MASTER THESIS

BUSINESS INFORMATION TECHNOLOGY

DEVELOPING A MEASUREMENT ITEM TO ASSESS THE SMARTNESS OF CITIES ACROSS THE WORLD

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"*If you want to go fast, go alone. If you want to go far, go together.*"
- African proverb

This thesis concludes my master's study of Business Information Technology at the University of Twente. I believe I learned a great deal in this study period. This required not only personal effort, but also support from multiple individuals. As the quote communicates a key theme to my studies was collaboration and thus, I would like to express my gratitude to those people.

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Executive Summary

Cities face many challenges today, which concern various problems linked to the trend of increasing urbanization in all countries. Examples of those challenges are climate change, high population density, or transportation issues within or around a city. To address them, cities are looking to become smarter (or increase their urban smartness) and thus, turn to the smart city (SC) concept. Cities may have a SC strategy or program and city government officials make decisions on how to develop urban smartness (US). These decisions need information that can be gained through using items that quantitatively measure their US, and the US of other cities it can compete with and learn from. Many US assessment measurement items are designed in the current body of research to assess the US of individual cities or specific groups of cities. These items often define lists of indicators that should be measured when conducting an assessment. Unfortunately, the applicability of these measurement items is limited.

This research looks to design and develop an US assessment measurement item that can be applied to any city across the world. This measurement item is called the Global Urban Smartness Model (GUSM). It is the artifact to be designed in this study, which is thus in the design science domain. This leads to the main research question of this study:

How can a city's urban smartness be measured for cities around the globe in a standardized universal approach?

This study conducts literature reviews to define its holistic, high-level interpretation of the SC concept and to investigate how US is measured in published research and what aspects of maturity models are relevant to US assessment. This analysis leads to the identification of several US assessment measurement item frameworks, which are synthesized into the Global Urban Smartness Framework (GUSF). GUSF displays the seven constructs, which when measured indirectly indicate the US of a city. These constructs are referred to as the focus areas and can be further divided into two groups, the goals (or desired outcomes) of cities and the drivers of the city to achieve its goals. GUSM assesses the US of a city by measuring the focus areas of GUSF, using indicators.

GUSM is designed and developed using a modified maturity model development methodology. The design of the model (or "the theoretical version" of GUSM) is tested by conducting six expert opinion interviews with published researchers in the SC domain. Following the changes based on their feedback, GUSM is operationalized for two cities, Enschede and Münster, neighboring cities across the Dutch-German border. A demonstration of GUSM is created and tested by interviewing two government officials from different cities who oversee the SC program or strategy. Results from these interviews indicate how useful GUSM can be from their perspectives.

The data collected from both sets of interviews are analyzed and several findings are identified. They indicate how an US assessment measurement item should be designed and de-

veloped if it is to be perceived as useful by cities, including that the item should account for the city's local context, the parties to be involved in the assessment, and how the item balances its flexibility and comparability capabilities. The findings are thus implications to the practice of making such measurement items.

In addition to these implications, this study contains the following contributions to practice and research. First, the body of knowledge on US assessment research is comprehensively reviewed and the main aspects relevant to measuring US are identified and included within GUSF. Second, based on relevant literature concerning maturity model design and SC related maturity models the design principles and development methodology used in the design and development of GUSM is generated. These are referred to as the GUSM Design Principles and the GUSM Development Method and they can be used when creating new US assessment measurement items. The GUSM Design Principles are the requirements that US assessment measurement items should seek to satisfy and the GUSM Development Method defines a process for developing a high-quality US assessment measurement item, before implementation. Third, the proposed model, GUSM, and its demonstration can be used by both researchers and practitioners to assess the US of cities, as it enables the measurements enabled by GUSM to be flexibly adapted to fit the local context of any city. Finally, the literature reviews and implications of practice in this study offers practitioners and researchers the opportunity to quickly understand the state of the play in the US assessment field.

In addition, these contributions and findings identify six topics concerning future research. The first is about developing GUSM further and researching how its perceived usefulness can be improved, for instance by converting GUSM into a SC maturity model or operationalizing it for cities in other areas of the world. The second involves researching how GUSM should be used in the future. For example, whether a second US assessment measurement item should be used to identify and measure individual problems within each area after GUSM is applied to assess the city's overall US and identify problem areas. Thus, how it can be combined with other items. The third topic concerns further validating GUSM including after implementation. This research covers the initial design and development of GUSM and would benefit from statistical validation. Finally, three suggestions when conducting research on US assessment are identified in this research. In the future, researchers should not only focus on the improvement of US, but also on measuring the city's performance on its desired goals. When researchers are looking to assess the US of a city, officials of that city's government should be involved in discussions on the identification and selection of the assessment criteria to be used. Lastly, more research is needed concerning assessing the US of cities that have a small to mid-sized population or are in the areas of the world that are not yet sufficiently covered by SC research including Africa, parts of Asia, South and Central America.

This study concludes that the research question above can be answered, as GUSM provides a repeatable, transparent and robust process and a standardized framework to support decision-making on which aspects a city should invest in. GUSM is designed to flexibly adapt to the local context, given the lack of international agreements as to the SC concept interpretation. Following the development of GUSM, this study shows how US assessment measurement items can be developed to measure urban smartness for cities around the globe in a standardized universal approach which allows for the cities to adapt the assessment criteria flexibly.

Contents

List of Tables

List of Figures

Abbreviations Used

Abbreviations used in the research are defined are sorted alphabetically in the table below.

Abbreviation	**Term**
Br-SCMM	Brazilian Smart City Model
DP	Design Principle
DSS	Decision Support System
GSCM	Guarda Smart City Mode
GUSF	Global Urban Smartness Framework
GUSM	Global Urban Smartness Model
ICT	Information and Communication Technology
IDC-SCMM	IDC Government Insights Smart City Maturity Model
ISO	International Standards Organisation
KPI	Key Performance Indicator
MM	Maturity Model
MRQ	Main Research Question
RSQ	Research Sub-Question
SC	Smart City
SCMM	Smart City Maturity Model
SDG	Sustainable Development Goal
SO-SCMM	Sustainability Outlook Smart City Maturity Model
US	Urban Smartness
UTAUT	Unified Theory of Acceptance and Use of Technology

CHAPTER 1

Introduction

This research study aims to develop a globally applicable tool that can measure the urban smartness of cities. This chapter details the problem this research addresses, the research goal, scope, questions, overall approach, various methodologies used in this research, and the structure of this report.

1.1 Motivation

1.1.1 The Rise of Urbanization and the Challenges it Creates

The United Nations found that in 2018, 55% of the world population lives in urban areas and they estimated that by 2050, that number would rise to 68% [86]. Those figures illustrate the high level of urbanization cities need to match. Each city needs to face challenges concerning its impact on the natural, social, and human-made environment of its people. By addressing these challenges cities become more livable, attractive (economic or otherwise) and sustainable [23]. The UN also estimated that ”cities consume around 60% To 80% of energy worldwide and are responsible for large shares of greenhouse gas emissions [5], meaning that cities can have a massive influence when it comes to sustainability aspects. This has led to many international organizations like the United Nations or European Union (EU) setting ambitious urbanization and sustainable development targets [3]. Newton in [69] identified and divided the challenges that rising urbanization creates into four groups: (1) Competitiveness and productivity, (2) Environmental sustainability, (3) Livability and (4) Social inclusion and equity. To address these challenges, cities around the globe are turning to the ”smart city” (SC) concept.

1.1.2 The Smart City Concept

Cities are complex as they cover and affect many aspects for the people in the city including the four groups of challenges from Section 1.1.1 [64]. The SC concept concerns making cities smarter through applying projects (or approaches to urban planning) to tackle issues created by urbanization [67]. Three terms are used to identify these projects: either ”smart solutions”, ”smart projects” or ”SC initiatives” [43, 67, 24]. These terms can be used interchangeably.

These SC initiatives are usually in the form of implementing information and communication technology (ICT) systems innovatively in the city with the ultimate aim of improving peoples’ lives. However, current research shows that smart solutions do not always need to use technology, as these problems can be dealt with appropriately in a myriad of ways. For example, an investment in education might be better than implementing a new ICT system for a particular situation concerning citizens’ public health. These solutions are often realized through SC initiatives and each one can be said to increase the city’s level of urban smartness (US), enabling cities to become SCs [67, 24].

1.2 Problem Statement

Developing a city to have a high level of US is difficult. There is no universally agreed upon definition of the SC concept or how to make cities smarter, as it differs depending on the city or nation defining it [66]. Leading to cities across the world labeling themselves as smart, without a consensus about what smartness requirements that entails (or if they qualify) [41, 6]. The researchers concluded that the smart label has become a marketing tool cities use to promote themselves, instead of an indication of the cities' development progress.

The common mistake is the belief that being smart is a goal to achieve and, once reached, a city is smart. Rather being smart concerns conducting processes to improving a city in certain ways [28]. In this research, a city is not identified as smart if its measurable aspects attain specific values. All cities have US, but they differ in their level of smartness compared to each other. In other words, the level of the US of cities are points on the ”US spectrum,” where it is not relevant if cities are smart or not, but whether they are more or less smart.

Researchers have even begun challenging whether SCs and US handle the urbanization challenges discussed in Section 1.1.1. This concerns especially the high sustainability objectives set by international organizations like the Europe 2020 Strategy from the EU [59, 96]. This confusion raises questions:

- What is a SC and what outcomes of US are desired?
- Can how smart a city is be measured to assess whether implemented SC initiatives have the intended impacts?

The last question indicates a challenge cities face, especially when considering several options, deciding which smart project will improve the city's US in the desired way.

While no universal definition of SC exists, the amount of SC research has drastically risen and, as a result, as Mora et al. notes in [64], it was established as a new field of research as of 2009. Most SC related research emphasizes one or more aspects at a city or national level. For example citizens' perceptions of how liveable of Brazilian cities are in a study by Macke et al. [57]. Or focuses on SCs at an international level like when the authors in [79, 90] discuss US, environmental and transportation aspects of technologically developed SCs across countries. Alternatively, they discuss one element of SCs theoretically. For example the role of ICT in SCs [38]. To the author's knowledge, there is currently no research on practically measuring the US of cities around the world, regardless of whether the smart label has been applied to the city or not. This global perspective of SC introduces two new questions:

- Is the SC concept similar around the globe?
- If so how can US assessments be done for cities around the globe?

The four questions indicated earlier can be summarized in the problem statement:

There is only a vague understanding of the SC concept and how the US of cities is measured, especially from a global perspective, which compromises the city's decision-making capability to select appropriate SC initiatives.

1.3 Research Goal and Scope

Determining which smart solutions to implement and which would most improve the level of US is a complex matter. Having a standard approach to assess the US of cities across the world would be useful as a basis for decision making. One such standard approach concerns using decision support systems (DSSs) which help cities and the people involved in deciding on which SC initiatives to implement, make better decisions and improve their decision-making processes [18]. The lack of clarity surrounding the SC concept and assessing US means this problem is ”messy” as described by Mackenzie et al. in [58], making decisions on which smart project to implement creates ”unstructured situations where there is disagreement about what needs to be done and why”. A standardized approach would thus provide substantial decision support or approaches that provide knowledge-based expertise to address relevant decisions [58] and enable cities to learn from each other in a comprehensive and goal-orientated manner.

Therefore this research concerns the development of such a DSS (in the form of a tool or artifact) for assessing the US of cities around the world. It is design science as described by Wieringa in [92] where an artifact that interacts with its context is developed as a treatment to address the problem statement from the previous section. Therefore this research is solution-oriented.

The artifact whose design and development is the focus of this research is the global US model (GUSM). The context the artifact interacts with is cities around the world, conducting US assessments to decide on implementing or analyzing SC initiatives. A term used frequently in this report, treatment, refers to the interaction between the artifact and its context. The problem statement from Section 1.2 can be reformulated in the form of a design problem from [92]:

”Improving support for city decision making concerning which SC initiatives to implement,
by creating a global urban smartness model,
such that a globally standardized approach to assess US is established,
in order to support the development of smarter cities.”

Given the confusion around the SC concept, this report sets out to investigate how US is measured and develop an US assessment measurement item that is applicable to cities around the globe. To the best of the author’s knowledge, current research does not cover this topic. This thesis contributes in two ways: (1) it contributes to research by bringing the global perspective to US assessment and (2) it develops an assessment tool that enables practitioners to assess and compare the US of cities across the world and supports decisions on how to develop the US of a city.

This thesis also investigates the potential of using maturity models (MMs) with the SC concept. However, the scope of this research is not looking to develop a MM, as this would require more time and resources.

The goal of this study is to design an artifact, GUSM, that meets three requirements:

- Build an understanding of the SC concept and what it seeks to achieve
- Measure the US of cities no matter the locations of those cities in the world
- Enable cities and other stakeholders to quickly assess and compare US across international boundaries so that smart solutions’ potential impacts can clearly be understood.

The scope of this research seems to be very broad as the research looks to develop a model to assess the US of cities around the globe. This scope would require an extended amount of time and more resources than available for this project. Rather the scope will be narrowed: design GUSM to measure the US for cities around the globe, but operationalize and demonstrate it for two cities in Europe. The demonstration can then be tested to determine whether such a measurement item would be possible to make and useful from a city’s perspective. Perceived usefulness is defined by Venkatesh et al. [89] as ”the degree to which an individual believes that using a system will help him or her attain gains on job performance” . The findings of this study indicate various paths US development and assessment research can follow in the future. The next section will discuss the methods this study uses to achieve its goals.

1.4 Research Methodology

This research follows the Design Cycle from [92] for its overall design science methodology. The Design Cycle is a subsection of the Engineering Cycle (shown in Fig. 1.1). It contains the three activity phases in design science when no real-world implementation of the artifact is done.

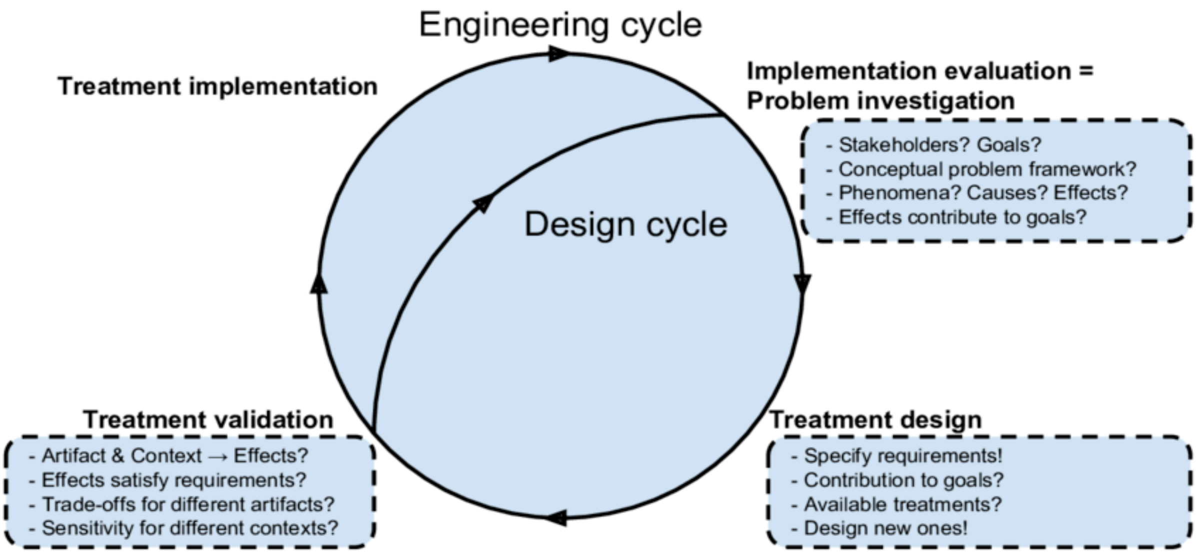


Figure 1.1: The Engineering and Design Cycles

They are the phases [92]:

1) Problem Investigation: Activities that inspect the current situation and identify issues and concepts to consider when designing an artifact.

2) Treatment Design: Activities to design the artifact so that the interaction between the artifact and the context (or the treatment) addresses the problems identified. Also, activities to review existing treatments and assess whether improvement is possible.

3) Treatment Validation: Activities to test and determine whether the treatment does what it is supposed to do! It is important to note that for validation the artifact is not implemented in a real-world situation.

The phases are done iteratively, the design cycle is repeated until the treatment is fully developed. Each iteration begins with Problem Investigation activities.

This design science methodology serves as the backbone of this report, which is split up in parts to designate which design cycle phase the research is in. Each of the three phases uses more appropriate methods. The following two subsections introduce the general methods used throughout the report.

1.4.1 Systematic Literature Review Methodology

In the Problem Investigation phase, two systematic literature reviews are done to identify, analyze, and review current research to address research questions in a repeatable, unbiased approach [49]. This thesis's reviews follow the guidelines from the studies [71, 47] and uses their guidelines eight steps, which are shown in Table 1.1.

No.	Step	Description
1	Purpose of the Literature Review	The identification of the purpose of the review for the readers and the researcher.
2	Define Review Protocol	The defined rules the reviewer will follow while systematically conducting the review.
3	Searching for the Literature	Explicitly describes the details of the search to justify that the search was complete.
4	Practical Screen	Explicitly state about what studies were considered for review or were eliminated to ensure readers can assume search is still comprehensive.
5	Quality Appraisal	Defines the criteria for judging which articles are of insufficient quality to be included in the review synthesis.
6	Data Extraction	Details how the information will be systematically extracted from the selected literature
7	Synthesis of Studies	Analysis of the information extracted using either quantitative, qualitative methods, or both.
8	Writing the Review	It needs to be reported in sufficient detail that the results of the review can be reproduced.

Table 1.1: Systematic Literature Review Method

In this thesis, step 1 is addressed in Section 1.3 the research questions the review is concerned with are described in Section 1.5, and steps 3-8 are covered in the chapters within the Problem Investigation phase of the design cycle (shown as Fig. 1.1).

The literature reviews in this thesis will be done in two iterations, with the first using a traditional systematic keyword search method. A second search iteration will be done using a ”Snowball” method on research found in the first iteration to make the search more comprehensive. In [93], Wholin describes the Snowball search method (referred in this report as the ”Snowball search”) as a backward (all the studies cited by the selected documents) and forward (all the studies that cite the selected research) citation search performed on a group of documents. Wohlin found the Snowball search method to be an excellent alternative to the systematic keyword search method, which is used for the first search iteration. The search method used by the review is shown in Fig. 1.2, which is the Literature Review Process Model on p. 16 [94]. By combining both search methods, the systematic literature review reduces the risk that relevant research is missed if it has not been found in the initial search.

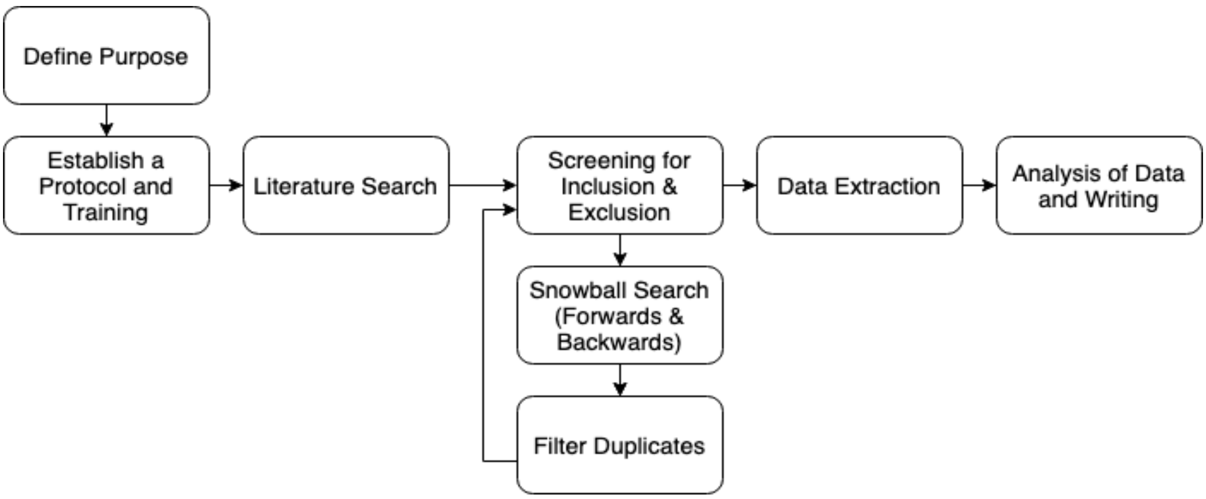


Figure 1.2: The Systematic Literature Review Process Model

The figure above shows that once the keyword search is done, the results are screened for inclusion and exclusion. If necessary literature reviews (if known) can be included. A snowball search is then conducted using the screening results (published in the last three years). The resulting list is again screened for inclusion and exclusion. The extended list of literature is then subjected to data extraction.

1.4.2 Validation Methodology: Expert Opinion

As stated in Section 1.3 a type of model that has been used to assess the US of cities is the MM concept. The artifact designed and validated uses some theories found in MMs and therefore, will apply a method that is appropriate for validating MMs. The authors of [17, 13, 91] note that a frequent tool used to test and validate MMs are conducting expert opinion interviews. This validation method is used in this thesis and will be discussed in this subsection.

According to Kallio et al. [46], consulting experts is one way to gain empirical knowledge of the study phenomenon. The method to collect those expert opinions that will be employed for this research is to conduct interviews, which, as Kallio et al. [46] noted, is the most used data collection method. A book on conducting social research [68] found that conducting interviews is a useful tool to collect feedback. Such interviews come in three forms as shown in Table 1.2 below [46, 68, 72].

Interview Type	Description
Structured	The interview questions and answers are all predetermined by the interviewer. The interviewee is thus limited in the answer he or she can give. All interview questions are ”close-ended”.
Unstructured	The interview question may not have been defined beforehand. The interviewee may answer the questions freely however they desire. This type of interview is more of a conversation, where the interviewee ”directs” the interview. All questions are thus ”open-ended” where after a question from the interviewer, the interviewee is encouraged to elaborate further (if it is relevant)
Semi-structured	Interview questions are predetermined and can be either open or close-ended, but the interviewee can elaborate further. These elaborations are encouraged (even if they stray from the topic) if thought relevant.

Table 1.2: Interview Types and their Descriptions

In this research, a number of semi-structured interviews will be done in two rounds (as shown in Fig. 1.3):

1) Theoretical Round: To test the theoretical model of the artifact six experts researching the SC concept will be interviewed. Their reaction to the model will be used to adjust the theoretical model as needed.

2) Validation Round: To validate the operationalized artifact two city government officials who oversee the SC programs of their city are interviewed. The feedback gathered on the artifact is analyzed to complete this research.

Figure 1.3: How the two rounds of interviews fit in this research.

All these Interviews were semi-structured, one-on-one, and they look to confirm whether the artifact, GUSM, is designed and developed appropriately. Their semi-structured and one-on-one format benefits this research as the data collected from the interviews captures the independent thought of each expert and allows for the asking of probing, open-ended questions [1].The two following subsections detail how the interviews in both rounds are prepared and how the results from those interviews are collected and analyzed.

1.4.2.1 Interview Preparation

This subsection describes how in general the interviews in both rounds are prepared for. All the interviews will use the interview preparation methods from Kallio et al. [46]. There will be some differences between the two rounds, like the selection of experts to be interviewed. Those differences will be addressed in the relevant separate chapters. Both interview rounds use ”non-probability sampling” for expert selection, meaning the sample of experts is not meant to be statistically representative of a larger group of experts. Schreuder et al. [76], note that non-probability sampling is a method that ”is generally a lot cheaper and offers more protection against small sample sizes.” This sampling method (also called purposive sampling) is used in this research to gain an understanding of expert opinion on the artifact being developed by identifying relevant experts who have knowledge on the SC topic. However, it must be emphasized that the sampled information is not generalizable beyond the scope of this research. The findings of these interviews are not sufficient and further research is needed to finalize and validate the artifact completely.

Kallio et al. [46] includes guidelines for developing materials essential to conducting the interviews. These materials contain the questions or topics discussed in the interview. Mainly these materials come in two forms: the Internal Interviewer Guide and the external Interview Discussion Guide. With the Internal Interviewer Guide being followed by the researcher conducting this interview and the Interview Discussion Guide containing the details and knowledge that the expert needs to participate in the interview. When the interviews are being held the interviewer and the experts use the guides to discuss the topics that will generate the feedback relevant to the purpose of the interview. The interview materials are developed further by conducting pilot tests at the beginning of the interview rounds to make sure that interview materials are clear and detailed enough to support interview discussion. If not, the materials are adjusted as needed. Of course, the topics to be discussed differ substantially between the interview rounds and thus, the chapters corresponding to each round detail their specific materials.

1.4.2.2 Data Collection and Analysis

This subsection covers how feedback or data for every interview is collected and analyzed for the two rounds. Although the same method is used for both rounds, it was applied separately during the two sequential rounds.

The interview discussion was recorded. This audio recording was then summarized. The online web service atlas.ti was used to code these summaries. According to Saldana [75], ”a code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based ... data.” The shared codes between interview summaries were used to identify the main topics discussed and participants’ comments concerning them. Finally, structured summaries were created for each interview which divides the collected feedback according to these main topics

These structured summaries are contained in the appendices of this report and are referred to by corresponding sections that discuss the results of these interviews.

This data analysis method of developing structured summaries of interviews is based on the qualitative analysis process theories of Dey [30] (the process framework is shown in Fig. 1.4). With the initial interview summaries forming descriptions of the data collected. Those summaries were then classified using the coding functions from Atlas.ti. Based on these classifications, the contents of those descriptions are connected under several topics in structured summaries of each interview. Thus, the structured summaries allow the interview responses to be analyzed and support addressing the research questions of this research introduced in the following section.

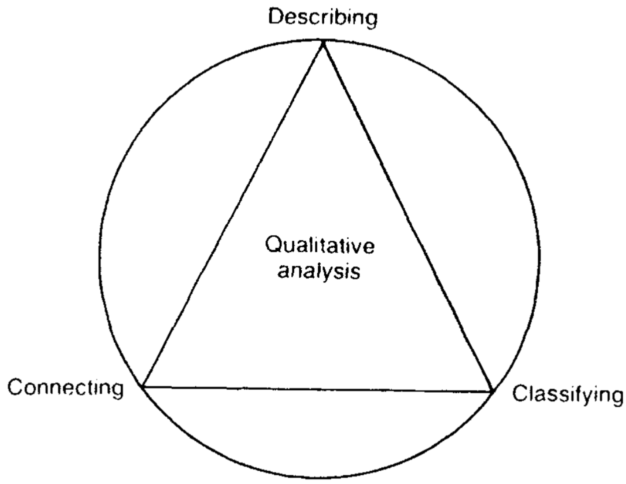


Figure 1.4: Qualitative Analysis as a Circular Process

1.5 Research Questions

The research goal calls for the design of an artifact that addresses the problem statement in Section 1.2. The artifact's design can vary in a myriad of ways, there is not one true design to address the problem statement. Furthermore, a clear artifact and context can be distinguished as done in Section 1.3 [92].

In design science research, questions concern "how" to develop the artifact. Thus, the research questions relate accordingly to the design problem from Section 1.3. The main research question (MRQ) is thus:

***MRQ**: How can a city's urban smartness be measured for cities around the globe in a standardized universal approach?*

The MRQ relates to how the artifact can be developed to address the design problem appropriately. The research sub-questions (RSQ), listed below, tackle different aspects of this broad question.

***RSQ 1.1**: What is a globally applicable definition of the smart city concept?*
***RSQ 1.2**: What are the commonly identified US constructs and issues found in smart city research about urban smartness assessment?*
***RSQ 1.3:** What potential do existing smart city maturity models have in relation to US assessment?*

These questions investigate the problem statement at the end of Section 1.2; they are in the Problem Investigation phase. First, it indicates two knowledge questions that, when addressed, provide the theoretical basis of the SC concept and US assessment. Second, the last knowledge question reviews existing smart city maturity models. These three RSQ provide background knowledge to develop GUSM artifact.

***RSQ 2.1**: How should the development of the model be done?*
***RSQ 2.2**: How can the US assessment constructs be incorporated into the urban smartness model?*

RSQ 2.3: *How should the global urban smartness model be operationalized?*

These questions concern the Treatment Design phase of the Design Cycle. When addressed, these questions indicate how GUSM should be designed and developed.

RSQ 3.1: *What is the usefulness of GUSM from practitioners' perspectives?*

This question is concerned with the Treatment Validation phase of the Design Cycle. Resolving the sub-question needs a method that is used to validate GUSM. Then the findings of that validation can be analyzed and discussed and the RSQ is answered.

1.6 Thesis Guide

The structure of this report is given in this section. Following the Design Cycle introduced in Section 1.4, this thesis is split into three parts: (1) Problem Investigation, (2) Treatment Design, and (3) Treatment Validation.

Part 1 contains chapters concerned with investigating the problem identified in Section 1.2. Chapter 2 proposes a global definition of the SC concept. Chapter 3 studies the current body of knowledge on the assessment of US. Chapter 4 discusses the use and potential of maturity models for assessing US.

Part 2 is concerned with designing and operationalizing GUSM. In chapter 5, the methodology to develop GUSM is detailed. Chapter 6 describes the theoretical model of GUSM. This theoretical model is tested and adjusted accordingly in chapter 7. The concept of how GUSM is demonstrated is discussed in chapter 8. GUSM's demonstration is operationalized in chapter 9.

Part 3 details how GUSM is validated and discusses the findings from the validation. Chapter 10 details the validation of GUSM's demonstration and analyzes the findings. Chapter 11 reflects on US assessment and discusses this report's contributions to research and practice. Finally, chapter 12 concludes the report and summarizes the previous chapters. In Table 1.3 the title of each chapter along with its associated research question is presented.

Part	Chapter No. & Title	Research Question
1	2: Defining the Smart City Concept	RSQ 1.1
1	3: Assessing Urban Smartness	RSQ 1.2
1	4: Smart Cities and Maturity Models	RSQ 1.3
2	5: Development Methodology	RSQ 2.1
2	6: The Global Urban Smartness Model	RSQ 2.2
2	7: Testing the Model	RSQ 2.2∗
2	8: Artifact Demonstration	RSQ 2.3∗
2	9: Operationalizing the Model	RSQ 2.3
3	10: Validation	RSQ 3.1
3	11: Discussion	-
3	12: Conclusion	MRQ

Table 1.3: Thesis Chapter Guide

∗ These chapters address aspects related to the corresponding research question.

Part I

Problem Investigation: Background Knowledge

CHAPTER 2

Defining the Smart City Concept

The definition of the SC concept that is used in this research is discussed in this chapter (addressing RSQ 1.1). This chapter is split into three sections. The first introduces the varying views on SCs and the effect on its definition. The second touches on the main goals of SCs. The final section presents the definition (and its perspective) that is used.

Many researchers have argued over the definition of the concept of the SC. This vague definition issue was thrust into the international spotlight by Hollands [41], who discussed the trouble with cities declaring themselves to be smart when it was unclear what being smart meant. Many studies have noted this issue of the vague definition of the SC concept [24, 7, 21, 48, 60].

The lack of a universal definition may be due to the complex nature of cities [67]. This confusion is amplified by the variety of city types, e.g. intelligent, sustainable and liveable cities, where each type of city focuses on the concept it was named after [5, 65, 39]. For example, a sustainable city is a city that focuses on sustainable development and the city's impact on the environment [63]. The SC concept looks to combine many of these city types. Which city types the SC concept covers is debated heavily by researchers like by Nam and Pardo in [65].

2.1 Different Perspectives and Definitions of the Smart City Concept

According to Neirotti et al. [67], the dimensions of a SC can be split into two domains: the ”hard” and ”soft” domains. The hard domain denotes the aspects of a SC where ICT systems are seen as key enabling technologies. These are usually tangible city assets (f.e. natural resources, buildings, waste management, transport, etc.). While the soft domains contain elements that are intangible assets (f.e. social and human participation, education, innovation, etc.). The domains define the two general perspectives as either SC research has a hard technology-centric perspective or a soft people-centric perspective [3]. Mora et al. [64] found that there were two SC research ”development paths” along these two perspectives. Researchers at European universities would produce peer-reviewed research with a soft, more people-centric perspective. While the North American business community produced grey literature with a hard, techno-centric perspective. This research uses a holistic perspective [43, 51], which seeks to combine both domains into one, with an emphasis on the people in a city. As a result, this research will focus on research with a holistic perspective of the SC concept. Al-Nasrawi et al. [66] encourage using this perspective as regardless of the hard, technological system implemented to tackle an urbanization challenge, it will not achieve its intended impact if people in the city do not use it or perceive it as improving their life.

Besides these two perspectives of the SC concept, there are two cases from which cities develop their US. Either a SC is built from scratch (the greenfield case), or an existing city is transformed into a SC (the brownfield case) [8] by implementing SC initiatives. Understanding these two cases is essential when envisioning the US of a specific city and this will be addressed in later chapters of this thesis.

Yigitcanlar et al. [96], presents some SC definitions from various studies and identifies their themes (or different elements they cover). Three of those definitions are presented in Table 2.1.

No.	Source	Definition	Themes
1	[21]	We believe a city to be smart when investments in human and social capital and traditional transport and modern ICT infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.	Community, technology, liveability, sustainability, governance, policy, accessibility
2	[70]	A city that capitalizes on the opportunities presented by ICTs in promoting its prosperity and influence.	Technology, productivity
3	[65]	A humane city that has multiple opportunities to exploit its human potential and lead a creative life.	Community, well-being, productivity

Table 2.1: Examples of Smart City Definitions

Thus, there are many existing definitions of the SC concept that emphasize different perspectives or aspects of the cities [5, 9, 81]. This issue has led to researchers needing first to discuss or define the SC concept in their papers. They must decide whether to define it [21] or not [4], or refer to another study that does [21], before pursuing the topic they wish to research. This difference in SC definitions leads to the US of a city being defined and measured in different ways too [9].

In Table 2.1, the second definition has a hard, techno-centric perspective, and the third has a soft, people-centric perspective. The SC definitions of those two papers are entirely different due to the different perspectives. This research, having a holistic perspective, would use the first definition, which covers a large number of aspects of a city. Before adopting this definition though, it must be modified slightly to account for the main desired outcomes of SCs.

2.2 The Desired Outcomes of Smart Cities

SCs are defined in various ways, but researchers in the existing body of research agree that at least one of the following three elements (in Table 2.2) is identified as the core desired outcomes (or goals) of the SC concept (along with a definition of each outcome and the source of the definition).

Desired Outcomes	Definition	Source
Quality of Life	Aspects concerning how well people in the city live and their wellbeing	[23]
Competitiveness	Aspects concerning the economic growth and attractiveness of a city and its competitive position to other cities	[63]
Sustainability	Aspects concerning the efficiency of a city's management of resources and impacts on its environment	[3]

Table 2.2: The Desirable Outcomes of Smart Cities

The first desired outcome, Quality of Life, is frequently given as the core reason for cities trying to become smarter as Lopes and Oliveira [55] state "the motto is always the use of information and communication technologies to make urban life easier." The relationships between people, city performance, and urban smartness have been investigated numerous times. For example, the researchers from several studies [21, 78, 83] found a connection between high urban growth and performance of a city with high human and social capital and a creative class of people living and working in that city. Thus, the soft perspective that emphasizes that people are the core of the SC concept is critical when assessing the US of a city. Their wellbeing and the liveability of their city (two intangible, subjective constructs) are just as important as any objective, tangible measure of the city [66, 32, 80, 23, 52]. Quality of Life is ”the fundamental value underlying smart cities’ ideational concept” according to Caragliu et al. [21] and is one of the significant desired outcomes.

The next desired outcome Competitiveness, as the definition in Table 2.2 shows, deals with the economic aspects of a city. It is a holistic concept, leading Monfaredzadeh and Berardi [62] to say, ”the economic growth, the business and regulatory environment, institutions, the quality of human capital, cultural aspects, and the quality of governance all matter for sustaining economic growth while securing present and future competitiveness.” They also state that ”a city with a high degree of economic competitiveness is considered as having one of the main drivers for a smart city.” Hatuka et al. [39], note that cities constantly compete with one another for human and financial resources. Researchers tend to use terms similar to ”Economy” (e.g. ”economic growth” on pg. 2 of Nam and Pardo [65]) instead of competitiveness. This narrows the economic assessment of a city and excludes non-financial aspects concerning its economic attractiveness. Economic attractiveness means the city’s ability to attract talent, visitors, business and capital [62]. Although the terms used by researchers differ, the economy of cities is included in most of the assessments of US [5, 20].

The third desired outcome, Sustainability (especially in the sense of sustainable development), is pursued by research and international organizations to see how US can tackle the environmental and related challenges presented by the increasing urbanization around the world. As stated in Ahvenniemi et al. [3], ”The initial target of smart cities, defined as attaining sustainability of a city with the help of modern technologies.” It is important to note that sustainability is a holistic concept that is not only concerned with natural environmental aspects of a city; it also relates to the sustainability of other city aspects (e.i., sustainable economic growth, social sustainability). The relationship between SCs and sustainability is the focus of many researchers with investigations of how sustainable SCs are [59, 53, 56]. Most studies conclude that while they may have some positive impact, for the most part, the current SCs pursue being ”smart” (technologically and socially) more than sustainable [3].

These three concepts are broad and represent the main goals a SC looks to attain. As stated by Monfaredzadeh and Berardi in [63], ”Smart cities are envisioned as creating a better and more sustainable city, in which people’s quality of life is improved, while their environment is more liveable and their economic prospects are stronger.” All three outcomes are holistic and need to be pursued together. In the case of sustainability and competitiveness, these goals need to be appropriately balanced as the pursuit of economic growth usually leads to the increased consumption of resources [63, 42, 50]. Thus, US assessment can be defined as the measure of how well the city achieves these desired outcomes.

Recently a fourth desired outcome of SC, Resilience, has been identified [10, 84]. Resilience is concerned with a city’s ability to absorb and recover from the impact of shocks and other stresses (f.e., construction in tight urban spaces, snow, and ice on a city’s streets, etc.) to ensure long term sustainability. Resilience is a fairly new desired outcome concept, that is often associated with certain city types (I.e. sustainable cities). Many documents on the SC concept link resilience with the three other desired outcomes (e.i. [10, 74, 12]). To avoid any confusion, the desired outcome of resilience will not be considered or discussed further.

2.3 The Smart City Concept Definition of this Report

For the purpose of the present research, this master thesis proposes to define the holistic SC concept similar to how Caragliu et al. did in [21]:

> *We believe a city to be smart when investments in human and social capital and general city- and ICT-infrastructure fuel sustainable competitiveness and a high quality of life, with a wise management of natural resources, through participatory governance.*

The definition was modified slightly to explicitly contain the three SC desired outcomes. The term ‘traditional transport’ from the definition of Caragliu et al. [21] was exchanged for ‘general city-infrastructure’ after the expert opinion interviews from the Theoretical Round (discussed further in Chapter 7).

In this definition, a reference is made to attaining the desired outcomes through ”participatory governance.” Participatory governance is thus an essential tool to be used by cities and not to be confused with the three goals themselves. It will be addressed later in this research.

As can be seen, this SC definition correlates to the three desired outcomes. It both directly mentions all three and the ”wise management of natural resources” part correlates closely with the definition of sustainability given in Table 2.2. This SC concept definition and the holistic perspective were used in the design of GUSM.

CHAPTER 3

How to Measure Urban Smartness

This chapter addresses RSQ 1.2 (introduced in Section 1.5) and contains the findings of a systematic literature review on research concerning assessing the US of cities. These findings cover three main topics: the shared constructs emphasized in US assessments, the issues that items conducting US assessments on a global scale face, and the two types of Quantitative US assessment processes found in SC research.

This research project is interested in the measurement of how smart a city is. In order to do that a number of US assessment measurement items can be used to support that measurement. US assessment measurement items are tools that identify areas of cities relevant to US and propose how the assessment can be made. These items can be used to provide information that can support decisions a city has to make to improve their US and monitor their progress. Thus, US assessment measurement items can be thought of as DSSs.

The assessment is conducted either through quantitative or qualitative means. If the measurement is done quantitatively, aspects of the city's US are measured in number and one or more specific values denoting the US of the city are determined. Examples of this include the US assessment measurement items identified in these research articles [36, 3, 96]. There are many studies where the US assessment includes an elaborate analysis of quantitative indicators and discusses the assessment of city smartness [31, 95].

This research is concerned with the development of an artifact that can conduct quantitative US assessments. When US assessments are discussed in this research report, quantitative US assessments are the type meant, unless qualitative US assessment is explicitly raised as a topic.

Note that this chapter is only discussing the US assessment types for brownfield cases as they concern measuring aspects of existing cities.

3.1 Shared Urban Smartness Assessment Constructs

In order to assess the US of a city, an US assessment measurement item must use a SC framework. This is a theoretical framework of aspects of a city relevant to the SC concept. It is helpful to understand the SC concept and keep an overview of the broad dimensions the urban area covers [96]. This section develops the theoretical SC framework that will form the basis of an urban smartness assessment measurement item that is developed in further chapters.

This section identifies the shared US constructs from research containing SC frameworks. To begin, however, the next subsection will detail how the studies with SC frameworks were selected. The following three subsections will detail the analysis and synthesis of those frameworks to identify constructs that they all share.

3.1.1 Identifying Smart City Frameworks

The results of the literature review were filtered to identify several research articles with SC frameworks. The chosen SC frameworks followed 4 explicit principles as modified from the study by Ahvenniemi et al. [3]: 1. The framework should clearly state that it is measuring smartness; 2. The SC framework in the article is unique; 3. The framework should cover three or more areas of city functions (as holistically as possible) and describe how to measure them; 4. The framework should apply to multiple cities, not one specifically. This subsection discusses the selected articles.

Eight research papers were chosen based on the 4 principles described above. They (shown in Table 3.1) explicitly propose SC frameworks, that are analyzed and synthesized to identify common constructs shared between them. To compare the frameworks, a method, similar to the one used by Venkatesh et al. [89], is used where the constructs of each framework are defined and constructs with similar definitions are clustered under a new construct.

No.	Reference	Constructs Identified
1	Carvalho et al. (2018) [23]	Political, Economic, Social, Natural, Artificial, Technological
2	Giffinger (2007) [36]	Smart Economy, Smart Living, Smart People, Smart Governance, Smart Mobility, Smart Environment
3	Li, Wang, Luo & Li (2018) [52]	Smart Infrastructure, Smart Economy, Smart Government, Smart Participation
4	Liu, Wang & Tzeng (2018) [53]	Smart Infrastructure, Smart Economy, Smart Environment, Smart Management, Smart Transportation, Smart Living
5	Neirotti et al. (2014) [67]	Government, Economy and People, Natural Resources and Energy, Transportation and Mobility, Buildings, Living
6	Shi, Tsai, Lin & Zhang (2017) [80]	Smart Individual, Smart Management, Smart Service, Smart Economy, Smart Guarantee, Smart Infrastructure
7	Yigitcanlar et al. (2018) [96]	Smart City Assets, Technology, Policy, Community, Society, Economy, Environment, Governance
8	Fernandez-Anez et al. (2018) [32]	Citizens, Technology Subsystem, Spatial Subsystem, Environmental Subsystem, 6 Global Trends$*$, and Living and Services, Environment, Mobility and Infrastructures, Economy and People SC Initiatives

Table 3.1: The Urban Smartness Measurement Item Research Articles Synthesized

The new constructs are identified and defined in the next subsection.

3.1.2 Introducing the Global Urban Smartness Framework

The constructs of the eight SC frameworks were synthesized into seven new constructs. Many of the constructs are shared between the frameworks. For example, they all identify a governance construct, although some use different terms to identify it like ”Political” [23], ”Service” or ”Management” [53, 80].

The new constructs are defined in Table 3.2 below. The table defines the name, definition, and category (Asset or Driver or Desired Outcome) of each construct. It also identifies aspect(s) related to the new constructs that can be measured and what frameworks from Table 3.1 above they were synthesized from.

Construct	Definition	Aspect(s)	References
Assets			
People	The stakeholders that are the core of smart cities	-	2, 3, 5, 6, 7, 8
City Resources	The resources that cities can use to attain the desired outcomes	-	1, 2, 3, 4, 6, 7
Drivers			
Community	Aspects concerning the capabilities of people who live in the city and their organizations	Education/Health of people in the city	1, 2, 3, 4, 5, 6, 7, 8
Technology	Characteristics of the use of technology in the city	Adoption and Diffusion of Technology	1, 2, 3, 4, 6, 7, 8
Infrastructure	Characteristics of the human-made elements in the urban environment	Public Transport Use, Population Density	1, 2, 3, 4, 5, 6, 7, 8
Governance	Elements concerned with performing appropriate planning, development, and management practices by the city	Public Services, Municipality Spending	1, 2, 3, 4, 5, 6, 7, 8
Desired Outcomes			
Quality of Life	Aspects concerning how well people in the city live	Satisfaction with Housing in the City	1, 2, 3, 4, 5, 6, 7, 8
Competitiveness	Aspects concerning the economic growth and attractiveness of a city and its competitive position to other cities	Productivity, Touristic Attractiveness, Entrepreneurship	1, 2, 3, 4, 5, 6, 7, 8
Sustainability	Aspects concerning the efficiency of a city's management of resources and impacts on its environment	Pollution, Waste Service Characteristics	1, 2, 3, 4, 5, 6, 7, 8

Table 3.2: Descriptions of the Shared Urban Smartness Assessment Constructs

Similar to the multidimensional framework proposed by Yigitcanlar et al. [96], Table 3.2 Table 3.2 separates the constructs into three categories: (1) Assets, (2) Drivers (instead of Driving Forces) and (3) Desired Outcomes. These categories follow the structure of a ”Input-Process-Output” model, where the city resources and its people (which form the city's ”Assets”) are the ”Input”, the identified Drivers form the ”Process”, and the Desired Outcomes are the ”Output”.

The Assets constructs in Table 3.2 are outside the scope of this research and thus are only vaguely defined. This report is not looking to identify assets that people provide a city or that a city has or which city resources can be considered as assets. The impact of the city assets on the relationship between the drivers and the desired outcomes is also not known. It can be argued that people are relevant for all constructs, (i.e. the driver construct Community concerns people's capabilities in the city). However, they are not discussed further.

The three category distinction has been made to emphasize the importance of these aspects to the SC concept, but also stress that the Drivers identified (Communities, Technology, Infrastructure, and Governance) form the process. They are essential tools used to achieve the desired outcomes [3, 59]; they are the ” means,” not ”ends” [65, 96]. Thus, a city government implementing a new policy or new technology system is not the goal itself, but rather a means to achieve the desired outcomes of the city.

The constructs were then combined into a SC framework called the Global Urban Smartness Framework (GUSF) with the seven constructs. This is the first version of GUSF (or GUSF V1) that will be updated later in this research project. This framework is shown in the figure below and it is discussed in Section 3.1.3.

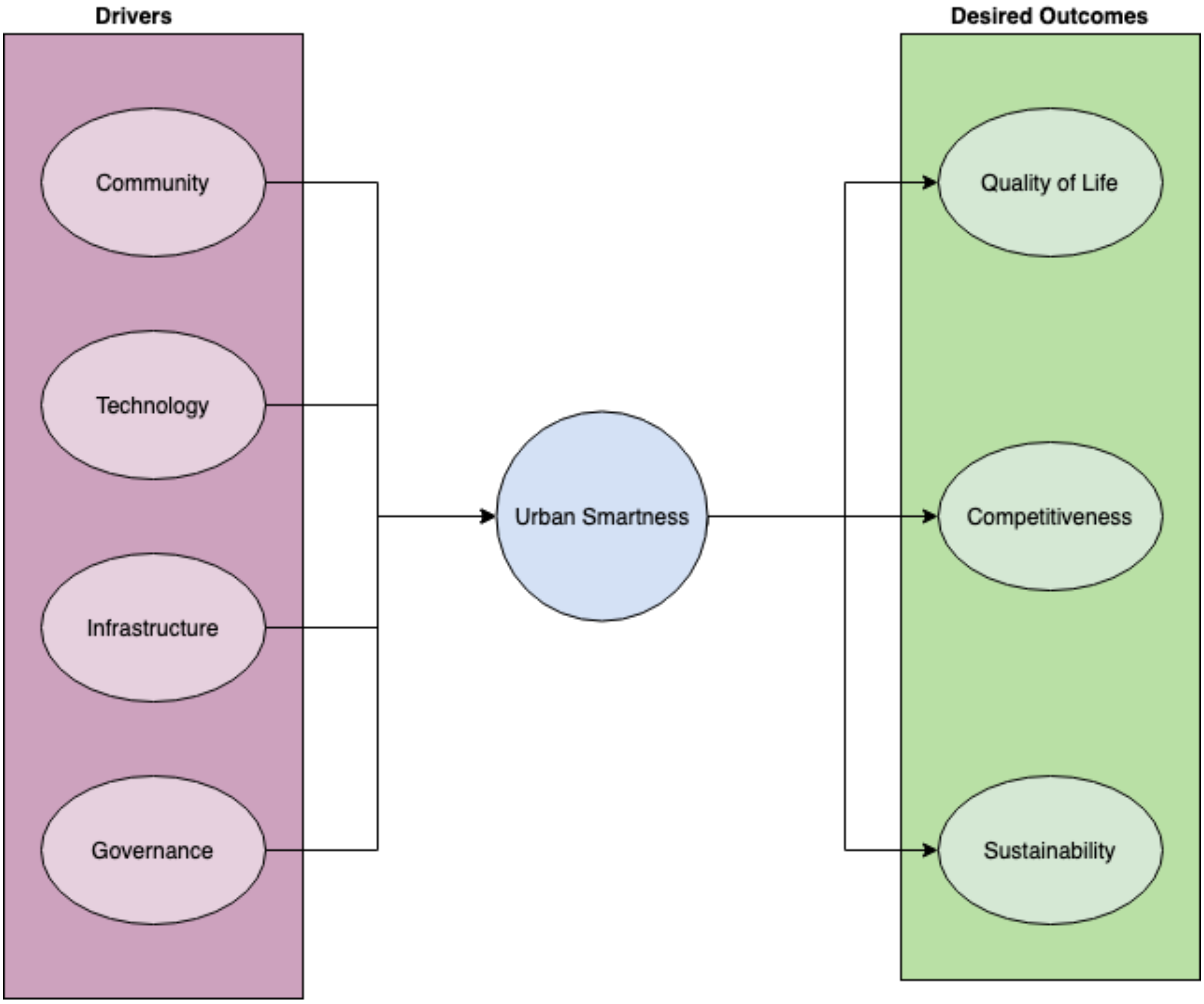


Figure 3.1: The Global Urban Smartness Framework V1

3.1.3 The Constructs of the Global Urban Smartness Framework

SC research in general discusses and focuses on at least one of these shared constructs. The desired outcomes (see Section 2.2) are the most agreed upon as being central to the SC concept. There is more debate around the four drivers. The following four paragraphs look at each of these driver constructs in further detail.

The Community construct is seen slightly differently as it represents the organization and capability of people in a city (their human and social capital). They are the stakeholders who determine which SC initiatives should be done and ultimately whether it was successful [96, 32]. This construct emphasizes the importance of human factors in the SC concept and that investing in improving such things as education and creativity, a city's US will also increase [65, 36]. By investing and implementing SC initiatives concerned with improving the Community construct, the desired outcomes are positively impacted as was argued by these researchers [67, 20, 21, 65, 51, 15].

SC researchers frequently debate the SC concept's relationship with technology. They often argue whether ICT systems are central to the SC concept or rather people are at the core of SCs and ICT systems are tangential to the concept. This argument mirrors the differences between hard and soft perspectives (detailed in Section 2.3). As previously stated, this research uses the holistic perspective where technology is seen as a supporting tool to enhance the quality of life, sustainability, and competitiveness of a city and the people in its urban area

[3, 67, 24, 63, 96, 53, 32]. Thus, the Technology construct is used to represent characteristics all cities share. For example, in [66] Al-Nasrawi et al. note a crucial general characteristic, technology adoption as a city can implement a large number of technology systems, but the city will only become smarter if the people adopt those systems. In this way, technology characteristics indicate the technological development (or technological advancement in [22]) of a city.

The Infrastructure construct seeks to measure the man-made environment of a city, which is one part of the local context. The natural environment is the other and is also relevant to the Sustainability construct. The local context of each city is different [67] and this fact influences both how smart they are and how they develop their US further. This local context is referred to as the spatial component of the city [32, 12]. The Infrastructure construct is concerned with elements of the man-made urban environment that must be considered or are utilized when implementing SC initiatives to achieve the desired outcomes of SCs. The exact local context is unique to every city, but some infrastructure characteristics apply to all of them. An example of a general infrastructure characteristic that has been found to correlate to city smartness both positively and negatively is the population density of a city (the number of people living in a km^2 [59, 67, 15]. One must be cautious when using such a characteristic to determine the US of a city as it must be determined if the specific characteristic correlates with smart aspects of the SC concept. City size, a characteristic that applies to every city around the world, was found to not correlate to US in several studies [67, 15, 26]. As stated by Balducci and Ferrara [12], ”the spatial dimension impacts significantly on smart city policies” . Since the Infrastructure construct emphasizes this dimension, it must be considered when assessing the US of a city.

The Governance construct is included in all the considered SC frameworks. It concerns the administration and management of people in the city, the provision of services to those people, and decision making on these aspects. It is defined here as a driver and not a desired outcome as SC governance tends ”to lead the development of other SC dimensions” [32]. It can positively impact the process of SC development. As Chourabi et al. [24] explain, SC initiatives or projects are done to make cities better serve their people and improve their quality of life. These projects involve multiple stakeholders. Cities are looking to improve governance to manage these initiatives or projects better. For example, a governance initiative promoting ”digitized public administration” That allows people to request services online at any time of day [67]. The output of governance activity, policy, also influences the whole city. For a city to transform into a SC, technological components must interact with political, human and social ones [24, 96]. Policy and governance determine how those interactions occur.

Current research and the identified shared constructs lead to the conclusion that by measuring the drivers and how well the desired outcomes are being achieved, the US of the city can be determined. Certain issues limit the assessment of US and the application of a SC framework and the US assessment measurement item that uses it, which are detailed in the following section.

3.2 Issues with Global Urban Smartness Assessment

This section addresses the potential differences of the quantitative assessment of US around the world. The measurement of the shared constructs, as identified in the previous section, can differ significantly.

The overall measurement approach applied in SC research is generally consistent. A city's US is assessed by measuring indicators that capture important aspects of a SC concept construct [5, 3]. These indicators are either objective or subjective (as detailed by Carli et al. [22]. Objective indicators are defined as indicators that capture data of a city's physical infrastructure, its urban assets, and the conditions of its general context. Subjective indicators measure people's satisfaction and well-being with diverse aspects of the city [22]. National and municipal authorities collect a vast amount of data that are available at national and international levels.

US assessment measurement items can use the data for indicators that capture and measure the concepts they are investigating. What set of indicators an US assessment measurement item uses varies greatly between measurement items. For example, Ahvenniemi et al. [3] investigate what indicators are used for eight European US assessment measurement items and found that they used a total of 510 indicators.

Two major variations of indicators used in an assessment differ significantly between researchers and countries [67], and are respectively addressed in the following two subsections.

3.2.1 Different Interpretations of the Smart City Concept

First, the indicators used to measure the US of a city or cities in an area (continent, countries, region) differ depending on how the SC researcher or city interprets the SC concept. According to Al-Nasawri, El-Zaart, and Adams, "smartness, in this case, is relative to the context of the city under question and its priorities and targets" [66]. As discussed in Section 3.1.2, most cities have a unique local context that must be considered when developing SCs. As the researchers for [67, 23, 4] found, when choosing appropriate indicators, the local context must be taken into account.

SC researchers may choose different indicators depending on the environments of their studies. For example, if they are analyzing the US of a city in Europe, indicators will be chosen that line up with the EU's Europe 2020 Strategy [59]. In China, where there is a notable focus on finding smart solutions to reduce the environmental impact of dense urban areas [67], SC researchers choose indicators that measure the city's transportation system [52, 53] or measure the quality appraisal methods of the city's development [80].

Every city having its unique local context implies that an US measurement framework (on which an US assessment measurement item is based) that applies to cities across the globe must either be modifiable or standardized. Modifiable in the sense that the framework is adaptable for each city and indicators appropriate for the city and its environment are identified and used. Dallo" O et al. [28] define a method to modify a SC framework for small and medium-sized cities in Italy was presented. Thus, the indicators will change depending on the city in question.

On the other hand, a SC framework supporting standardized US assessment means the framework uses a very similar or equivalent set of indicators when it is applied to different cities, regardless of the cities' local environments. It is limited in its specificity. Such a framework cannot account for the unique aspects of cities (it can only have a general "high-level" view of the US of cities) that are in different environments, countries, and continents [67]. For example, The SC frameworks measuring and comparing the US of cities in Europe in [36, 20, 21] are standardized. Based on the literature, this research concludes that global SC frameworks must either be modifiable (be adaptable to account for every city's local context) or standardized (and maintain a high-level view of the SC concept).

To be explicit, in this research a city's local context includes four elements: the local SC definition, the challenges/problems a city faces, its environment, and the goals the city government wants to achieve.

3.2.2 Availability of Indicators and Data

The other major reason for the difference between quantitative urban smartness measurements concerns what indicators can be feasibly used in the US assessment. This availability issue depends on the technical development of a particular city and which indicators are publicly available. The level of technological development of cities often varies greatly nationally and even more so internationally. Meaning, a technologically advanced city collects many indicators that other, less technology developed cities cannot [22]. This is mainly an issue for subjective indicators, which according to Al-nasrawi et al. are essential for measuring US [66]. People are the core of the SC concept and subjective indicators capture their perceptions about the city. People's opinions must be considered when measuring constructs like the Quality of Life of a city. In developing countries like China, Li et al. [52] found that there was a significant difference in the technological development between Chinese cities and thus some cities did not collect the indicators used in their SC framework [52].

A potential solution to address this data availability issue is the identification of and general agreement on a standardized set of SC indicators. Such a standardized set can provide many benefits, including "establishing measurements over time" or "aligning with city strategies and operational levels of city development" [19]. Unfortunately, such a standardized set has not been developed yet.

Ultimately, the US of the city can only be measured transparently and readily if the indicator data a city collects are publicly available. In Europe this data is made available in online accessible data sets like the Eurostat and Urban Audit, frequently used as a source for US indicators in prominent SC studies like in [36, 21].

The applicability of US assessment methods is limited by the indicators that are collected and available in the respective cities, countries, or areas. If an US assessment measurement item was designed to apply to European cities (it takes account of the European context, and its indicators are appropriate and available for European cities), then that US assessment measurement item would potentially not be applicable (or would be difficult to apply) to cities in Asia. Even though an US assessment measurement item is not applicable to a city today, that city may choose to collect specific indicators so that they can be part of US assessments in the future.

The application limitation must be explicit when designing a global US assessment measurement item, concerning what cities in the world can feasibly use the US assessment measurement item's indicators. To ensure that the indicators can be used, the global US assessment measurement item has the most potential to apply to cities in developed countries or cities that have a high level of technological development (like recognized SCs). They can provide some accessible, online databases that collect a large number of indicators (for example in Europe many databases collect indicators for cities in many countries [36, 20, 21]).

However, it is important to note that even if an US assessment measurement item is designed to apply to a specific region in the world, it can be used in other places in the world, but its applicability is limited. For example, the studies [31, 4] use the framework described in [36] as the theoretical basis for research on how certain Saudi Arabian cities are smart. They were not able to use all the indicators used in the model from [36] and thus they could not fully assess the US of these cities according to [36].

3.3 Urban Smartness Assessment Process Types

Assessments based on an US assessment measurement item use two types of processes. The first type is the relative assessment process and the second is the absolute assessment process. This section details these two types.

In the relative assessment process, the constructs are measured within a group of cities by collecting indicator data. The indicator data is then compared between the cities and relative values are assigned for each indicator (for example Lee et al. in [51] compare Seoul and San Francisco). The process can potentially include ranking like in [80] where a large number of cities in China are ranked relatively against each other.

In the absolute assessment process, the constructs are measured and analyzed for an individual city and an absolute measurement of the US of that city is given. Some of the articles from Table 3.1, covered by this research, use this process in combination with ranking cities in an area. Notably, Giffinger [36] proposed a model that assesses the US of individual European mid-size cities and ranks them against each other according to the absolute assessment values of each city.

Recently, a small number of researchers have started creating SC Maturity Models to assess the US of individual cities and can use both US assessment process types. This flexibility is interesting given the importance of local context as discussed in Section 3.2.1. For example, in [2], Afonso et al. analyzed Brazilian cities and compared them against each other using a maturity model.

3.4 Summary

In this chapter, SC research was analyzed, resulting in: (1) Seven shared constructs of US assessment were identified and the theoretical Global Urban Smartness Framework V1 was introduced; (2) two major issues in US assessments were discussed from a global perspective, and (3) the two types of US assessment processes were detailed. The main challenge facing a literature review into SC research is that it is mainly produced in certain parts of the world, namely Europe, the USA, Canada, and South-East Asia. However, this study identified relevant research that contains pertinent knowledge on US assessment across the globe. This is to say, the presence of commonalities across areas gives us the ground to think that knowledge on US assessment accumulated in these areas could be a good candidate for being reused in other areas (countries). The next chapter elaborates on the use of maturity models for the assessment of US.

CHAPTER 4

Smart Cities and Maturity Models

This chapter investigates MMs and their use and compares existing smart city maturity models (SCMMs) against each other. A brief literature review on SC research related to MMs was done to collect and analyze knowledge. This investigation and comparison provides the knowledge essential to the development of aspects of MMs in the artifact and addresses RSQ 1.3.

4.1 Maturity Models

This section serves as an introduction to maturity models. MMs that are designed to apply to the SC concept are discussed in the rest of this chapter, as SCMMs can be a kind of US assessment measurement items.

Maturity Models are useful tools with a wide range of applications. They, ”describe the development of an entity over time” [91]. This entity is the topic of the maturity assessment, it can be a person, organization, item, etc. They determine the ”maturity” of that entity's development in other words. Maturity in this case means that the entity is fully developed or its development is complete.

MMs define discrete levels of maturity so that when the entity is assessed, the entity's development can be placed in a particular level. The maturity level provides a description (relevant to the concept being assessed) of the ”state, importance, potentials, requirements, complexity, and so on” [91] of the entity. Each MM has a range of maturity levels. These levels are placed in a sequential order where the next level is seen as a significant improvement or change from the last. It can be said that the entity has reached the maturity stage or phase corresponding to the assessment results. This implies that MMs also support decision making as they explicitly detail the steps to take to move the city to the next maturity level. Thus, MMs can be considered to be DSSs.

Having reached a maturity stage, MMs can be used for three purposes [73]:

1) Descriptive: A MM is used to conduct ”as-is assessments where the current capabilities of the entity under investigation are assessed with respect to given criteria”;

2) Prescriptive: A MM is used to indicate ”how to identify desirable maturity levels and provides guidelines on improvement measures”;

3) Comparative: A MM ”serves a comparative purpose of use if it allows for internal or external benchmarking” where assessments performed on multiple entities are compared against each other.

MMs can be used for at least one of these purposes and in some cases for all three purposes.

The purposes of use are connected to MM design principles (DPs) [73] which are separated into three categories (displayed in Fig. 4.1):

1) Basic DPs are the principles that apply to all MMs regardless of their purposes of use;

2) Descriptive DPs apply to MMs that have a descriptive purpose of use and can also apply to MMs with a prescriptive purpose of use;

3) Prescriptive DPs apply to MMs with a prescriptive purpose of use.

Comparative DPs are not defined by Poppelbuß and Röglinger [73] who note, ”the fact of whether corresponding DPs can be met largely depends on external factors (e.g., standardized and publicly available specifications ...)”. These DPs serve as a ”checklist” to be used when comparing existing MMs or designing and developing new MMs [73].

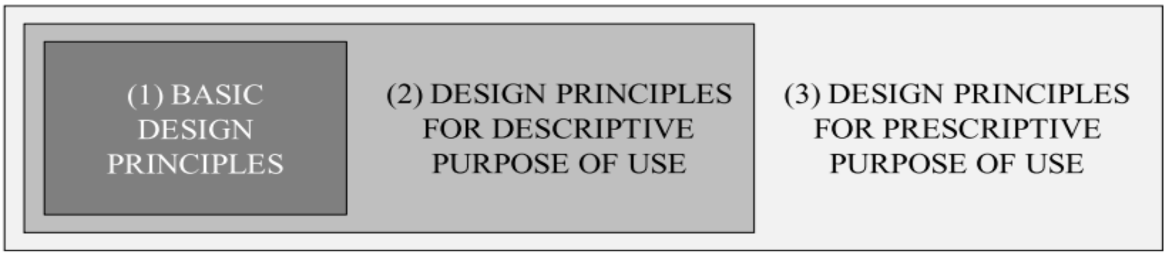


Figure 4.1: Design Principle Categories

Other research defines similar MM DPs (for example [17, 13]). As noted by the researchers of several studies [17, 13, 73], MMs can be seen as design products which are the outputs of design science (which this research also is). Meaning that a MM, which is designed and developed appropriately, should meet appropriate requirements (or DPs),

Besides the three purposes of use, MMs can be divided into three types (note that ”focus areas” are the relevant aspects of the entity the MM is assessing) [82, 88]:

1) Staged fixed-level models: MMs of this type ”distinguish a fixed number of generic levels of maturity, usually around five”;

2) Continuous fixed-level models: This MM type differs ”from the staged fixed-level models in that in the continuous models, focus areas are not attributed to a level, but rather the generic maturity levels are distinguished within each focus area”;

3) Focus area models: The type of MM ”based on the incremental improvement of a collection of focus areas to improve a domain.”

As discussed in [91], Wendler stated that the publication of maturity related research is growing in scale and the diversity of topics covered. Wendler found that MMs predominantly covers fields from software engineering and software development, but it extends to over 20 domains. For example, the Cloud Maturity Model Integration, a prominent MM, ”was published in 2010 and combined concepts from software development, systems engineering, and product development.” [91]. The applicability of MMs to the SC concept is investigated to determine the potential for using MMs for US assessments in the next sections.

4.2 Smart City Maturity Models

A brief second systematic literature review was conducted to identify and compare existing holistic SCMMs. It is brief as not much research has been done on using MMs to assess SCs as is evident from the research found by this review. Relevant research of SCMMs found two reviews [85, 35] and four ”holistic” SCMMs (or determined to be holistic by the reviews) shown in Table 4.1. Therefore, SCMMs that were deemed non-holistic (i.e. the ICT and Blockchain focussed SCMM discussed in [16] or the transportation emphasizing SCMM from [27]) were not included.

Source	Maturity Model
[2]	Brazilian Smart City Maturity Model (Br-SCMM) ∗
[84]	Sustainability Outlook Smart City Maturity Model (SO-SCMM) ∗
[34]	Guarda Smart City Model (GSCM)
[25]	IDC Government Insights Smart City Maturity Model (IDC-SCMM) ∗

Table 4.1: Holistic Smart City Maturity Models

∗ : indicates that Torrinah review determined the MM was holistic.

The identified SCMMs are each described and analyzed in their own subsections.

4.2.1 Br-SCMM

In [2], Afonso et. al. developed the Br-SCMM to ”measure how smart a city can be, and propose mechanisms to assist in improving social and economic policies” [85]. This measures ten components of cities regarding their social conditions and infrastructure. These components are meant to cover the areas of cities that are relevant to the SC concept. The components are each measured using indicators. Table 4.2 shows the city component with its ”Basic” indicator. Afonso et al. [2] describe these basic indicators and note that each basic indicator is associated with two secondary indicators, but do not detail those secondary indicators further.

City Component	Basic Indicator
Water	Piped water
Education	HDI–Education∗
Energy	Access to energy
Governance	HDI/Employment∗
Housing	Private residence
Environment	Garbage collected
Health	HDI – Health∗
Security	Homicides/1000
Technology	Computers/home
Transport	Mass transport

Table 4.2: Aspects and Indicators Measured by the Br-SCMM

∗ HDI = Human Development Index

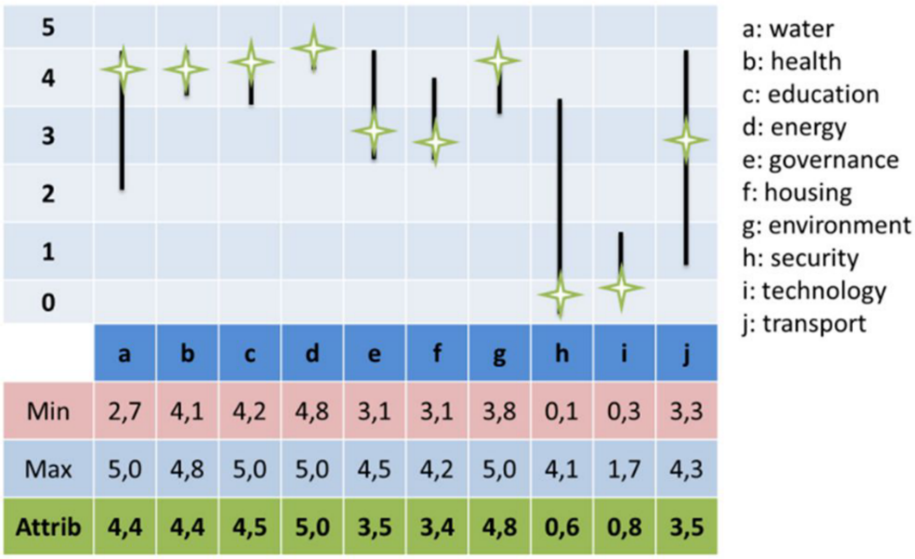
The maturity levels of the Br-SCMM are separated into five categories (or SMART Levels), which each address a question for each city component [2]:

- Level S (Simplified): ”Does the city reach threshold scores for so-called basic indicators?”
- Level M (Managed): ”Does the city have goals and practices that point to an optimized management of resources?”
- Level A (Applied): ”Does the city use a maturity model to establish public policies?”
- Level R (Measured): ”Does the city establish strategic indicators and has measurement practices and performance improvement?”

- Level T (Turned): ”Does the city reach desired notes in the areas planned in the previous level?

Levels A, R, and T are not described further. So what these questions imply, is not clear.

The US maturity of a city is evaluated based on the ”Smart Level” being analyzed. For Level S, the basic and secondary indicators for each city component are measured. Based on the values from those indicators (and whether they reach certain desired thresholds) the city is placed within a maturity level from 0 to 5. For Level M, the SCMM observes local laws and the style of governing to verify good management practices for each city. In addition to Level S and M, the Levels A, R, and T can be assessed independently [2]. The SMART Levels are not incremental as stated in [2], ”the municipality can choose to evolve in domains which have greater capacity, resources and strategic interests.” An example of this is shown in Fig. 4.2 (shown figure 5) where the US of a city is being assessed on Level S [2]. As each city component’s (or focus area) maturity is assessed, this model falls in the category of a Continuous fixed-level MM.



	a	b	c	d	e	f	g	h	i	j
Min	2,7	4,1	4,2	4,8	3,1	3,1	3,8	0,1	0,3	3,3
Max	5,0	4,8	5,0	5,0	4,5	4,2	5,0	4,1	1,7	4,3
Attrib	4,4	4,4	4,5	5,0	3,5	3,4	4,8	0,6	0,8	3,5

Figure 5. Recife, located in northeastern Brazil, mapped by the level of the S-Br SCMM..

Figure 4.2: Br-SCMM Assessment Example

The Br-SCMM was developed and operationalized for Brazil explicitly. Torrina and Machado [85] give two implicit reasons why. The first reason is that its basic indicators denote generic indicator topics, but they specify indicators that are publicly available in Brazil and that are collected by Brazilian cities only. For example, in [2] for the basic indicators associated with the Education city component (from Table 4.2), the Br-SCMM uses the HDI-Education. This indicator is based on measures designed and published by the Ministry of Education of Brazil [2]. The second is that Afonso et. al. explicitly identify relevant topics and issues facing Brazilian cities when discussing each city component.

This model would not apply to other areas of the world as it was specifically designed to apply to the reality of Brazilian cities. Allowing them to measure how smart they are, compare themselves against each other, and provide ”mechanisms that assist managers to improve social and economic policies” of their city [2]. This MM is very relevant as researchers on the inequality between cities in Brazil, study the SC concept as a potential solution to address these differences [2, 57, 56].

4.2.2 SO-SCMM

In order to address the issues the accelerated pace of urbanization has created in cities, the Indian Government has decided to transition its cities to smart cities. As part of that effort, in [84], the organization Sustainability Outlook details a SCMM designed for cities in India, the SO-SCMM. The SO-SCMM emphasizes that it is based on the SC concept and looks to address many domains of the city it is used for. It gauges the preparedness of cities against a set of measures relevant to how smart they are [85]. It is concerned with the basic infrastructure and urban resilience of those cities. This SCMM also uses indicators (they use the abbreviation KPI for key performance indicators) to assess the city. The model has four maturity levels (as shown in Fig. 4.3). These four maturity levels capture the phases that a city goes through until it has reached a high level of urban resilience.

Maturity Model	1	2	3	4
	BASIC URBAN SERVICES	→	→	HIGH URBAN RESILIENCE
KPIs relate to....	Access	Efficiency	Behaviour	Systems Focus
What success looks like...	*Urban infrastructure and technologies are available and urban services are being delivered*	*Efficient resource & energy use is actively measured and embedded in a future city*	*People interact with physical assets in ways which unlocks new pathways for sustainability*	*Closed-loop & sustainable resource & energy exchanges are being strengthened within a city*

Figure 4.3: Maturity Levels of the SO-SCMM

The SO-SCMM is summarized in Fig. 4.4, It covers ten domains of the cities. As can be seen in Fig. 4.4 for each maturity level, ”Key Resources” have been identified for each domain [84].

SCMM	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
	BASIC URBAN SERVICES			**HIGH URBAN RESILIENCE**
	Access	**Efficiency**	**Behaviour**	**Systems Focus**
Transport	Convenient and affordable access to light rail, high capacity transport & non- motorized pathways	Infrastructure metrics, load factors & route optimisation Efficient last mile transport options	Online, seamless, real time mobility services which enable mode-switching based on criteria (cost, time, footprint)	Shifting mobility from asset ownership to public transport or shared services models, as per type of trip
Spatial Planning	Availability of green space, Socially cohesive communities; Green building & sustainable physical infrastructure creation	Reduced mobility & congestion; Climate-resilient urban planning	Toolkits and behavioural practices to empower communities to become resource secure & efficient; Maintenance & upgrades of existing infrastructure	Opportunities for collaborative industrial & residential ecologies (e.g. common ETP, decentralized energy)
Water Supply	Sustained access to potable supplies of water; Visibility of domestic & other water consumption	Water consumption, metering and collections; Smart grids for water; Standards for water efficient devices, storage & transport; Lost / unaccounted water; Water markets	Water re-charge metrics for groundwater; Preventative action on unintended pollution sources from goods consumed or practices	Location specific risk metrics & tracking, dependent on water sources; Real-time disaster response & monitoring for water security; Embodied value of water to GDP
Sewerage & Sanitation	Access to toilets; waste water collection and treatment services	Process efficiency KPIs on collections, treatment & recovery infrastructure	N/A	Closed loops for organic matter recovery and biogas
Solid Waste	Solid waste collection; treatment & disposal services (incl basic recycling)	Efficient, aggregated and sustainable solid waste streams for processing	Reduction in waste through regulatory measures & behavioural support tools	Solid waste tracking, auditing, and recovery channels
Storm Water Drainage	N/A	Absence of water clogging	N/A	N/A
Energy & Electricity	Reliable, sustained access to electricity; Access and share of non-electrical forms of energy	Energy efficient infrastructure, devices & standards; Grid control and grid infrastructure performance	Demand side management; Reduction of peak load, power consumption; Incentives for fuel switching; Infrastructure to enable uptake of RE energy	Electrification of all energy needs; Share of renewable energy for electricity; Share of renewable energy for non-electrified energy needs
ICT & Systems Intelligence	Access to Telecom and WiFi / digital services which is convenient, affordable and non-exclusionary; Geospatially, real time access to services	Resource efficiency analysis; resource monitoring; scenario testing through reliable & secure data streams and integrated data platforms	Predictive resource load management; predictive risk management; enable negligible response time to failure-events. Open data to enable service innovation	Technology-enabled optimization of urban service delivery, resource efficiency; immediate response; urban governance; & city performance management
Economy & Finance	Access to opportunities for affordable healthcare, education and financial services (e.g. insurance)	Labour force productivity, skills & talent distribution and growth; human health & savings growth	Performance metrics on the provision of services delivered	NA
Environment	Institutional, technical, financial and R&D facilities to grow natural capital; track & manage pollution	Pricing of eco-system services and investment in natural capital; Efficient linkages & connectivity with other cities, rural & peri-urban areas	Regulation and legal enforcement to protect common environmental goods	System-based view of material, climate and energy flows between urban areas and peri-urban and rural linkages

Figure 4.4: SO-SCMM Summary

The indicators for SO-SCMM come from either of two sources: an International Standard Organisation (ISO) standard 37120 for Sustainable Development for Communities: Indicators for City Services & Quality of Life from 2014 [44] and Government of India's Smart Cities Concept Note [84]. This SC concept note provides Indian cities with a list of benchmark indicators that have been defined by their national government.

The SO-SCMM is holistic as it is designed to cover the relevant domains of the SC framework of India [84]. Although, the SO-SCMM defines four maturity levels as shown in Fig. 4.3 and Fig. 4.4, [84] notes that indicators from the two sources do not allow for cities' US to be measured in full the higher the maturity level gets. However, the four levels are all defined and detailed (see Fig. 4.4) and thus, the SO-SCMM is a Staged fixed-level MM.

As stated explicitly in [84], the SO-SCMM was not designed to apply to other cities outside India. The organisation Sustainability Outlook [84] details the issues facing Indian cities and discusses the funding of SC initiatives in India. Also, SO-SCMM analyzes the indicators in the Smart City Concept Note from the government of India and compares them with the indicators found in ISO standard 37120 [84, 44]. The purpose of the SO-SCMM is to support the decision making of Indian cities' development to smarter cities in particular by enhancing infrastructure and using ICT to solve urban problems. Thus, the SO-SCMM is mainly descriptive in use, although it offers some prescriptive use. Indian cities can make decisions on their development towards improving their infrastructure and urban resilience, using the results from the SO-SCMM [84].

4.2.3 GSCM

The GSCM (whose framework is displayed in Fig. 4.5) is the most recently produced SCMM identified in this search. It is a maturity model that serves as a guide to developing smart cities in Indonesia [34]. Its objectives can be summarized as defining and assessing the existing condition of the implementation of the SC concept in a city. The GSCM can be used as a roadmap and provide recommendations for SC development in the future [34].

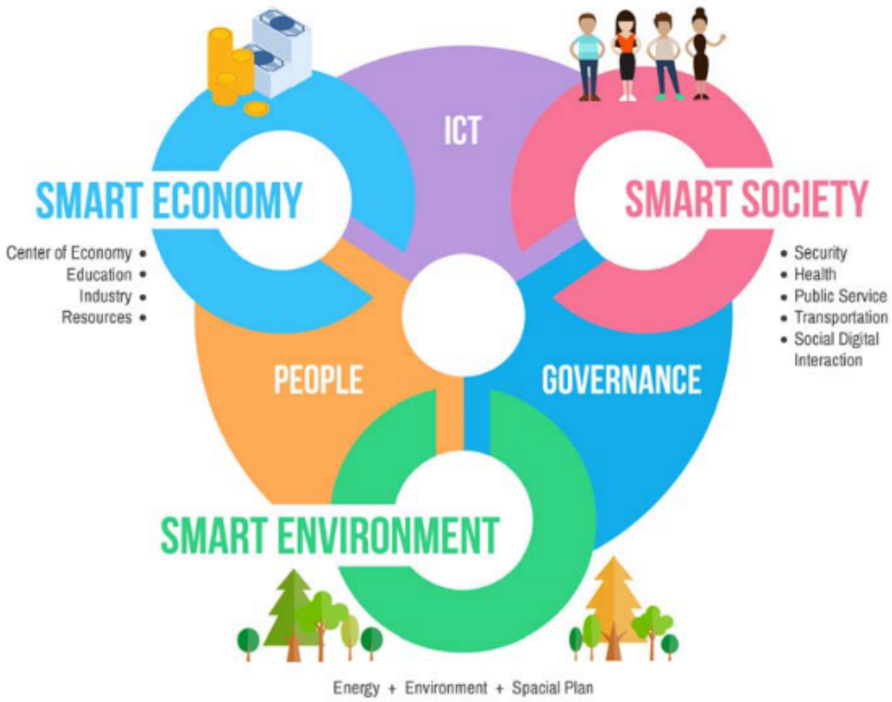


Figure 4.5: The GSCM Framework

It focuses on six areas (as shown in Fig. 4.5), but specifically assesses the city's smart environment, economy, and society by measuring 111 indicators. The indicator results of a city are then aggregated into a SC maturity score, which is linked to the five maturity levels (shown in Fig. 4.6).

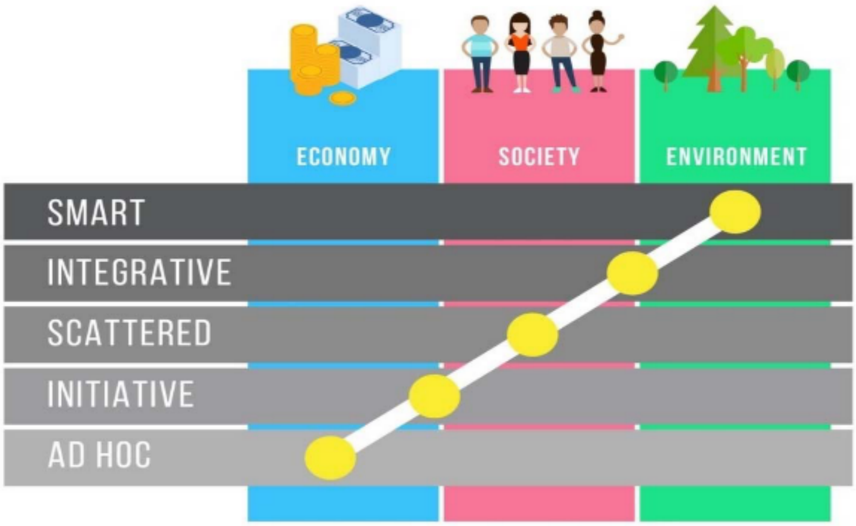


Figure 4.6: The GSCM Maturity Levels

The measurements of the indicators indicate whether the city is mature in terms of its economic growth, social development, and environment. The maturity levels relate with the increases in these dimensions [34]. A city in the lowest level ”Ad Hoc” indicates the city has a ”low economic level, uncomfortable environment, minimum ICT, governance, and human resource support.” While being in the ”Smart” maturity level means the city has a ”Very comfortable environment and ICT-based services are ubiquitous”. The three levels in between feature the sequential improvements of the city concerning these dimensions. As there are five general maturity levels, the GSMM is a Staged fixed-level MM.

Firmansyah et al. [34] defined the six constructs of the GSCM (see Fig. 4.5) To assess the US of Indonesian cities holistically. The GSCM is mainly meant to be used for descriptive purposes as Indonesian cities' US can be assessed. It can also be used for prescriptive purposes as it provides more information on SC development to improve decision-making [34].

Unfortunately, a complete version of the GSCM itself is not available online at the time of writing. Firmansyah et al. [34] provide limited details of the GSCM, without detailing the indicators used, and applies the model to ten Indonesian cities. What is clear is that while the GSCM is holistic and operationalized, it was developed to apply to Indonesian cities. It will probably require intense modifications if it is to be applied elsewhere in the world.

4.2.4 IDC-SCMM

The IDC-SCMM [25] is different from the other SCMMs described in this report. It is a SCMM created for a city's government by a researcher, Clarke, from the organization IDC Government Insights, which is concerned with the city's governance processes and their improvement. The model provides a planning tool for both assessing the city's current situation and determining how it can and should adopt SC development practices in the future [85]. It is a staged fixed-level MM which places cities in five maturity levels (shown in Table 4.3), which are named with standard maturity level titles. The IDC-SCMM proposes what domains should be measured to determine what maturity stage the city has reached [25].

Maturity Level	Description
Ad Hoc	”This stage is the traditional government modus operandi with ad hoc projects, department-based planning, and discrete smart projects.”
Opportunistic	”Opportunistic project deployments result in proactive collaboration within and between departments. Key stakeholders start to align around developing strategy, common language is developed, and barriers to adoption are identified.”
Repeatable	”In this stage, recurring projects, events, and processes are identified for integration. Formal committees document defined strategies, processes, and technology investment needs with stakeholder buy-in. Sustainable funding models and governance issues become a focus.”
Managed	”Formal systems for work/data flows and leveraging technology assets are in place and standards emerge. Performance management based on outcomes shift culture, budgets, IT investment, and governance structure to a broader city context.”
Optimized	”A sustainable city wide platform is in place. Agile strategy, IT, and governance allow for autonomy within an integrated system of systems and continuous improvements. Superior outcomes deliver differentiation.”

Table 4.3: Maturity Levels Description from the IDC-SCMM

As the maturity levels in Table 4.3 show, the IDC-SCMM is principally concerned with development processes and the management of cities (especially in terms of technology). It identifies five domains namely: Strategy, Culture, Process, Technology, and Data, which evaluate the SC development processes of a city and can be used to plan how to improve those processes in the future. For each of the five domains, they describe the status at each maturity level and potential approaches to developing that domain according to the level descriptions [25]. Thus, the IDC-SCMM offers both the descriptive and some prescriptive purposes of use.

Clarke [25] proposes using KPIs to assess the success of each stage. However, it is important to note that the IDC-SCMM is not operationalized and does not define what areas of the world it applies to. Rather it has been operationalized by other parties, like the organization Urban Tide, in [87], who adapted and operationalized the model for Scottish cities. It was operationalized by combining the IDC-SCMM with the indicators from British Standards Institution PAS181 published in 2014 [87]. It enables Scottish cities to evaluate their SC development process by using a Self-Assessment Tool to determine their ”Smart City Readiness” (the quality of their SC development processes). This shows that although the IDC-SCMM is more globally applicable than other models it must be adapted to a country and operationalized before it can be used.

The IDC-SCMM is only indirectly holistic. It is concerned with the governance of the city and its SC development processes and not the city’s US itself [85, 35]. However, this SCMM explicitly discusses how the maturity assessments impact the five domains identified and the city’s overall US [25]. It represents another type of holistic SCMM, where the model assesses the maturity of the processes that develop SC, not the US of the city itself. This research refers to such holistic SCMMs as Urban Smartness Development Process type models.

The next section will compare these four SCMMs to explore the potential of using MMs for US assessments.

4.3 Comparison of Smart City Maturity Models

This section compares the four identified SCMMs from Table 4.1. In the first subsection, the comparison is presented and in the final subsection, the findings of that comparison are discussed. Before the comparison is discussed any further though, the method of that comparison will be detailed in the next paragraphs.

The comparison uses the method described by the researchers from the articles [85, 73] which checks whether the SCMMs fulfill the DPs used in this comparison. It uses the DPs from Torrinha and Machado [85], which are aggregated from multiple sources and are designed to apply to SCMMs. These DPs represent requirements a SCMM must satisfy if it is to be effective for its purpose(s) of use and thus a high-quality maturity model.

The SCMM comparison of Torrinha and Machado [85] divides its DPs into the same three categories (identified in Fig. 4.1). The Basic DPs are shown in Table 4.4. Table 4.5 displays the Descriptive DPs. Finally, the Prescriptive DPs are presented in Table 4.6. The MM DPs serve as the items on a ”checklist” [73], applied on MMs to ensure their quality.

DP	Name	Description
1.1.1	Application Domain	”Defines the specificity of the model and distinguishes it from other models”
1.1.2	Pre-requisites of Applicability	”Conditions for applicability and the intended benefits from using it”
1.1.3	Purpose of Use	”The outcome of the maturity assessment, whether it is comparison, description, prescription”
1.1.4	Target Groups	”The requirements of the intended audience, who needs the model, why its application, how to be applied”
1.1.5	Differentiation Factors from Similar MM	”Understand the needs for a new model; support the development of a new model or improving an existing one”
1.1.6	Validation of the Model	”Support appropriate model development by understanding domain through literature review and validation through experts interviews or case studies”
1.2.1	Description of the Maturity and its Dimensions	”Clear and concise identification of the levels and the model dimensions”
1.2.2	Definition of Maturity Levels	”Descriptions of the characteristics of each level”
1.2.3	Definition of Maturity Paths	”Define the paths between the stages and the description activities to be performed at each level”
1.3.1	Model Documentation	”The design process should be documented, which methods were applied”

Table 4.4: Basic Design Principles

DP	Name	Description
2.1.1	Verifiable Assessment Criteria for each Maturity Level	”The used criteria should be verifiable, so the maturity assessment can be compared and replicated”
2.2.1	Procedure Model	”To support user guidance on how to conduct the maturity assessment”
2.2.2	Advice on the Application of Assessment Criteria	”To support the understanding of what needs to be measured, as well as how it can be measured”
2.2.3	Guidance on Adaptation and Configuration of the Criteria	”Maturity Models should be able to be tailored to particular environments, accommodate changes to meet particular needs, assessment criteria should also be configured to specific characteristics”
2.2.4	Verifiability of the model	”A model needs to be tested to verify measurement validity, ensure the results are accurate and that it fits its objectives, to support improvements if needed”

Table 4.5: Descriptive Design Principles

DP	Name	Description
3.1.1	Improvement measures for each maturity level	”Recommendation of actions that lead to an improvement from the ”as-is” situation, to a higher maturity level”
3.1.2	Prioritization of actions	”A model containing process or dimension prioritization is able to support reaching the defined goals”
3.2.1	Procedure model	”Similar to DP 2.2.1 a user should be guided during the improvement process”
3.2.2	Advice on the Application of Assessment Criteria	”The same reasoning from a model fit for a descriptive use, can be applied to a prescriptive use”
3.2.3	Guidance on Adaptation and Configuration of the Criteria	”The same reasoning from a model fit for a descriptive use, can be applied to a prescriptive use”
3.2.4	Verifiability of the model	”A prescriptive model should be verifiable to ensure the prescriptions are able to improve the maturity level. This is also valid from the standpoint of the model validity in domain, as well as its relevance”

Table 4.6: Prescriptive Design Principles

4.3.1 The Comparison

The tables in this subsection show what MM DPs the four SCMMs (from Table 4.1) satisfy. Table 4.7 concerns the Basic MM DPs. Table 4.8 shows whether the SCMMs contain the Descriptive and Prescriptive DPs. The symbol X is used in the tables below to display when a SCMM abides by the DP of the column. As was shown in Table 4.1, several of these SCMMs were previously compared by Torrinha and Machado [85], but this research deviates for one of the models.

	1.1						**1.2**			**1.3**
	1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**1**
Br-SCMM	X	X	X	X	X	X	*	*		*
SO-SCMM	X	X	X	X			X	X		
GSCM	X	X	X	X			X	X		
IDC-SCMM	X	X	X	X			X	X		

Table 4.7: Comparison Results Based on the Basic Design Principles

	2.1	**2.2**				**3.1**		**3.2**			
	1	**1**	**2**	**3**	**4**	**1**	**2**	**1**	**2**	**3**	**4**
Br-SCMM	* *	* *	* *		* *						
SO-SCMM	X	X	X								
GSCM * * *		X									
IDC-SCMM		X				X		X			

Table 4.8: Comparison Results Based on the Descriptive and Prescriptive Design Principles

* Torrinha and Machado [85] conclude that the Br-SCMM has defined maturity levels and model dimensions, but this is not true. This SCMM has 0-5 generic maturity levels and they are divided into SMART Levels (see Section 4.2.1). However, the relationships between those five categories and the maturity levels are not stated, and only Levels S and M have been defined [85, 2]. The other Levels (which are dimensions of the model) are not. This comparison did not find the Br-SCMM to comply with Basic DPs 1.2.1, 1.2.2 and 1.3.1.

* * Afonso et al. [2] describe the assessment of the maturity of the 10 domains only vaguely. Measuring and validating the Levels S and M is explicitly detailed. The measurement of the

other Levels is not discussed. This comparison finds that the Br-SCMM does not support user guidance on how the maturity levels for all SMART Levels can be assessed and, as a result, does not validate them. Thus, this comparison did not find the Br-SCMM to satisfy descriptive DPs 2.1.1, 2..2.1, 2.2.2, and 2.2.4.

$***$ Since this research only has access to a brief description of the GSCM in Section 4.2.3, the MM DPs it follows cannot be assessed completely.

4.3.2 Analyzing The Comparison Findings

The results of the comparison of the SCMMs (identified in Table 4.1) are discussed in this subsection. The comparison findings can be divided into two groups: the similarities and differences.

Besides providing cities with a quantifiable US related assessment process, the SCMMs have two main similarities. The first concerns a lack of transparency in every SCMM as the descriptions of the models and the logic of how US relates to maturity levels is not developed. Therefore, it was difficult to determine which MM DPs were satisfied. This transparency issue can be seen in MMs that cover other domains also, as can be seen in Hamann et al. [37].

The second similarity is that these SCMMs do not satisfy a number of DPs which are essential to using SCMMs. For example, basic DP 1.2.3 which demands that the model provides explicit details on the paths between maturation level; basic DP 1.3.1 which concerns documenting the model design process; descriptive DP 2.2.3, which is concerned with the SCMMs explicitly describing approaches to keep the SCMMs flexible, are not satisfied by any SCMMs. This similarity shows that while well-crafted MMs in other domains fulfill more DPs, the SCMMs in this comparison don't.

The findings of the comparison identify two major differences. The first concerns that all the SCMMs use different constructs in their theoretical framework. For example, the GSCM framework (shown in Fig. 4.5) has the constructs: Smart Economy, ICT, Smart Society, Governance, Smart Environment, People. While similar constructs are used in other models, the whole set is not used by any other model. This shows that no holistic standardized set of constructs for the SC concept exists (confirming what was discussed in Section 3.2.1).

The second difference (as can be seen in Table 4.8) is that only one SCMM follows prescriptive purposes of use DPs (which can be found in Table 4.6), namely IDC-SCMM. This SCMM meets only 2 out of the 6 prescriptive DPs: DPs 3.1.1. and 3.2.1, which concern the description of approaches to improve the maturity level reached. However, these approaches are only discussed on a basic level and other prescriptive DPs are not met. In addition, it is the only SCMM not operationalized, which means it cannot be used for its stated descriptive and prescriptive purposes of use. The other SCMMs are operationalized, but only follow the descriptive DPs [85].

The findings of the comparison are utilized to discuss the implications SCMMs have on US assessments.

4.4 Implications of Smart City Maturity Models

This section discusses the implications SCMMs can have on US assessments. The descriptions of the four SCMMs (see Section 4.2) and the comparison findings detailed above (see Section 4.3.2) led to the following implications.

The first concerns the purposes of use. Regardless of the purpose of use, you want to establish the as-is US of a city. All the SCMMs analyzed (identified in Table 4.1) were descriptive (they all seek to fulfill descriptive DPs). Even though the SCMMs have prescriptive elements, assessing the existing state of the city was the basis of every model. When designing and developing an effective US measurement item, the focus of this research will be on developing a model with a descriptive purpose of use. On this basis, improvements in the city can be discussed without the SCMM fulfilling all the prescriptive DPs. This research will assume this implication to hold with all US assessment measurement items.

The next implication concerns the question of what kind of SCMMs can be considered as US assessment measurement items. First, the SCMM must consider the city as a whole, it must be a holistic SCMM. This brings us back to the description of the IDC-SCMM (in Section 4.2.4), where the development process of the city is the focus of the model in an indirectly holistic way. Thus, holistic SCMMs can be divided into two groups:

- **Urban Smartness Assessment SCMM:** SCMMs from this group assess the US of cities and place them in sequential maturity levels. In addition, the SCMM may implicitly or explicitly propose an approach to improve the city's US in the future.
- **Urban Smartness Development Process Assessment SCMM:** This group assesses the maturity of processes that cities use to develop US. The SCMM can provide guidance on how to improve these processes.

This difference in these groups of holistic SCMM can be identified in other MM research, as the MMs in the city governance [91] and business process management [73] domains can be grouped in a similar way. The second implication is that US assessment measurement items look to assess the US of the city itself and not their development processes.

The third implication concerns the broader applicability of SCMMs. As is often discussed concerning the Br-SCMM, SO-SCMM, and GSCM, these models were designed specifically to apply to cities in specific countries (see Section 4.2). Only the IDC-SCMM is designed to apply internationally, but due to this broad applicability, it could not be operationalized. The implication is that unless a model is designed for specific cities, defining standardized measurements is a complex task that all US assessment measurement items deal with, especially from a global perspective.

The fourth implication discussed in Section 4.3.2, identifies the transparency issue that SCMMs have. Namely that understanding how maturity assessments are derived from the individual measurements is difficult to understand from an external perspective. This implication is that SCMMs (and by extension, all US assessment measurement items) need to be designed to be transparent.

The penultimate implication concerns the satisfaction of the DPs shown in Table 4.7 and Table 4.8 by the SCMMs. As detailed in Section 4.3.2, the SCMMs do not comply with many basic and descriptive DPs (and almost none of the prescriptive DPs). One could consider the overall development of SCMMs as lacking. However, US assessment measurement items may not need to fulfill all the DPs as described in Table 4.4, Table 4.5, and Table 4.6 because they can still be used to assess aspects of US. This implies that DPs may be adapted when developing an US measurement item that is not a SCMM.

The last implication concerns the constructs measured by the holistic US assessment SCMMs being different. This implies that there is no standard set of constructs for analyzing SC related topics. The constructs in GUSF, described in Section 3.1.2, can apply to the SC concept according to current knowledge and are relevant for US assessment measurement items. Determining a standardized set of constructs is a complex task and requires further SC research and the international agreement on the definition of the SC concept.

4.5 Summary

Four SCMMs were identified, described, and compared to produce the six implications, discussed in this chapter. These implications can be used to design and develop US assessment measurement items. As stated in Section 1.3, while the artifact developed in this project (GUSM) uses aspects of a SCMM, it is not a fully developed maturity model as this is outside the research scope. The next part of this report will concern the development of the artifact, the Treatment Design phase of this research.

Part II

Treatment Design

CHAPTER 5

Development Methodology

In the Treatment Design phase of this thesis, the design and development of the artifact, GUSM, is the focus. This chapter will discuss the developmental method of the global urban smartness model (or GUSM), the artifact of this design science research, and is divided into four sections. The contents of this chapter address RSQ 2.1 by analyzing the development method of MMs and modifying it as needed to develop the artifact of this design science research.

5.1 Key Difference

While Chapter 4 discusses MMs and SCMMs, this section will cover the key difference between the SCMMs and the artifact developed in this research, GUSM, is that GUSM *does not define maturity levels*.

According to the three types of MMs as defined in Section 4.1, the identified SCMMs are either staged or continuous fixed-level MMs. As such, they each define a number of maturity levels for either a city's US or focus areas (or subcomponents) of that US. The identification of maturity levels and determining how to place the desired entity in the defined levels is a key step when creating a MM [17, 13, 73]. The SCMMs described in Section 4.2 defined relevant methods to quantifiably measure aspects related to the US of cities and provide support for developing cities as desired. Section 4.3.2, highlighted several ways that SCMMs are lacking, namely in terms of transparency and satisfying the DPs displayed in Section 4.3.

As previously discussed, the definition of a standardized set of maturity levels for the US of cities around the world is a complex task and is not in the scope of this research. Therefore GUSM is referred to as an US assessment measurement item and not a MM or SCMM. As GUSM is designed from a global perspective, it can be used as a basis for designing a globally applicable SCMM in the future. However, that would require more research and standardization of the SC concept. Rather, a MM development methodology is followed as a template that is appropriately modified to design and develop the US assessment measurement item, while incorporating the quantifiable measurement methods seen in SCMMs. The MM development methodology, as modified in this research, is presented in the next section.

5.2 Maturity Model Development Methodology

Although the design cycle (see Fig. 1.1) describes a general methodology for design research, the development of MMs requires a more specific approach that covers the requirements for the development of a MM.

Becker et al. [13] proposed a MM development methodology that can be applied to any type of MMs (as displayed in Fig. 5.1).

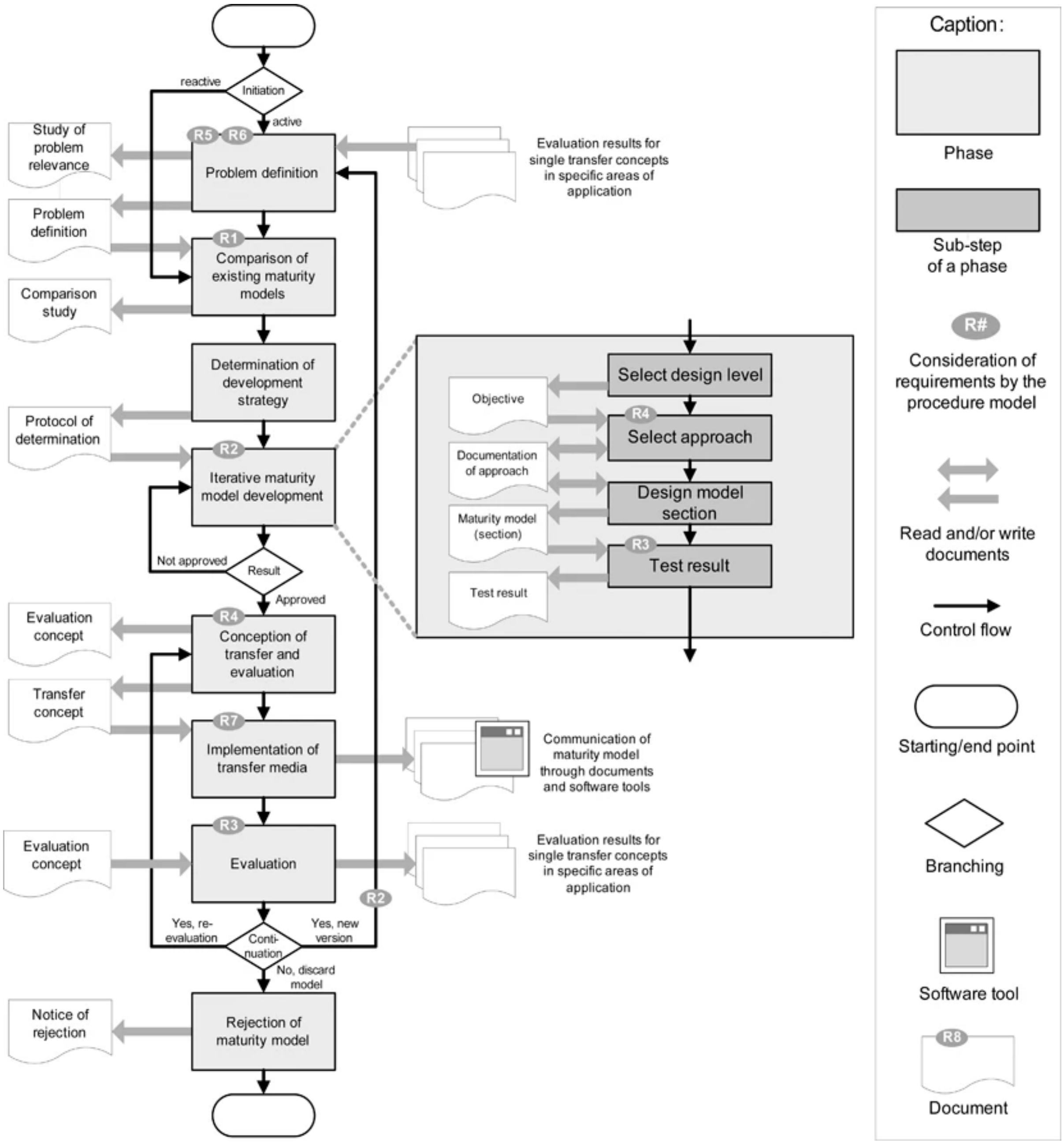


Figure 5.1: Maturity Model Development Methodology of Becker et al. (2009)

In [13], Becker et al. describe the design and development of MMs should follow the steps shown in Table 5.1. This method will be modified and then applied to develop GUSM.

No.	Name	Description
1	Problem Definition	The application domain of the maturity model, as well as the conditions for its application and the intended benefits. Also defines the relevance of the problem
2	Compare existing maturity models	Reviewing the current MMs relevant to the functional domain
3	Determination of development strategy	Deciding what approach to take to develop the maturity model. E.g. Will a new MM be made, or will an existing MM be used, or will a few MMs be synthesized together?
4	Iterative Procedure	Iteratively designing the maturity model cycling through 4 tasks: selecting the design level, selecting the approach, designing the model section, and testing the results will be iterated.
5	Concept transfer and evaluation	A reasoned selection of the different forms that the communication of the maturity model can take.
6	Implementation of transfer media	The purpose of the phase is to make the MM accessible in the planned fashion for all previously defined user groups.
7	Evaluation	Establish whether the maturity model provides the projected benefits and an improved solution for the defined problem.

Table 5.1: Maturity Model Development Methodology

GUSM is similar to a MM, as indicated in Section 4.4, but does not define maturity levels. Thus, this development methodology will be modified appropriately to apply to US assessment models that do not include maturity levels. This methodology fits the design cycle phases used throughout this thesis as the research scope is not to implement GUSM in a real-world situation. Accordingly, steps 4-7 are recreated, using elements from the original steps. Step 4 concerns the design of the theoretical model, step 5 the demonstration of the model, step 6 details the validation of the demonstration, and step 7 analyzes the findings of this research. Thus, step 1 correlates with the Problem Investigation Design Cycle phase, steps 2-5 with the Treatment Design phase, and steps 6-7 with the Treatment Validation phase. The modified development methodology does not concern maturity or implementation/evaluation.

Following the comparison of SCMMs, the next activity that has to be done concerns the determination of development strategy (step 3 in Table 5.1). The next section will look at deciding the approach to further develop the model.

5.3 Determination of Development Strategy

To follow up on the comparison made in Section 4.3.1, this section discusses whether an existing SCMM can be modified to meet the design goal from Section 1.3 or a new model justifiably should be developed.

As discussed in Chapter 4, the four identified SCMMs are not appropriate for global US assessment and are lacking in terms of the MM design principles they comply with. All SCMMs (when not based on each other) differ on the aspects of cities they measure and none look to identify US aspects of cities from a global perspective.

Coupled with the fact that overall MMs for SCs is a relatively new concept and not many extensively validated SCMMs have been produced, creating a new model following GUSF (see Fig. 3.1 is needed. It will be beneficial for conducting US assessments that can support decision making concerning developing smarter cities.

5.4 GUSM Development Method

In this section the MM design methodology from Becker et al. [13] was modified as is shown in Fig. 5.2. This figure is the GUSM development methodology that will be used for the design and development of the artifact of this research.

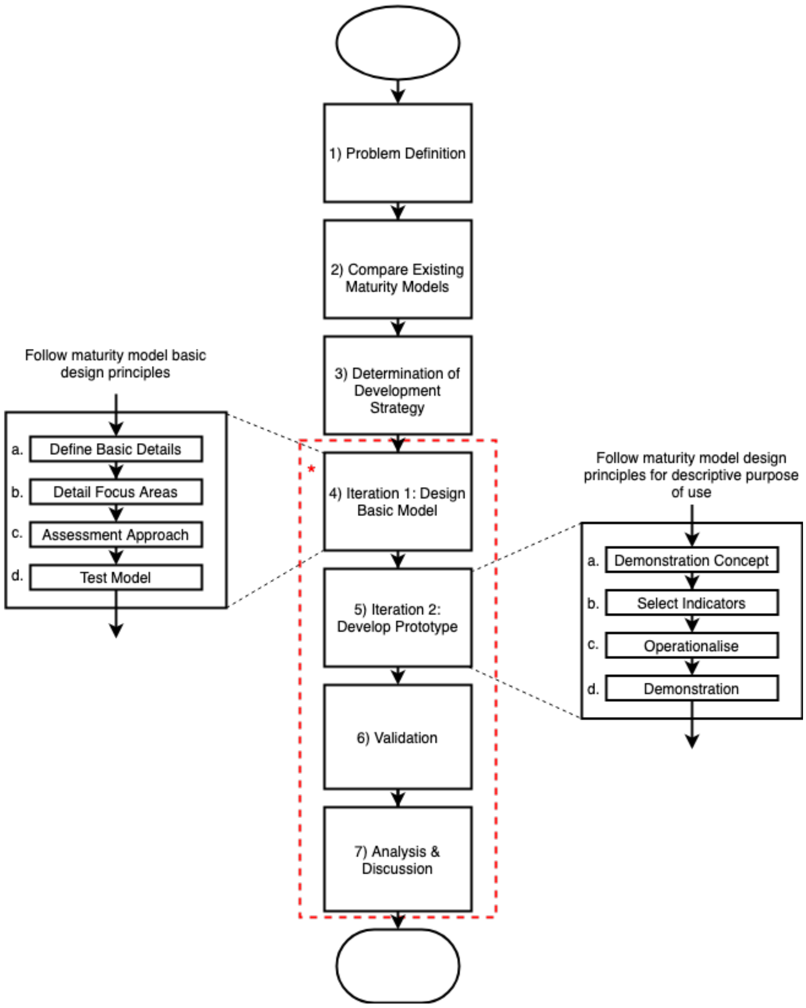


Figure 5.2: GUSM Development Methodology

∗ The rectangle includes the development methodology steps (and their corresponding substeps) that have been modified.

A number of steps have been completed by this and previous chapters. The Problem Definition (step 1) is covered in Chapters 1, 2 and 3. Step 2 ‘Compare Existing Maturity Models’ is addressed in Chapter 4 and step 3 ‘Determination of Development Strategy’ is covered by the previous section.

In this research, the amount of iteration is limited to two. Thus, step 4 from the methodology described in [13] is divided into 2 iteration procedure steps. The first iteration focuses on designing the theoretical version of GUSM. The second iteration focuses on developing the prototype or demonstration of GUSM and operationalizing it. The goal of both iterations is to prepare and test the model for these steps. As shown in Fig. 5.2, these iteration steps contain substeps.

In Iteration 1 (step 4) the basic theoretical model of GUSM is designed and tested. This iteration contains four substeps and it uses a modified version of the MM Basic DPs (from Table 4.4) as a checklist. The modified Basic DPs are presented in the following chapter.

The substep 4a. defines the general details of the model. It relates to the MM Basic DPs 1.1.1 to 1.1.6 in Table 4.4. It includes making explicit the functional domain, purpose, and target audience of GUSM. In general this iteration step requires the least amount of modification from the MM DPs from Torrinha and Machado in [85].

The iteration substep 4b. details the aspects of the city to be measured to assess a city's US. These aspects are each referred to as "focus areas". According to Smits [82], focus areas are the areas of the city to be assessed to indirectly measure US. For this research, the focus areas are the driver constructs and desired outcome constructs of GUSF (see Fig. 3.1). By assessing these focus areas, GUSM can support decision making concerning the development of a city's US.

Next, substep 4c. describes the US assessment approach of GUSM. For these two substeps 4b. and 4c., the Basic MM DPs 1.2.1 to 1.2.3 (see Table 4.4) are modified as GUSM does not have maturity levels. Substeps 4a, 4b, and 4c are each completed in the following chapter.

The final substep 4d. for the first iteration, mirrors the last activity of the iteration procedure in the MM design methodology defined by Becker et al. [13], where at the end of each iteration the model is tested by qualitative evaluations. Feedback is then collected from that evaluation and the model is refined for the next iteration based on the evaluation results. The Iteration 1 activities are described in more detail in the following chapter. The last substep is described in Chapter 7.

In Iteration 2 (step 5), the theoretical model is operationalized. This iteration modifies the Descriptive MM DPs from Table 4.5. This iteration is divided into four substeps. The first iteration substep 5a describes how the theoretical GUSM is operationalized and demonstrated in this research. This substep is covered in Chapter 8. This chapter discusses how the demonstration concept satisfies the MM Descriptive DPs. Iteration substep 5b determines the indicators that will be used in the demonstration of GUSM. This substep relates to MM Descriptive DP 2.1.1. The next substep 5c operationalizes the other parts of the model as needed to combine the indicators to assess US. This substep correlates with MM Descriptive DPs 2.2.1 and 2.2.2. The last substep 5d is the end of the iteration, where GUSM is demonstrated by creating a prototype of a practicable DSS that will be tested in the validation. The substeps 5b, 5c and 5d are covered in Chapters 8 and 9. The relevant modified Descriptive DPs are detailed in Chapter 8.

Note that MM Descriptive DP 2.2.3 and the GUSM Development Methodology are approaching the adaptation and configuration of the criteria of the artifact from opposing perspectives. MM Descriptive DP 2.2.3 starts from the premise that the model is fully defined and should be adapted before an assessment. While the GUSM Development Methodology considers that adaptation needs to be part of the set up of the model. Thus, MM Descriptive DP 2.2.3 which is concerned with providing guidance on adaptation and configuration of the criteria used, is covered more generally in several chapters. This includes the following chapter, and Chapters 7 and 8. Chapter 9 describes the operationalization of the prototype of GUSM and in that operationalization shows how its assessment criteria can be adjusted according to a particular environment.

Step 6 from Fig. 5.2 conducts the validation and details the feedback collected from that validation. This step addresses the MM Descriptive DP 2.2.4 concerning the verifiability of GUSM. This step is discussed in Chapter 10.

For the final step 7, an analysis and discussion of the research findings is made and this concludes the thesis activities. Fig. 5.3 shows the numbers of the chapters that cover each methodology step as described in the paragraphs above.

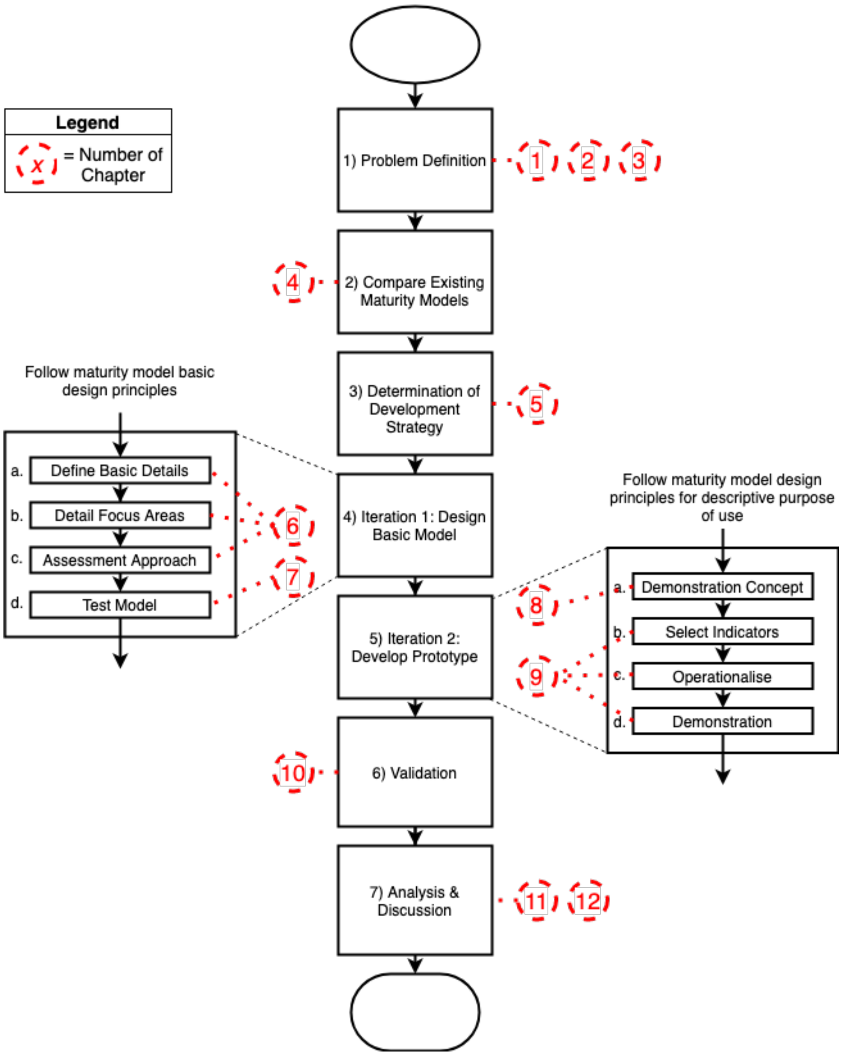


Figure 5.3: Chapters and the GUSM Development Methodology

CHAPTER 6

Global Urban Smartness Model

This chapter details the design of the theoretical model of GUSM and discusses the first three substeps of Iteration 1 from the development methodology of GUSM in Fig. 5.2. Thus, the contents of this chapter address RSQ 2.2.2 by defining the basic details of the non-operationalized GUSM and identifying how it assesses US.

6.1 Defining Basic Model Details

This section defines the basic details of the model by describing how GUSM satisfies the modified Basic DPs. In Table 6.1, seven DPs of the MM Basic DPs of Torrinha and Machado in [85] are modified. These DPs are DP 1.1.1-1.1.6, which identify generic details a model should satisfy, and 1.3.1 that concerns documenting its design process. This set does not include DPs 1.2.1-1.2.3 as these are discussed in the next section, which concerns detailing how the focus areas of US are assessed. Most have been discussed in some form already in the first 5 chapters. These modifications are defined explicitly to make the model details clear and improve its transparency. In this research, they are referred to as GUSM Basic DPs.

DP	Name	Description
1.1.1	Application Domain	”Defines the specificity of the model and distinguishes it from other models”
1.1.2	Pre-requisites of Applicability	”Conditions for applicability and the intended benefits from using it”
1.1.3	Purpose of Use∗	The outcome of the model’s assessment, whether it is comparison, description, prescription
1.1.4	Target Groups	”The requirements of the intended audience, who needs the model, why its application, how to be applied”
1.1.5	Differentiation Factors from Similar MM∗ ∗	”Understand the needs for a new model; support the development of a new model or improving an existing one”
1.1.6	Validation of the Model	”Support appropriate model development by understanding domain through literature review and validation through experts interviews or case studies”
1.3.1	Model Documentation	”The design process should be documented, which methods were applied”

Table 6.1: GUSM Basic Design Principles 1.1.1 to 1.1.6 and 1.3.1

∗ DP 1.1.3 has been modified since the maturity concept is not used by GUSM.

∗ ∗ As GUSM's design is based on MM development methodology, therefore this DP is concerned with existing SCMMs.

The following seven subsections explicitly define the basic details of GUSM for each of the DPs in Table 6.1.

6.1.1 Application Domain

This subsection discusses GUSM DP 1.1.1, which defines the main subject of GUSM and distinguishes it from other models [17]. This subject was discussed in the first 5 chapters of this thesis.

The application domain of GUSM concerns assessing the US of a city following a holistic SC concept.

6.1.2 Pre-requisites of Applicability

This subsection concerns GUSM DP 1.1.2., which correlates to a requirement from Becker et al. [13] where the conditions of the model's application, and its intended benefits are determined before the model is developed any further. This DP is discussed in Chapters 1 and 3.

GUSM is applicable if three conditions are met:

1) GUSM is applicable to existing cities (or urban areas where people live and/or work). It is important to note that it must be a brownfield case as to measure city indicators there must be an existing city to measure;
2) The city being assessed is in a region of the world for which GUSM has been operationalized, and as a result, the indicators used in the assessment are available in that city;
3) If comparing multiple cities a third condition concerns the availability of indicators used. The cities in the comparison must have the same or similar indicators available. This shouldn't be an issue as GUSM is designed to avoid this problem, but where this condition is not met, a comparison is not possible.

The intended benefits: GUSM provides a repeatable, transparent and robust process to support decision-making on which smart city project(s) a city should invest in. GUSM provides a breakdown of the US of a city and identifies the different city focus areas that impact its US. The model measures these aspects and the measurement result indicates possible areas that can be improved by implementing smart projects (or SC initiatives). GUSM was designed from a global perspective. The end goal of the model is that it can be applied to cities across the world, but in this research its operationalization is limited.

GUSM improves the understanding of the SC concept by providing knowledge of the current (as-is) reality of US of a city and the impact a particular project can have on US. The results of GUSM are presented visually to support the analysis of the focus areas and communication between decision makers. Ultimately, this will improve the decisions made by cities about how to become smarter.

6.1.3 Purpose of Use

This subsection is about GUSM DP 1.1.3, which defines the outcome of assessment using the model, namely whether the model has the comparison, description or prescription purpose of use [17]. This DP is discussed in Chapters 1, 4 and 5.

The primary purpose of the use of GUSM is descriptive, similar to the MM purpose of use from Section 4.1. The model describes the as-is US situation of a city. However, GUSM can also be used to identify possible areas where implementing a project can impact the city's US in the to-be situation of a city. Therefore, GUMS provides an implicit prescriptive purpose of use as well. Indications of the progress of the focus areas of US development are identified, but guidance on possible decisions is not explicitly provided. However, GUSM does explicitly provide a comparative purpose of use, where the measurements of focus areas of cities can be compared. This allows cities to learn from each other by exchanging information on what smart projects had the desired impact on US.

Thus this model has three purposes of use:

1) **Descriptive**: concerning assessing the US of an existing city. This can be done for example once or twice per year in order to track the US of a city over time;

2) **Implicitly Prescriptive**: supporting decision making concerning smart project selection. This can be done on an ad-hoc basis, whenever deciding on SC initiatives;

3) **Comparative**: allowing for the comparison of US assessment results of multiple cities. This can be done on an ad-hoc basis.

The second purpose of use can be developed further, by providing GUSM results with more guidance on how to improve a city and analyze the potential impact of SC initiatives. Additional functions that predict the impact of smart project implementation to a city's US can be included to create the to-be situation the city desires. Including such predictive functions in GUSM would provide more guidance for smart project selection decision-making. However, currently GUSM is not explicitly prescriptive and none of the SCMM prescriptive DPs from Table 4.6 are modified and applied in this study.

6.1.4 Target Groups

This subsection concerns DP 1.1.4 from Table 6.1, which discusses the audience that needs and will use the model, why its application is needed, what the audience's needs are, and how the model is to be applied [17]. This DP is initially discussed in Chapter 1.

There are four groups for whom the model is relevant:

1) **City Government (Executive board level)**: Those who officially oversee the city and manage its development. They decide what projects to implement to make the city smarter as desired. The city government can use practical, transparent, and repeatable processes to support and communicate the decisions they make concerning the city's US. This need is established in multiple studies including [24, 51, 67]. They have a high interest and power in determining what the city US is and how to develop it further;

2) **External Consultants**: They advise the city on how to improve its US and, when needed, provide services and resources for city development. This can be in the form of implementing SC initiatives. These consultants wish to sell their products and services to the cities. While they have a high interest in the SC concept and city US, they do not have the authority to decide which services and products are needed;

3) **Citizens**: They live or operate in the city in question and are impacted by and impact its US. Citizens that reside in the city are at the center of the SC concept from the holistic perspective, as discussed in Chapter 2. Citizens and citizen organizations want the city to improve in terms of the desired outcomes of GUSF (see Fig. 5.2). As noted by Al-Nasrawi et al. [66], engaging the citizens and their organizations is the key to US. Regardless of what smart projects are implemented, citizens' and citizen organizations' use and response to those smart projects ultimately determine the city's US;

4) **SC researchers**: Academic researchers in the SC field study topics related to the SC concept. This study is concerned with researchers that focus on the assessment of US. They desire to identify a standardized process for assessing the US of one or multiple cities. An US assessment measurement item provides them with such a process to measure specific characteristics of SCs and compare them between cities in a transparent way. Academic researchers while interested in the topic do not typically have power over the decisions on SC initiative selection.

The possible target groups of GUSM can be characterized like in the stakeholder analysis process of Mendelow in [61] shown in Fig. 6.1; where stakeholders are mapped depends on the interest or power they possess.

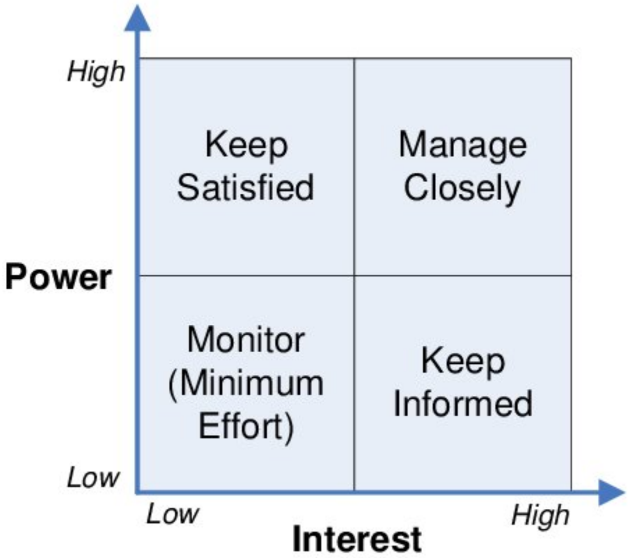


Figure 6.1: The Stakeholder Analysis Grid

This stakeholder analysis grid was adapted to apply to the groups described above. The adaptation does not imply a scale but rather divides the different groups into distinct categories.

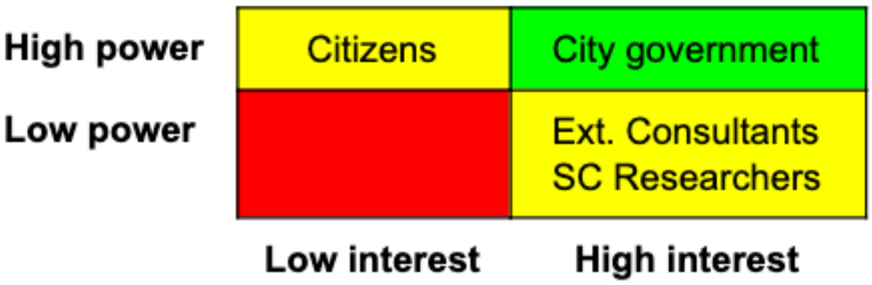


Figure 6.2: Adapted Stakeholder Analysis Grid for GUSM

By looking at Fig. 6.2 one group highlighted as being both interested in conducting US assessments and having a level of power on SC development, is the city government (especially officials responsible for managing the US of the city). Citizens are not the target group, but hold a considerable amount of power and thus their interests must be considered when using GUSM. Both the external consultants and SC researchers do not have power concerning smart project selection, but are interested in the subject. Therefore, the target group of GUSM is the officials in the city government that directly make decisions about which smart solutions to implement.

The target group of GUSM wants a practical US assessment measurement item that can be flexibly applied. Currently, the SC concept is unclear and standardized methods to make a city smarter have yet to be defined (as discussed in Chapters 2 and 3). Allowing a city to base their decisions on quantitative data in GUSM, enhances their US assessment and smart project selection decision-making capabilities.

Such a model is complex for a city government to understand at first. A third party with knowledge of the theories used for GUSM and how it conducts US assessments, would help the city government to learn about GUSM and set it up as required to conduct the US assessments according to the local context of the city. Eventually, the city government would conduct self-assessments and use GUSM as desired. Ultimately, the perception of usefulness and ease of use of GUSM for the target group is essential for its adoption [29].

6.1.5 Differentiation Factors from Similar MMs

This subsection shows how GUSM satisfies GUSM DP 1.1.5. This DP reviews existing MMs and determines whether a new model should be developed or an existing one should be improved [17, 13]. This point has already been discussed in Section 5.3. The conclusions of this section will be given below.

Four existing SCMMs were compared and it was determined that developing a new model was appropriate due to three differentiation factors:

1) Existing US MMs are country specific and operationalized to apply to cities in one country. They all lack a global perspective;

2) No universal group of city aspects to measure when assessing US has been identified;

3) Lack of unclear details on existing similar MMs makes improving one difficult.

6.1.6 Validation of the Model

This subsection details how the study satisfies GUSM DP 1.1.6, which concerns providing support for appropriate model development by understanding the domain through literature review and validation through expert interviews or case studies.

A systematic literature review has been done to investigate the SC and US assessment field. The findings of the literature review are discussed in Chapters 3 and 4. The reviews contribute to the understanding of US assessment, differences of US assessment between countries, the design of MMs, and existing SCMMs. The literature review methodology used for this research was discussed in Section 1.4.1. For Chapter 4, a short literature review of SCMMs was done, using the same methodology.

GUSM is tested at the end of iteration 1 and validated after iteration 2 as shown in Fig. 5.2. This is done through the expert opinion methodologies discussed in Section 1.4.2. This will be discussed in upcoming chapters.

By applying these methodologies the appropriate development of GUSM was supported.

6.1.7 Model Documentation

The last MM Basic DP is not modified [85]. It is DP 1.3.1 from Table 6.1. It concerns documenting the design processes and methods applied when developing the model, in this case, GUSM. The design processes and methods used are documented in this research.

While this section discusses GUSM's basic details (relating to DPs 1.1.1-1.1.6, and 1.3.1), the next section elaborates on the focus areas of GUSM. It details the aspects of a city that will be assessed by the model.

6.2 Focus Areas of Urban Smartness

In this section, two modified DPs are introduced and will be further detailed in the corresponding subsection. As discussed in section 5.1, GUSM is not an SCMM as it does not use the concept of maturity for its US assessments. The MM basic DPs 1.2.1 - 1.2.3 from Torrinha and Machado in [85] are modified. Basic DP 1.2.1 has been modified to reflect the SC concept. Basic DP 1.2.2 and 1.2.3 have been combined to form GUSM basic DP 1.2.2. The two GUSM basic DPs are shown in Table 6.2.

DP	Name	Description
1.2.1	Descriptor of Urban Smartness and its Dimensions	Clear and concise identification of the focus areas of urban smartness and their dimensions
1.2.2	Definition of the Model's Assessment Approach	The approach to measuring the focus areas and city urban smartness is explicitly described

Table 6.2: GUSM Basic Design Principles 1.2.1 and 1.2.2

The GUSM basic DP 1.2.1 concerns the focus areas of US that GUSM will measure. The subsection below describes how the model satisfies this DP.

The subsection after that details how the model fulfills GUSM basic DP 1.2.2. This DP defines the US assessment process of GUSM.

6.2.1 The Detailed Global Urban Smartness Framework

This subsection details what the focus areas of GUSM are and how they can be measured. The described content concerns GUSM basic DP 1.2.1 (shown in Table 6.2).

As Fig. 3.1 shows, in order to assess how smart a city is, seven outside constructs need to be measured. These constructs displayed are the seven high-level focus areas of US assessments conducted by GUSM. Each focus area can be understood by one or multiple subcomponent(s). These subcomponents represent relevant topics to be assessed by one or more indicator(s). This demonstrates what aspects of the city are measured when GUSM assesses US. This is the first version of the Detailed GUSF (or Detailed GUSF V1), as shown in Fig. 6.3 that will be updated later in this research.

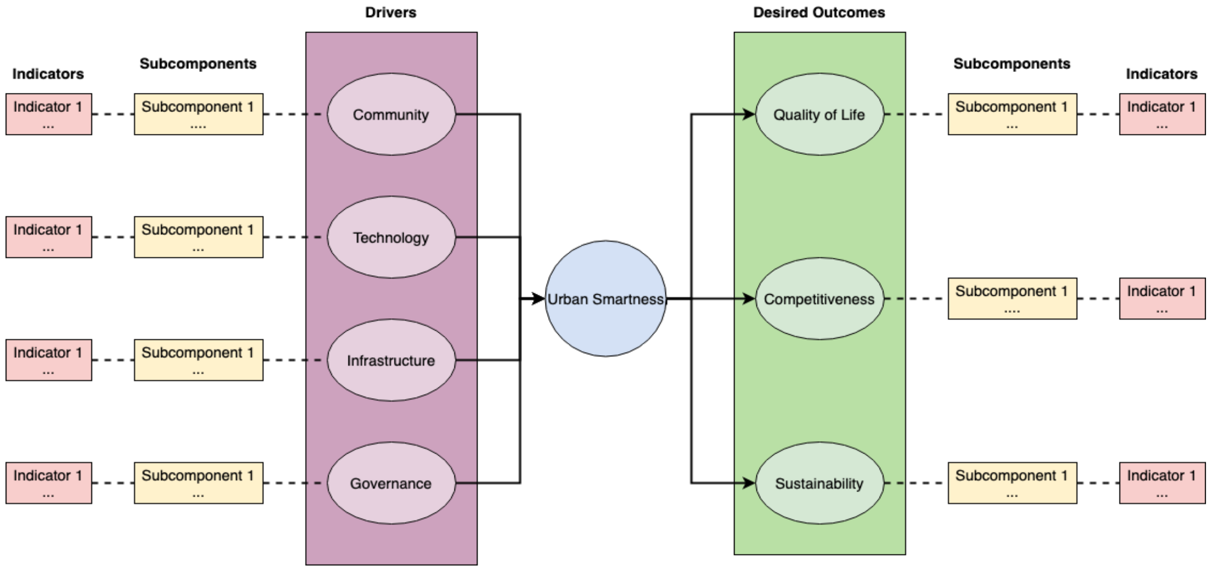


Figure 6.3: Detailed Global Urban Smartness Framework V1

As Detailed GUSF V1 shows, GUSM identifies a set of indicators to measure a number of subcomponents for each focus area of the framework introduced in Section 3.1.2. While subcomponents may be relevant to different cities, as described in Section 3.2.2, indicators used between those cities may not be shared. Therefore, GUSM looks to define a list of subcomponents to be used during the assessment, but acknowledges that the set of indicators may have to be adapted between cities. The idea is that the indicators used are the same or similar between the cities being assessed.

Table 6.3 describes the seven focus areas of US assessment as identified in the Global Urban Smartness Framework (shown in Fig. 3.1). Along with descriptions of each focus area, examples of the subcomponents to be measured are identified.

Focus Area Name	Definition	Example Subcomponent(s)
Communities	Concerned with indicators that measure the human and social capital of a city.	The health and education of citizens
Technology	Seeks to assess overall characteristics of the use of technology in the city.	Use and access to technology in the city
Infrastructure	Seeks to assess characteristics of the human-made elements in the urban environment	Traffic safety, housing
Governance	Concerns the management of people, policies, and services in the city	Public services, municipality spending
Quality of Life	Aspects concerning how well people in the city live	Satisfaction with education/health facilities, poverty rate
Competitiveness	Aspects of the economic growth and attractiveness of a city and its competitive position to other cities	Productivity, touristic attractiveness
Sustainability	Aspects related to the efficiency of a city's management of resources and impacts on its environment	Pollution, energy

Table 6.3: GUSM Focus Area Definitions and Examples

For this research, a list of subcomponents was drafted with the intention to standardize the subcomponents GUSM would seek to measure. The draft list was based on the topics from the indicators identified by the ISO standards 37120 and 37122 [44, 45], and the research article [36]. However, after the first round of expert opinion interviews (discussed in the next chapter), it became clear that such standardization is difficult and needs a lot more work. Thus, this draft list of subcomponents is only briefly discussed in the following chapter.

The next subsection details how the measurement of the focus areas and their subcomponents are used in the US assessment processes of GUSM.

6.2.2 Urban Smartness Assessment Approach

This subsection describes how GUSM satisfies GUSM basic DP 1.2.2 (shown in Table 6.2), which is concerned with detailing the US assessment process of the model.

Each focus area is measured by the indicators associated with the focus area's subcomponents. These indicator values can be merged to identify the subcomponent value and through normalization, required for certain indicators, the values can be utilized in this process. The values for each subcomponent can be similarly combined per focus area. The values of the indicators, subcomponents, or focus areas can be plotted and displayed on a spider chart, as shown in Fig. 6.4. Finally, the area covered in the spider chart can be calculated, generating one total US score for a city. This general description of the US assessment approach of GUSM (shown in Fig. 6.5) will be discussed in more detail below.

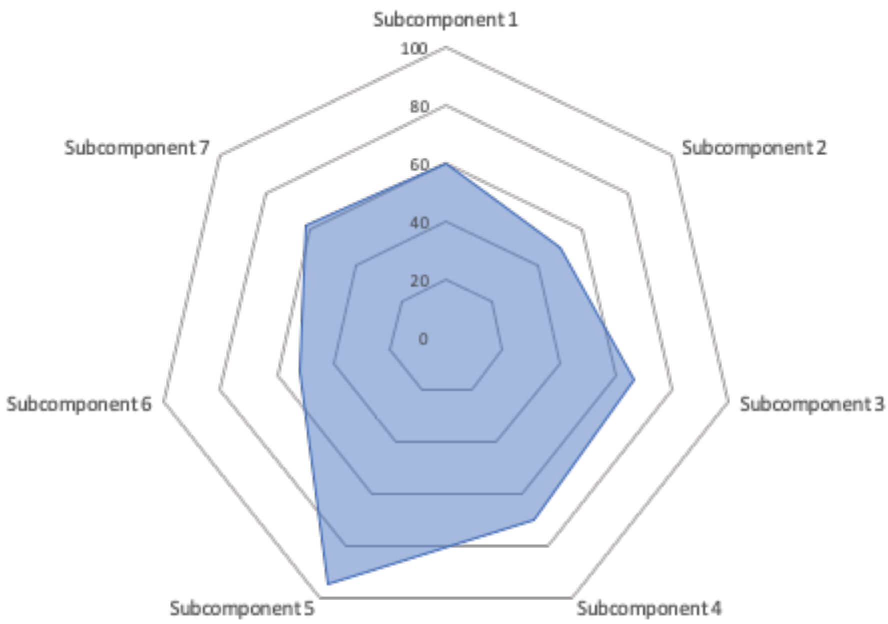


Figure 6.4: Generic Spider Chart Example

Note that the spider chart example, shown in Fig. 6.4 displays the values of subcomponents. Depending on the number of subcomponents and indicators used in the assessment, the information shown in this chart would need to be adjusted. As the number of subcomponents and indicators increases, this chart would become unclear. Additional spider charts displaying the indicators per subcomponent and subcomponents per focus area may be needed. In this research, the spider charts display all the subcomponents of the focus areas of city US.

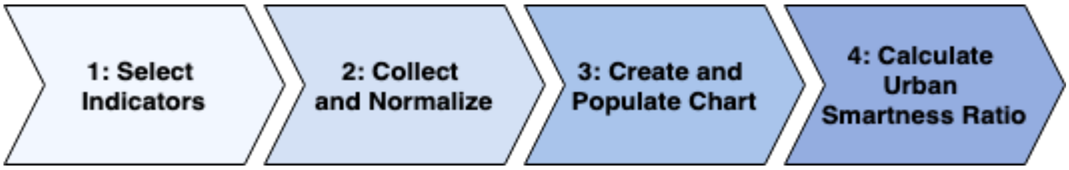


Figure 6.5: GUSM's Assessment Approach V1

Fig. 6.5 shows that the first version of the US assessment approach of GUSM (or GUSM's Assessment Approach V1) is divided into 4 actions:

1) **Start Assessment**: Serves as the preparation step to conducting the assessment. In it, the indicators associated with each subcomponent of all the focus areas and the sources of those indicators are identified and selected;

2) **Collect and Normalize**: Those indicators are gathered, measured, and normalized so they all share the same range or scale of numbers and can be easily plotted. Also to avoid the impacts of city size [67, 28] and technology development (in the case two cities with different but similar indicators are being assessed) [52] on indicators, the selected indicators must be normalized to standard ratios or percentages;

3) **Create and Populate Chart**: Create a spider chart with the subcomponents of the focus areas from Fig. 6.3 with a standard scale that fits with all the indicators. Then plot their associated values on the chart. This spider chart visually represents the US of the city assessed, and be used in discussions;

4) **Calculate Urban Smartness Ratio**: Calculate the surface area of the chart covered by the normalized values and divide it by the total surface area of the chart. The area coverage ratio gives a score for the US of the city. This coverage ratio is the US Ratio and it is the final output of GUSM. This ratio provides a number that can be used for further analysis (i.e. monitoring the US of a city over time).

The method to calculate the US Ratio must be defined in more detail. As can be seen in the generic spider chart example (shown in Fig. 6.4), the chart is an n-sided polygon where n is the number of edges. In this case n equals the number of values plotted in the chart. As a result, this chart can be envisioned as n triangles; an example of this relationship can be seen in Fig. 6.6. The spider chart example from Fig. 6.4 can be divided into seven of these triangles.

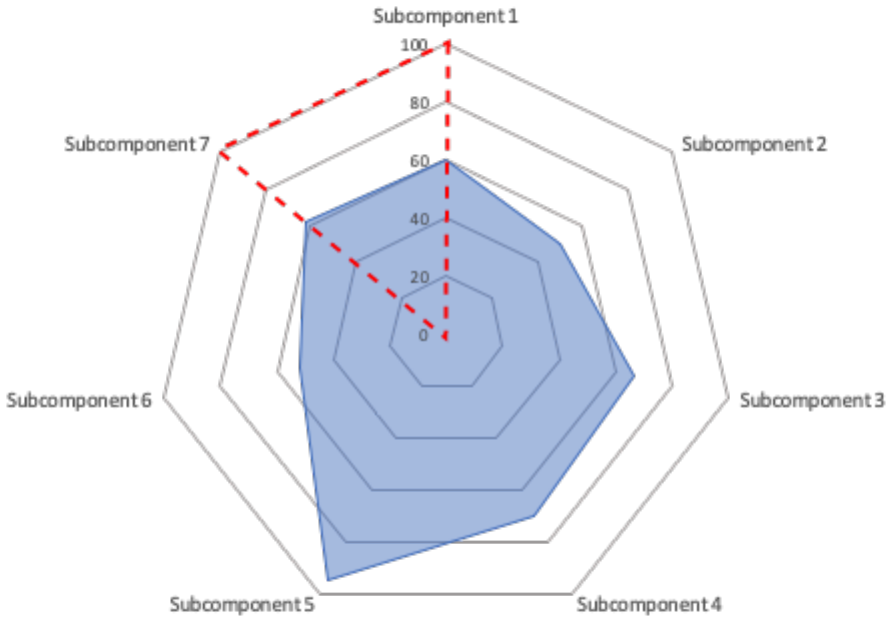


Figure 6.6: A triangle in the Example Spider Chart

Each triangle in the spider chart visually indicates how much it is covered by the values from the assessment. In order to quantify this coverage, this triangle can be divided into two areas: the coverage area (the area covered by the values of the assessment) and the total area (the area covered by the maximum values possible). Fig. 6.7 expands the example triangle shown in Fig. 6.6 to show these two areas and displays three quantities known about every triangle: the values found in the assessments (in this case the values for subcomponents), the maximum value possible, and the angle shared between all the triangles in the chart. The angle is fixed and it can be found by using the formula in equation 6.1.

$$Angle^{\circ} = 360/n \tag{6.1}$$

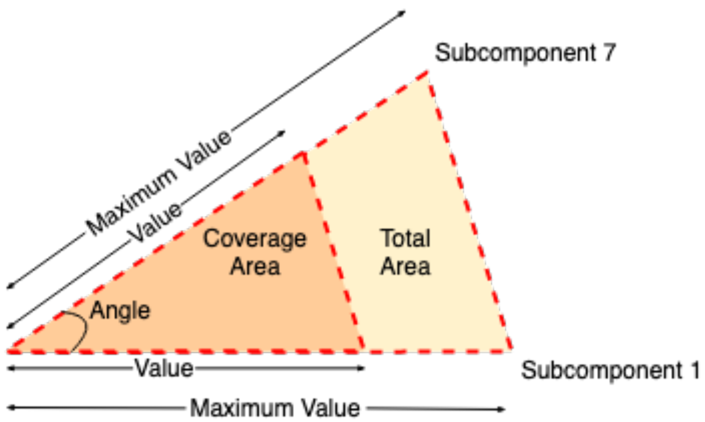


Figure 6.7: The Two Areas of a Triangle

These areas are calculated for each triangle in the spider chart, and are separately added to provide the coverage area of all the subcomponents and the total area of the whole chart. The areas covered in each triangle can be calculated using an equation [11]. In equation 6.2, 'C' is the angle, while 'a' and 'b' are either the maximum value or the two measured values plotted. This is a geometry equation that stems from the Pythagorean theorem.

$$Area = 1/2 * a * b * Sin(C) \tag{6.2}$$

The US Ratio is then calculated by combining the two areas, as shown by equation 6.3. $Area_C$ is the coverage area of all the values and $Area_T$ is the total area of the whole chart.

$$USR = (Area_C / Area_T) \tag{6.3}$$

The US Ratio uses the scale 0 - 1 and does not have any units. Rather GUSM gives this ratio to score the city's US as-is situation. Once the US Ratio is calculated, the fourth action of GUSM's assessment approach is completed. The results of the assessment are presented to the users of the model, who can then use the information as desired.

Note: The US Ratio provides a specific number relative to the set up of the assessment and the city using GUSM to conduct the US assessment. If the US of multiple cities or one city at different points in time is assessed, then the order of the list of subcomponents and the set of indicators needs to be kept consistent. If not the coverage area changes resulting in a different US Ratio. This issue can be seen most often between cities in different regions of the world, but may also occur between cities within a country (i.e. coastal cities may have different indicators available than cities inland). Unless the cities use the same measurement schema.

6.3 Summary

This chapter defines the basic details of the theoretical GUSM. It applies a number of GUSM basic DPs to ensure appropriate model development. It describes such activities as: what the application domain of the model is, what target group it applies to, its purpose of use, its applicability, how it differs from similar models, and how it is validated and documented. This chapter also defines how GUSM measures US and describes its measurement processes. The following chapter will conclude iteration one, or step four from Fig. 5.2, by testing this theoretical model with expert opinion interviews.

CHAPTER 7

Theoretical Round Evaluation

This chapter tests the theoretical version of GUSM, designed in the previous chapter. This is done by qualitatively evaluating what experts think of the model and is an important check in answering RSQ 2.2. This is the last substep of iteration 1 (substep 4d) from the development methodology of GUSM in Fig. 5.2. For this text, six expert opinion interviews are conducted, as is discussed in Section 1.4.2. These interviews concern the theoretical version of GUSM and are in the Theoretical Round. The first section describes how the interviews in this round are prepared (what experts are interviewed and the materials used). The next section details the findings of the interviews. The final section describes the three changes that are made to the theoretical version of GUSM.

7.1 Theoretic Round: Interview Preparation

In Section 1.4.2 it was made clear that the model is evaluated by conducting semi-structured, one on one, confirmatory interviews. There are two rounds of interviews. This section concerns the Theoretical Round of expert opinion interviews. Section 1.4.2 describes the methods to be used during the interviews. It has subsections on interview preparation, data collection, and analysis.

As noted in Section 1.4.2.1, there are considerable differences between the two rounds. Therefore, interview preparation for the Theoretical Round is discussed here. The interview preparation methods from Kallio et al. [46] are used for both rounds, but the preparations are specific to each round.

As discussed in Section 1.4.2.2, collecting and analyzing the data gained from these expert opinions is the same for both rounds. The data is collected by recording the audio of these interviews and analyzing them by creating structured summaries of these recordings. For more details on the methods used, see Section 1.4.2.2.

The rest of this section concerns the preparation of the expert opinion interviews. The first section details the experts (or participants) to be interviewed. The second section describes the materials used for the interviews and how they are produced.

7.1.1 Experts Interviewed

As detailed in Section 1.4.2.1 one of the activities essential to interview preparation, is the selection of experts who are to be interviewed. This subsection will describe the selection of the six experts to be interviewed.

The experts in question are all researchers who have studied topics in the SC field. While they have not all published research on US assessment, they have studied the SC concept and have knowledge of how US should be assessed or what should be considered in such a measurement. Four of the experts that participated in the Theoretical Round are from the University of Twente, who have all published concerning the SC concept. One researcher is from the Technical University of Madrid and has published multiple papers on US assessment. The sixth expert is from the Netherlands organization of applied research (TNO) and has also published on US assessment. In this research, they will be referred to as Expert A, Experts B, . . . , Expert F.

The opinions of these experts are solicited on whether the theoretical version of GUSM can assess US and on whether it would be useful from a city's perspective. As they have all conducted research on the SC concept and have an understanding of aspects of US assessment as a result their feedback is crucial to the development of the artifact in this research.

7.1.2 Materials Used

Materials for the interviews in the Theoretical Round were created. To design the interviews, the framework for the development of a qualitative semi-structured interview guide from Kallio et al. [46] was followed. It produces a complete interview discussion guide that identifies the general structure, and the justification and reasons for holding interviews. It establishes the main topics of the interviews and defines the interview questions, which look to collect the experts' opinions on the theoretical version of GUSM. This discussion guide is given to each expert before their interview and includes information on the SC concept, GUSF, the theories behind GUSM, and US assessment. This guide is shown in Appendix A.

Note that the Interview Discussion Guide uses and displays the draft list of subcomponents (discussed in Section 6.2.1) that is not used or discussed after this chapter.

This Interview Discussion Guide is further developed by conducting two types of pilot tests [46]. The first type is referred to as "internal testing" , where the supervisors of a project review the discussion guide. This review determines such things as whether the topics of conversation and questions were clear to the reader. The second type of pilot test is the "field-testing" technique, where the Interview Discussion Guide is tested by using it in interviews with experts. As field-testing simulates the real interview situation, it "provides crucial information about the implementation of the interviews" . For example, the order of the questions can be reviewed, and as well as whether the questions identified "truly elicited the participants' perceptions and experiences" [46], relevant to GUSM and US assessment. In this research, an internal test was done and two field-tests were done in the two first expert interviews. In these interviews, additional time was used to allow for discussion reviewing the Interview Discussion Guide and the interview process (relevant to the field-testing type of pilot test). By conducting these pilot tests, the Interview Discussion Guide was refined.

The expert opinion interviews (with the six researchers identified in the previous subsection) used the material described to collect feedback on the theoretical version of GUSM. This feedback was analyzed and findings described in the next section were identified.

7.2 Theoretical Round Interview Findings

Once the interviews were conducted, and data from them were collected, coded, and analyzed, structured summaries were developed using the method described in Section 1.4.2.2.

The overall response to GUSM was that such an US assessment measurement item might be useful from the expert's perspective. However, the experts provided feedback on four main topics that can impact the potential usefulness of GUSM. They are *the SC Definition, the Focus Areas Contents, the Relationships within GUSF, and the Index Issue*. These topics form the structure shared between the summaries and are also used for the following subsections. These structured summaries can be found in the appendix, separate for each expert (see Appendices B- G).

7.2.1 The Smart City Definition

Three of six experts identified one of the main challenges when it comes to SC research in general: the lack of a universally agreed upon SC definition. All six noted that the definition of how a city is smart differs from city to city, regardless of the location of the two cities. Currently, there is no knowledge or expertise on how to measure US that is standardized across the world and is universally accepted. This brings the context-dependent SC definition issue to the forefront. Depending on how SC is defined, measurements of the focus areas differ as well. This issue impacts the assessment GUSM wishes to make.

The original working SC definition was modified from Caragli et al. [21]:

We believe a city to be smart when investments in human and social capital and traditional transport and modern ICT infrastructure fuel sustainable competitiveness and a high quality of life, with a wise management of natural resources, through participatory governance

While the six experts found the holistic definition of the SC concept that was in the interview discussion guide, was generally acceptable, five of six experts suggested changes to the definition. The experts suggested that the definition used by this research should cover certain aspects or use certain perspectives. For example, one expert suggested that the definition used by this research should align more with the constructs in GUSF.

7.2.2 The Focus Areas Contents

The second topic concerns the uncertainty all six experts expressed on what the focus areas and/or their subcomponents covered in GUSF (see Fig. 3.1). This was a general issue that was implied when the experts would ask questions concerning what city areas should be measured or suggested new focus areas or subcomponents be included. For example, whether ”Productivity” should be added to the Desired Outcomes focus areas or whether it’s already a part of the Competitiveness focus area.

All six experts expressed this uncertainty specifically for the content of the focus areas, five experts also emphasized that this uncertainty extends to its subcomponents. This regards both whether new subcomponents need to be added or the existing list of subcomponents needs to be rearranged. For example, if new subcomponents need to be added to the Quality of Life focus area or whether existing subcomponents associated with other focus areas should be moved to the Quality of Life focus area.

Three experts, in particular, highlighted that they believed the focus areas of GUSF did not adequately cover ‘people’ given their central role in the SC concept. This question was linked to their uncertainty of what the focus areas contain.

7.2.3 The Relationships Within the Framework

Four out of six interviewees expressed uncertainty on the relationships between the constructs in GUSF (see Fig. 3.1). This uncertainty concerns the relationships between the desired outcomes focus areas and the US construct, as well as the relationships between the constructs for the drivers and desired outcomes.

Two of the experts discussed the complexity when identifying the relationships between the desired outcomes focus areas and the US construct. They note that the desired outcomes are also the main ”goals” of US; they both impact and are impacted by a city’s US. In other words, the desired outcomes have a vague dual role, they are the ”goal-impact” of US.

Four of the experts also expressed uncertainty about the relationships between the driving forces and the desired outcomes constructs of GUSF. While SC research identifies these constructs, the exact relationships between them are unknown.

This uncertainty of the relationships in GUSF is exacerbated due to the fact that many focus areas cover aspects that are correlated with aspects from other focus areas. For example Quality of Life, which concerns the wellbeing of people in a city, is impacted by how that city is governed. The Quality of Life and Governance constructs impact not only each other, but also impact city US, which is difficult to quantify. Determining these relationships is not in the scope of this research.

7.2.4 The Index Issue

The index issue refers to the suggestion by the experts for GUSM (as described in Chapter 6) to avoid developing a standard index that is applied to all cities due to a number of reasons, which will be detailed in this subsection. The assumption is that such an index is always calculated in a standardized manner. The organizations behind such indexes usually conduct US assessments from a top-down perspective and use one rigid SC definition. This definition ignores the unique situations that cities are in. Five out of six experts addressed this index issue specifically, while three experts indicated that GUSM's assessment approach was generally acceptable (including the one expert who did not discuss this issue further).

The experts shared the three reasons for avoiding the development of an index:

1) **Accounting for Different Local Contexts**: How US assessment should be conducted changes depending on the local context of a city. Two experts noted that an index likely does not adapt to the cities' local context, and will not be useful to cities in general. They note that this local context is based on the challenges/problems the cities face, their environments, their SC definitions, the indicators available to them, and their desired goals. In order to address this issue, they propose that any measurement item must be designed to be as flexible as possible and include city officials when deciding the measurement criteria for an assessment. A standardized index cannot fulfill this requirement.

2) **Non-transparency**: Indexes may not be transparent, meaning that cities do not know what the index covers and/or how they are calculated. One expert highlighted that this leads cities to find that such an index is not useful, as they are not involved in decision making on the index and may not agree with its results. The expert emphasizes that US assessments should be adapted to the city in question, so that they can be useful for policy makers. The expert suggests that in order to address this issue, the measurement item must be as transparent as possible. Standardized indexes may not be transparent enough.

3) **Potential Misuse**: Two experts noted that indexes are often misused by cities. Cities may claim they're the smartest and may not really understand what this index shows or is based on, and will use such an index incorrectly. The two experts suggested different ways to address this potential of misuse; both insisted that this entails avoiding the design of an index. The first advised making the measurement item as transparent as possible. The other proposed defining separate scores for each of the seven focus areas of GUSF (see Fig. 3.1) and showing these scores individually to emphasize the smartness in every area of the city.

7.3 Changes to the Model

In response to the expert opinion interview findings, as described in the section above, the working SC definition, GUSF, and the theoretical version of GUSM are modified accordingly. These modifications are described in the three subsections below. The first concerns adjusting the SC definition of this research. The second concerns modifying the relationships in GUSF. The final concerns developing the flexibility and transparency of the model.

7.3.1 Adjusting the Smart City Concept Definition

As suggested by the experts the SC definition used by this research was changed. Following the recommendation from one expert the SC definition was aligned with the seven focus areas of GUSF (see Fig. 3.1).

In the original definition (which is displayed in Section 7.2.1) the phrase ”traditional transport and modern ICT infrastructure” has been replaced with ”general city and ICT infrastructure” . The SC definition used in this report is thus:

> *We believe a city to be smart when investments in human and social capital and general city and ICT infrastructure fuel sustainable competitiveness and a high quality of life, with a wise management of natural resources, through participatory governance.*

This definition will be used as the basis for this research.

7.3.2 Modifying the Global Urban Smartness Framework

A majority of the experts gave feedback concerning the uncertainty they have towards the relationships in GUSF. They suggested two main adaptations of the relationships in GUSF (as shown in Fig. 3.1). The first concerned the relationships between the desired outcomes and US constructs. The second concerned the relationships between the drivers and desired outcomes constructs.

These adapted relationships are displayed in the next version of GUSF (GUSF V2), as shown in Fig. 7.1.

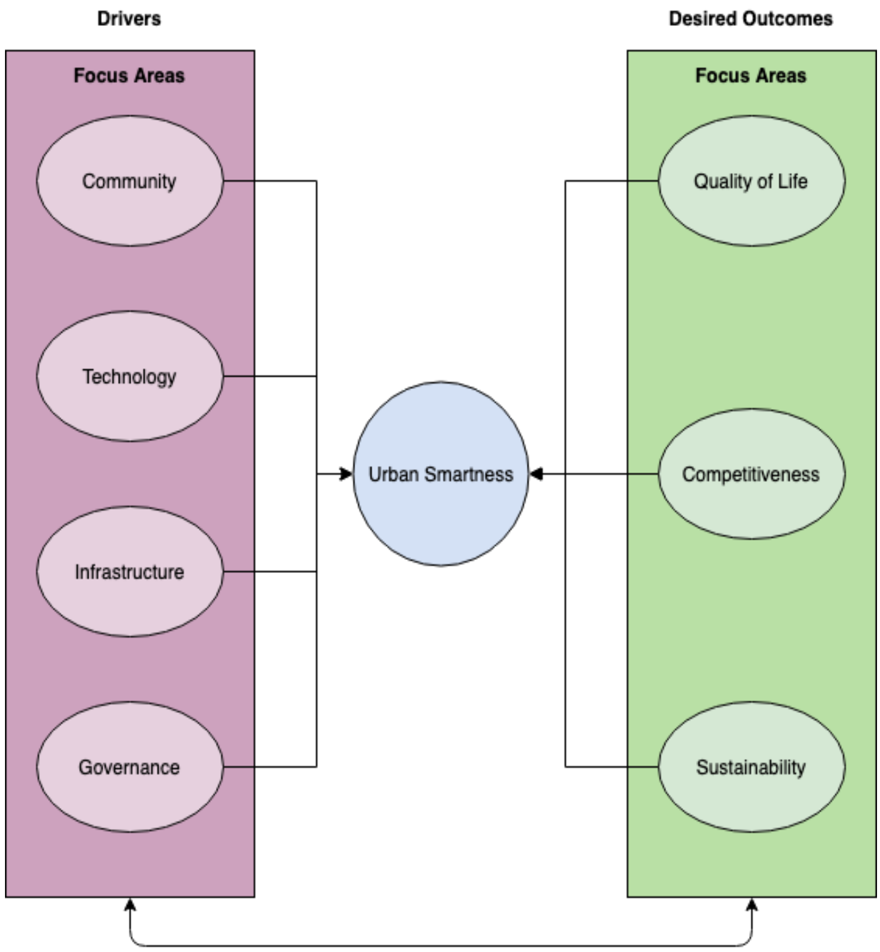


Figure 7.1: Global Urban Smartness Framework V2

Notice that a relationship between the drivers and desired outcomes focus areas is added. It is bi-directional as the relationships between the constructs are not currently known, but are expected to interact with each other. The relationships between the US and the desired outcomes constructs have been flipped around to show that the relationships in GUSF are not meant to imply causality, but that the US construct can be assessed by measuring the focus areas.

GUSF V2 will be used for the further development of GUSM.

7.3.3 Developing the Flexibility and Transparency of the Model

GUSM will be adjusted appropriately to address the uncertainty concerning the focus area contents of GUSF (as discussed in Section 7.2.2) and the index issue (as discussed in Section 7.2.4). This subsection details how it will be achieved.

Expert opinion interviews and reviewed research literature make clear that as the SC definition differs from city to city, US assessments will also be different as a result. This creates uncertainty as to what aspects of the city should be assessed and how to measure those aspects. This uncertainty is extended to what subcomponents should be associated with which focus areas and what they measure. This uncertainty can be addressed in two ways: enhancing the flexibility or transparency of the model. The uncertainty of focus area contents plays a part in creating the index issue.

Five experts suggested avoiding the development of an index due to 3 reasons concerning the local context of cities, problems with non-transparent indexes, and the possible misuse of those indexes. The experts suggest making the US assessment measurement item as flexible or transparent as possible.

To address the uncertainty about what the focus areas and their associated subcomponents cover and avoiding the index issue, GUSM has been updated in the following manner. The draft list of subcomponents shown in the interview discussion guide (see Appendix A) will not be used. Rather the first action in the second version (or V2) of the GUSM assessment approach will also concern the selection of subcomponents (as shown in Fig. 7.2).

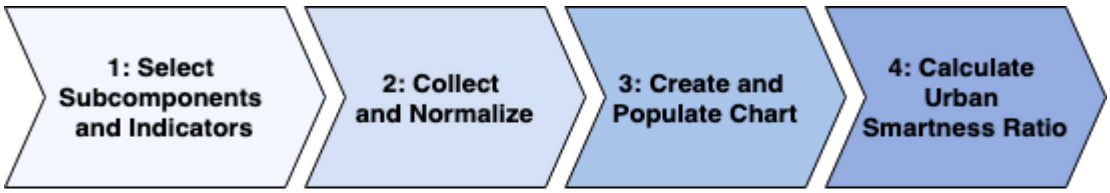


Figure 7.2: GUSM Assessment Approach V2

This is done to enable the US assessments conducted by GUSM to flexibly adapt to the cities as needed. The people conducting the assessment determine what the focus areas and their subcomponents cover so that the results of the assessment are useful for the city. This initial action sets up GUSM for the US assessment by selecting the subcomponents (and indicators that measure them) that will be used. The flexibility of GUSM can be further supported by providing users different options of sets of subcomponents (with associated indicators) for every focus area. GUSM's users can then select the set that most appropriately fits the local context of the city.

To ensure that GUSM remains as transparent as possible the indicators, subcomponents, normalization methods and calculation methods need to be documented and displayed so as to allow the users of GUSM a clear understanding of how the figures are generated.

This transparency is also enhanced through the use of the spider charts when conducting assessments (as discussed in Section 6.2.2). In spider charts, the values for the subcomponents of the seven focus areas are individually displayed. The spider chart visually combines these values and allows users of GUSM to understand how much each subcomponent contributes to US and illuminates the areas that are most in need of development.

GUSM's use of spider charts also helps to address the uncertainty of the relationships within GUSF (as discussed in Section 7.2.3). An US assessment measurement item can acknowledge the uncertainty in these relationships, but still identify, measure, and combine the main elements of the SC concept, by using a spider chart. What is important to note here is that the relationships within GUSF and their impact on each construct do not need to be researched and understood when conducting US assessments. Since the nature of the relationships within GUSF is unknown, unitless values are plotted in the spider charts from which a holistic picture of the US of a city can be gained. These charts can be used in communication as desired.

7.4 Summary

This chapter discusses the findings from the expert opinion interviews, conducted in the Theoretical Round. From the feedback collected, four main topics are identified in a previous section, and the working SC definition, GUSF, and GUSM are adapted according to these results.

CHAPTER 8

Artifact Demonstration

This chapter describes how GUSM is demonstrated and thus addresses part of RSQ 2.3. This is the first substep of iteration 2 (substep 5.a) from the development methodology of GUSM in Fig. 5.2. The demonstration of the artifact is referred to as the first version of the prototype of GUSM (or GUSM V1) and is described below. In this chapter, two cities will be introduced, whose US is assessed by the demonstration (GUSM V1). However, this chapter will begin by describing the purpose of this prototype.

8.1 The Purpose of Demonstration

This phase of development concerns the descriptive MM DPs from Table 4.5. These DPs are modified as described in the table below. The modified DPs are called GUSM Descriptive DPs and are shown in Table 8.1.

DP	Name	Description
2.1.1	Verifiable Assessment Criteria for each Focus Area	The used criteria should be verifiable so that the US assessment can be compared and replicated
2.2.1	Procedure Model	To support user guidance on how to conduct the US assessment
2.2.2	Advice on the Application of Assessment Criteria	To support the understanding of what needs to be measured, as well as how it can be measured
2.2.3	Guidance on Adaptation and Configuration of the Criteria	US assessment measurement items should be able to be tailored to particular environments, accommodate changes to meet the particular needs, assessment criteria should also be configured to specific characteristics
2.2.4	Verifiability of the Model	A model needs to be tested to verify measurement validity and ensure the results are accurate and that it fits its objectives, to support improvements if needed

Table 8.1: GUSM Descriptive Design Principles

The prototype, GUSM V1, conducts US assessments on two cities, which are introduced in the following section. For these assessments, a documented list of subcomponents and indicators are presented in the following chapter as required by GUSM Descriptive DP 2.1.1. GUSM Descriptive DPs 2.2.1, 2.2.2, and 2.2.3 are previously addressed by explanations in Section 6.2 and 7.3.3. The prototype description in Section 8.3 discusses how the prototype responds to GUSM Descriptive DP 2.2.1 and 2.2.2. GUSM Descriptive DP 2.2.3 concerns the guidance on the configuration of the assessment criteria that the model uses and is touched on throughout this chapter. The application of GUSM V1 to the two cities in the following chapter supports the understanding of conducting an assessment, required by the GUSM Descriptive DPs 2.2.1-2.2.3. GUSM Descriptive DP 2.2.4 concerns the verifiability of GUSM and the assessment results of GUSM V1 are used to validate the model and determine how potentially useful it can be from a practitioner's perspective. The validation will be detailed in Chapter 10.

The Purpose of the Prototype of GUSM (GUSM V1): It provides a practical measurement instrument to conduct an US assessment according to GUSM. This prototype gives example assessments, detailing how the measurement is done and illuminates how the GUSM Descriptive DPs are satisfied.

8.2 The Cities to be Assessed

The two cities whose urban smartness will be assessed to validate GUSM are briefly introduced in this section. In Iteration 2 (step 5) from the development methodology of GUSM in Fig. 5.2, the theoretical version of GUSM is operationalized for two cities: Enschede and Münster, two European cities.

As Mora et al. found [64], Europe produces the most SC research including how to assess US in cities. Country and city governments around Europe collect and provide a large amount of data in publically available online databases. This data allows GUSM to use publicly available indicators and assess the US of European cities. In published SC research one such database, Eurostat, is often used [21, 36, 54]. Eurostat provides indicator data from European cities, regions, and countries, combining the data in a number of publicly accessible online databases. GUSM V1 uses the indicator data in the Eurostat databases to assess the US of the two cities.

An important thing to note is that these two cities are brownfield cases (as discussed in Section 2.1), in that they exist, thus their US can be assessed. This is a prerequisite of the applicability of GUSM (as discussed in Section 6.1.2).

The city of Enschede is in the Overijssel Region of the Netherlands and one of the cities to be assessed. It is one of the test cases for the prototype. Enschede is a medium-sized provincial city with around 160.000 citizens in January 2019, based on the Netherlands' Central Bureau of Statistics Statline webpage. It has implemented a number of smart projects under the "Smart Enschede" platform[1].

The city of Münster is located in the state of North Rhine-Westphalia in Germany and is the second city that will be assessed. It is the second test case for GUSM V1. Münster is a mid- to large-sized city with around 315.000 citizens, based on Eurostat population data, published in 2018. Münster officially began its platform "Einfach. Smart. Münster" in 2020[2].

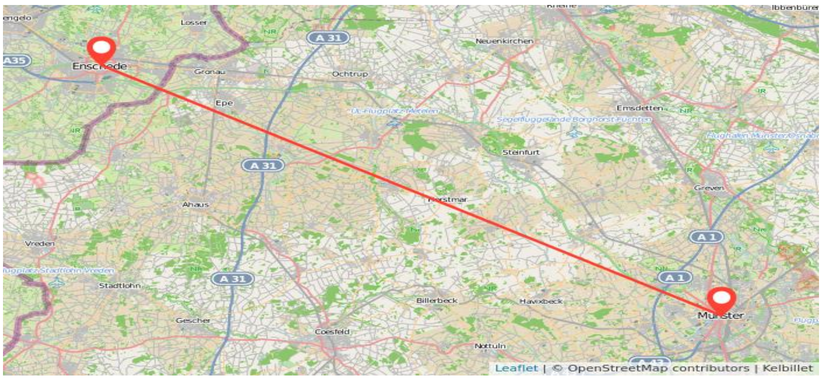


Figure 8.1: Enschede and Münster

[1]As can be seen on the Smart Enschede platform website: https://smartenschede.nl/)
[2]See Münster's smart city platform website: https://smartcity.ms/

In 2019 these two cities formed a partnership and became twin cities, where they can work together with EU funding [40]. The two cities are only 70 km apart and are located across the Netherlands-German border (see Fig. 8.1).

GUSM V1 is operationalized using data from these twin cities in the following chapter.

8.3 The GUSM Prototype

This section will describe certain details of the prototype of GUSM including the medium it is in, the theory it will use and a general description of its structure. This is not a comprehensive description of the operationalization, but explains the GUSM V1 concept. This section will describe how the demonstration of GUSM conceptually satisfies GUSM Descriptive DP 2.2.1 from Table 8.1.

GUSM V1 is based on the second version of the Detailed GUSF (or Detailed GUSF V2) as shown in Fig. 8.2. This is an updated version concerning the relationship adjustments of GUSF V2. As discussed in Section 6.2.1, this model shows how GUSM conducts US assessments, namely that for every focus area one or more subcomponents are measured through the use of indicator(s) associated with every subcomponent. Thus, the descriptions of these measurements address GUSM Descriptive DP 2.2.2.

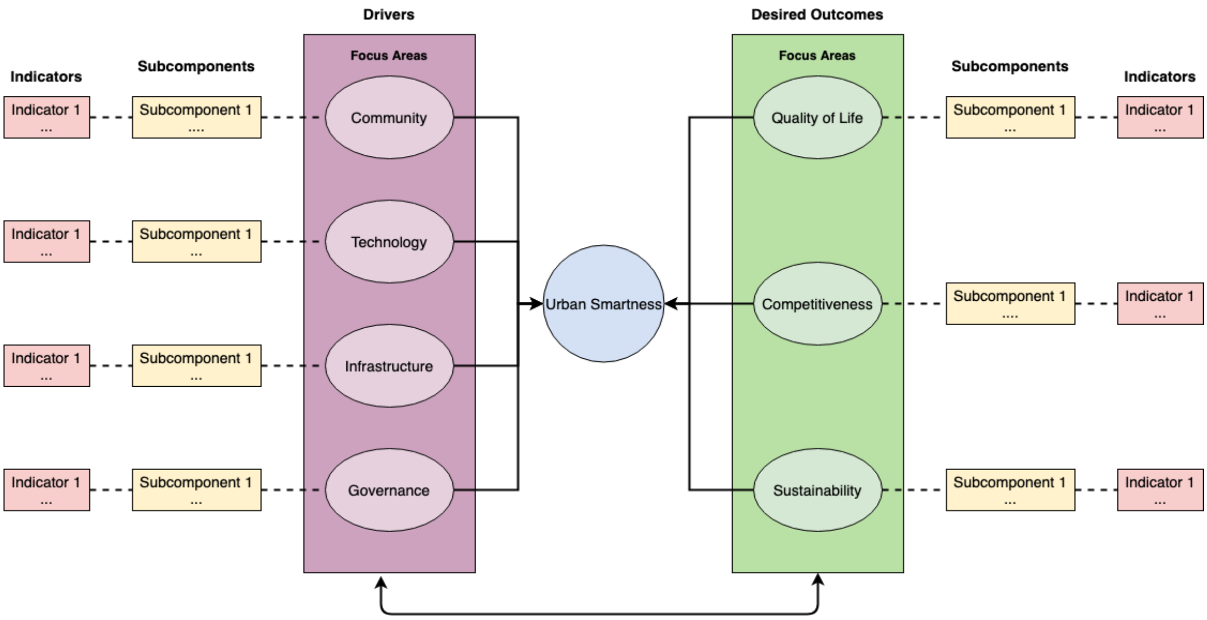


Figure 8.2: The Detailed GUSF V2

GUSM V1 was developed in the format of a Microsoft Excel file. This file contains 13 worksheets with the first four the main worksheets, the following two are reference worksheets that provide more information, and the last seven contain the background raw data used by the four main worksheets. The four main worksheets are: (1) The Introduction of GUSM; (2) The Individual City Assessment Dashboard; (3) The Comparing Assessments Dashboard; and (4) The Potential Development of GUSM. In addition, two reference worksheets are provided to support the use of the four main worksheets. Worksheet 5 contains the methods and formulas used by the dashboards of worksheets 2 and 3. A glossary of terms used by GUSM V1 is given in worksheet 6. The four main worksheets have the six elements A to F, as shown in the worksheet template in Fig. 8.3. They are described in the following paragraphs.

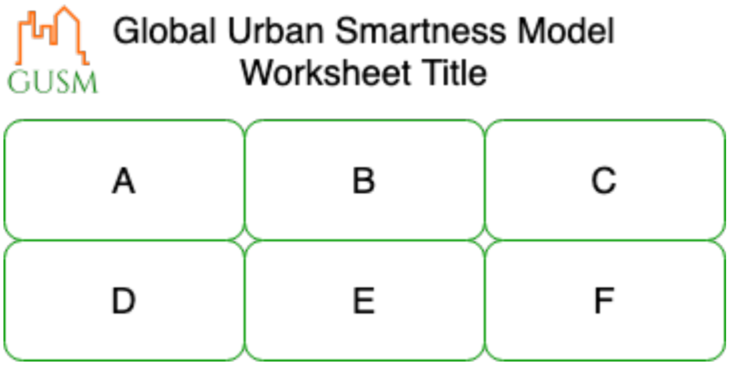


Figure 8.3: GUSM V1 Worksheet Template

The introduction of GUSM: In the first worksheet, the theories behind GUSM and US assessment are explained. How GUSM conducts US assessment is also detailed. In element A the general concept of US and SCs are introduced and defined. Element B's content identifies what decisions and questions must be addressed to improve US. GUSM's framework and how to measure the focus areas in the framework are discussed in element C. Element D briefly describes the four action steps in the GUSM Assessment Approach (see Fig. 7.2). A guide on what the first six worksheets contain is given in element E. Finally, element F shows the main benefits of GUSM. With this worksheet, users of GUSM V1 have an overall understanding of what theories GUSM uses, how it conducts US assessments and how it can benefit the users.

The Individual City Assessment Dashboard: The second worksheet presents the results from an US assessment of one of the two cities. Element A lists and details the focus area measures. For each focus area a list of the associated subcomponents and indicators is displayed (including the unit and the year of the indicator data). In element B the values of those indicators are shown in a bar chart. Element C contains 3 filters. The first of which allows the user to choose whether the data are normalized. The second filter allows the user to select the city whose data is displayed. The third filter enables the user to select one or more focus area(s) shown in the worksheet, allowing the associated measurements to be highlighted more. Element D has what is referred to as the "US Spider Chart" that contains a spider chart that plots the indicators and their values, thus providing a visual representation of the city's US. The US spider chart is similar to the spider chart in the Fig. 6.4. Note that for the US spider chart to work, the filter for normalization in element C must be set to 'Yes'. Element E exhibits the US Ratio if, in element C, normalization is set to 'Yes' and the focus area filter has all the focus areas selected. The US ratio is calculated as discussed in Section 6.2.2, and is displayed in a bar chart. Element F's contents provide general descriptions of the normalization methods used. This element also points to the two reference worksheets.

The Comparing Assessments Dashboard: The third worksheet is very similar to the previous, the Individual City Assessment Dashboard, in that it presents and combines the results from US assessments conducted on the two cities. These assessments are conducted using the same set of subcomponents and indicators. Therefore the two cities' US assessments can be compared. This worksheet elements mirror the elements of the previous worksheet, except that they include data from both cities. Element A contains the main information and values from the indicator data from both cities. In elements B, D and E results are shown for both cities. Element C is slightly different as the city filter no longer exists. Finally, element F displays the same general descriptions and references as element F in the Individual City Assessment Dashboard.

The Potential Development of GUSM: The fourth worksheet discusses how GUSM can be developed to be more useful by adding certain features. The elements A to D describe how GUSM can be improved through these features. In order to identify and prioritise features that improve the usability of GUSM, element A emphasizes the need for more user-centric studies. This suggests several features that focus on improving the visualization capability (of all charts but especially the US spider chart) of the two dashboards and GUSM's fit with other user systems. Element B concerns how automation (or making the set-up and data collection automatic) can improve the ease of use of GUSM. Element C's contents suggest optional sets of subcomponents, indicators and normalization methods to be chosen by the users when setting up an US assessment. This is in order to support the flexibility and transparency of the model and help users set up GUSM as desired in a more easily understood and clear fashion. Element D discusses how the US Ratio can be used to conduct long-term analysis. Element E covers the benefits these additional features provide, while element F shows the additional features in an example.

8.4 Summary

In this chapter the demonstration concept is discussed. The first section introduced the prototype of GUSM, GUSM V1, which is an US assessment measurement item. It provides an example of how GUSM conducts US assessments, by using the data from the two cities of Enschede and Münster, introduced in the next section. The final section gives an overview of the prototype and the worksheets that it contains. The next chapter identifies how GUSM V1 is operationalized and used.

CHAPTER 9

Operationalization and Demonstration

This chapter details how the prototype of GUSM (GUSM V1) is operationalized for two cities, Enschede and Münster. It demonstrates how GUSM conducts the US assessments of those cities and what results it produces. Thus this chapter completes the discussion on RSQ 2.3. GUSM V1 is operationalized by conducting the four actions from the GUSM Assessment Approach (see Fig. 7.2). In connection with these actions, this chapter covers the last three substeps (5b-5d) of Iteration 2 from the development methodology of GUSM in Fig. 5.2. These substeps are concerned with GUSM Descriptive DPs 2.1.1 and 2.2.1-2.2.3, and the operationalization and demonstration in this chapter show how the prototype satisfies the DPs.

This chapter is divided into five sections with the first four concerning the four actions from the GUSM Assessment Approach. The first details the selection of the subcomponents and indicators to be used in the US assessments. The next three sections detail how the indicators are normalized, GUSM V1's use of the US spider chart, and an example of how the US Ratio is calculated and displayed by GUSM. The final section shows how GUSM V1's US assessment results can be used by the city being assessed.

Note that this research is more concerned with whether such a US assessment measurement item can be built. The subcomponents, indicators, and normalization methods selected for the prototype allow for an approximation of an US assessment the instrument can provide. They have not been identified as items to always use, rather they will need to be changed depending on the local context of cities.

9.1 Action 1: Select Subcomponents and Indicators

This section describes how action 1 of the GUSM Assessment Approach is conducted for the two cities. As was previously discussed the operationalization of GUSM V1 is not a real-world implementation of GUSM, where the cities are involved in the selection of subcomponents and indicators to be used in the assessment. This research does not implement GUSM and the cities were not involved in this operationalization. Rather this operationalization focuses on identifying available indicators, shared by both cities. These lead to a list of indicators each associated with a topic, which become the subcomponents associated with each focus area.

The list of subcomponents and their list of indicators fulfill the requirement set by GUSM Descriptive DP 2.1.1 from Table 8.1 as they define the verifiable assessment criteria used to conduct US assessments with GUSM. The following section first details the data source of the indicators to be used. The next identifies the selection method used to find the indicators. The final section identifies the subcomponents and the associated indicators used.

9.1.1 Indicator Regions

This section concerns how the EU's publicly available database, Eurostat, defines what their indicators measure. In Eurostat, every indicator measures certain aspects of a region. These regions are divided into several categories, and Eurostat has complex codes it uses to identify the regions that its indicators apply to. However, this research seeks to simplify these region categories and uses three levels.

In this research, each indicator is assigned a **Local**, **Regional**, or **National** level respectively: for a city or its local environment; for a state, province, or part of a country; or for a country. When the indicators to be used in this demonstration are presented, they are each assigned with a specific level.

It is important to highlight that data that pertain to the local context of a city should be used as much as possible. This study only uses publicly accessible data for its demonstration of GUSM. In a real-world implementation where cities are involved in setting up the model for US assessments, the cities may have more internal data sources available and thus more local level indicator data can be used.

9.1.2 Indicator Selection Method

This section details the method used for selecting the indicators (and as a result the subcomponents as well). The indicators are selected from the study of Giffinger [36], or from two ISO standards, ISO 37120 [44] and ISO 37122 [45]. ISO 37122 was published in 2019, the referred source is a working draft of the standard. In the two ISO standards over 200 indicators in total are proposed and they are split into broad categories. In [36], Giffinger proposes 74 indicators, which are separated by US assessment constructs. The proposed indicators are further separated by what aspect/topic they cover within each construct. However, the indicators from this study published in 2007 are older and many are not collected currently by Eurostat. The ISO standards contain more indicators (and cover other aspects) than the Giffinger research [36]. The aspects not covered by Giffinger's study are included as well. In those cases, relevant indicators are selected from the ISO standards.

Those sources list indicators that are relevant to measuring topics of the SC concept. In this research, these topics are referred to as subcomponents. For most of these subcomponents, there are multiple indicators to use. In this demonstration, if multiple indicators cover the same subcomponent only one indicator is selected.

To select the indicators (and the associated subcomponents) five rounds were conducted. The rounds of the indicator selection method are described below:

1) **Set up Selection of indicators**: In [36], Giffinger proposes 74 indicators dividing them between 31 subcomponents (or indicator topics). Those subcomponents are realigned to the focus areas in GUSM, which are comparable to the constructs in the US assessment framework from [36]. For example, the Competitiveness focus area is related to the Smart Economy construct in [36]. These indicators are filtered in the following two rounds.

2) **Eliminate Subjective Indicators**: as noted by Al-nasrawi et al. [66], a city's smartness depends heavily on its citizens' perceptions of living in their city. Capturing data on citizen perceptions often involves using more qualitative data. This qualitative data is collected by using subjective indicators. However, as Carli et al. [22] found, across the world objective indicators are more generally collected by cities than subjective indicators, regardless of the level of technological development of a city. Most indicators that Eurostat collects are objective and this is reflected in this round as subjective indicators will be eliminated in this demonstration. In the case, where only one possible indicator is left, the remaining indicator is selected.

3) **Eliminate Unavailable Indicators**: The Eurostat database is checked to see if the indicator data is available for the two cities, Enschede and Münster, and concern the same year. If that indicator is not available, another indicator with a similar or the same topic is used instead. Again in the case, where one possible indicator is left, the remaining indicator is selected. If it is not available then it is eliminated.

4) **Repeat for ISO Standards**: If no indicator is found for a subcomponent, all the previous rounds are repeated, using the two ISO standards as a source. The two standards define around 40 subcomponents and suggest over 200 indicators [44, 45]. The subcomponents proposed by the standards and Giffinger's study [36] overlap, but new subcomponents are proposed that fit into the focus areas of GUSM. In the case where no indicator has been found in a subcomponent identified in [36] this research will look to select one of the indicators in the standards. This is also done where the standards contain indicators related to subcomponents not covered by Giffinger's research, for example, indicators concerned with solid waste.

5) **No Available Indicator**: For the case that no indicators can be found for a subcomponent, that subcomponent is not included in the assessment.

Using this selection method indicators were found for most topics, but the Eurostat databases did not have any indicators for both cities for a few subcomponents, especially for the new ISO standard 37122. For example, Eurostat databases did not collect indicators on cities' urban/local agriculture and food security situations.

Eighteen indicators, associated with subcomponents, were found for both Enschede and Münster. These are presented and detailed in the following section.

9.1.3 Selection Results: The Subcomponents and their Indicators

This section presents the eighteen indicators and the subcomponents they are associated with. The identified indicators and subcomponents are the initial verifiable assessment criteria used by GUSM V1 as is needed to satisfy GUSM Descriptive DP 2.1.1. These indicators are shown in the operationalized version of the Detailed GUSF in Fig. 9.1. As the Detailed GUSF has been operationalized, this can also be referred to as the US assessments conducted by GUSM V1. More details on these indicators are displayed in Table 9.1 below.

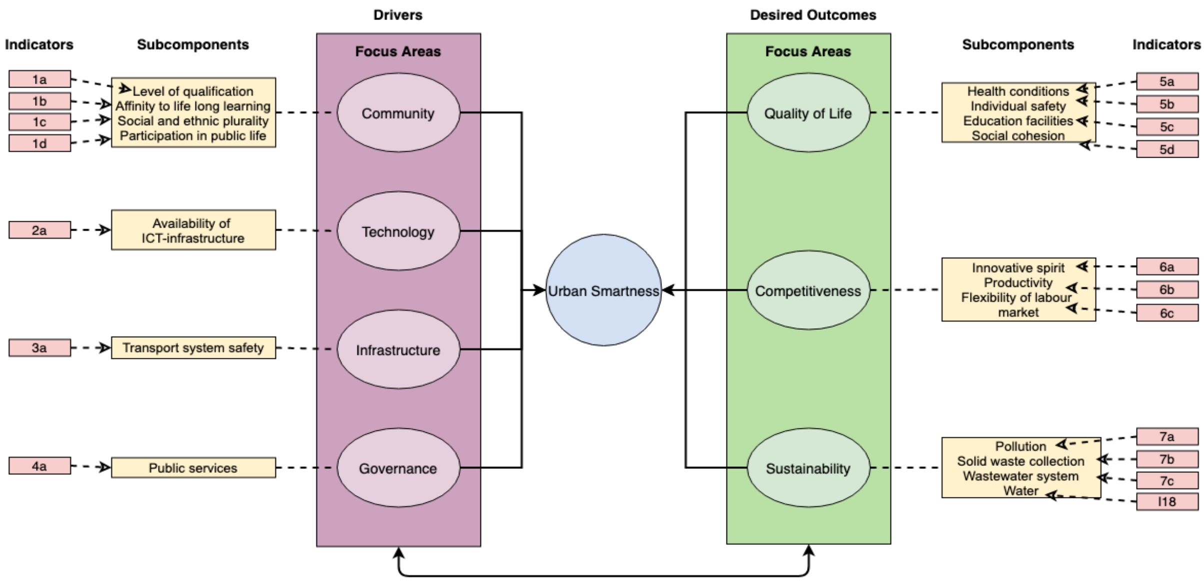


Figure 9.1: The Operationalized Detailed GUSF V2

Note that the indicators are numbered according to what focus area they are associated with.

For each indicator, Table 9.1 specifies the subcomponent it is associated with and its number is referenced in Fig. 9.1. They both show what focus area the indicators measure. Besides their association with the focus areas, the region coverage level and the year each indicator pertains to is also shown.

No.	Subcomponent	Indicator	Level	Year
1a	Affinity to life long learning	**Participation in life-long-learning (Adult Learning)**	Regional	2018
1b	Level of qualification	% **of pop. qualified at level 5-8 ISCED**	Local	2012
1c	Social and ethnic plurality	**Foreigners as a proportion of the population**	Local	2016
1d	Participation in public life	**Participation in voluntary work**	National	2015
2a	Availability of ICT-infrastructure	**Broadband internet access in households**	Regional	2018
3a	Transport system safety	**No. of victims killed in road accidents per 100k people**	Local	2013
4a	Public services	**Use of the internet to interact with public authorities**	Regional	2018
5a	Health conditions	**Life expectancy**	Regional	2017
5b	Individual safety	**Death rate by assault**	Regional	2016
5c	Education facilities	**Students per inhabitant**	Regional	2015
5d	Social cohesion	**Share of persons at risk of poverty after social transfers**	Local	2012
6a	Innovative spirit	**Patent applications per inhabitant**	Local	2012
6b	Productivity	**GDP per employed person**	Local	2016
6c	Flexibility of labour market	**Unemployment Rate**	Local	2016
7a	Pollution	**Crude death rate of chronic lower respiratory diseases**	Regional	2016
7b	Solid waste collection	% **of city population with municipal waste collection**	Regional	2013
7c	Wastewater system	% **of pop. connected to wastewater collection and treatment system**	Regional	2010
7d	Water	% **of city pop. with potable water supply service**	Local	2011

Table 9.1: The Indicators and Subcomponents used by GUSM V1

It is clear that the indicator data that are publicly available through the Eurostat databases may not be at the lowest region coverage level or for the most recent year. The lack of availability of more appropriate and up to date indicators limits the US assessments carried out by GUSM V1 as a result. As previously discussed in this chapter, the scope of this research is on developing an US assessment measurement item. A high-quality indicator selection process is outside the scope of this research. The eighteen indicators, their associated subcomponents and their data sources are meant to be approximations of the US assessment criteria that GUSM could use. When conducting US assessments with GUSM, the use of indicators that are measured in the same year is not needed. However, not using measurement of the same period of time has an effect on the perceived validity or accuracy of the US assessment results. Therefore, the information on each indicator concerning the year they measure must be (as discussed in Section 7.3.3) and is displayed transparently by GUSM.

These indicators are used to apply GUSM V1 to the two cities and are expected to provide a useful overview of the US situation of both cities. To provide this overview, the next three actions of the GUSM Assessment Approach (see Fig. 7.2) are conducted. These actions will each be detailed in the next three sections and concern GUSM Descriptive DP 2.2.2, which regards how the verifiable assessment criteria (identified in Table 9.1) are used to measure US.

9.2 Action 2: Collect and Normalize

This section describes how the second action of the GUSM Assessment Approach (see Fig. 7.2) is done. It concerns how the verifiable assessment criteria for GUSM Descriptive DP 2.1.1 (see Table 9.1) are prepared for the next actions in the GUSM Assessment Approach. This section describes how the assessment criteria are manipulated so that they can be applied in the measurement GUSM V1 conducts. Thus, it concerns GUSM Descriptive DP 2.2.2.

As discussed in Section 6.2.2, when this action is conducted, the collected indicator data are manipulated through normalization. This normalization ensures that the data fits into the same numerical scale and thus can be combined as needed. Normalization is needed in cases where indicators have:

- **Different Targets**: When the general desire (or the target) of cities is for the indicator data to score as high as possible or as low as possible. For example, for indicators like ”death rate by assault” , the target of cities is to keep the numbers found as low as possible. While for other indicators like ”broadband internet access in households” , the target often is to attain the greatest accessibility possible. The desire is for the indicator data to be scored very high. This issue is further exacerbated by indicators such as the ”unemployment rate”, where the target is explicitly not at the extremes. Rather the target would be closer to the ”natural unemployment rate” [14].
- **Different Units**: Some indicators have percentages (scale of 0-100) for its unit, like ”the foreigners as a proportion of the population”. While others use different scales, like ”number of victims killed in road accidents per 100.000 people” or are not limited by a set scale, for example ”life expectancy” (expressed as an age, which is always greater than 0 and there is no set maximum limit).

To enable US assessments all the indicators must be normalized due to the two reasons described in the paragraph above. This is done, using one of the following two normalization methods. All methods refer to normalizing the indicators by combining them with the indicator data from similar regions. These similar regions are based on the Eurostat regional coverage categories (as discussed in Section 9.1.1).

1) **Max-Min**: This method calculates the percentile of the city's indicator data amongst the range of indicator data from similar regions within the city's country.
2) **Max Coverage**: The city's indicator data value as a percentile of the maximum value of the other similar regions.

These two methods are examples of the types of normalization methods that can be used. Finding appropriate methods for such an assessment is outside the scope of this research. This prototype being a demonstration of GUSM, it is not concerned with identifying which normalization methods should be used with US assessments.

What normalization method is used for each indicator is displayed in Table 9.2.

No.	Indicator	Normalization Method
1a	Participation in life-long-learning (Adult Learning)	Max-Min
1b	% of pop. qualified at level 5-8 ISCED	Max-Min
1c	Foreigners as a proportion of the population	Max-Min
1d	Participation in voluntary work	Max-Min
2a	Broadband internet access in households	Max Coverage
3a	No. of victims killed in road accidents per 100k people	Max-Min
4a	Use of the internet to interact with public authorities	Max Coverage
5a	Life expectancy	Max-Min
5b	Death rate by assault	Max-Min
5c	Students per inhabitant	Max-Min
5d	Share of persons at risk of poverty after social transfers	Max-Min
6a	Patent applications per inhabitant	Max-Min
6b	GDP per employed person	Max-Min
6c	Unemployment Rate	Max-Min
7a	Crude death rate of chronic lower respiratory diseases	Max-Min
7b	% of city population with municipal waste collection	Max Coverage
7c	% of pop. connected to wastewater collection and treatment system	Max-Min
7d	% of city pop. with potable water supply service	Max Coverage

Table 9.2: The Normalization Methods of the Indicators

Once the indicator data values are normalized, these normalized values can be used for the next GUSM Assessment Approach actions, as are described in the following sections.

9.3 Action 3: Create and Populate Chart

For the third action, the now normalized indicator data values are visually combined and plotted on a spider chart. This chart is referred to as the US spider chart. The use of the US spider chart is discussed in Section 6.2.2. The US spider chart combines and presents the assessment criteria from Table 9.1. Therefore, that plotting concerns the application of those criteria or how GUSM V1 satisfies GUSM Descriptive DP 2.2.2.

The areas covered by the indicator data in the US spider chart are used to display the assessment results for one city or visually compare the assessments of the two cities. The area covered in these charts is also used to conduct the final action of the GUSM Assessment Approach. This last action is detailed in the next section.

9.4 Action 4: Calculate the Urban Smartness Ratio

The fourth action of the GUSM Assessment Approach concerns the calculation of the US Ratio.

Once the normalized indicator data are plotted on a US spider chart, the area that those indicator data cover can be measured for a city. The surface area covered in the US spider chart can be calculated into the US Ratio. The formulas to calculate the US Ratio are discussed in Section 6.2.2. The calculation of this ratio is the final way the assessment criteria (from Table 9.1) are applied, and address GUSM Descriptive DP 2.2.2.

This US Ratio, which is only one number, offers great potential for further analysis of the US situation of a city. For example, the US Ratio can be monitored over time and thus how it is trending can show if the city is developing as desired. If more detail is needed, the US spider charts corresponding to the US Ratios contain additional information on the measurements of the individual focus areas.

This section deals with the last action from the GUSM Assessment Approach. The next section will demonstrate the results these actions produce, using the criteria to conduct US assessment on the two cities.

9.5 Demonstrating the Global Urban Smartness Model

Completing the actions of the GUSM Assessment Approach produces a number of visual displays of indicator data for a city. This section will describe how this data is presented.

To provide an example of the assessment results for an individual city, the data for Münster will be used. Once the indicators are normalized they can be presented in a bar chart, see Fig. 9.2. As can be seen in the chart, the indicators have been given different colours respective to what focus area they measure. For example indicators of the "Competitiveness" focus area are coloured green. This allows for a clear understanding of what the indicator data measurements are.

In Fig. 9.3, the US spider chart of Münster is shown. The US spider chart visually presents those indicator values and how much surface they cover. The more surface is covered, the higher its resulting US Ratio is. This chart provides a simple overview of the US of a city that can be communicated and discussed as needed.

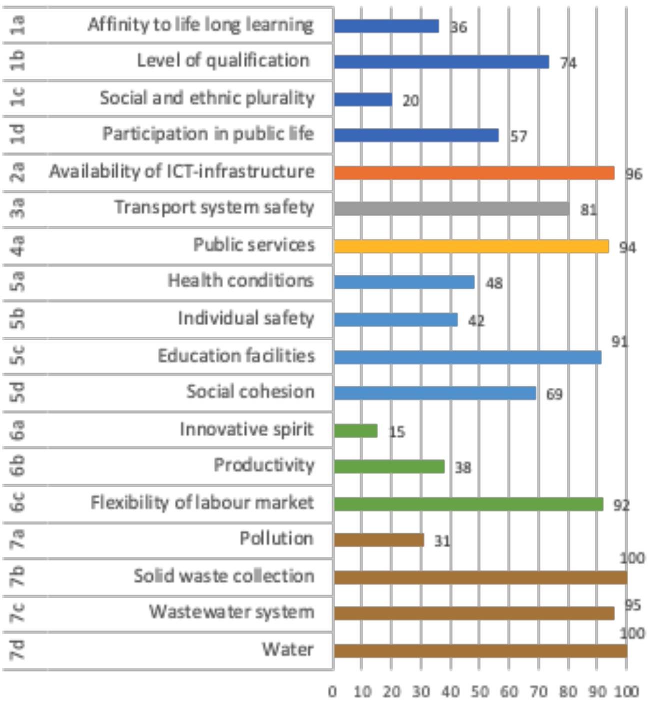


Figure 9.2: Normalized Indicator Data for Münster

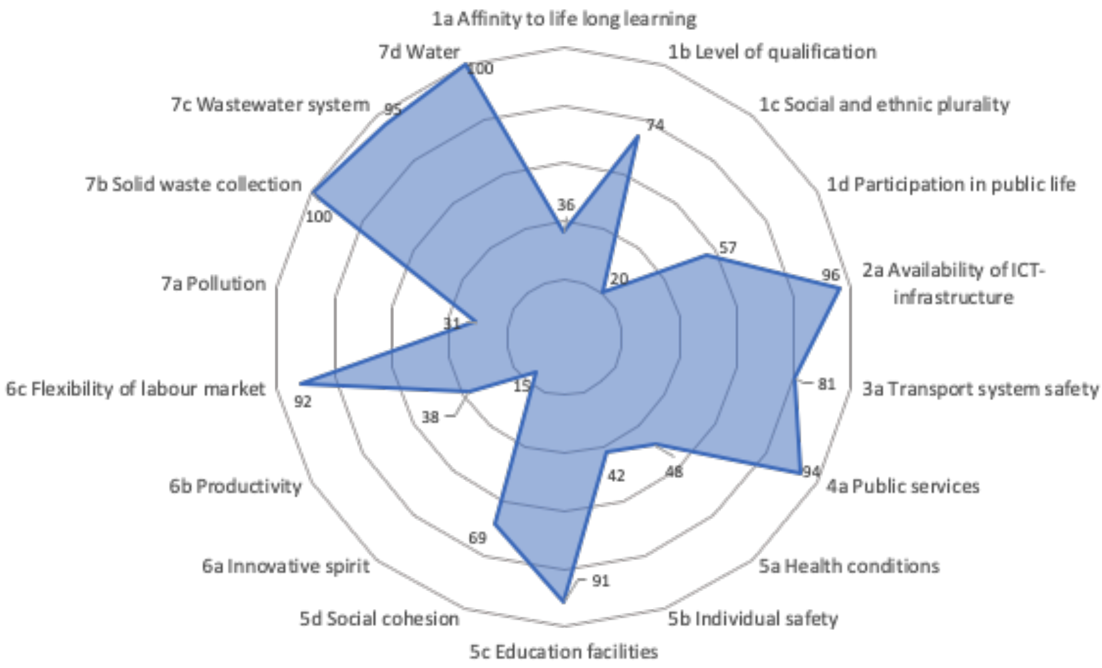


Figure 9.3: The US Spider Chart of Münster

The US Ratio of Münster is presented in the bar chart (see Fig. 9.4). This is the final output of GUSM V1, when assessing an individual city.

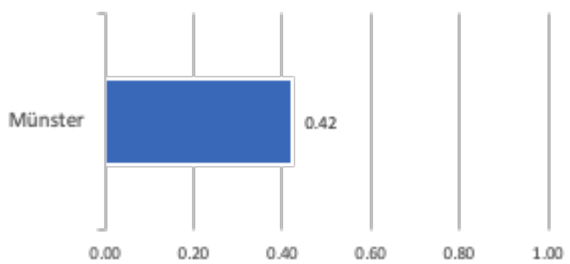


Figure 9.4: The Urban Smartness Ratio of Münster

When comparing the US assessments of two cities (assuming both US assessments are set up with the same assessment criteria), each of the charts in the previous three figures can include data from both cities, as can be seen on the Comparing Assessments Dashboard (described in Section 8.3). An example of this is shown in Fig. 9.5, where the US spider chart displays the indicator data from both Münster (whose data is shown in blue) and Enschede (whose data is shown in orange). The visual differences between the two surfaces covered by the indicator data show areas where the two cities can learn from each other. Another example of this is shown in Fig. 9.6, the US Ratio bar chart shows the ratios of both Münster and Enschede.

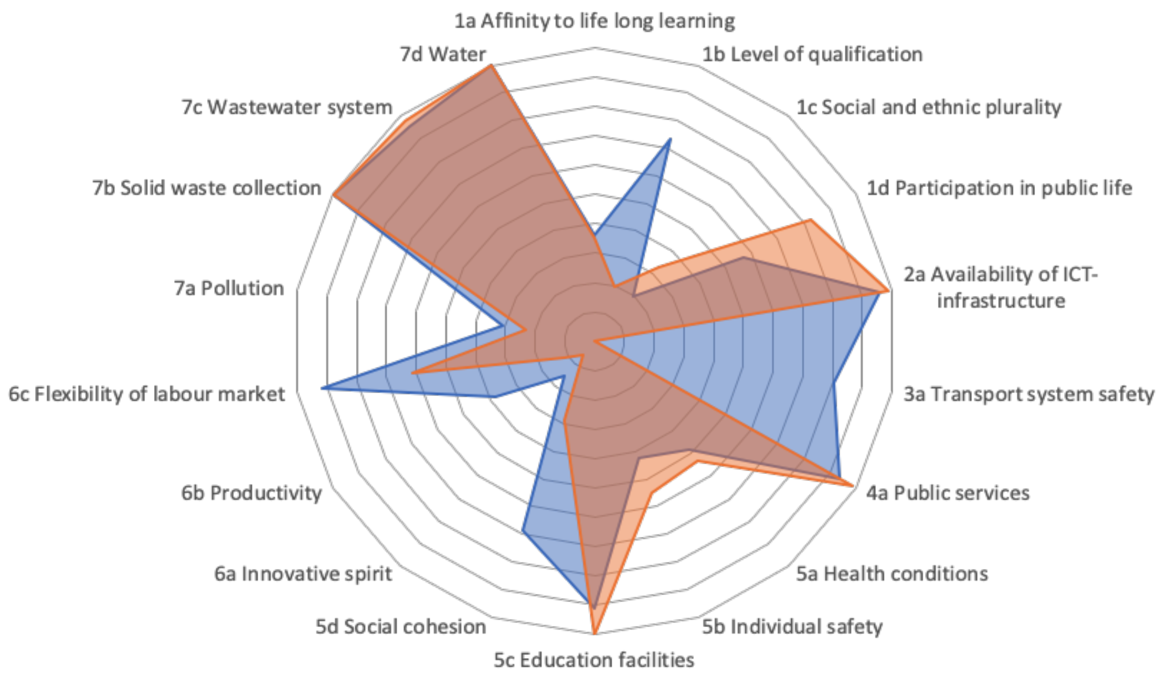


Figure 9.5: The Urban Smartness Spider Chart Comparing the Data from Both Cities

GUSM V1 being operationalized for the two cities can conduct US assessments and can be used to gain an overview of the US of Enschede and Münster, and provide support for decision making concerning smart project implementation. The results of the assessment are designed to be visually clear so that they can be included in communications relating to the US of the city. The next chapter concerns testing the demonstration of GUSM.

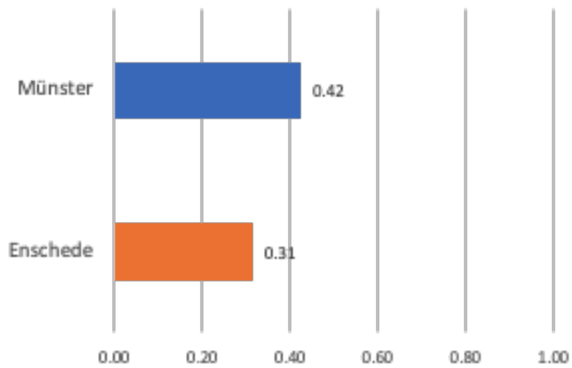


Figure 9.6: The Urban Smartness Ratios of Both Cities

Part III

Treatment Validation

CHAPTER 10

Validation Round Evaluation

This chapter concerns validating the usefulness of the demonstration of GUSM from the target group's perspective (the target group is identified in Section 6.1.4). This is done by qualitatively evaluating what experts think of the prototype of GUSM (as described in Chapters 8 and 9). For this evaluation, two expert opinion interviews collected feedback on the demonstration of GUSM, GUSM V1, and are in the Validation Round. Thus, this chapter addresses RSQ 3.1 and step 6 of the GUSM Development Methodology in Fig. 5.2. The first section discusses how the demonstration of GUSM is validated and the next describes how the expert opinion interviews in this round are prepared. The last section details the findings of these interviews.

10.1 Concept of Validation

This section describes the concept of the validation that occurs in the Validation Round. Much like in Chapter 7, GUSM V1 will be tested by conducting two expert opinion interviews. The expert opinion interviews satisfy GUSM Descriptive DP 2.2.4 in Table 8.1, as they are used as tests of this demonstration to evaluate the validity of GUSM and that it fits its objectives and can be useful for cities who want to conduct US assessments.

The results of these expert opinion interviews are analyzed in order to provide a complete answer to the main research question. This question concerns "how can a city's urban smartness be measured for cities around the globe in a standardized universal approach". GUSM V1 is a demonstration of a potential solution to address this question and supports decision-makers to identify project areas or topics that the city should focus their investment in. The focus of these interviews is to determine how potentially useful GUSM is from the perspective of relevant city authorities (or the target group).

People who make such decisions for a city are interviewed about the usefulness of the prototype of GUSM. However, a city government official from Münster was not available to be interviewed. Therefore, a city official of a different city is needed. More detail on the selection of these experts will be described in Section 10.2.1. Their responses in the expert opinion interviews are collected and analyzed in order to generate findings on the usefulness of GUSM and its prototype from their perspective. The next section describes how these interviews are prepared.

10.2 Validation Round: Interview Preparation

In Section 1.4.2 it was made clear that the model is evaluated by conducting semi-structured, one on one, confirmatory interviews, and it has subsections on the methods of interview preparation, data collection, and analysis.

As noted in Section 1.4.2.1, there are considerable differences between the two rounds. The interview preparation methods from Kallio et al. [46] are used for both rounds. Interview preparations for the Validation Round is discussed in this section.

Like for the Theoretical Round interviews (discussed in Section 7.1), standard data collection and analysis methods are used. See Section 1.4.2.2 for more details on these methods.

The following two subsections respectively detail the experts to be interviewed, and describe the development and content of the interview materials used.

10.2.1 Experts Interviewed

An activity that must be conducted to prepare for any interview, is the selection of experts who are to be interviewed (highlighted in Section 1.4.2.1). This subsection will describe the selection of the two experts to participate in the expert opinion interviews.

The experts in question are from the city governments. As noted before (in Section 10.1), an official from Münster is not taking part in these interviews. Therefore, a city government official (referred to in this chapter as expert) from a nearby German city of similar size, Wuppertal, was interviewed.

The second expert is another government official for the city of Enschede. Both experts are tasked with overseeing the SC programs of their cities (and in the case of the expert for Wuppertal, other areas and cities within it's SC ”cluster”). They thus both have knowledge on the SC concept and US assessment, and they were identified as the city government officials to interview about conducting US assessments. This research refers to those experts by the name of their cities, Enschede and Wuppertal.

The opinions of these experts are solicited on whether GUSM V1 is potentially useful from the expert's perspective. Their feedback is crucial to determining whether such an artifact is interesting to be developed further for use by their cities. These two participants were interviewed using the material described in the next subsection.

10.2.2 Materials Used

This section describes the materials used for the interviews in the Validation Round and how these materials are created. The method for developing material for a semi-structured, qualitative interview from Kallio et al. [46] was followed. It produces a complete Interview Discussion Guide that identifies the general structure, the purposes for the interviews, the main topics, and the interview questions. The interview questions concern the experts' opinions on the prototype of GUSM. This discussion guide is given to each expert before their interview and includes information on the SC concept and the theories behind GUSM. This guide is shown in Appendix H.

The Interview Discussion Guide asks the experts to respond to a number of statements. These statements concern identifying how people feel about using and accepting a technology system. The statements come from the Unified Theory of Acceptance and Use of Technology (UTAUT) model of Venkatesh et al. [89] and more specifically Table 16 in that study. Fifteen of those statements (at least one item for each root construct defined in the article) were chosen for this research; as all could not be discussed in one interview. They are displayed in Table H.4 of the Interview Discussion Guide in Appendix H. This research project will analyze the potential usefulness of GUSM by collecting the experts' responses to those fifteen statements. The experts respond using a five point Lickert scale (see Table H.3) which reflects how positive or negative their reactions are to the statements. Per statement, the experts are then asked for the reasons behind their response.

In addition to the Interview Discussion Guide, the prototype of GUSM (GUSM V1) is also used during the interviews, as the object the experts would share their feedback on. GUSM V1 is designed to visually show the US assessment results for both cities, thus can be presented during the interviews.

These two pieces of interview materials are further developed by conducting three pilot tests (defined in Section 7.1.2). First an internal test was done, where the supervisors of this thesis reviewed the Interview Discussion Guide to determine such things as whether questions were clear to the reader. Two field tests were done, where the Interview Discussion Guide is tested with potential experts simulating the real interview situation. The experts interviewed are experts identified in the Theoretical Round (see Section 7.1.1). In these field tests the Interview Discussion Guide and the interview process were reviewed and refined by identifying areas, words or phrases, where if not improved, it could lead to confusion. In one of the pilot tests, the expert suggested creating and using a presentation to quickly and clearly explain the theory behind GUSM and present GUSM V1 within the allotted interview time.

During the interviews in the Validation Round, the experts are taken through this presentation, which is referenced in the Interview Discussion Guide in Appendix H. The presentation is used as visual support of the experts' understanding of GUSM and it's prototype, so they are confident enough to respond to the fifteen statements. At the end of the presentation, the experts are provided with a list of the main themes of the presentation that the experts can consult during the rest of the interview.

The expert opinion interviews used the material described above to collect feedback on the potential usefulness of GUSM and its prototype. The feedback was analyzed and the next section details the findings of these interviews.

10.3 Validation Round Interview Findings

Once the interviews were conducted, and data from them were collected, coded, and analyzed, structured summaries were developed using the method described in Section 1.4.2.2. These structured summaries can be found in the appendix, separate for each expert (see Appendices I and J).

The two experts provided feedback on five main topics. These topics are: *the Ease of Use of GUSM, Users of GUSM, Indicators to Use in an Assessment, Focus of GUSM, and Perceived Usefulness of the Model*. The experts' feedback is grouped by the five topics and discussed in their own subsections respectively. These topics are based on feedback gained from the reactions of the experts on the statements from Venkatesh et al. [89] (in Sections 10.3.1 to 10.3.6), but the topics do not correlate with a specific category from Table 16 in the article. Rather the reactions and discussions the statements generate, are relevant to one or more of these categories. They also shared some suggestions on features that should be added to GUSM in the future. These suggestions are described in the last subsection.

10.3.1 Ease of Use of GUSM

This section concerns the ease of use of GUSM, perceived by the experts. This perceived ease of use is renamed by Venketash et al. [89] as Effort Expectancy and is defined as "the degree of ease associated with the use of the system". This concept is the subject of several studies, reviewed by Venketash et al. and is critical when determining the usability of a ICT system, i.e. DSSs like GUSM. This also concerns the Self-efficacy, Facilitating Conditions and Behavior Intention to use the System categories in Table 16 from [89].

The experts generally both agreed that GUSM V1 seems easy to use, but that they feel that they need more time to study and use GUSM V1 to confidently state whether it is easy to use or not. Wuppertal, who has a more technical background, felt confident that the US assessment measurement item would be easy to learn and use. Enschede noted that they find GUSM somewhat dense and intimidating as it contains a large amount of information. However, Enschede found that it was clear that through spending time going over and using the measurement item, you would lose that sense of intimidation.

The assumption that the assessment criteria used by GUSM would be adapted depending on the local context of the city and the desired goals its government wishes to attain, requires that GUSM is set up when conducting US assessments. The ease of setting up GUSM appropriately was not discussed in the expert opinion interviews, as the experts agreed that with the support of consultants this would be done satisfactorily.

10.3.2 Users of GUSM

The section identifies who the experts think the users of GUSM should be. This is relevant to the Social Influence, Facilitating Conditions and Self-Efficacy categories in Table 16 from [89]. This topic is about who should conduct US assessments and use GUSM.

Both experts noted that when US assessments have been conducted on their city in the past; an outside party would request the needed data from them and eventually send the US assessment results to them. For example, German's digital association, Bitkom, assesses the US of major German cities every year with their Smart City Index[1]. The expert for Wuppertal (which is one of those cities) has experienced this outside party US assessment approach.

In the GUSM Assessment Approach the city governments are the party conducting the US assessments. Initially an outside party might be needed in order to support the set up of the system to conduct US assessments, but the idea is to enable cities to self-assess their US. Both experts found this idea intriguing.

Both experts expressed that the users of GUSM should be higher-level city government officials, overseeing the city performance. They did not expect that GUSM and the data its results show would be interesting to the government officials lower in the government's organisational chart (i.e. smart project managers). Wuppertal specified that the higher-level officials that should be involved, should be the people who oversee the city's SC strategy or program. Enschede emphasized that the users of GUSM should be officials overseeing the whole city performance and its ability to achieve the desired goals it has.

10.3.3 Subcomponents and Indicators to Use in an Assessment

This section describes the third topic both experts expressed that the US assessments conducted by GUSM must be relevant and appropriate for the city. This topic concerns many categories in Table 16 from the study by Venkatesh et al. [89], including Performance Expectancy, Attitude towards using Technology, Anxiety, etc. This topic places subcomponent and indicator selection at the centre of making US assessments, conducted by GUSM, useful from the perception of the experts.

Both Wuppertal and Enschede agree that the set of subcomponents and indicators used for conducting an US assessment differ between cities depending on their local context. According to them, when conducting US assessments cities must be able to select subcomponents and indicators that are appropriate for them and other cities to be assessed.

Wuppertal illustrated this topic with the following note, if appropriate indicators are selected, the city's performance and goals can be measured and the city government has more control. Selecting indicators that fit and measure a city's local context constitutes a new decision-making process. Wuppertal emphasized the importance and impact of selecting indicators on how useful the expert considers GUSM.

Enschede also found that the indicators used in an assessment should be relevant to and account for the sustainable development goals (SDGs) adopted by the UN member states in 2015 (see Fig. 10.1). These goals don't only have to do with the Sustainability focus area of

[1]See Bitkom's Smart City Index webpage: https://www.bitkom.org/Smart-City-Index

GUSM (see Fig. 9.1), but concern if the focus areas are sustainably developed. For example, goal eight about ”decent work and economic growth” is relevant to the ”Competitiveness” focus area.

Figure 10.1: The Sustainable Development Goals

The SDGs are agreed upon international goals for every country (and local authorities). Enschede’s suggestion is detailed more in Section 10.3.6.

10.3.4 Focus of GUSM

This section describes the fourth main topic about what the experts think the focus of GUSM should be. This is relevant to four categories in Table 16 of the study by Venkatesh et al. [89]. They are Performance Expectancy, Attitude towards using Technology, Social Influence and Behavior Intention to Use the System. This topic addresses how the two experts believe GUSM can be most useful to their city. Currently GUSM is designed for conducting US assessments to provide an overview of the as-is situation of a city and support a city’s decision-making process for SC development.

Each expert identified a different focus they thought GUSM should have. Wuppertal found that the principal focus of GUSM should be for enabling cities to compare their US situations to other cities. From these comparisons, every city can gain insight into the SC concept, measure how they and other cities are developing regarding US, and compete with and/or learn from one another. Determining what subcomponents and indicators are measured to enable such comparisons, as discussed in Section 10.3.3, emphasizes the importance of the indicators used in the assessment. Both experts agree that the comparison feature is one of the most interesting capabilities of GUSM. Enschede notes that especially the US Spider Chart is a good visual tool for presenting the US assessment results of these cities being compared. However, Enschede does not think this should be the focus of GUSM.

Enschede thinks that the focus of the model might change from assessing the US of cities to assessing city performance over the goals the city desires to achieve. An example of such goals would be the SDGs. Enschede explicitly states that they would find GUSM more useful if this was the case, but GUSM doesn't address these desired goals necessarily.

10.3.5 The Perceived Usefulness of the Model

This section discusses the topic of usefulness of GUSM as perceived by the two experts. This in essence concerns the expert opinions on RSQ 3.1 from Section 1.5. This topic concerns the Use Behavior construct from the UTAUT model from Venkatesh et al. [89] as shown in Fig. 10.2. As can be seen this construct directly concerns how the actual use of GUSM and thus how useful it is perceived to be. To measure this Use Behavior construct all the categories from Table 16 in [89] are relevant and need to be measured. Especially the Performance Expectancy and Behavioral Intention to use the System categories is relevant to this topic.

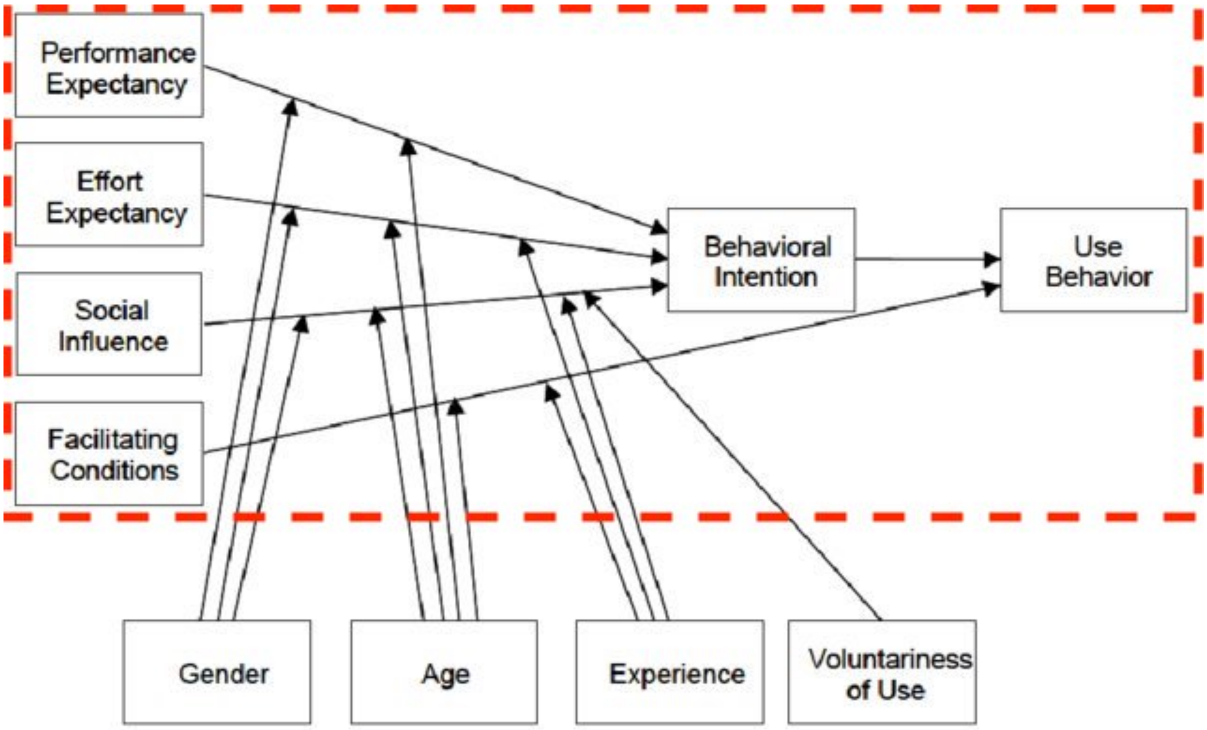


Figure 10.2: The UTAUT Model from Venkatesh et al.

Venkatesh et al. in [89] renames perceived usefulness to performance expectancy. This perceived usefulness concept is what the research scope is limited to. However this perceived usefulness also concerns the intention to use GUSM in the future (represented by the Behaviour Intention construct in Fig. 10.2). The UTAUT model shows six constructs (highlighted in Fig. 10.2) that concern how useful a technical system actually is. The four constructs at the bottom of the figure are moderators that impact some of the relationships between the highlighted constructs. DSSs (like GUSM) are such technical systems.

Both experts agreed that GUSM provides a repeatable, transparent and robust process to measure US, assuming that assessment criteria have been adapted to the local context and the desired goals of the city appropriately. However, they express different opinions on whether GUSM and the US assessments it conducts are useful.

Wuppertal stated that GUSM would be useful to city governments if appropriate indicators for the city are selected. GUSM enables them to quantitatively measure the very abstract SC concept. Thus, using this measurement item allows for enhanced discussion around the project areas (that are relevant to US) to focus on and the smart projects to implement. Wuppertal noted that, "controlling what you are doing" in this case is a good idea. In the sense that, getting measurables (in the indicator data) and results for the focus areas, strengthens their ability to manage the focus areas and to oversee the city's desired development progress. The expert believes that the city of Wuppertal would support the use of GUSM.

On the other hand, Enschede does not think that GUSM currently is useful, although they do see the benefits it can provide as it does propose an appropriate US assessment process. Enschede notes that the desired goals of the cities are not necessarily to become smarter (or increase US), but to address problems they've identified. The city selects projects that address or "solve" those problems. What problems need to be addressed may differ for cities depending on their local context. GUSM allows its users to measure focus areas, not necessarily relevant problem areas, and not problems directly. The opinion of Enschede on the usefulness of GUSM mirrors the previous topic in Section 10.3.4, in that if the focus of GUSM changes to reflect the desired goals of the cities conducting the assessment, then GUSM becomes useful. If GUSM is limited to assessing the US of cities, it is merely interesting.

The two experts proposed ways that GUSM could potentially increase its usefulness in their perspective. Their suggestions will be discussed briefly in the following subsection.

10.3.6 Suggestions for Improvement

This section covers the suggestions the two experts gave that could potentially improve their perceived usefulness of GUSM. These suggestions are not related to the additional features presented in the Potential Development Worksheet, described in Section 8.3. They both shared a general reaction of uncertainty regarding how much more useful the demonstration would be with these features. Except the repeated use of GUSM for monitoring indicator data over a longer time period. As this addition allows for more analysis of the assessments done on cities.

Wuppertal, as discussed in Section 10.3.4, proposed to change the focus of GUSM to primarily enable comparisons. Wuppertal suggested enhancing the comparison features of GUSM accordingly and enabling comparison between three or more cities. By improving GUSM's comparison capabilities, in US assessments using the same criteria, more cities can compete and learn from the other cities in the assessment.

As discussed in Section 10.3.3, Enschede suggested that instead of assessing US, GUSM should use indicators that measure the performance of the city towards achieving the SDGs. They believe that this would make the measurement item more interesting and useful to cities, as working towards the SDGs is currently a popular international concept. Cities are looking to evaluate their performance on these goals, and GUSM provides a relevant process that can fulfil this need. This is especially the case, if the feature discussed in the introduction of this subsection, long-term assessment tracking (or monitoring assessments result over a longer period), is added. However, Enschede emphasized that they would consider this addition to improve the usefulness of GUSM only slightly. The experts' suggestions will be discussed further in Section 11.4.

10.4 Threats to Validity

Using qualitative approaches in confirmatory studies such as this one poses some threats to validity [92]. Here they are described them in more detail. First and most importantly, there are threats regarding generalizability, as only two participants are interviewed. This number might be considered too small. However, both participants are experts in their profession. If typicality were assumed, it would mean that experts in the same jobs in comparable organizations to the one in Enschede (in the Netherlands) and the one in Wuppertal (Germany) might share similar observations. This similarity might be possible due to similarity in contexts, following in the methodological argumentation of Seddon and Scheepers [77]. However, it is obvious that including more practitioners will be beneficial if one wants to draw stronger conclusions. Second, a threat to constructive validity is considered. In the interviews, a well-established model (UTAUT) that has been used by other researchers in contexts of introducing artifacts and evaluating their usefulness and utility. Therefore this study thinks that a constructive validity threat is reduced to minimum. Third, internal validity issues are traceable to researcher's bias in interpreting the information received from the participants. This study contends that this threat is minimal as the interview guide and the coding procedures were set up with the participation of the senior researchers and the author's findings have been reviewed by them.

10.5 Summary

This chapter concerns the expert opinion interviews from the Validation Round; what form they are in, how they are prepared for and the experts' feedback in the interviews. Five main topics were identified from the interview results. These topics from the structure of the interview findings, and discuss the experts' opinions on the ease of use, users, focus and the perceived usefulness of GUSM, and the indicators to use when conducting US assessments with GUSM. The findings from the interviews are combined with the findings from previous chapters, and are discussed further in the following chapter.

CHAPTER 11

Discussion and Reflection

This chapter reflects on the US assessments from the demonstration of GUSM and the findings of this research. This discussion does not address a specific RSQ, it looks to analyze the findings from several questions, which is the last step (step 7) of the GUSM Development Methodology in Fig. 5.2. In this chapter, the discussion is categorized into four subjects on the contribution this research has for relevant practical and research domains. The subjects are the implications for practice, the implications for research, reflecting on the limitations of this research project and future work. Each subject is detailed in their corresponding sections.

11.1 Implications for Practice

In this section, the practical implications of this study are examined and reflected on. Five main topics were identified as being relevant for practice: *the vague SC concept issue, aligning with city goals, flexibility vs. comparability, the party conducting the assessment, and the perceived usefulness of US assessment measurement items like GUSM*. With the first four topics concerning issues that impact that usefulness. These topics can be considered as the contribution of this research to practice.

The five topics are detailed in their own subsections below. The next subsection identifies and details an issue that impacts all the following subsections.

11.1.1 The Vague Smart City Concept Issue

Most of the issues surrounding US assessment concern the differing interpretations of the SC concept of cities around the world. This section defines this vague SC concept issue that impacts the US assessments done on cities around the world.

When measuring the US of a city, that assessment must be based on the city's interpretation of the SC concept. The criteria used in an US assessment should reflect the interpretation of the city conducting the assessment. If not, the assessment might not be appropriate for that city. The city's interpretation of the SC concept depends on the local context of the city. In this research, the local context concerns the city government's definition of the SC concept, the city's environment, the challenges/problems it faces, and the goals the city government desires to achieve.

This issue becomes more prominent when comparing the assessments of two cities. If the two cities' local contexts are different, then how their US is assessed should differ as well. A good example of this is provided in the study by Dall'O et al. [28], which indicated that US assessment for large and small cities in Italy need to be measured differently due to city size. Thus, when a city is conducting US assessments on multiple cities (in the case of comparisons), the assessment criteria should be appropriate for that and the other cities. That appropriateness depends on whether the cities being compared share a similar context. If not appropriate, then the results of the assessments are not generalizable concerning cities' US, but the individual subcomponent measurements can be used by cities to compete and learn from each other.

As discussed in Chapter 2, the current body of knowledge includes a lot of debate about how to interpret and define the SC concept. Many studies explicitly specify what types of cities are SCs according to them. However, this research contends that the SC concept is concerned with making cities "smarter" through a holistic and high-level process. This process should be applicable to all cities regardless of local contexts. Unfortunately, this general applicability is not the case for many US assessment measurement items as most items are designed for a specific local context (or local contexts that are similar in nature).

This begs the question of whether city types or city labels like SC are relevant, or rather the different city concepts (i.e. "smart city" , "resilient city" , "intelligent city" , etc.) denote processes that can be applied to any city. These processes are based on the theories relevant to the city concept (i.e. how a city can be smart or sustainable or etc.), and guide city development and relevant city concept assessment. This research is limited to the SC domain (Hollands [41] found this with the SC concept), but it would not be surprising that this use of city labels occurs with other city concepts as well.

The vague SC concept problem is exacerbated when using a global perspective as no internationally agreed-upon definition of the SC concept exists and must be accounted for in an US assessment measurement item. As such this issue is relevant for each of the following four subsections.

11.1.2 Aligning with City Goals

This section reflects on the topic of the selection of subcomponents and indicators for an US assessment. The perceived usefulness of any US assessment measurement item differs depending on what assessment criteria are used. This is caused by the vague SC concept issue defined in Section 11.1.1. Thus, to ensure that an US assessment measurement item is useful, the criteria it uses must be adapted appropriately. In this research, it was observed that the city and city governments use two different approaches when assessing their cities.

The first approach concerns aligning the SC concept interpretation of the city with its desired goals and the challenges it faces (addressing these challenges through the implementation of projects form additional goals). This alignment is reflected in what should be measured in an US assessment. US assessment measurement items are aligned with the city's goals when they use subcomponents and indicators that are also relevant to the challenges the city faces. A good example of this can be seen when looking at the transportation situations of two Dutch cities, Enschede and Amsterdam. Amsterdam is a large and population-dense city in the Netherlands with over 815.000 residents as per the UN in 2015. Amsterdam also uses a smart city platform to conduct mobility projects[1]. Meanwhile, Enschede is a much smaller spread-out city in a rural part of the Netherlands (as discussed in Section 8.2). It does not fase the same mobility challenges as Amsterdam and has less of a focus on mobility on its smart city platform. Mobility challenges in Amsterdam do not apply to Enschede and implementing smart projects on Mobility are not as relevant to Enschede. The SC concept of Enschede and the appropriate US assessment criteria will differ regarding the concept Mobility than that of Amsterdam. Fernandez-Anez et al. [32] notes that each city faces a mix of these challenges and the assessment criteria needs to measure how the city is doing to address those challenges. An US assessment measurement item is more useful if it uses subcomponents and indicators that measure how the city is performing on the challenges it wishes to address (or the city's goals).

The second approach is that cities and their governments believe that the SC concept is

[1]As can be seen on the Amsterdam's SC platform webpage: https://amsterdamsmartcity.com/projects

not suitable for addressing the challenges they face and thus, turn to another city concept (as defined in Section 11.1.1) and reject the SC concept. Rather they use city concepts like Sustainable, Resilient or Smart Sustainable cities, etc. that correlate with the vision the city government has of the local context of the city (including the challenges it faces) and the government's priorities. Therefore, when they conduct assessments, they do not look to measure US, but instead assess city performance as desired.

Cities and their governments thus are faced with the choice of which approach to follow. By enabling the adaptation of an US assessment measurement item, cities may find the measurement item more useful as its SC concept interpretation is aligned with the city's local context. If it is not aligned, the cities are more inclined to use other (more adaptable) US assessment measurement items (the first approach) or turn to another city concept entirely (the second approach).

This implies that when designing an US assessment measurement item, adapting it to the local context of the city (including what challenges they face and the city's other desires) conducting the assessment, it is crucial if you want cities and their city governments to follow the first approach. GUSM, which is such a measurement item, uses an SC concept interpretation that is as holistic as possible to adhere to this implication of practice.

11.1.3 Flexibility vs. Comparability

This section reflects on the topic of the balance between flexibility and comparability an US assessment measurement item provides. To structure this study's reflection points, Figure 11.1 presents the relationship that all US measurements share. This figure was constructed by the author as part of carrying out this research. It depicts the relationship between the flexibility and comparability capabilities of the measurement items. These two qualities have an inverse relationship. The first quality, flexibility, indicates how much the criteria of the assessment can be adjusted and aligned to the local context of cities. The second quality, comparability, concerns whether the US assessments of cities (that use the same criteria) can be compared against each other. As the figure shows the higher the flexibility an US assessment measurement item provides, the less the US assessments results can be compared to another city's assessment results from a standard perspective. As an US assessment measurement item's comparing capability is increased by using a standard set of indicators (for example an index that seeks to rank cities by smartness), its capacity for flexibility is decreased. US assessment measurement items need to account for this balance between comparability and flexibility, depending on the purpose of their use. Based on this balance, measurement items can be categorized to one of three groups.

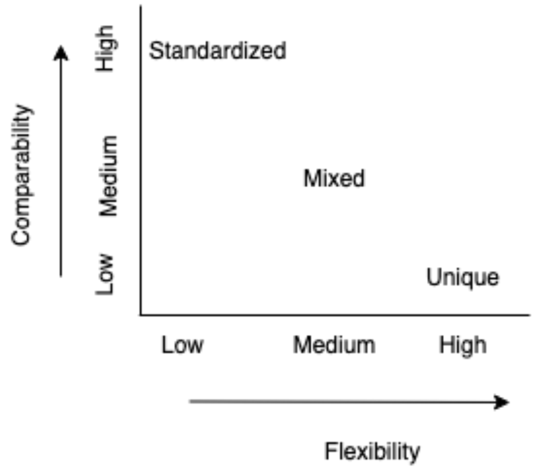


Figure 11.1: The Flexibility vs. Comparability Relationship

US assessments and their measurement items can be classified by how they balance these two qualities. The classifications are:

1) **Standardized**: This classification concerns low flexibility US assessment measurement items that define a standard set of subcomponents and indicators and a standard assessment approach to measure the US of all cities to be assessed. In other words the flexibility capability of the model is low. This assessment approach and criteria are not adjusted to account for the cities' local context. Through standardization the cities can be explicitly and directly compared to each other, as the assessment is based on a standard interpretation of the SC concept. In other words the comparability capability of the model is high. Cities that interpret the SC concept differently may not find the US assessment results valid and not relevant to them. This is a prominent classification of US assessment measurement items and often only applies to a set of cities: (1) for prominent international cities, for example Lee et al. [51] define an US assessment measurement item to measure the US of two large-sized cities, Seoul in South Korean and San Francisco in the USA; (2) for cities within a country or region, for example the SC indexes for metropolitan cities in the Italian context, the ICity Rate and Smart City Index [28]; or (3) a group of countries like measurement items made for cities in Europe [36, 33].

2) **Mixed**: This classification looks to use US assessment measurement items to accurately assess the US of a city (also taking into account the local context of the city) and still allow comparison with other cities in that assessment and where the same or similar subcomponents and indicators are available and are appropriate for those cities' local contexts. US assessment measurement items in this classification, thus, allow for adaptation (flexibility is medium) while providing comparison capabilities (comparability is medium). To facilitate the selection of assessment criteria such US assessment measurement items can propose sets of subcomponents and indicators, and methods for how they are combined (through normalization). These propositions form options that cities can select depending on their interpretation of the SC concept. To the best of the author's knowledge no US assessment measurement items, except the measurement item proposed by this report, GUSM, can be classified as mixed.

3) **Unique**: For this classification, US is assessed on a city by city basis and an assessment process is created with the specific city in mind. The city's US can be assessed

and analyzed through a mix of quantitative measures and qualitative discussions on the city's performance on the specific aspects relevant to the city's local SC concept definition. For this classification the use of an US assessment measurement item might not be necessary and rather a framework of such a measurement item is used. An example of this is the research study from El Ela [31] which uses parts of the framework defined by Giffinger in [36] to analyze the geographical characteristics of the US of Medina in Saudi Arabia. For the assessment of Medina, although parts of the framework from [36] are used, its indicators are not. Instead the city is analyzed by collecting other indicator data and discussing that data's impact on relevant US aspects. This report considers the study [31] as an example of the unique classification, as although parts of a standardized US assessment measurement item's framework is used, an US assessment process was designed to only apply to one city and its local context. This approach would be difficult or impossible to apply to other cities. It is complex especially as it conducts assessment through qualitative means. Thus, while in this classification US assessment is completely flexible in that it adapts to the city's local context (flexibility is high), it is difficult or impossible to compare the US assessment results between cities if this assessment approach was used (comparability is low).

The practical implication of this topic concerns the design and development of US assessment measurement items. When creating an US assessment measurement item, it will fit into one of the three categories and the measurement item should be explicit as to which classification it belongs to. This should be done to ensure that the measurement item and its balance between flexibility and comparability is as transparent as possible.

GUSM being in the Mixed classification, means it does not limit itself to a city or cities in a specific region, but it is designed to account for the local contexts of cities. Thus, it offers its users flexibility and comparability. It does not have the Unique classification as it was designed to apply to cities across the globe and it does not have the Standardized classification as GUSM's assessment criteria can flexibility adjust to the cities' local contexts. GUSM is purposely designed to fit this Mixed classification so that it can be adjusted and used by cities as needed, no matter what area of the world they are in.

In general, US assessments and their measurement items provide cities opportunities to learn more about the SC concept and understand their as-is situation regarding US. This brings up the questions concerning which parties conduct such US assessments. Is it the city governments themselves or external parties? This question will be addressed in the next subsection.

11.1.4 The Party Conducting the Assessment

This section reflects on the two parties, the external and internal parties, who can interact and conduct US assessments. The external party is an organization that is not part of the city government and the internal party contains city government (or in certain cases national government) officials who are involved in US development. These parties can work together during the process of US assessment, concerning who designs and uses the US assessment measurement item (including the selection of subcomponents and indicators) and who collects the data needed. How these two parties interact can be grouped in three types.

The three types of interactions in the US assessment processes used by US assessment measurement items (see Fig. 11.2), are:

1) **External**: For this interaction, an US assessment measurement item is designed and used by an external party and this party also collects the data for the measurement. Many US assessment measurement items use this type of interaction. For example, in [36, 21, 67] external parties design US assessment measurement items, collect indicator data for cities, assess the US of those cities and discuss the results of those assessments. The cities themselves are not involved in the assessment process and often an

external source of publicly available indicator data is used. If there were interactions with the internal party, they are not documented in the articles.

2) **External-Internal**: This interaction occurs depending on how the two parties work together. Either, the US assessment measurement item is designed and used by the external party, but they work with the city to collect the data used in the US assessment. Or during the creation of the measurement item, the internal party is involved in discussions and decisions regarding what is assessed and how it is measured. An example of the first interaction is provided by the Smart City Index of Bitkom as discussed in Section 10.3.2. Bitkom designed its Smart City Index based on a standardized SC concept for all German cities and works with the cities to check and update the data it uses in its US assessments. The results of these assessments are then sent to the cities. An example of the second interaction is given by Fernandez-Anez et al. [33], where the smart city project assessment matrix is designed for cities in the Mediterranean region of Europe. Officials in the cities being assessed are asked to prioritize the challenges their city faces and the assessment criteria are adapted according to this city specific data on prioritization.

3) **Self**: For this interaction the internal party is the main user of the US assessment measurement item, where the cities (or relevant city government officials) use the measurement item and collect the data to be used themselves. Although support from external parties in setting up these measurement items might be needed, the cities themselves are the primary users. Examples of US assessment measurement items that use this interaction type are considerably less in number. One example of such a measurement item is provided by Urban Tide, an organization that operationalized the IDC-SCMM (introduced in Section 4.2.4) for the Scottish Government [87]. This operationalization is done through qualitative means where the assessment is conducted by cities answering a list of questions concerning the areas identified by the IDC-SCMM. This SCMM is adapted to cities in Scotland (using the Scottish national interpretation of the SC concept) and is designed to be a self-assessment tool. GUSM is designed to use this interaction type and is highlighted green in Fig. 11.2.

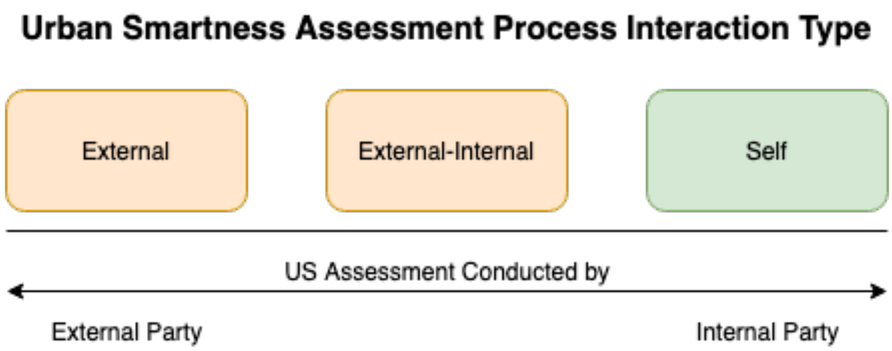


Figure 11.2: The US Assessment Process Interaction Types

Most US assessment measurement items are explicitly applied by external parties, but for many measurement items it is not explicitly stated if the external party worked with cities in the assessment to collect the data needed. If the two parties did interact the main benefit is that the cities work with the external party and are involved with the design and development or collecting the data to be used in the assessment. Through these interactions the city gains a clear understanding of what data is needed and how that data is used by the US assessment measurement item. Thus, the measurement item is transparent and as a result the cities in such interactions can clearly determine if the US assessment measurement item is valid according to the city's interpretation of the SC concept. The benefit of involving cities when designing or conducting US assessment measurement items is identified and discussed further in Section 7.2.4.

The practical implication of this topic is that when designing and developing an US assessment measurement item, one of the three interaction types should be specified for the sake of transparency. This research contends that the internal party should be able to provide input into what aspects of the city are measured and what assessment criteria should be used.

As previously indicated, GUSM uses the 'Self' interaction type with the aim to enable cities to conduct assessments themselves as needed. The next subsection will discuss how useful cities find such an US assessment measurement item.

11.1.5 The Perceived Usefulness of Urban Smartness Assessment Measurement Items

This section discusses the topic of the usefulness US assessment measurement items provide from the perspective of city government officials. In order to comment on the usefulness such measurement items provide, the findings from the Theoretical Round and the Validation Round expert opinion interviews form the basis of the reflections on this topic.

The previous four subsections impact how useful US assessment measurement items like GUSM are perceived to be. In addition, this perceived usefulness is enhanced if the measurement item is used by city government officials of a higher-level that oversee or are decision makers regarding the city's SC strategy or program. These officials use their interpretation of the SC concept (based on the city's local context) to define an SC strategy or program that identifies how the challenges the city faces can be addressed, areas relevant to city US should be improved, and the city should approach its development. An US assessment measurement item such as GUSM (that is focused on a higher-level holistic perspective of the city) is perceived as useful if it is used by officials on this higher-level when such a strategy or program is or has been defined. US assessment measurement items like GUSM do not build a project portfolio and thus may not be useful for officials deciding on the implementation of individual smart projects. As identified in Section 11.1.2, the specific smart city development approach depends on the local context, including the challenges the city faces and the goals it wants to achieve. The appropriate officials can use US assessment measurement items like GUSM to support deciding what areas or aspects should be emphasized. This can be seen in a study by Fernandez-Anez et al. [32], where they find that a city must identify and address the challenges if it wants to be a smart city (the study refers to these challenges as "Global Trends and Urban Challenges" that each city may face).

The practical implications and findings from the two rounds of expert opinion interviews indicate that US assessment measurement items such as GUSM can be useful as they provide quantitative measures for the city's US. Cities and their governments can use these quantitative measurements of US to base their discussions and decisions regarding appropriate city development and reflecting on the city's SC strategy or program. To be perceived as useful, the measurement item must be able to adapt and align with the local context (including the challenges faced by the city and goals it wants to attain) of the city conducting the assessment. However, this raises the question concerning what can be standardized to still allow for relevant US assessment comparisons. GUSM answers this question by not standardizing the criteria used when conducting US assessments, but standardizing an US assessment approach.

This concludes reflecting on the implications for practice. The next section concerns what this study implies for further research.

11.2 Implications for Research

This section discusses four implications for research in the domains of US assessment and SC relevant fields that the findings of this study provide. The implications concern four items: the GUSM Development Method, the modified SCMM Basic and Descriptive DPs, the design of GUSF and the design of GUSM. Each item is associated with one of four implications for research.

The four implications are:

- The GUSM Development Method, introduced in Section 5.4, is a method that can be used to design and develop US assessment measurement items like GUSM. This method contains an iterated development strategy that can be applied regardless for which cities or regions the measurement items are operationalized. Researchers can use this method to develop appropriate US assessment measurement items for their studies.
- The modified SCMM or GUSM Basic and Descriptive DPs, presented in Tables6.1, 6.2 and8.1, represent the design principles US assessment measurement items should satisfy. Researchers can refer to these design principles as requirements their measurement items should fulfil.
- The framework of the artifact of this research, GUSF (as introduced in Section 3.1.2 and updated in Section7.3.2) contains the constructs that should be assessed when measuring the US of cities from a holistic and high-level perspective. When studying US assessment related topics, researchers can refer to the synthesized framework for further research into each focus area, for example the relationship between the constructs in GUSF can be researched further and validated.
- GUSM, as introduced in Chapter 6 (and its assessment approach is updated in Section 7.3.3), as a US assessment measurement item can be used by researchers if US assessments and the quantitative measurements of US is needed for their studies. Also, GUSM itself provides opportunities for further study. For example, how GUSM should be operationalized for cities across the world requires further research or which normalization methods should be used during US assessments. GUSM is a potential source for multiple paths of future research.

In this research, GUSM is a first step to developing a truly global US assessment measurement item. Its demonstration gives promising indications that the artifact can be useful towards that goal. However, more empirical research (including validation) is needed to understand the contexts in which GUSM can be applied, especially in other cities across the world.

11.3 Research Limitations

Three main research limitations in this study are identified. These limitations will be discussed in this section.

The first limitation concerns that this study and its literature reviews may have missed relevant research on US assessment. This limitation is also a result of the vague SC concept issue defined in Section 11.1.1, where the terms used for SC concept theories vary greatly between researchers. Same or interchangeable concepts use different terms, i.e. competitiveness, economy, productivity (while each concerns a slightly different topic they may be used to represent the economic characteristics of a city). This is compounded by the fact that the authors of potentially relevant literature may focus on assessing slightly different aspects of US assessment that match the focus of the cities' local context in their research and thus may use different terms. Those articles that use different terms are not found by the literature search as specific terms are used.

Another limitation concerns the SC publication difference between regions in the world as identified by Mora et al. [64]. They found that SC research is mainly published in certain areas of the world, including Europe, South-East Asia, the USA and Canada. The areas of the world not covered by SC research might indicate that US assessment measurement items (and GUSM) as a result need to be adjusted. Additional research on the SC concept published in those areas would clarify this uncertainty.

The third main limitation concerns that the demonstration of GUSM is only partially validated. Due to limited resources (especially time), the demonstration of GUSM is only validated for two cities. In this research the demonstration is presented and a city government official (who oversees the SC strategy or program) from each city is interviewed on how useful they perceive the demonstration to be. The responses gathered during the interviews are used to evaluate the demonstration of GUSM, but it must be emphasized that this cannot be considered a full validation of GUSM. Rather if the demonstration would be implemented over a longer period of time for more cities, it could be validated in depth and more information could be gained about it's perceived usefulness and necessary adaptations.

11.4 Future Work

This section discusses three different paths to work on GUSM in the future. The first path concerns how the perceived usefulness of GUSM can be improved, the second is about how GUSM should be used in future practice, the third path relates to suggested future research on GUSM and US assessment.

The first path regards that the perceived usefulness of GUSM can be improved in three ways. The first way is to add additional features that were identified when conducting the expert opinion interviews in both rounds (as described in Chapters 7 and 10). One is a long-term US assessment results tracking feature, which was frequently discussed during the validation round interviews where it was determined to be the feature that would improve the perceived usefulness of GUSM and its demonstration the most. Features that improve the flexibility, transparency and comparability functions of GUSM would also lead to a large increase in perceived usefulness for cities with very different SC concept interpretations. Another feature to add would be an indicator registry with information on the indicators that can be used during the US assessments. Here the idea is that these indicators have been selected and validated by experts and that while cities have the flexibility to decide which indicators to use, the indicators they select from have been shown to be appropriate for measuring elements of US. To improve the perceived usefulness of GUSM these additional features should be added according to the experts interviewed in both rounds.

The second way to improve the perceived usefulness is by operationalizing GUSM for cities in other areas of the world. This way it overlaps with one of the subjects from Section 11.2 concerning the design of GUSM. In addition to this, once operationalized the US assessment GUSM conducts can be validated with more cities. This research only contains the first step in developing this measurement item. Thus, further operationalization also provides new opportunities to validate GUSM for more cities, which is beneficial as the goal of GUSM is to be an US assessment item that can be applied globally.

As this research mainly develops the first version of GUSM, a possible next step and the third way to improve the perceived usefulness is to convert GUSM into a SC maturity model and define maturity levels for city US (and focus areas if desired). A key issue with converting GUSM into a SCMM is how to ensure that GUSM maintains a high-level of transparency and flexibility. The definition of maturity levels and explaining the logic of transition between those levels or why a maturity level is reached at certain indicator values (by defining the "maturation paths"

[85]) would make this conversion a complex transformation. SCMM development provides a similar challenge to flexibility. Keeping the US assessment measurement item as transparent and flexible as possible is crucial in its development and adaptation and requires constant effort.

The second future path concerns how GUSM should be used in the future, namely GUSM can be used in combination with another measurement item. For example, GUSM can be used to oversee US on a high-level and identify the city's problem areas that need to be addressed, while the other measurement item can be used to analyze the individual projects that can be implemented to address those problem areas. Researchers following this path can study whether such a combination approach would make GUSM being perceived as more useful or how such a combination should be done.

The final path aligns with the Implications for Research section (see Section 11.2) and involves researchers conducting further research in the US assessment and related SC domains. When conducting these studies, this research suggests:

- Focusing not only on making cities smarter, but also on the specific goals (or the performance goals) of the city itself.
- Involving the cities and their governments when identifying and selecting the assessment criteria to use when assessing the US of that city. This is especially important when attempting to create a standardized set of subcomponents and indicators.
- Conducting more research on assessing the US of small and mid-sized cities (in terms of population) around the world; and especially more research on assessing the US of cities outside Europe, South-East Asia, the USA and Canada (regardless of population size).

11.5 Summary

This chapter discussed the findings from previous chapters and reflected on their implications for practice and research. These implications for practice concern GUSM, the artifact designed and developed in this research, and topics that impact its perceived usefulness. The implications for research highlight topics for further research on US assessment measurement items like GUSM. In addition, this chapter identifies limitations to this research and discusses possible opportunities for future research in the SC related domains. The next chapter will look to answer the research questions shown in Section 1.5.

CHAPTER 12

Conclusion

This chapter contains the main conclusions of this project. It addresses and answers the main research question (or MRQ) from Section 1.5. However before this MRQ can be addressed, seven RSQs are answered in the three sequential phases of this project. These parts are based on the phases in the design science methodology, discussed in Section 1.4, they are Problem Investigation, Treatment Design and Treatment Validation. The first phase concerned collecting and analyzing previous knowledge on US assessment and the SC concept. This knowledge is used in order to develop a framework for an US assessment measurement item and identify approaches and issues concerning US assessment. For this phase, the answers to RSQ 1.1 to 1.3, with references to associated chapters, are given. The second phase of this project seeks to create an US assessment measurement item to carry out US assessments using the framework developed in part one. RSQ 2.1 - 2.3 are answered in phase two and these answers also reference the chapters associated with the RSQs. The third phase looks to validate the US assessment measurement item proposed by this research, GUSM and its demonstration. This part is concerned with addressing RSQ 3.1, which covers a qualitative evaluation of the demonstration. This chapter summarizes the answers to these sub-questions in the following three sections. The MRQ is addressed and answered in the final section. The findings from all chapters, as discussed in Chapter 11, are used where relevant.

12.1 Investigating Urban Smartness Assement

This section covers the chapters in the Problem Investigation phase of this research to address and answer the RSQs, presented in Table 12.1.

No.	Question
1.1	What is a globally applicable definition of the smart city concept?
1.2	What are the commonly identified US constructs and issues found in smart city research about urban smartness assessment?
1.3	What potential do existing smart city maturity models have in relation to US assessment?

Table 12.1: Research Sub-Questions 1.1, 1.2 and 1.3

RSQ 1.1: This question is concerned with defining the SC concept on a high-level so that it applies to cities around the world. This RSQ is relevant to the vague SC concept issue discussed in Section 11.1.1, as the SC concept interpretation changes depending on the different perspectives of researchers and the different local context of cities. In this research, a high-level definition of the smart concept is given from a holistic perspective. Thus, the answer to RSQ 1.1 is:

We believe a city to be smart when investments in human and social capital and general city- and ICT-infrastructure fuel sustainable competitiveness and a high quality of life, with a wise management of natural resources, through participatory governance.

This definition contains the three main goals or the desired outcomes a SC looks to attain (detailed further in Section 2.2). The purpose of this definition is to give an overview of the SC concept and not explicitly define the specific goals a city can have.

RSQ 1.2: The response to this question is covered by Chapter 3. In order to answer this question, the constructs from eight research studies (which contained US assessment measurement items) were analyzed and synthesized into a new framework, GUSF. The constructs of the framework were presented in Section 3.1.2 and the relationships between them are updated in Section 7.3.2 (see Fig. 12.1) after the Theoretical Round expert opinion interviews. The figure contains the constructs of GUSF. By measuring the outside constructs or focus areas (excluding the construct in the middle of the framework) the US of the city can be indirectly measured.

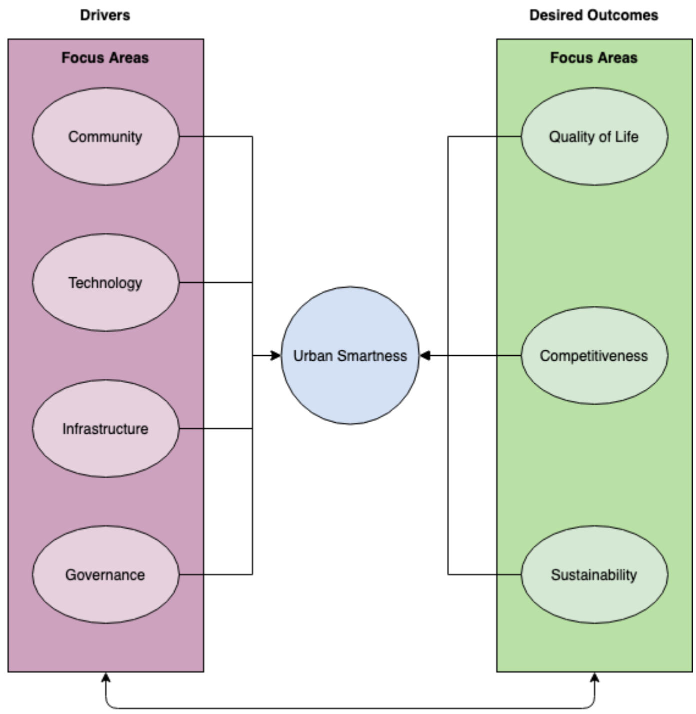


Figure 12.1: The Global Urban Smartness Framework

In addition to the US constructs of GUSF, RSQ 1.2 seeks to identify the main issues facing US assessment across the world. Two main issues can be identified in the current body of knowledge, the different interpretations of the SC concept and the availability of indicators and data that can be used in US assessments. Due to the different interpretations of the SC concept of cities (depending on their local contexts), what areas or criteria should be measured and used in US assessments vary. This issue becomes very prominent when trying to develop a standardized US assessment measurement item that can be applied globally. The second issue relates to the fact that the availability of indicators and data used in an US assessment differs between cities and thus, finding a standardized set of indicators to be applied to cities around the world is a complex (and maybe impossible) task. These two issues emphasize the complexity of developing an US assessment measurement item that applies a standard set of indicators to cities around the globe.

RSQ 1.3: It regards the findings of Chapter4 where four SCMMs were introduced and analyzed according to the MM DPs from Torrinha and Machado [85] in the tables in Section 4.3. The four SCMMs are checked to see which DPs they satisfy, the results of the check are presented in tables in Section 4.3.1. These results indicate that the identified SCMMs do not currently satisfy all the MM DPs (and require further development) and provide several implications. These implications concern the potential of existing SCMMs: their purpose of use, their applicability to cities around the world, the transparency issue they all experience, their lack of operationalization and a standard list of constructs whose US maturity must be measured, and that the artifact of this research should be more like an US assessment SCMM (a SCMM type defined in Section 4.4). The artifact, GUSM, uses aspects of SCMMs in its development, especially concerning the MM DPs to ensure that it conducts high-quality US assessments. The DPs are split into three groups: the Basic, Descriptive and Prescriptive DPs. Although GUSM uses aspects of SCMMs it is not a fully developed MM as this is outside the research scope and this conversion would require more work.

After addressing these three RSQs, the Treatment Design phase of this work is initiated and discussed in the following section.

12.2 Developing an Urban Smartness Assessment Measurement Item

This section concerns RSQs 2.1, 2.2 and 2.3, which relate to the design and development of GUSM. These questions are presented in Table 12.2 and correlate with the Treatment Design phase of this research.

No.	Question
2.1	How should the development of the model be done?
2.2	How can the US assessment constructs be incorporated into the urban smartness model?
2.3	How should the global urban smartness model be operationalized?

Table 12.2: Research Sub-Questions 2.1, 2.2 and 2.3

RSQ 2.1: This question concerns how GUSM should be developed, which is discussed in Chapter 5. To answer this question a development methodology for GUSM was created. This development methodology is modified from the MM development methodology from Becker et al. [13] to account for the key difference between SCMMs and GUSM. The modifications to the development methodology are detailed in Section 5.2. As identified in Section 5.1, GUSM explicitly will not define maturity levels that can be applied to the US of cities around the world. This is done to avoid the issues of SCMMs identified by RSQ 1.3, while still incorporating the process of SCMMs that allows for quantifiable measurement of intangible concepts like US. The GUSM Development Methodology provides a guide with steps in order to develop US assessment measurement items like GUSM. The SCMM DPs from Torrinha and Machado [85] correlate with the requirements that must be satisfied in each step of the methodology and are modified to apply to GUSM (referred as GUSM DPs). The GUSM DPs only cover Basic and Descriptive MM DPS.

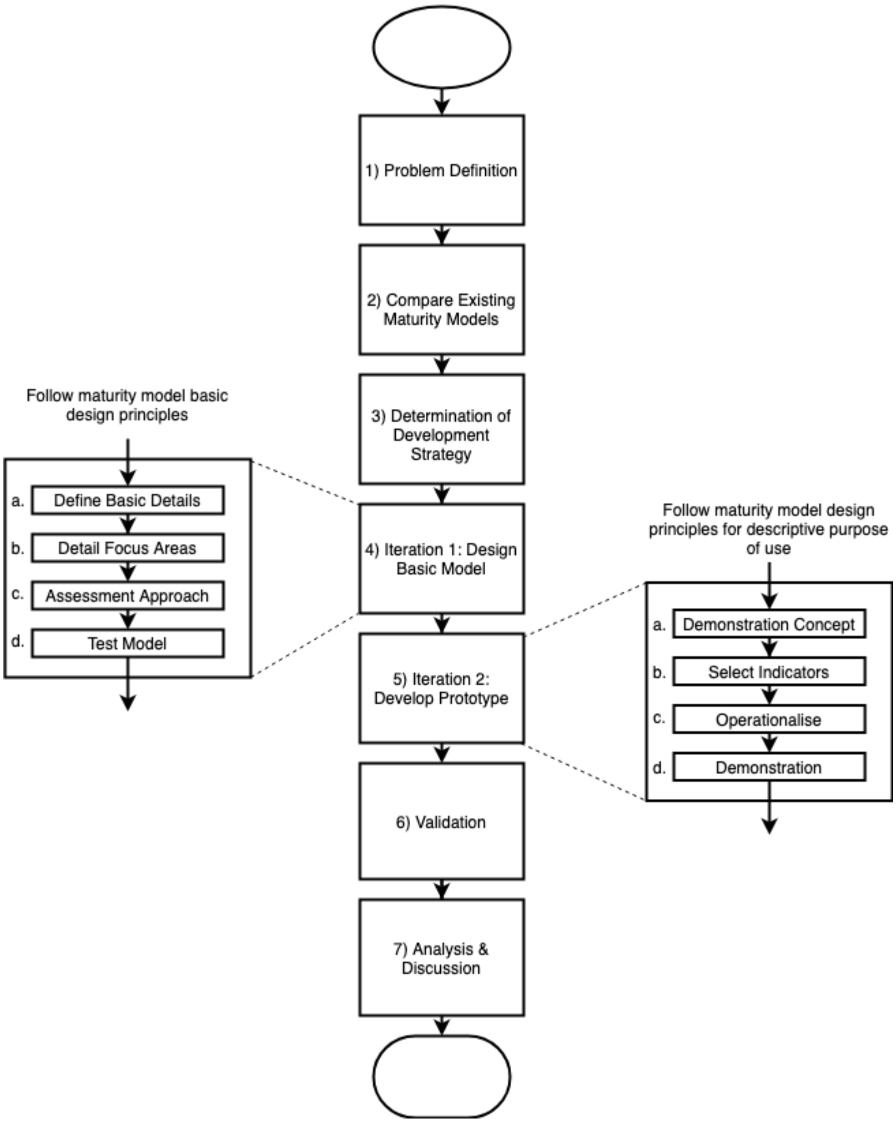


Figure 12.2: The Development Methodology of GUSM

RSQ 2.2: The answer to this question details how the constructs identified by GUSF can be measured and used by GUSM to conduct US assessments. GUSM's basic design regards the GUSM Basic DPs and this design is described in Chapter 6. This includes defining GUSM's purpose of use, its application domain and describing the target group it is designed for. The chapter also describes how the focus areas of GUSF (all the constructs except the US construct) are measured by GUSM using the Detailed GUSF. The Detailed GUSF is first introduced in Section 6.2.1 and updated in Section 8.3. It is presented in Fig. 12.3 and shows how each of the focus areas can be measured by associating it with at least one subcomponent that is measured by one or more indicators.

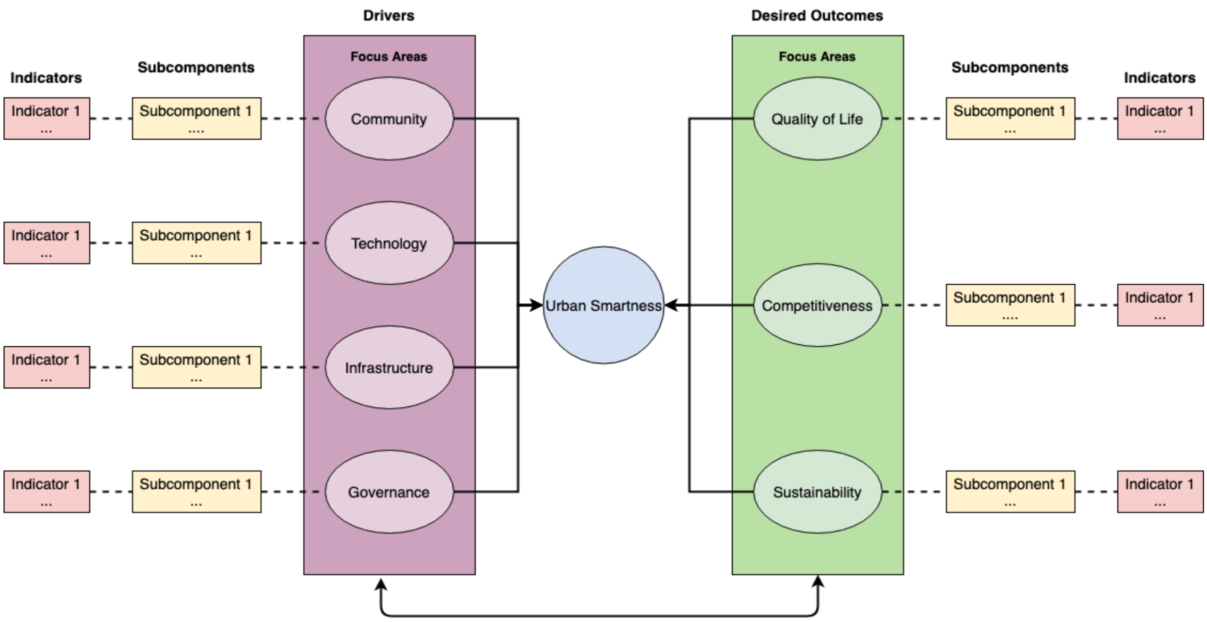


Figure 12.3: The Detailed GUSF

This measurement method for the focus areas is incorporated in the overall GUSM Assessment Approach, shown in Fig. 12.4. The GUSM Assessment Approach is introduced in Section 6.2.2 of Chapter 6 and updated in Section 7.3.3. For every US assessment, the four sequential actions of the approach are conducted to produce US assessment results for a city. The first action concerns selecting the subcomponents and indicators whose placeholders are shown in Fig. 12.3. The second regards collecting the data for each indicator and normalizing their values so that they all can be combined together. The third is creating relevant charts and plotting those values so that the US of the city can be visually communicated. The final action calculates the US Ratio, which provides a quantitative, unit-less value that can be used for further analysis. These four actions of the GUSM Assessment Approach are done to provide a repeatable, transparent and robust process to assess the US of cities. This process supports decision-making on the development of cities and their US.

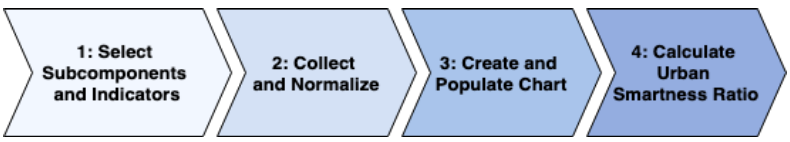


Figure 12.4: The GUSM Assessment Approach

This Theoretical Version of GUSM was qualitatively evaluated by conducting the Theoretical Round of expert opinion interviews, discussed in Chapter 7, leading to the Detailed GUSF and the GUSM Assessment Approach being updated as mentioned above. Fig. 12.3 and Fig. 12.4 display these updates.

RSQ 2.3: This question concerns how GUSM can be operationalized. It is concerned primarily with the GUSM Descriptive DPs, described in Section 8.1.This topic is covered by Chapters 8 and 9. In Chapter 8, the demonstration of GUSM is discussed, namely what cities are assessed by the demonstration and provides a description of the structure of the demonstration. In Chapter 9, the demonstration is operationalized by conducting the four actions from Fig. 12.4. RSQ 2.2 describes how the measurement item the focus areas from Fig. 12.3 are measured and combined theoretically, according to Fig. 12.4, while RSQ 2.3 is concerned with how the demonstration assesses the US for those cities. In order to generate these assessments, the demonstration must be actually operationalized using indicators and calculation methods. RSQ 2.3 uses the four actions in the GUSM Assessment Approach accordingly.

Section 9.1 describes how indicators to use for the demonstration are selected, as per the first action of Fig. 12.4. The selected indicators and their associated subcomponents are connected to certain focus areas, as shown in Fig. 12.5. To see more details on the indicators, refer to Section 9.1.3.

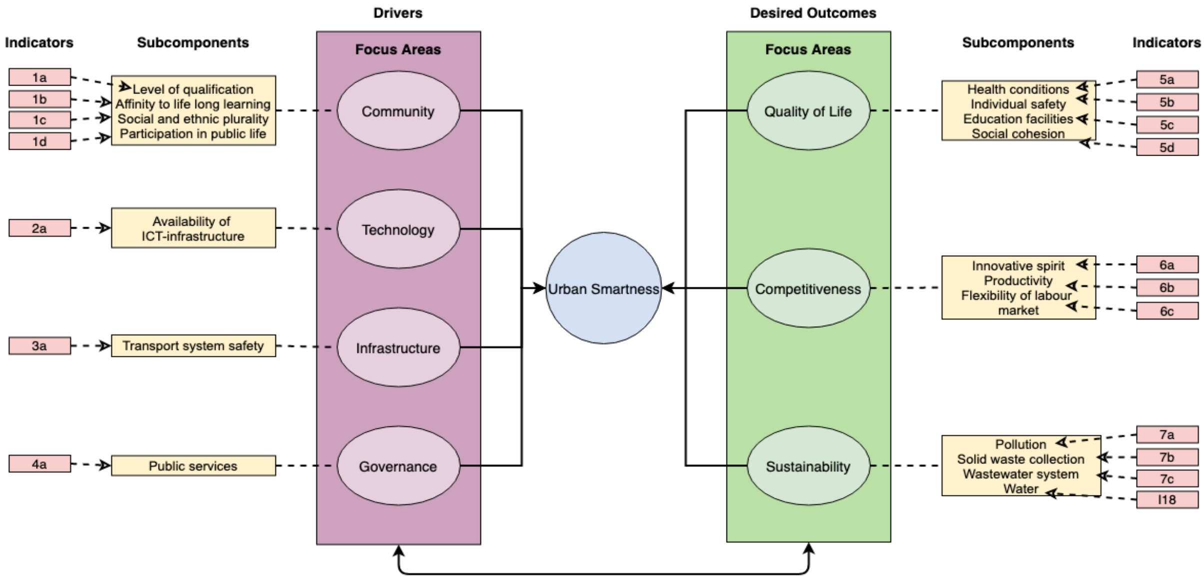


Figure 12.5: The Operationalized Detailed GUSF

In Section 9.2, the data for these indicators are then collected and normalized (as required for the second action of Fig. 12.4) by applying one of two normalization methods discussed in that section. The normalized data are then displayed for the cities per the third action of the GUSM Assessment Approach, as discussed in Section 9.3. Finally, in Section 9.4, the fourth action of Fig. 12.4, a quantitative measure of US, the US Ratio, and the manner in which it is calculated, is described. The operationalization of the demonstration of GUSM allows for the demonstration to produce US assessment results for each of the two cities.

These results are shown in Section 9.5, but are not answers to RSQ 2.3. Rather how GUSM and its demonstration are operationalized can be understood by referring to the chapters mentioned and specifically Chapter 9 provides a guide as to how to operationalize GUSM.

Operationalizing GUSM is the final activity of the Treatment Design phase. The next subsection will discuss how the demonstration of GUSM is validated in this study.

12.3 Evaluating an Urban Smartness Assessment Measurement Item

This section details the answer to RSQ 3.1, which deals with the qualitative evaluation of the demonstration of GUSM. This question is shown in Table 12.3 and is in the Treatment Validation phase of this study.

No.	Question
3.1	What is the usefulness of GUSM from practitioners' perspectives?

Table 12.3: Research Sub-Question 3.1

RSQ 3.1: To address this question the expert opinion interviews in Chapter 10 were conducted to gather feedback on the demonstration of GUSM, to gage how cities (or relevant city government officials) perceive the usefulness of this US assessment measurement item. These interviews form a qualitative evaluation of the demonstration. However, this evaluation was limited to two experts from two different cities and thus, this can only be considered a partial validation of GUSM. The findings from this evaluation indicate how useful they perceive GUSM to be.

These findings that impact the perceived usefulness of the demonstration concern the users of GUSM, the subcomponents and indicators it should use and the focus GUSM should have. In terms of users (discussed in Section 10.3.2), the experts indicate that they perceive the usefulness of GUSM being improved if relevant city government officials provide input on what criteria to use in US assessments, conducted on their city. They also note that GUSM can only be useful from their perspective if high-level government officials that oversee the SC strategy or program can use GUSM to gain an overview of the current US situation. In terms of the sets of subcomponents and indicators, GUSM should use. Both experts noted that sets vary between different cities, discussed in Section 10.3.3. GUSM's perceived usefulness depends on whether the criteria used in the US assessment are appropriate and fit the cities' local contexts.

In terms of what the focus of GUSM should be, each expert proposed a different change of focus (both are detailed in Section 10.3.4). This change in focus would make them perceive GUSM as being more useful. One expert found that the main focus of GUSM should be to enable the comparison between cities to create more opportunities where cities can compete against and learn from each other. Thus, the perceived usefulness of GUSM increases by improving the comparability capabilities of GUSM and its demonstration (using slightly more generic assessment criteria). In other words, moving it in between the Standardized and Mixed classifications (as defined in Section 11.1.3) in the relationship between flexibility and comparability capabilities of US assessment measurement items, as shown in Fig. 12.6. The other expert expressed that the focus of GUSM must change to align with the goals desired by the city and look to assess city performance, rather than only assessing US. These goals concern not only the city's local context (especially the challenges a city faces), but also targets not connected to US and the SC concept that the government wants their city to reach. An example of such targets are the SDGs, which may call for broader development than what is considered to be covered by the SC concept. According to the expert, assessing city performance on these targets (along with assessing US) would increase their perception of the usefulness of GUSM.

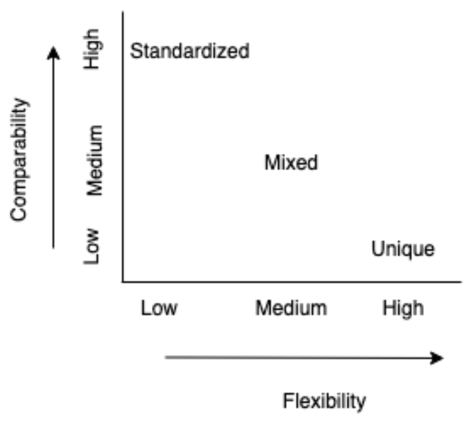


Figure 12.6: The Relationship Between Flexibility and Comparability

For the last finding relevant to the perceived usefulness of GUSM and its demonstration, experts explicitly gave their feedback on how useful they believe GUSM to be. They both found that GUSM is a repeatable, transparent and robust process to measure US, assuming that assessment criteria have been adapted appropriately to the local context and the desired goals of the city. Both experts agreed that GUSM could be beneficial to use as it allows for enhanced discussion around areas relating to the SC concept and can be used to support US development. Especially, as GUSM enables cities to quantitatively measure and visually display the measurements on the abstract SC concept. These measurements can be used to oversee the city's current situation regarding US and guide its development. However, one expert does not think that GUSM is currently useful, and only becomes useful if the focus of GUSM changes to assessing city performance (including their performance relevant to certain goals or targets) and not just US.

The experts' feedback on the perceived usefulness of GUSM and its demonstration can only be considered a partial validation as more cities need to be involved in such a validation before its results can be considered generalizable. However, this partial validation is a strong indication that GUSM can be perceived as useful. With RSQ 3.1 answered, the next section will look to answer the MRQ of this research.

12.4 Answering the Main Research Question

This section addresses the main research question. The MRQ is:

How can a city's urban smartness be measured for cities
around the globe in a standardized universal approach?

This question concerns the design problem, introduced in Section 1.3, about the development of an US assessment measurement item that would support decision making on US relevant city development through a globally standardized approach. For this research, GUSM is that measurement item. This design problem was broken down into three research goals that GUSM must achieve:

1) Build an understanding of the SC concept and what it seeks to achieve;

2) Measure the US of cities no matter the locations of those cities in the world;

3) Enable cities and other stakeholders to quickly assess and compare US.

The MRQ is answered based on how GUSM satisfies these three research goals.

The first research goal requires GUSM to support its users' understanding of the theories that such US assessments are based on. This is especially important if GUSM is to be used with a Self interaction type process, as described in Section 11.1.4, where the internal party (or the city governments) are the main users of GUSM.

Following Wieringa's understanding of theories and theory-building processes [92], GUSM is a descriptive conceptual model whereby the GUSM assessment constructs are grounded on this study's analysis of theories of other authors. The empirical analysis of the participants' feedback in the Validation Round's interviews indicates that when GUSM and its demonstration are applied and validated for more cities, this may result in a better understanding of the SC concept and what GUSM seeks to achieve. This study notes that GUSM is not prescriptive and should not be considered to be "carved in stone". Instead, it should be treated as a living artifact in the sense that if an organization consistently uses it on a regular basis, this organization's understanding of GUSM constructs would grow over time and their choice of assessment criteria to use will be based on more solid evidence.

The second research goal concerns the generalizability of the US measurement model across locations in which it could be possibly used. This means that when GUSM assesses the US of cities, it accounts for the Vague SC Concept issue as discussed in Section 11.1.1. As GUSM is descriptive, its list of assessment criteria represent a starting point in an US assessment process regardless the location where it is applied. In the current GUSM version, these assessment criteria used by GUSM must be flexibly adapted to fit the SC concept interpretation of the city using GUSM. That interpretation is linked to the local context of the city including the challenges it faces and the goals it wishes to attain (as described in Section 11.1.2). This study envisions that the process of starting from the initial list of assessment criteria and then adapting them to local contextual settings, is generalizable across locations. This thinking is grounded on the reasoning of the research methodologists Seddon and Scheepers [77] and Wieringa [92], who consider that organizations with similar goals (assessing US, in this case) could possibly create organizational mechanisms that are also similar. Therefore if the application steps of GUSM worked for one organization, one might possibly expect to work also for other organizations interested and prepared to assess and improve US. Of course, more research is needed to produce stronger evidence to ascertain the extent to which GUSM is suitable to countries in other geographic zones that so far have been under-researched by the SC community of scholars. Moreover, further research is needed as for the demonstration a set of indicators are used as an approximation of assessment criteria. They are not selected by considering if they fit the SC concept interpretation of the cities to be assessed. The fact that GUSM is designed to account for this issue (see Section 11.1.3), means this research goal can be attained in future use.

The third research goal is about enabling quick US assessments and comparisons between cities. GUSM achieves this by using a standardized assessment approach that provides cities with: (i) a repeatable, (ii) transparent and (iii) robust process to assess US. If the same or similar assessment criteria are used by cities, this standardized process will allow those cities to compare their US assessment results.

In addition, this research also explored another path to develop the comparing capabilities of GUSM, namely through standardization of the sets of subcomponents and indicators. However, it turned out that due to the Vague SC Concept issue, the lists of subcomponents and indicators are very complex to standardize. To date, there are no internationally agreed upon indicators. No globally standardized sets of subcomponents and indicators are identified. However, as the interest in US grows, and the global community, researchers and practitioners continue working on US evaluation, one might expect that some proposals for standardization might be possibly made in the relatively near future. Considering such standardization proposals in the further refinement of GUSM seems an interesting and relevant line for research in the future.

12.5 Summary

This thesis research presents a potentially standardized US assessment measurement item that pairs an US assessment approach with an US assessment framework (synthesized from a number of published frameworks) that can be applied to cities globally. This approach and framework are designed to be standardized, while the criteria to be used are not. Standard assessment criteria cannot be identified currently as they would require international agreements as to how the SC concept should be interpreted. Rather this research argues that allowing the criteria to be flexibly adapted so they are appropriate for the cities conducting the assessments, makes US assessment measurement items more relevant, valid and useful to cities. As GUSM is developed further and more US assessment related research is published, more evidence will become available and, in turn, the answer to the MRQ will become more complete.

Future research avenues concerning the development of GUSM and US assessment related domains have also been identified by this study. This research contends that GUSM can be developed to become a globally valid US assessment measurement item, and proposes that GUSM is the initial step to reach that goal.

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Appendices

APPENDIX A

Theoretical Round: Interview Discussion Guide

Interview Details

Time Needed	1 hour
Interview Topics	Smart City, City Smartness Assessment, GUSM's Assessment Approach
Interview General Format	Semi-Structured one-on-one confirmatory interview
Project Description	Develop a tool that assesses the smartness of cities on a *high-level globally* and can be used by cities to measure their current smartness and the potential impact a project will have on their future smartness when implemented.
Tool Limitations	GUSM is designed to *be practically applicable* in cities across the world. Thus, *the amount and specificity of city aspects to be measured must be limited.*
Interview Purpose	Confirmatory study. The purpose is to gather feedback on the city smartness assessment framework and approach, e.g. whether I am missing any vital research or dimensions for assessing city smartness
Interview Data Use	Interview responses will be used to modify the model or assessment approach if necessary

Table A.1: Interview Details

Interview Questions

Three terms used throughout this interview are defined in the table below:

Term	Definition
Smart City	We believe a city to be smart when investments in human and social capital and traditional transport and modern ICT infrastructure fuel sustainable competitiveness and a high quality of life, with a wise management of natural resources, through participatory governance
Urban Smartness	The smartness of a city.
City	Any urban area around the world with a population of at least 50,000

Table A.2: General Term Definitions

Introducing the Global Urban Smartness Framework

I reviewed literature in the area of urban smartness assessment research. Based on this, I propose the Global Urban Smartness Framework (displayed in Figure 1), which identifies 7 constructs that need to be measured to assess the urban smartness of a city.

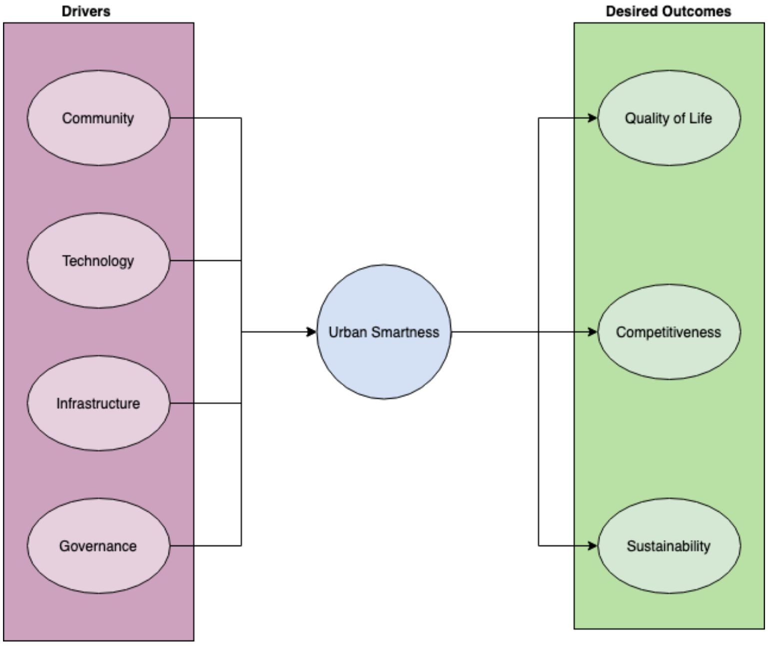

Figure A.1: The Global Urban Smartness Framework

The 7 constructs in Figure 1 are classified as driving forces (see the items on the left) and desired outcomes (the items on the right). These terms separate the tools or process (driving forces) to achieve the goals (desired outcomes) of smart cities. These 7 constructs are each defined in Table 3 on page 5.

2) **What is your feedback on the framework regarding the completeness of the constructs?**

    a) **In your opinion, does the framework include the main desired outcomes of smart cities? Is there any construct that you think is missing?**
    b) **In your opinion, does the framework include the main driving forces of smart cities? Is there anything that you think should be added?**
    c) **If you think that I should add any constructs, could you suggest some published research that these new constructs can be based on?**

Introducing a Smart City Assessment International Standard and Incorporating it into the Framework

The next two questions concern the incorporating indicator categories from a ISO standard into the Global Urban Smartness Framework.
This year, the International Standards Organization (ISO) published a new standard that identifies and defines the indicators to use to assess the urban smartness in cities. This standard is **ISO 37122** called “Sustainable cities and communities — Indicators for smart cities” and when paired with another ISO standard, **ISO 37120**, a complete set of *around 200* indicators for assessing a smart city is made. The indicators are categorized into 19 groups which are listed below:

- Economy
- Health
- Sport and Culture
- Education
- Housing
- Telecommunication
- Energy
- Recreation
- Transportation
- Environment and climate change
- Population and social conditions
- Urban/local agriculture and food security
- Finance
- Safety
- Urban Planning
- Governance
- Solid Waste
- Wastewater
- Water

Each indicator group is defined in Table A.5 on page 6.

3) **In your opinion, are these 19 indicator groups of ISO 37122 complete? Are there any groups you think the standard is missing?**

These 19 indicator groups were matched against the correlating urban smartness assessment constructs, as shown in the Detailed Global Urban Smartness Framework (Figure 2).

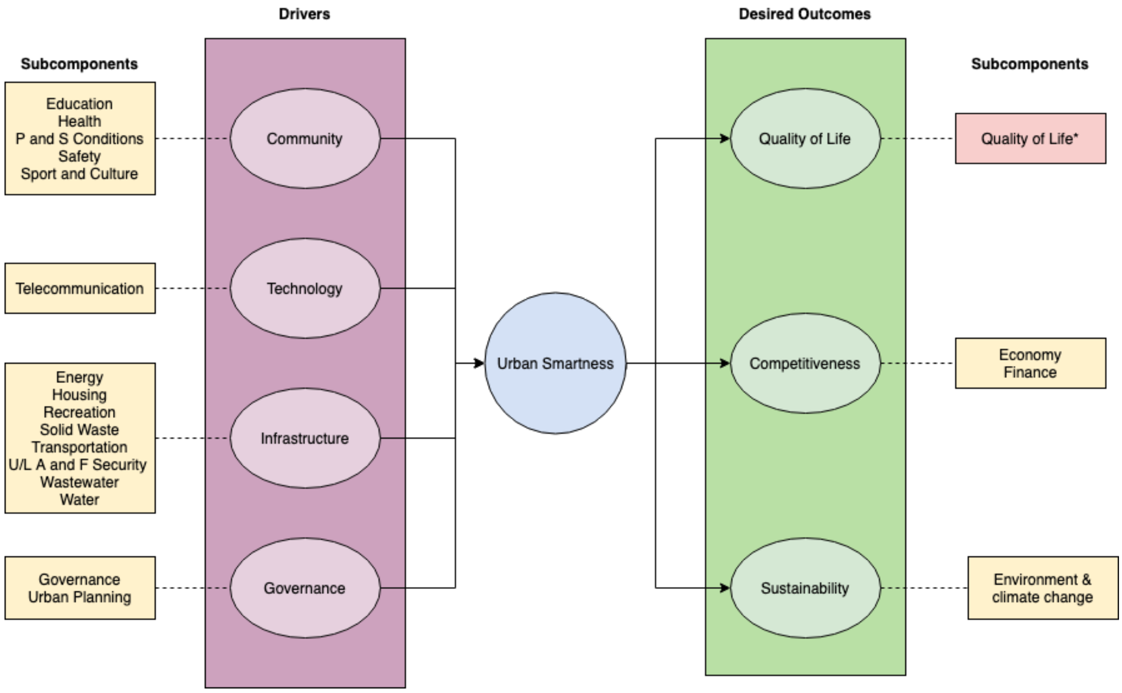

Figure A.2: The Detailed Global Urban Smartness Framework

As can be seen in Figure 2, the const1ructs used to assess urban smartness in the detailed framework are to be measured by the indicator groups or subcomponents.

Note 1: To ensure that every focus area is connected with at least one subcomponent, the additional subcomponent "Quality of Life" was added to the detailed framework.
Note 2: There is no universally accepted model to measure the driving forces and desired outcomes constructs. The subcomponents of Figure 2 are a practical approximation of measurable aspects of the constructs.

Table A.3: Global Urban Smartness Model Notes

4) **What subcomponents in the detailed framework (see Figure 2) are missing in your opinion?**
   a) **Do you have any other comments on the detailed framework?**
   b) **If you think that I should add any subcomponents, could you suggest some published research that these new subcomponents can be based on?**

The Assessment Approach of the GUSM

The Global Urban Smartness Model assesses the urban smartness of a city by completing the following four steps:

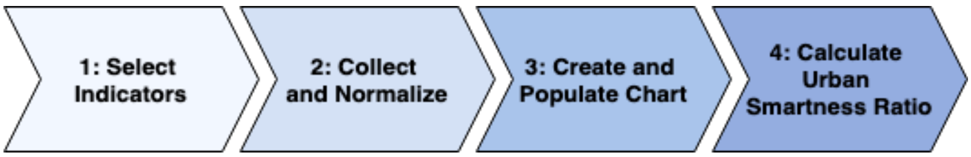

Figure A.3: The Overall Assessment Approach of GUSM

First, *one indicator is selected for each subcomponent*. Thus, the GUSM will use 20 indicators in total. The measurement data from the set of indicators is then collected and normalized. Each data value in the set is combined in the next step. Finally, using a mathematical formula, a ''Urban Smartness Score" is calculated for the city.
The Urban Smartness Score can be calculated either for the current situation of the city by gathering indicator measures, or for the city's future potential situation by estimating indicator values assuming a smart project is implemented in the city.

5) **Would you agree with how the framework is operationalized when the approach of Figure 3 is followed? How would you operationalize the detailed framework?**

The next question is a general question concerning the next model development steps in this project.

6) **What are good digital automatic sources for assessment indicators in Europe?**

Definitions of Global Urban Smartness Framework's Constructs

The table below defines the urban smartness assessment construct in the framework in Figure 1. Examples of what city aspects need to be measured to assess the construct are shown in the rightmost column.

Construct	Definition	Example of What is Measured
Communities	Aspects concerning the capabilities of people who live in the city and their organizations	Education/Health conditions of citizens, Social participation. . .
Technology	Characteristics of the use of technology in the city	Accessibility of ICT-infrastructure. . .
Infrastructure	Characteristics of the human-made elements in the urban environment	Quality of local public transport, Consumption of Energy/Water. . .
Governance	Elements concerned with performing appropriate planning, development, and management practices by the city	Citizen engagement, Accessibility of online government services. . .
Quality of Life	Aspects concerning how well people in the city live	Satisfaction with the quality of education facilities, Poverty Rate. . .
Competitiveness	Aspects concerning the economic growth and attractiveness of a city and its competitive position to other cities	Entrepreneurship, Productivity, Attractiveness for foreign investment. . .
Sustainability	Aspects concerning the efficiency of a city's management of resources and impacts on its environment	Pollution, Environmental protection. . .

Table A.4: Definitions of Constructs in the Global Urban Smartness Framework

Definitions of ISO 37122's Indicator Groups

The following table contains the definitions of the 19 indicator groups of ISO 37122. The definitions were made by looking at the indicators within each group. An example of a possible measure that connects to the indicator group is given in the second column. For example, the survival rate of new businesses is a measured by an indicator in the Economy indicator group.

Indicator Group	Definition
Economy	The general economic characteristics of the city. E.g. the survival rate of new businesses
Education	The education capabilities of the citizens in the city. E.g. of city population with professional proficiency in more than one language
Energy	The sourcing, accessibility and use characteristics of energy within the city. E.g. Energy produced from wastewater treatment
Environment and climate change	The environmental context of the city and its impact on the global climate. E.g. buildings built/refurbished using green building principles
Finance	Specific financial aspects of the city's economy E.g. Percentage of payments to the city done electronically
Governance	Aspects concerning the management of the city. E.g. Percentage of city services accessible online
Health	The healthcare situation of citizens in the city. E.g. Number of healthcare appointments conducted remotely
Housing	The residential facilities in the city and citizens housing situation. E.g. Percentage of households with smart energy meters
Recreation	The quality and other aspects of the recreation facilities in the city. E.g. Percentage of public recreation services that can be booked online
Population and social conditions	The social capability of the citizens of the city. E.g. Capability of physical disabled citizens
Safety	The safety of citizens in the city. E.g. City area covered by digital surveillance cameras
Solid Waste	The collection, recycling and disposing of solid waste in the city. E.g. Amount of waste in the city that is used to generate energy
Sport and Culture	The capability of citizens in terms of sport and culture activities in the city. E.g. Active library users as a percentage of total population
Telecommunication	The accessibility and use of ICT systems in the city. E.g. Percentage of the city population with access to sufficient speed broadband
Transportation	The city aspects concerning the transportation infrastructure in the city. E.g. Percentage of traffic lights that are intelligent/smart
Urban/local agriculture and food security	The food production aspects of the city. E.g. Annual total collected municipal food waste sent to a processing facility for composting per capita

Urban Planning	Characteristics and management of city development. E.g. City population living in medium-high population densities
Wastewater	The collection, treatment, and reuse of wastewater in the city. E.g. Percentage of treated wastewater being reused
Water	The city's infrastructure for distributing and consuming water. E.g. Percentage of buildings with smart water meters.

Table A.5: Definitions of Focus Area Subcomponents

APPENDIX B

Expert A Structured Summary

B.1 Introduction

This is a summary of the responses the Expert A gave during their expert opinion interview. This summary describes their responses concerning four topics in the following four sections. Finally, this interview is concluded in the final section. This interview was one of the two field tests conducted in the Theoretical Round. It also concerned asking for feedback on the interview process, materials, and questions. The results of which are not contained in this summary.

B.2 The Smart City Definition

- Thinks definition should be changed to line it up with the focus areas from the Global Urban Smartness Framework
  - Specifical notes that the terms ”traditional transport” from the original definition should be as they are not sure as to what these terms mean
  - Otherwise, he found the working definition to be holistic and good.

B.3 Focus Areas Contents

- They are unsure of what the contents of each focus area in the GUSF are
- Therefore they ask a lot of clarification questions on what was meant to be measured by these constructs
- Expert A also proposes changing the name of a focus area
  - In this case, change the name of the Sustainability construct to ”Environmental Sustainability”
- Expert A then comments about the uncertainty surrounding the subcomponents that measure each focus area
  - Namely, that new subcomponents need to be added and replace some existing subcomponents to measure relevant parts of the focus areas
  - Suggested new subcomponents for Quality of Life, Competitiveness, Governance, Technology, and Sustainability
  - However, also expressed uncertainty for what other subcomponents need to be measured

B.4 The Relationships within the Framework

- Expert A asked about the relationships between the constructs in the GUSF and whether weighting between the desired outcomes constructs is known.
- They expressed uncertainty on this topic

B.5 The Index Issue

- Expert A did not comment on the issue of avoiding the definition of a US index, but did indicate that they found the assessment approach of GUSM to be acceptable for US assessment

B.6 Conclusion

In conclusion, the expert opinion interview with Expert A generated feedback on three topics: (1) the necessary change to the SC definition in order to line it up with GUSF; (2) the uncertainty on what the focus areas and their subcomponents contain; and (3) the uncertainty of the relationships within the framework. They do not have any comments on the index issue, but do agree that the US assessment approach of GUSM is acceptable.

APPENDIX C

Expert B Structured Summary

C.1 Introduction

This is a summary of the responses the Expert B gave during their expert opinion interview. This summary describes their responses concerning four topics in the following four sections. Finally, this interview is concluded in the final section. This interview was one of the two field tests conducted in the Theoretical Round. It also concerned asking for feedback on the interview process, materials, and questions. The results of which are not contained in this summary.

C.2 The Smart City Definition

- Expert B generally finds smart city definition holistic and okay
  - ○ Although they believe it may be too technical in focus (and needs have a more people-centric perspective)

C.3 Focus Areas Contents

- Expert B suggests adding new constructs to both the driving forces and desired outcomes sides of the Global US Framework
  - ○ Also, the ”Reasons for Making the City Smarter” needs to be measured
    - ∗ Add to the driving forces constructs, but she also noted that this construct might be an external concept to smart city assessment (a construct/tool that evaluates the reasons that a city wishes to become smarter)
  - ○ ”Circular Economy” to the desired outcomes side
  - ○ ”Efficiency/Optimization of Management of City Resources” construct needs to be added to the desired outcomes side
    - ∗ They note it may be an aspect of the Sustainability construct
  - ○ the ”Efficiency/Optimization of Addressing Citizen Problems/ Improving Citizen Well-being” construct needs to be added to
    - ∗ They note that it may be an aspect of Governance
  - ○ Combine the Technology construct w/ Transport to make ”Mobility”.
  - ○ Expert B Notes that the seven focus areas generally lack emphasis on the important role people play in smart cities

  - Thus, they while suggesting a large number of new focus areas, expressed uncertainty of what the focus areas of GUSF contained

- This uncertainty extends to what subcomponents the focus areas should be associated with

  - Expert B comments that subcomponents need to be changed and new subcomponents are needed to emphasize the central role of people in smart cities
  - They determined that the draft list of subcomponents in the interview discussion guide should be aligned with other focus areas
  - However, they could not think at the moment of research sources to base new subcomponents or realignments on

C.4 The Relationships within the Framework

- Expert B did not have any comments concerning this topic

C.5 The Index Issue

- Expert B feels that it must be made explicit that the final outcome of GUSM is not taken as an absolute score or measurement of urban smartness
- They note that if you attach a single number to represent an idea, that number can be used inappropriately
- They commented to maybe avoid this problem, define separate scores for each of the seven focus and show them individually to emphasize smartness in an area
- This concerns the need for GUSM to avoid developing an index that says it can assess the US of cities using a standard as such an index may not be correct for all cities and can be misused

C.6 Conclusion

In conclusion, the expert opinion interview with Expert B generated feedback on three topics: (1) agreement with the holistic SC definition; (2) the uncertainty on what the focus areas and their subcomponents contain, including suggesting additions; and (3) the index issue. They do not have any comments on the uncertainty with relationships within the framework.

APPENDIX D

Expert C Structured Summary

D.1 Introduction

This is a summary of the responses the Expert C gave during their expert opinion interview. This summary describes their responses concerning four topics in the following four sections. Finally, this interview is concluded in the final section.

D.2 The Smart City Definition

- Expert C notes that there are many different definitions of smart city
    - The Smart City concept is not a ”one-size fits all” concept and thus it is important to allow for flexibility when assessing urban smartness
    - So, cities can base their assessment on their definition of smartness
    - This definition is based on what problems the city wants to address and the cities expectations of what they want to become
    - Expert C has no strong opinion of smart city's main aspects and definition as it can differ so greatly between cities
        - They prefer vague SC definition like ”using technology to achieve city goals (i.e. improve education)”
- Expert C thinks the working smart city definition covers a lot of aspects and is a generally acceptable definition
    - However, the definition in the interview discussion guide is one definition
    - There are many different SC that may be appropriate based on the local context of the city
    - So they do not understand why GUSM looks to predetermine a SC definition for all the cities assessed

D.3 Focus Areas Contents

- In general, Expert C is ok with the focus areas of GUSF, but still expressed uncertainty as to what these focus areas contain

- They note the constructs are very broad, which is ok from a certain perspective, as the framework highlights the main aspects of cities on a high level
- But it's very difficult to know what each construct contains
- Depends on what the person conducting the assessment thinks (or from what perspective they view the focus areas)
- What is contained in the focus areas also depends on who is part of this (who is part of each construct that this assessment would focus on)
  - For example the Quality of Life focus area mainly concerns citizens
    - † The focus areas can be measured differently depending on who is the focus of each focus area
    - † Multiple indicators can be used to measure the focus areas depending on who is the focus that focus area
  - They think that the organization of the subcomponents can be changed concerning how the draft list of subcomponents are associated with the focus areas

D.4 The Relationships within the Framework

- Expert C proposed several alterations to the relationships in GUSF:
  - Display relationship arrows between driving force constructs and also between the desired outcome construct.
  - Also, perhaps a positive feedback loop from the desired outcomes to the driving forces constructs, as strong desired outcome performance might lead to stronger performance for the driving forces constructs
  - Maybe change the direction of the Urban Smartness to Desired Outcomes arrows
- They also note that making the issue more difficult is that constructs overlap with each other (F.e. Quality of Life can be said to contain elements in and directly related to the other constructs like Housing quality)

D.5 The Index Issue

- Expert C is generally ok with the assessment approach, but thinks an initial step is needed where the person/city conducting the assessment can flexibly decide how to weight the desired outcomes
- Expert C emphasizes that since urban smartness differs from city to city, how it to assess urban smartness appropriately differs as well between cities and the tool must offer cities flexibility
- Therefore, Expert C encouraged avoiding the index issue by make GUSM flexible, so that it will appeal to more cities
  - It can offer flexibility by letting cities pick which option to use different sets of indicators, sets of subcomponents and weights

D.6 Conclusion

In conclusion, the expert opinion interview with Expert C generated feedback on four topics: (1) the SC definition differing between cities as the definition changes depending on the local context; (2) the focus areas are acceptable, but the expert expresses uncertainty on what the focus areas contain; (3) the uncertainty of the relationships within the framework and they proposed three relationship changes to GUSF; and (4) that this research study should avoid developing an US index by making GUSM flexible.

APPENDIX E

Expert D Structured Summary

E.1 Introduction

This is a summary of the responses the Expert D gave during their expert opinion interview. This summary describes their responses concerning four topics in the following four sections. Finally, this interview is concluded in the final section.

E.2 The Smart City Definition

- Expert D notes that there are many different definitions of smart city
  - They note that there are many definitions for Smart city for the research they reviewed over the years and so there are many aspects for smart cities
  - They prefer to define it as using technology to focus on 3 aspects: Productivity, Efficiency, and Quality of Life
  - Expert D notes that identifying the main Urban Problems cities face when they want to become a smart city is a wicked problem as from city to city this differs (even in cities in the same region)
  - The SC definition depends on what problems the city wants to address and the cities expectations of what they want to become
- Expert D thinks the working smart city definition covers a lot of aspects and is generally acceptable
  - However, they are not sure what the term ”traditional transport” means from the original smart city definition

E.3 Focus Areas Contents

- Expert D is uncertain as to what these focus areas contain
- They noted:
  - Difference between Technology and Infrastructure focus areas
    - They asked If aspects of infrastructure contain technology what constructs will they fall under and what is contained in the Technology construct
  - Also noted that they would like to see a Productivity focus area and more about the city economy, but later thought that it's a part of Competitiveness

- They think that the organization of the subcomponents can be changed concerning how the draft list of subcomponents are associated with the focus areas
  - Also that the Desired Outcomes focus areas need more subcomponents
  - Especially for the Quality of Life focus area

E.4 The Relationships within the Framework

- Expert D proposed that the relationships between the focus areas of GUSF be changed in two ways:
  - They think the relationship arrows between the Urban Smartness and the Desired Outcomes construct should be reversed to reflect ”higher urban smartness leads to higher desired outcomes” relationship.
  - Expert D notes that it is not clear what the relationships between the desired outcomes and driving forces are

E.5 The Index Issue

- According to Expert D, a big challenge of the operationalization of the framework will be to input data, specifically when different cities measure f.e. Safety differently
- To address this challenge, Expert D encourages GUSM avoiding determining a score or index and attempting to rank cities to find the ”smartest” city
  - They expect plenty of cities will try to claim that they are the smartest based on this index
  - But this raises the questions: what components are the index based on?; do these components appropriately assess the US of the cities measured?; How are these components measured?
  - Cities may not understand what and how the index is calculated and may as a result not find the US assessment measurement item that produces it, very useful
  - Thus, in the development of such a model, maintaining a high-level of transparency is crucial to how useful the measurement item is for cities
  - Expert C also highlighted that showing how each value/subcomponent contributes to the final GUSM output is another component of maintaining a high-level of transparency
- Therefore, Expert D encouraged avoiding the index issue by make GUSM transparent, so that it will appeal to more cities
  - By fully documenting and displaying what component and how those components are to be measured and combined to assess the city US, the model can be transparent
- Also, Expert D identified flexibility as an important trait for US assessment measurement items
  - They suggested that the assessment process included weights to the assessment formula with goal of making the measurement item as flexible as possible

E.6 Conclusion

In conclusion, the expert opinion interview with Expert D generated feedback on four topics: (1) the SC definition differs between cities based on their local context; (2) the uncertainty as to what the focus areas contain; (3) the uncertainty of the relationships between focus areas and they proposed two relationship changes to GUSF; and (4) GUSM must be as flexible and transparent as possible due to the varying nature of US assessments (ensuring it is appropriate for each city).

APPENDIX F

Expert E Structured Summary

F.1 Introduction

This is a summary of the responses the Expert E gave during their expert opinion interview. This summary describes their responses concerning four topics in the following four sections. Finally, this interview is concluded in the final section.

F.2 The Smart City Definition

- In the SC research Expert E has conducted, they share the holistic perspectives of smart cities used by this research
  - However, they note that there is a major focus on implementing technology to improve city smartness, but some cities focus on doing things in the other ways (making a city smarter does not have to involve Technology i.e fact-based decision making)
- Thus, Expert E would define SCs similar to the working definition of this research

F.3 Focus Areas Contents

- Expert E proposes one new focus area for GUSF
  - They want to add a new Driver focus area, ”Financing” (elements may be covered by existing focus areas)
  - According to them, no new Desired Outcomes focus areas are needed as they are very broad
    - But they do propose renaming the Sustainability construct
- They note that the Quality of Life constructs need a mix of new subcomponents that might cover topics from the other constructs
  - They also found that existing subcomponents need to be reassociated to the focus areas
- Therefore, Expert E indicates being somewhat uncertain about the focus areas

F.4 The Relationships within the Framework

- Expert E did not make any comments concerning this topic

F.5 The Index Issue

- Expert E who published US assessment research and has investigated city attitudes towards US assessment measurement items has found that city administrators generally don't like absolute indexes
  - Especially in the cases where such indexes are unclear as to what they measure and how they are calculated
  - Where a vague change (that is not transparent) in the index calculation changes the results
    - Leaving the cities to ponder how the index calculation and their rank changed
  - As a result Expert E found that cities decide that the index might not capture the aspects they are interested in and thus do not find the index useful
  - They encourage that any US assessment should be adapted for the local context of the city so that it can be useful for policy makers
- Thus, Expert E believes that carrying out such an assessment will be improved by including the decision-makers as much as possible
  - They noted that the selection of indicators is crucially linked to the policy intentions and the policy priorities of a certain city, as the assessment should help policy-making and benefit policy decision-makers
  - Expert E is in favor of improving the flexibility of the US assessments of any measurement item by offering a portfolio of indicators for cities to select

F.6 Conclusion

In conclusion, the expert opinion interview with Expert E generated feedback on three topics: (1) a holistic perspective and a similar SC definition is shared between this research and Expert E; (2) the uncertainty as to what the focus areas and subcomponents should measure; and (3) from the experience of Expert E's research, developing an index should be avoided in order to account for the desires and the local context of the cities and its policy makers. They propose making any US assessment measurement item as flexible as possible to address the index issue. They do not have any comments on the relationships within the framework.

APPENDIX G

Expert F Structured Summary

G.1 Introduction

This is a summary of the responses the Expert F gave during their expert opinion interview. This summary describes their responses concerning four topics in the following four sections. Finally, this interview is concluded in the final section.

G.2 The Smart City Definition

- Expert F found that which SC initiatives in a city are most needed, changes based on the challenges faced by a specific city (each context is different)
  - The indicators needed for an appropriate US assessment differ according to the challenges the city is facing
- Expert F published research article(s) with their own smart city definition and US assessment methodology.
  - The expert's definition is slightly different than the working SC definition of this research, but captures most of the same aspects

G.3 Focus Areas Contents

- Expert F expressed uncertainty in what the focus areas contained, but thinks they are very broad and should be holistic
  - However, they don't know what exactly might be missing
  - As a result, their feedback on these focus areas is limited
- This uncertainty extends to the subcomponents of the focus areas, where a large number of them need to be rearranged.
  - They are also uncertain of what these subcomponents are meant to measure

G.4 The Relationships within the Framework

- Expert F expressed uncertainty as to why the focus areas in GUSF are grouped separately (drivers vs. desired outcomes constructs) and the relationship between those groups

    - They propose designing an assessment grid or matrix that analyses the complex relationships between the two groups of focus areas and with the challenges faced by the city
    - The expert explicitly notes that the constructs do interact with each other, but how exactly is not known
    - I.e. Technology may not be a driver (rather something used by the driver focus areas)

- Expert F also highlights that the relationship between subcomponents and focus areas also needs to be changed, but this change depends on the city its local context and the possible challenges it faces

G.5 The Index Issue

- Expert F agreed with the general US assessment approach of GUSM, but noted that any final output figure it gives that summarises the US of a city into one number, the individual values of the subcomponents are more interesting
    - It allows a city to assess how well it is doing in individual areas and learn amongst cities
        * i.e. City 1 has a high score for Education - what project did they implement that impacted Education?
    - Makes the US assessment measurement item useful as it offers practical insight into urban smartness and helps identify cities/smart projects to follow/show how a city can appropriately develop itself further
- Expert F advises that measurement items conducting US assessments should adapt to the possible challenges faced by cities in the region
- Thus, US assessment measurement items should not look to calculate a standardized index that does not adapt to the challenges faced by the city concerned
    - They note that cities can performpoorly on indicators which are standardized internationally and still find appropriate answers to the issues they face
    - Easier for a city to choose a problem (or challenge) than which indicator to use
        * Therefore, Expert F suggests making the measurement item flexible to be able to adapt the subcomponents and indicators to the situation of the city
- They do agree with the four actions GUSM's assessment approach

G.6 Conclusion

In conclusion, the expert opinion interview with Expert F generated feedback on four topics: (1) the SC definition of a city changes based on the challenges faced by that city; (2) the uncertainty on what the focus areas and their subcomponents contain; (3) the uncertainty of the relationships within the framework and the importance to include those relationships in the assessment; and (4) the expert recommends that GUSM does not calculate a standardized index that does not account for the local context of a city and possible challenges it faces.

APPENDIX H

Validation Round: Interview Discussion Guide

Interview Details

Time Needed	1 hour
Interview Topics	Smart city, Urban smartness assessment, GUSM's usefulness
Interview General Format	Semi-structured validation interview
Project Description	Develop a tool that assesses the smartness of cities globally and can be used by cities to measure their own current smartness and the potential impact a project will have on their future smartness when implemented.
Interview Purpose	Validation study. The purpose of this interview is to gather feedback on the usefulness of the GUSM prototype developed for this project.
Interview Data Use	Interview responses will be used to validate the prototype of the GUSM (or GUSM V1.0).

Table H.1: Interview Details

To begin, two terms that will be used throughout this interview, are defined in the table below:

Term	**Definition**
Smart City	We believe a city to be smart when investments in human and social capital and general city and ICT infrastructure fuel sustainable competitiveness and a high quality of life, with a wise management of natural resources, through participatory governance.
Urban Smartness	The smartness of a city.

Table H.2: General Term Definitions

Interview Discussion

Before proceeding in this interview, the next two sections introduce the GUSM.

Developing the Smartness of Cities

There has been a growing trend of urbanization across the world. Cities face more and more challenges. To address these challenges, cities often turn to solutions linked to the smart city concept. The concept is defined on a holistic, high-level in Table 2. However, on a low-level, every city has its own local context that forms the basis for its unique urban smartness definition. While there is no standardized definition of smart city, many cities do want to develop their urban smartness.

That begs the question: How do you improve a city's urban smartness?

The solution is to select and implement effective projects to develop urban smartness. This selection is a complex matter for the people responsible for making such decisions. Central questions in this decision-making process are: What aspects of urban smartness are stronger and weaker in the city? What projects would best improve that smartness? How effective were they elsewhere?

Introducing the Global Urban Smartness Model and its Prototype

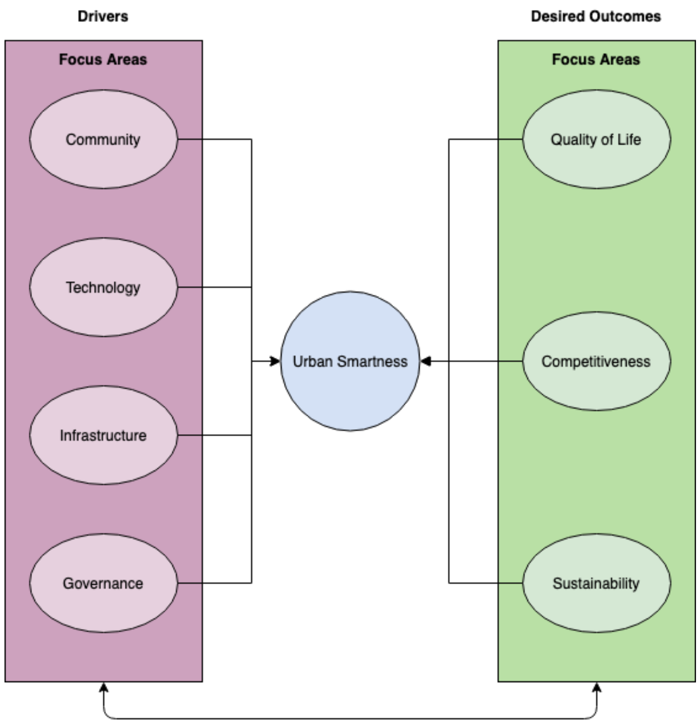

Figure H.1: The Framework Used by GUSM

The Global Urban Smartness Model was developed to support this decision making. The model framework in Figure 1 defines the seven constructs – the focus areas - of urban smartness on a high-level. Urban smartness cannot be directly measured. Rather it can be indirectly assessed by measuring these seven constructs.

What aspects each focus area concerns is defined in the Appendix. The focus areas can be measured by collecting data from one or more indicators.

Indicator data is analyzed for the assessment of the smartness of the city. The data is then presented to be discussed by the model's end users.

Note that this assessment is based on the unique urban smartness definition of the original city. Other cities can be assessed and compared with the original city. However, they define urban smartness differently when conducting assessments and they would use different indicators.

For this project, I have developed an Excel-based prototype of the model. I have selected indicators to assess the smartness of your city. This is not meant to be a perfect assessment, but an approximation of such a measurement. The selection of an ideal set of indicators is not the focus of this research.

The model and its prototype visualize the data of urban smartness, allowing easy communication of the urban smartness assessment and comparisons of assessments between cities.

Overall the Global Urban Smartness Model provides a repeatable, transparent and robust process to support decision-making on which smart city project(s) a city should invest in.

Responses

At this point, you will be provided with GUSM V1.0 (the GUSM prototype) and we will go through it together. You will then be asked to discuss a number of statements listed in the following section.

Per statement you will be asked:

How much do you agree with all of the statements according to the scale shown in Table 3 below?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Table H.3: Five Possible Responses Scale

For each statement, explain your response.

Would your response differ for GUSM V2.0? If yes, you will be asked to explain how and why.

Statements to Discuss

The statements are based on the Unified Theory of Acceptance and Use of Technology (UTAUT) model which is used here to determine how useful GUSM V1.0 can be for decision-makers. They are displayed in the table below. To improve the readability of the statements, they have been grouped in sets of four. The statements in the table refer to the GUSM prototype as GUSM V1.0.

No.	Statement
1	I would find GUSM V1.0 useful in my job.
2	Using GUSM V1.0 would increase my productivity.
3	My interaction with GUSM V1.0 would be clear and understandable.
4	I would find GUSM V1.0 easy to use.
5	It would be easy for me to become skillful at using GUSM V1.0.
6	Using GUSM V1.0 to support my tasks is a good idea.
7	I would like working with GUSM V1.0.

8	In general, my organization would support the use of GUSM V1.0.
9	I have the knowledge necessary to use GUSM V1.0.
10	GUSM V1.0 is compatible with other systems I use.
11 - 12:	**I could complete a job or task using GUSM V1.0**. . .
11	. . . if there was no one around to tell me what to do as I go.
12	. . . if I had just the built-in help facility for assistance.
13	I feel apprehensive (or uncertain) about using GUSM V1.0.
14	GUSM V1.0 is somewhat intimidating to me.
15	I predict I would use GUSM V1.0 in the next 6 months.

Table H.4: UTAUT Statements

Finally, two general question to capture anything not discussed previously:

16) Do you have any recommendations of what features should be added or removed for GUSM V2.0?

17) Do you have any other comments on GUSM V1.0 or anything related?

I would like to thank you for participating in this interview!

Appendix

The aspects from each focus area in the Global Urban Smartness Model framework (shown in Figure 1) are defined in Table 5 below.

Focus Area Name	Definition
Community	Aspects concerning the capabilities of people who live in the city and their organizations including social participation or health/education conditions of citizens.
Technology	Characteristics of the use of technology in the city including the accessibility of ICT-infrastructure
Infrastructure	Characteristics of the human-made elements in the urban environment including the transport system or population density
Governance	Elements concerned with performing appropriate planning, development, and management practices by the city including public services or citizen engagement
Quality of Life	Aspects concerning how well people in the city live including satisfaction with education/health facilities or poverty rate
Competitiveness	Aspects concerning the economic growth and attractiveness of a city and its competitive position to other cities including productivity or entrepreneurship
Sustainability	Aspects concerning the efficiency of a city's management of resources and impacts on its environment including pollution or energy

Table H.5: Focus Area Definitions

APPENDIX I

Enschede Interview Structured Summary

Introduction

This is a summary of the responses the participants gave during the Enschede Interview. This summary describes their responses concerning five topics in the following five sections. Finally, this interview is concluded in the final section.

Indicators to Use

- They noted that while appropriate indicators to use to assess the US of a city would be based on that city's SC definition that the major obstacle for any such assessment
    - Understood that the set of indicators could not be standardized and would be changed depending on the city's definition and available indicators
    - To enable the comparison of assessments, they agreed with the following:
        - Cities can select indicators from a list of indicators preselected research or experts
        - Cities assessed by same or similar indicators (which are then appropriately normalized) can be compared to each other
        - Enabling comparison is an important point as they note it is interesting to see how other cities are doing
- According to them, the indicators used in most of GUSM's assessments would be relevant to the Sustainable Development Goals (SDGs[1]) defined by the United Nations
    - Assessments should account for the SDGs (as they also use almost the same indicators)
    - indicators for measuring the SDGs should be used in assessments
    - This idea is addressed further in other sectionss

[1]https://sustainabledevelopment.un.org/?menu=1300

The Focus of the Model

- The focus of GUSM (and its prototype) should be changed to not only assess the US of a city, but assess the performance of a city as whole or assess the performance in terms of the SDGs
  - ○ The needed change in focus is aligned to the ''Indicators to Use" , ''Use of Model" and ''Recommendation" sections
  - ○ Now any assessment result GUSM produces is interesting
    - ∗ But US in itself is not the goal of cities or theirGI SC projects
    - ∗ "The smartness of a city is interesting, but it's not urgent. When we look at the city as a whole and how we're doing and how well the city is doing on education, well being and health, all of a sudden it's urgent and important"
    - ∗ "It's not about how smart we are, but how is everyone doing in the city and what can we do to make it better for them. That's the main goal for the city and the city government."
    - ∗ So GUSM usefulness changes from the tool is interesting to it assess the city's main goal
  - ○ According to them, most of the focus areas in GUSM do not concern smartness alone (except maybe Technology)
    - ∗ Thus, the model can easily be adjusted to cover the components of the whole city or SDGs relevant components
  - ○ GUSM's usefulness greatly improves when it's focus changes
    - ∗ Many comments in this interview noted that GUSM would be more useful if not just US is assessed but the city as whole (or the SDGs) is assessed

Use of the Model

- They do not think that GUSM can currently be useful, although they do see the benefits it can provide
  - ○ Noted that GUSM and its prototype did provide aa repeatable and robust process to measure US and it would help project selection decision-making
  - ○ But for city problems as a whole, than only for US
  - ○ They identified the US Spider Chart as as a good way to visualize such indicator date
- Key issue with its use:
  - ○ The goal of cities is not to be smart (or increase US) but to address problems they've identified
  - ○ Select projects that "solve" those problems
  - ○ What problems need to be addressed differ for the cities
    - ∗ F.e. Enschede does not experience the mobility problems that Amsterdam, a city with a higher population (and higher pop. density) than Enschede.
    - ∗ Thus Enschede does not need to invest much in projects that address mobility problems alone
  - ○ The key focus is the urgency of the problem

- One begins by identifying the problem one wants to lose, you don't start with a solution to a problem you don't have
- When deciding which project a city wish to implement:
  - the most important thing is to analyze a problem that you can address with new current and available technologies
  - Then you need to measure the impact of the project
- SC-Project Selection decision-makers would want a tool that identifies the urgent problems faced by the city, the model does not do that.
  - GUSM might indicate several areas where such problems are but it does not indicate the level of urgency or analyze specific problems that need to be addressed
- In their experience, for such projects, you want to start by identifying what problems the project solves
  - As ones started with identifying the IT solution first leads to projects being implemented which don't solve anything
    - † Maybe in the short term, but not in the long term
  - A way to quantify and measure project impact (or desired impact) will ensure that the project "solves" (or keeps solving) the problem over the long-term
  - They do agree that GUSM can identify problem areas but then you have to study those problem areas thoroughly
  - GUSM can be more useful for looking at the city as a whole and not only smartness
    - † They are always looking to answer these questions:
      - ▷ How are we doing compared to other cities? How well is the city doing? And how well are things going in the city?)
      - ▷ They're unsure of how GUSM answers these questions
    - † Key point: this does not just concern smartness, but all subjects in the city
    - † In GUSM all the indicators are very important for the city
    - † All the indicators for the model capture crucial aspects of city performance
      - ▷ Important for cities to know and have quantifiable evidence of this performance
      - ▷ Then it is interesting to see how other cities are doing
      - ▷ But all this is not as interesting if just assessing US but assessing the city as a whole
      - ▷ Then it would be very interesting for city spatial development as a whole

- GUSM and it's prototype seems clear, understandable and easy to use
  - But they need more time to study it to comment on how compatible it is with systems they use or if they and their colleagues would feel uncertain about using it in the future
  - These comments are taking account of the fact that the city will receive help initially to set the model up with the indicators desired by the city
    - In other cases, the city only has to provide an external party with data and they give back the results
    - GUSM contains a lot of information, so it is intimidating

    * With more time on their part to study the model, they says it's quite clear that you would lose that sense of intimidation in the future

- As explained by them, people that would most benefit from using GUSM (assume the focus is changed as described in the next section) are government employees who oversee the whole city and keep track of the city's performance

  - Not people who oversee and manage the SC projects themselves

Potential Additional Features

- According to them, including additional features (like assessment monitoring) that enable the tracking of assessments over the long-term will make GUSM and its prototype more useful, but only if the focus of the model is changed as discussed in the previous section

Recommendation

- Enable assessment of the city with indicators for measuring the SDGs
  - This is currently a very popular international concept (cities sticking to the SDGs) and would make the tool more interesting to cities evaluating their performance on the SDGs
  - Cities need a way of measuring their performance on these goals and the GUSM provides a relevant approach

Conclusion

In conclusion, the Enschede interview participants find that GUSM and its prototype would not be currently useful as the measurement item's focus is on assessing US. That focus should be on the assessing of the performance of the city as a whole or the city's performance concerning the SDGs. If the focus of GUSM is changed, the model can be very useful as it will measure how the city is doing on its main goals and not how smart it is (which is only interesting to certain people).

APPENDIX J

Wuppertal Interview Structured Summary

Introduction

This is a summary of the responses the participants gave during the Wuppertal Interview. This summary describes their responses concerning five topics in the following five sections. Finally, this interview is concluded in the final section.

Indicators to Use

- They noted how useful such a model would be, depends on the indicators used in the assessment
  - For example: Wuppertal emphasizes social inclusion, so if the assessments conducted are to be useful for the city of Wuppertal: they must use indicator(s) that measure the social inclusiveness of the city (among others)
- Selecting which indicators to use is a new concern that must be addressed before this tool can be used
- They do agree that even if two cities from different parts of the world used different (but similar indicators) through appropriate normalization
  - They could be used in assessments and those assessments could be compared together

The Focus of the Model

- The focus of the model must be on comparing the US assessments of different cities
  - They find this to be the most interesting part of GUSM
  - Every cities' insight into SC and what it means for them is getting better
  - Cities want to compete but also need to learn from one another
  - Determining indicators to enable such comparisons again emphasizes the importance of the indicators used in the assessment

Use of the Model

- Intention to use:
  - GUSM allows one to quantify (or provide numbers) to the very abstract concept of Smart City.
    - Thus, using this tool allows for enhanced discussion around what project areas to focus on/what projects to implement
    - ”Controlling what you are doing” in this case is a good idea
      - † Getting measurables (in the indicators) and getting results for the focus areas gives them the ability to control the focus areas and to oversee the city’s desired development progress.
    - The city of Wuppertal would support the use of GUSM
    - They say they would use GUSM and its prototype within the next six months
    - They note that it would used by them as they oversee the SC program, but the deeper you go in the organization they oversee, one deals with other processes which don’t need such an assessment done
  - Disagrees that GUSM would improve the productivity of project selection decision making as now the selection of indicators to use in the assessments is a new critical task
- Ease of Use:
  - They are confident that they would be able to use GUSM and its prototype as its theory and processes have been explained in the interview
    - But they note that any new user would need for the theory behind the model to be explained before it can be used.
    - Once the user understands that theory, the model becomes clear and easy to use
      - † But they do indicate that their confidence in using the system is due to their technical background and they need to study the system more before they can address the pluggability of the systems into the processes used in SC project selection
  - Strongly disagrees when asked if GUSM’s prototype makes them feel apprehensive or intimidated

Potential Additional Features

- The usefulness of GUSM and its prototype is enhanced slightly by including additional features like long-term tracking (or monitoring) of US assessment or making the model more autonomous

Recommendation

- Provide enhanced comparison features to GUSM
  - Allowing the assessing cities to compare their assessments to assessments (using the same or similar indicators) to more cities at once
    - The prototypes only compares 2 cities’ assessments

* Increase the amount of cities in the comparison
* Also incorporate cities around the world and enable their assessments to be included in any comparisons
* Reasons for importance of comparisons detailed in ‘‘The Focus of the Model” section above

Conclusion

In conclusion, the Wuppertal interview participants find that GUSM and its prototype can be a useful tool to support SC project selection decision making assuming that appropriate indicators are used in the assessment. Determining what the ‘‘appropriate indicators” are is difficult to do and can dramatically impact the usefulness of this measurement item. They find that the focus of this model must be enabling the comparison of US assessments and recommend enhancing the comparison capability even further.