Towards digitalisation of urban social sustainability

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2022

Thesis for the degree of Licentiate of Engineering

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Digital tools to evaluate social performance of neighbourhood design

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to my family

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Abstract

The primary goal of the built environment is to create the infrastructure that facilitates the needs of the people that use them and elevate their quality of life. Sustainable development has encouraged architects and urban planners to be more sensitive toward the built environment's economic, environmental, and social dimensions. Digital tools for performance assessment are commonly used to shorten the feedback loop in testing designs for buildings and neighbourhoods. However, these tools do not extend to the social dimension in the same way as the economic and environmental dimensions.

This thesis aims to contribute to USS research and bridge the gap between theory and practice through digitalisation. It investigates USS in general and explores how it can be conceptualised and made operational to support architects and urban planners in their design process. The focus is on digital tools and how they can be integrated into the current architectural and urban design process. Two studies are carried out (A and B). Based on systematic literature analysis, study A explores the theoretical background of USS. It investigates the reasons for the lack of consensus on USS's conceptualisation and how digital tools can be developed around these issues. Study B explores the development of an indicator to support practitioners in evaluating the ability of residents to achieve their daily needs and uses interviews with practitioners for feedback on the indicator and how it can be improved.

The findings indicate that USS is a complex and often "fuzzy" topic. There are many definitions for USS but little consensus among them. By viewing USS as an empty signifier, stakeholders can collaboratively decide what social themes are important to them. Two categories of social themes are identified - social equity and social capital. Focusing on social and spatial equity, a USS indicator called Trip Completion Rate is developed and used to explore the ability of residents to fulfil their daily needs through examples. The interviews with practitioners suggest that an indicator for evaluating social issues is appreciated, but further development is required in communicating complex results to stakeholders. In conclusion, the findings of this thesis contribute to a better understanding of USS and how to operationalise it for architects and urban planners through indicators. To further advance the integration of USS into the design process of neighbourhoods, digital tools must focus on enhancing social equity in the built environment. Finally, it identifies the indicators, methods and future pathways to advance the design of socially sustainable neighbourhoods through digitalisation.

Keywords: Social Sustainability, digitalisation, digital tools, neighbourhood, indicators.

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Sanjay Somanath
Göteborg, May 2022

List of Publications

This thesis is based on the following appended papers:

Paper 1. (Published)

Sanjay Somanath, Alexander Hollberg and Liane Thuvander. *Toward digitalisation of socially sustainable neighbourhood design* Published in Local Environment 2021, VOL. 26, NO. 6, 770-789.

Contribution: Somanath planned and designed the database search, reviewed the literature and wrote the paper as the main author. Thuvander and Hollberg contributed to the analysis, the writing and provided feedback on the research design.

Paper 2. (Submitted)

Sanjay Somanath, Liane Thuvander, Jorge Gil and Alexander Hollberg. *Using trip completion rates to evaluate urban social sustainability* Submitted to Cities 2022, The International Journal of Urban Policy and Planning.

Contribution: Somanath reviewed the literature, performed the construction of the indicator and analysis of the data, interviewed stakeholders and analysed the transcripts, and wrote the paper as the main author. Thuvander contributed to the design and planning of the interviews and provided feedback on the paper. Gil contributed to the design of the research methodology, the construction and evaluation of the indicator and provided feedback. Hollberg contributed to the planning of the paper, the research design, and provided feedback.

Other relevant publications co-authored by Sanjay Somanath:

S. Boyukliyski, D. Petrova-Antonova and **Sanjay Somanath**. *Evaluation of social facilities coverage: A case study of Sofia city* CSC Sofia, Conference paper - Accepted (2022).

V. Naserentin, **Sanjay Somanath**, O. Eleftheriou, and Anders Logg. *Combining Open Source and Commercial Tools in Digital Twin for Cities Generation.* CSC Sofia, Conference paper - Accepted (2022).

Stahre Wästberg, B., Billger, M., Thuvander, L., Latino, F., **Sanjay Somanath** and Raalte, S. van. *MiljöVis: Effektiv representation av miljödata i digitala modeller.* Technical report. Göteborg: Trafikverket, Report - Published (2021).

Sanjay Somanath, Hollberg, A., and Thuvander, L. *A user interaction model for digital tools to support socially sustainable neighbourhood planning* Proceedings for CUPUM 2021 - 17th International Conference on Computers in Urban Planning and Urban Management. CUPUM - Computational Urban Planning and Urban Management, Helsinki, Finland, Conference paper (2021).

Sanjay Somanath, Hollberg, A., Beemsterboer, S., and Wallbaum, H. *The relation between social life cycle assessment and green building certification systems.* SLCA2020: 7th International Conference on Social Life Cycle Assessment: Impacts, Interests, Interactions, Gothenburg, Sweden, Conference paper (2020).

Acronyms

CAD	–	Computer-aided Design
DAD	–	Digital Architectural Design
DDP	–	Digital Design Process
GIS	–	Geographic Information Systems
GWP	–	Global Warming Potential
GHG	–	Green House Gas
NHTS	–	National Household Travel Survey
NSS	–	Neighbourhood Social Sustainability
OSM	–	Open Street Maps
PCA	–	Personal Carbon Allowance
PPGIS	–	Public Participation Geographic Information Systems
QoL	–	Quality of Life
SD	–	Sustainable Development
SDGs	–	Sustainable Development Goals
SoSu	–	Social Sustainability
TCR	–	Trip Completion Rate
UIM	–	User Interaction Model
USS	–	Urban Social Sustainability

Contents

Chapter 1

Introduction

The primary goal of the built environment is to create the infrastructure that facilitates the needs of the people that use them and elevate their quality of life; to shape the physical and spatial surroundings for human purposes (Hillier 2008b). As such, the design and planning of the built environment are inherently social endeavours. However, in the conceptual framework of sustainable development (SD), the social dimension of the built environment was left under-theorised (Vallance et al. 2011) and operationally challenged (Shirazi and Keivani 2019b).

Social sustainability is a broad topic that finds itself entwined among several disciplines like sociology, anthropology, architecture and urban planning to name a few. The concept traces its roots to the 1980s at the start of the SD agenda. The "Brundtland Report" or "Our Common Future" (WCED 1987) is considered the springboard that led to the current state of discourse on SD (Boström 2012; Dixon 2011; Vallance et al. 2011; Littig and Grießler 2005). However, SD, as it first emerged in the late 1980s, was underpinned by an environmental vision (Åhman 2013). The Brundtland report presented SD as a conceptual framework consisting of three dimensions, environmental, economic and social, which, when combined, would lead to "holistic" sustainability. This triple bottom line model of SD has since seen widespread adoption in planning and architecture. SD demands the combination of the environmental, economic and social dimensions of societal development (Littig and Grießler 2005). In response to the escalating social inequalities and injustices of the previous decades (Bouzguenda et al. 2019), the social and economic dimensions were included as one of the four core sections of *Agenda 21* (United Nations 1997); a product of the United Nations Earth Summit held in 1992 at Rio de Janeiro. The adoption of the updated *Agenda 2030* (United Nations 2016) produced the SD Goals (SDGs), a set of goals and indicators to guide global efforts towards SD from 2016 to 2030. The SDGs comprise 17 sustainability goals in-line with the three dimensions of SD - environment, economy and society.

Over the past two decades, there has been a steady increase of focus on social sustainability both in research and practice (Janssen et al. 2021) (See Figure 2.3). This new era of social sustainability has led to increased efforts to theorise and conceptualise it. Though still in its early stages, social sustainability in the built environment (or Urban Social Sustainability - USS) is now widely recognised as an important dimension of SD that warrants further research and discussion to operationalise it. In the last decade, most works on USS (Boström 2012; Dempsey et al. 2011; Vallance et al. 2011; Bramley, Dempsey, Power, Brown, and Watkins 2009) often discussed how social sustainability was left out of the SD discourse. They describe social sustainability as *the missing pillar* (Boström 2012), *a concept in chaos* (Vallance et al. 2011) and *the forgotten pillar* (Opp 2017) among other things. The research discourse has now moved towards discussions on the meanings and conceptualisation of the topic. More recently, research has focused on advancing the topic using empirical evidence (Shirazi and Keivani 2021). There is a long-standing discourse on urban form, and its relationship to sustainable cities and communities (Janssen et al. 2021; Shirazi and Keivani 2021; Bramley, Dempsey, Power, and Brown 2006), and recently this discourse has intersected with USS.

USS literature suggests that the built environment, in the present and the future, is crucial for achieving social sustainability and improving human well-being while mitigating environmental risk (Hedayati Marzbali et al. 2021; Eizenberg and Jabareen 2017). To achieve a sustainable built environment, a design process that ensures a sustainable relationship between human beings and the built environment must be followed (Lami and Mecca 2021). While scholars focus their efforts on theorising the social aspects of sustainability (Vallance et al. 2011) urban policies have continued to discuss theoretical notions of what constitutes a socially sustainable community (Hedayati Marzbali et al. 2021; Davidson 2009). Problems such as USS benefit from being well-framed and solved collaboratively (Frich et al. 2018). Including the views of the residents and other stakeholders in the early stages of the design process improves the stability of the community and interaction between community members (Hedayati Marzbali et al. 2021). *Softer themes* (Shirazi and Keivani 2019b) such as social inclusion and developing a sense of belonging contribute to the overall social capital of a community thereby contributing towards socially sustainable communities (Dempsey et al. 2011). In this process, the role of architects and urban planners as designers and practitioners of the built environment becomes quite important. At the early stages of design, architects and urban planners often mediate intent between the various stakeholders, synthesising design from its various requirements. Architects and urban planners are well-positioned to incorporate the seeds of USS principles into their designs. However, they lack the necessary tools and methods to support their decision making, especially digital tools.

Evidence-based decision-making has proven to be a *potent vehicle* to achieve the SDGs (Bell and Morse 2010). This is also reflected in the built environment, evident from the proliferation of performance indicators in the design and planning process (Huang et al. 2015; Hiremath et al. 2013). But in practice, designers still need to ask questions such as *is this solution better than that in this context?* or *will this work for these people?* (Hillier 2008a). Compared to social sustainability, indicators and tools relating to environmental sustainability are more developed (Bouzguenda et al. 2019). Sustainability evaluation frameworks such as Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Built Environment Efficiency (CASBEE) and German Green Building Council

(DGNB) are reflective of the environmental underpinnings of SD (Olakitan Atanda 2019; Ali and Al Nsairat 2009). The scope of such evaluation frameworks primarily focuses on the environmental and sometimes the economic dimensions of SD (Sharifi and Murayama 2013). The social aspects included in such tools are often limited to occupant well-being and comfort. They do not extend to the broader social sustainability themes like social equity and justice.

The design process in the built environment, like all design processes, is one of iterative exploration. Each iteration is evaluated to identify how the design performs or how it can be improved. Traditionally, this evaluation process depends on the designers' knowledge, and competence to a large extent (Hillier 2008a). In recent years, however, evidence-based design has gained attention for its ability to facilitate a well-informed debate of potential solutions (Loyola 2018; Head 2008). As various fields related to the design of the built environment have progressed (such as energy performance, transport modelling, and life cycle assessment) so have the opportunities for evaluating them in an evidence-based manner. But the environmental focus still remains. Designers can now answer questions such as *will residents feel comfortable?* or *how energy efficient is this building?* Tools addressing SD need not just be evaluation frameworks or indicators but can also be digital. Digital tools in the built environment are used to quicken the feedback loop in the design process. Digital tools allow designers to supplement their *instruments of designerly inquiry* (Dalsgaard 2017) along with rules of thumbs and collective wisdom.

The transition to this first-principles approach to design has only recently been made possible. Most, if not all, design in the built environment uses digital tools to expedite the design process. Digital tools for performance assessment of the built environment are commonly used to quickly test designs for buildings, neighbourhoods, and even cities. The development in environmental sustainability and increased access to computational resources have enabled performance assessment tools for evaluating energy consumption, energy performance, and life-cycle assessment, to name a few (Mackey and Roudsari 2017). Digital tools in social sustainability however, cover different aspects of the design process, primarily to facilitate digital collaboration and participation or to gather insights from the end-users to determine a baseline of the current situation for the design process. Public Participation Geographic Information Systems (PPGIS) is one such application (Kyttä et al. 2016). Digital tools have been leveraged here to include the various stakeholders in the design process and foster collaboration and inclusion but do not address performance based evaluations.

1.1 Problem statement

If planning is to become an instrument for implementing social sustainability goals, efforts must be focused on better connecting planning procedures, and policy goals (Stepanova and Romanov 2021). For architects and urban planners to answer questions of *who* is affected or disadvantaged by their designs and *in what way*, new evaluation methods are required that include the collaborative aspects of social sustainability and provide designers with digital tools to evaluate the social consequences of their designs.

1.2 Aim and research questions

This thesis aims to contribute to USS research and bridge the gap between theory and practice through digitalisation. *It investigates USS in general and explores how it can be conceptualised* and *made operational to support architects and urban planners in their design process*. The focus is on *digital tools and how they can be integrated into the contemporary architectural and urban design process*. The overarching research question (RQ) formulated is:

How can digital tools support architects and urban planners in evaluating the social consequences of their designs?

Figure 1.1: The variable operationalisation process, adapted from Allen (2017)

To address the aim outlined above, two specific research questions are formulated. These specific research questions focus on (i) conceptualisation of USS in the literature and (ii) operationalisation of USS through indicators (Figure 1.1).

RQ1. How to conceptualise urban social sustainability?

RQ2. How to operationalise urban social sustainability through digitalisation?

1.3 Research scope

The scope of this thesis is defined by its focus on the social consequences of proposed designs, the target users, spatial scale, and finally, the nature of support provided by a tool.

This thesis begins with an abstract conceptualisation of USS. It recognises a relationship between the built environment and social sustainability, which is called USS. It is understood as being ontologically related to SD as one of the crucial dimensions within the tri-partate conceptualisation of the environment, economy and society. Design in the built environment is understood as the exploration and transformation process by which a designer draws upon their repertoire of knowledge, competence and resources to create something novel and appropriate that changes the current situation for the better. As such, it is the architect or urban planner that is considered the *designer* and the *target user* as they have a large impact at the early stage of the design process (See Figure 1.2). This research is positioned within architecture and urban design. There are subtle but significant differences between the two. They share similarities in that they deal with shaping the built

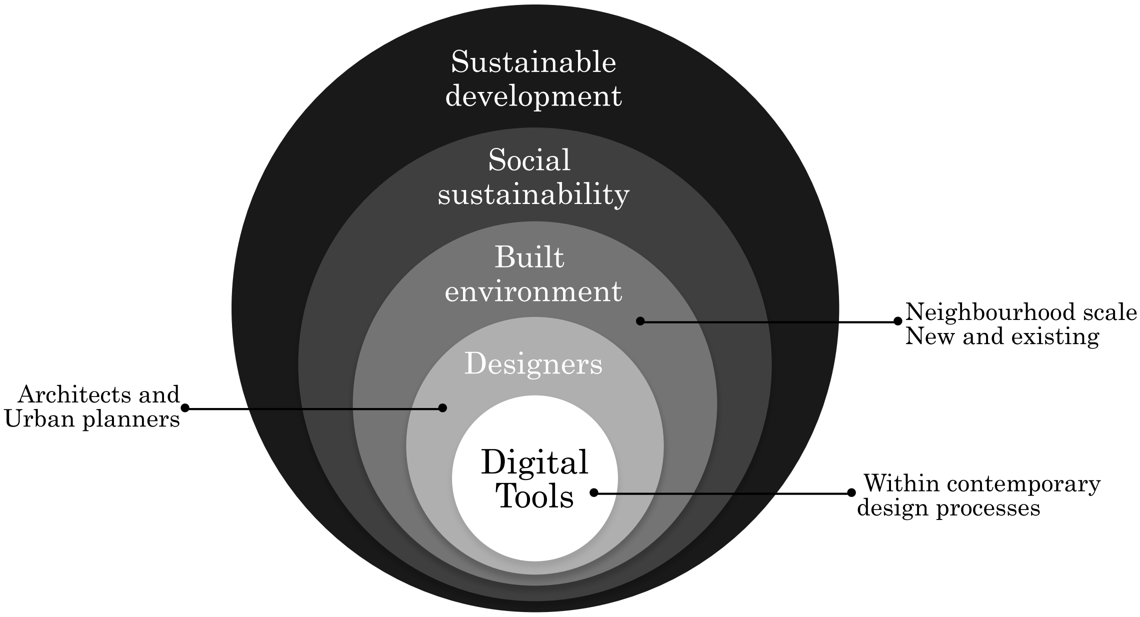


Figure 1.2: Positioning the scope of the research

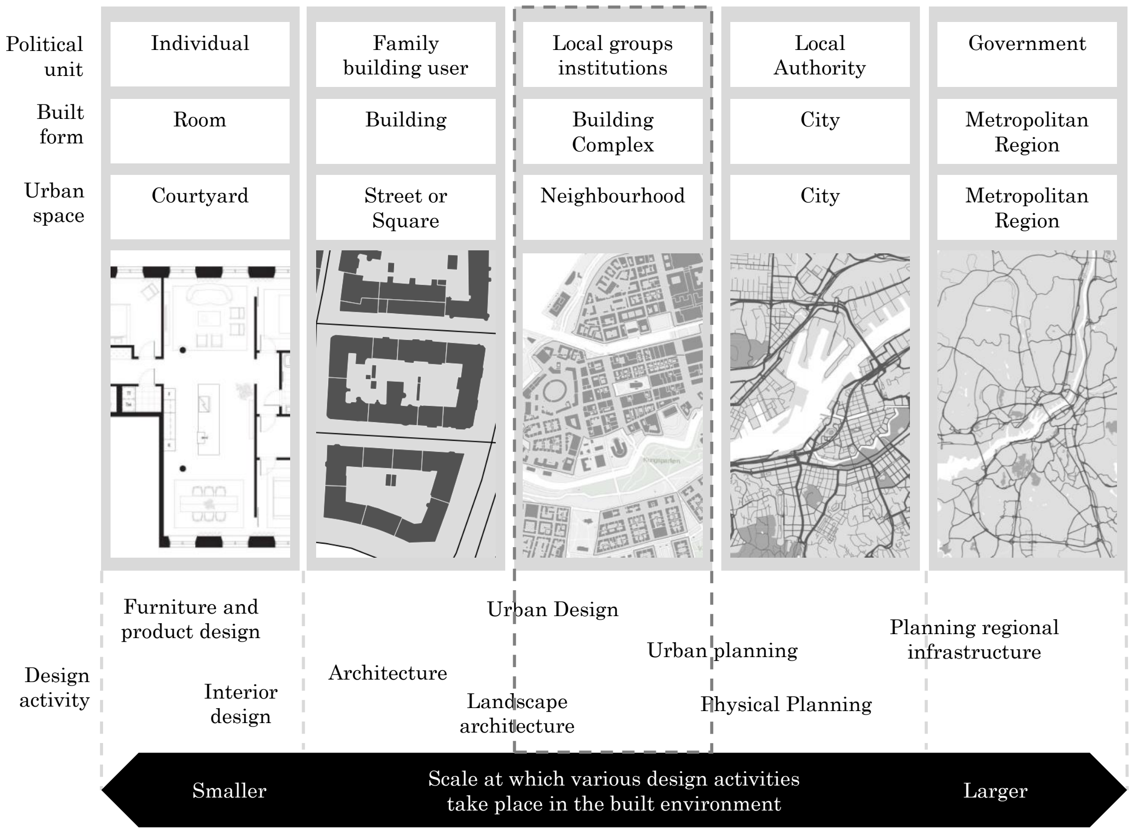


Figure 1.3: Scale of design activity in the built environment, adapted from Erickson and Lloyd-Jones (2001)

environment from a design and planning perspective and mediate between the design and the stakeholders. However, they differ in the nature and scale of intervention. Architecture deals with the design and planning of the built environment at the building scale, while urban design involves interventions on the neighbourhood, city or regional scale. The neighbourhood is selected as the spatial scale of interest. The neighbourhood is an ideal scale for intervention as it provides an interface between individual residents, local authorities, policymakers and the community as a collective. It is also a practical scale to address social problems and challenges as several neighbourhood-oriented sustainability assessment tools work directly at this scale already (Shirazi and Keivani 2019a). Finally, the nature of support is limited to digital tools that provide decision support at the early stages of the design process (See Figure 1.3).

There are other topics that relate to shaping the built environment relevant to this thesis's investigations. The field of transport and mobility planning offers interesting insights into using analytical tools to evaluate complex and interconnected relationships between the built environment, the people who interact with it and the policy that shapes it. Concepts such as *accessibility* and *mobility* offer a means to model the movement of residents and how they interact with different scenarios of planning and design. These topics are also considered while exploring the conceptualisation of USS.

1.4 Research approach

Considering that there is a lack of digital tools that support the evaluation of designs in the built environment, and that explorations of USS often result in inconsistent conceptualisations and numerous definitions, this thesis uses inductive approaches to explore USS literature. Inductive methods help formulate the theoretical background of USS and understand the stakeholder perspectives of social sustainability indicators. *Induction* is a qualitative research method that suggests that theoretical and empirical generalisations must be derived from the data (Miller and Brewer 2003). Induction allows the data to *speak for itself*. In comparison, deductive research methods propose that hypotheses are derived from theory and then tested against data. Other qualitative research methods like *interviews* and *conceptual framework analysis* are used to evaluate the stakeholder feedback on the initial findings and ideas developed from the theoretical background of social sustainability.

First, this thesis explores the landscape of academic literature and policy documents on USS in study A. Once the reasons for issues in the discourse around USS are identified, the results are used to understand how digital tools for architects and urban planners can be developed to avoid the common pitfalls identified in the literature through a model for digital tool development. Then, study B investigates how indicators for the multi-dimensional evaluation of USS can be developed. The outcome of this study is Trip Completion Rate (TCR) as an indicator for architects and urban planners to evaluate *the ability of a resident to fulfil their daily needs*. (Figure 1.4).

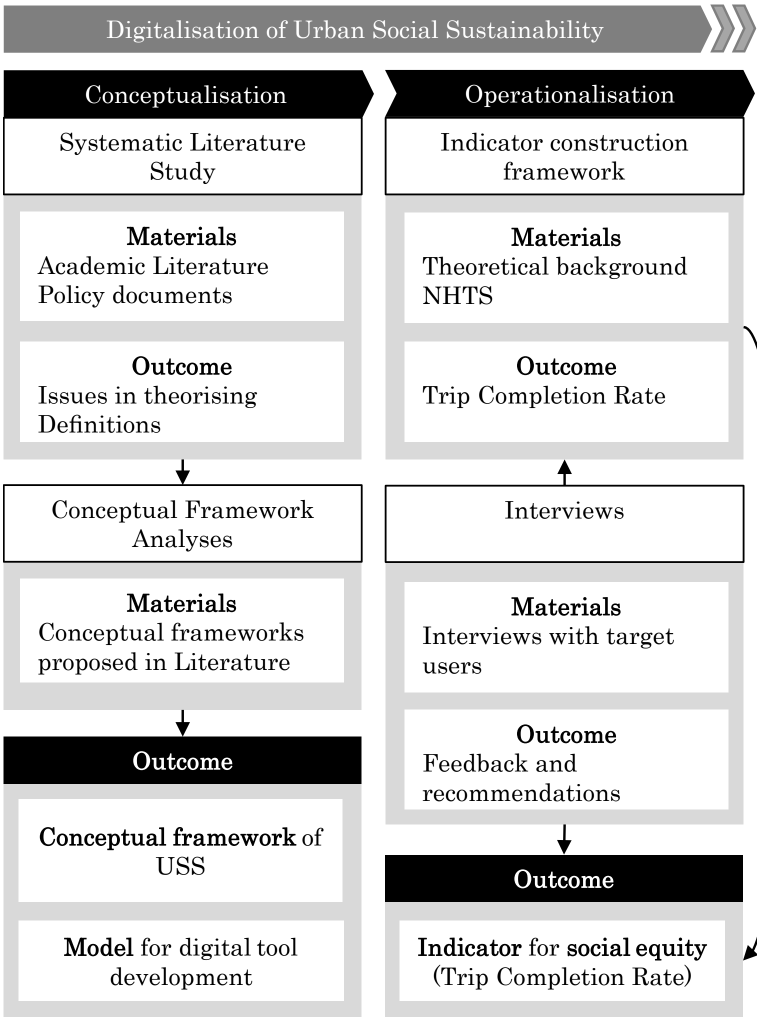


Figure 1.4: Research Approach

1.5 Outline of the thesis

This thesis consists of two parts. Part I is a general introduction to the field and puts the appended papers into context through summaries. Part II contains the appended papers.

The structure of Part I is as follows:

Chapter 1 presents an overview of the previous research relating to USS. Subsequently the aim, overarching research question and specific research questions are outlined.

Chapter 2 presents an relevant previous research that provides an extended background for this thesis.

Chapter 3 describes the overall design of the research and the methods for the two studies included in this thesis.

Chapter 4 summarises the findings of the studies.

Chapter 5 and discusses the findings in relation to the research questions and previous research.

Chapter 6 provides the conclusion to this thesis.

Chapter 7 presents directions for future research with an overview of the identified paths to be investigated in the next stages of the Ph.D. project.

Finally, there are two papers that are appended to this thesis in Part II (Paper 1 and Paper 2).

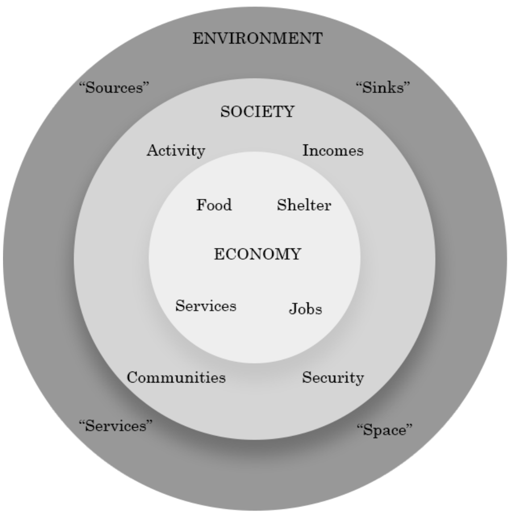
Chapter 2

Extended Background

2.1 Sustainable development

The Brundtland Report set forward a new path for urban development (Kohon 2018). It introduces Sustainable Development (SD) as: "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs" (WCED 1987). SD is understood as *advancements that enable individuals to live in a healthy and safe environment by improving their quality of life, thereby heightening the environmental, economic and social aspects of the present and future generations* (Atanda and Öztürk 2018). Due to its wide scope, SD as a research discipline has led to many interpretations and definitions (Visvaldis et al. 2013). As this approach gained significance in policy, practice and research, SD came to be recognised as a mainstream urban policy (Shirazi and Keivani 2021).

The triple-bottom-line model of SD implies equal importance to its constituent



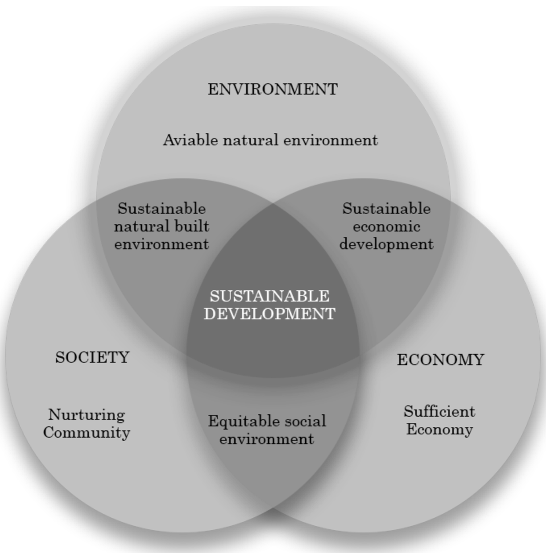


Figure 2.1: Concentric model of Sustainable Development (Left), Triple bottom-line model of Sustainable Development (Right), adapted from Felberg et al. (1999) and Purvis et al. (2019))

dimensions (see Figure 2.1). In the 1980s, the environmental dimension was the most relevant aspect (Lami and Mecca 2021); at the end of the 1990s, the economic dimension also gained greater importance (Lami and Mecca 2021). The social dimension, however, has received much less attention in this regard (Cope et al. 2022).

SD is just one of many possible solutions to *the way forward* in human development. Other approaches are either presented as being complementary to SD or as alternatives. Regardless of the conceptual differences in these approaches, their motivation is closely aligned to facilitating human development to ensure that present and future generations of humans have a satisfactory quality of life. One such approach is the *capabilities approach* (Sen 2005). Sen (2013) argues that while SD is an improvement from earlier approaches to development, it is incomplete. Rather than limiting the focus of development to fulfilling *felt needs*, one must look further towards sustaining *human freedoms*. The central theme of the capabilities approach is to first sustain the freedom to choose which needs must be fulfilled. Another approach is that of *urban resilience*. Urban resilience is defined as *the ability of an urban system to maintain or rapidly return to desired functions in the face of a disturbance* (Meerow, Joshua P. Newell, et al. 2016). It is often referenced alongside concepts linked to *sustainability, adaptation,* and *vulnerability*. Amirzadeh et al. (2022) suggest that the ultimate goal of resilience is *achieve sustainability*; in that resilience is contingent on sustainability. Resilience is sometimes also viewed as conceptually in conflict with the idea of sustainability (Meerow, Joshua P Newell, et al. 2019). While sustainability seeks to find an optimal balance between current and future needs, resilience stresses uncertainty and building *adaptive capacity* in present systems in preparation for unexpected future changes.

2.2 Social Sustainability in the built environment

At the outset, social sustainability (urban or otherwise) can be hard to grasp. Primarily due to being at the nascent stages of its development (Vallance et al. 2011). Walker and Attfield (1989), on what constitutes a discipline suggests that a discipline can be *described briefly as the ensemble of assumptions, concepts, theories, methods and tools employed by a particular group of scientists or scholars.* As social sustainability gains interest and relevance and moves towards a discipline from a concept, such conceptualisations are particularly useful. As a discipline matures and attains *self-awareness* (Walker and Attfield 1989) the assumptions that constitute its conceptual formulations become more explicit. Over the past two decades, social sustainability as a concept has become increasingly self-aware; this is evident by the number of indexed documents available on the subject but its conceptualisations are not yet explicit (See Figure 2.2 and Figure 2.3).

Like SD, social sustainability has been a concept with many understandings and definitions (Chiu 2003), and the path towards creating sustainable communities is often paved with a myriad of challenges and contesting conceptualisations (Kohon 2018). Dempsey et al. (2011) has advocated for social sustainability to be considered a dynamic concept, one that changes over time. This conceptualisation is reflected

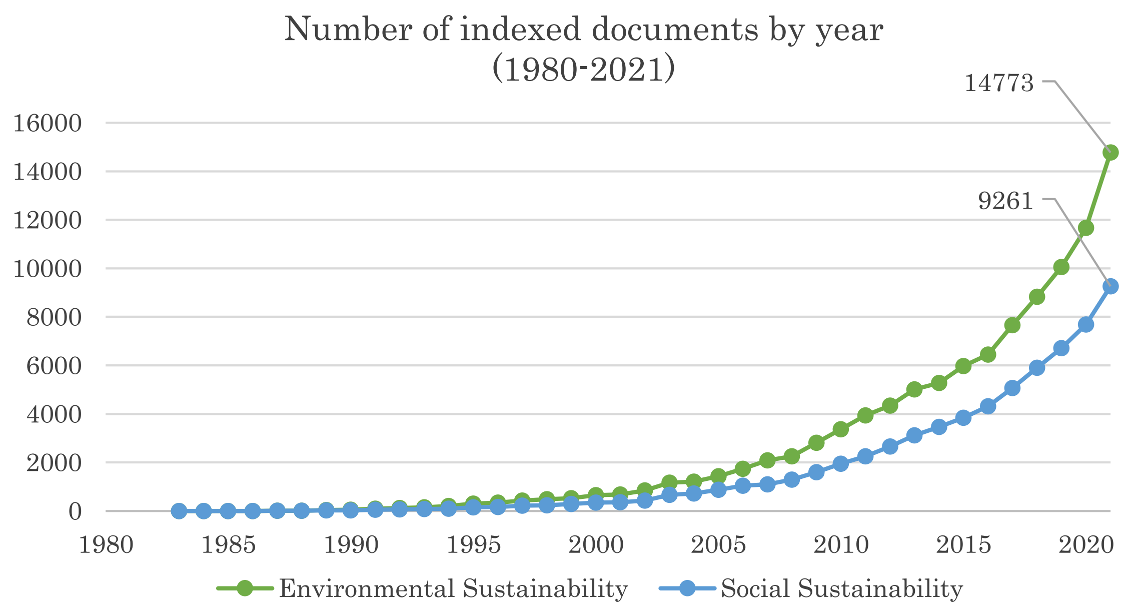


Figure 2.2: Results for the query strings *"(TITLE-ABS-KEY(environmental AND sustainability))"* and *"(TITLE-ABS-KEY(social AND sustainability))"* on the research document indexing website Scopus (Elsevier B.V. 2022)

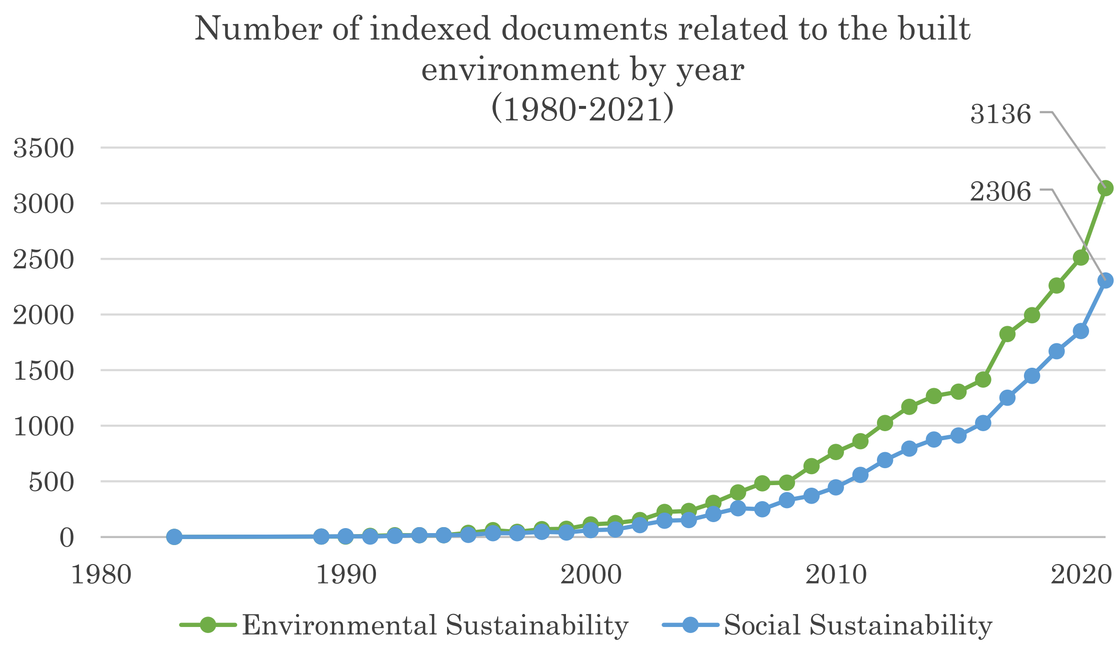


Figure 2.3: Results for the query strings *"(TITLE-ABS-KEY((environmental AND sustainability) AND (urban OR city OR neighbourhood OR building OR (built AND environment))))"* and *"(TITLE-ABS-KEY((social AND sustainability) AND (urban OR city OR neighbourhood OR building OR (built AND environment))))"* on the research document indexing website Scopus (Elsevier B.V. 2022)

in the works of Shirazi and Keivani (2019b) who identify a socially sustainable environment as a place with *dialectic character*, one where hard infrastructure like the physical qualities of the built environment and soft infrastructure like the social capital of a community are both highly sought out.

Concerning the built environment, the term *Urban social sustainability* is commonly used (Shirazi and Keivani 2019b; Kyttä et al. 2016; Dempsey et al. 2011); indicating a relationship to the built environment. Shirazi and Keivani (2019b, p. 2) defines socially sustainable neighbourhoods as *localities where social qualities are exercised and practised within the neighbourhood space at an acceptable and satisfactory standard*.

The research literature on USS suggests a strong connection between improving social qualities and aspects of the built environment. Kain et al. (2022) and Jenks and Jones (2010) discuss the role of densities and land use typologies of the urban form and their relationship to social qualities. The authors provide numerous examples of research that suggest higher densities and mixed-use urban forms lead to a higher quality of life due to an increase in social interaction and community spirit. At the same time, they point out that there are also several claims that compaction could lead to negative impacts on social qualities, such as lower access to green spaces, deteriorating health, a reduction in living space and less affordable housing.

Caulfield et al. (2001) discuss case studies of ten cities, including Vienna, Herzegovina and Cape Town, as examples of *extraordinary success* in terms of urban environments that are *conducive to the compatible cohabitation of culturally and socially diverse groups*. The authors identify clear connections between social factors and the environment. They state that cities must reflect on the social and spatial fragmentation that led to the exclusion of marginal or/and disadvantaged groups to achieve social sustainability. Sustainable cities are formed through the synergies between infrastructure and policies. Social infrastructures (such as schools and hospitals), public services (such as water, public transport and electricity), housing and inclusive public spaces complemented by good governance and socio-cultural policies collectively form the policy areas that lead to sustainable cities.

Shirazi and Keivani (2021) discuss specifically the social implications of urban form and density. Through the case study of Berlin, the authors discuss the role of compact densities in offering a higher quality of life for their citizens. Density as a measure of the concentration of physical structures is shown to have both *promises and pitfalls*, similar to the findings by Caulfield et al. (2001) wherein the built form affects notions of safety, home satisfaction, interaction and networking. However, the authors note that density is a relative concept; what is considered high to some may not be the same as another. This relative perception of density implies that the relative nature of urban form to the composition of its inhabitants is also a relative one. Though highly dependent on the context, the built environment has strong correlations to the ability of a space to achieve USS.

In policy circles, notions of social justice, social equality and social cohesion are widely used to describe USS at different levels of scale (Stepanova and Romanov 2021). Social sustainability as a policy tool can help authorities assess the social sustainability qualities of a neighbourhood or a region - or any scale for that matter, by deeply understanding the object of interest and identifying the challenges and concerns (Shirazi and Keivani 2019b). In the context of planning policy, however, researchers have pointed out a lack of understanding of the relationship between planning and social sustainability goals, often criticised for being normative and visionary (Stepanova and Romanov 2021). Such fuzziness in the discourse has equally critical implications for policy and practical implementation. For SD as a policy measure, however, no environmental policy can be truly effective without an equally sound social policy (Caulfield et al. 2001).

2.3 Design process of the built environment

Given the importance of the built environment in shaping USS, the designers of the built environment play an important role in this process. Professional designers, the practitioners in the built environment - architects and urban planners (henceforth referred to as *designers*), play a role not just as makers of urban forms but more so as cultural intermediaries (Kimbell 2011).

In the design process, there are several stakeholders with varied interests, and designers can often find themselves employed by any one of them; however, they must often address the interests of those who are not necessarily their employers (Erickson and Lloyd-Jones 2001). It is often the designer that intermediates between the intent of the decision-makers and the ones most affected by these decisions. According to Kimbell (2011), the designer serves the role of the *glue* in the multidisciplinary teams that are involved in the shaping of the built environment; they are the interpreters and facilitators of changes in the culture who then synthesise new kinds of cultural forms. According to Dalsgaard (2017, p. 24) design can be viewed as *a field concerned with finding novel and useful ways of approaching and transforming an uncertain situation in which there are no straightforward answers.* Such problems are often referred to as *wicked problems* (Rittel and Webber 1974) or *ill-structured problems* (Buchanan 1992; Cross 1982). Rittel and Webber (1974) states that in a pluralistic society, there can be no objective definitions of equity. The information necessary to sufficiently understand wicked problems depends on one's approach to solving them, requiring an exhaustive inventory of all potential solutions ahead of time. Wicked problems are fundamentally different from the objective and well-defined problems from classical engineering in that even though the latter may be complex, they have clear set goals, and unambiguous boundary conditions (Rittel and Webber 1974). As Cross (1982, p. 227) puts it, wicked problems are *problems for which all the necessary information is not or ever can be available to the problem solver* as opposed to the *puzzles* of scientists and mathematicians who can suspend decision making until more information about the problem is known. In addition to the lack of information and clearly defined boundaries, time is another intrinsic component of design tasks. A designer is often tasked with synthesising a design within a specific time limit. Rather than a prolonged analysis of the problem, design activity relies on generating satisfactory solutions fairly quickly (Cross 1982). Another distinctive attribute of design tasks is their association with a human-centred approach to problem-solving. Kimbell (2011) describes design and design thinking as an iterative problem-solving

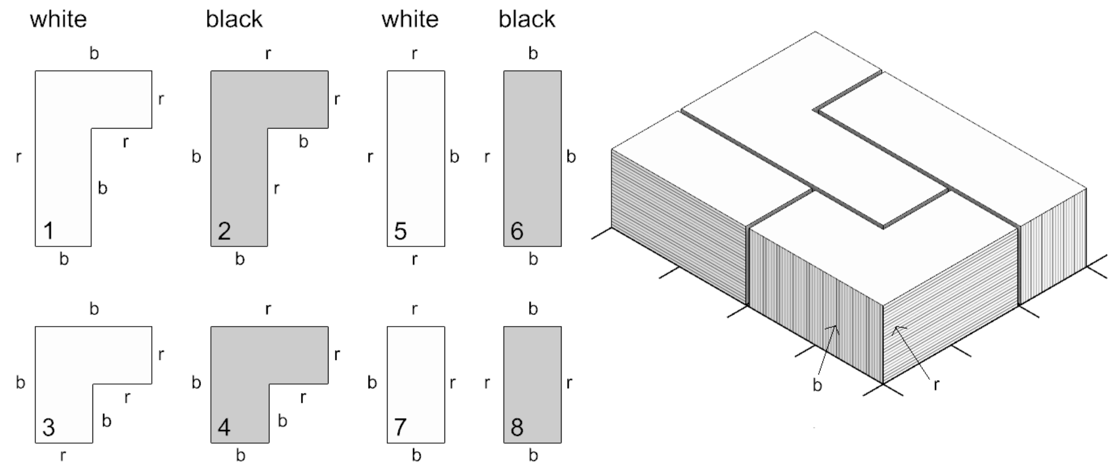


Figure 2.4: Lawson's experiments on cognitive differences between designers and scientists. Plan view of blocks that were presented to the architects and scientists (Left) . Solution to the problem (Right). r = Red, b = blue, adapted from Lawson (1979)

approach that *moves from generating insights about end-users, to idea generation and testing, to implementation.* Cross (1982) in an article on design education in the UK, writes about studies that support the view that there is a *designerly* nature to exploring design solutions that separate designers and scientists. Comparing the problem-solving strategies of designers and scientists, Cross cites Lawson (1979) 's experiments on design cognition and the differences in approaches to design problems. To investigate whether there was something of substance to the architects' *designerly ways of knowing*, Lawson set up an experiment. He presented both architecture and science students with a design problem; the subjects were required to arrange four of the eight blocks provided, one from each pair, on a grid such that the blocks covered all twelve squares. No edges from the final form were to protrude from this square grid, and white or black surfaces must face the top. Finally, subjects were also required to maximise either the blue or red surfaces on the external vertical face (See Figure 2.4). The problem was designed with three underlying rules - one block must be present, two blocks must both be present, and either or both of two blocks must be present. This underlying structure of rules was not disclosed to the subjects. Rather than instruct the subjects to discover the rules, the objective was to produce a solution that satisfied one of the rules.

What Lawson (1979) discovered was that the two groups approached the problems differently. The scientists systematically investigated the possible combinations of the blocks to discover the underlying rules. The architects proposed a series of solutions until they discovered an acceptable solution. The essential difference between these two approaches was that the scientists focused on discovering the rule whereas the architects focused on discovering the solution (Cross 1982); thereby learning something about the underlying rules by exploring the solutions. The research on the cognitive design describe the methods of designers to solve design tasks as *design thinking*, *designerly ways of knowing* (Cross 1982) or *designerly*

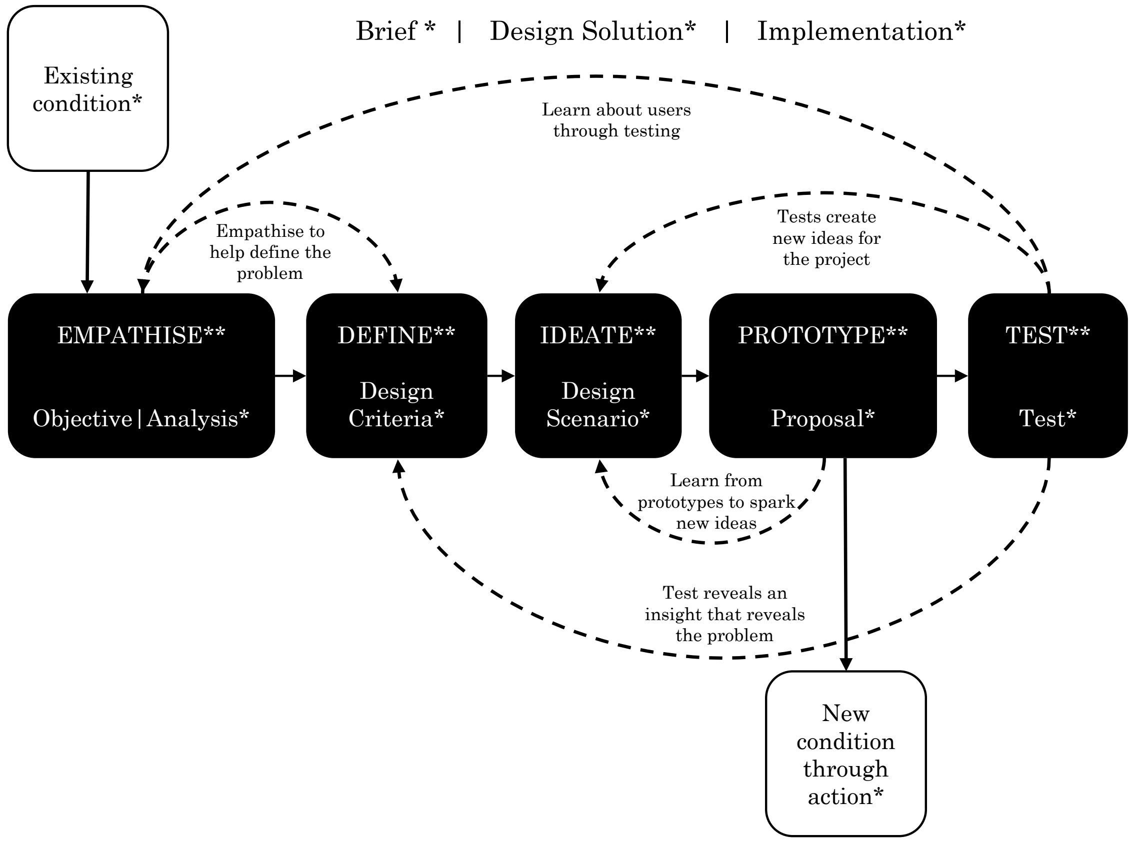


Figure 2.5: Design process in the built environment, adapted from Erickson and Lloyd-Jones (2001)* and the Interaction Design Foundation (2021)**

inquiry. It is broadly defined as *an exploratory and transformative process through which designers draw upon their repertoire of knowledge and competencies as well as resources in the situation, including instruments, in order to create something novel and appropriate that changes an undesirable situation for the better* (Dalsgaard 2017). The exploratory nature of the design process may be telling of the nature of design problems, that they warrant exploration. However, there are also some drawbacks to such an approach. Designers may rely on hunches or presuppositions, and not just facts (Kimbell 2011). The materials that contribute to these hunches need not always stem from accumulated experience but also be instinctual or from theories, trends and widespread beliefs. These materials influence design and planning. Hillier (2008a) points to the example of planning theories from the 20th century; it was thought that lower densities would lessen crime, that open-plan schools would support children's learning, or that enclosed outdoor public spaces would be successful. In hindsight, solutions that were presented as materials to support solutions may have been a part of the problem than the solution.

Erickson and Lloyd-Jones (2001) describes the design process as being open-ended rather than linear, consisting of three phases, the brief, the solution and the implementation (See Figure 2.5). The design process in the built environment is not that dissimilar to other design processes in its requirement to interact with and iterate over the design solution till a satisfactory design solution is obtained.

The first task in the design process is to evaluate the existing condition and ask questions that help define the goals of the design task; where are we and where we want to be (Erickson and Lloyd-Jones 2001). In this analysis, designers may employ various *instruments of inquiry* that aid in better understanding the existing condition. This exploration results in a *design criteria* or the *goal of the design task*. The second task is to try new scenarios. Similar to the observations made by Lawson (1979), a solution-focused approach is applied to evaluate new scenarios and see if they fit (Erickson and Lloyd-Jones 2001). This process is similar to the concept of *ideation* (Jonson 2005); as a matter of generating, developing and communicating ideas. Ideation, according to Jonson, is the *fuzzy front-end* of design. The ideation process occurs at the early stages of the design, sometimes called the *pre-design* or the *generative phases of design* (Peters et al. 2021). Each proposed solution is then evaluated against the previously determined design criteria. As this iterative process progresses, solutions to this design problem emerge.

2.4 Design tools

Collective wisdom and *rules of thumb* (see Chapter 1) are used to aid the design process, supplement the lack of information or expedite the design process; however, the designer cannot interact with them. It must be noted that these materials are not the same as design tools as they lack the interactivity to contribute to the iteration of the design. Wicked or ill-structured problems are complex to solve and, in practice, often solved by teams of individuals that use tools to help them solve such problems (Peters et al. 2021). Peters et al. define *design tools* as *something that provides materials with which a designer interacts to create a situation that talks back to the designer*. Dalsgaard (2017) refers to such tools of design as *instruments of inquiry*, consisting of five qualities - perception, conception, externalisation, knowing through action and mediation. Design tools are fundamental to the design process, and they scaffold the process of inquiry (Dalsgaard 2017).

Design tools can be purely conceptual, analogue or even digital. Simple, analogue instruments of inquiry could be generic tools like pen and paper, allowing the designer to interact with them to explore the design space. Design tools enable and influence the design outcome and are arguably critical to successful design outcomes. By improving the understanding of and access to such design tools, designers can make better choices in their design process (Peters et al. 2021). Not only do designers employ such tools to create new solutions, but also to better understand the design situation and the problem and explore potential solutions (Dalsgaard 2017).

Sustainability tools in the built environment primarily focus on the environmental and sometimes economic dimension of SD. At the building scale, there are Green Building Assessment Tools such as Leadership in Energy and Environmental Design (LEED) [1](Olakitan Atanda 2019), Building Research Establishment Environmental Assessment Method (BREEAM) [2] (Ali and Al Nsairat 2009), German Green Building

[1]USGBC - US Green Building Council

[2]BREEAM - Building Research Establishment Environmental Assessment Method

Council (DGNB) [3] (Stender and Walter 2019) and Global Sustainability Assessment System (GSAS) [4] (Phondani et al. 2016). Such tools often focus on the social dimension through occupant wellbeing and comfort. The WELL certification programme [5](Danivska et al. 2019) goes one step further to assess the personal wellbeing of an occupant mentally as well as physically. Extensions of Green Building Assessment Tools such as LEED neighbourhood and BREEAM neighbourhood focus on similar dimensions of SD but at the neighbourhood level.

In some European countries, specifically Sweden and Norway, the neighbourhood scale of USS has seen direct intervention from the city and municipal bodies through the provision of social tools. In Sweden, the city of Gothenburg has developed *Sociala konsekvensanalyser* (social impact assessment), *Barnkonsekvensanalyser* (child impact assessment) and *Kulturkonsekvensanalys* (culture impact assessment) [6] to evaluate the social and cultural consequences of designs. There also exist complimentary planning tools such as PRISMA [7] (Fine Licht and Molnar 2019), developed by researchers for use at the neighbourhood scale. General criticisms of these tools are the lack of transparency in the development of the tools, follow up on the results of the tool and the vague approach to dealing with stakeholder value systems (Eken et al. 2017). To promote inclusivity and encourage citizen participation in the design process, stakeholders have increasingly used collaborative planning tools (Haklay and Jankowski 2018). These tools provide a structure to the discourse between stakeholders involved in a design project of the neighbourhood scale.

Other tools have focussed on digital participation, such as Public Participation Geographic Information Systems (PPGIS) (Kyttä et al. 2016) and community engagement tools. During the last decade, involving the community in the early stages of the design gained significant popularity as it reduced the citizens' scepticism towards proposed designs that affect the public. Public involvement is seen as a medium to enhance the quality of decision making by inviting local knowledge and alternative perspectives from those most affected by the design decisions (Münster et al. 2017). Collaboration, in general, is heavily mediated by tools to manage the diversity of stakeholders involved (Avdiji et al. 2018). In the broader context of creativity-enhancing tools related to the Human-Computer Interface, research shows that tools that support the collaborative nature of creativity are the most prevalent subject focus (Avdiji et al. 2018).

2.4.1 Indicators

Design tools for evaluating USS usually present themselves in the form of indicators (Bouzguenda et al. 2019). USS indicators are used to develop evaluation tools to support the designers and other stakeholders in identifying appropriate solutions to

[3]DGNB - Deutsche Gesellschaft für Nachhaltiges Bauen
[4]GORD - Gulf Organisation for Research and Development
[5]WELL - WELL Building Standard
[6]Boverket
[7]RISE - Research Institutes of Sweden

increase social sustainability. The adoption of evidence-based methods for design and policy-making has increased due to its ability to facilitate a well-informed debate of potential solutions (Loyola 2018; Head 2008; Hillier 2008a). Researchers have argued for such indicators of social sustainability to be viewed as performative measures used to evaluate scenarios, measures capable of driving change (Hale et al. 2019). Some examples of USS indicators are civic engagement (Hale et al. 2019), walkability (Carr et al. 2010; Pak and Verbeke 2005), service availability, trust, attractiveness and visibility (Craglia et al. 2004), among others. In the following sections, indicators that investigate the relationship between the built environment and how it shapes human ability are further explored.

Accessibility based indicators

Accessibility based indicators focus on the relationship between people and their built environment by assessing geographical accessibility or the ease of reaching destinations. Geographical accessibility depends on the spatial distribution of destinations, land use, and transportation (Boisjoly and El-Geneidy 2017). Accessibility indicators are sensitive to the scale at which a region is studied. Often, trade-offs are made between local and regional scales that cause shifts in the distribution of accessibility. In operationalising accessibility measures and indicators for neighbourhood planning, *cumulative-opportunity* measures such as distance and travel-time thresholds are better suited as they are easy to communicate and interpret (Boisjoly and El-Geneidy 2017). Accessibility studies have a long tradition of being mathematically modelled (J. G. Koenig 1980) and have evolved into specific research domains focusing on the different components of accessibility. Accessibility branches such as *unmet travel needs*, *latent demand*, and *barrier effects* (Eldijk 2019; Luiu et al. 2018; Clifton 2017) subsequently developing a wide variety of methods for modelling and evaluating accessibility.

Achieving daily needs

Achieving daily needs is a key component of USS; it contributes to maintaining good health, and wellbeing (Kolodinsky et al. 2013; Luiu et al. 2013; Reis et al. 2000). Studies have shown that people that demonstrate higher levels of autonomy and competence in their daily activities tend to report greater levels of wellbeing in general (Reis et al. 2000). In addition to individual wellbeing, notions of equitable access to amenities and services also contribute to developing resilient and socially sustainable communities (Widborg 2017).

The satisfaction of needs through physiological, social and self-actualisation needs in individuals is identified as a common characteristic of socially sustainable communities (Mehan and Soflaei 2017). Notions of spatial equity or justice are achieved by providing residents with opportunities and resources to achieve their needs. It leads to socially cohesive and physically integrated urban units (Mehan and Soflaei 2017). Kolodinsky et al. (2013) draw a connection between personal mobility and accessibility to notions of quality of life and wellbeing is also well established in traditional transportation.

Indicators from transportation planning

The relationship between the ability to achieve daily needs and the built environment is also seen in transportation planning literature, for example, in *travel demand forecasting* through travel models. One of the most ubiquitous approaches to travel demand forecasting is the *four-step model*, where current travel behaviour is used to forecast future travel patterns (Mcnally 2007). Travel patterns are modelled as a supply and demand problem (Rodrigue et al. 2016). The demographic and socioeconomic composition of residents and their travel behaviour contribute to the travel demand and dimensions of the built environment, such as transport infrastructure and spatial distribution of origin and destinations constitute the supply (Talen and L. Anselin 1998). The ability to achieve one's daily needs can be evaluated by examining resident travel behaviour. However, due to the complex interactions between travel demand and available amenities, the relationship to social aspects is not direct. For instance, research has shown that increased mobility does not necessarily directly translate to improved quality of life (Curl et al. 2011). Though travel patterns can provide insights into the ability to achieve one's daily needs, a comprehensive view of the various cross-sections of the data must be evaluated.

2.4.2 Digital design tools

Real-world design problems in the built environment comprise complex domains, often characterised by multiple design variables of interest. To arrive at a testable design proposition where the performance of the design can be evaluated, designers encounter a vast problem space (Rycke 2017). As the complexity of design problems increases, designers have turned to digital tools to help manage this complexity. As computers and computational power has become more accessible, the design process has also become more digital. Digital tools are used in several aspects of the design process; they vary by dimensions of scale, phases in the design process, the life-cycle of the built environment, stakeholders and design criteria. Digital tools are used most prominently in the visualisation process through computer-aided visualisation (Isenberg et al. 2011), and computer-aided design (Hasler et al. 2017). Oxman (2008) uses a taxonomy of three distinct models for digital design; formation models, generative models and performance models.

On the design process in urban planning, Hasler et al. (2017) outlines three phases to the design process similar to those set out by Erickson and Lloyd-Jones (2001) - diagnostic (brief), development (design solution) and decision-making (implementation). The diagnostic phase concerns setting the goals by examining the existing situation and identifying challenges and shortcomings. The last step is the development phase, where the vision or the plan is developed (Hasler et al. 2017). The Digital Design Process (DDP) primarily occurs within the development or the design solutions phase (see Figure 2.6).

Oxman (2008) makes a distinction between the different forms of digital design; Computer-aided Design (CAD) and Digital Architectural Design (DAD). CAD tools re-introduce classical analogue methods such as building scale models or paper-based conceptualisation methods into a digital medium. DAD is much more than a simple

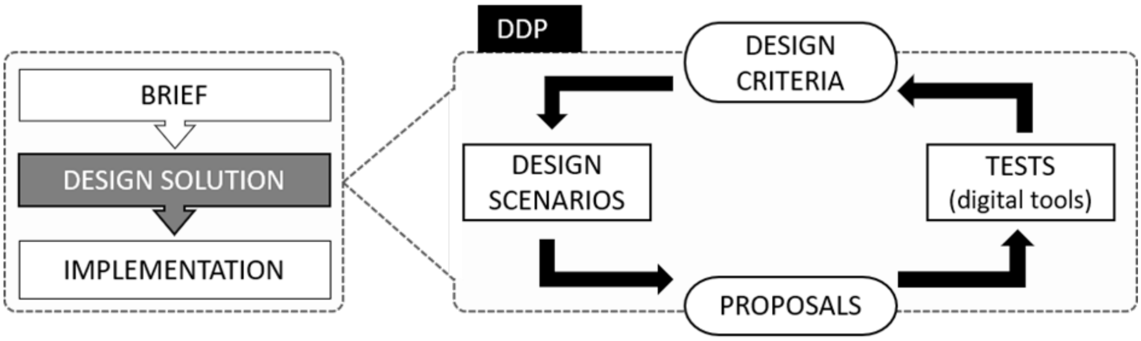


Figure 2.6: Digital design process in architecture and urban planning, adapted from Erickson and Lloyd-Jones (2001)), originally developed for paper 1

re-introduction of analogue methods; it requires designers to build domain knowledge in the area that the tool is focused on.

Digital performance assessment tools often focus on the built environment's environmental performance. At the building scale, these specialised tools range from daylight modelling, HVAC sizing, and thermal comfort prediction to embodied carbon estimation (Mackey and Roudsari 2017; Rycke 2017). At the urban scale, digital tools provide performance-based assessment through street network analysis on the morphology of the built environment. DepthmapX (depthmapX development team 2017) builds on the family of space syntax methods and tools by Hillier (2008a), OSMnx (Boeing 2017) provides network analysis capabilities using open source GIS data. DecodingSpaces Toolkit (R. Koenig et al. 2018) and Urbano (Dogan, Yang, et al. 2020; Dogan, Samaranayake, et al. 2018) provides network analysis and accessibility analysis within the parametric modelling software Grasshopper (Rutten, McNeel, et al. 2007).

With a proliferation of information and communication technology (ICT), cities have made data gathering and serving more accessible. Cities themselves have now become *smarter*. Researchers have argued that the many *smart* projects in Europe, for example, still focus on the efficient management of the environment (Bouzguenda et al. 2019). In addition to smart digital cities, there is a recent emergence of digital twins of cities. Researchers have discussed the wide range of fields in which they can be applied, including data modelling, data analysis and simulation, urban planning, and citizen engagement (Ketzler et al. 2020). Though the urban design and planning aspect of digital technologies and smart cities is not sufficiently explored (Gil 2020), the potential for digitalisation to accentuate the planning process is acknowledged in the literature(Hasler et al. 2017). The extension of digital tools to the social dimension contributes to how the built environment is designed and managed in the future. In the digital age of cities and neighbourhoods, new tools and knowledge must be developed to leverage the increase in computational ability and access to data. Doing so redefines the role of the urban planner from an expert to more of a facilitator for synthesising pieces of relevant output (Hasler et al. 2017).

2.4.3 Providing appropriate tools

Based on the previous sections, three requirements for USS tools are identified. Tools for a multi-dimensional evaluation of USS must have a *social focus*, be within the *scope of influence* of target users, and must not be limited to users with *specialised knowledge*.

Social focus - Accessibility consists of multiple components and can be measured differently (Boisjoly and El-Geneidy 2017). Previously, location-based studies have been conducted where the person-based metrics are incorporated with location-based metrics by stratifying the population by socioeconomic or demographic characteristics (Curl et al. 2011). However, the target users are often transport planners, and the focus is often on network capacity or mobility. It is possible to evaluate socially relevant variables such as age groups, gender, trip purpose or mode of transport affected by changes in policy or the built environment individually. However, there is a lack of methods to evaluate cross-sections of variables intuitively and flexibly.

Scope of influence - The Scope of an architect or urban planner's ability to shape an area's social performance is limited by factors such as spatial scale, phase of involvement, and the subset of the built environment in question. Architects and planners are not only tasked with shaping the built environment but also as mediators of intent between stakeholders. They can influence the programmatic distribution of the demand and supply of urban infrastructure. Traditional mobility and accessibility indicators focus on large-scale transportation infrastructure bridging the demand and supply side of the residents' needs. Whereas resilience and social-sustainability indicators focus on local or regional macro socioeconomic indicators. Quite often, influencing these indicators is beyond the scope of the target user.

Specialised knowledge - Accessibility studies have a long-standing tradition in mathematical modelling. Over the decades, several modelling techniques and accessibility indicators have been mathematically proven and validated. However, as (J. G. Koenig 1980) pointed out in the 1980s, for many of the stakeholders involved in the planning process, *the natural way of reasoning would be much closer to an empirical conception of accessibility than to sophisticated approaches.* From a practitioner's perspective, these concerns are still valid decades later, as pointed out by Curl et al. (2011) and more recently re-affirmed by Boisjoly and El-Geneidy (2017).

2.5 Summary

With increasing social indicators, databases, and analytical methods such as exploratory spatial data analysis (Luc Anselin et al. 2007), insight into the social performance of neighbourhoods has never been more accessible. However, these indicators and methods explore individual aspects of USS and are limited to data exploration. They lack a holistic overview of SD and the means of integration into the DDP. Design tools guide how design problems are perceived and aid in constraining the space of potential solutions. An important aspect of using such tools in the design process is for the designer to understand how a tool operates to be aware of how such tools guide them towards specific design solutions (Peters et al. 2021). Considering the *intertwined and co-evolving* nature of design tools and the design process (Dalsgaard 2017) and the digitalisation of cities, digital tools have the potential to increase the knowledge gained about the design problem as well as expedite the process of iterating and testing against the design criteria.

With the hindsight of past failures, those who invest in the built environment favour evidence-based functional design using tested theories (Hillier 2008a). The nature of design problems has shaped the design process (See section 2.3); in the absence of sufficient information about the design problem and a time-sensitive task, digital tools have the potential to bridge the analysis based approach of the scientists with the synthesis based approach of the designers. Understanding the social behaviour of space requires designers first to understand its potential to behave at all (Hillier 2008a). Designers require appropriate instruments of inquiry to further the agency in improving the social qualities of the built environment. There is a need to develop novel tools and methods in emergent fields of design, in some fields more so than others (Dalsgaard 2017). A capabilities-based approach that focuses on enabling residents to achieve their daily needs is important to address the social equity issues in the built environment. Mobilising existing research and methods from fields of transportation planning and accessibility is an ideal starting point. It is important to recognise that the design of the built environment is fundamentally a social endeavour. Providing agency to designers in exploring the social consequences of their solutions can improve the social sustainability of the community and provide a better quality of life not only for the present generation but also for the future.

Chapter 3

Methods

3.1 Research design

The research presented in this thesis uses qualitative research methods placed within the broader context of a mixed methods research design. Qualitative research methods are generally regarded as an appropriate approach for exploring and understanding the meanings that individuals or groups attach to a social or human problem (Berta et al. 2018). They are well suited to not only test the existing theory but also build new theory by developing a better understanding of the phenomena being studied (Bansal and Corley 2011).

To satisfy the aims of this thesis (see Section 1.2), two research phases are established, theoretical background and indicator development (see Figure 1.4). In the first phase, the theoretical background makes use of two qualitative research methods, *systematic literature study* - to evaluate the academic and policy literature on social sustainability followed by a *conceptual framework analysis* - to evaluate the conceptual frameworks proposed in the literature. The second phase, indicator development, makes use of an *indicator construction framework* - to develop an indicator for urban social sustainability based on the theoretical background developed in the previous step. The results of the indicator development are then discussed with target users using *interviews*. The interviews provide feedback on the resulting indicator; based on the feedback.

Systematic literature study - is a systematic procedure for evaluating documents and interpreting the data to *elicit meaning, gain understanding and develop empirical knowledge* about the phenomena being observed (Corbin and Strauss 2008). In the case of social sustainability, despite being a *concept in chaos* (Vallance et al. 2011), there is a considerable amount of literature (both academic and policy) discussing the theorisation of social sustainability. The analysis of documents is commonly used in combination with other qualitative research methods to triangulate the study of a phenomenon (Bowen 2009). This method contributes to the development of a theoretical background by highlighting potential questions that may not have been discussed in past research, providing a means of tracking the development and changes within a field of research, as well as providing supplementary knowledge to support the overall research goals (Bowen 2009). A detailed description of the steps is presented in the paper 1.

Conceptual framework analysis - A conceptual framework is often a network of interlinked concepts that establish a framework-specific philosophy (Jabareen 2009). The early stages of a discipline often consist of an ensemble of assumptions, concepts, theories and methods, most of which will be implicit and unconscious (Walker and Attfield 1989). Conceptual framework analysis is a grounded-theory-like approach for analysing this ensemble of conceptual frameworks relating to the phenomena of inquiry (Jabareen 2009). This thesis employs conceptual framework analysis to identify and trace a phenomenon's main concepts that constitute its theoretical framework. Similar to grounded theory methods, conceptual framework analysis requires a constant comparison across the evidence to control the level and scope of the emerging theory (B. G. Glaser 1965). The process of conceptual framework analysis is iterative, requiring a *steady movement between concept and data.* It comprises seven phases - mapping the selected data sources, extensive reading and categorising of the selected data, identifying and naming concepts, deconstructing and categorising the concepts, integrating the concepts, synthesis and resynthesis and making it all make sense and finally validating the conceptual framework (Jabareen 2009). A detailed description of the method is presented in the paper 1.

Indicator construction framework - Indicators are the primary means by which social sustainability is evaluated (See Chapter 2). *Social sustainability* is a complex multidimensional concept that often relies on multiple indicators. An eleven step framework for the construction of composite indicators (OECD 2008) is used to ensure that the developed indicators are based on the appropriate theoretical framework and data and can be visualised or presented appropriately. The steps for constructing the indicator use the theoretical background from the previous steps. Further evaluation of the data selection and multivariate analysis of the constituent indicators rely on previous research. A detailed description of the steps is presented in the paper 2.

Interview analysis - Interviews are used to gather feedback from the target users for the indicators developed in study B. The semi-structured interview method has proven to be both versatile and flexible (Kallio et al. 2016). It is chosen to gather a rich understanding of how target users perceive the developed indicators and gather feedback on improvements and further applications of the indicator. In a semi-structured interview, the researcher asks the interviewees a set of pre-determined but open-ended questions. This provides the researcher with more control over the topics of the interview than an *unstructured interview* (Given 2008). The gathering of data through interviews is a part of a broader study, parts of which are outside the scope of this thesis and relates to future studies. An interview guide is prepared with guiding questions on the interviewees' profession and experiences with USS. A set of questions regarding the indicator to be evaluated are presented to collect practitioners' impressions. The interview transcript is then coded and analysed.

The following section describes the methods used in the studies that shape this thesis. A detailed description of the methods is provided in the appended papers 1 and 2. The broader research design comprises both qualitative and quantitative

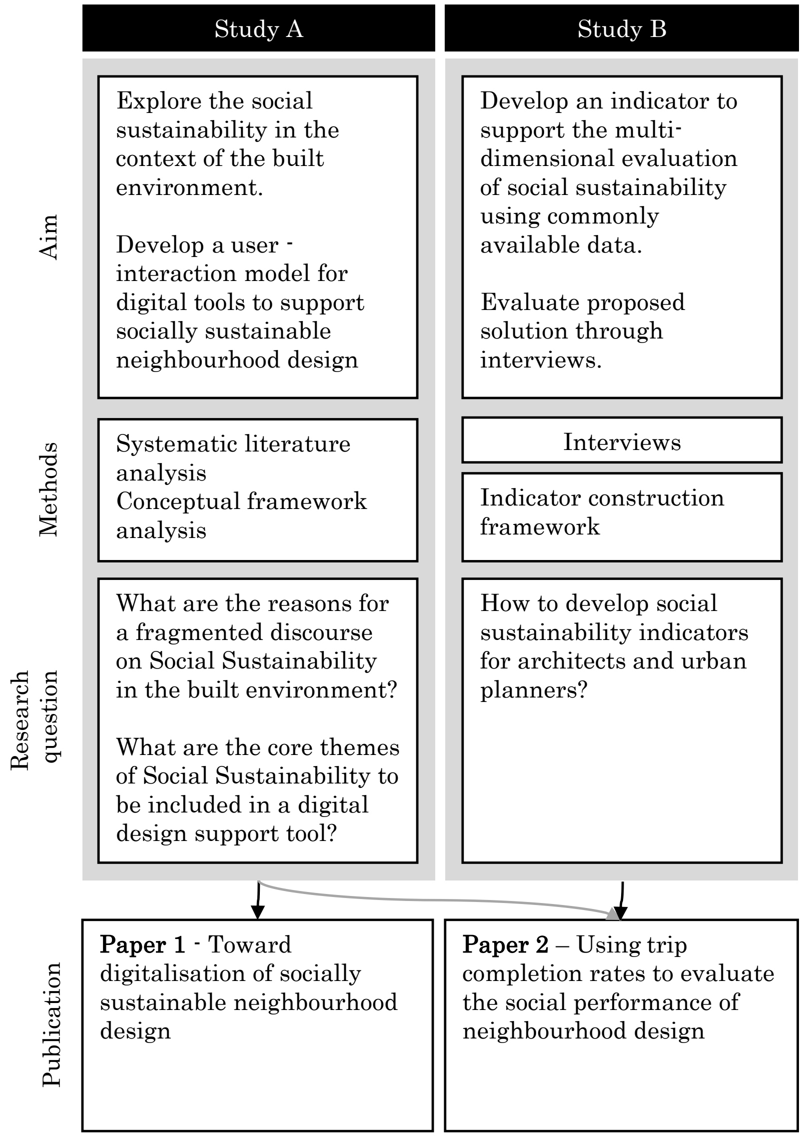


Figure 3.1: Research design in relation to appended papers

methods. The qualitative methods form the theoretical background on USS, which is further used to develop an indicator to enable a multidimensional evaluation of social sustainability. The findings from the qualitative research methods supplement the quantitative research methods. These qualitative methods are further discussed in Chapter 6. Figure 3.1 illustrates the research design in relation to the appended papers within the context of this thesis.

3.2 Study A

The aim of study A (resulting in paper 1) is twofold: first, to explore social sustainability in the context of the built environment and second, to develop a user interaction model for digital tools to support socially sustainable neighbourhood design. To achieve these aims, a systematic literature analysis of academic literature and policy documents is conducted in addition to a conceptual framework analysis method outlined by (Jabareen 2009). The conceptual framework analysis method comprises six steps. These steps are grouped to align with the aims of this study. First, the systematic literature analysis is used to understand the reasons for contention around the theorising and conceptualisation of social sustainability through steps one, two and three. Second, the theoretical background developed from the literature review is used to supplement the analysis of the conceptual frameworks identified through steps four, five and six.

Three research questions are framed to meet the aims of this study.

- RQ1. What are the reasons for a fragmented discourse on Social Sustainability in the built environment?

- RQ2. What are the prevailing definitions of Social Sustainability in the built environment?

- RQ3. What are the core themes of Social Sustainability to be included in a digital design support tool?

The steps followed in this study are summarised below. They consist the mapping,reading and categorising of data sources, identifying and naming concepts, deconstructing and categorising concepts, integrating concepts and finally the synthesis and re-synthesis of the results. Figure 3.2 illustrates the selection of the literature as well as the steps that contribute to the model development.

```
( TITLE ( "Social Sustainability" )
AND KEY ( social AND sustainability ) )
AND ( LIMIT-TO ( DOCTYPE , "ar" ) )
AND ( LIMIT-TO ( EXACTKEYWORD , "Social Sustainability" ) )
AND ( LIMIT-TO ( LANGUAGE , "English" ) )
AND ( LIMIT-TO ( SRCTYPE , "j" ) )
```

Listing 3.1: Scopus query string

Mapping, reading and categorising of data sources: Step one is mapping data sources, and step two is reading and categorising data sources. The research indexing website, Scopus (Elsevier B.V. 2022), is used to query the term "Social sustainability" to retrieve 304 documents. The documents are limited to journal articles in English (see Listing 3.1).

An exclusion criterion is applied to ensure that no duplicate documents and documents without access are included. Only documents discussing social sustainability in the built environment are included by evaluating the title and abstract of the documents. Additional grey literature is included from supplementary sources and policy documents. A set of 115 documents are selected from the filtering process (see Figure 3.2).

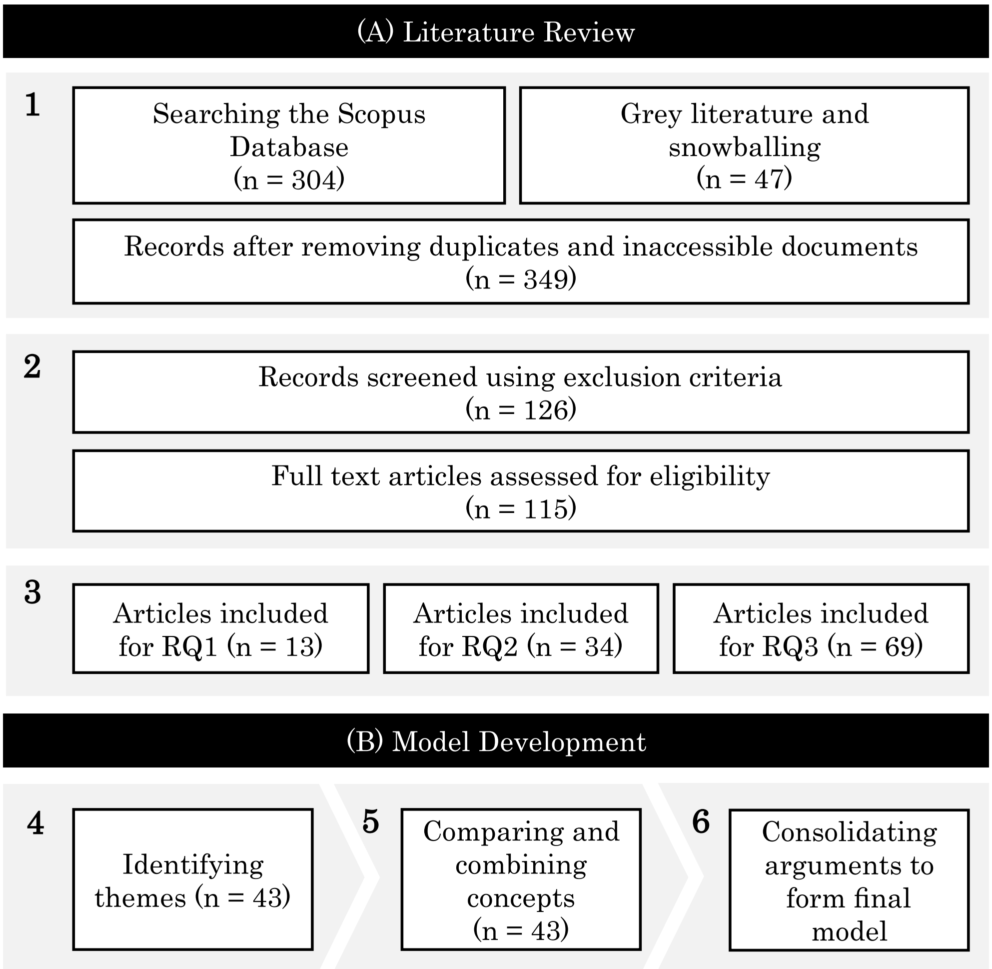


Figure 3.2: Graphical method diagram for selection of literature and model development, adapted from paper 1

Identifying and naming concepts: Reasons for a fragmented discourse on social sustainability were catalogued in a table with the authors' names and relevant supporting arguments. Then the reasons based on their relationship to issues are classified. Next, definitions of social sustainability found in the documents are catalogued, and the terms used by authors to describe social sustainability are tallied. Finally, social themes specified by the authors are catalogued along with notes on the context of the discussion. The social themes used by different authors discussing the same idea are then collapsed into overarching social themes. The number of documents that discuss the social theme is tallied for each of the final social themes.

Deconstructing and categorising concepts: First, the reasons presented by the authors are further classified by common characteristics. Next, the definitions are analysed, and the identifiers that the author associates with social sustainability are extracted and categorised and finally, the social themes and sub-themes of social sustainability are listed, integrated, and organised to develop a common conceptual framework for social

Integrating concepts: Integrating the results from the previous steps in combination with the supplementary literature sources allows for a broader exploration of potential solutions to operationalising USS in a digital environment.

Synthesis and re-synthesis: Finally, a conceptual framework for socially sustainable decision making is proposed by incorporating concepts supported by the grey literature to address the operational issues identified from RQ1.

The resulting conceptual framework is used to propose a user interaction model to develop future digital tools to evaluate social sustainability. The user interaction model is designed around architects and urban planners being the target users of the tool. The reasoning behind selecting architects and urban planners is presented in Section 2.3.

3.3 Study B

The aim of study B (resulting in paper 2) was to use the concept of *completion rates* to construct an indicator for the social equity of a region or a neighbourhood called Trip Completion Rate (TCR). The data source used in this study is the National Household Travel Survey (NHTS) for Sweden. TCR is the proportion of trips by a resident that satisfy an evaluation criteria (ex. trips under 10 minutes). It is a measure of *a population's ability to fulfil their daily needs subject to completion criteria*. TCR is aimed to support architects and urban planners when working on a neighbourhood scale to explore how a policy affects the social equity of a neighbourhood. Completion rates are not a novel concept; they have been used to measure service providers' productivity in last-mile logistical services such as food delivery and taxi services but not necessarily as an indicator of Urban Social Sustainability (USS). In logistics and delivery services, a trip refers to delivering a package or transporting a customer from an origin to a destination; a completion rate is commonly understood as the share of trips completed from the total number of trips accepted by the services provider.

The following sections outline the indicator development process supported by a conceptual framework of indicator development (OECD 2008). The methodological steps for developing the indicator consist of selecting variables, formulating TCR and data selection. TCR is then evaluated using two hypothetical examples or policies that impact the social equity of the residents. Finally, interviews with nine practitioners are conducted to gather feedback on TCR. Figure 3.3 summarises the steps.

3.3.1 Selection of variables

The *Organisation for Economic Co-operation and Development* (OECD) indicator development framework consists of eleven steps for the construction of composite indicators (OECD 2008) (Table 3.1). These steps are designed to ensure seven

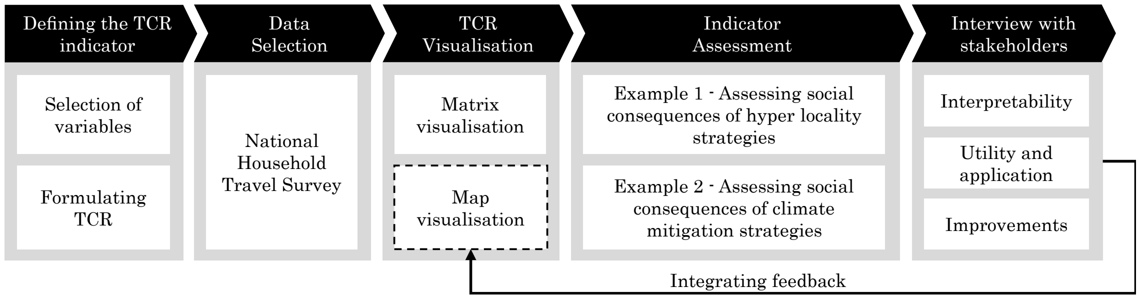


Figure 3.3: Method diagram showing the evaluation of TCR, originally developed for paper 2

qualitative dimensions that an indicator must satisfy, see Table 3.1. The phenomenon that is intended to be measured is *the resident's ability to fulfil their daily needs*. The theoretical underpinning of this phenomenon and its relation to USS is described in Chapter 2 and the selection of variables is further elaborated in the appended papers (see Paper 2).

Table 3.1: Quality dimensions of composite indicators (OECD 2008), originally developed for paper 2

	CONSTRUCTION PHASE	QUALITY DIMENSIONS						
		Relevance	**Accuracy**	**Credibility**	**Timeliness**	**Accessibility**	**Interpretability**	**Coherence**
Step 1	Theoretical framework	•		•			•	
Step 2	Data Selection		•	•	•			
Step 3	Imputation of missing data	•	•	•	•			
Step 4	Multivariate Analysis		•				•	•
Step 5	Normalisation		•				•	•
Step 6	Weighting and Aggregation	•	•	•			•	•
Step 7	Back to the data	•		•			•	
Step 8	Robustness and sensitivity		•	•			•	
Step 9	Links to other variables	•		•			•	•
Step 10	Visualisation	•					•	
Step 11	Dissemination	•		•		•	•	

3.3.2 Formulating TCR

TCR is calculated on $x \in h \bigcup y$ where h and y describe two categorical variables in the data-set. Variables are selected from commonly collected socioeconomic or trip related variables in an NHTS, such as age group, gender, trip purpose or mode of travel. Equation 3.1 shows the notational representation of TCR, where the trips satisfied under a condition are divided by the total number of trips in the dataset.

$$x_{ij} = \frac{\sum_{p \in A_f} N : cond(k)}{\sum_{p \in A_f} \forall N} \tag{3.1}$$

3.1: Notational representation of TCR

Where:
A = Set of all trips
A_f = Subset of trips $\{h_i \bigcup y_j\}$
p = The intersection of attribute h and y
N = A trip attribute such as trip duration, trip distance, carbon footprint or mode choice*
$cond(k)$ = A conditional operator that serves as the evaluation criteria on N. For example, if N is the trip duration, then $cond(k)$ may be < 15 to evaluate all trips completed in under 15 minutes.
* Dividing the satisfactory trips with the total number of trips gives the proportion of the sub-group affected relative to the total population of the sub-group. This proportion can highlight issues across sub-groups regardless of their population size. Finally, equal weighting of all variables is used in the TCR. A min-max normalisation is used to scale to data within an identical range [0,1] and present these values as percentages.

3.3.3 Data selection

The Swedish NHTS (Göteborgs stad trafikkontoret 2017) was collected through a survey sent out to more than 46,600 residents aged 16-84 in 21 western Swedish municipalities. About 12,200 people responded to the survey. The data set is then filtered for respondents living in the Gothenburg municipality.

3.3.4 TCR Visualisation

TCR can then be represented as a two-dimensional $m \times n$ matrix M, constituting row vector h and column vector y describing two categorical variables in the dataset. Each element of the matrix x_{ij} where i and j are the categories of the two categorical variables selected lie at the intersection of the two dimensions (see Equation 3.2).
Where:
M = The TCR Matrix
h = First categorical variable (such as age group)
y = Second categorical variable (such as trip purpose)
m = The number of categories in row h
n = The number of categories in column y
Such that -

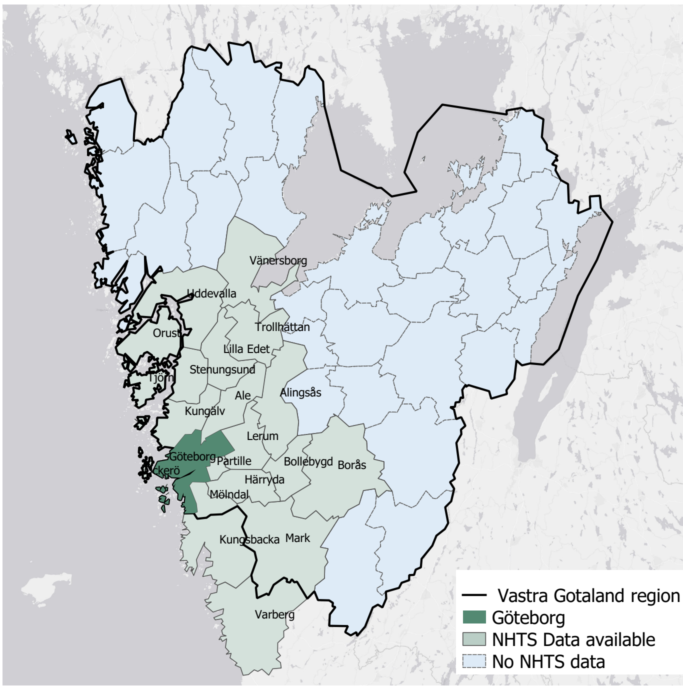


Figure 3.4: Map of the Västra Götaland region for which the NHTS data is filtered. The bold black line shows the boundary of the Västra Götaland region. The Gothenburg municipal region is shown in dark green, the municipalities with available data within the NHTS are shown in light green, and the municipalities with no data available are shown in light blue, originally developed for paper 2.

$$M = y \downarrow \overset{h \longrightarrow}{\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}} \tag{3.2}$$

3.2: Notational Matrix representation of TCR

Each element of the matrix is x_{ij}, where i and j are the categories of the categorical variables selected. Furthermore, x_{ij} lies at the intersection of the two categories i and j. In the example, h is the age group, and y is the trip purpose. The age group consists of seven categories - 16-24, 25-34, 35-44, 45-54, 55-64, 65-74 and above 75. The trip's purpose consists of business, education, groceries, health, home, leisure, picking and dropping off kids, shopping, work and others. x_ij represents the TCR for all 16 to 24-year-old members who complete all business trips under the set criteria.

3.3.5 Indicator assessment

Two hypothetical examples are created to illustrate the applications of TCR. The first example looks at a *15 minute city* scenario, and the second example looks at climate mitigation policies through PCAs. Though both examples are policy-based, they affect how the built environment is shaped. They affect how people travel and where they go; as such, the effects on social equity are within the scope of influence for an urban planner or an architect.

Example 1 -Assessing social consequences of hyper locality strategies: Recently, there has been an interest in a *chrono-urbanism* concept of urban planning, where residents of a city are in close temporal and spatial proximity to basic services (Moreno et al. 2021). As such, Moreno et al. (2021) suggest that a 15 minute travel time is considered an acceptable threshold to incorporate a resident's basic requirements. In this example, the TCR matrix for all trips completed in less than 15 minutes is queried across the two dimensions of resident age-groups and trip purpose.

Example 2 - Assessing social consequences of climate mitigation strategies: Using TCR, climate change mitigation policies can also be evaluated to identify social equity issues. Example 2 evaluates TCR for trips completed with less than 0.68 kgC-e in the Gothenburg region. An evaluation criterion of 0.68 kgC-e is chosen as a hypothetical personal carbon allowance. The value is derived from the individual carbon goals for 2030 set by the city of Gothenburg in the *Environment and Climate Programme for the City of Gothenburg 2021–2030* (Göteborgs Stad 2021).

3.3.6 Interview

Interviews are conducted with architects and urban planners to receive feedback on the indicators and to identify how they can be further improved. The semi-structured interview method has proven to be both versatile and flexible (Kallio et al. 2016) to encourage responses from interviewees and is selected as the method of data collection. Interviews were conducted digitally through video using a video conferencing system (Zoom Video Communications Inc. 2022). The questions were presented on the screen first for each section, and then a free-flowing conversation was held. At the start of the interviews, the conceptual framework developed from previous steps was presented to establish a common vocabulary for the conversation.

Data collection

The purpose of the interview was to gather insights on USS from a practitioner's lens and obtain impressions and feedback on TCR.

Nine interviews were conducted with urban planners, architects, and other related professions (see Table 3.2). The feedback from the interviewees was aimed at evaluating the utility and interpretability of the indicator and receiving feedback on potential improvements. An interview guide consisting of the discussed topics was sent ahead of time to guide the dialogue. The TCR matrix was then presented to the interviewees, and a set of guiding questions related to TCR was presented (see paper 2)

Table 3.2: Description of interviewees.

#	Profession	Country	Years of experience	Company size
01	AT, CD	Sweden	5	43
02	UP, GIS Analyst	Sweden	3	14
03	UP, AT	Denmark	15	80
04	UP	Sweden	8	250
05	UP	Sweden	6	250
06	UP	Netherlands	10	41
07	MC, UP	Netherlands	4	7
08	UP, LA	Sweden	5	250
09	UP	Netherlands	4	12

AT: Architect, **UP**: Urban Planner, **CD**: - Computational Designer, **MC**: - Mobility Consultant. **LA**: Landscape Architect

Data Analysis

The transcribed interviews were coded using the text analysis software NVivo (QSR International Pty Ltd. 2020). The method for the coding and analysis is based on the Gioia methodology (Gioia et al. 2013). First, text concerning the TCR matrix was coded to separate impressions from topics presented in other parts of the interview. Then, individual impressions were coded at each instance. This process was repeated for all the interviews forming the basis of the first-order themes. Next, the first order themes were grouped into aggregate dimensions for each case. Finally, the aggregate dimensions were grouped into overarching categories of interviewee impressions informed by the aim of the interview - evaluating the *utility* and *interpretability* of the indicator, and *receive feedback on potential improvements.*

Chapter 4

Findings

The findings from study A (resulting in paper 1) identify the issues in conceptualising USS and present an overview of how it is defined and conceptualised in literature. Addressing the issues in conceptualisation, a conceptual model of USS is proposed. Finally, a User Interaction Model of USS is presented along with pre-requisites to facilitate the development of a digital tool. In study B (resulting in paper 2) an indicator of USS is developed. This indicator allows its users to measure the residents' ability to fulfil their daily needs using commonly available datasets. After USS is conceptualised and operationalised through themes of social equity, the IUM can be developed to incorporate TCR towards digitalising USS.

4.1 Study A

This chapter summarises the findings of Study A (resulting in paper 1), in which research articles on Urban Social Sustainability were evaluated along with policy documents. The sections below present the three findings of the study. These three findings make up the theoretical background of USS. They are further used to propose a user interaction model for developing digital tools and a set of pre-requisites for such a tool to be successfully operationalised.

4.1.1 Issues with conceptualising USS

Six commonly occurring reasons (factors) that indicate why the USS discourse has been fragmented and often results in a lack of consensus were identified and divided into two categories: intrinsic factors and extrinsic factors (see Table 4.1).

Intrinsic factors arise due to the nature of USS, the complexities of the actors involved in the social system, and the overlapping disciplines that study it. We have identified four such intrinsic factors.

- **Dependency on stakeholder value systems** results from the fact that people have different value systems. Conflicting value systems often result in disagreement and, consequently, a lack of consensus as to what USS means (Eizenberg and Jabareen 2017; Boyer et al. 2016; Boström 2012; A. Colantonio

Table 4.1: Reasons for a fragmented discourse of USS mentioned in the reviewed literature, reproduced from paper 1

Category	**Factor**	A. Colantonio (2010)	Mehan and Soflaei (2017)	Eizenberg and Jabareen (2017)	Åhman (2013)	Eken et al. (2017)	Littig and Grießler (2005)	Boström (2012)	Shirazi and Keivani (2017)	Boyer et al. (2016)	McKenzie (2004)	Dillard et al. (2009)	Landorf (2011)	Shirazi and Keivani (2019a)
Intrinsic	Dependency on stakeholder value systems	•		•	•		•	•		•				
	Multi-disciplinary nature of Social Sustainability				•	•		•	•					
	Quantifiable nature of social interactions		•					•			•		•	•
Extrinsic	Tangibility of social consequences			•			•	•	•	•				
	Chronology of Sustainable Development discourse	•		•	•		•	•				•		
	Comparison with Environmental sustainability	•					•	•	•	•	•	•		

2010; Jabareen 2009; Littig and Grießler 2005). Here, stakeholders refer to those individuals or institutions that can influence, are involved in, or are directly affected by decisions taken in the built environment.

- **Multi-disciplinary nature of USS**, is related to the many disciplines involved in the study of societies. It introduces competing interests in the discourse of USS, once again leading to conflicting priorities (De Fine Licht and Folland 2019; Shirazi and Keivani 2017; Åhman 2013; Boström 2012).

- **Quantifiable nature of interactions** - Social data is often complicated, nuanced and best represented qualitatively (Boström 2012; Landorf 2011; McKenzie 2004). Most primary gathering of social data in the built environment is through interviews and questionnaires. Translating qualitative information to quantitative indicators often results in the loss of information. Hence the disagreements on how USS should be measured or even represented.

- **The tangibility of social consequences** - Social consequences that emerge from interactions between people are often intangible concepts. Emergent consequences such as wellbeing, quality of life, and happiness often mean different things to different people, which in turn results in a lack of consensus on what USS means (Eizenberg and Jabareen 2017; Shirazi and Keivani 2017; Boyer et al. 2016; Boström 2012; Littig and Grießler 2005).

In addition to the intrinsic factors, two extrinsic factors are identified. These are factors that arise due to USS's political backdrop or stakeholder perceptions of SD.

- **Chronology of Sustainable Development (SD) discourse** - Boström (2012) discusses the early roots of the SD discourse and the chronology of the various dimensions. The environmental and economic dimensions evolved prior to the social, resulting in the social dimension receiving less focus than its counterparts (Eizenberg and Jabareen 2017; Åhman 2013; A. Colantonio 2010; Littig and Grießler 2005).

- **Comparison to environmental sustainability** - In the sustainability discourse, environmental sustainability has several desirable quantitative features that allow it to be represented, measured and tracked (Shirazi and Keivani 2017; Boyer et al. 2016; A. Colantonio 2010; Dillard et al. 2009; Littig and Grießler 2005; McKenzie 2004). For instance, the human-made contributions to climate change correlate with worsening ecology. However, it is not easy to establish such causal relationships in the social dimension. It is also unclear what exactly one must aim to improve or sustain as compared to the environmental dimension (Boström 2012).

4.1.2 Definitions of USS

The literature review resulted in USS identifiers within the following three categories; *an ability, a conditional state*, and *a process*. Sometimes a weak identifier or a loose definition is used; such instances are grouped as *a vague concept* (4.2).

Table 4.2: Identifiers used in the definition of USS, reproduced from paper 1

Source	**Identifier**			
	Ability	**Conditional state**	**Process**	**Vague Concept**
Atanda and Öztürk (2018)				•
Bacon et al. (2012)				•
Bacon et al. (2012)			•	
Baehler (2007)	•			
Barron and Gauntlet (2002)		•		
Barron and Gauntlet (2002)		•		
Boschmann and Kwan (2008)		•		
Bramley, Dempsey, Power, and Brown (2006)				•
Chiu (2003)				•
Chiu (2003)			•	
Colantonio (2007)	•		•	
A. Colantonio (2010)			•	
Coleman (1988)				•
Davidson (2009)			•	
Dillard et al. (2009)			•	
Dillard et al. (2009)	•	•	•	
Dillard et al. (2009); McKenzie (2004)		•	•	
Eizenberg and Jabareen (2017)			•	
Enyedi (2002)		•		
Holden (2013)			•	
Laguna (2014)		•		
Landzelius and Thodelius (2017)	•			
Littig and Grießler (2005)				
Littig and Grießler (2005)			•	
Shirazi and Keivani (2017)		•		
Shirazi and Keivani (2017)			•	
ODPM (2003)		•		
Opp (2017)		•		
Pieper et al. (2019)	•			
Ročak et al. (2016)		•		
Sachs (1999)				•
Søholt et al. (2012)				•
Stender and Walter (2019)				•
Stren and Polèse (2017)		•	•	
Stren and Polèse (2017)			•	
Valdes-Vasquez and Klotz (2013)			•	
Vallance et al. (2011)			•	
Woodcraft (2015)			•	
O. Yiftachel and D. Hedgcock (1993)		•		•
Yoo and Lee (2016)	•			

The identifiers found in the definitions are defined as follows:

- Ability – An ability of a society to satisfy a given condition implies that it must possess the resources to facilitate positive interaction between various actors in society. An ability also emphasises the exhaustive nature of these resources. “Ability” has the inherent implication of a limitation to the ability.
- Conditional state – USS as a conditional state implies that USS is achieved due to successfully satisfying a set of conditions proposed in the definition. Here, USS is often described as an end state of the social system; it results in positive interactions between stakeholders when achieved.
- Process – USS as a process implies that it is a series of decisions, actions or steps taken to achieve an expected outcome of positive interactions between stakeholders.
- Vague Concept – USS is often defined using terms such as “a quality” or by describing it through a relationship to certain necessary but not satisfactory. Hence the meaning is vague and often left open to interpretation.

4.1.3 Conceptual framework for USS

Social themes under social equity arise from opportunities for interactions between members of society and their physical environment. Social equity concerns itself with the availability of and access to services, facilities, and amenities (the distributive notions of social justice). The social themes of social equity are amenities, community infrastructure, recreation and open spaces, connectivity, jobs and housing. The social theme of amenity is the most referenced in the literature and has the most availability of data and indicators. Social themes under social capital are the emergent properties that arise from social interactions between members of society through interpersonal relationships. Social capital is closely linked to the notion of community cohesion. In the literature, social capital and community cohesion are often used interchangeably. Social capital can also be seen analogous to Colantonio’s (A. Colantonio 2010) soft or emerging themes of Social Sustainability. The social themes of social capital are interaction, participation, the stability of the community, a sense of attachment, and safety and security. The social theme of the sense of attachment is the most referenced in the literature. The distribution of social themes under social equity and social capital is once again supported by the view that socially sustainable development needs to address both physical and non-physical aspects of USS. Themes of social equity reflect the physical aspects, and themes of social capital reflect the non-physical aspects of USS (Table 4.3).

4.1.4 User interaction model

To enable a guided decision-making process for architects and urban planners in collaboration with other stakeholders, a four-step user-interaction model for the development of digital tools for USS is proposed (Figure 4.1).

#		Social Themes	Sub-Themes (Indefinite)
60	SOCIAL EQUITY	Amenities	Health (27) Food (7) Facilities and Services (25)
43	SOCIAL EQUITY	Community infrastructure	Education/Child Care/health (33) Aesthetic/ Maintenance (9)
40	SOCIAL EQUITY	Recreation and Open spaces	Availability of open spaces, recreation, public realm (28)
42	SOCIAL EQUITY	Connectivity	Pedestrian Comfort/ Microclimate (10) Transport, Location and connectivity, Accessibility (28) Walkability (12)
24		Jobs	Distribution of wealth, Economic Welfare, Employment. (24)
34	SOCIAL CAPITAL	Housing	Housing / Living Conditions (34)
49	SOCIAL CAPITAL	Interaction	Social Interaction in Society (38) Social Networks (10)
50	SOCIAL CAPITAL	Participation	Public Participation (50)
30	SOCIAL CAPITAL	Stability of the community	Stability of the community/Tolerance (30)
65	SOCIAL CAPITAL	Sense of Attachment	Sense of belonging, community responsibility (41) Culture (23)
36		Safety and Security	Safety, Security, Crime, Peace and Justice (30)

Table 4.3: Conceptual framework for neighbourhood USS (Adapted from Bramley, Dempsey, Power, and Brown (2006) and Dempsey et al. (2011)), reproduced from paper 1

- Step one provides the stakeholders with the ability to choose their scope of USS. It requires the user to select the site and the social themes deemed important by the stakeholders. This allows users to explore the data available for the selected area and iterate on the social themes selected for the study in collaboration with the stakeholders.

- Step two addresses the problem of conflicting stakeholder values identified. It allows the stakeholders to consolidate the various weights on the social themes based on the requirements of the project.

- Step three addresses the issue of the quantifiable nature of USS, by aggregating indicators developed from available data sources.

- Once the stakeholders collectively establish a design criterion, step four allows the user to measure the existing social performance of the selected area. The user can further make design proposals informed by the existing social performance,

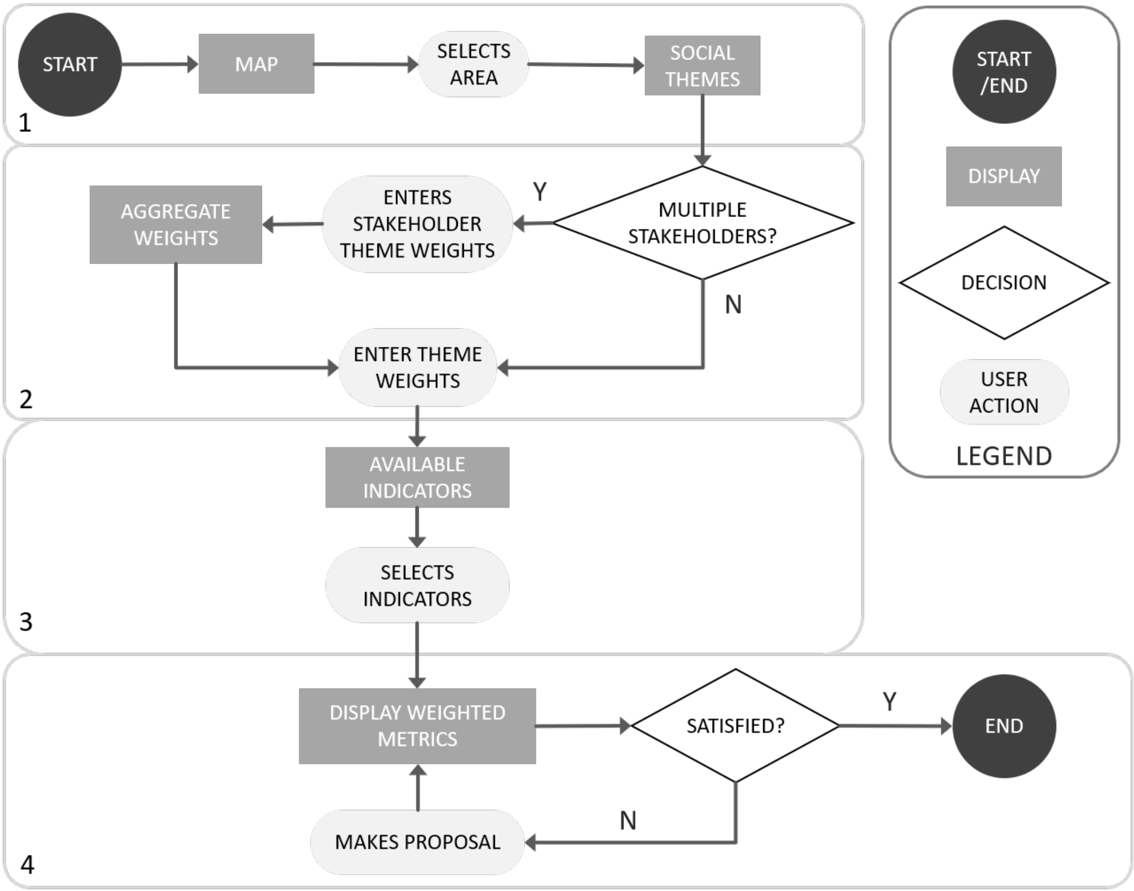


Figure 4.1: User interaction diagram for a digital USS tool to support architects and planners design process, originally developed for paper 1

evaluate different design proposals, and provide the stakeholders with a basis for decision-making.

Finally, the following pre-requisites for implementing the proposed user-interaction model are outlined.

- Adopt an inclusive and collaborative planning process in the design development of the project.
- View USS as an empty signifier, capable of accommodating different value systems.
- Use a digital design environment capable of communicating with the geo-database. The digital design environment should preferably be commonly used by architects and urban planners in the region.
- Build a database consisting of available spatial data such as administrative boundaries, street networks, building footprints, locations of trees, street furniture and pedestrian crossings.

- Identify meta-data concerning residents and buildings such as population, demographics and building function.

4.1.5 Summary

The findings of study A contribute to the understanding of USS through four main contributions:

1. It indicates that USS is a complex concept with unambiguous boundaries and identifies extrinsic and intrinsic factors for these complexities.
2. The various definitions of USS are explored, and four identifiers are identified. The identifiers help in understanding different perspectives in conceptualising USS.
3. A conceptual framework of USS is presented. These three findings contribute to the theoretical framework of USS.
4. The theoretical framework is used to outline a User Interaction Model (UIM) for digital tools to support USS. A set of pre-requisites to support such a model is also provided.

The findings from this study contribute to the existing body of literature and provide a means to conceptualise USS. However, the findings by themselves are not sufficient to develop digital tools. USS must further be operationalised by formulating suitable social themes and indicators. Once USS is operationalised, the UIM can be applied using the suggested pre-requisites.

4.2 Study B

This chapter summarises the findings of Study B (resulting in paper 2). An indicator development framework is used to develop Trip Completion Rate (TCR) - an indicator for the ability of a resident to fulfil their daily needs. The development of the indicator is an important step in the operationalisation of USS. In the following section, results from the two example policy scenarios are presented in the form of the TCR matrix. A map visualisation of TCR then follows this. The indicator, its construction and its visualisation are then discussed with architects and urban planners through interviews.

4.2.1 Indicator assessment

In Figure 4.2 and Figure 4.4 the TCR matrix is visualised as a heat-map consisting of square grids. The heat map consists of the main title, axis titles, category labels, data labels for the TCR within the cells and a legend. A TCR of 0 represents that none of the trips from the total trips recorded satisfies the evaluation criteria. Red is a lower TCR, and green is a higher TCR.

In Figure 4.3 and Figure 4.5 following the feedback from the interview candidates, a map visualisation is developed for each example scenario to explore the social equity effects of different policy measures across municipalities. It presents the differences between TCR for men and women using a bi-variate colour scheme. The scaling of the bi-variate colour scheme is chosen at equal intervals to fit the range of the data. In Figure 4.3, the colours are scaled between a TCR of 20% to 50%. In Figure 4.5, the colours are scaled between a TCR of 10% to 70%. The map visualisation is presented along with the matrix representation of TCR in the following section.

Example 1 - Assessing social consequences of hyper locality strategies

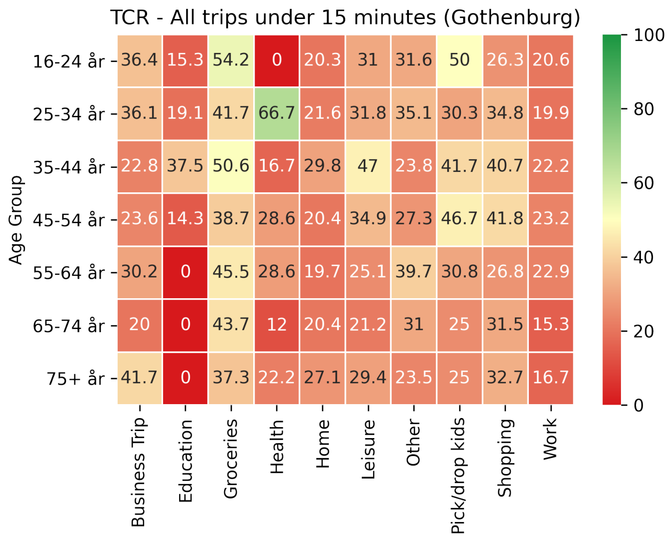


Figure 4.2: TCR Matrix for total trips completed under 15 minutes in Gothenburg municipality. Data source - Swedish National Household survey (Göteborgs stad trafikkontoret 2017). Missing data is left blank, originally developed for paper 2

A TCR matrix is calculated for all trips under 15 minutes for the Gothenburg region is presented in Figure 4.2. Trips for groceries and picking up and dropping children at school appear to have higher completion rates under 15 minutes than the other modes of transport. In contrast, work-related trips are visibly longer and have a lower completion rate. TCR can also be visualised spatially over a map. Results from the same scenario are used to compare different municipal regions for which data is available. Figure 4.3 shows the TCR for different municipalities in the Västra Götalands region evaluated according to gender. The map can be interpreted to highlight regions that show potential equity issues in achieving daily needs within 15 minutes in the current state of the built environment and demographic composition. The results highlight that the municipalities of *Borås, Härryda and Mark* (in grey) have low completion rates compared for both men and women. However, in municipalities like *Trollhättan, Orust and Varberg* (in pink), the policy affects men and women differently. With men being more severely impacted in comparison to women. In the municipality of *Stenungsund*, the equity issues are reversed, with women being affected more severely than men.

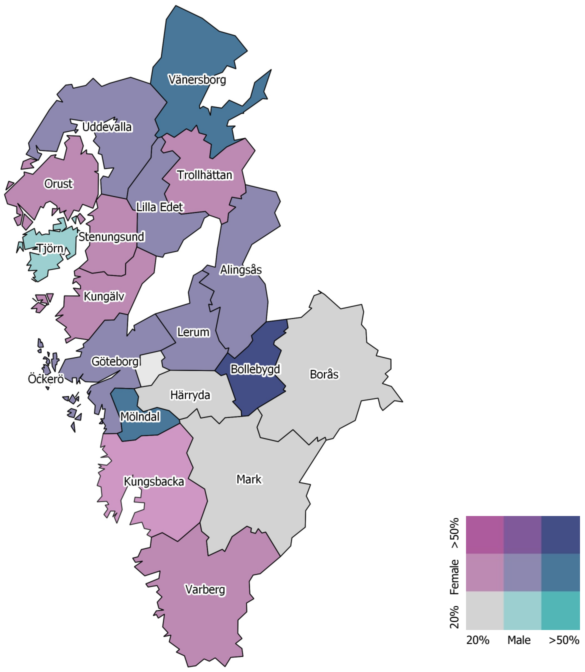


Figure 4.3: TCR for trips completed under 15 minutes by municipality. The data is represented using a bi-variate colour scheme. Grey shows municipalities where both men and women have low TCR for a 15-minute travel scenario, and purple shows municipalities where men and women have higher TCR. Whereas pink shows municipalities where women have a higher TCR than men, turquoise shows municipalities where men have a higher TCR than women, originally developed for paper 2

Example 2 - Assessing social consequences of climate change mitigation strategies

Figure 4.4 shows that business trips are most affected by a PCA, followed by picking and dropping off children. Residents between 35 and 75 years are most affected. Trips for education are relatively unaffected by a PCA. All trips by 16 to 24-year-old residents picking and dropping off their children appear to be entirely incomplete. The reasons behind this would require further exploration of the data. Figure 4.5 shows TCR visualised spatially to compare the ability of residents to fulfil their daily needs across municipalities. The results show that the municipalities of *Trollhättan and Mark* have an overall lower TCR, both for men and women. Whereas in *Borås* the policy severely affects women more than men. The two regions require different approaches to mitigate the potential inequities of such a policy.

4.2.2 Results from stakeholder interviews

The identified overarching themes are *Potential applications of TCR, General comments and criticism, Informants generating insights from TCR* and a particularly common impression that *TCR is better suited for technical users than non-technical users*. Bridging the overarching themes and initial goals of the interview, the results

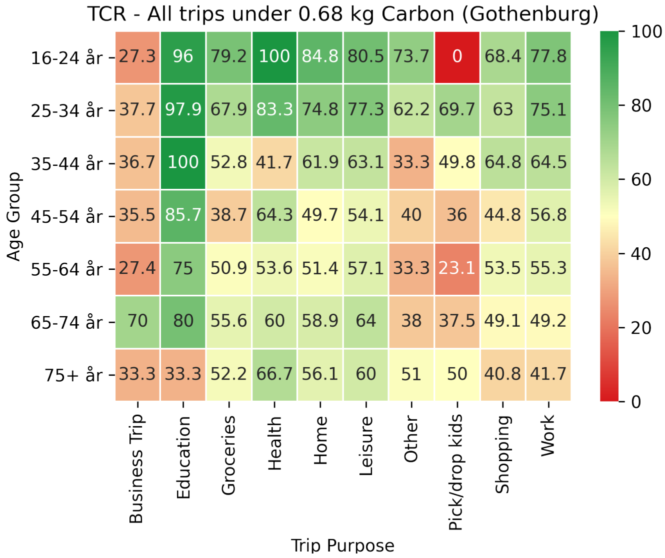


Figure 4.4: TCR Matrix for all trips across three thresholds for trip global warming potential. Data source - Swedish National Household survey (Trafikanalys n.d.). Missing data is left blank, originally developed for paper 2

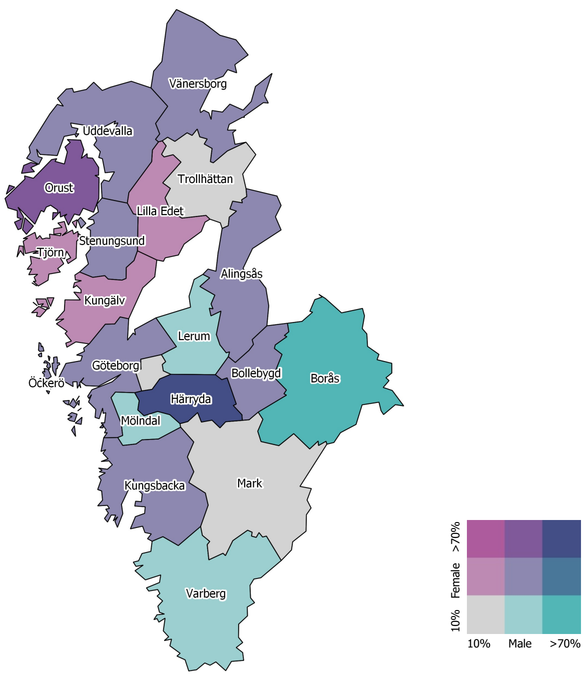


Figure 4.5: TCR for total trips completed under 0.68 kgC-e by municipality. Grey shows municipalities where both men and women have low TCR, purple shows municipalities where both men and women have higher TCR. Whereas pink shows municipalities where women have a higher TCR than men and turquoise shows municipalities where men have a higher TCR than women, originally developed for paper 2

of the analysis are presented under the three categories of interpretability, utility and application and improvements (See Figure 4.6).

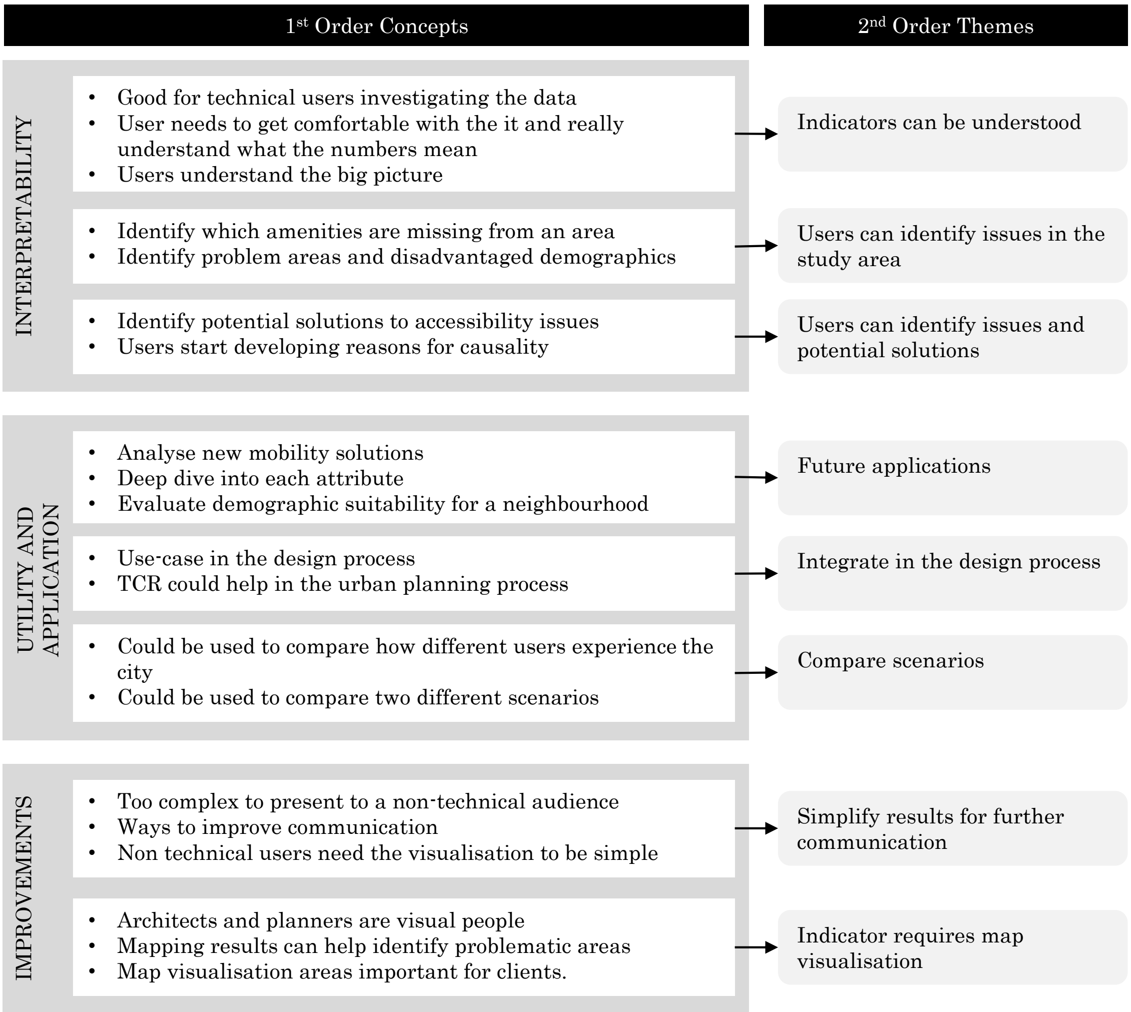


Figure 4.6: Interview coding structure, originally developed for paper 2

Interpretability

The interpretability of an indicator is described as *the ease with which the user may understand and properly use and analyse the data* (OECD 2008). In the analysis of the interview transcripts, instances of informants interacting with the TCR matrix to generate insights were treated as a measure of interpretability of the indicator.

Utility and application

In addition to interpretability, informants proposing further indicator applications are observed. These are grouped under *utility*. The utility is identified through potential applications of TCR in the design process of neighbourhoods.

A recommendation to extend the indicator to include the climate impact of the different modes of transport is illustrated above in example 2 (see Figure 4.4). The *utility* of the indicator can be viewed as an extension to the *interpretability* of the indicator, wherein the informant understands the wider goal of the indicator and envisions new applications that may not have been within the initial goal of the indicator design.

Potential improvements

A frequent comment for the potential improvement of the indicator was on the visualisation. The informants are mainly urban planners and architects or professionals who work close to urban planners and architects. As an architect or a "technical user", the informants feel comfortable using the indicator to inform their decision-making process but presenting the visualisation of the matrix in its current form is potentially too confusing to other stakeholders. All informants with a similar concern suggested using a map visualisation to communicate the information further to other stakeholders. These results are presented in Figure 4.3 and Figure 4.5.

4.2.3 Summary

The findings from this study contribute to the existing body of literature on USS indicators and provide a means to operationalise it. Indicators like TCR can be included with the User Interaction Model to form a part of a digital tool to enable USS evaluations. Study B makes the following specific contributions:

1. The TCR indicator allows the evaluation of a resident's ability to fulfil their needs across multiple dimensions of age, gender and purpose of travel, among other variables.

2. TCR contributes to measuring and evaluating social equity in the built environment.

3. It allows practitioners to evaluate the social consequences of planning policy and formulate solutions to mitigate them.

4. Two options for visualising TCR are presented in this study. While they make it possible to include more information, the visualising of such an indicator becomes challenging.

Chapter 5

Discussion

The aim of this thesis was defined as: *to contribute to Urban Social Sustainability (USS) research and bridge the gap between theory and practice through digitalisation.* Based on the findings and considering previous research, I will discuss the following points:

- Conceptualisation of USS
- Operationalisation of USS through indicators
- Towards digitalisation of USS
- Limitations
- Reflections on research philosophy

5.1 Conceptualisation of USS

RQ1. How to conceptualise urban social sustainability?

The underlying theme of this thesis is that there is no singular accepted definition of what USS is, and perhaps there never will be. Instead, it offers a *working conceptualisation* of USS as:

A phenomenon observed in society when a positive human condition is achieved through social equity and social capital as a result of the built environment.

There are several interpretations of what USS is - *an ability* (A. Colantonio 2010; Baehler 2007), *a conditional state* (Shirazi and Keivani 2019a; Opp 2017), *a process* (Colantonio 2007; Littig and Grießler 2005) or *a vague concept* (Bramley, Dempsey, Power, and Brown 2006; Oren Yiftachel and David Hedgcock 1993). To contextualise USS as it is understood in this thesis, USS is considered a *phenomenon*; it is observed to exist or happen without sufficient clarity as to why it happens. To research or discuss the consequences of any phenomenon, there first must be a clear idea of what that phenomenon is (Quarantelli 1988); and for digital tools to be built around USS, the architect or urban planner must first be able to measure the phenomenon tangibly. Allen (2017) suggests that to measure a phenomenon, it must first be conceptualised and defined and finally, it can be operationalised.

In the design of a research methodology, defining and conceptualising a phenomenon to establish a common meaning frame is often the first step (Maxwell 2012). Defining and conceptualising are both methods of generating meaning but have some key differences. Conceptualisation is concerned with the idea, or the concept itself (Allen 2017). It is the image created when thinking of a cluster of inter-related ideas. In comparison, a definition is meant to be more precise. It is a syntactic representation designed to draw the boundaries around a phenomenon through the use of language (Lavrakas 2008). Through this process of generating meaning, a concept can be operationalised (Allen 2017). At first glance, it may seem easy to

Figure 5.1: The variable operationalisation process without definition, adapted from Figure 1.1

conceptualise what constitutes USS, but the task is far more complicated. The term social sustainability appears to be self-evident, but on closer inspection, the fuzziness of the phenomenon becomes more apparent. Social sustainability is ontologically related to the concept of sustainable development, which in itself has challenges in conceptualisation (Beckerman 2017). Then there are the plethora of definitions on which there is little consensus (Boström 2012). To handle this, intrinsic and extrinsic factors are defined in Study A. Paper 1 discusses the intrinsic and extrinsic factors that add to the challenges in conceptualising USS in further detail.

While there is no consensus on definitions for USS, there is strong consensus on the conceptualisation of USS. USS is comprised of two overarching categories - *social equity* and *social capital*. On the foundations laid out by this conceptualisation, several studies and policy documents have furthered the research on USS (Shirazi and Keivani 2019b; Kyttä et al. 2016; Dempsey et al. 2011) without requiring a consensus on definitions. Given that there is no consensus on defining USS and efforts to operationalise it have progressed based on the conceptualisation alone raises the question of whether there is much utility in defining the phenomenon to begin with? (see Figure 5.1)

Davidson (2009) provides an useful view on this topic. He suggests that USS may be viewed as an empty signifier, a concept that does not have inherent meaning but derives its meaning from a collection of inter-related concepts. It performs an organisational duty within a social discourse. This view of USS is not intended to be permanent; rather, it provides an opportunity for further exploration and refinement of a concept whose definition is constantly in flux. Study A adopts this view of USS to present the conceptual framework of USS consisting of Social Capital and Social Equity (see Paper 1) and enables further operationalisation of the phenomenon.

Study A showed that social themes under social equity arise from opportunities for interactions between members of society (agents) and their (physical) systems and (social) institutions. It concerns itself with the availability of and access to

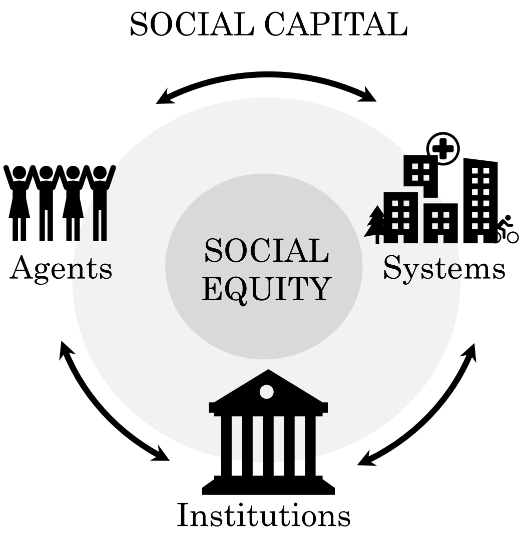


Figure 5.2: Illustration depicting the relation between Social Capital and Social Equity, adapted from Amirzadeh et al. (2022)

services, facilities, and amenities (the distributive notions of social justice). In comparison, social capital is understood as the *emergent properties that arise from social interactions between members of society through interpersonal relationships.* Social capital can be seen as analogous to A. Colantonio (2010)'s soft or emerging themes of Social Sustainability (see Figure 5.2).

5.2 Operationalisation of USS through indicators

RQ2. How to operationalise urban social sustainability through digitalisation?

Within the scope defined in this thesis, USS is operationalised through social equity. Trip completion rate (TCR) is proposed as an indicator of residents' ability to fulfil their daily needs. TCR is one part of the whole concept, intended to be used along with other indicators that satisfy the criteria of social focus, the scope of influence and specialised knowledge.

For practitioners to operationalise USS; i.e. have a tangible grasp on making socially sustainable interventions in their practice, they require tools and indicators (G. Payne and J. Payne 2004). In this thesis, three criteria are outlined to identify opportunities to operationalise USS:

- **Social focus -** Operational USS indicators must first and foremost have a social focus

- **Scope of influence -** Operational USS Indicators must focus on social themes within the users' scope of influence.

- **Specialised knowledge -** Operational USS indicators must be constructed in the users' natural way of reasoning.

Building social capital is not a technical problem requiring expert solutions. Social capital is understood as a self-organising concept; as such, one cannot control a self-organising concept; only serve them (Wilson 1997). Osborne et al. (2016) provides four examples of how urban planning can contribute towards building positive social capital in a community through: ensuring co-location of human service agencies, planning social infrastructure concurrently with residential growth, facilitating social interactions, a sense of community and health through physical infrastructure or inclusion of human abilities through neighbourhood design enables greater mobility, inclusion and activity. These examples describe the contribution of positive social capital indirectly through physical means. Fischler (2012), notes that urban planning performs a societal function by *combining the spatial organisation of society, the relationships between people and their environment.* Study A defines social capital in relation to social equity as *emergent properties that arise from social interaction between members of society through interpersonal relationships.* At the intersection of theory and practice of urban planning and architecture, it is primarily through physical interventions that practitioners can contribute to building social capital.

Compared to social capital, social equity is a more tangible concept that has a social focus and is within the scope of designers. This is not to suggest that the two dimensions are independent of one another, but as Dempsey et al. (2011) states, it is merely a useful conceptual distinction. While social capital has a social focus, it is not directly within an architect or urban planner's scope of influence. In study B , social equity is selected as a practical point of entry into USS around which digital tools can be built while being within the scope of a designer's influence.

The Trip Completion Rate (TCR) indicator proposed in study B is developed under these criteria. Study B demonstrates the potential of the indicator to operationalise the measurement and evaluation of *a residents ability to achieve their daily needs* as a social theme of social equity. A resident's ability to achieve their daily needs or their TCR is not in itself a full characterisation of social equity. It is an indicator of one part of the whole concept to be combined with other indicators. TCR is developed using an indicator design framework (OECD 2008) that considers the theoretical background, data selection, construction and visualisation of TCR. Visualising the results as a two-dimensional matrix allows the user to frame complex questions related to the multitude of socially relevant variables captured in readily available data sets, such as the National Household Travel Survey (NHTS) (Trafikanalys n.d.). Social equity has to be operationally defined into indicators that can be measured. Study B shows that through indicators like TCR, USS can be operationalised (see Paper 2).

5.3 Towards digitalisation of USS

Study A, presents a User Interaction Model (UIM) for digital tools that enables a guided decision making process for architects and urban planners to collaborate with their stakeholders. The UIM consists of four steps that address the issues identified with operationalising social sustainability. The recommendations provided in the pre-requisites of the UIM facilitate a low threshold for participation and are intended to reduce technical barriers to accessing such tools. (see paper 1).

5.4 Limitations

In the following section, three limitations are identified and discussed. The first is on the current conceptualisation of USS, the second on the relationship between stakeholders and finally, limitations on data availability and access.

Limitations in current conceptualisation: Attempts to measure social capital through quantitative methods are flawed by problems of separating form, source, and consequences (Adam and Rončević 2003). While there is a plethora of evidence supporting the positive relationship between social equity and social capital, there is a risk of placing a larger emphasis on social equity (since it is within the designer's scope of influence) rather than social capital. Doing so may mislead the designers into viewing the generation of social capital as a commodity. The generation of social capital cannot be commoditised by "adding more of something". For example, the designer may decide to add a square or a park into their designs, but this does not ensure that levels of social interaction will increase or that members of the community will now be more integrated. In the next stages of the research, the conceptualisation of USS from theory will be compared to perceptions of stakeholders to further investigate this limitation.

Relationship between stakeholders: The User Interaction Model (UIM) proposed in study A does not explicitly address the disparity in decision making powers between different stakeholders and their abilities to deploy resources. For example, in the design of a neighbourhood or a public square, among the various stakeholder involved in the design of the built environment, it is the resident that is directly impacted by the design decisions. In many cases, the resident may not have the same ability to allocate resources as the developer, contractor or designer involved in the decision-making process. While study A discusses the importance of stakeholder value systems and emphasises the importance of a collaborative decision-making process, it is unclear how the user of the tool would deal with conflicts between stakeholders. Additionally, the methodology involved in aggregating and ranking social themes (an important qualitative step for the collaborative decision-making process) is not discussed in detail. While aggregating quantifiable components of qualitative data are useful in a digital workflow, nuances of the qualitative data may be lost in the process. Future steps in this research will investigate a combination of qualitative and quantitative methods and look to techniques in participatory planning to explore these issues further.

Limitations on data availability and access: The methods and indicators proposed in studies A and B rely on digital social and spatial data. While there are several efforts to digitalise existing data and make them accessible through open data initiatives in Sweden and Europe in general, many countries do not yet have such initiatives. Study B makes careful efforts in the data selection to choose data sets that may be widely available (like a national household travel survey), but this does not ensure that the data is always accessible or even available. Novel methods from remote-sensing and GIS may provide ways to extract semantic data on the built environment using ubiquitous data sources like satellite imagery, but it does not ensure that the methods proposed in this thesis will be universally applicable.

5.5 Reflections on research philosophy

Given the conceptual inconsistencies of USS, the research design of this thesis is exploratory in nature. The research phases outlined in section 3.1 (theoretical framework and indicator development) use inductive theory discovering methods (Jabareen 2009) to discover theory through systematically obtained data (M. Glaser 2003). The grounded theory perspective to theory building is perhaps the most widely used framework in qualitative research. In recent years, authors have advocated for techniques that imbue inductive studies with *qualitative rigour* (Gioia et al. 2013).

While inductive methods have proven to be quite fruitful in theorising USS, it is in the conceptualisation phase of the phenomenon that an *epistemological deadlock* (Friedrichs and Kratochwil 2009) is observed regarding the definitions of USS. Perhaps this is because consensus is a necessary pre-requisite for social scientific knowledge (Friedrichs and Kratochwil 2009). To deal with this epistemological deadlock, this thesis adopts the position proposed by Davidson (2009) by viewing USS as an empty signifier from the functional pragmatism theory of knowledge (Davidson 2009). This is not to use pragmatism as a pretext for doing empirical research without the methodological and epistemological considerations of the theory. Rather, to use pragmatism as an instrument to conduct research with an appropriate level of awareness of the epistemological issues (Friedrichs and Kratochwil 2009). The results from study A show that there is a disconnect between USS theory and policy; while theory struggles to deal with consensus on definitions, USS is a widespread notion in policy. There are many policy programmes built around the very concept (Stepanova and Romanov 2021). This research aims to develop digital tools that address USS in a practical way and make them accessible to urban planners and architects.

Abductive reasoning is described as an approach that addresses the weaknesses associated with deductive and inductive approaches and follows a pragmatic perspective that takes *messy* observations to lead to a "best prediction of the truth" (Mitchell and Education 2018). Abductive reasoning is commonly used in action research to achieve change by simultaneously taking action and doing research. Perhaps pragmatism as a research philosophy is better suited to operationalise USS to achieve this aim. In doing so, the inductive approaches employed in this thesis to build theory from multiple data sources can become a part of a larger *abductive methodology* towards the digitalising urban social sustainability.

Chapter 6

Conclusion

This thesis presented the conceptualisation of urban social sustainability (USS) and addressed the challenges in operationalising it for architects and urban planners (study B). Additionally, it explored how new indicators could be developed to explore the social consequences of different urban and environmental policies through an indicator to evaluate a resident's Trip Completion Rate (TCR). Finally, it proposed a User Interaction Model for digital tools that accommodates USS and its indicators and presents a path towards the digitalisation of USS through digital tools.

USS is a complex and interdisciplinary concept and presents several challenges in conceptualising it; the chronology of its origin, its multi-disciplinary nature and the role of stakeholder value systems have caused contention at several stages of its conceptual development. The existing body of literature shows that though the core concept is grounded in theory, USS has many interpretations. Incorporating stakeholder values and the ability to analyse social themes quantitatively play an essential role in designing socially sustainable neighbourhoods. To address these issues, viewing USS as an empty signifier is suggested. Further, adopting a collaborative planning process to ensure multiple stakeholder perspectives is considered vital for achieving USS. USS is conceptualised as consisting of social equity and social capital.

Social equity is selected as a practical point of entry for digital tools to be developed around operationalising USS. TCR - an indicator of residents' ability to fulfil their needs is proposed. TCR aims to provide practitioners with the means to evaluate the social consequences of their designs. It is developed on data sets and variables accessible to the practitioner and within their scope of influence. It has a social focus and does not require specialised knowledge to evaluate. Traditionally, these evaluations depend on best practices, recommendations from policy or input from practitioners specialising in these techniques. These practices often lead to the social dimension of sustainability being left out of performance assessments. Through interviews with architects and urban planners, it was identified that the TCR indicator proposed in this paper can generate insights about the area being analysed and be integrated into the design process. The interviewees were able to envision additional applications of the indicator beyond what was presented to them. The thesis identified that while USS indicators may be used to evaluate its multiple dimensions, the visualisation and communication of the results require consideration.

To address this, alternative methods to visualise the results are provided.

Finally, a user interaction model for digital tools is proposed to serve as a blueprint for the digitalisation of USS by providing the user with a guided decision-making process. It enhances the user's understanding of current USS levels and provides stakeholders with the freedom to define the scope of USS and the design criteria. The users can then incorporate the views of the other stakeholders such as residents, neighbours, owners and local authorities in the design process by using their input through the digital model. Digital design tools developed using the pre-requisite conditions and the user-interaction model can serve as a common digital platform to enable a collaborative, inclusive and informed decision-making process while removing the technical barriers in the flow of information. Overall, the findings of this thesis contribute toward digitalising USS to develop digital tools to support architects and urban planners in designing socially sustainable neighbourhoods. The digitalisation of the built environment enables designers and policymakers to understand the social consequences of their designs and provide equitable solutions to realise them at the early stages of design.

Chapter 7

Future research

Further research is required to explore the stakeholder perspectives and build on current findings. I identify the following future directions for research below (See Figure 7.1):

This research primarily focuses on data from literature reviews and policy documents through literature reviews and conceptual framework analysis. However, it is crucial to gather perspectives from the target users - the architects and urban planners. Study C will explore the practitioners' perspectives on USS and identifies the relationships between various stakeholders and how USS affects them. It also identified challenges, opportunities and requirements of developing digital tools for architects and urban planners. This study is already in progress. The research question framed here are:

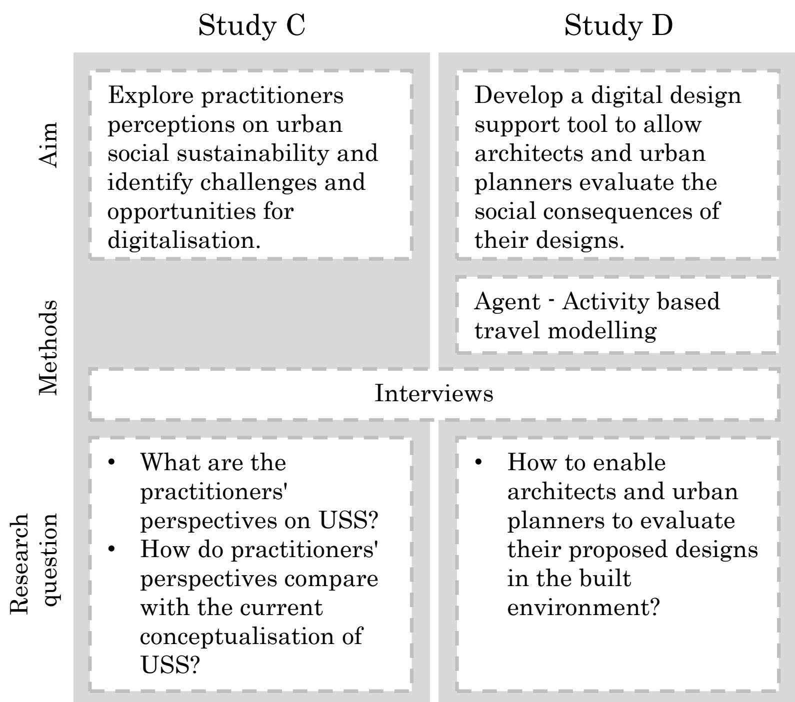


Figure 7.1: Research design for future studies

- *What are the practitioners' perspectives on USS?*
- *How do practitioners' perspectives compare with the current conceptualisation of USS?*

In study B, the primary data source is the National Household Travel Survey (NHTS). However, this data is collected on a national level and does not capture neighbourhood level variations in demographic composition and access to amenities. Methods for evaluating complex human interaction have been developed and used in computational social sciences, traffic planning and integrated urban modelling. However, these methods have not yet been applied to the problem of evaluating the USS of neighbourhood design. Study D plans to explore agent-activity-based models using synthetic population data to model resident travel behaviour; this study is currently in progress. The research question framed here is:

- *How to enable architects and urban planners to evaluate their proposed design in the built environment?*

In study A, a UIM to develop digital tools is presented. In the next steps, decision support tools to facilitate the aggregation and ranking of social themes to facilitate a collaborative planning process are planned. Explorations on what methods are available for aggregating and ranking social themes are planned. These tools would then be tested with potential users to identify appropriate methods and further improve on them.

The interview results from study B indicate a need for new methods of visualising complex and multi-dimensional data. Alternative methods of visualising social data and how complex results can be communicated efficiently to different stakeholders will be further explored. The Digital Twin City Centre at the Chalmers University of Technology provides an ideal opportunity to explore these methods.

Finally, a case study has been identified in which new development is planned. The project is in its early stages and is identified as a suitable example to test the methods proposed in this section.

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Appended papers

Paper 1

Towards digitalisation of socially sustainable neighbourhood design

Sanjay Somanath, Alexander Hollberg and Liane Thuvander

Local Environment 2021, VOL. 26, NO. 6, 770-789

The paper was reformatted for uniformity, but otherwise is unchanged.

Paper 2

Using trip completion rates to evaluate urban social sustainability

Sanjay Somanath, Jorge Gil, Liane Thuvander and Alexander Hollberg

Cities (2022).

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