest socio-economic had a value of 2.0.

CITY INFLUENCE ON PRODUCT — Influence score	1.44
Urban Design	**1.36**
Morphology	1.3
Visual	0.6
Perception	1.3
Functional	1.3
Social	1.7
Temporal	1.9
Urban Resilience	**1.56**
Inclusive	1.8
Transformative	1.6
Adaptive	2.4
Governance	0.9
Absorptive	1.3
Networks	2.0
City Sustiainability	**1.29**
Environmental	2.1
Socio-economic	1.0
Economic	1.1

Table.2. City influence on product dimension

CITY INFLUENCE ON FACTORY — Influence score	2.01
Urban Design	**1.93**
Morphology	2.4
Visual	1.1
Perception	2.2
Functional	1.6
Social	2.4
Temporal	2.6
Urban Resilience	**2.13**
Inclusive	1.9
Transformative	2.2
Adaptive	2.6
Governance	1.7
Absorptive	2.5
Networks	2.6
City Sustiainability	**1.99**
Environmental	2.2
Socio-economic	1.8
Economic	2.0

Table.3. City influence on factory dimension

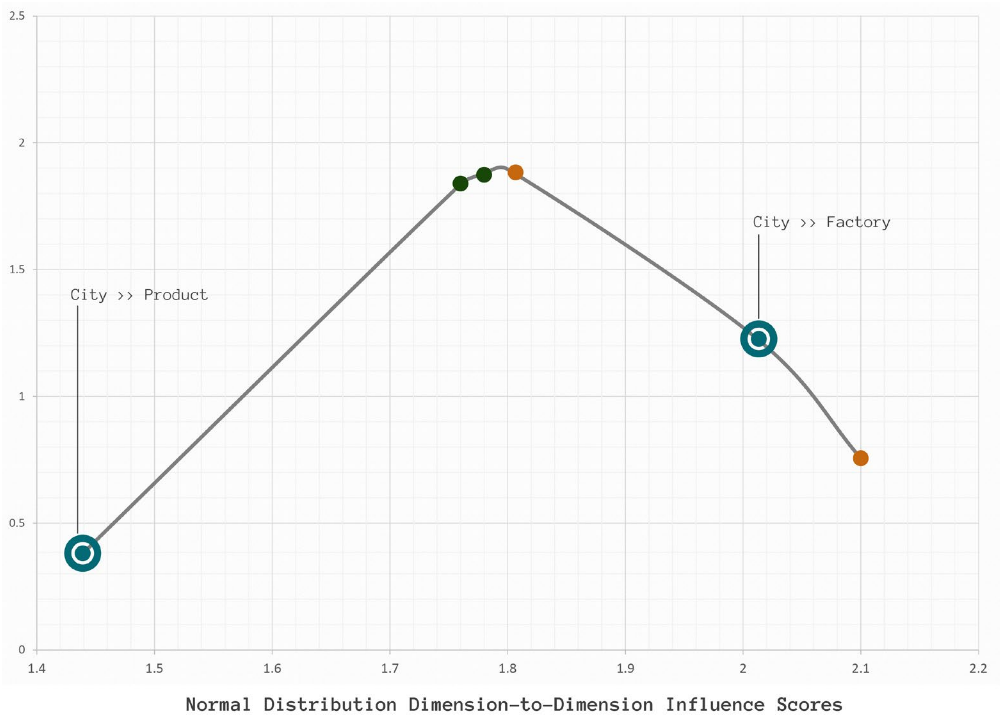


Figure.22. City influence highlighted in the normal distribution spread of influene scores of each dimension city, factory and product.

URBAN RESILIENCE INFLUENCE	**RESULT**

Urban resilience has the highest sum of influence cores as compared to other categories of the city dimension. This category is also shown to be twice as influential over urban factory and PSS as seen in figure 23. The service category has a 2:1 ratio as compared to urban resilience.

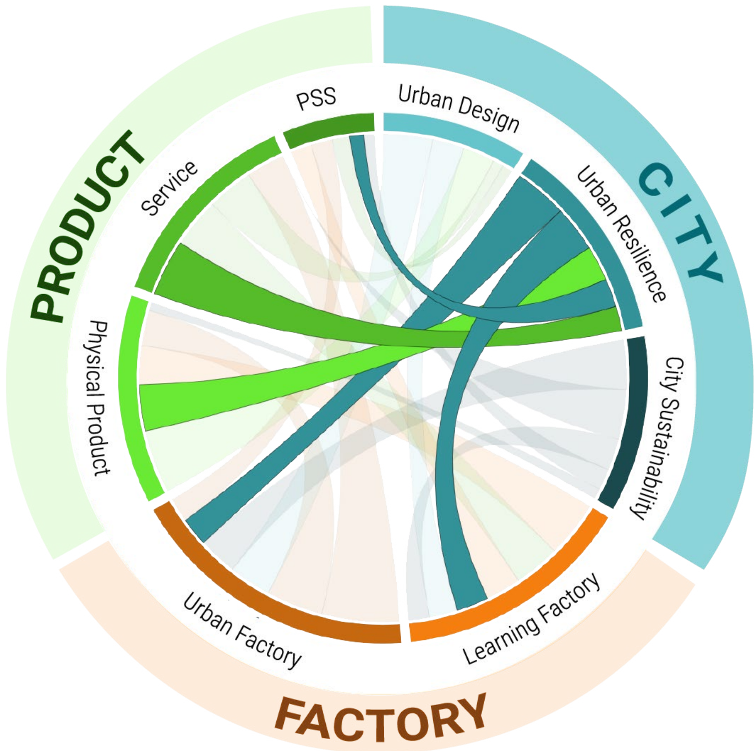


Figure.23. Chord diagram describing the influence flows attributed to urban resilience

URBAN DESIGN INFLUENCE

RESULT

Of all 3 categories that define the dimension of the city, urban design has the lowest total influence scores. As can be seen by the length of the urban design arc in figure 25. It is shorter than the other categories in the city dimension. When looking at the chords connecting urban design to the categories urban factory and learning factory, they have similar thicknesses at either end, with a slight advantage to urban design. This shows the ratios of the influence scores are close to 1. The physical product category has a 2:1 ratio as compared to urban design. Service is notably 4 times as influential as compared to urban design. Lastly urban design and PSS have very low influence scores in either direction.

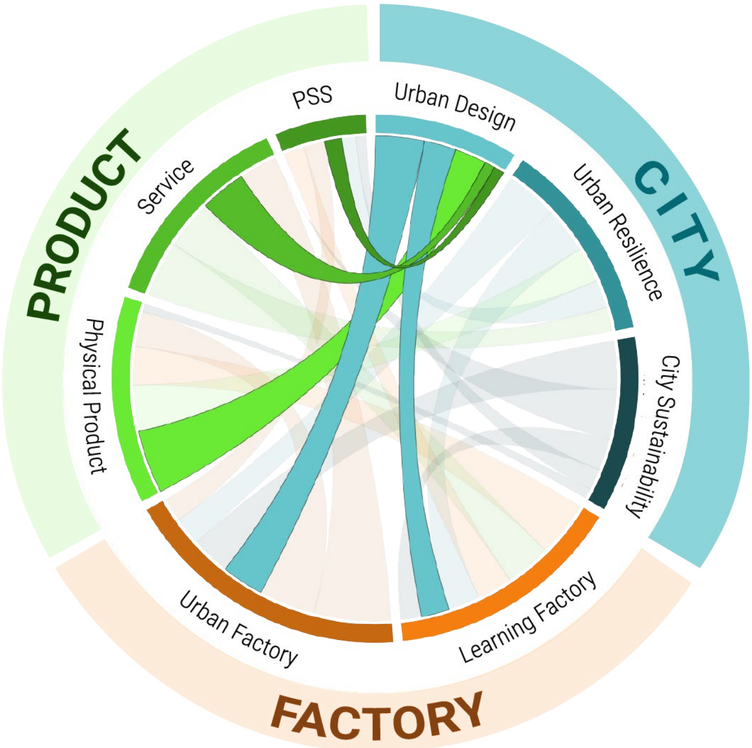


Figure.25. Chord diagram describing the influence flows attributed to urban design

CITY SUSTAINABILITY INFLUENCE

RESULT

City sustainability has the most influence of all the categories in the city dimension. In figure 24 all the chords connected to the city sustainability arc show that it has the higher influence score in all its flows. The flow with the lowest ratio of influence scores in the connection of city sustainability and urban factory. The influence flow ratio is dramatically one sided in the case of city sustainability to PSS and service. City sustainability and physical product have very small influences on each other.

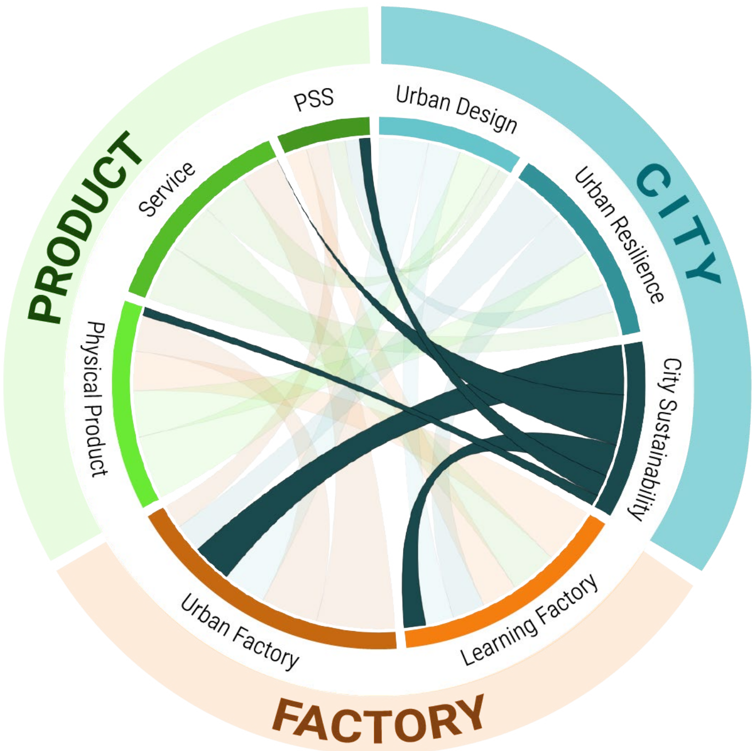
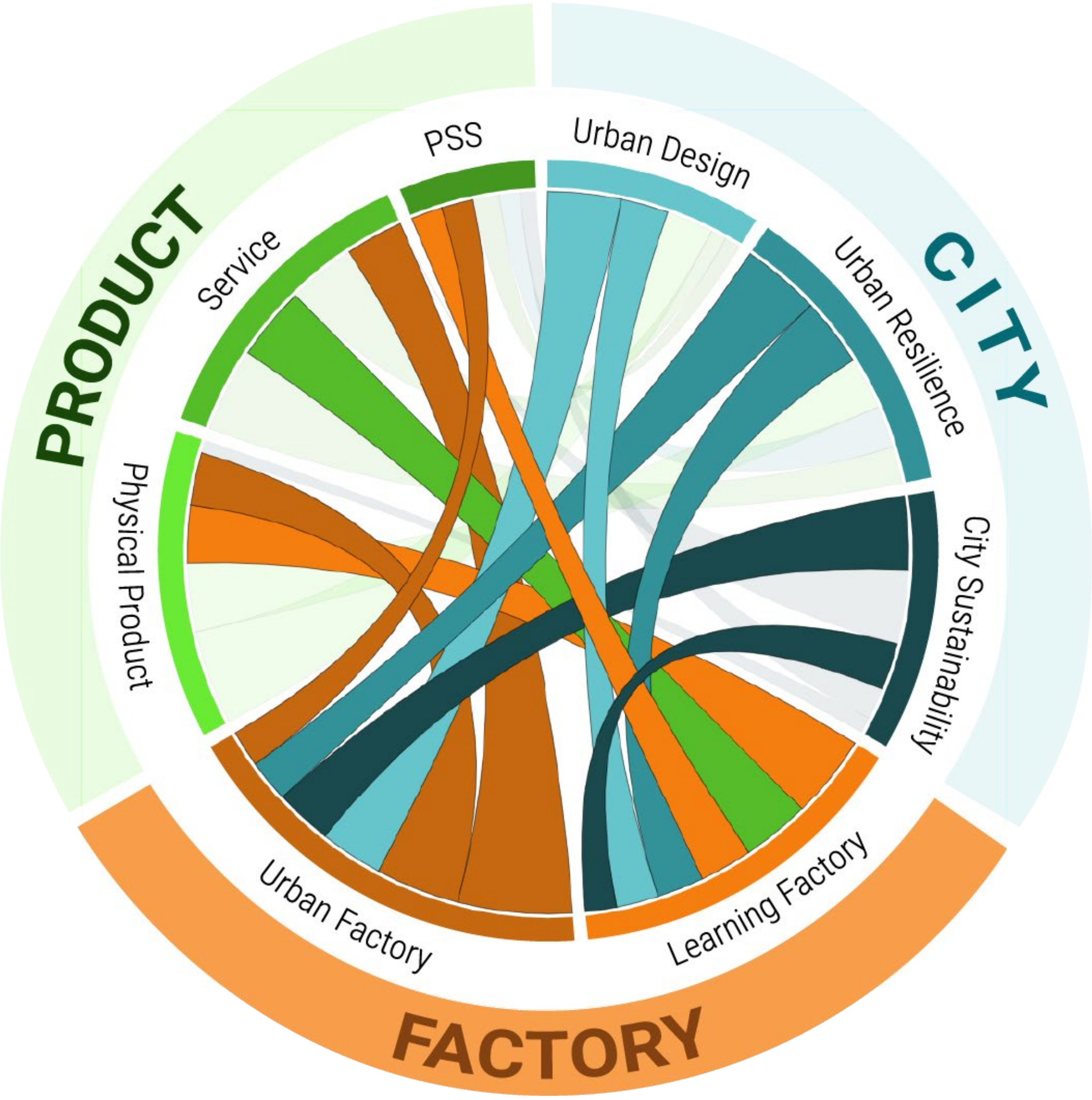


Figure.24. Chord diagram describing the influence flows attributed to city sustainability

Figure.26. Chord diagram describing the influence flows attributed to the factory dimension.



FACTORY INFLUENCE

When understanding the factory perspective in the cross-impact matrix it is important to follow the influence flows detailed in figure 26. The factory dimension is comprised of 2 categories, the learning factory, and the urban factory. The urban factory category is the bigger of the two indicating a higher total influence score.

The dimension of factory has the most influence over the product dimension and its three categories of physical product, service, and PSS. The urban factory category has the highest influence flow towards the service category of the product dimension. Conversely it has the lowest influence flow towards the PSS category of the product dimension. The learning factory category is mostly influenced by other categories than it has an influencing power. The largest influence learning factory has is towards the category of physical product and its lowest influence flow was towards city sustainability.

The city dimension's categories are more influential towards the factory's categories than the factory is on the city. With the factory dimension categories of urban factory and learning factory each having lower influence scores in those influence flow chords. Generally, the city dimension's categories dominated the influence flows between themselves and the learning factory category.

FACTORY INFLUENCE ON CITY

The factory dimension's influence towards city is detailed in the table 4. Dimension-to-dimension factory has a score of 1.8 on the dimension of city. This is on the higher spectrum of dimension-to-dimension influence scores. Learning factory as a category of the factory dimension has an influence score of 1.7 on the city dimension. The highest subcategory influence score of 'urban factory' is resilience with a score of 2.7. The lowest subcategory is logistics & mobility and circular production with a score of 1.3.

FACTORY INFLUENCE ON PRODUCT

The factory dimension's influence towards the dimension of product can be seen in table 5. The influence score of the factory dimension is 2.1, which is towards the higher end of the dimension-to-dimension influence score spectrum. The learning factory category has an influence score of 1.95 on the product dimension. When looking at the figure 27 it can be seen that this is towards the higher end of the category-to-category influence score spectrum. This category has its highest subcategory of a 2.9 influence score being production. The lowest subcategory was that of operating model and purpose & targets with a score of 1.5 each. The urban factory category has an influence score of 2.04 which is also a relatively high value. The highest scoring subcategory of it is factory site & construction with a score of 2.8. The lowest subcategory value was 1.7 for the subcategory of social.

FACTORY INFLUENCE ON CITY — Influence score	1.80
Learning Factory	**1.70**
Operating Model	1.8
Purpose and Targets	1.2
Process	1.3
Setting	1.3
Production	0.8
Urban Factory	**1.94**
Logistics & Mobility	1.3
Technology	1.4
Social	2.2
Circular Production	1.3
Environmental Impact	1.4
Factory Site & Construction	2.2
Economic	2.1
Resilience	2.7

Table.4. Factory influence on city dimension

FACTORY INFLUENCE ON PRODUCT — Influence score	2.10
Learning Factory	**1.95**
Operating Model	1.5
Purpose and Targets	1.5
Process	2.3
Setting	1.9
Production	2.9
Urban Factory	**2.04**
Logistics & Mobility	1.8
Technology	1.9
Social	1.7
Circular Production	2.3
Environmental Impact	2.2
Factory Site & Construction	2.8
Economic	2.1
Resilience	2.4

Table.5. Factory influence on product dimension

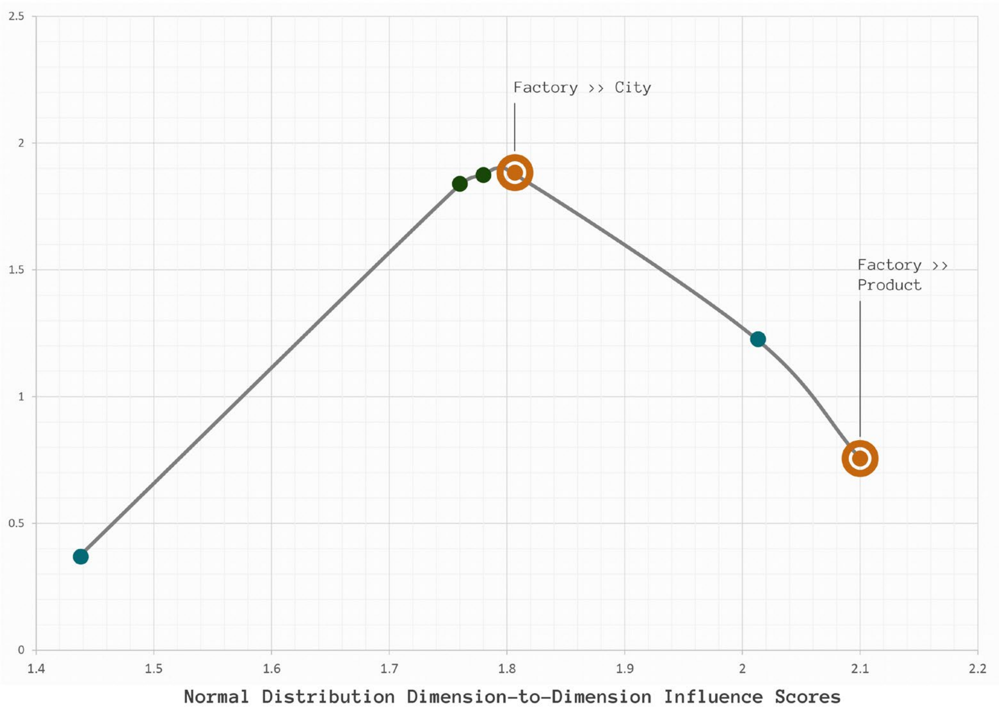


Figure.27. Factory influence highlighted in the normal distribution spread of influene scores of each dimension city, factory and product.

LEARNING FACTORY INFLUENCE

RESULT

The influence of the learning factory in the cross-impact matrix can be seen in figure 29. The learning factory category has an influence flow one and a half times higher than the categories of physical product and urban resilience. The service and urban design categories have a marginally higher score, which means it can be assumed they have the same influence on one another. The learning factory category is of a moderately higher influence flow towards the product service system (PSS) category. The city sustainability category is moderately higher in influence score than the learning factory. Lastly, the urban design category is of a minimally higher influence score than that of the learning factory.

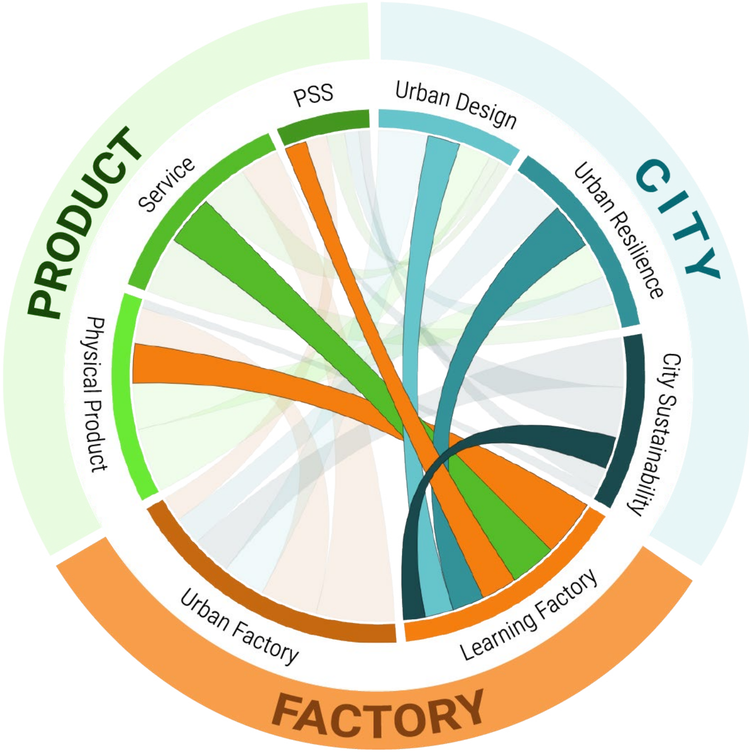


Figure.29. Chord diagram describing the influence flows attributed to learning factory

URBAN FACTORY INFLUENCE

RESULT

The influence flows of the urban factory category are visualized in the figure 28. The urban factory category is twice as influential as the service category. Conversely the urban resilience category has an influence flow twice as large towards urban factory. The urban factory category is one and a half times more influential towards the physical product category. The influence flow of city sustainability towards urban factory is moderately higher. Lastly, the influence flow of urban factory towards the categories of PSS and urban design is marginally higher.

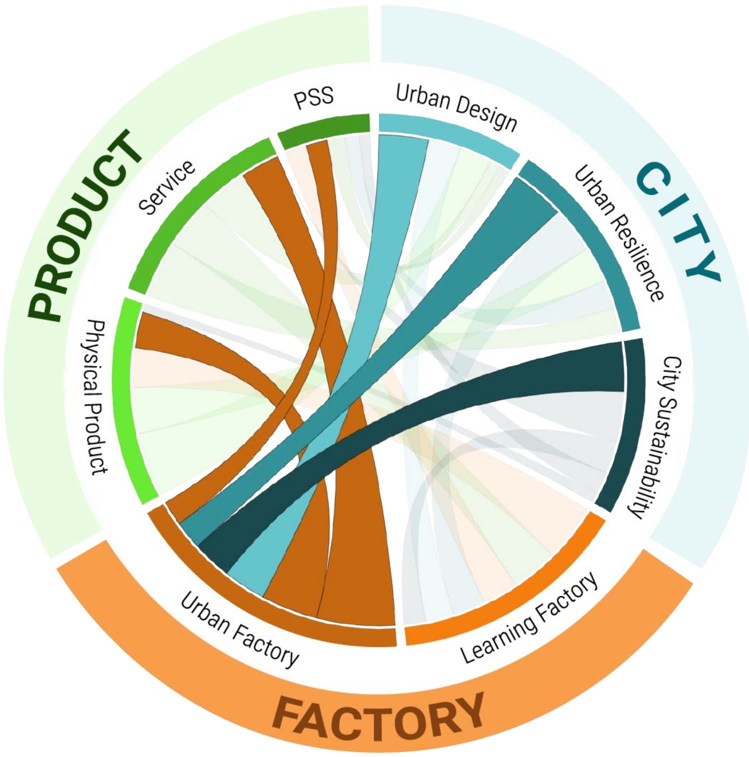
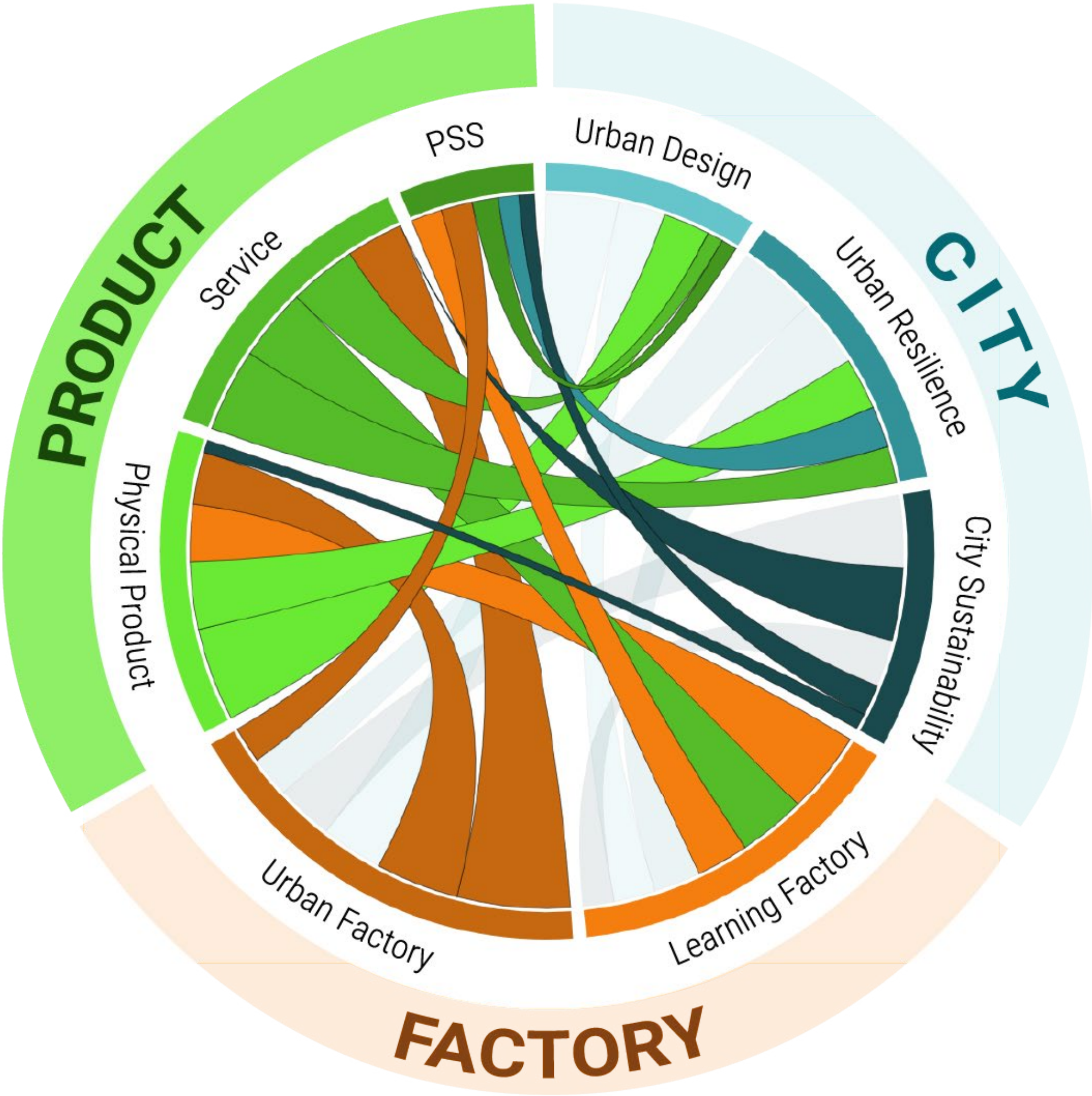


Figure.28. Chord diagram describing the influence flows attributed to urban factory

Figure.30. Chord diagram describing the influence flows attributed to the product dimension.



PRODUCT INFLUENCE

When looking at the product dimension in figure 30 the service and physical product categories seem to have almost equal influence score totals with PSS having a much lower influence. The physical product's design has the most influence over the urban design category and the least towards the city sustainability category.

The dimension of city has been described by the flows of influence of the nodes urban design, urban resilience, and city sustainability in figure 30. Of the three nodes urban resilience shows the greatest influence score values as it has the largest arc in the inner circle comprised of all the nodes. After which is city sustainability then urban design.

From the diagram it can be seen that the design of the city greatly influences the factory designed whether it be an urban or learning factory. Urban resilience also has a stronger influence flow than the urban factory and learning factory. Interestingly the products dimension also influences the urban design and urban resilience. With the urban design having very little influence on the service and product service system (PSS) nodes. While the city sustainability does not have the highest influence scores of the city nodes it does have the strongest influence flows. When compared to every other node in the product and factory dimensions, the city sustainability had the stronger influence flow.

The dimension-to-dimension influence of product on city and factory are towards the centre of the distribution of values as seen in the figure 31. The product's influence on the city dimension is a value of 1.76. The physical product category of the product dimension is the most influential of the categories on the city, with the highest subcategory of it being use design and the lowest being the material component (for more details see appendix) The service category is the next highest in the product dimension's categories with a score of 2.06 influence. The maintenance of the product is more influential on the city dimension than customer integration than customer integration. Lastly the product service system had a much lower influence score total on city. With the economic subcategory having the most influence and the end of life of the product the least.

The average influence of the product dimension on the factory was slightly higher than that of its relation to the city dimension, with a score of 1.78. The most influential subcategory of the product dimension on the factory was service, then physical product then lastly PSS. The maintenance of the product had more influence than the customer integration over the factory dimension. The material components were the most influential of the physical product with the use design being the least influential subcategory. The product service system had a much lower influence score as compared to the other categories (see appendix). The economic subcategory of PSS was the most influential on the factory with end of life being the least.

PRODUCT INFLUENCE ON CITY	Influence score 1.76
Physical Product	**2.19**
Material Components	1.8
Use Design	2.4
Function	2.2
Service	**2.06**
Maintenance	2.3
Customer Integration	1.5
Product Service System	**1.07**
End of Life	0.6
Resource Consumption	1.1
Cost Properties	2.3

Table.6. Product influence on city dimension

PRODUCT INFLUENCE ON FACTORY	Influence score 1.78
Physical Product	**1.72**
Material Components	2.2
Use Design	1.5
Function	1.7
Service	**2.10**
Maintenance	2.3
Customer Integration	1.7
Product Service System	**1.33**
End of Life	0.7
Resource Consumption	1.3
Cost Properties	2.2

Table.7. Product influence on factory dimension

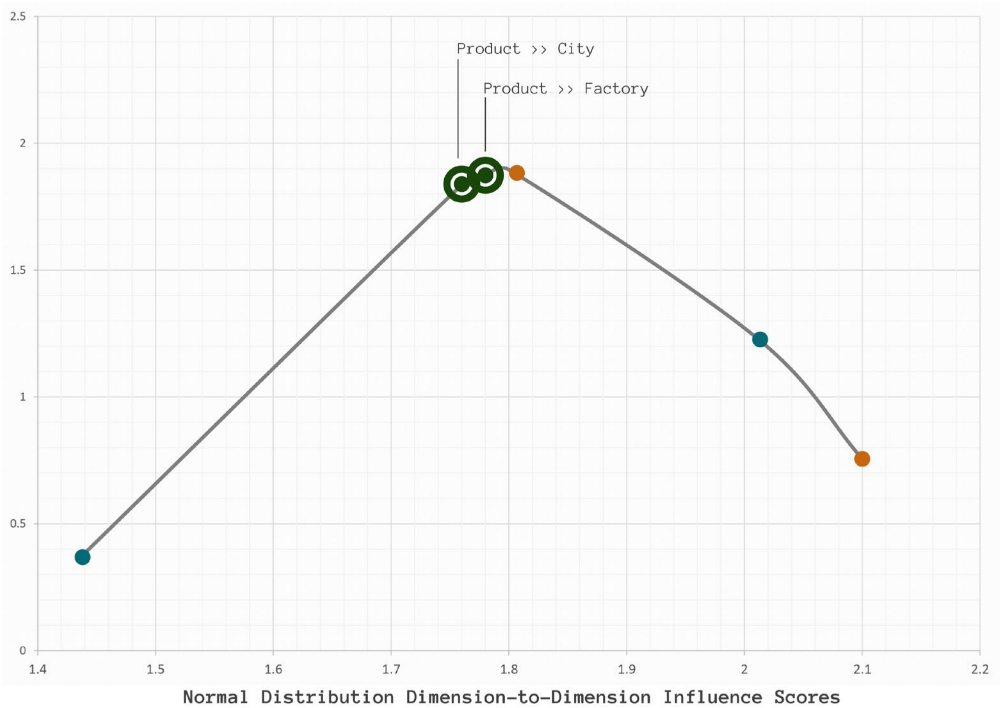


Figure.31. Product influence highlighted in the normal distribution spread of influene scores of each dimension city, factory and product.

PRODUCT SERVICE SYSTEM INFLUENCE	**RESULT**

Overall, the product service system has low influence score totals on the other categories of the city and factory dimensions. PSS has a negative influence weight in the influence weights towards the categories of the factory dimension. With both the urban and learning factory categories having the advantage in those influence flows. Towards the city dimension PSS has negative influence weights in the influence flows towards the urban resilience and city sustainability. It has a small but positive influence weight in the flow towards urban design.

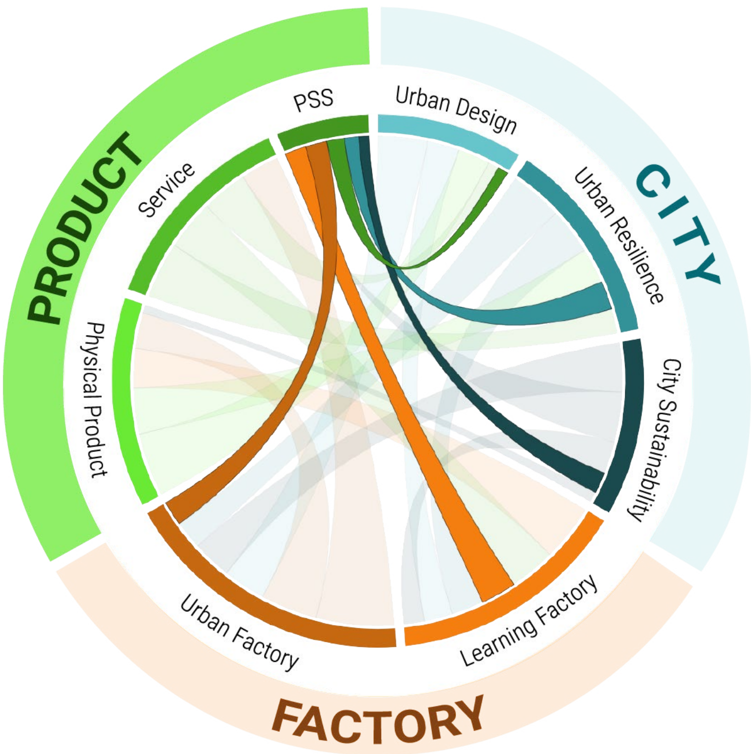


Figure.32. Chord diagram describing the influence flows attributed to PSS

PHYSICAL PRODUCT INFLUENCE

RESULT

To understand the influence of the physical product category of the product dimension observe figure 34. Urban design largest influence as seen by the thickness of its chord towards urban design. In this influence flow the physical product has a positive weight towards urban design. Urban Resilience similarly has a large influence flow of the physical product towards it. This influence flow has a positive weight in favour of the physical product also. The influence flows from the physical product towards the factory categories have a negative weight to them. Thus, urban factory and learning factory have more influence on the physical product category and not vice versa. Lastly the influence flow of the physical product and the city sustainability is quite low. This is also a negative weighted flow relationship.

Figure.34. Chord diagram describing the influence flows attributed to physical product

SERVICE INFLUENCE

RESULT

The service category has a large positive influence weight in the influence weight towards urban resilience. This category also has a large positive influence weight towards learning factory and urban design. The influence flow of the service category towards urban factory is twice as small as the influence score of the urban factory towards the service category. This is a large negative influence weight. Lastly, the service category also has a very low influence towards city sustainability. And does not influence it in a meaningful way according to the cross-impact matrix.

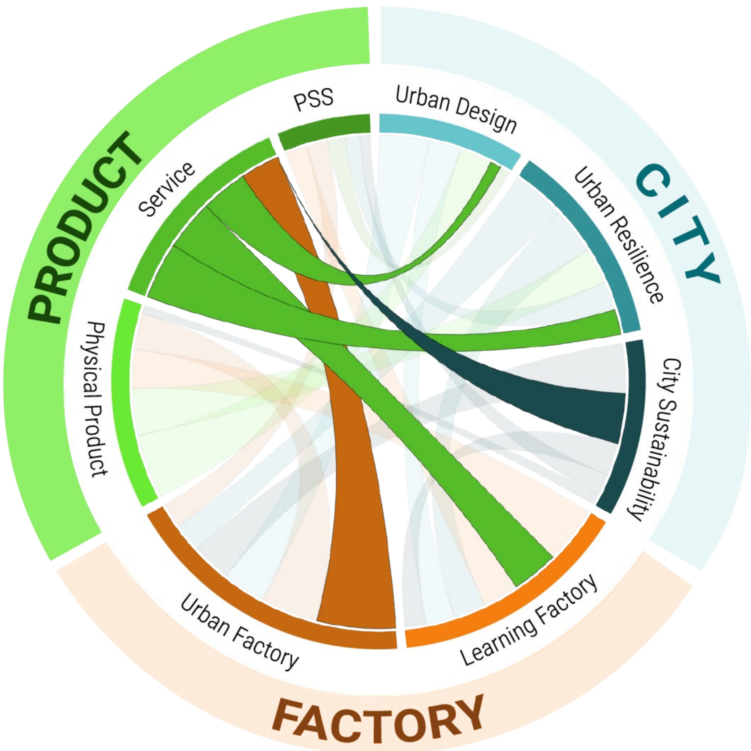


Figure.33. Chord diagram describing the influence flows attributed to service

DISCUSSION

Interesting trends were uncovered from the observations of the cross-impact matrix. The connections relating to resilience and sustainability are important to highlight as it helps to answer the sub research question “How can urban resilience goals be translated into metrics that apply to a factory set in an urban context and products for a local market?” The discussion will focus on notable influence flows relating to urban resilience and city sustainability.

URBAN RESILIENCE

INFLUENCE FLOW TOWARDS FACTORY DIMENSION

Urban resilience dominates influence flows towards the categories of the factory dimension. The subcategories of networks and adaptive, had the highest influence score of 2.6 in that category. The absorptive category was a close second with a score of 2.5. The influence of networks extends to aspects relating to circular production, processes and factory site and construction. The network subcategory is about the material and energy flows in the city as well as the transportation network. Considering this it is evident that circular production is greatly influenced by how materials are sourced and disposed of, as well as environmental impacts stemming from energy use and transportation. Energy usage is also related to processes and factory site and construction, as the types of equipment used in the factory will result in the majority of the energy usage.

The adaptivity category influences the circular production, the factory site and construction as well as the resilience of the factory itself the most. Factories (both learning and urban) are required to be robust to severe weather and keep track of data by updating standards and analysing data. In urban environments, severe weather conditions can include flooding or overheating because of the nature of the built environment. Trends and shifts in consumer behaviour and culture emanate from city centres outwards. With many early adopters located in populus areas. To keep relevancy, factories have to keep track of their data. Even more so if they take advantage of personalization of their products. The resilience on the factory internally and externally is dependent on these things. The way the factory is constructed, and methods of production are closely linked to its capacity for circular production. The extent to which a factory can become circular is often dictated by the policies and regulations of the city it is in. Factories therefore have to respond to the adaptive nature of a city. Policies are generally stricter when manufacturing is closer to people. The absorptive subcategory is also important to mention as it had an influence score of 2.5. It impacts the production, factory site and construction and resilience of the factory. The absorptive capacity in the urban resilience deals with having flexibility to shock situations as well as redundancies as fail-safe measures. This means that factories have to remain flexible to changes in stakeholder needs, supply chains and emerging markets. Redundancy measures help to absorb shocks, an example of this could be a city’s measures to make their electricity grids with higher modularity. A choice like this can influence choices made internally in the factory about energy uses in production.

INFLUENCE FLOW TOWARDS PRODUCT DIMENSION

Physical product and service categories of the product dimension are more influential towards urban resilience than vice versa. While the category of product-service system is less influential than urban resilience. Looking at the subcategories of physical product, use design and function are the ones of most influence on urban resilience. In particular it is the inclusive and transformative aspects of urban resilience that are impacted most by the use design of the product. The use design should encourage a sense of ownership and foster community participation, as urban factories are in the unique position of being highly interconnected with a local area. A product’s design can serve the needs of the community while empowering them and allowing them to develop a sense of identity. The transformative aspect of urban resilience is also influenced by the use design, as it specifically relates to risk management. Using responsible design techniques, the use design of the product can try to anticipate the side effects/unwanted outcomes of the product as it relates to its impact on the consumer and the society.

The functionality of the product influences the adaptive and absorptive capacity of urban resilience. By considering the lifetime of the product, consumption in use and functional complexity of the product, safeguards can be implemented. Theses safeguards can focus on the response to the climate and environmental conditions of the product's use. The more a product is designed to accommodate these factors the more adaptive the citizens of that urban space can become. The changes to the functionality aspects can also influence how flexible conditions are and how redundancies can be built into the design.

The most influential aspect of the service category on urban resilience is maintenance. Maintenance allows for self-organization and risk management. Designing products to be maintained gives users' autonomy. When citizens have the skills and resources to adjust to situations this increases urban resilience. Maintenance also accounts for the possibility for users to manage risk. The design for maintenance also gives a moment to reflect on old standards and collect data about how the product is used.

The product service system category does not have a large influence flow as compared to the rest of the cross-impact matrix. The influence is marginal however the adaptive aspect of urban resilience does push for more conscious resource consumption. With a push for innovation being important for a city's adaptability this requires a particular demand on skilled human resources.

CITY SUSTAINABILITY

INFLUENCE FLOW TOWARDS FACTORY

The environmental subcategory of city sustainability is the one of the most influence on the factory and relates to the environmental condition of the urban space. Factors such as the environmental impact of the factory, the factory site and construction and the factory's resilience all are impacted environmental standards of the city. These standards include access to clean water air and greenspaces, waste management, renewable energy, and the overall ecological footprint of the city. These environmental conditions have precedence over the design wishes of the factory (whether urban/learning). The factory site and construction will be energy intensive once the site is built and as well as from the machines involved in future production. The goals for the factory's environmental impact standards can also be highly regulated by a city's municipality and national government. The ability of the factory to both comply with these standard and remain profitable also determines the resilience of it.

The socioeconomic subcategory is the category of the least influence on the factory dimension. As with the city's environmental conditions, the factory resilience is impacted by the socioeconomic category. This relates to the external and internal adversity of the factory. Socioeconomic factors can determine the political leanings of the citizens in an urban space, as well as their ability to stay healthy and productive at work. Satisfaction with the city workers live in has a huge deciding factor in which kinds of jobs they chose to apply to as well. The integration of certain technologies is also limited by the skill capacity of the local workforce. Factors such as population age and access to schooling affects, he adoption of certain high-tech practices in learning and urban factories.

Lastly the economic category influences the operating, process, and resilience categories of the factory dimension. The main driver for development is money, there is no factory to operate without that initial investment in the development. Cities are limited by the economic realities of the municipality and existing markets. There is the ability for a factory to create an emerging market, however it is similar to the chicken and egg story but only who invests when. The factory and product lifecycles are also greatly influenced by the local and economic conditions. The choice in processes elating to those two are shaped by the economic constraints of the economies in which these factories become part of. The resilience of the factory is influenced by its ability to fund itself and be competitive in the economic conditions it is in.

INFLUENCE FLOW TOWARDS PRODUCT

The most influential subcategory of city sustainability is the environmental one as it is twice as influential of both socio-economic and the economic subcategories. The environmental subcategory of city sustainability mostly influences the maintenance, end of life and resource consumption of a designed product. The way a product can be maintained is limited by the legislations regarding the safety of exposing the internal components of that product to the consumer. While being able to maintain a product gives consumers a higher level of agency and allows for an extended lifetime of a product, the municipality and national government have to keep them safe. Exposure to chemicals or use of machinery by untrained individuals can result in more harm than good. The end of life of a product is also greatly impacted by the logistical opportunities for waste management in an area. While a producer may want to implement reuse or recycling practices if there isn't a supporting infrastructure available to them the likelihood of adopting these practices is low. The resources used to produce a product locally are limited to what is available in the immediate area. If the local supply chain is unstable or limited this will force producers to go outwards regionally and internationally.

The socioeconomic subcategory mostly influences the resource consumption capability of a product. In this case the resource consumption is not about the ability to extract resources from local ecosystems but about the availability of human resources. The population make up of the city has to include both the quantity and quality of workers needed to produce goods in an urban factory. Many urban factories focus on high tech product offerings. These products require employees with higher education and specific skill sets that could be limited in the population make up of a certain city.

Lastly, the economic subcategory of city sustainability impacts cost properties of a product the most, specifically the cost of the product. The economic growth of the city impacts the product cost, as this gives an indication to the cost of labor, the availability of a market for the product and possible support from local governmental bodies. The cost of the product is something dependent on the context in which it would be sold, in the case of urban manufacturing that would be locally and regionally.

LIMITATIONS

This method does have the risk of oversimplification of complex concepts. The differences in knowledge basis of urban concepts vs factory design and product design makes for a difficult comparison when discussing relationships involved in urban factories. Therefore, the trade off is made between encapsulating the full view of these parts of the city-factory-product nexus and making assumptions about their relation to one another. The cross-impact matrix is also can become a tedious method if the detail and number of variables increases. This method also doesn't highlight if a relationship has a positive or negative impact just the strength of the influence. Also like the life cycle assessment, it is a time dependent model and takes into consideration what factors are most important to include based on what is relevant in the present day. This information could become outdated in the future.

CHAPTER ROUND UP

URBAN RESILIENCE

Urban resilience dominates influence flows towards the categories of the factory dimension. It particularly influences choices made about circular production, the factory site and the factory's resilience. The aspects of a product such as the physical and service design are more influential towards urban resilience. Aspects such as inclusivity, adaptability and the ability to absorb risk were all influenced by the product's design

CITY SUSTAINABILITY

The environmental aspect of sustainability was the most influential on both the factory and product design. While the socio economic and economic factors were of similar lesser influence. Legislations designed to protect citizens needs, the skills and motivation of the citizens and the conomic environment of the city more specifically influenced the factory and product design.

In this chapter the concepts of city factory and product were detailed in relation to the research question as well as the methodology and outcomes of the cross-impact matrix.

Here the relationships between each dimension were shown as influence flows. Through this description one can begin to understand how impacts made in one dimension can influence another and vice versa. With this knowledge a toolkit could be further developed so that a layman can explore these interrelationships.

In chapter 3 Toolkit framework and logic the research looks at the human interaction side of the toolkit as well as integrating the outcomes of chapter 2 in a logical way. Here theory is translated into practical application.

CHAPTER 3

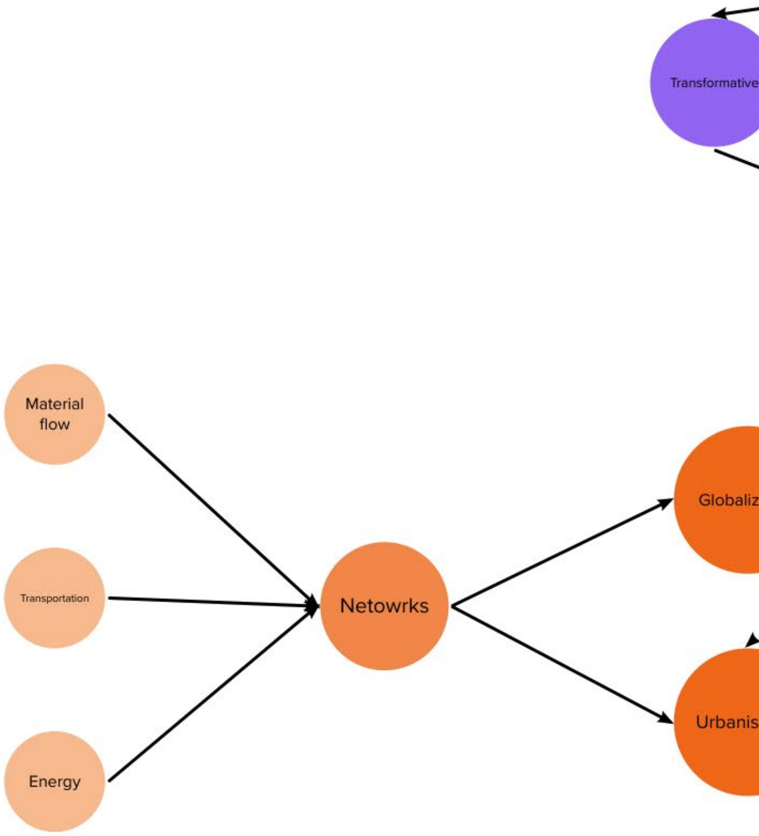
TOOLKIT FRAMEWORK AND LOGIC

PROBLEM MAPPING

The manufacturing industry has to evolve with the needs of its customer by taking advantage of the latest technical advancements. Customers want more personalization, authenticity, and responsible products. However, some needs are based on the larger benefits to society of how products are produced. It is hard to visualize how to align current manufacturing standards to one in an urban setting.

This moves manufacturing into the more densely populated areas at a time when urbanization is on the rise in Europe and gentrification is pushing urban sprawl. The manufacturing industry can benefit from seeing how a resilient factory environment interacts with a city context. In this way the topic of urban resilience and manufacturing can venture into practical applications instead of just the theoretical realm.

The logical influence diagram (figure 35) shows how the concept of reliant urban factories is interrelated to other topics in this research.



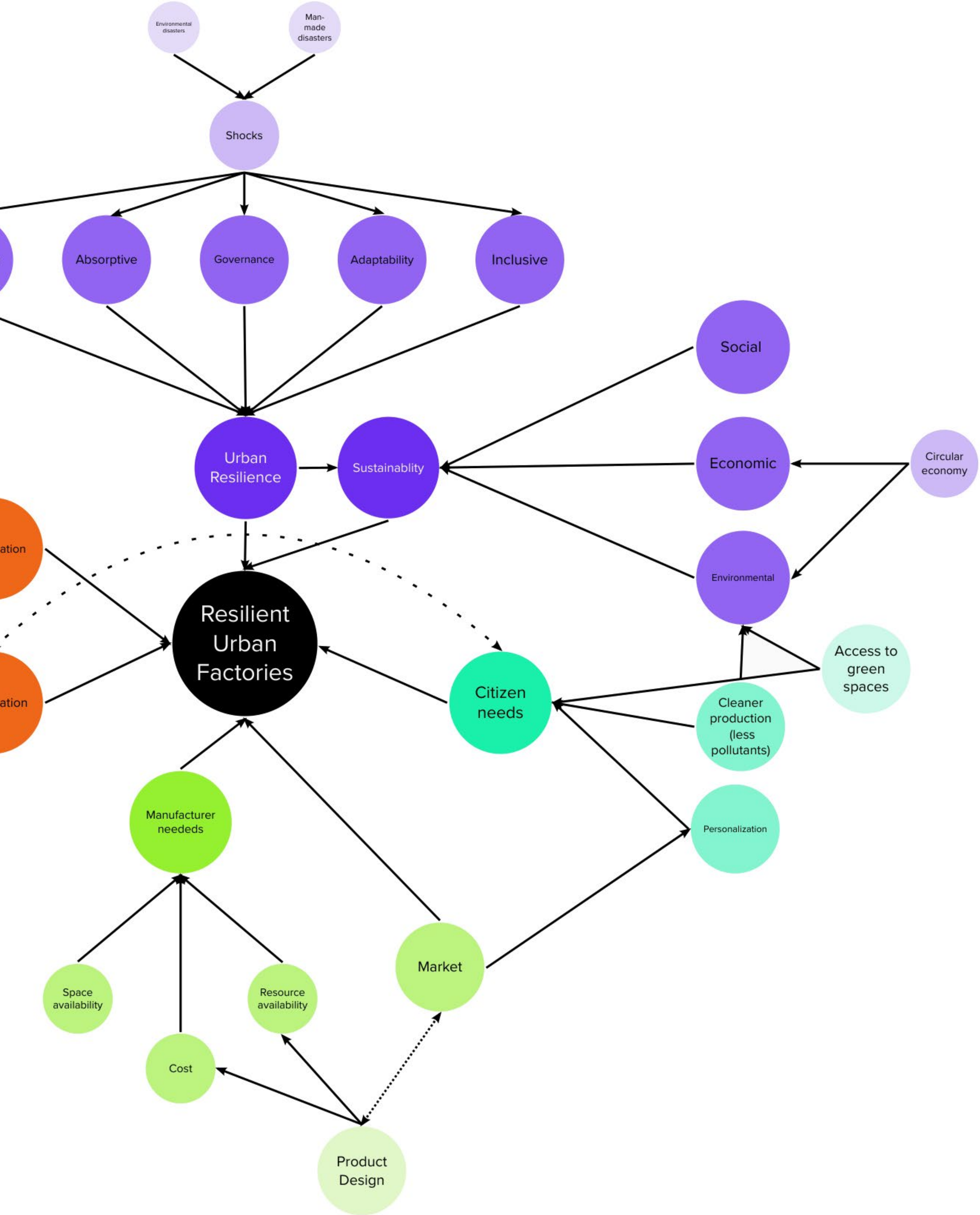


Figure.35. Logical influence diagram of resilient urban factories

UNDERSTANDING STAKEHOLDERS

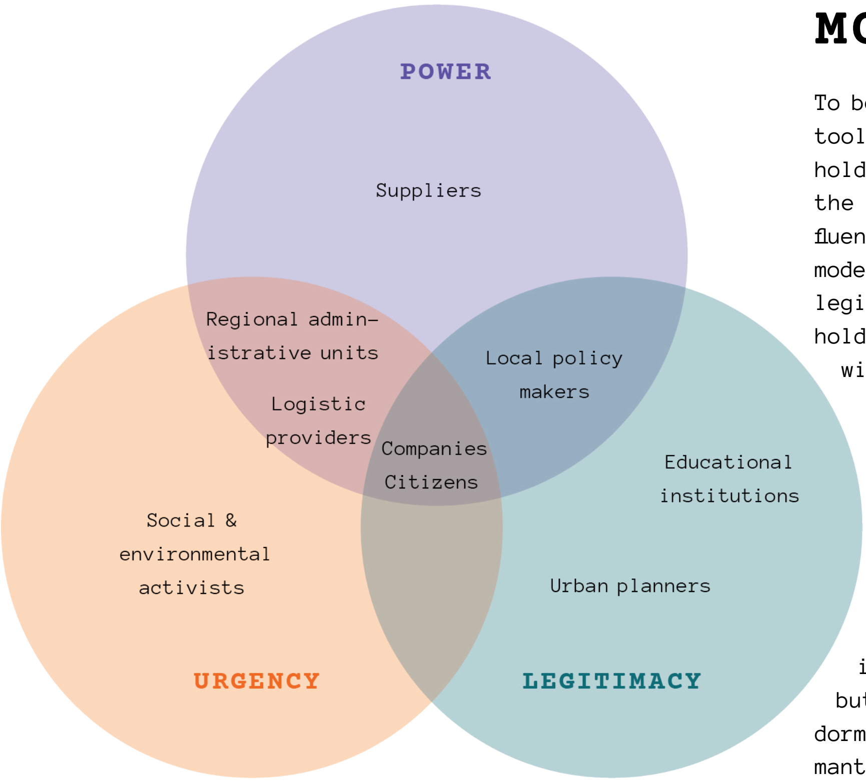


Figure.36. Salience model diagram of the stakeholders involved.

HIGH PRIORITY STAKEHOLDERS

The stakeholders who possess all three traits of power, legitimacy and urgency are called definitive stakeholders. These are the most important stakeholders to consider. The definitive stakeholders identified were industrial companies as well citizens. Industrial companies are evolving rapidly because of the increase in market growth of technology and have gained power and legitimacy through this growth. Citizens are workers and consumers, they have the highest legitimacy when it comes to urban spaces they inhabit, they also have democratic and purchasing power. All changes in their urban environment are immediately of importance to them so they also possess urgency.

SALIENCE MODEL

To best understand the use of the proposed toolkit one must first identify the stakeholders that will be affected by it. Using the saliency model by SOURCE the most influential stakeholders were identified. This model groups stakeholders according to their legitimacy, power, and urgency. The stakeholders who possess all 3 traits are those with the highest priority.

LOW PRIORITY STAKEHOLDERS

The stakeholders possessing urgency but lack power and legitimacy are called demanding stakeholders. In this case a demanding stakeholder was identified as social and environmental activists. The stakeholder possessing power but not urgency or legitimacy are called dormant stakeholders. An example of a dormant stakeholder in this case are suppliers. The stakeholder possessing legitimacy but neither power nor urgency are called discretionary stakeholders. In this scenario that would be educational institutions.

MID PRIORITY STAKEHOLDERS

Stakeholders with two of the three characteristics are mid-priority stakeholders as they are more motivated, powerful, and legitimate than the previously mentioned stakeholders. Stakeholders possessing characteristics of both power and urgency are described as dangerous stakeholders. Although these are not your main stakeholders they have to be watched as they can gain legitimacy and become a main stakeholder with time. These stakeholders are regional and international administrative units as well as logistic providers. Stakeholders possessing traits of legitimacy and power are described as dominant stakeholders. Some examples of these are local policy makers and urban planners. In this scenario there are no stakeholders identified as being both legitimate and urgent.

EXPERT INTERVIEWS

In this project 4 different experts were interviewed, an urban planner, a researcher specializing in urban resilience a project manager for a science and business park as well as an expert in SME development.

URBAN RESILIENCE INTERVIEW:

Urban resilience is a concept based in social sciences and as such is outside the knowledge base of an engineer. There was therefore the need to consult with an expert on the topic of urban resilience. In the interview with the researcher on the topic of urban resilience they highlighted the importance of community building, agency and accessibility. The development of a toolkit to explore urban manufacturing with the aim of urban resilience was seen as a potential opportunity for small scale local entrepreneurs to flourish. These could be potentially first-time business owners. Because urban resilience focuses on inclusivity and more connectedness within communities and their local government, a potential toolkit could be seen to facilitate this. While this researcher has worked on digital interactions before they mentioned a preference towards codesign sessions and workshops in person. The researcher also stressed the importance of democratizing information and access to resources to achieve resilient production in cities.

URBAN PLANNING INTERVIEW:

The perspective of a city planner also proved to be invaluable as the expert highlighted areas of opportunity for urban manufacturing, limiting factors and insight into decision making of municipalities. The interview was centred around Enschede as this urban planner was currently working for that municipality. In the city centre of Enschede there are a lot of old empty buildings from the textile industrial age. This presents a good opportunity for urban manufacturing as those buildings can be converted into high tech factories. The interviewee thought that mixed use spaces could provide benefit to citizens through making different parts of their daily lives more interconnected. However, they warned that citizens are very sceptical of changes to their urban spaces. From the municipality perspective they are most concerned with the growth of their cities. The more people are living in their city the more public funds they receive from the national government. With this supply of funding, they can offer more and better services to citizens in their city. Currently, the municipality is interested in developing more housing and workspaces. There isn't much discretion about the kinds of industry that are being developed in Enschede and thus not as much emphasis on fostering urban resilience in manufacturing industries. Lastly, the urban planner mentioned that a city can best be characterised by the following traits: the physical size, the population (size, education & history), connection to other parts of the country, political preference, landscape, economy and general history.

SCIENCE AND BUSINESS PARK PROJECT MANAGER INTERVIEW:

A business park is a unique ecosystem of companies in similar industries huddled together in a designated area. This concept varies from the idea of urban factories which are located within a city centre but have similar goals in relation to sustainability and innovation. Therefore, it was important to understand the perspective of an expert on the topic of science and business parks. This expert discussed the motivations of businesses large and small, their influence and connection to municipalities. Bigger companies tend to have more influence than smaller companies in business parks and are more favoured by government agencies. The expert said quote" If a bigger company wanted there to be more coffee rooms in the business park, we would take that concern more seriously as they use more space in the area".

Generally companies are more willing to move their research and development departments than their manufacturing centres. This is mostly because of regulations regarding sustainability and the interconnectedness of supply chains and logistics.

The expert on business parks also mentioned that the concept of urban manufacturing seemed to go backwards to a simpler time. They used the Dutch term 'gezellig' to describe a feeling of coziness. In a time where perhaps things were closer together such as having a bakery down the street and your workplace not too far away from home. The biggest concern for the expert was how to reshape a city to accommodate a manufacturing cite, i.e., having enough space to set up a site. Regarding manufacturing trends, the expert also mentioned they noticed a trend of SME renting more spaces than out right buying property to invest more money into technological developments. Sustainability and responsibility measures are economically driven for companies. There is a push from government offering jobs and subsidies regarding sustainability and more demand from their clientele.

Over time design cycles have gotten shorter to match consumers' needs for more personalized goods. SME also must accommodate to regulations they have a hard time navigating. They have very limited interactions with local government unless they are part of a developmental hub or actively trying to scale upwards (and thus accommodate to different regulations). Lastly the expert expressed that the industry should have a role in the city's development if that aligns with the city's own goals.

BUSINESS DEVELOPMENT INTERVIEW:

The last interview conducted was with a business developer specialised in academic and business relations in the Twente region. This individual commented on differences in how larger and smaller companies approach manufacturing, how companies are reacting to recent trends and how integrated companies are with their local municipalities.

Bigger companies have an existing knowledge base and better capability to make use of resources like student workers. These companies tend to want students for internships. Smaller companies, on the other hand, need more guidance and don't know what to expect from the university. Human capital is a very big issue for the manufacturing and technology industries currently. It is the biggest driver for where all companies (big and small) choose to set up a location. This presents an opportunity for companies to invest in learning factories directed at training staff.

On the topic of SMEs, the expert interviewee mentioned the innovation cycle trap. Start-ups also, often get stuck in the innovation cycle and are not sure when a product is finished. They are not confident with promoting a good before it is 100% finished in their minds. The expert also mentioned that these start ups also have issues defining their largest customer. There is potential for urban factories to make up that gap in product confidence by involving consumers in the development cycle earlier on. This gives direct feedback with the agility to make changes earlier in the development cycle.

Currently the expert mentioned that networking and companies supporting entrepreneurship are the most used tool for deciding how to invest in development. There are no existing tools that smaller companies use in that process. The criteria for an SME company when considering investing in development is based on what knowledge they have internally, the fit to the company strategy and the expected resource demand.

The expert believed a benefit of urban manufacturing is the proximity to clients. This would allow SME to gain knowledge about customers and have a greater company acceptance in the area. The concerns of urban production were about, how to effectively combine work & life, risk management, changes to production methods and pollution. For SME, the expert said, ideas are easy to generate their biggest limitations are human capital and resources. To overcome that deficit SMEs are gathering to help each other out in organizations such as innovation groups.

When facing trends such as personalization and responsibility, the manufacturing industry has responded in the flowing ways. The push for personalization was more proactive as new technologies emerged to give consumers more personalized goods. While more often the response to being a responsible company has been reactive. Clients are demanding higher sustainability standards and greater transparency.

SME's have a lack of knowledge where to start with local municipalities. Therefore, they rely of business development companies for help with understanding regulations. The expert believes, industry should have a very big role in city development and for their local employees. The idea of urban manufacturing is positive. Companies cand benefit from the marketing transparency of it as well. However, they need to be as flexible as possible for human capital, logistics management is going to be a big hurdle. Smaller companies tend to rely on materials sourced outside of Europe. This is because of cost and time constraints, as well a lack of producers locally and regionally. There is a push for less reliance on goods produced in China for two reasons: a shift in the political climate and a need for greater transparency in their supply chains.

SYSTEM REQUIREMENTS

1. CITY-FACTORY-PRODUCT INTERFACE SYSTEM

1. The system shall provide urban resilience outcomes of an urban factory concept given a technical, governance and space-cultural scenario.
2. The system shall provide sustainability outcomes of an urban factory concept given a technical, governance and space-cultural scenario.
3. The system shall provide metrics on urban resilience that are scalable and replicable.
4. The system shall translate urban factory needs to their urban resilience outcomes within a given space-cultural scenario.
5. The system shall identify tradeoffs for urban resilience a sustainable development.
6. They system shall inform the user experience through a transdisciplinary narrative.

1.1 FRONT-END SUBSYSTEM

7. Subsystem 1.1 (Front-end) shall present the user with decision points that are logical to understand use and find.
8. Subsystem 1.1 (Front-end) shall connect the interface application design with the dynamic data management of the back-end development.

1.1.1 DESIGN SUBSYSTEM

9. Subsystem 1.1.1 (Design)shall allow for a user to detail technical, governance and space-cultural criteria to shape a conceptual scenario.
10. Subsystem 1.1.1.1 (Characterization) shall allow a user to act out the part of a character to provide context in the design process.
11. Subsystem 1.1.1.2 (Scenario builder) shall offer personalization inputs such that a conceptual scenario design unique to the user can be made.
12. Subsystem 1.1.1.2 (Scenario builder) shall provide users contextual knowledge on urban resilience and sustainability.
13. Subsystem 1.1.1.2 (Scenario builder) shall provide constraints for detailing design requirements for the conceptual scenario design to remain with the scope.

1.1.2 RESULT DELIVERY SUBSYSTEM

14. Subsystem 1.1.2 (Result delivery) shall translate the calculated information of subsystem 1.2.2 (Integration) into a visual story.
15. Subsystem 1.1.2 (Result delivery) shall present results such that the user can understand the design's impact on urban resilience and sustainability, and the level of cohesion between the city, factory, and product elements.
16. Subsystem 1.1.2.1 (Health card) shall present urban resilience and sustainability metrics that are predicated on the output of the designed conceptual scenario in a visual summary.
17. Subsystem 1.1.2.2 (City-Factory-Product match) shall present the level of cohesion between the city-factory-product elements of the designed conceptual scenario.
18. Subsystem 1.1.2.2 (City-Factory-Product match) shall present the trade-offs to be considered when making a city-factory-product match.
19. Subsystem 1.1.2.3 (Advice on next steps) shall synthesize the results from subsystems 1.1.2.1 (Health card) and 1.1.2.2 (City-Factory-Product match) to result in suggestions and calls for action for the user.

1.2 BACK-END SUBSYSTEM

20. Subsystem 1.2 (Back-end) shall store and organize data input from subsystem 1.1 (Front-end).
21. Subsystem 1.2 (Back-end) shall communicate with subsystem 1.1 (Front-end) to send and receive information displayed.

1.2.1 IMPACT WEIGHTING AND MATCHING SUBSYSTEM

22. Subsystem 1.2.1 (Result delivery) shall provide traceability between user inputs of subsystem 1.1.1 (Design) and corresponding outputs of subsystem 1.1.2 (Impact weighing & matching).
23. Subsystem 1.2.1.1 (Cross impact matrix matching) shall determine the level of cohesion of the city, factory, and product elements of the designed conceptual scenario.
24. Subsystem 1.2.1.2 (Factor weighing) shall weigh the importance of design criteria set by the participant to result in information on urban resilience and sustainability rank.

1.2.2 INTEGRATION SUBSYSTEM

25. Subsystem 1.2.2 (Integration) shall translate the output of subsystem 1.2.1 (Impact weighting & matching) into intelligible information for subsystem 1.1.2 (Result delivery)

SYSTEM DIAGRAM

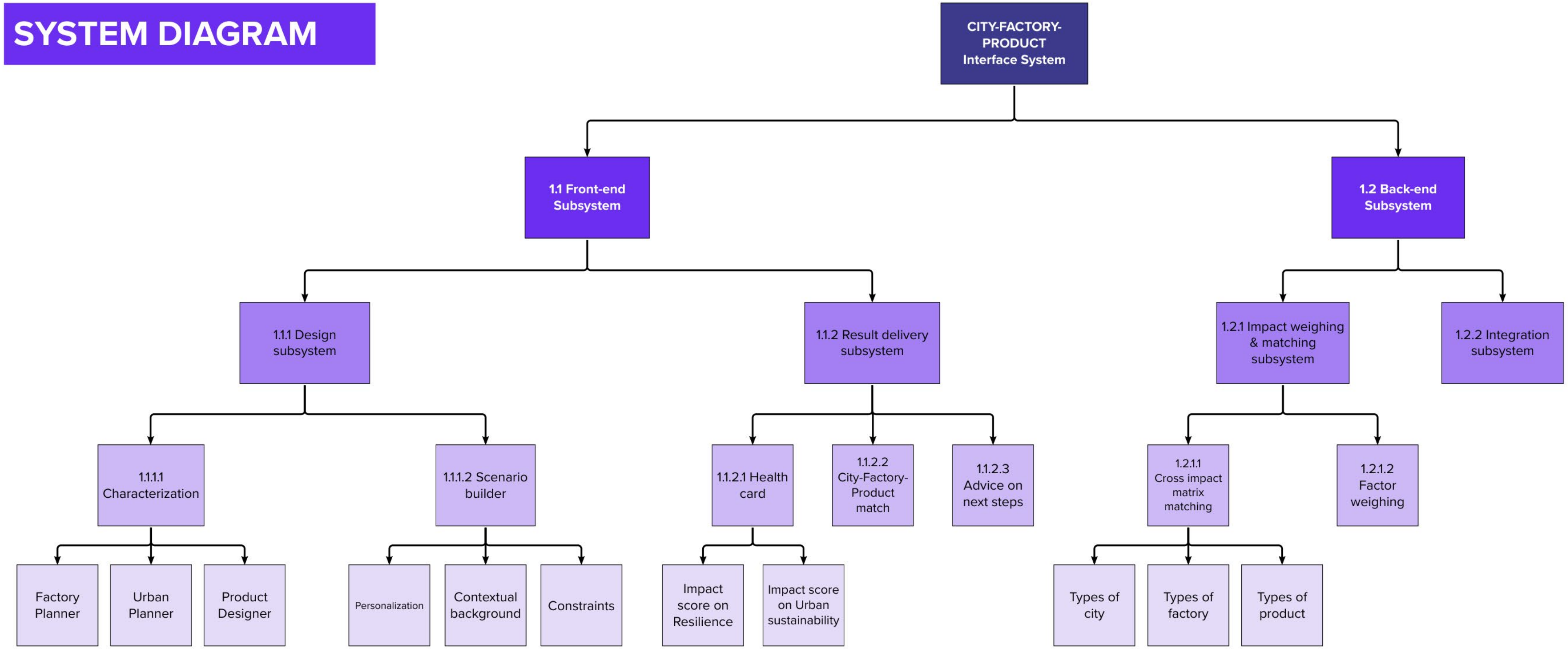


Figure.37. System diagram of city-factory-product interface simulation

FUNCTIONAL ANALYSIS

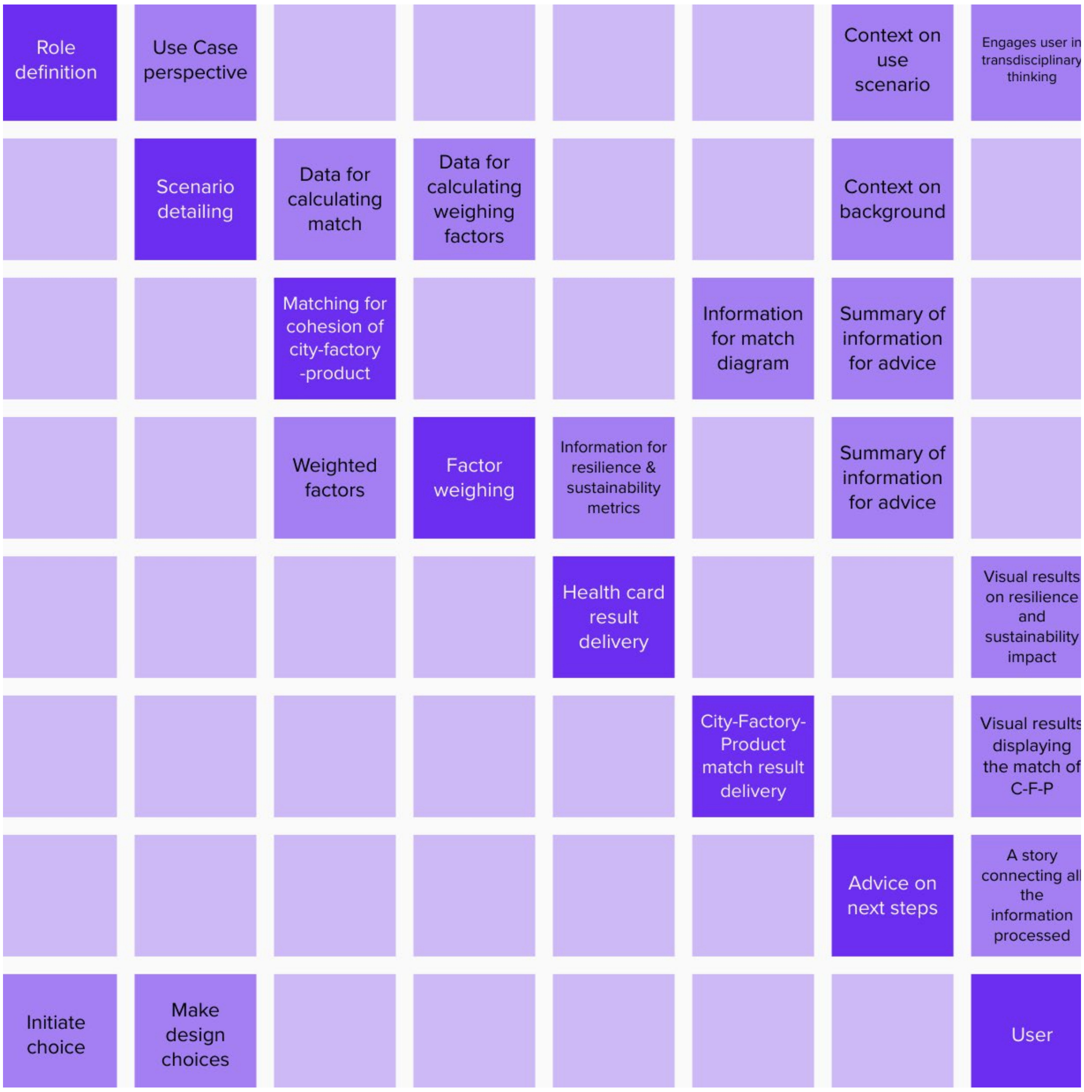


Figure.38. N2 diagram of the system

N2 diagrams are useful for identifying the implicit interconnections inside a system. In this way one can identify critical sub system structures, understand system behaviours, and areas of weakness.

In the N2 diagram of our system, there are some areas that need more careful consideration to avoid errors. Beginning with the role definition, there needs to be clear instructions for the user when interpreting the design challenge and inputting information to create context for the scenario. When engaging in scenario detailing, there is mainly inputting of data by the user. This similarly can be a moment of user error if the input prompt is not directed in an understandable way. Matching for the cohesion of city-factory-product and factor weighing, depends upon the weighted criteria of the user as well as an internal analysis of data and output of information. The methods for interpreting data must avoid systematic errors (such as a constant variation in answers due to an uncalibrated measurement device) and avoid random errors (such as absolute errors). The health card result delivery and city-factory-product- match result delivery should avoid misinterpretation due to inaccessible visuals (such as colour blindness). Lastly the advice on next steps, must be a coherent and linear story to avoid a disconnect between the advice and the user interactions up to this point.

VERIFICATION & VALIDATION STANDARDS

The way to check the system, sub systems and components and overall product design is through verification and validation. Verification checks if the toolkit is being designed in the right way and validation is to see if we have designed the right toolkit for the user.

To verify the proposed design for a toolkit one must make use of the requirements when detailing each subsystem from figure 37. The next verification step after forming the system requirements is the detail design of each subsystem and its components. With the high-level knowledge of how each interface interacts with one another in the N2 diagram it was possible to further detail how each interaction works in the toolkit prototype. In chapter 4 “Conceptualization” the methods of gathering and interpreting data and delivering information to the user are explained further.

Validation of the system is based on the results of prototyping and testing with users, as well as analysing the degree to which the goals from the conceptual model were captured in the final product. In chapter 5 “Final Concept” the final prototype features are detailed. Also, in chapter 6 “Evaluation and Discussion” the user testing is described as well as the discussion of how the designed toolkit addressed the research question and central questions as well as the expectations from the users.

CHAPTER ROUND UP

TARGET GROUP

Small and medium enterprises need nurturing to grow into sustainable companies and add to the economy of their resident cities. In earlier stages of investment and development there is less focus on responsibility measures outside of city regulations. A toolkit could offer an important reflection of the impact of their choices on their city's resilience.

THE NEED

There is a need to understand how new methods of production (such as urban production) can empower SMEs to consciously make responsible design decisions. Thereby discovering how relevant future scenarios can be explored in an urban resilience context such that the desires/needs of stakeholders are also considered.

In this chapter the problem space was explored. This was done using insights from experts and defining the most important stakeholders. The conceptual framework for the research was defined with objectives for the deliverable to achieve. Requirements and a system structure was also detailed. With this information ideas for concepts of the toolkit can also be made.

In the next chapter, conceptualization, the research is continued focusing on the user experience of the toolkit.

CHAPTER 4

CONCEPTUALIZATION

LEAN UX CANVAS

RESLIENCE BUILDER TOOLKIT

Jeff Gothelf describes the User experience (UX) canvas as a process to help teams to frame their work as a business problem to solve (rather than a solution to implement). After this they can dissect that business problem into its core assumptions. This allows them to weave those assumptions into hypotheses and then design experiments to test the riskiest hypotheses[29]. Sections 1 and 3 address the current state. Sections 2 and 4 describe what happens later. Section 5 describes how to get from where one is at now and where they will be later. And sections 6 to 8 describe how to find out if what was described earlier is correct (see figure 39). The toolkit made should be practically feasible while addressing the needs of the users, in this way the use of the UX canvas provides an added benefit to the research. This method is normally reserved for multidisciplinary teams; however, this was carried out in individual research.

BUSINESS PROBLEMS

In the first section of the canvas the business problem is described. This is about what a potential issue a business can solve. The toolkit addresses urban production with the aim of improving the urban resilience of cities. This could resolve some pain points for the target user, SME manufacturers. A big issue for companies currently is access to skilled talent. For these workers their values are broader than their pay, the environment in which they live, and the values of their companies are very important to them. Smaller companies are often ill prepared to deal with legislation targeting sustainability and are more reactive than proactive. Another issue for companies is instability with sourcing resources and a movement to rely less on one global supplier. And lastly, zoning and land costs are pushing factories further outside of cities and further away from their customers and employees.

BUSINESS OUTCOMES

Section 2, business outcomes, describes ways to measure if business problem has been solved. If a business makes more intuitive responsible choices, this communicates to prospective workers that this company shares similar values to them. Also increased workplace satisfaction will help with retaining employees. More investments in urban manufacturing can lead to production becoming less intrusive and disruptive. This will show progress with the distance of factories from cities. Also better connected and more diversification of supply chains can indicate a decrease in the instability of resources. Lastly, more dialogue between stakeholders (municipalities, industry and designers) for knowledge sharing helps to alleviate the inexperience of SME's.

USERS

While the target users of the toolkit would be SMEs, additionally there is the added benefit for municipalities discussing urban planning with industry.

User Outcomes and Benefits

In this section positive outcomes and benefits are detailed for the potential user. For the user one outcome is they have a way to rapidly prototype using this toolkit. They receive advice on decision making and investing in new business strategies as well. It can offer a means of translating business needs into its urban resilience and sustainable impacts. For many SMEs it can also help them to visualize what a transition to urban manufacturing could be like.

SOLUTIONS

The solutions section is dedicated to what can be made to solve the business problems highlighted and meet the need of the users. This is regarding product features and enhancement ideas. The toolkit would offer metrics related to resilience of cities (making the city more attractive for employees) and Metrics related to sustainability (see how company is addressing sustainability). There is also the ability to roleplay future scenarios, visualize design choices in designing a factory and their relation to product and factory. And lastly, suggestions on ho to explore future developments.

HYPOTHESES

Now that the potential benefits and business problems have been detailed in the earlier sections, hypotheses can be made about the toolkit offering. These hypotheses were made by combining the assumptions from sections 2 to 5. Three hypotheses were developed they are as follows:

- It can be believed that more investments in urban manufacturing in the industry will be achieved if municipalities and companies attain a way to visualize the transition to urban manufacturing with metrics related to urban resilience and sustainability.
- It can be believed that more responsible choices in the manufacturing industry will be achieved if companies attain advice on decision making and investing in new business strategies with roleplaying future scenarios.
- It can be believed that workplace satisfaction will increase for workers if companies attain a means of translating business needs into its resilient and sustainable impacts with suggestions on how to explore future developments.

The first and last hypotheses are not possible to test in this research as it is outside the scope. However, it could be an interesting stating point for future research into the topic of urban production.

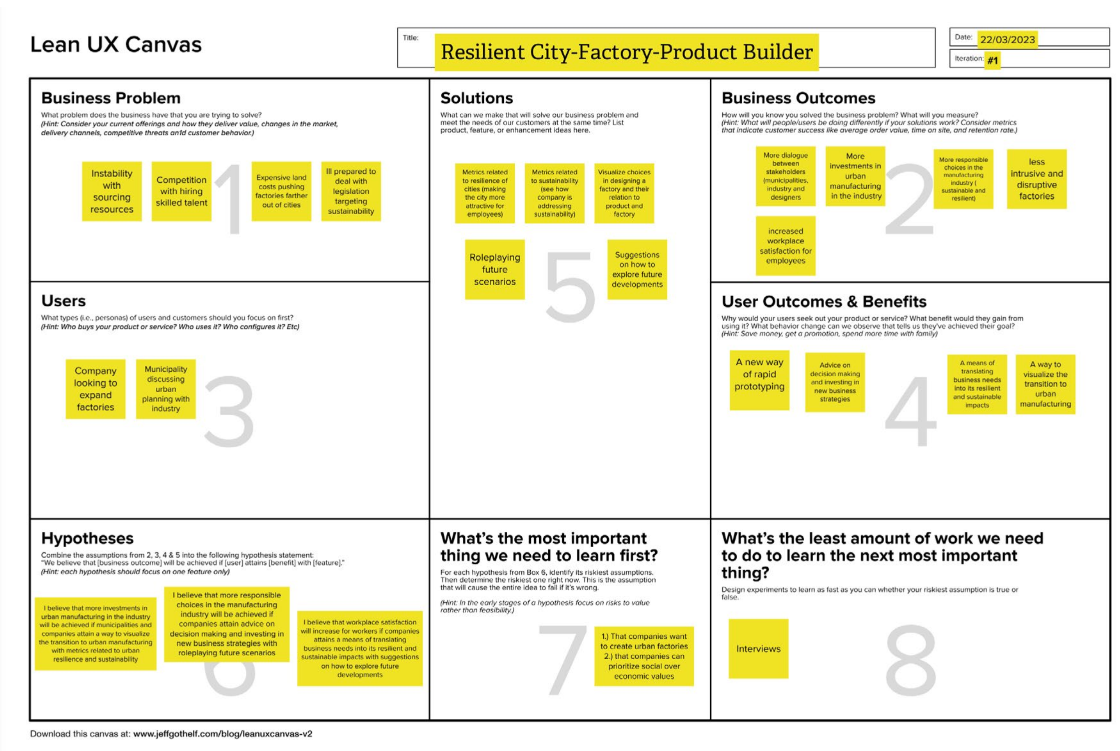
WHAT'S THE MOST IMPORTANT THING WE NEED TO LEARN FIRST.

In section 7, the most important thing to learn first is identified. This will help in identifying the riskiest assumption that would fail the hypotheses identified earlier. What should be learned first is a.) if SMEs want to create urban factories and b.) if companies can prioritize social and responsibility values inherent in the urban resilience approach over economic values.

WHAT'S THE LEAST AMOUNT OF WORK WE NEED TO DO TO LEARN THE NEXT MOST IMPORTANT THING.

The last section focuses on the actions one can take to learn the answer to the questions in section 7. With these actions one can determine if the riskiest assumption is true or false. Two methods that can be used are interviews and user testing with prototype.

Figure.39. Lean UX canvas with details



USER EXPERIENCE JOURNEY

Before creating concepts for the UX design of the toolkit, it was important to understand the experiences of the user to a potential toolkit. With an understanding of the desirable outcomes and what aspect was important to investigate during testing an experience journey was made (see figure 40). The experience journey of a customer is based around the five stages of their interaction with a product. The stages include entice (how the user is made aware of the product), enter (the first interactions with the product),engage (the core of the product experience), exit (how the user ends the experience) and extend (what happens after the user experiences the product). The journey diagram in figure 40 is also divided by goals, steps and motivation over time, anxieties and opportunities of the user.

In the first stage of 'entice', the goal of the user is "to stay up to date on relevant practices, network and build skills." During this stage they may learn of the toolkit through conferences on the topic of urban production, at networking events or through company workshops. The anxieties of the user at this point are" the desire to be at the forefront of technology" and an "unfamiliarity with the topic". There are opportunities to "learn about urban factories in a low effort environment" and "form connections with likeminded individuals".

The second stage is 'enter', the goal of this stage is "to provide relevant background to users and help connect a perspective to the scenario." Some activities of the user include "opening the starting page of the toolkit", "an introduction to key terms" and "choosing a role" to continue the experience in. The user may have anxieties such as "overcoming a personal bias" and "having a lack of context on topic". There are opportunities to "provide information to help fill in knowledge gap in neutral way" and "help the user to be more objective through role playing."

The next stage is 'engage', the goal of this stage is "to help the user to become personally invested in the scenario being built. Also give the user a starting point to engage with the scenario building through a design challenge." In this stage the user would "get the design challenge prompt", "add customization of the current state of their city/factory/product" and "designing the future scenario concept for their city/factory/product". With any user interaction there are bound to be anxieties the user may face. During this stage those anxieties could include "the potential to become confused/overwhelmed" and "the user not having enough knowledge to answer particular questions for defining current state". To alleviate these anxieties there are opportunities to "make a generalized design challenge that is void of industry jargon "and to "keep questions simple, with answers that don't specify detailed fixed answers but more ranges. Like yes or no questions."

The fourth stage is 'exit', the goal for the user in this stage is "to connect the scenario designed to its implications for urban resilience. Also, to understand the feasibility of the scenario.". Some actions the user has during this stage are "receive the city health card results", "discover their city-factory-product match and "learn some future suggestions." Some anxieties users could have are, they "might be skeptical of results" or "not sure what to do with the information they are given." Therefore, there are opportunities to "to show how inputs are reflected in results to user", "results can be expressed in terms of urban resilience and sustainability focus" and "the advice can give call to actions for the user."

The final stage is 'extend', the goal of this stage is "to foster development that benefits all stakeholders in a responsible manner". The user could have "companies and municipalities discuss what future projects make the most sense to them" for future development in the city. An anxiety the user might have at this point is "being unsure of how to connect with others outside their own background". To overcome this there is an opportunity to "give users context for relating their own design process to other people and issues such as resilience and sustainability."

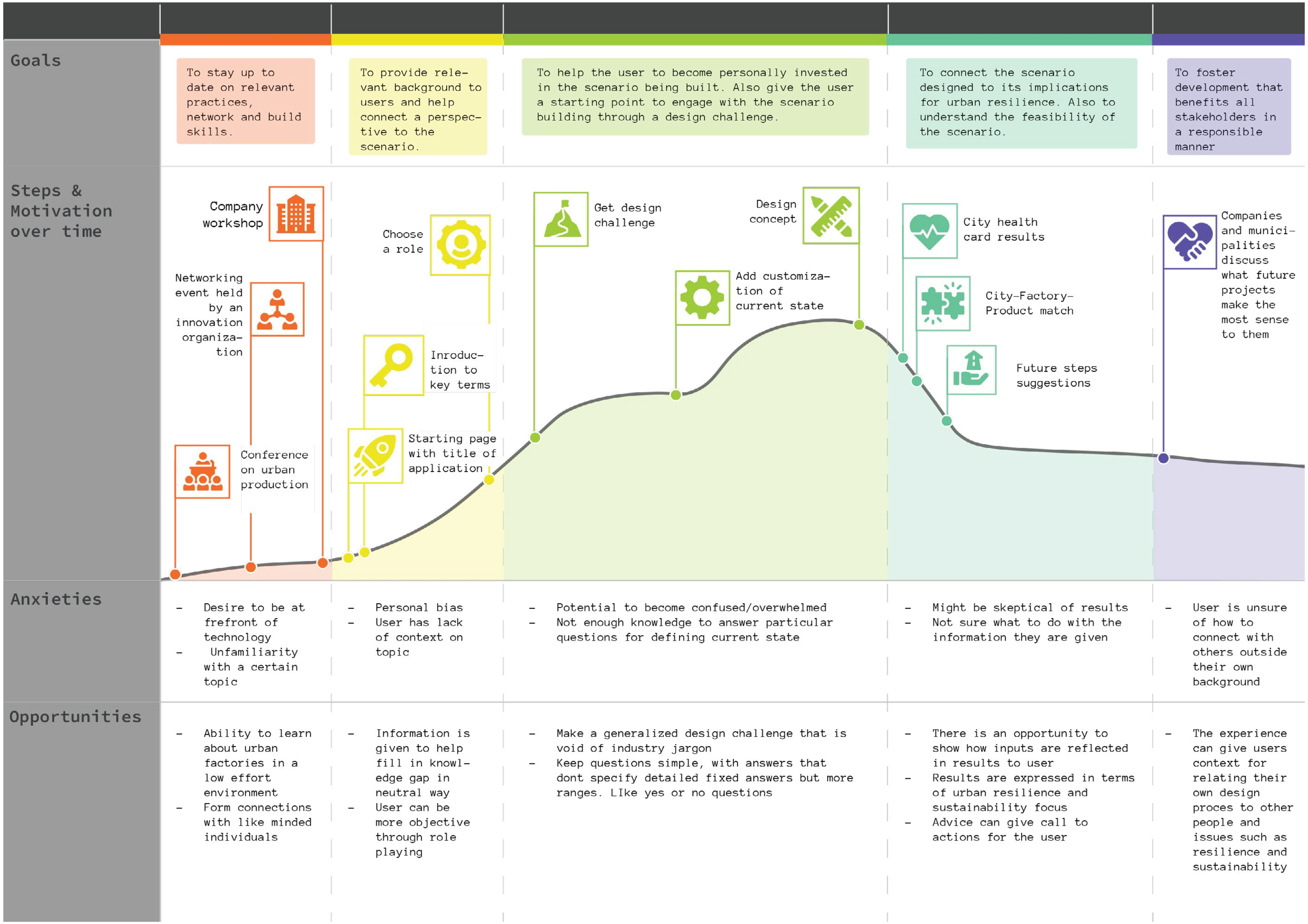


Figure.40. Diagram of example dimension, categories and subcategories

UX CONCEPTS

The potential applications for users in a toolkit depend on the needs and potential accompanying solutions for them. Ideas were generated to develop potential layouts for the application pages and for interaction experience possibilities. The interaction of the user with the application is in both passive and active forms. In the passive form they read and understand information to give context to user experience. In the active form they control how the design of a future urban manufacturing scenario plays out.

CONCEPT: ROLEPLAYING

Roleplaying is a technique used to get users to empathise with another perspective while giving them mental distance from their own frame of reference. In the toolkit a user is given the choice between 3 different roles. These are urban planner, factory planner and product designer. These roles correspond to the 3 main elements of the city-factory-product nexus. Each role must address the same design challenge but from different perspectives. As an urban planner you will have the ability to design a future city scenario. If the user choses the role of a factory planner, they will design a future urban factory scenario and product designer will make a hypothetical product scenario. Each of the results given per role will be shown through the perspective corresponding to that role.

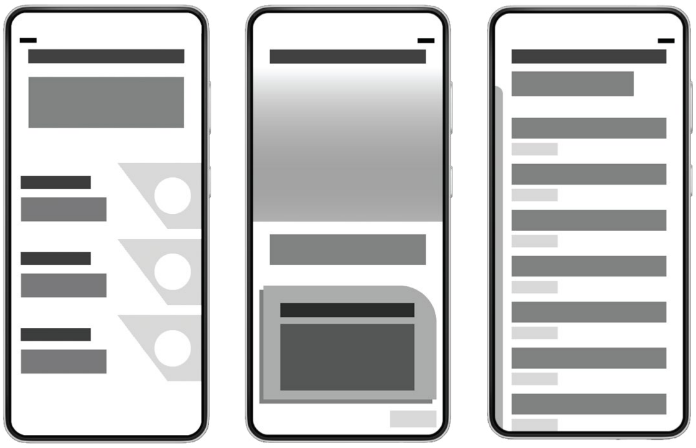


Figure.42. Concept pages for left to right: Role selection, Role description, City/Factory/Product definition pages.

CONCEPT: FUTURE TOKENS (RANKING)

Ranking a set group of elements can potentially give an insight into the prioritization of factors involved in decision making. In this case, the ranking would occur by the user dividing a set number of resources over different areas of development when designing their future city/factory/product scenario. The user would be able to mimic real life contexts in which resources such as time and money are limited. These options to be ranked would be based on the subcategories described in chapter 2. However, they would be reframed such that it isn't explicit that a user is putting resources into an 'inclusive' or 'end of life' option. This is done with the aim to avoid biases and overuse of jargon. To avoid information, overload these ranking moments are divided into three stages namely, 'getting started', 'technological innovation' and 'thinking responsibly'.

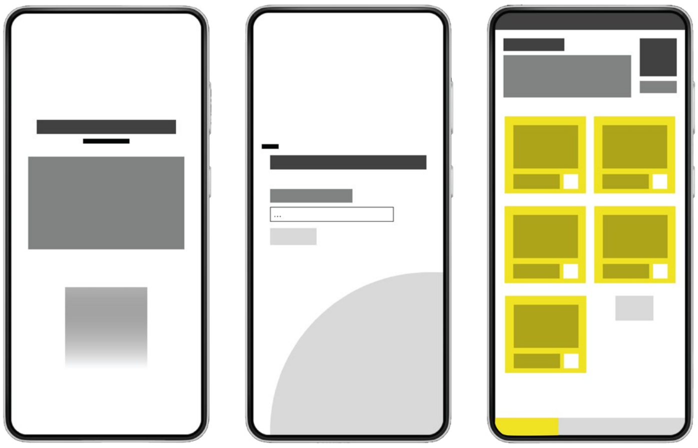


Figure.41. Concept pages for left to right: Future token description, Design general and,City/Factory/Product builder stage 1 pages

CONCEPT: CITY-FACTORY-PRODUCT MATCH

For the user to see how their future scenario matches to their current context, a matching interaction was also made. This involves the user giving background information on their city/ factory/product current situation. So, if for example the user selected the role of factory planner, they would have to give information on their current city and product offering. Then go onto design their factory scenario during the ranking interaction. This information gained would then be translated into results on a matrix with two axes of the remaining elements in the city factory product nexus. So, continuing from the previous example. The page would show a matrix with axes pertaining to city and product to display the factory fit. This page would also have supporting text explaining the figure.

Figure.43. Concept page of City/Factory/Product
Figure.44. Fit

CONCEPT: RESULT DELIVERY SYSTEM

The results are given in 3 ways but all fall under the title of the “city health card”. This gives an indication of what the user’s future scenario would play out like in terms of urban resilience, city sustainability and advice for the next steps. The urban resilience results would include an overall calculated resilience focus score, then information on how the scenario ranked for each metric of urban resilience (see chapter 2 for more details). Similarly, the information would show the overall sustainability focus of the designed scenario, using the criteria for city sustainability (see chapter 2). The last section would give advice to the user based on all the information accumulated in the scenario design process.

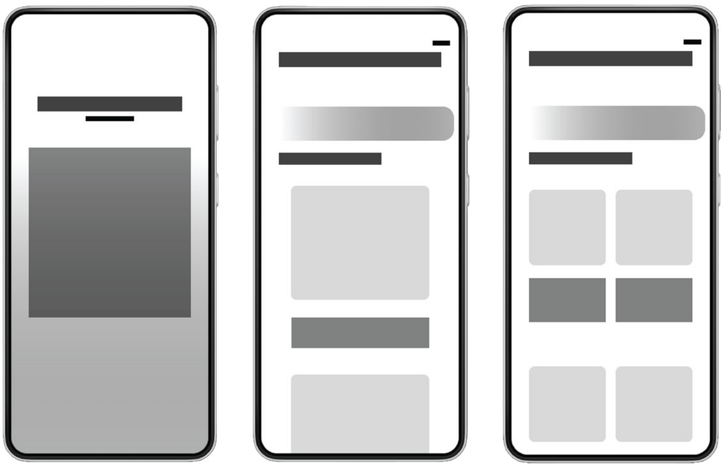


Figure.45. Concept pages for left to right: Advice,City sustainability results and, urban resilience results pages

CHAPTER ROUND UP

HYPOTHESIS AND NEXT STEPS

A hypothesis was developed for testing the validity of the toolkit. “It can be believed that more responsible choices in the manufacturing industry will be achieved if companies attain advice on decision making and investing in new business strategies with roleplaying future scenarios.”

To best answer this hypothesis the riskiest assumptions of a.) if SMEs want to create urban factories and b.) if companies can prioritize social and responsibility values inherent in the urban resilience approach over economic values, were identified. Using this as a true or false qualifier, it was determined that time efficient options for investigating the hypothesis were both interviews and user prototype testing.

In this chapter the user was the focus, specifically their motivations, struggles and interactions with a potential toolkit. By understanding this some user experience concepts were developed. These concepts also aligned with the various subsystems found in chapter 3. In the next chapter final concept, these initial concepts are fleshed out into a high-fidelity prototype. Also, in the next chapter the choices behind why a concept was developed are explained as well as some technical choices.

CHAPTER 5

FINAL CONCEPT

PROOF OF CONCEPT

The final concept is the practical answer to the research question "How can a city factory interface be simulated such that configurations supporting urban resilience are explored?". This concept is a toolkit that simulates a city-factory-product interface such that the needs of an urban factory are translated to their urban resilience outcomes within a given space-cultural scenario. This is in the form of a mobile application for a smartphone.

In the previous chapters of the report, the literature base was investigated to be able to define the scope of parameters in the toolkit. The logic behind converting user inputs into results and advice was based on the influence relationships explored in the cross-impact matrix. After this, the system behind the toolkit was defined. The requirements for what would be needed to build the toolkit in the correct way were also defined. To understand better if the right kind of toolkit was being developed, there was an exploration of the business case of the toolkit using the Lean UX Canvas. Afterward, some interaction concepts were outlined to be further refined in the final concept.

The software used to make this toolkit was a combination of Figma, Apipheny, and Google Sheets. Figma was used to create the visual aspects of the application as a high-fidelity prototype. This allows for the 'play through' of using the application to a 'wizard of oz' level of prototyping. Apipheny allows for the user interface of Figma to be connected to a database using an API. This allows for users to input data as well as real-time information to be mapped onto pages in Figma. Lastly, Google Sheets provided a platform to host databases. With this user data could be collected and processed into information that was later sent back to the application.

The toolkit delivers urban resilience and sustainability outcomes of an urban factory concept given a technical, governance and space-cultural scenario. It allows users to enter the experience through a transdisciplinary narrative by offering various roles to take on. A user can build a future city, factory, or product scenario. Thereby gaining information on how it relates to urban resilience and sustainability outcomes. The toolkit also offers metrics on urban resilience that are scalable and replicable by using targeted advice suggestions. The advice is relatable for the target group of SMEs as it uses real-world examples from other existing urban factories. In addition to that the system also highlights trade-offs for urban resilience a sustainable development for the user.

The next section in this chapter addresses user interactions. Here there are five sub-sections: user introduction, role selection, future tokens, and result delivery system (which is divided into urban resilience and sustainability results, city factory product match, and advice). Each of these subsections relates to the system description of the toolkit (see Chapter 3 figure 37). User introduction is part of subsystem 1.1.1.2 Scenario builder as it offers contextual background. Role selection falls under subsystem 1.1.1.1 Characterization. The future tokens section addresses subsystems 1.2.1.2 Factor weighing and 1.2.2 Integration subsystem. The city health card subsection is part of the subsystem 1.1.2 result delivery system.

Figure.46. Mockup of toolkit displaying the welcome screen and the future tokens-city builder stage 1 screen

USER INTERACTIONS

USER INTRODUCTION

The introduction section of the toolkit describes the first entry point of the user to the toolkit. In these series of screens, the user receives information on the purpose of an urban factory and the design challenge which they must answer.

This section addresses subsystem 1.1.1 (Design), see Chapter 3 for more details. The aim of the section is to provide users with contextual knowledge on urban resilience and sustainability. This will help users to then detail technical, governance, and space-cultural criteria to shape a conceptual scenario.

The welcome screen (screen 1 in figure 48) shows the first page the user sees when opening the toolkit. After this, the user is asked to fill in their name on the next screen. Next, there is a screen that describes the aim of the toolkit and the user's expected experience during it (the toolkit introduction screen, 3 in figure 49). The next series of screens that follow this focus on introducing the user to the concept of urban resilience (these can be found in the appendix). The next screen after this is the journey to resilience introduction. This details the progression of a city from a digital city to a resilient city as can be seen in figure 47 [18]. This section ends with a final screen detailing the design challenge for the user (screen 3 in figure 49). Any information collected from a text input is then saved to a database to form a record of the user experience.

ROLEPLAYING

In this section of the user experience the user makes the choice of role they will take on to tackle the design challenge. This is the moment the user must consider a perspective from which to address their future scenario.

This section of the toolkit addresses subsystem 1.1.1.1 (Characterization). It allows a user to act out the part of a character to provide context in the design process. The first screen is an overview of all 3 options for a particular role a user can take on (screen 1, figure 49). Depending on which role a participant selects they will see either screen 2,3 or 4. Each of these 3 screens has similar content: an image to give context to the role taken, a short text description of the role, and a reminder of the design challenge. There is the option for the user to return to the role selection screen if they want to make a different selection. The aim of this interaction section is to get participants to feel involved in the design challenge from a perspective relating to the city factory product nexus.

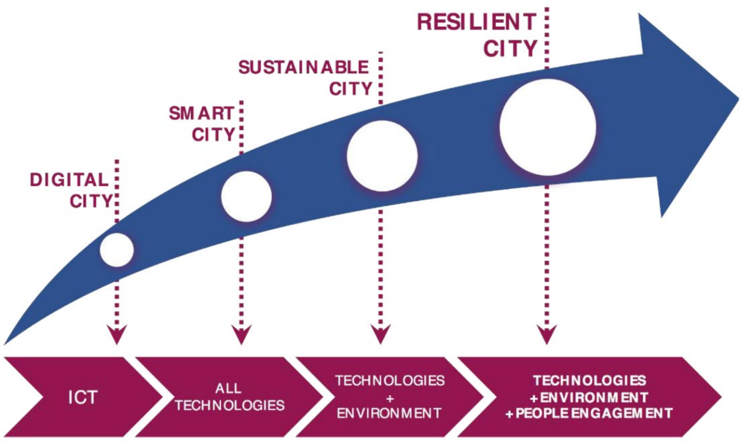


Figure.47. Mockup of toolkit application on iphone displaying role selection screen.

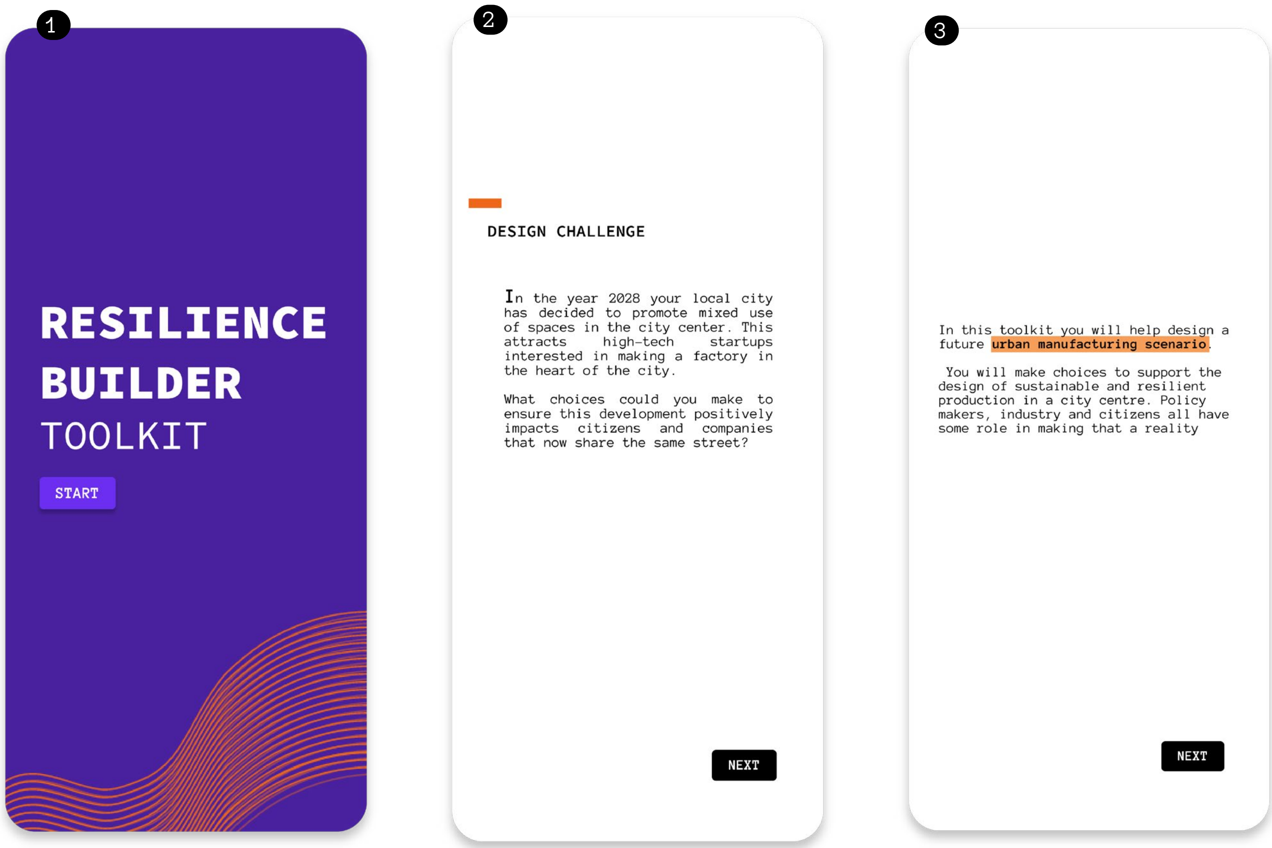


Figure.48. Screens from toolkit left to right: Welcome screen, Introduction to toolkit screen and design challenge.

FUTURE TOKENS

This user experience helps a user to detail future characteristics of their city/factory/product with the aim of creating a resilient city ecosystem. Here a user can decide what aspects of creating a hypothetical city/factory/product are most important to them. A user must choose a future factor to rank (such as industrial development or circular production, in figure 51 screen 3). These choices happen over 3 stages of developing the scenario: the first is ‘getting ready”, the second is ’technical innovation’ and the third is ‘thinking responsibly’. A user uses an in-game currency called ‘future tokens’ to spend resources on different factors (such as industrial development mentioned earlier). These different factors are called future factors. Amongst each stage, for all the design types of city/factory/products, there were between 2 to 6 future factors per stage.

This experience section of the toolkit is based on subsystem 1.1.1.2 ‘scenario builder’. It offers personalization inputs such that a conceptual scenario design unique to the user can be made. It also provides constraints for detailing the design of the conceptual scenario design using the concept of the future token.

Each future factor has a title an image to give context to its meaning, a short description, and a text field to place the number of tokens assigned to it. These future factors are all based on the subcategories defined in the cross-impact matrix. They have been rephrased to avoid biases and confusion over academic jargon. For more details on how each subcategory was assigned over each stage per dimension (city, factory, or product) see the appendix. The future token quantities were based on a Likert scale, (which asks a person to rate a statement or question on a scale of 1 to 5). Each future factor has 5 future tokens dedicated to it in the total a user can select from. If there are 4 future factors in a stage, then there would be 20 future tokens dedicated to that stage, for example. Thus, if a user assigns 2 or fewer tokens to a future factor it can be assumed it is not important to them.

Each future factor has a certain weighting factor in relation to its influence on urban resilience and city sustainability. This was derived from the cross-impact matrix. This means that even if the future tokens are all distributed equally amongst the different factors not each factor would give an equal influence on urban resilience and sustainability.

CITY-FACTORY-PRODUCT MATCH

A city, urban factory, or product scenario can't give an insight into urban resilience by itself. Therefore this section is meant to add context to give the user a more complete understanding. Here a user must think of the current state of their city, the most influential manufacturing companies around them, and the product offering they provide. It is not necessary that the user is an expert on these topics but to give their own perception of the current state.

This section relates to subsystem 1.2.1.1 (Cross impact matrix matching) the aim of it is to determine the level of cohesion of the city, factory, and product elements of the designed conceptual scenario. This begins with a screen that asks the user to name their scenario (whether it be for a city/factory/product) as can be seen in screen 1 of figure 51. The next screens the user sees are a com-

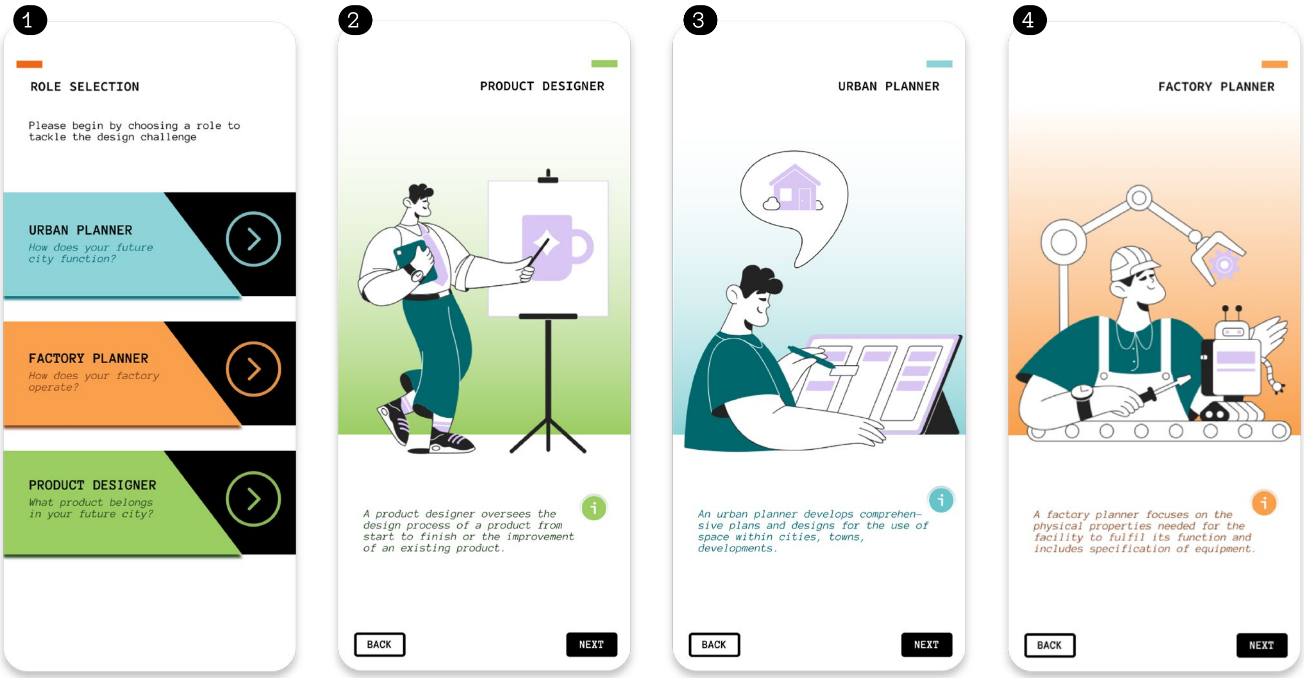


Figure.49. Screens of toolkit from left to right: Role selection screen, product designer screen, urban planner screen and factorry planner screen.

Figure.50. Screens of toolkit from left to right:
Design general (city screen), city builder stage 1 screen, factory builder stage 2 screen and product builder stage 3 screen

bination of two of the screens in figure 51. They will be asked to give context to support the design of their scenario. Therefore, if a user is designing a future product, they will only be asked to give context on the current state of their city and factory. Once the user has answered all the questions, they are asked to confirm their selection and move on to the next screen.

These questions were developed using various literature underpinnings. First, the attributes of a city, factory, and product that show differences in types of them were identified. Using that information, the subcategories from the cross-impact matrix were mapped to each attribute. In this way, any answer about a particular attribute could be interpreted using the working logic of the toolkit. To see the breakdown of each question and their corresponding subcategory match and attribute see the appendix. In figure 50 screens 1 through 3 show the questions asked to the user during the experience. Each question is given a binary answer scheme. This is intentional as each answer correlates to a movement positive or negative along the x and y-axis of the city/factory/product fit diagram (see figure 52, screen 1). Given the example in figure 52, screen 1, the y axis relates to the factory match and the x to the product match. The city lies in the upper right quadrant which means it has a good match to the factory as it has an integrated infrastructure but a poor match to the product as it has a low to limited product use in the city. The results user experience section details more about this screen.

Figure.51. Mockup of toolkit application on iphone displaying role selection screen.

RESULT DELIVERY SYSTEM

In this section, all the inputs from the user are translated into information about the urban resilience and sustainability focus of their future (city/factory/product) scenario. There is also a section dedicated to the (city/factory/product) match of the scenario and an advice section on the next steps for the user. This is an exiting experience for the user in the toolkit. The aim of this section is to present results such that the user can understand the design's impact on urban resilience and sustainability, and the level of cohesion between the city, factory, and product elements. This is determined by the influential nature of the three elements of the city factory nexus. While a user may create a resilient product design (for example), they can still have restrictions based on the city and factory characteristics. In the case that a product would make use of recycled waste streams, the city would need to have infrastructure supporting the processing of that waste and the factory should also have machines calibrated for that impure version of the materials.

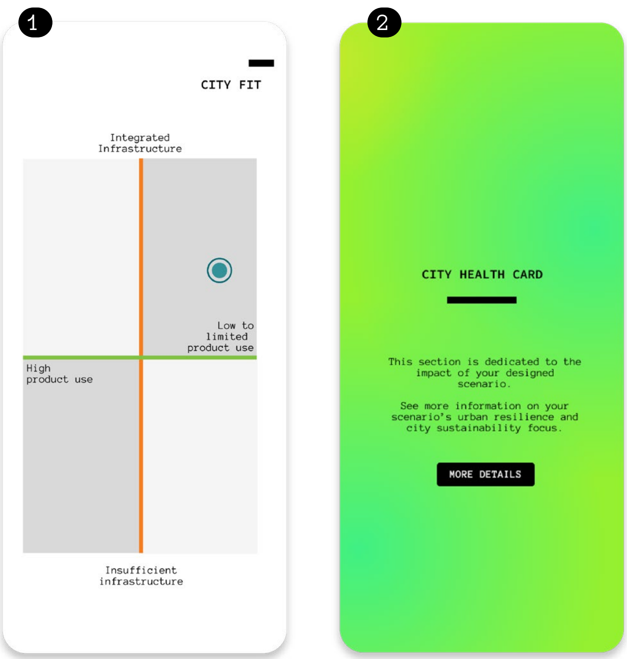
The first screen the user experiences in this section is a loading page to show that their answers are calculated. This then dissolves into the next screen explaining the results section. After the user selects the 'more information' button, it navigates them to the urban resilience results screen (see figure 52 screen 3). The user can see details about the total influence of their scenario on resilience and which aspects of resilience is it highlighting. After this, the user clicks more information to go to the city sustainability focus page where they similarly see the overall focus and the focus per category of city sustainability (see figure 52, screen 4). The next screen is the city/product/factory fit. It shows a 4-quadrant matrix with a dot representing where your scenario lies. Finally, the user clicks to the advice page where advice on the user's next step is shown based on the location of their scenario in the previous screen's matrix.

This user experience section involves subsystems: 1.2.1 (Result delivery), 1.1.2 (Impact weighing & matching), 1.1.2.1 (Health card), 1.1.2.2 (City-Factory-Product match), and 1.1.2.3 (Advice on next steps). Following the user interactions of the city/factory/product match and the future tokens; user inputs are converted from data into information. There is traceability between user inputs of subsystem 1.1.1 (Design) and corresponding outputs of subsystem 1.1.2 (Impact weighing & matching). The data is converted by subsystem 1.1.2 as follows..

CITY-FACTORY-PRODUCT MATCH RESULTS

In figure 52 screen 1, shows the city fit matrix, with four quadrants representing: 'integrated infrastructure and high product use', 'insufficient infrastructure and high product use', 'low to limited product use and insufficient infrastructure', and lastly 'integrated infrastructure and low to limited product use'. The spectrum of each axis is based on the city nexus diagram, see figure 5 [10] . The y-axis focuses on the city factory fit and the x-axis focuses on the city product match. The user understands where their scenario lies in these spectrums of integrated infrastructure to insufficient infrastructure (factory match) and high product use to limited to low product use (product) by looking at the dot indicator's position. This information is derived from two sources: context building of the current state and the conceptual scenario design.

The binary answers for the context-building interaction give a total percentage for the x and y-axis position values. For example, every yes answer is plus 1, and every no answer is minus 1. These values are then totaled. This total is then made as a percentage of all the possible questions. If there is a negative total, then this means a movement on the negative side of the axis. The zero point lies at the intersection of both axes. After this, the information



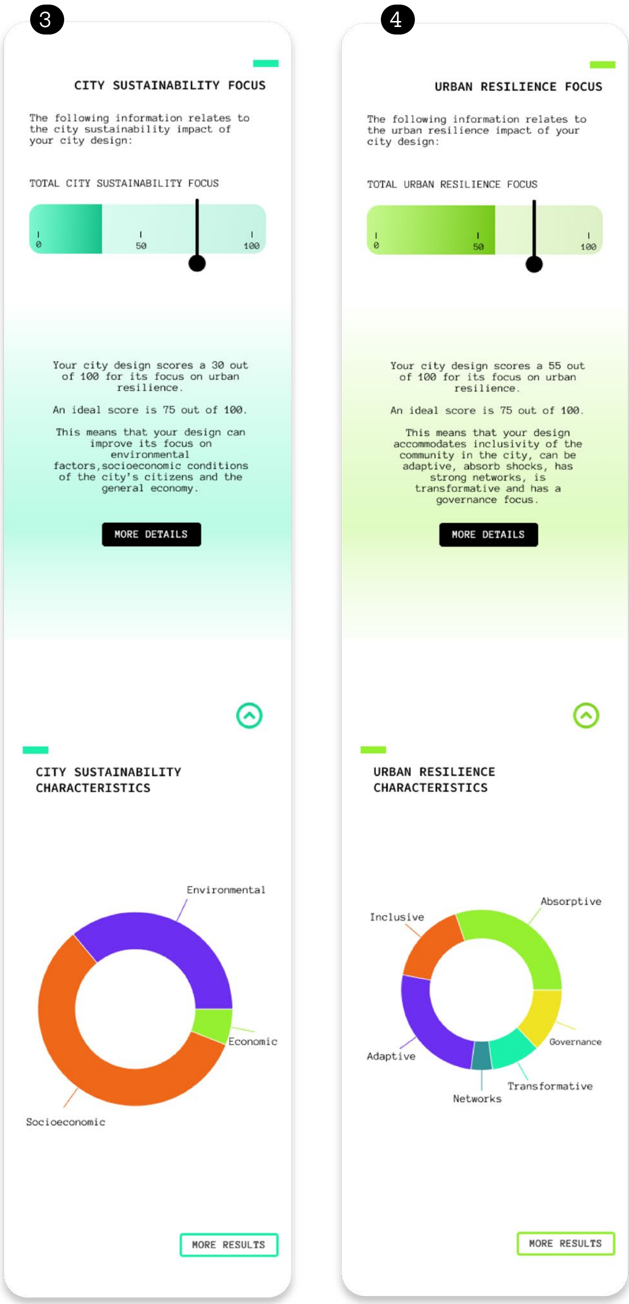


Figure.52. Mockup of toolkit application on iphone displaying role selection screen.

from the future tokens section is combined to give a final x and y-axis value for the conceptual scenario.

The future tokens information is derived by multiplying the future factor's influence on the dimensions of each axis (city/factory/product) by the future token/s allotted. The future tokens then act as a weighting factor for each future factor (this is the same as the subcategories mentioned earlier). However, a weighted value (from the future tokens) can either be positive or negative. It has a positive value if it has received 3 or more future tokens. If the future factor was given 2 or fewer future tokens, then it has a minus value of that influence score. If the user assigns 2 tokens, then that has a weighing factor of -2, if 1 token then a

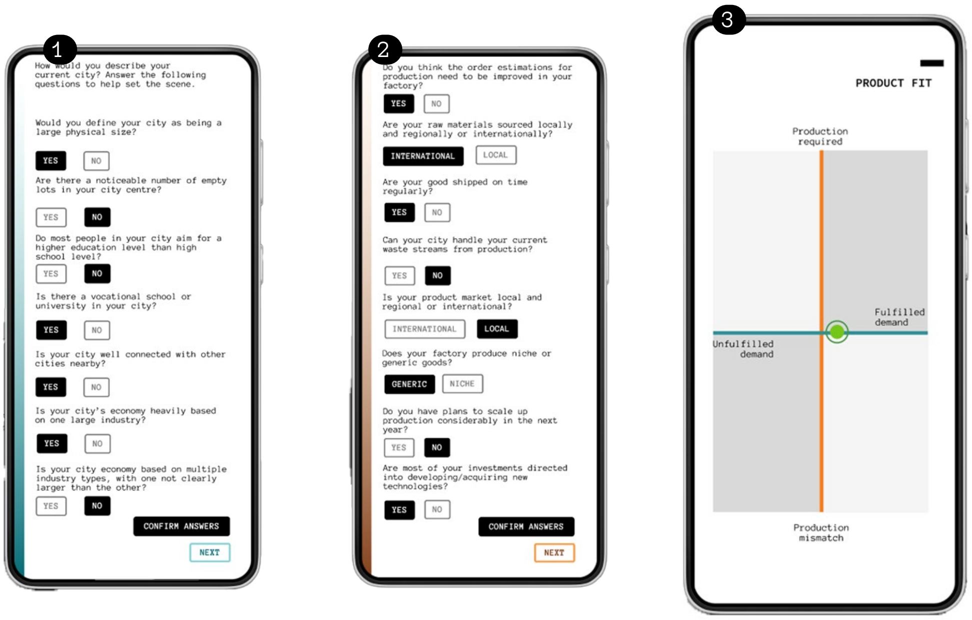


Figure.53. Mockup of toolkit application on iphone displaying role selection screen.

Figure.54. Mockup of toolkit application on iphone displaying role selection screen.

factor of -3, and if 0 tokens, then that has a weighting factor of -5. If a user gives a score over 5 to a future factor the weighing factor is limited to a multiplication of 5. This is then totaled for all the future factor future token allocations for all 3 stages. This is also expressed as a percentage so that both sections' scores are comparable. This percentage is calculated as the total weighted influence on the dimension (city/factory/product) of a perfect score (the sum of all the influence scores per category x 5). If the total weighted influence is negative, then the position is moved towards the negative values of the axis. The totals for the context building and the future tokens section are then combined to give the final total for each axis of the matrix.

Product Scenario Influence on City

Stage	Subcategory	Future Factor Name	Influence Score	Weighing Factor	**Weighed Score**
Getting Started	Material components	Physical configuration	1.8	3	5.4
	Use design and lifecycles	Ease of use	2.4	2	-4.2
	Cost properties	Marketing	2.3	10	11.5
Technical Innovations	Maintencance	Serviceability	1.3	7	6.5
	Customer integration	-	1.5	1	-4.5
	Function	Functionality	2.2	7	11
Thinking Responsibly	End of life	Circular waste management	0.6	5	3
	Resource consumption	Resources	1.1	5	5.5
TOTAL WEIGHTED INFLUENCE ON CITY					35.2

Table.8. Mockup of toolkit application on iphone displaying role selection screen.

Product Scenario Influence on Factory

Stage	Subcategory	Future Factor Name	Influence Score	Weighing Factor	**Weighed Score**
Getting Started	Material components	Physical configuration	2.2	3	6.6
	Use design and lifecycles	Ease of use	1.5	2	-3
	Cost properties	Marketing	2.2	10	11
Technical Innovations	Maintencance	Serviceability	2.3	7	11.5
	Customer integration	-	1.7	1	-5.1
	Function	Functionality	1.7	7	8.5
Thinking Responsibly	End of life	Circular waste management	0.7	5	3.5
	Resource consumption	Resources	1.3	5	6.5
TOTAL WEIGHTED INFLUENCE ON FACTORY					39.5

Table.9. Mockup of toolkit application on iphone displaying role selection screen.

The following is an example of a user defining a future product scenario. Taking the examples of the figure 54, screens 1 and 2 the product fit matrix would allot a score of 1 out of 7 (14%) for the y-axis (city) and a score of 0 out of 8 (0%) for the x-axis (factory).
City score: 4(yes) - 3 (no) =1
Factory score: 4(yes and local)-4 (no,international and generic)=0

This leads to a starting value (before the product scenario has been detailed) as seen above. The position is expressed as seen in figure 53 screen 3.

Considering that a perfect score would be 71 (all the influence scores summed x 5), the following totals can be expressed as percentages. The total weighted influence on the city would move to the right on the x-axis by 50 % (35.2/71) of the total length of the positive x-axis length. And the total weighted influence on the factory would move 56% (39.5/71) up the positive y-axis length. This gives the final output as seen in figure 54 screen 4.

URBAN RESILIENCE AND SUSTAINABILITY RESULTS

Figure 52 screen 4 shows an example of the urban resilience results page of a city scenario. The first graph on the page is a bar chart indicating a total urban resilience focus value. This value is an expressed percentage of the data calculated from the future tokens section of the toolkit. In the future tokens section, a user is asked to divide a set number of tokens over a list of future factors. The number of tokens listed is based on the number of future factors x 5. This mimics a traditional Likert scale used in surveys, where a user can rate a question or statement on a scale of 1 to 5 (1 being completely disagree, 2 being somewhat disagree, 3 being neutral, 4 being somewhat agree and 5 being completely agree). Where the future tokens game mechanic diverges from the scale is the 0-score possibility and the ability to rate higher than 5. The purpose of allotting future tokens is to give a weighting factor to the subcategory that each future factor represents. Therefore, the internally calculated urban resilience score is a weighing factor (based on future tokens) x influence score to urban resilience. This gives an insight into the urban resilience focus a user has in their scenario.
These weighing factors are not directly associated to the numerical value they assign to future tokens. Misleadingly, a future token assignment greater than 5 is not going to give a multiplication higher than 5. If a user assigns 5 or more future tokens to a future factor, that factor receives a weighing factor of 5 maximum. Also, a token allocation of 2 or lower gives a negative weighting factor. If the user allocates 2 tokens, then there is a weighing factor of -2. If they assign 1 future token, then there is a -3-weighing factor. And if 0 future tokens are allotted then it receives a weighing factor of -5.

The percentage of the bar chart is based on the total sum of the conceptual scenario's resilience score over the perfect score (all the influence scores per future factor x 5). As the user continues the same screen there is information on the characteristics of urban resilience. This is in the form of a pie chart where the characteristics of adaptive, absorptive, and transformative capacity, as well as inclusivity, governance and networks, are expressed as percentages. These percentages are calculated by taking the influence score of each future factor based on their influence scores towards each facet of urban resilience and putting that over the total urban resilience score of the scenario.

The city sustainability results are calculated in the same manner as the urban resilience results but using the influence scores towards city sustainability instead.

ADVICE

The advice screen shows relevant information based on the scenario's city/factory/product fit. This information was based on the city of the making report [31] . The information shown correlated to the quadrant of which the scenario falls in the city/factory/product matrix.

CHAPTER ROUND UP

In this chapter the proof of concept was discussed in detail regarding the functionality of user interactions and their relation to the system. Next, in the final chapter 'Evaluation and Discussion', the toolkit will be tested and judged for its ability to address the research and sub research questions.

USER INTRODUCTION

The introduction section of the toolkit describes the first entry point of the user to the toolkit. In these series of screens, the user receives information on the purpose of an urban factory and the design challenge which they must answer.

ROLE SELECTION

In this section of the user experience the user makes the choice to role they will take on to tackle the design challenge. This is the moment the user must consider a perspective from which to address their future scenario.

FUTURE TOKENS

This user experience helps a user to detail future characteristics of their city/factory/product with the aim of creating a resilient city ecosystem. Here a user can decide what aspects of creating a hypothetical city/factory/product are most important to them.

CITY-FACTORY-PRODUCT MACTH

A city, urban factory or product scenario can't give an insight into urban resilience by itself.Therefore this section is meant to add context to give the user a more complete understanding. Here a user must think of the current state of their city, the most influential manufacturing companies around them and the product offering they provide.

RESULT DELIVERY

In this section all the inputs from the user are translated into information about the urban resilient and sustainability focus of their future (city/factory/product) scenario. There is also a section dedicated to the (city/factory/product) match of the scenario and an advice section on next steps for the user.

CHAPTER 6

EVALUATION AND DISCUSSION

EVALUATION

In the previous chapter, the final concept was detailed with how each UX concept functioned. With this functioning prototype, it is now possible to see how potential users interact with it. The evaluation of the prototype will give useful information as to the validity of the toolkit. This evaluation happens in two parts over the course of a 30-minute session with participants.

The first part is the user task completion test (quantitative and qualitative based) and the user experience test. These tests directly follow one another in the session with the user task completion test focusing on the playthrough experience and the user experience test reflecting on the playthrough experience.

USER TASK COMPLETION TEST (PART A)

AIM:

The testing will focus on the front-end subsystem, which include the design and result delivery subsystems. This is a quantitative and qualitative test. The described tests aim to investigate the following research question: *"How can a city factory interface be simulated such that configurations supporting urban resilience are explored?"*

Specifically assessing the degree to which the requirement for the front-end subsystem is achieved: "Subsystem 1.1 (Front-end) shall present the user with decision points that are logical to understand use and find."

RELEVANT THEORY:

Thinking out loud: In a thinking aloud test, you ask test participants to use the system while continuously thinking out loud — that is, simply verbalizing their thoughts as they move through the user interface. https://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/

CONTROLLED VARIABLES:

User Tasks. ("A task needs to reflect the researcher's goal accurately and adequately, as well as provide clear instructions about what participants need to do." https://www.nngroup.com/articles/better-usability-tasks/) These tasks were developed based on the requirements.

1. Find more information on urban resilience and sustainability.
2. Find out how to answer the design challenge if you are interested in designing an urban factory scenario.
3. Find out how to describe your current city setting.
4. Find out how you remind yourself of the design challenge when designing the future scenario.
5. Find information on how the scenario design scores for its focus on governance.
6. Find out how well the factory scenario matches to the city and product context described earlier.

MEASURED VARIABLES:

1. Time taken to complete a task (quantitative variable).
2. Task success rate (quantitative variable).
3. Thought process to complete tasks (qualitative variable).

MATERIAL/APPARATUS:

- Tripod,
- Camera,
- Smart phone,
- Laptop.

METHOD:

Start by preparing the user tasks beforehand. This can be done by using the system requirements to first understand the user interaction's goal and then rephrasing it into a non-leading task.

After this is done prepare the testing area by placing the camera on the tripod such that the movements of the user's hands on the phone screen are tracked by the device. Tape an area on the table so that you can align the phone to be visible and consistent during recording multiple sessions. Ensure that all the recording equipment is calibrated accordingly.

Next inform the participant of how the session will work and ask for their consent to begin recording. Explain to them the thinking-out-loud method, provide them with the task list and then begin recording. Ask the participant to read the task aloud before they begin to solve the task.

Note down which tasks are successfully completed and review the time to complete the tasks using the recording after the session.

CONDITION/RESULT:

The result of this test will see if the user can navigate the app experience such that they are informed during the experience. Another interesting result is to assess the logical placement of information. The tasks should assess if the following goals are feasible for the user.

1. *Task goal: User should detail scenario for building a factory.*
   Related user task: Find out can you remind yourself of the design challenge when designing the future scenario.

2. *Task goal: Choose the factory builder role*
   Related user task: Find out how to answer the design challenge if you are interested in designing an urban factory scenario.

3. *Task goal: Enter personalization inputs such that a conceptual scenario design unique to the user can be made.*
   Related user task: Find out how to describe your current city setting.

4. *Task goal: User should find contextual knowledge on urban resilience and sustainability.*
   Related user task: Find more information on urban resilience and sustainability.

5. *Task goal: User can interpret metrics on the design's impact on urban resilience and sustainability*
   Related user task: Find information on how the scenario design scores for its focus on governance.

6. *Task goal: User can find information on cohesion between the city-factory-product elements of the designed conceptual scenario.*
   Related user task: Find out how well the factory scenario matches to the city and product context described earlier.

LIMITATION:

This method is limited in how the tasks are phrased and if the user can interpret them. To avoid telling the user to search for items on the screen the user tasks were phrased as realistic interaction scenarios.

Not all pages of the prototype were used during the testing for time management. The advice screen for example was excluded from this test.

OBSERVATIONS

There were three participants that went through the same tests. For participant 1, they were unable to complete because the overall goal of why they were doing the experience was unclear. Also, the participant expressed a bias towards the terms manufacturing and factory. Tasks 1,2 and 3 were successfully completed. The user did not finish the test play through to complete the other 3 tasks as they had a limited time for the session.

Participant 2 completed 4 out of 6 tasks, with successful completion of tasks 1,2,3 and 5. The user found it tedious to answer questions about the current context and thought it could be better organized by topic. They also expressed that they forgot they were building for a future scenario and just tried to answer everything thinking about the present day. The meaning of the final graph was also unclear (the city-factory-product match)

Participant 3 completed all 6 tasks successfully. However, there were moments that were unclear for the participant. For task 1 "Find out how to start designing an urban factory scenario." They found it confusing that after they chose the role city, it immediately asks you to define your current factory situation. This was disorienting for the participant. They also found it difficult to describe the factory and product setting as it was too abstract. An example product would help to first define the factory for example. While the user was able to find information on the results of the scenario the link between the parts of resilience and the choices made were still left unclear. An example to compare your results could give more context for results relating to urban resilience, city sustainability and city-factory-product match.

USER EXPERIENCE TEST (PART B)

AIM:

The testing will focus on the knowledge transfer that occurs during the application experience. This is a qualitative test. The described tests aim to investigate the following research question: "How can a city factory interface be simulated such that configurations supporting urban resilience are explored?"

Specifically assessing the degree to which the following requirements for the system were achieved:

1. The system shall translate urban factory needs to their urban resilience outcomes within a given space-cultural scenario.
2. They system shall inform the user experience through a transdisciplinary narrative.

CONTROLLED VARIABLES:

INTERVIEW QUESTIONS

1. How do you think the results page was related to the inputs you used during the session?
2. To what extent did you feel connected to the role given during your experience in the session?
3. Did this experience change how you thought about urban factories, urban resilience, or sustainability?
4. How would you rate your satisfaction of the experience on a scale of 1 -10, 1 being terrible and 10 being excellent?

MEASURED VARIABLES:

- User response

MATERIAL/APPARATUS:

- Voice recording device,
- Interview questions,

METHOD:
Beforehand, prepare a quiet room for an interview with the participant as well as interview questions. Prepare the participant by letting them play through the prototype of the toolkit. Ask them if they consent to being recorded for an interview.

Start the recording (if the participant consents) and begin to ask the interview questions. Speak slowly and clearly when asking questions. Afterwards transcribe the interviewee's answers.

CONDITION/RESULT:
The result of this test will see if the user connects the experience of designing the scenario to the results delivered. It will also give insight into how effective the toolkit is at delivering lasting information and with expanding perspectives of the participant.

LIMITATION:
This method is limited in how the questions are phrased and if the user can interpret them.

OBSERVATIONS
For participant 1 because they could not complete the full gameplay, they were unable to comment on question 1. This participant did not feel any connection to the roleplaying aspects of the session. They were already aware about manufacturing and thought an explanation on urban manufacturing did not add much. In their mind the phrase manufacturing is already too negatively associated, they suggested to rephrase this term. They would also like more clarification on the term urban resilience. Their overall satisfaction was rated as 6 out of 10.

In the case of participant 2 they thought the inputs were related but felt some information was lacking. It wasn't made clear how the different parts of resilience were related to the future factors they assigned tokens to earlier. Similarly, to participant 1, they expressed zero connection to the role given and only used their personal values. The participant felt that there was some information learnt about the topic of urban resilience. Lastly, they rated their overall satisfaction as an 8 out 10.

Participant 3 saw that the results were related to the inputs they had earlier. They felt that the amount of time the avatar was on the screen was too short to connect with it and gain a feeling of entering a new role. Their knowledge of sustainability was not improved by the session and urban resilience was marginal. Also, they felt they couldn't give a definition on urban factory at the end of the experience. They rated their satisfaction of the experience as a 7 out of 10.

IMPROVEMENTS FROM TESTING

Some takeaways from this experience for improving the toolkit are:

- Having an avatar for introducing topics to you and a separate avatar to describe yourself. That would help with acceptance of the roleplaying aspect.
- Simplifying the design challenge to make clear what the goal is, how to achieve it and how to know when it is achieved.
- Making the content less dense so users can start actions earlier.
- Adding a resilience explanation throughout experience not just at end and beginning
- Including a visual reminder of where you are at in the timeline of the toolkit gameplay.

DISCUSSION

This report has delved into the theoretical and practical aspects of urban factories in the context of urban resilience and sustainability. The definitions of the city-factory-nexus parts was used as a basis for the cross-impact matrix. The results of this matrix were the influential measures and the influence on one another, of aspects of the city-factory-nexus parts.The cross-impact matrix then became a logical foundation for the city-factory-product simulation interface. This interface was developed as according to the current needs of the target user. Who are small and medium enterprises in the manufacturing industry. The interface allows for a user to simulate a city/factory/product scenario and gain information on its focus on urban resilience and sustainability. In the discussion the choice of toolkit, central questions, and push and pull factors for promoting urban resilience focus with urban factories is discussed.

CHOICE OF TOOLKIT TYPE

The toolkit was made into an application for smartphones. The choice behind this was based on a combination of factors: digital accessibility, barriers to information and characteristics of the target user group. The smartphone is the most preferred way to access the internet as mobile phones accounted for 74% of internet usage in Europe in 2021 [32]. Mobile applications are therefore a low entry point for most people. It was chosen to make for the greatest number of users to access the toolkit. Unlike sustainability, which has become more mainstream in recent years, information about urban resilience and urban manufacturing tends to be very academic. To help the information dispensing about these topics in a relatable manner the toolkit was made interactive. The combination of user inputs and personalized information about the topics helps with that relatability. Lastly,SME owners have an average age of 38 years in Europe [33] . This age group tends to be mixed in terms of computer literacy. European SMEs tends to have multiple founders per start up. While there are accessibility advantages to having a digital toolkit, a physical toolkit in the form of reports or workshops are also viable options. Physical workshops can offer more opportunities for clarification with the target group and offer opportunities for socialization amongst various participants. Workshops do require more time and planning on the side of the user. As well as the need for a skilled moderator to be physically available for the session. It isbest to use this toolkit in combination with other resources available on the topic.

WERE THE CENTRAL QUESTIONS ANSWERED?

The way the toolkit addresses the central question shows how well the research answered the research question. The first question “In what ways does a city’s design, influence a factory’s design, and their offered products?” is addressed in Chapter 2 of the report. The literature research on the topics of urban manufacturing, urban design, urban resilience, and sustainability detailed the ways in which city, urban factories, and products influenced each other. This was synthesized into the cross-impact matrix in which these qualitative relationships were best summarized as a quantitative influence score.

The second question “How can urban resilience goals be translated into metrics that apply to a factory set in an urban context and products for a local market?” was addressed by the result delivery subsystem of the toolkit as seen in Chapter 5. This was done using the urban resilience and sustainability focus scores. These metrics were directly based on the user’s goals, needs, and wants. As the user inputs were used as weighing factors on previously established relationships from the cross-impact matrix.

The next central question of "How can relevant future scenarios be explored in an urban resilience context such that the desires/needs of stakeholders are also considered?" was addressed through the combination of detailing the current context of the user and designing a conceptual scenario. The user could reflect the current state of their city, factory, or product offering against a hypothetical future scenario. This was expressed through the city-factory-product match result. The final central question of "What can be done in the design of the interface to make the simulation results scalable so that it can give a good impression on impacts to its urban environment?" was addressed by the personalization of advice based on the outcomes of their future scenario. The toolkit doesn't create quantitative-based advice but uses existing resources to help tailor advice based on their input. In this way filtering the most important information for the user. It makes a clear starting point which the user can choose to use to go deeper into the topic.

PUSH AND PULL FACTORS FOR URBAN RESILIENCE AND SUSTAINABILITY

There is a series of pushing and pulling forces that influence the adoption of urban manufacturing in cities. And thus, the degree to which they can live up to urban resilience and sustainability standards. Push forces can be defined as circumstances and actions that promote the movement away from a certain place or situation. Pull forces describe appealing situations or incentives that attract people to certain places or situations.

Looking at the push forces, there are issues such as community acceptance, lack of space, circular waste management, and transportation infrastructures. Urban factories by design will create interconnectedness of citizens with manufacturers. This comes with its fair share of value conflicts. Previous unregulated manufacturing in the 19th and early 20th centuries led to the unintended consequence of increased health issues from noise and air pollution. This pushed lawmakers to segregate land uses and force manufacturing away from citizens [31]. Even with the innovations in sustainable manufacturing processes, these strict zoning practices remain and with that a negative perception of production sites. City residents are still highly sceptical of manufacturing near housing areas.

However small and micro manufacturers thrive in city environments due to the proximity to their clientele base. Potential neighbours of urban factories don't have much connection to the production happening there and do not see the immediate value of it. Instead focusing on nuisances such as sounds and odours. Also, these small businesses lack the legitimacy to be involved in urban planning and to advocate for themselves[31]. However, at the same time, some communities are struggling to stay innovative and attract young people to live there. These concerns of residents are relevant and can be used to push the design of future urban factories towards sustainable practices and to value community involvement and transparency more. Thereby increasing their potential urban resilience and sustainability.

The potential for urban resilience and sustainability impact is also influenced by the availability of space for the urban factory. Sajadieh et.al. identified demographic changes as a mega trend impacting the adoption of urban factories. It can be simplified into smaller trends of urbanization, population growth and population ageing [34]. Urbanization shows a general trend in prioritizing city design for residential spaces, as more people move into cities and away from rural areas. This comes at the cost of limiting the space available for urban factories not only to produce goods but also to store materials. Herrmann et.al. describe the limited inner-city space as one of the biggest challenges of manufacturing companies.[5] This pushes companies to make efficient use of space. This multiplies in sustainability impact by developing buildings with more efficient heating/cooling per square meter. Population growth and ageing are very important metrics for municipalities and manufacturers alike. Municipalities get funding based on their population size. With a larger budget they and can offer more targeted activities and resources to residents. While companies need to find human resources with diverse skills to work in their urban factories. Currently, there is a deficit in available workers. This also forces manufactures to create better and more attractive workspaces for potential employees. Thereby increasing their social sustainability and urban resilience.

Similarly, circular waste management is closely related to the issue of space availability for sustainability impact. Circular waste streams can be used to create closed loops for manufactures, as the waste can become reusable raw materials. This is only a given if those waste streams are well sorted and a city has the capacity to process them[35]. There are needs to be enough space for urban manufacturers to store waste they produce as well as the converted waste for raw materials. As each producer becomes part of a circular waste stream network supplying each other with raw materials. A manufacturer could also produce renewable energy and have excess energy to give to another production site. Without the logistic support of proper waste stream management by municipalities it is too risky for SMEs to use circular waste as a raw material.

There is also the challenge of moving goods and citizens within city boundaries [10]. The trend of revitalisation of neighbourhoods is also limiting the potential of urban factories to exist. The narrowing of street corners, adoption of wider footpaths and infrastructure of cycling paths mean that goods cannot be transported by traditional time and cost-efficient methods [31]. This reduced the strength of networks within the city thereby reducing its capacity for urban resilience. This push manufactures and urban planners to collaborate earlier in city development plans.

When looking at the pull forces, there are opportunities to address: a need for more human resources, incentives from municipalities, a lack of European manufacturers and stimulating innovation. There is a pull force to develop resilient urban factories to attract potential workers of diverse skills. There is a need for more human resources. Workers put the largest emphasis on overall satisfaction with life, security and safety, total income and proximity to friends and family [3]. To ensure these security safety and life satisfaction, increasing the resilience of a city is inevitable. There must be the ability to adapt to change, absorb shocks and stop or reduce the causes of risk and vulnerability thereby ensuring equitable risk sharing.

Investments from municipality into resilient and sustainable production can also act as an attractive pull force for SMEs. SMEs lack the power and resources to set up urban factories in such a manner. With the support of a municipality this is suddenly achievable for smaller companies. Because there are so few European based manufacturing sites as compared to a 50 years ago, there is a knowledge gap occurring. The space for innovating is lost when production sites are physically separated from their research and developers [31]. As there are tacit knowledge and skills lost when the communication of both departments is strained through physical or cultural distances.

LIMITATIONS

Some factors influenced the nature of the results. These factors include those related to the: scope of the research the timeline of the thesis, the cross-impact matrix, the user interface design, and testing limitations. The project scope had a larger focus on learning factories than other kinds of urban factories. Also, the research could have benefited more from a greater detail of input on end-of-life waste streams. In the future, it would be best to include views on social science aspects about political factors that influence resilience. The research timeline was the length of one academic year and as such was limited in how detailed certain aspects could be described. Therefore, choices were made on what aspects to give priority to in verification and testing.

The cross-impact matrix was not verified by a third party and as such the results of it should be taken in the context of this research and not applied elsewhere without further consideration. It is also important to note that the way in which a dimension is defined impacts the rating of the relationships within the matrix. There is also a lack of consensus about the definition of urban resilience and what a city is. This varies based on the academic field of the researchers. Literature reviews were used to redefine it for the context of this research.

The language used in the toolkit also can influence participants answers and choices. The phrases manufacturing and factory are also heavily biased my negative associations for some users as well. Lastly, the number and variation of testing subjects could be improved in further research. Due to the limited time frame, only 3 participants all of which have engineering backgrounds were used as participants. If the participants were diversified in their skill background testing results could be more insightful.

CONCLUSION

The research question of "How can a city-factory-product interface be simulated such that configurations supporting urban resilience are explored?" was answered through the delivery of an interactive toolkit application. Through the various types of user interactions introduced the user can learn about the topic of urban resilience while exploring the exchanges between city, factory, and product.

The city-factory-product interface was expressed through the use of a future scenario. In which the characteristics of the city nexus could be weighed for importance by the user. It is because the scenario allows for both reflection on the current state of the user and the desired future outcome that they can interpret urban resilience responses. Which exist in a given space-cultural scenario, both from a technical and governance perspective. As the user must make choices about how to spend resources, they encounter trade-offs in resilient and sustainable development. The ability to choose different roles also gives the user the opportunity to expand their own perspective and take on a transdisciplinary narrative. Lastly, the evaluation metrics given in the results of urban resilience focus, city sustainability focus, city-factory-product match and advice gave some context for the user to replicate such a scenario in reality. While the application does not provide immediately scalable results, it does filter personalized advice to create urban manufacturing sites at scale.

There are opportunities for future research about this toolkit. Firstly, the logical underpinning of the toolkit, the cross-impact matrix could be further verified and researched for the relationships found. There is the need to address political influence as well which this toolkit does not accommodate. Another version of the toolkit which can involve multiple SMEs could also be beneficial. As it, would stimulate industry connections and discussions on the topic of resilient urban factories.

Finally, this toolkit developed from this research would be suitable in the project development phase to test different business concepts against each other. It is recommended to use this toolkit in combination with other literature on the topic of urban manufacturing and urban resilience. This can be the starting point for SMEs to gain knowledge on the possibilities of moving production back to cities.

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APPENDIX

PRODUCT INFLUENCE ON URBAN DESIGN	Influence score	Weight
		2.07
Physical Product	**2.65**	**+0.9**
Material Components	2.1	
Use Design	3.1	
Function	2.8	
Service	**2.10**	**+1.0**
Maintenance	2.2	
Customer Integration	2.0	
Product Service System	**1.34**	**+0.2**
End of Life	0.3	
Resource Consumption	1.1	
Cost Properties	2.5	

Appendix.1. Product influence on urban design

PRODUCT INFLUENCE ON URBAN RESILIENCE	Influence score	Weight	1.83
Physical Product	**2.10**	**+0.3**	
Material Components	1.7		
Use Design	2.3		
Function	2.3		
Service	**2.41**	**+0.9**	
Maintenance	3.1		
Customer Integration	1.7		
Product Service System	**1.24**	**-0.4**	
End of Life	0.6		
Resource Consumption	0.8		
Cost Properties	2.3		

Appendix.2. Product influence on urban resilience

PRODUCT INFLUENCE ON CITY SUSTAINABILITY	Influence score	Weight	0.93
Physical Product	**1.04**	**+0.0**	
Material Components	0.7		
Use Design	1.5		
Function	0.9		
Service	**0.78**	**-1.4**	
Maintenance	0.9		
Customer Integration	0.7		
Product Service System	**1.10**	**-0.3**	
End of Life	0.5		
Resource Consumption	1.2		
Cost Properties	1.6		

Appendix.3. Product influence on city sustainability

PRODUCT INFLUENCE ON LEARNING FACTORY 1.73	Influence score	Weight
Physical Product	1.93	+0.5
Material Components	2.1	
Use Design	1.7	
Function	2.0	
Service	2.20	-1.4
Maintenance	2.3	
Customer Integration	2.1	
Product Service System	1.43	-0.3
End of Life	0.3	
Resource Consumption	1.1	
Cost Properties	2.9	

Appendix.4. Product influence on learning factory

PRODUCT INFLUENCE ON URBAN FACTORY 1.67	Influence score	Weight
Physical Product	1.76	-0.6
Material Components	2.3	
Use Design	1.4	
Function	1.5	
Service	1.87	-1.1
Maintenance	2.4	
Customer Integration	1.4	
Product Service System	1.41	-0.1
End of Life	1.0	
Resource Consumption	1.4	
Cost Properties	1.8	

Appendix.5. Product influence on urban factory

CITY INFLUENCE	ON SERVICE Influence score	Weight	1.50
Urban Design	1.12	-1.0	
Morphology	0.7		
Visual	0.7		
Perception	1.7		
Functional	0.7		
Social	1.3		
Temporal	1.5		
Urban Resilience	1.53	-0.9	
Inclusive	1.2		
Transformative	1.5		
Adaptive	2.0		
Governance	1.0		
Absorptive	1.4		
Networks	2.3		
City Sustianability	2.18	+1.4	
Environmental	1.9		
Socio-economic	1.0		
Economic	1.0		

Appendix.6. City influence on service

CITY INFLUENCE	ON PRODUCT-SERVICE SYSTEM Influence score	Weight	1.26
Urban Design	1.14	-0.2	
Morphology	2.0		
Visual	0.3		
Perception	0.6		
Functional	1.0		
Social	1.8		
Temporal	1.2		
Urban Resilience	1.64	+0.4	
Inclusive	1.4		
Transformative	1.4		
Adaptive	2.6		
Governance	1.3		
Absorptive	1.3		
Networks	1.9		
City Sustianability	1.38	+0.3	
Environmental	2.7		
Socio-economic	1.3		
Economic	1.7		

Appendix.7. City influence on product service system

CITY INFLUENCE	ON LEARNING FACTORY		2.01
	Influence score	Weight	
Urban Design	1.73	+0.1	
Morphology	1.7		
Visual	0.9		
Perception	2.0		
Functional	1.4		
Social	2.0		
Temporal	2.2		
Urban Resilience	2.07	+0.4	
Inclusive	2.6		
Transformative	1.7		
Adaptive	2.2		
Governance	1.6		
Absorptive	2.6		
Networks	1.9		
City Sustianability	1.74	+0.3	
Environmental	1.3		
Socio-economic	1.8		
Economic	2.0		

Appendix.8. City influence on learning facory

CITY INFLUENCE	ON URBAN FACTORY		1.97
	Influence score	Weight	
Urban Design	2.22	+0.2	
Morphology	2.8		
Visual	1.1		
Perception	2.2		
Functional	1.7		
Social	2.5		
Temporal	2.8		
Urban Resilience	2.25	+0.7	
Inclusive	1.5		
Transformative	1.9		
Adaptive	2.9		
Governance	1.8		
Absorptive	2.4		
Networks	3.0		
City Sustianability	2.21	+0.3	
Environmental	2.8		
Socio-economic	1.9		
Economic	1.9		

Appendix.9. City influence on urban factory

CITY INFLUENCE *ON PHYSICAL PRODUCT*	Influence score	Weight	1.53
Urban Design	**1.73**	**-0.9**	
Morphology	0.9		
Visual	0.9		
Perception	1.6		
Functional	2.1		
Social	1.9		
Temporal	2.9		
Urban Resilience	**1.83**	**-0.3**	
Inclusive	2.5		
Transformative	1.9		
Adaptive	2.6		
Governance	0.6		
Absorptive	1.4		
Networks	2.0		
City Sustianability	**1.09**	**+0.1**	
Environmental	1.6		
Socio-economic	0.8		
Economic	0.6		

Appendix.10. City influence on physical product

FACTORY INFLUENCE ON URBAN DESIGN	Influence score	Weight	1.85
Learning Factory	**1.61**	**-0.1**	
Operating Model	2.1		
Purpose and Targets	1.2		
Process	0.6		
Setting	1.2		
Production	0.5		
Urban Factory	**1.99**	**-0.2**	
Logistics & Mobility	1.1		
Technology	1.2		
Social	2.8		
Circular Production	1.1		
Environmental Impact	1.7		
Factory Site & Construction	3.1		
Economic	2.8		
Resilience	2.1		

Appendix.11. Factory influence on urban design

FACTORY INFLUENCE ON URBAN RESILIENCE	Influence score	Weight	1.63
Learning Factory	**1.74**	**-0.4**	
Operating Model	2.1		
Purpose and Targets	1.4		
Process	1.7		
Setting	1.5		
Production	0.9		
Urban Factory	**1.63**	**-0.7**	
Logistics & Mobility	1.3		
Technology	1.5		
Social	2.0		
Circular Production	0.9		
Environmental Impact	0.7		
Factory Site & Construction	1.3		
Economic	1.5		
Resilience	2.7		

Appendix.12. Factory influence on urban resilience

FACTORY INFLUENCE ON CITY SUSTAINABILITY 1.71	Influence score	Weight
Learning Factory	**1.37**	**-0.3**
Operating Model	1.2	
Purpose and Targets	1.2	
Process	2.3	
Setting	1.5	
Production	0.9	
Urban Factory	**1.90**	**-0.3**
Logistics & Mobility	1.2	
Technology	1.5	
Social	2.0	
Circular Production	2.0	
Environmental Impact	1.9	
Factory Site & Construction	2.3	
Economic	2.3	
Resilience	3.4	

Appendix.13. Factory influence on city sustainability

FACTORY INFLUENCE ON PHYSICAL PRODUCT 2.49	Influence score	Weight
Learning Factory	**2.39**	**+0.5**
Operating Model	1.2	
Purpose and Targets	2.1	
Process	2.5	
Setting	2.8	
Production	3.8	
Urban Factory	**2.42**	**+0.6**
Logistics & Mobility	1.9	
Technology	2.0	
Social	1.9	
Circular Production	2.2	
Environmental Impact	2.9	
Factory Site & Construction	3.5	
Economic	2.4	
Resilience	1.6	

Appendix.14. Factory influence on physical product

FACTORY INFLUENCE	Influence score	ON SERVICE Weight	2.70
Learning Factory	**2.06**	**-0.1**	
Operating Model	2.4		
Purpose and Targets	1.7		
Process	1.2		
Setting	1.4		
Production	2.4		
Urban Factory	**2.97**	**+1.1**	
Logistics & Mobility	1.8		
Technology	2.7		
Social	1.9		
Circular Production	2.3		
Environmental Impact	2.0		
Factory Site & Construction	2.9		
Economic	2.7		
Resilience	3.5		

Appendix.15. Factory influence on-service

FACTORY INFLUENCE	Influence score	ON PRODUCT SERVICE SYSTEM Weight	1.57
Learning Factory	**1.82**	**+0.4**	
Operating Model	1.3		
Purpose and Targets	0.7		
Process	2.9		
Setting	1.4		
Production	2.2		
Urban Factory	**1.90**	**+0.1**	
Logistics & Mobility	1.6		
Technology	1.4		
Social	1.4		
Circular Production	2.3		
Environmental Impact	1.7		
Factory Site & Construction	1.9		
Economic	1.3		
Resilience	2.4		

Appendix.16. Factory influence on product service system

Lean UX Canvas (v2)

Title of initiative:

Date:

Iteration:

Business Problem

What problem does the business have that you are trying to solve?
(Hint: Consider your current offerings and how they deliver value, changes in the market, delivery channels, competitive threats and customer behavior.)

1

Users

What types (i.e., personas) of users and customers should you focus on first?
(Hint: Who buys your product or service? Who uses it? Who configures it? Etc)

3

Hypotheses

Combine the assumptions from 2, 3, 4 & 5 into the following hypothesis statement:
"We believe that [business outcome] will be achieved if [user] attains [benefit] with [feature]."
(Hint: Each hypothesis should focus on one feature only.)

6

Solutions

What can we make that will solve our business problem and meet the needs of our customers at the same time? List product, feature, or enhancement ideas here.

5

What's the most important thing we need to learn first?

For each hypothesis from Box 6, identify its riskiest assumptions. Then determine the riskiest one right now. This is the assumption that will cause the entire idea to fail if it's wrong.

(Hint: In the early stages of a hypothesis focus on risks to value rather than feasibility.)

7

Business Outcomes

How will you know you solved the business problem? What will you measure?
(Hint: What will people/users be doing differently if your solutions work? *Consider metrics that indicate customer success like average order value, time on site, and retention rate.)*

2

User Outcomes & Benefits

Why would your users seek out your product or service? What benefit would they gain from using it? What behavior change can we observe that tells us they've achieved their goal?
(Hint: Save money, get a promotion, spend more time with family)

4

What's the least amount of work we need to do to learn the next most important thing?

Design experiments to learn as fast as you can whether your riskiest assumption is true or false.

8

Download this canvas at: **www.jeffgothelf.com/blog/leanuxcanvas-v2**

Appendix.17. Lean UX Canvas

Dimension	Subcategory	New Title	Description
Stage 1 :Getting Started			
City	Temporal	Forethought	Planning for future changes to the space in how it is used and shared over time.
	Morphology	Spatial design	Organizing the distribution of streets and building plots
	Perception	Citizen Insight	Investing in research of how people feel in and interpret the space
	Social	Community well-being	Supporting safety and accessibility in neighborhoods and city
	Visual	Attractiveness	Enhancing the beauty of the city (buildings, lampposts etc.)
Factory	Operational Model	Investments	Financing the development of your urban factory (support from institutions)
	Setting	Mixed Reality	Investing in digital integration for the factory floor.
	Process	Lean Production	Refining and updating the ordering plan for maximum efficiency
	Logistics and Mobility	Logistics	Ensuring easy movement of goods and people (both employees and consumers)
	Purpose and Targets	Research and Development Goals	Supporting a vision for research and making research targets
Product	Material Components	Physical configuration	Sourcing & designing the shape, materials and weight of the product
	Use Design and Lifecycles	Ease of Use	Research and development into the mental load and physical ergonomics of the product
	Cost properties	Marketing	Market research and cost analysis of

Appendix.18. Table of future factors for stage 1

Dimension	Subcategory	New Title	Description
Stage 2 :Technical Innovation			
City	Functional	Functions of spaces	Investing in the design of public spaces whether it be to promote comfort, engagement, privacy, and other activities.
	Adaptive	Adjustment capacity	Create adaptive planning schemes that include reflection on standards and stimulate innovation
	Absorptive	Elastic response	Developing flexibility and redundancy measures for your city.
	Networks	-	Streamlining the transfer of resources (e.g., energy) and the transportation infrastructure
Factory	Production	Product catalogue	Refining of the number, types, and variation of products made in the factory.)
	Technology	Industry 4.0	Investment into advanced technology, new and developing high-tech machinery
	Circular production	-	promoting the development of green transportation, renewable technology, and waste management into useful materials.
	Factory site and construction	Quality Measures	Setting high quality standards for production and factory site maintenance.
Product	Function	Functionality	Detailing functional requirements that addresses the lifetime, consumption in use and complexity of the product.
	Maintenance	Serviceability	Providing maintenance services during the lifetime of the product.
	Customer integration	-	Involving consumers in the production of the product and support after purchasing the product.

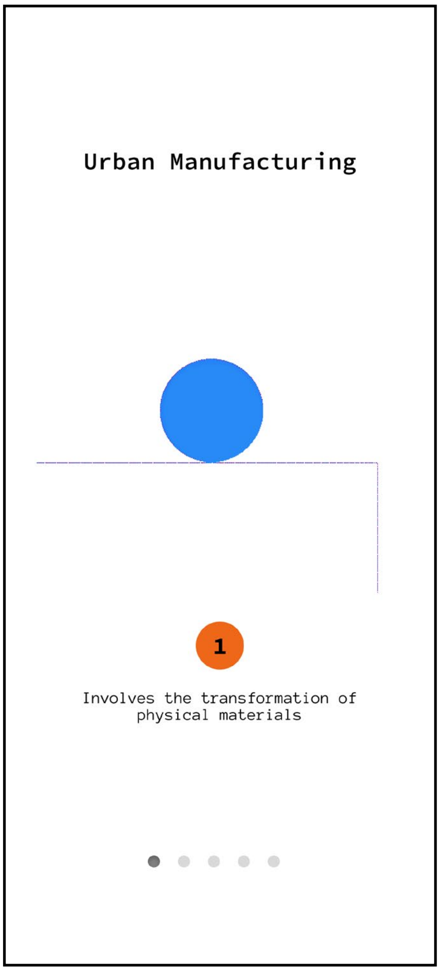
Appendix.19. Table of future factors for stage 2

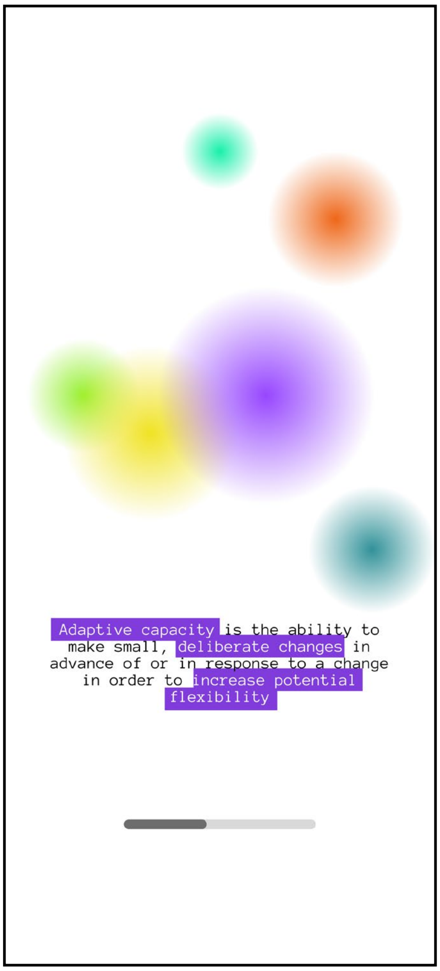
Dimension	Subcategory	New Title	Description
Stage 3 :Thinking Responsibly			
City	Inclusive	Inclusivity	Involving all social groups in a city, both in numbers and with agency in matters pertaining to city development.
	Transformative	Risk Management	Implementing changes to stop or reduce the causes of risk and vulnerability.
	Governance	Local government	Funding the bureaucratic structures that organize, legislate, and protect a city and its citizens.
	Environmental	-	Tracking and managing the ecological footprint, waste management, access to green space, and fresh water and air availability of the city..
	Socio-economic	Social	Supporting health services, schooling and urban growth in relation to population demographics.
	Economic	City Economics	Developing economic sustainability through a variety of occupations, economic growth and integration with regional economies.
Factory	Social	Human welfare	Ensuring employee well being and community engagement.
	Environmental	Environmental Consciousness	Reducing negative environmental influences caused by the factory to the urban environment.
	Economic	Financial sustainability	Setting realistic business targets that balances production costs with profit.
	Resilience	Perseverance	Protecting the factory from internal (e.g. equipment failure) and external shocks (e.g. natural disasters)
Product	Resource consumption	Resources	Ethical and sustainable extraction of resources and human resources.
	End of life	Circular waste management	Innovating waste stream processing such as recycling, re-use and disposal.

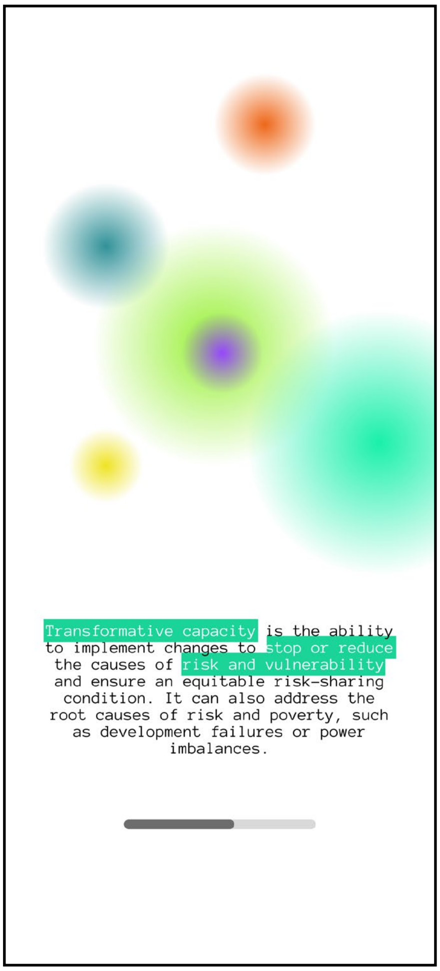
Appendix.20. Table of future factors for stage 13

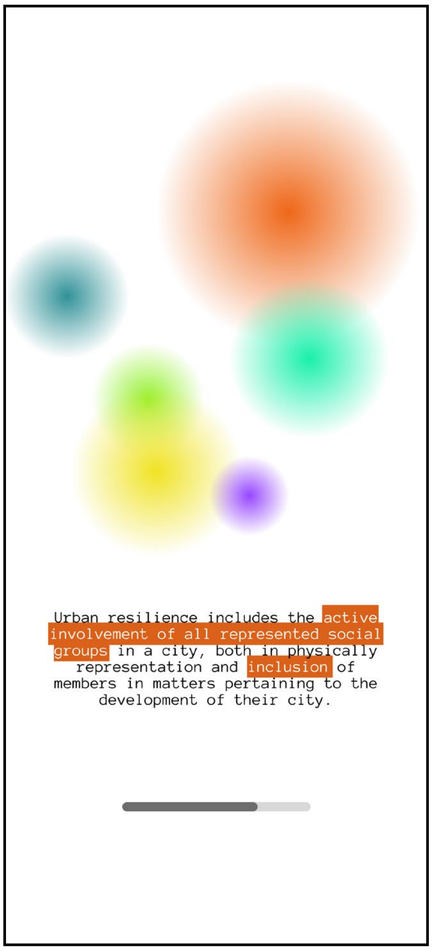
Dimension	Characteristic	Question
City	Physical size of city	i. Would you define your city as being a large physical size? ii. Are there a noticeable number of empty lots in your city centre?
	Population education	i. Do most people in your city aim for a higher education level than high school level? ii. Is there a vocational school or university in your city?
	Connection of cities to other cities	i. Is your city well connected with other cities nearby?
	Economy	i. Is your city's economy based on one large industry? ii. Is your city economy based on multiple industry types, with one not clearly larger than the other?
Factory	Supply chain	i. Are you confident in predicting the number of products to order for production? ii. Are your raw materials sourced locally and regionally or internationally? iii. Are your good shipped on time regularly? iv. Can your city handle your current waste production?
	Market in/outside city	i. Is your product market local and regional or international? ii. Is your factory close to neighbourhoods?
	Niche to generic spectrum	i. Does your factory produce niche or generic goods?
	Production scale	i. Do you have plans to scale up production considerably?
	Technology/production machinery	i. Do you put majority of your investments into developing/acquiring new technologies?
Product	Customer buying behaviour	i. Do your customers choose your products for convenience or is it for its speciality? ii. Can your product allow for a high degree of personalization or is it standardised?
	Price	i. Is your product of a relatively low or high price as compared to other products of its kind on the market?
	Distribution	i. Is your product distributed for a local market or an international market?
	Promotion	i. Is your product marketing more generalized or highly targeted? ii. Is your largest consumer well defined?
	Design for production	i. Are your products dimensions large (outside the typical dimensions for shipping products on pallets as a complete piece)? ii. Is your product weight very heavy? iii. Is your product shape so complex as to require non-standard production methods? iv. Is your product made from chemically unstable raw materials? v. Does your product require frequent maintenance (after every use or multiple times a week)? vi. Is your product made from OEM parts outside of your region (i.e., internationally)?

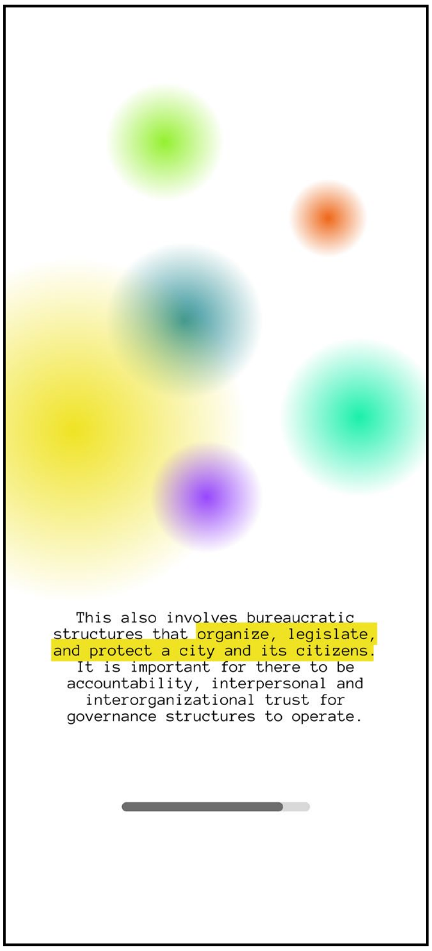
Appendix.21. Table of questions for context building

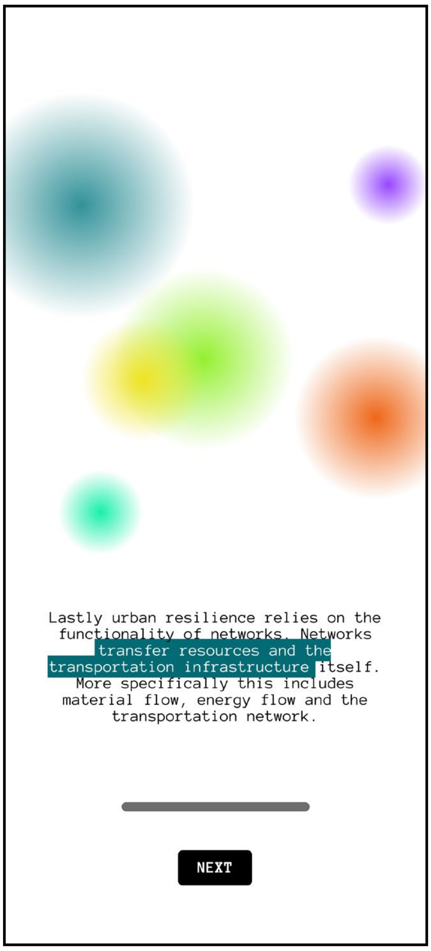

Urban Manufacturing
1
Involves the transformation of physical materials

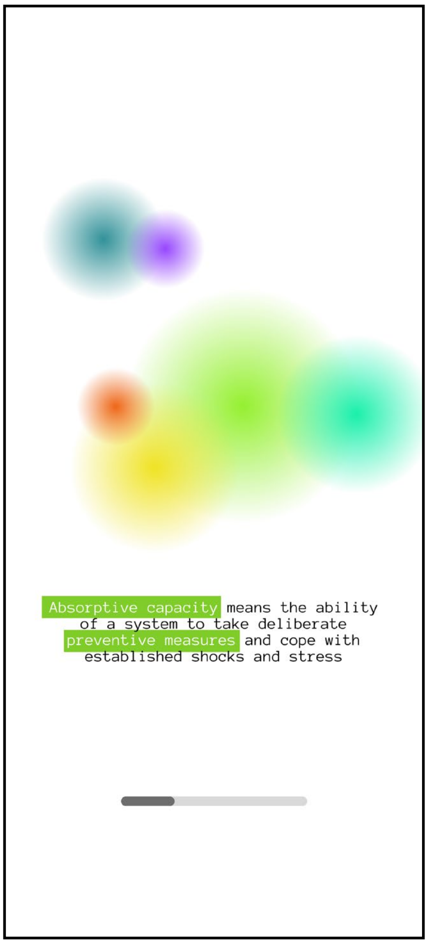

Adaptive capacity is the ability to make small, deliberate changes in advance of or in response to a change in order to increase potential flexibility

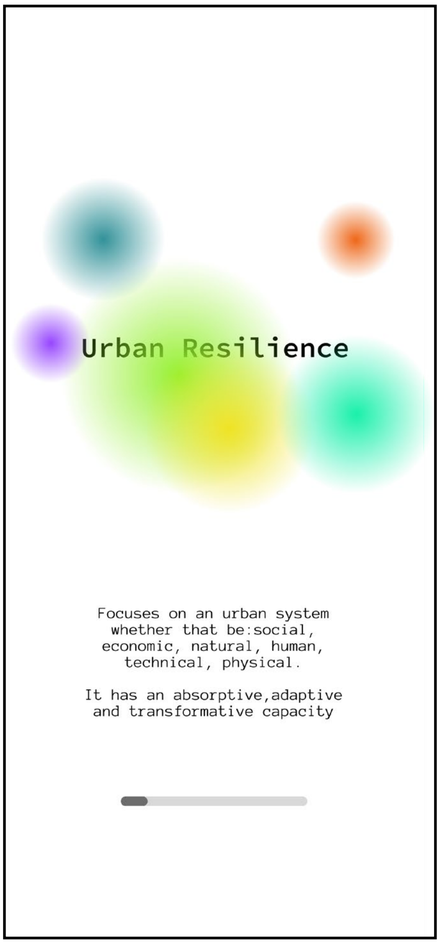

Transformative capacity is the ability to implement changes to stop or reduce the causes of risk and vulnerability and ensure an equitable risk-sharing condition. It can also address the root causes of risk and poverty, such as development failures or power imbalances.

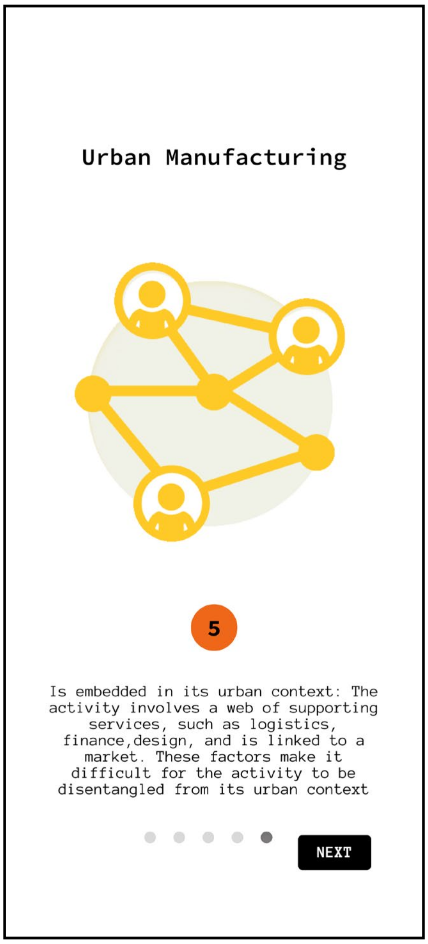

Urban resilience includes the active involvement of all represented social groups in a city, both in physically representation and inclusion of members in matters pertaining to the development of their city.

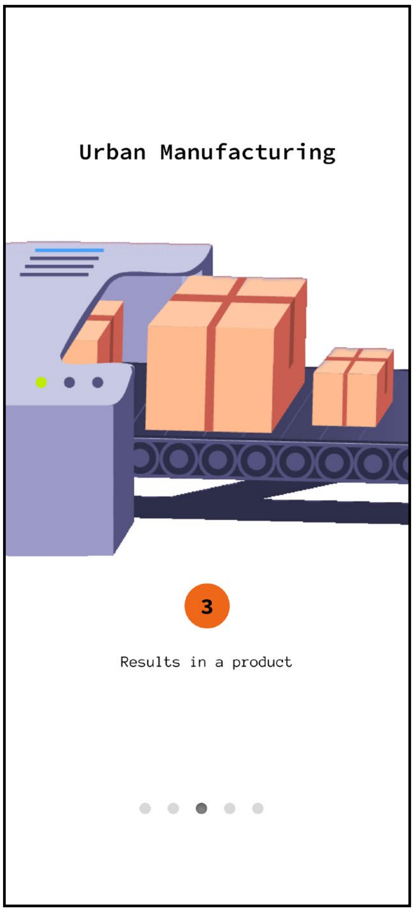

This also involves bureaucratic structures that organize, legislate, and protect a city and its citizens. It is important for there to be accountability, interpersonal and interorganizational trust for governance structures to operate.

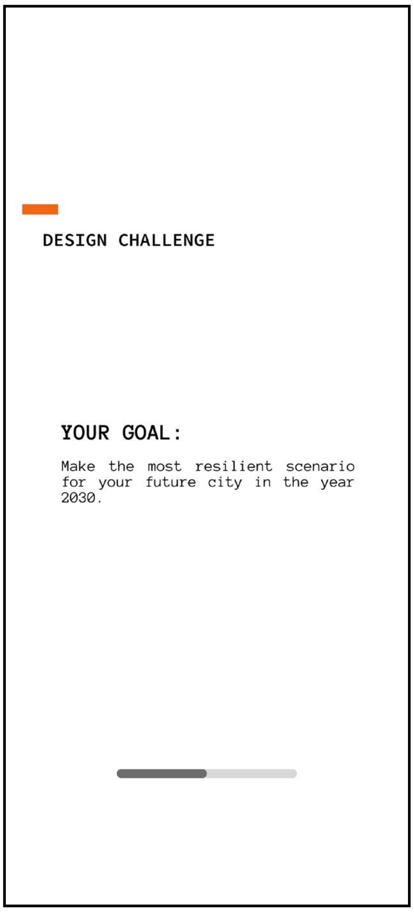

Lastly urban resilience relies on the functionality of networks. Networks transfer resources and the transportation infrastructure itself. More specifically this includes material flow, energy flow and the transportation network.
NEXT

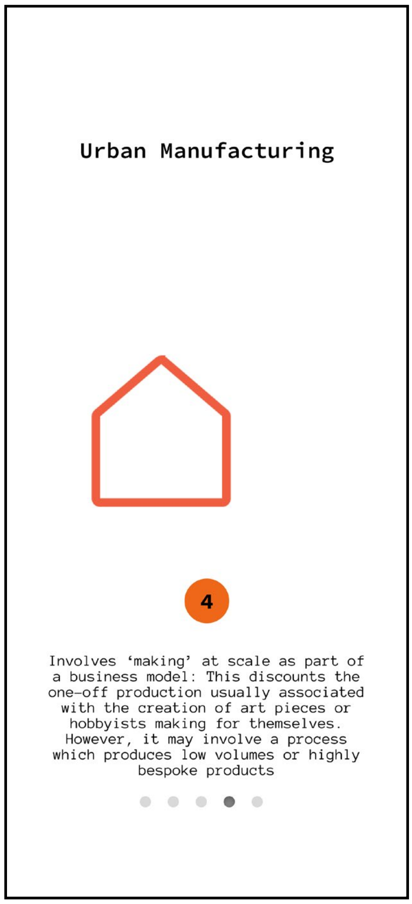

Absorptive capacity means the ability of a system to take deliberate preventive measures and cope with established shocks and stress


Urban Resilience
Focuses on an urban system whether that be:social, economic, natural, human, technical, physical.
It has an absorptive,adaptive and transformative capacity

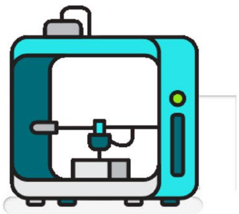

Urban Manufacturing
5
Is embedded in its urban context: The activity involves a web of supporting services, such as logistics, finance,design, and is linked to a market. These factors make it difficult for the activity to be disentangled from its urban context
NEXT


Urban Manufacturing
3
Results in a product


DESIGN CHALLENGE
YOUR GOAL:
Make the most resilient scenario for your future city in the year 2030.


Urban Manufacturing
4
Involves 'making' at scale as part of a business model: This discounts the one-off production usually associated with the creation of art pieces or hobbyists making for themselves. However, it may involve a process which produces low volumes or highly bespoke products

Urban Manufacturing



2

Employs labour, tools and/or machines

DESIGN CHALLENGE

YOUR GOAL:

Make the most resilient scenario for that future city.

HOW?

1. Add context: Answer a few questions to get some background on your current state.
2. Use the definition of resilience to choose "future factors" to invest resources into. Be careful you have a limited amount to spend.

DESIGN CHALLENGE

YOUR GOAL:

Make the most resilient scenario for that future city.

WHEN HAVE YOU ACHIEVED YOUR GOAL?

1. If your designed city/ urban factory/product is suitable for a mixed use situation.
2. When citizens have value creation from your future scenario.
3. Your designed city/urban factory/product has the largest positive impact on urban resilience in the future scenario.
4. When your designed scenario has an excellent match of city, factory and product functionalities and needs.

I AM READY TO BEGIN

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