Navigating Tomorrow's Cities:
Data in Transitioning Urban Transport Systems

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Abstract

This thesis explores the application of data in transitioning Urban Transport Systems (UTS) by investigating the kind of data needed to facilitate successful transitions. The study takes a qualitative research approach, combining expert interviews and secondary research to gain valuable insights into the practical application of data in UTS transitions.

The research begins by analysing the objectives of UTS transitions, drawing from the "Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan" (Rupprecht Consult, 2019) and expert interviews. These objectives encompass economic, social, and environmental dimensions of sustainability, emphasising the importance of multimodality and active mobility in an inclusive and accessible transport system. The analysis highlights the need for an integrated governance approach, utilising the Transition Management (TM) framework. It involves developing a shared long-term vision for UTS and planning short- and mid-term tactics to achieve it. Political support, stakeholder engagement, and data utilisation are vital in this process.

Data is identified as a key factor in UTS transitions, and the research delves into its characteristics. The study identifies various data elements and corresponding data sets, providing a framework for understanding the diverse types of data relevant to UTS transitions. Aligning with the visioning approach of UTS transitions, the collection of demand data and prescriptive data is essential to explore future pathways.

The collection of accessibility data is crucial to transition UTS. While challenges exist in assessing this type of data, efforts should be made to gather more accurate information. However, the research findings reveal that practitioners tend to prioritise mobility measurements, influenced by the emphasis on Sustainable Urban Mobility Plans (SUMPs). To shift the focus towards improving accessibility, it is recommended that EU guidelines incorporate a stronger emphasis on accessibility planning. Furthermore, a holistic approach to UTS transitions is emphasised, considering the interconnectedness of various urban systems and their impacts on liveability, health, safety, and the environment.

Overall, this thesis provides valuable insights and recommendations for policymakers, practitioners, and researchers in the field of UTS transitions. Analysing the practical application of data and addressing knowledge gaps contributes to understanding complex system transitions for sustainable cities. Furthermore, it provides a foundation for further exploration and advancement in this important area of study.

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Abbreviations

UTS	Urban Transport System
TM	Transition Management
DPP	Descriptive, Prescriptive, Predictive
TMA	Traffic, Mobility, Accessibility
SUMP	Sustainable Urban Mobility Plan

1. Introduction

Once dedicated to cars, street space lately is transformed into bicycle lanes and parklets, creating more room for active mobility and opportunities to spend time in the urban area. There are ongoing debates about making our city centres car-free. A lot of action is taking place in our cities to improve the so-called "sustainable urban mobility". However, some changes happen surprisingly for the citizens and cause disputes and resistance. Since the publication of the EU Mobility Package in 2013 (Rupprecht Consult, 2019), more European cities have been planning the transition of their urban transport systems (UTS).

An increasing quantification is happening in our society (Mennicken & Espeland, 2019). Coupled with increasing digitalisation, data has become a valuable resource, also in the field of transport planning. This growing value of data is pointed out by statements such as "data is the new oil" (Javornik et al., 2019, p. 295). However, the narrative about transport data centres around smart approaches that aim to quantify urban life (Bibri, 2018; Kandt & Batty, 2021; Zawieska & Pieriegud, 2018). But what information is actually needed to transition UTS?

Kalakou et al. (2021) identified a gap in practice between envisioning and implementing change in UTS: After developing the vision of their future UTS, practitioners are facing the question of how to approach the implementation and effectively collect, evaluate and use data in the process.

Concerning data application in UTS transitions, it is stated that:

> "Transportation professionals should become familiar with the various measurement methods and units available, learn about their assumptions and perspectives, and help decision makers understand how they are best used to accurately evaluate problems and solutions."
>
> (Litman, 2003, p. 16)

Therefore, this thesis aims to investigate the transition of UTS, focusing on the data sets and elements needed to successfully facilitate the changes. The question "What kind of data is needed to transition UTS?" is approached with qualitative research investigating the issue in practice. The use of transition theory and data frameworks helps to organise the data gathered through expert interviews and the EU policy document for Sustainable Urban Mobility Plans (SUMPs). This research contributes to the planning and implementation practice of UTS transitions by pointing out assessments needed. The focus lies on urban areas in the European context.

Figure 1 presents an overview of this research. The thesis's outline is as follows: The introduction of the concepts of sustainability and UTS is used to explain the perception of the research objects. Following this is a literature review of UTS transitions and data, which explores existing knowledge and approaches and identifies research gaps. Then, the theoretical framework presents the Transition Management (TM) framework, which is used in this thesis to analyse the governance approach to UTS transitions. Data frameworks, such as Descriptive – Prescriptive – Predictive (DPP) and the data organisation framework, are used to organise the data sets identified in the research. These are then analysed with the Traffic – Mobility – Accessibility (TMA) framework to discuss the data needed to implement UTS transitions. The method chapter describes the gathering and organisation process of the data for this thesis, which is based on the qualitative research methods secondary research and expert interviews, and the coding process. After the analysis of the research results, the implications of the findings are discussed. Lastly, limitations and future recommendations are pointed out, and the research is concluded.

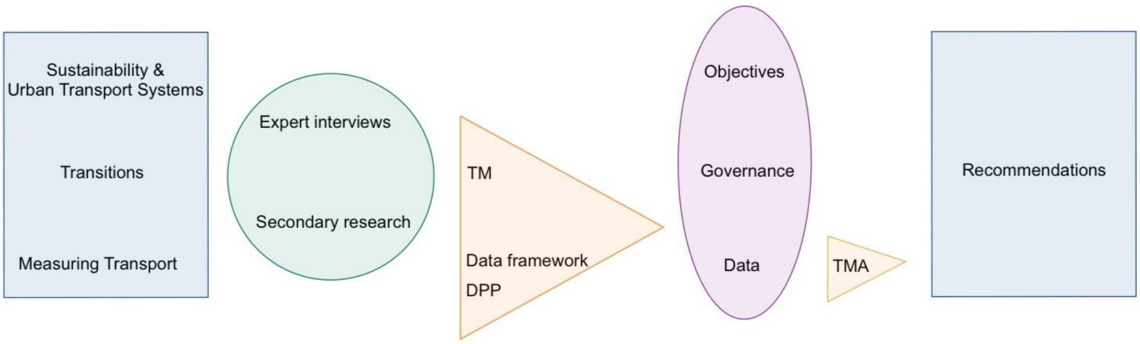

Figure 1: Overview over the research (own figure).

2. Sustainability and Urban Transport Systems

This chapter introduces the concepts of sustainability and urban transport systems (UTS) in order to lay the groundwork for understanding UTS transitions, which are in the focus of this thesis.

At the end of the 20th century, the concept of sustainability became present in society. The World Commission on Environment and Development, called Brundtland Commission, published the report "Our Common Future", in which sustainable development is defined as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987 in Gudmundsson et al., 2010, p. 50). A common framework for the different dimensions of sustainable development is the three pillars of sustainability: the economic, social and environmental, also called the triple bottom line (Litman, 2011). In the following, it is explored what sustainability means in UTS.

Sustainable development is a worldwide goal, and the United Nations have developed the 17 Sustainable Development Goals (SDGs), which define objectives in various areas (United Nations, 2023). The 11th goal focuses on sustainable cities and communities. With the ongoing growth of cities worldwide, they represent the melting pot for human interaction, which is a challenge and a potential at the same time. Cities, therefore, are places where a variety of systems are located and interact with each other. The transport system is one of these so-called socio-technical systems (Geels, 2012; Geels & Schot, 2010). The rethinking of transport plays a vital role in the sustainable development of cities since transport makes up for one-third of emissions in major cities (OECD, 2020). SDG 11.2 aims to "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all" (United Nations, 2023).

Transport systems provide cities with "facilities for the exchange of people, goods and ideas" (Gudmundsson et al., 2010, p. 46), and since people move more and more, UTS are an indispensable part of everyday life. According to Gudmundsson (2010), Mobility and Accessibility are the central objectives of transport systems. Accessibility, also referred to as proximity, is described as "the opportunity, or potential, provided by the transport and land-use system for different types of people to engage in activities." (p. 46). Mobility is described as the ability to move, which is related to the "availability, affordability and efficiency of transport systems" (Gudmundsson et al., 2010, p. 46).

Banister (2008) introduces the sustainable mobility paradigm as an alternative approach to traditional transport planning. The method is to envision goals and develop scenarios to reach them, also referred to as the strategic planning process of backcasting. Visioning is described as "an important management instrument for achieving new insights and starting points" (Loorbach, 2010, p. 175) and therefore is a progressive approach to imagining future developments.

The sustainable mobility paradaigm differs from traditional transport planning and its predict-and-provide approach, which is based on forecasting and modelling traffic (Holmberg & Robert, 2000). The traditional transport planning approach is described as not applicable to cities, which are constituted by high-density and mixed-use developments, and instead require the inclusion of land use into transport planning. Contemporary transport planning approaches are comprehensive (Litman, 2011) and strategic integrated planning (Rupprecht Consult, 2019). The aim is to focus more on social dimensions, which not only aims to plan for people instead of vehicles but also to include citizens, although only in order to gain public acceptance. It includes all different transport modes instead of focusing on motorised transport. Therefore, walking and cycling, also referred to as "active transport" (Litman, 2011, p. 81), are supported, with the street being regarded as a space instead of a road. The focus is therefore not only on the economic evaluation of transport systems but includes environmental, as well as social concerns. (Banister, 2008)

Cities worldwide are planning the transition of their UTS. Tafidis et al. (2017) refer to the main sustainable mobility objectives, which are summed up as:

- Integration of land use and transport planning,
- Accessibility,
- Increased mobility,
- Promotion of non-motorised means,
- Encouragement of public transport,
- Environmental concerns,
- Economic welfare, and
- Road safety.

The article "Sustainable Mobility at Thirty" by Holden et al. (2019) argues that sustainability in the context of mobility extends beyond addressing climate change and encompasses a broader range of considerations such as equity, accessibility, and social well-being. UTS are therefore connected to liveability since they directly affect citizens' everyday lives and impact a city's liveability. Liveability describes the perceived quality of an area by its users. This includes safety and health, environmental conditions, and also aesthetics, uses and social climate (Litman, 2005). UTS can decrease liveability through noise and air pollution or by not providing areas with sufficient transport opportunities (Rees et al., 2020). On the other hand, the transition of UTS can increase liveability by creating a good transport connection and quality of stay in an area by planning for people instead of vehicles. Connected to this, the transition of UTS can increase health by supporting active modes of transport.

Since the concepts of sustainability, liveability, mobility, and accessibility overlap and are partially used interchangeably, the term "transitioning UTS" is used in this thesis to describe this change. UTS transitions in this context are related to sustainability while at the same time providing more liveability and health by improving mobility and accessibility for all. This wording intends to not limit the transitioning process to certain goals but to provide a holistic transition. However, since sustainable mobility is a prominent term and concept, it is partially used in the research process, and Sustainable Urban Mobility Plans (SUMPs) are regarded as a strategy to transition UTS.

Based on this understanding of sustainability and UTS, the next chapter focuses on a literature review of existing literature on UTS transitions and the role of data in it.

3. Literature Review

This chapter presents a literature review on transitioning UTS and data's role in it. First, the field of system transitions is explored, focusing on UTS, followed by the investigation of studies on TM. Then, the role of data in UTS transitions is introduced and underpinned by the transport planning approach. After that, studies on transport data types are examined, and finally, research in the field of SUMPs is summarised. Based on this literature review, research gaps are identified.

Policy approaches to sustainable development, such as the SDGs introduced in the previous chapter, are criticised for focusing "on a limited set of dimensions of (un)sustainability" (Geels, 2012, p. 472). Instead, systems understanding is needed to achieve such significant shifts (TRB, 1997 in Litman, 2011; Sachs et al., 2019; Voulvoulis et al., 2022). Shifts from one system to another are regarded as "long-term and complex socio-technical transitions" (Geels & Schot, 2010, p. 11). The research field of socio-technical system transition emerged in the early 2000s within innovation studies. Since then, much research has focused on the dynamics of the transitions. The existing literature on the transition of UTS primarily studies the process from a multi-level perspective (MLP), aiming to understand the prevailing regimes and future development paths (Geels, 2012; Geels et al., 2017; Moradi & Vagnoni, 2018).

A growing field of research focuses on the governance of transition processes with the framework of Transition Management (TM) (for example, Frantzeskaki et al., 2018; Kuss & Nicholas, 2022; Roorda et al., 2012). It is used to analyse transition processes, identify barriers and opportunities, engage stakeholders, develop transition pathways, and facilitate monitoring and evaluation of initiatives (ibid.). This thesis adds to the research about governance transitions by studying UTS transitions from the position of experts from practice. This approach is further explored in the theoretical framework.

The debate about data in the transition of UTS is centred chiefly around research on big data and smart technological approaches (Bibri, 2018; Bisello et al., 2021; Campos-Cordobés et al., 2017; ITF, 2023; Lissandrello, 2021; Schröder, 2022; Zawieska & Pieriegud, 2018). Having access to as much data as possible is seen as beneficial in planning transport systems (Javornik et al., 2019). However, it is discussed that an evidence-based planning approach alone might be a pitfall (Kandt & Batty, 2021). This aligns with the critique on traditional transport planning with its predict-and-provide approach, namely forecasting, as described in Chapter 2.

The traditional transport planning approach is based on planning for travel demand (Litman, 2003). This, combined with the focus on data about vehicles, has led to an increase in the development of car-based infrastructures. With the promotion of active mobility, the collection of cycling and walking count data has gained more attention. In "We count what we care about", Piatkowski and Marshall (2018) promote a paradigm shift in data collection from count data to gathering more qualitative data assessed through surveys or accessibility analyses. Litman (2003) also advocates for a change in focus from vehicles and movement to the opportunities provided by transport systems. He argues that the measurement of current conditions might limit the exploration of possible pathways to the prevailing constraints and highlights the importance of decision-makers being aware of their data choices' impact on the success of their actions since they bring along different perspectives and assumptions (ibid.).

Litman (2003) phrases: "You can't manage what you can't measure" (p. 2) and therefore emphasises the pivotal role of selecting appropriate indicators to assess the performance of achieving envisioned objectives. However, it is suggested that indicators "should be derived as much as possible from existing accounting data sets" (Litman, 2011, p. 7) to reduce the effort needed to start the process. One current challenge in comprehensive and sustainable transport planning is the absence of standardised indicator sets (ibid.). While there has been much research on different indicators for transport system transitions (Badland et al., 2015; Chatziioannou et al., 2023; Gudmundsson et al., 2010; Litman, 2005; Tafidis et al., 2017; Toth-Szabo & Várhelyi, 2012), there is a research gap in classifying this data into a broader framework, which identifies what kind of data should be measured on. Therefore, this thesis aims to define data elements and sets needed in UTS transitions. This is further investigated in the theoretical framework with the TMA framework.

Since SUMPs are an EU approach to transitioning UTS, many cities have developed their plans and are beginning to implement the measures. SUMPs are studied in scientific research, however, mainly in the form of comparison of plans and their effectiveness (Jordová & Brůhová-Foltýnová, 2021; Kalakou et al., 2021; May, 2015; Michelini et al., 2023; Papaioannou et al., 2016; Reform, 2018). These studies reveal that data plays a crucial role in SUMPs, highlighting its importance in decision-making, assessing transport patterns, and addressing challenges related to availability, quality, integration, and stakeholder engagement (ibid.). This knowledge gap is addressed in this thesis.

Overall, there is a gap in research combining transition theory and transport data, which this thesis explores. The following chapter presents the theoretical framework, introducing the concepts to structure and analyse the research results.

4. Theoretical Framework

Building on the literature review, this chapter introduces the theoretical framework used to structure and analyse the research results. It is formed by TM, which is used to analyse the governance approach to UTS transitions and serves to investigate the role of data in this process. A framework to classify transport data is formed thereafter based on DPP and the data organisation framework. The TMA framework is used to identify what the measurements are focusing on. The results later facilitate a discussion about what data is needed in UTS transitions.

4.1. Transition Management

A transition is defined as "a fluent change towards a new future, which is an improved version of the existing" (Moradi & Vagnoni, 2018, p. 233). Transitions are characterised by co-evolution and multi-actor processes that radically change a system over a long period (Geels and Shot, 2010). Therefore, they are nonlinear processes in which persistent problems are faced, making transitions complex and unmanageable (Loorbach, 2010). However, TM presents a framework to govern such operations (ibid.).

TM is based on governance and complex systems theory, and it is a framework to regulate the development of modern industrial societies. The persistent problems faced in the process are characterised by affecting different actors with differentiating perspectives. Therefore, strategies to overcome these are not pre-given but need to be explored. Long-term strategies at the societal level are required, which include prescriptive approaches that go beyond the analytical. TM is a partly descriptive and partly prescriptive framework, considering the prevailing conditions while simultaneously developing visions for desired future developments. (Loorbach 2010)

The TM cycle, displayed in figure 2, contains four types of governance activities that are used for implementing strategies and instruments in a transition process: the strategic, the tactical, the operational, and the reflexive. They are presented in the following in order to investigate the elements needed to successfully govern a transition.

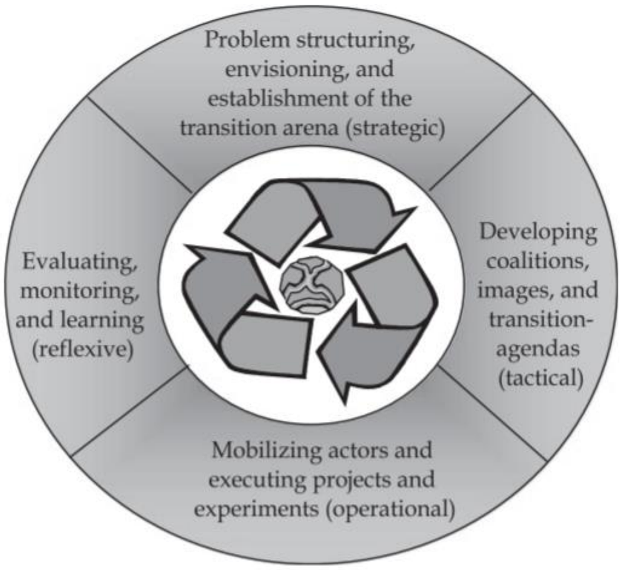

Figure 2: The Transition Management Cycle (Loorbach, 2010, p. 173).

Strategic activities are related to the culture of a system and focus on the socio-political process of policymaking in the early stages of a transition. In TM, it is related to the so-called Transition Arena, which is "a societal network of innovation" (Van Buuren and Loorbach, 2009 in Loorbach, 2010, p. 174). It consists of actors from governments, businesses, science, and civil society, which do not represent their own wishes, but those of their group. The aim is for them to develop a shared understanding of the problem to generate a long-term vision for the system's transition collectively.

In the ***tactical*** phase, steering activities change the dominant structures of a system. Here, it refers to the Transition Agenda in which transition paths are identified to develop short- and mid-term strategies to achieve the emerged vision.

In the ***operational*** phase, action takes place based on the previously developed Transition Agenda in the Transition Arena. In the form of experiments, innovative projects are supposed to initiate a transition process. Once proven successful, these actions can be scaled up.

Reflexion is related to all previously described activities and "needs to be an integrated part of governance processes" (Loorbach, 2010, p. 170). In the form of monitoring and, based on that, evaluation, both the transition process itself and the transition management are analysed and potentially adjusted. (Loorbach, 2010)

In this thesis, it is investigated what kind of data is needed to transition UTS. The focus lies on the tactical phase of the TM cycle, which is characterised by short- and mid-term strategy development to reach the long-term vision. A framework to classify the data is based on the theories introduced in the following section.

4.2. Measuring Transport

This section aims to create a framework to classify the data needed to successfully transition UTS. Therefore, DPP, the data organisation framework and the TMA framework are introduced, which are used to structure and analyse the results from the research process.

The literature review in Chapter 3 states that data has a vital role in transport planning. However, in order to successfully transition UTS without forecasting, the focus should not be on predicting vehicle traffic volumes but consider other data elements that lead to implementing the desired goals.

First, an overview of different data types is created to understand what kind of data there is to structure the research results section. In the "Guidelines for developing and implementing a Sustainable Urban Mobility Plan", it is distinguished between different types and collection methods of transport data:

- Quantitative data from automatic measurements or GPS,
- Quantitative and qualitative data from surveys or observations,
- Qualitative data from interviews or focus groups,
- Qualitative data from journals, blogs, social media, and
- Modelling data to fill data gaps (Rupprecht Consult, 2019, p. 68).

This demonstrates that not only the quantified perception of data in the form of numbers but also qualitative data is important to consider when planning to transition UTS.

Another characteristic of data used in big data analytics is the classification into descriptive, predictive and prescriptive data (DPP) (Lian et al., 2020). Descriptive analyses describe what happened and what is there. In this context, it aims to understand the current situation, which can be used as a baseline to compare future developments. Prescriptive analyses explore possible future actions, and predictive studies foretell what will happen to adapt to future situations.

The data organisation framework for transportation planning is displayed in figure 3. It structures data in different data components with a variety of data elements. The data components are supply and demand attributes, as well as the system performance and impact. (Huang, 2003; Jack Faucett Associates, 1997)

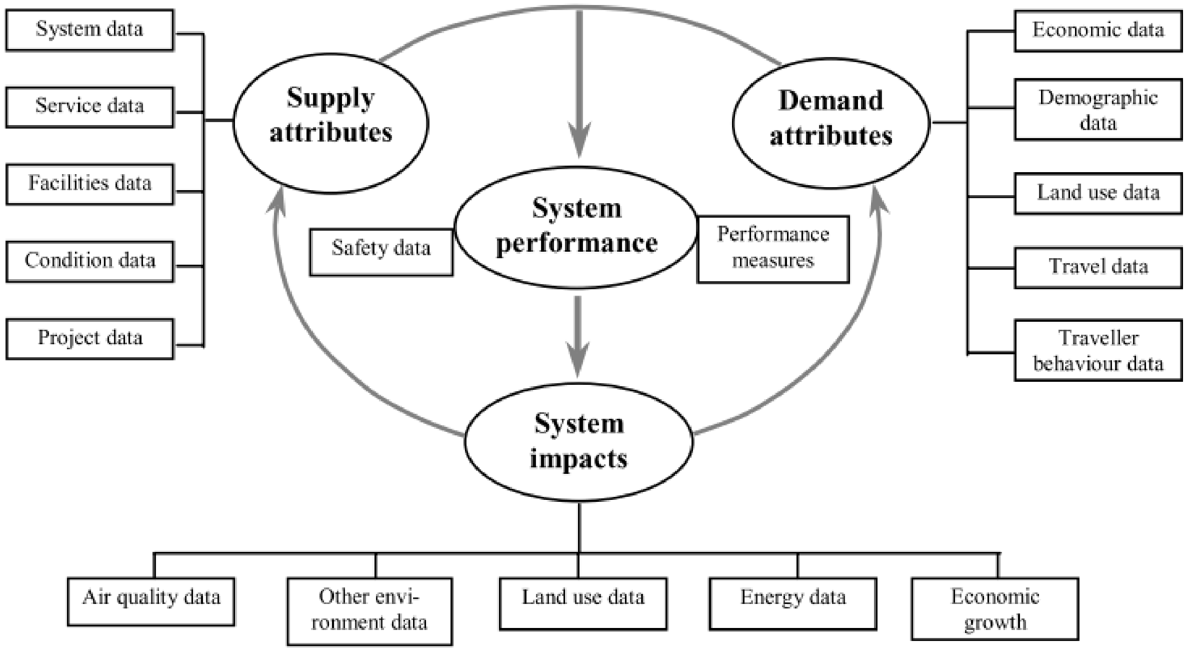

Figure 3: Data organisation framework (Jack Faucett Associates, 1997 in Huang, 2003, p. 21).

Supply data contains information about existing facilities and networks and represents the system to be transitioned. Demand data focuses on the users of the system that undergoes the transition. Performance indicators show how supply and demand combine to deliver effective transportation services. And the system impacts investigate the UTS' external effects on related systems. These last two data components are related to monitoring and evaluation. Table 1 displays data elements and sets related to these data components.

Data components	Data elements	Data sets
Supply attributes	System	Capacity, mileage, lanes
	Service	Service providers, fare structure data
	Facilities	Inventory of facilities, land use
	Condition	Road conditions
	Project	Related previous and future plans
Demand attributes	Economic	Income, employment, vehicle ownership
	Demographic	Population & household characteristics
	Land use	Acreage, access, distribution, mix
	Travel	Traffic volume, trip generation and distribution
	Traveller behaviour	Mode and route choice, preferences
System performance	Safety	Accidents, security, medical service
	Performance measures	Efficiency and performance
System impacts	Air quality	Emissions, impact assessment
	Other environment	Aesthetics, noise, ecosystem
	Land use	Socio-economic, neighbourhood
	Energy	Consumption, efficiency, price
	Economic growth	Employment

Table 1: Data organisation framework (own table, based on Jack Faucett Associates, 1997, A2)

Even though this framework is developed in the context of traffic data, in this thesis, it is transferred to UTS transitions and includes its characteristics, such as active modes, instead of focusing only on vehicles.

This section introduces the framework of Measuring Transportation by Litman (2003). It differentiates between measuring Traffic, Mobility, and Accessibility (TMA). The aim of using this framework is to analyse the focus of the data identified in this research.

The measurement of ***traffic*** is characterised by its focus on vehicles and the objective to increase vehicle mileage and speed in order to improve the transport system. ***Mobility,*** on the other hand, is related to the movement of people and considers multimodality, i.e., the use of different modes of transport. Therefore, it aims to increase travel mileage or speed to improve the system. ***Accessibility*** is defined as the ability to reach destinations, also referred to as opportunities. In order to improve transport systems from an accessibility perspective, various factors come into play, such as the improvement of mobility or land use accessibility, also called proximity. Litman (2003) describes accessibility as "the ultimate goal of transportation" (p. 16). (Litman, 2003)

Table 2 gives an overview of the characteristics of traffic, mobility, and accessibility.

	Traffic	Mobility	Accessibility
Definition of Transportation	Vehicle travel	Person and goods movement	Ability to obtain goods, services and activities
Unit of measure	Vehicle-miles and vehicle-trips	Person-miles, person-trips and ton-miles	Trips
Modes considered	Automobile and truck	Automobile, truck and public transit	All modes, including mobility substitutes such as telecommuting
Common performance indicators	-Vehicle traffic volumes and speeds -roadway Level of Service -costs per vehicle-mile -parking convenience	-Person-trip volumes and speeds -road and transit Level of Service -cost per person-trip -travel convenience	-land use accessibility -Multi-modal Level of Service -generalised cost to reach activities
Assumptions concerning what benefits consumers	Maximum vehicle mileage and speed, convenient parking, low vehicle costs	Maximum personal travel and goods movement	Maximum transport options, convenience, land use accessibility, cost efficiency
Consideration of land use	Favors low-density, urban fringe development patterns	Favors some land use clustering, to accommodate transit	Favors land use clustering, mix and connectivity
Favored transport improvement strategies	Increased road and parking capacity, speed and safety	Increased transport system capacity, speeds and safety	Improved mobility, mobility substitutes and land use accessibility

Table 2: Comparing Transportation Measurements (Litman, 2003, p. 12).

Litman describes the measuring of traffic as the easiest way to measure transportation. For instance, it can be done based on vehicle ownership and miles statistics. Measuring mobility is described as more difficult because it includes people's travel behaviour. On top of traffic data, it can be assessed through travel surveys. Accessibility is the most difficult to determine because it depends on many factors, including land use. The evaluation of accessibility is based on generalised costs, which are the time, money, discomfort, and risk required to reach destinations.

Litman (2003) points out the "tendency of decision-making to focus on easy to measure goals and impacts while ignoring those that are more difficult to measure" (p. 3). He differentiates between the accuracy and precision of data. While accuracy refers to correctness, precision refers to the level of detail. In order to accurately measure transport systems, he emphasises the importance of measuring accessibility aspects, such as walking conditions or proximity, even though they are more challenging to measure than traffic and might not be measurable with as much precision. This highlights the importance of quality instead of quantity regarding the data needed to transition UTS. (Litman, 2003)

The identified data types needed in UTS transitions are classified with the data organisation framework and the DPP categorisation. This helps to create an understanding of the characteristics of the data pointed out by the interviewees. The TMA framework is used to analyse these research results regarding their orientation to discuss whether the data elements are expedient or if other important measurements need to be undertaken to transition UTS.

Following the presentation of the theoretical framework, the methods used to gather and organise the data for this thesis are described in the next chapter. The frameworks presented in this chapter are used to analyse the data. It needs qualitative research methods to investigate the approach taken in practice.

5. Methods

This chapter presents the methods used to gather and organise the data for the thesis. Qualitative research was conducted to investigate how to transition UTS and what data therefore is needed. The research results are also treated qualitatively by examining what is said and not how often something is said. The secondary research approach lays the theoretical foundation for the thesis through the literature review. It also provides insights into the general policy aims of the EU, which lay the foundation for how SUMPs are supposed to be approached. Following this, the interview process is described, including a presentation of the interview partners and the questions asked. The interviews provide expertise from practice and therefore explore the gap between theory and practice by looking at what is actually done. After that, the coding is described based on which the gathered data has been organised and analysed.

5.1. Secondary Research

Qualitative secondary research was conducted by studying existing literature and the European policy on the topic (Largan & Morris, 2019). The literature was identified through scientific databases, such as Elsevier, and organised in Mendeley. The main research terms, as displayed in figure 4, are related to the field of study, "Data in Urban Transport System Transitions".

Figure 4: Main research terms (own figure).

Using these terms in the research process facilitated an understanding of the theoretical background of the research context and existing knowledge in the field. Based on the information gathered, the research problem was formed, and the research approach was developed. The qualitative secondary research builds the foundation for the literature review, the theoretical framework, and the introduction of the concepts in Chapter 2.

The "Guidelines on Developing and Implementing a Sustainable Urban Mobility Plan" (Rupprecht Consult, 2019) are based on the EU's Mobility Package. The guidelines aim to assist cities in the transition of their UTS. They were analysed to understand how the transition of UTS is strategised from an EU perspective. The research results form the analysis of objectives and the governance approach of transitioning UTS.

The analysis is structured through the literature review and theoretical frameworks presented in Chapter 4.

5.2. Semi-structured Interviews

Semi-structured interviews consist of predetermined but open-ended questions, which allows the researcher to guide the interview in the desired direction while at the same time following up on the interviewees' statements (Given, 2008). This method was chosen to react to the interviewees' information and adjust the questions accordingly.

Different interview guides with open-ended questions were developed beforehand for each interview. The questions addressed the research objectives, beginning with a definition of Sustainable Urban Mobility and then focusing on what kind of data or information is needed to transition UTS, after the vision is developed. The term information was used on purpose to extend the understanding of data from being quantitative only. The questions were phrased broadly, aligning with the backcasting process of envisioning a desired state and how to get there.

The following section introduces the seven experts interviewed in this research. Interviewees with diverse backgrounds were chosen, representing a range of stakeholders from both public and private institutions. These stakeholders operate at various levels, from the neighbourhood to the national level, and their responsibilities encompass a wide array of tasks related to transitioning UTS. As a result, the interviewees bring valuable insights derived from their practical experience and research expertise. While most interview partners are based in Copenhagen, one interviewee is from the Netherlands to broaden the scope of knowledge gathering within a European context.

This diverse selection of interviewees has proven beneficial in obtaining a variety of perspectives. The first group of interviewees comprises individuals from administrative institutions. They shared valuable insights into their planning and implementation processes for UTS transitions. Thomas Sick Nielsen is Senior Consultant at Vejdirektoratet (English: the Danish Road Directorate) and provided transport planning and analysis expertise. Søren Bom, Chief Consultant at Region Hovedstaden (English: Capital Region of Danmark), offered insights into the transition of UTS from the perspective of the capital region. Additionally, two interviews were conducted at the municipal level. Annette Kayser, Project Manager for sustainable mobility at Københavns Kommune (English: the City of Copenhagen), was responsible for developing Copenhagen's SUMP "Action Plan for Green Mobility". André de Wit, who is a Mobility Advisor at Gemeente Rotterdam (English: the City of Rotterdam), shared the Dutch city's approach to its walkability strategy.

Subsequently, interviews were conducted with academics and scholars affiliated with universities in Copenhagen. These interviews shed light on ongoing research projects related to transport data. Mayara Moraes Monteiro, a Postdoctoral Researcher at the Department of Technology, Management and Economics at Danish Technical University (DTU), offered expertise in transport demand modelling. Ane Rahbek Vierø, a PhD Student at the department of NEtwoRks, Data, and Society at IT University (ITU), shared her insights on bicycle network analysis.

Valuable insights were also gleaned from a professional from the private sector, James Thoem, who is an Associate at the research and design consultancy Gehl in Copenhagen, which prioritises creating "cities for people".

The selection of interviewees with diverse backgrounds aimed to capture a wide range of insights from different domains. Rather than comparing the interviewees' answers, the objective was to integrate their contributions into a comprehensive overview. Consequently, in the results section, no distinction is made regarding the individual sources of information.

5.3. Coding

The analysis of the interview data involved a coding process to extract and organise relevant information. The collected quotes were initially compiled into an Excel table, which served as the foundation for the coding process. This approach allowed for a systematic examination of the data, enabling the identification of patterns and insights relevant to the research objectives. The coding process followed an iterative and dynamic approach without pre-established categories (Given, 2008).

To begin with, the quotes were assigned to specific labels that corresponded to the topics explored in the research, namely:

- Objectives
- Governance
- Data
- Key statements

These labels were derived inductively from the research results obtained through the interview questions, which aimed to investigate various aspects of UTS transitions, including objectives, governance, and data.

Subsequently, connections between statements were identified and organised within an overview. This process allowed for grouping related statements and condensing their content into more concise wording. It is worth noting that the focus was on capturing the overall essence of the answers rather than prioritising the frequency of mention or the individuals who provided the statements.

The next chapter presents the analysis of the data gathered with this qualitative research methods.

6. Analysis

In this chapter, the research results are analysed, organised into three sections. First, the objectives of transitioning UTS are investigated based on the requirements for a sustainable transport system (Rupprecht Consult, 2019). Alongside, the answers gathered in the interviews are described. After that, the focus is on how to govern the transition of UTS, and identifying the role of data in this process. Similar to the first section, the approach presented in the guidelines is outlined and corroborated by the information resulting from the interviews. Lastly, the question of "What kind of data is needed to transition UTS?" is addressed with the interview results. The data is organised according to the framework of DPP and the data organisation framework. In the next step, the orientation of the data is analysed with the TMA framework.

6.1. Objectives for Urban Transport Systems

In order to plan for UTS transitions, it first aimed to understand what constitutes it and, connected to this, how it is defined (Webinar, 2023). Therefore, requirements for a sustainable transport system, as pointed out in the guidelines, are described, and the interview results are outlined, aligning with it.

The "Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan" (Rupprecht Consult, 2019) are introduced since SUMPs are regarded as an EU approach to transition UTS. The document was developed to give an overview of the practice and guide planners and decision-makers in the SUMP process. The document adds to the EU Mobility Package from 2013. A SUMP is defined as:

> "A strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles."
>
> (Rupprecht Consult, 2019, p. 9).

The guidelines present the desired strategic integrated planning approach, contrasting the traditional transport planning approach described in Chapter 2, and requirements for a sustainable transport system are pointed out. These requirements are presented and compared to the interviewees' statements on UTS objectives.

According to the guidelines, a sustainable transport system should fulfil all three pillars from the triple bottom line of sustainability: the economic, the social, and the environmental (Rupprecht Consult, 2019). The interviewees also emphasised that next to the consideration of the environmental perspective of sustainability, the social

(Interview 2, 2023; Interview 4, 2023) and economic (Interview 3, 2023) are also important.

From an economic viewpoint, the intention is to meet businesses' and industries' demands, which is also addressed in one interview (Interview 3, 2023). Furthermore, an efficient and cost-effective system is intended (Rupprecht Consult, 2019). This is described by an interviewee as "There is an easy, cheap, convenient mobility option available to you that doesn't require you to like, destroy the planet" (Interview 5, 2023). The prevailing car-centeredness of cities needs to be taken into account. However, alternatives to private vehicles should be provided (Interview 5, 2023; Interview 7, 2023),. Thereby, pedestrians should be prioritised over cars (Interview 6, 2023) by promoting walkability (Interview 2, 2023). This ties in with the aim to have fewer cars in the urban space (Interview 2, 2023; Interview 6, 2023). Connected to this, electrifying private vehicles is not seen as expedient since this does not reduce the number of cars on the streets (Interview 2, 2023).

Aligning with this, the aim is to effectively use the existing infrastructure and develop different transport modes, thereby providing multimodality (Rupprecht Consult, 2019). This is connected to the objective of a sustainable transport system to be accessible and meet the needs of all users (ibid.). UTS should provide a cohesive network (Interview 2, 2023), which brings the field of land use into play. Urban environments should be attractive and promote quality of life and public health (Rupprecht Consult, 2019). The interviewees approve of this vision and propose greening and mixed-use developments in order to create a place for sojourning (Interview 2, 2023), which describes the quality of staying at a location. The prevailing high density in urban areas is beneficial for creating mixed-use spaces, which in turn reduces the need to travel (Interview 3, 2023; Interview 4, 2023). This is also aimed for with the sustainable mobilty paradigm (Banister, 2008).

Another objective of UTS is safety and security, which is pointed out in the guidelines and the interviews (Interview 1, 2023; Interview 2, 2023; Interview 3, 2023). After all, it is still intended for the transitioned UTS to reduce air and noise pollution, greenhouse gas emissions, and energy consumption (Rupprecht Consult, 2019), which is also touched upon in the interviews. Finally, the goal of meeting the citizens' demands is mentioned repeatedly in the guidelines and the interviews. How to approach this will be further investigated in the following section.

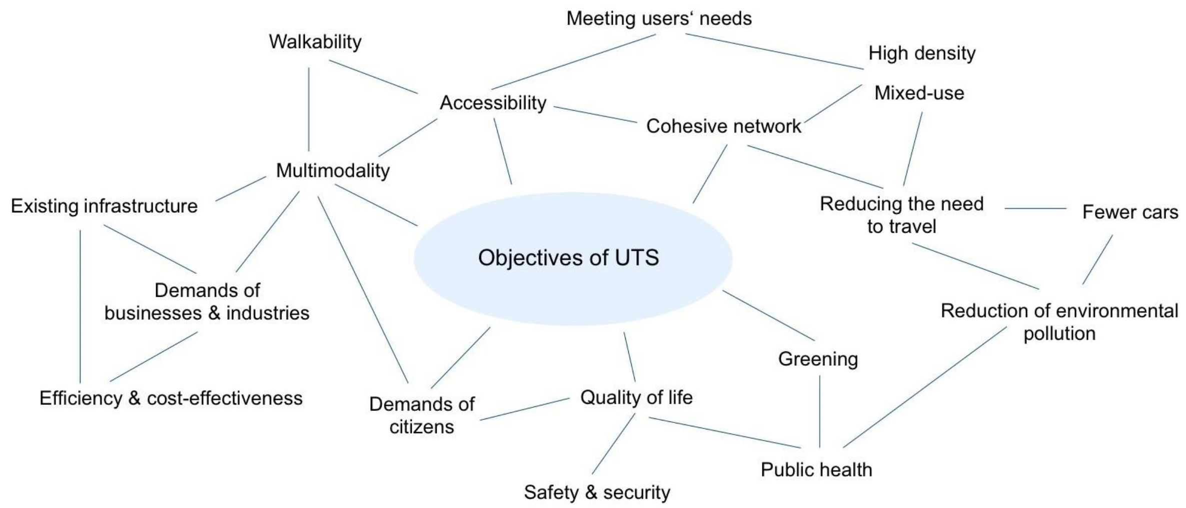

Figure 5: Objectives of UTS (own figure).

Figure 5 presents an overview of the variety of objectives of UTS. Summing up, it can be said that a sustainable transport system is constituted of many interrelated elements, which are affecting various people and processes, as described in Chapter 2. Based on this knowledge, the analysis of the research results is continued, starting with the governance approach of UTS transitions.

6.2. Transition of Urban Transport Systems

This section focuses on challenges in UTS transitions and the governance approach with necessary actions. Complex systems, such as UTS, need a comprehensive approach to their transition, which is facilitated through TM (Loorbach, 2010). This section uses the TM cycle to structure the information from the guidelines and the interviews. It concludes with the role of data in the governance approach in order to further investigate what data is needed to transition UTS.

The different phases of the TM cycle are described as the four governance activities: strategy, tactic, operation, and reflection, in the TM framework (Loorbach, 2010).

In the ***strategic*** phase, a long-term vision for the transition of the UTS should be developed with various stakeholders (TM). This approach is described in the guidelines as well as the interviews (Interview 2, 2023; Interview 3, 2023; Interview 7, 2023; Rupprecht Consult, 2019).

Once this vision is developed, the ***tactical*** activity of transition agenda development should be done. The importance of gradually planning the steps towards achieving the vision is emphasised in the interviews (Interview 7, 2023). In practice, this backcasting approach is more challenging to follow because there are different burdens that cities are facing (Interview 1, 2023; Interview 6, 2023; Interview 7, 2023). It is mentioned that the facilitation of UTS transitions mainly depends on the city's political support (Interview 7, 2023). The measures need to be accepted by politicians in order to receive permission and resources to implement them (ibid.). The interviewees mention that the engagement of citizens is an essential contributor to gaining political acceptance. The engagement of citizens is also emphasised in the guidelines (see graphic), and overall, the importance of citizens' acceptance concerning the measures is pointed out as high. In this context, the carrot vs stick approach is intended to be followed, which refers to the aim of attracting citizens rather than restricting them with measures (Interview 1, 2023; Interview 7, 2023; Webinar, 2023).

Figure 6: Involvement tools and methods for SUMP development (Rupprecht Consult, 2019, p. 48).

Figure 6 presents engagement strategies for the different SUMP phases in four levels of public participation: inform, consult, collaborate, and empower (International Association for Public Participation, 2018). The lowest level of citizen engagement is to inform, which does not include assessing their opinion. Next are consult, in which public feedback on suggestions is considered, and collaborate, which aims to partner with the public in the decision-making. Finally, the highest level, empower, places final decision-making in the hands of the public and therefore implement what the citizens decide on. The interviewees describe their approaches to citizen participation through surveys and workshops, in which they are asked for their development ideas (Interview 2, 2023; Interview 7, 2023). This is connected to the collaborate approach, as displayed in figure 6.

Cooperation generally is an important factor in the SUMP process (Rupprecht Consult, 2019), as well as in TM (Loorbach, 2010). On the institutional level, cross-departmental cooperation during the planning and implementation phase is beneficial to reach common goals more efficiently (Interview 2, 2023). Related to this, it is aimed for the plans to include the areas across the city borders, which the interviewees describe as a challenge due to the lower density and lower mix of uses in rural areas, which results in higher car dependence (Interview 2, 2023; Interview 3, 2023; Rupprecht Consult, 2019). It is also mentioned that the link of SUMPs to climate action plans is a helpful step to get stakeholders on board (Interview 3, 2023).

Cooperation with private companies is described as fruitful for reaching desired transition goals and gaining economic benefits. The need for data sharing is linked to this, which faces some boundaries but would significantly improve the transition process. (Interview 3, 2023; Rupprecht Consult, 2019)

In the ***operational*** phase, actions are intended to be tested with pilot projects to test measures on a small scale and demonstrate the activities' success (Interview 6, 2023; Loorbach, 2010).

In the ***reflexive*** phase, implementation monitoring is essential to evaluate and potentially improve the transition (Interview 6, 2023; Loorbach, 2010; Rupprecht Consult, 2019). However, practitioners describe it as challenging due to the high amount of time and financial resources needed.

This thesis aims to identify data needed to transition UTS, which is related to the tactical phase of transitions. However, data also plays a vital role in the other stages of the TM cycle, especially in the form of monitoring, which is an essential step in the successful transition. Here, data collection should be supported.

All in all, it can be said that data plays an important role in the transition of UTS. However, the guidelines do not explain what kind of data is needed. The following section investigates this question based on the interview results.

6.3. Data in Urban Transport Systems

As stated before, the importance of collecting transport data is regarded as crucial in transitioning UTS. However, it is not explicitly described what kind of data is needed. Therefore, these questions have been investigated during the interviews by asking the interviewees about what type of data is required and how it can be gathered and utilised in UTS transitions. This chapter presents the interview results, beginning with general statements about data in UTS transitions. The following two sections analyse the different types of data mentioned by the interviewees by organising them into a framework and investigating their orientation.

"Nothing really counts until it's counted" (Interview 6, 2023). This statement points out the importance of collecting data about the things that are intended to be transformed in UTS. One interviewee points out the need for a paradigm shift in transport data:

> "Most cities do a paradigm shift: putting the pedestrians first and then the car at the bottom. But we do this only for designing and not for data collecting. So [...] we should stop collecting data about the car and start collecting data about the pedestrian."
>
> (Interview 2, 2023)

Decision-makers do not have as much data on pedestrians as on other transport modes (Interview 3, 2023; Interview 7, 2023). "They are kind of not counted and not taken seriously, you know, as the other modes of transport" (Interview 7, 2023). As Litman (2003) discusses, practitioners fear collecting unprecise data. However, the data on vehicles is also based on assumptions and is not very precise (Interview 2, 2023). The guidelines say that existing data should be used "without requiring unrealistic amounts of new data collection" (Rupprecht Consult, 2019, p. 18). Even though cities already have limited resources, it is important to consider a paradigm shift and focus on collecting accurate data about all modes of transport. The statement of one interviewee that "we have been doing the same thing for a lot of years" (Interview 3, 2023) proves the awareness of the need for change, which should be tackled.

However, it is mentioned in the interviews that evidence-based planning, which relies solely on existing data, is not the perfect solution (Interview 5, 2023). This points out that collecting numerical data about active mobility is a step in the right direction. However, as discussed in literature, other data should be collected (Litman, 2003; Piatkowski & Marshall, 2018). Not only descriptive data about the existing situation but also prescriptive data about possible future solutions should be considered.

6.3.1. Transport Data Framework

The kind of data identified to be used in the transition of UTS are presented in Table 4. It is organised after the data components: supply, demand, performance, and impacts, and it displays the data elements, as well as data sets, as presented in the theoretical framework. The data sets are marked as being descriptive, prescriptive, or predictive. Descriptive data (yellow) is about the existing system and processes, prescriptive data (red) explores possible actions and predictive data (blue) prognoses future developments.

Data components	Data elements	Data sets	Examples and assessment
Supply attributes	Service	Service providers	Private operators' intentions: where and what to develop, at what price (communication)
	Facilities	Inventory	Analysis of existing infrastructure (databases, local analyses)
		Inventory	How to improve existing infrastructure (analyses)
		Inventory	Future modes of transport (inform)
	Project data	Current and future plans	Combination of measures in urban interventions (exchange)
Demand attributes	Demographic	Population	Characteristics (e.g., gender, age, amount) (databases, surveys, sharing)
		Population	Characteristics (modelling)
	Land use	Distribution	Daily locations (surveys, local analyses)
		Mix	Current uses (local analyses)
		Mix	Desired uses and how to change what we have (surveys, local analyses)
	Travel	Traffic volume	Count data per transport mode, often available in city databases (databases, sensors, countings)
	Travel behaviour	Mode and route choice	How do people get from A to B (surveys, sharing)
		Mode and route choice	Preferences with reasons (surveys)
		Mode and route choice	Future behaviour (modelling)
System performance	Safety	Accidents	Traffic accidents (databases)
	Performance measures	Performance	Implemented measures (monitoring)
		Performance	Good practice (exchange with other cities)
System impacts	Air quality	Air quality	CO_2 emissions (databases, sensors)
	Other environment	Aesthetics Noise	Greening and heat (databases, sensors)
		descriptive, prescriptive, predictive	

Table 3: Data in UTS transitions (own table).

Beginning with ***supply attributes***, obtaining prescriptive service data is crucial for understanding the *service providers'* intentions regarding future development and cooperation. Maintaining effective communication with private partners is vital to jointly develop possible future actions. Another example is fare rates which could be improved. (Interview 3, 2023)

Facilities data makes up for another important data element, which is focusing on infrastructure. Descriptive data about the existing infrastructure can be taken from city databases and analysed locally to understand the area (Interview 2, 2023; Interview 3, 2023; Interview 5, 2023). This includes data about street space and networks, considering all modes of transport. Prescriptive data about improvements in the inventory is another data set (Interview 1, 2023; Interview 3, 2023). Lastly, information about future modes of transport can be researched to adapt to future technology (Interview 4, 2023).

As pointed out in the guidelines (Rupprecht Consult, 2019), cooperation plays a vital role in UTS transitions. One example is cross-departmental cooperation in *projects*, where different measures can be combined in order to save resources (Interview 2, 2023; Interview 3, 2023; Interview 7, 2023). For example, a road construction project can be combined with greening the street space.

Demand attributes about the system users should be assessed to understand the target group and its needs. It includes descriptive *demographic* data about the population's characteristics, such as gender, age, and the number of people, which can be collected through databases, citizen surveys, or sharing of anonymised data by service providers people (Interview 1, 2023; Interview 2, 2023; Interview 3, 2023). Added to this, demographic trends could be predicted to prepare for future system users (Interview 4, 2023).

Data about *land use* should be collected to understand the planning context and identify potential improvement areas. This includes the distribution of services assessed through surveys and local analyses (Interview 4, 2023; Interview 5, 2023) and the mix of uses. Here, both the current uses (Interview 5, 2023) and prescriptive data about desired uses (Interview 1, 2023; Interview 2, 2023; Interview 3, 2023; Interview 4, 2023) should be analysed. Based on this, approaches like the 15-Minute City can be followed, which are based on high density and mixed-use. An essential way of assessing demand data is through citizens themselves, for instance, with surveys. The engagement of citizens is also aimed for in the guidelines (Rupprecht Consult, 2019).

Next, descriptive *travel* data on traffic volumes should be gathered for all modes of transport in order to develop a baseline system based on which interventions can be planned and monitored (Interview 2, 2023; Interview 3, 2023; Interview 5, 2023; Interview 6, 2023; Interview 7, 2023). These data can be collected via sensors or countings. Some cities have already developed databases with an overview of these numbers (see, for example, open data.dk).

Travel behaviour makes up for another demand attribute. Descriptive data about mode and route choice should be collected, with the purpose of understanding the target group (Interview 1, 2023; Interview 3, 2023; Interview 4, 2023; Interview 6, 2023; Interview 7, 2023). Prescriptive data about the citizens' preferred modes and routes, for instance, gathered through map-based surveys, can be used to identify potential areas of action (Interview 2, 2023; Interview 4, 2023). This data could also be predicted in order to model the users' future behaviour towards actions (Interview 2, 2023; Interview 4, 2023). This data could be used to influence people's behaviour and set incentives (Interview 3, 2023).

System performance assessment can be based on *safety*, with descriptive data about accidents tracked in databases. Furthermore, *performance measures* can be analysed descriptively by monitoring implemented measures and prescriptively through an exchange with other cities on their good practice examples. (Interview 2, 2023; Interview 6, 2023; Interview 7, 2023)

Lastly, data about the ***system impacts*** needs to be gathered. It can be assessed through sensors, which is done in most cities and displayed in their databases (see, for example, opendata.dk). Related data elements are *air quality* and other descriptive *environment* data, including aesthetics and noise. System impacts are related to the quality of life that UTS can decrease or increase in cities, as discussed in Chapter 2. Based on this assessment, areas of improvement can be analysed. For example, the analysis of green spaces and heat islands is related to this. (Interview 2, 2023; Interview 3, 2023)

As mentioned in the Theoretical Framework, system performance and impacts should be monitored in order to evaluate measures and display their improvement of the system. This ties in with Loorbach's (2010) statement that reflection is an essential part of governance processes.

Overall, it can be said that sharing information is expedient for creating a holistic overview of the system. This information should be combined into a bigger picture in which interrelations can be identified and integral strategies can be developed. The visualisation of data, for example, with maps, is a helpful tool to combine information and displays it, which "triggers the mind" (Interview 2, 2023).

Data plays a central role in transitioning UTS. Most data elements identified in the research are supply and demand attributes. These focus on analysing the prevailing resources and their improvement, as well as studying what to plan for. Many of the data elements are descriptive, meaning it reports the existing system. However, prescriptive data about possible developments is an important part to be studied, aligning with the envisioning approach of transitions. The following section analyses the focus of the identified data based on the TMA framework.

6.3.2. Measuring Transport Transitions

In this section, the data needed to transition UTS is analysed in the context of the TMA framework by Litman (2003). He defines three ways to measure transportation: based on traffic, mobility, or accessibility. While traffic data focuses on vehicles, mobility data centres around people and their movements. The assessment of accessibility is connected to land use. These data are related to the quality of life in cities, as discussed in Chapter 2, and is described as the goal of UTS. This section investigates how the identified data, described in the previous section, is categorised.

Data elements related to ***traffic*** are partially mentioned by the interviewees, for instance, with traffic volumes of vehicles or parking lots. However, these are acknowledged to be part of traditional transport planning and, therefore, not the right approach to transition UTS (Interview 2, 2023). Nevertheless, their assessment is needed to understand the existing system and create a baseline situation.

Most data elements identified in the interviews are related to the measurement of ***mobility***. These are data about supply and demand attributes focusing on system users and their movements. This includes the consideration of multimodality.

Looking at ***accessibility*** data, information about land use and the system impacts are assessed. However, in the interviews, it has been mentioned that these data "should" be collected, but there is a gap in the implementation.

The difficulty of measuring accessibility is pointed out by Litman (2003). Due to its connection to land use, more comprehensive approaches need to be considered. He proposes activity-based travel models and integrated transportation/land use models for the assessment. These consider the destinations of people and the travel behaviour and generalised costs, which are the time, money, discomfort, and risk required to reach destinations connected to these (Center for Transportation Studies, 2010). Pajares et al. (2021) study tools that can be used to plan for accessibility.

Summing up, it can be said that the data elements identified in this research are mainly focusing on the field of mobility. After this comes accessibility. However, there is potential to further strengthen the collection of it. The interviews uncover a lack of resources, such as time, finances, and knowledge, in assessing accessibility in UTS. Concluding, there is a gap between theory and practice that should be overcome. However, Traffic data is the least focused on, which is a good sign of the practitioners' awareness towards the objectives of UTS.

In the next chapter, the research findings and their implications are discussed. This helps to conclude the research in a broader context and develop recommendations for practice and research.

7. Discussion

The analysis of the research results sheds light on several key aspects related to the transition of UTS. This chapter discusses these research results and their implications.

The first section explored the objectives of UTS, with the requirements for a sustainable transport system as outlined in the "Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan" (Rupprecht Consult, 2019), and the seven expert interviews. These objectives encompass economic, social, and environmental dimensions of sustainability. Overall, UTS should provide multimodality while especially promoting active mobility. Paired with measures on land use, it is intended to facilitate an inclusive and accessible system that increases liveability.

The various objectives of UTS analysed support the assumption that an integrated governance approach is needed to transition the systems. Therefore, the TM framework with its strategic, tactical, operational, and reflexive phases (Loorbach, 2010) is used to analyse the approach described in the guidelines and interviews. Most importantly, a collective long-term vision for the UTS needs to be developed. The panning of mid- and short-term tactics for the system transition builds upon it. Political support is essential for the resource provision for the transition process. Stakeholder engagement, particularly with citizens, is emphasised as a crucial factor in achieving successful UTS transitions and also for gaining political support. Furthermore, cross-departmental collaboration and cooperation with private companies is needed to reach common goals effectively. The use of data plays an important role in all phases of TM.

The analysis further delves into the role of data in UTS transitions and identifies data elements along with corresponding data sets, providing a framework for understanding the diverse types of data relevant to UTS transitions. It is recognised that collecting accurate and comprehensive data is an essential part of the transition process and that data sharing and monitoring play significant roles in it. The interviewees highlight the need for a paradigm shift in transport data collection, emphasising the importance of collecting data about pedestrians and other transport modes rather than focusing solely on vehicles. However, while descriptive data is valuable, it should be complemented with prescriptive data to explore future possibilities. This ties in with the TM approach and the concept of backcasting, as introduced in the first chapters. The collection of demand data that focuses on the system users' needs is essential to engage citizens, as intended in the objectives and the governance approach. An emphasis should be on gathering data about accessibility, which is described as "the ultimate goal of transportation" (Litman, 2003, p. 16). Even though this type of data is not easy to assess, practitioners should focus on collecting more accurate data. This demonstrates that it should be aimed for quality over quantity in the data collection process.

Based on the interviews, it can be said that there is an awareness amongst practitioners that accessibility assessments are needed to transition UTS. However, a gap is identified in the implementation of this concept. The results revealed that practitioners are currently more inclined to measure mobility rather than accessibility. The emphasis on assessing mobility rather than accessibility by practitioners may be related to the fact that SUMPs are focusing on mobility. In order to shift cities' focus to improving the accessibility of UTS, the EU guidelines could be updated, ensuring that they incorporate a stronger emphasis on accessibility planning.

Using the term "transitioning UTS" in this thesis has widened the scope from "sustainable mobility" to actively including changes in land use and society, next to the technological aspects. Transitions need a systems thinking approach, which involves understanding and analysing the interconnectedness and interdependencies of various urban systems to develop holistic strategies (Voulvoulis et al., 2022). The transition of UTS significantly impacts other systems, including liveability, health, safety, and the environment. By promoting active mobility, UTS transitions can reduce energy consumption and emissions from vehicles, leading to improved environmental conditions. Furthermore, these transitions can have positive synergy impacts on water systems, for example, by including climate adaptation in transport systems with blue-green streets, which improves the design and reduces heat in urban areas. These effects contribute to the development of sustainable cities that operate within social and ecological boundaries.

It needs a holistic approach to system transitions based on developing a long-term vision in a multi-stakeholder network (Loorbach, 2010). To reach this vision, mid- and short-term tactics need to be developed. The significant role that cooperation plays in this is emphasised in this thesis. Previous research, such as that conducted by Banister (2008), has focused on citizen involvement primarily to gain acceptance for proposed changes. However, it is argued that citizens should be seen as experts and users of the city who should be transitioned together with them. In this context, putting citizens first and actively engaging them in the decision-making process is essential. Here, it is also crucial to emphasise that citizen engagement in the process of transitioning UTS should align with the core objectives of sustainable urban mobility. These objectives encompass a shift from car-centric city centres to promoting and enhancing active mobility. By involving citizens in decision-making, their perspectives and contributions can help shape inclusive and effective solutions that benefit the entire community.

Citizen engagement can help to overcome common challenges in urban transitions arising from missing political support, which affects the allocation of resources. Overall, the political decision-making process in UTS transitions requires significant improvement. The inherent challenge lies in the structure of our political systems, characterised by short-term electoral cycles typically lasting four years. This limited timeframe poses obstacles to the development and execution of long-term visions for sustainable urban transport. It is crucial for politicians to actively engage in UTS transitions and prioritise the collective interest over short-term political gains. Politicians can play a pivotal role in driving meaningful and lasting transformations in UTS by fostering a forward-thinking mindset and embracing the necessity for change.

The important role that data has in UTS transitions is pointed out in this thesis. Philippe Christ says, "Data is not the solution, but a way to understand a problem better in order to develop the policies needed to create change" (Rambøll, 2023, p. 32). This supports the approach of needing data to develop short- and mid-term tactics that lead to reaching the long-term vision of UTS transitions.

The research approach employed in this thesis contributes to assessing the current status of data in UTS transitions from the perspective of practitioners. It has effectively shed light on the existing challenges and identified areas that require improvement. However, it is important to acknowledge that the choice of interviewees provides valuable insights into the best practice examples from two Danish and Dutch cities, which are forerunners in UTS transitions, which may limit the findings' generalizability to a broader context. Additionally, the exploratory nature of the interviews implies that there may be additional information that the interviewees did not capture. Future research can delve deeper into this data framework and the assessment and use of relevant data.Future research should consider a diverse range of participants from different geographical locations to obtain a more comprehensive understanding.

Lastly, it is important to acknowledge the role of interpretation in qualitative research. The potential influence of the researcher’s subjectivity was aimed to be mitigated by employing a diverse and in-depth data collection process, combining expert interviews and qualitative secondary research. The results show alignment between the practical and theoretical situation, and were critically investigated to identify potential improvements. In this way, the research contributes to the body of knowledge surrounding the application of data in transitioning UTS, providing valuable insights that can inform future research and practice.

The following chapter sums up and concludes this research and gives an outlook into the future.

8. Conclusion

This thesis aimed to explore the application of data in transitioning UTS by investigating “What kind of data is needed to transition UTS?”. Based on insights from seven expert interviews and qualitative secondary research, it can be concluded that prescriptive data and data about accessibility are essential for transitioning UTS. These data should be utilised during the tactical phase of the TM process to develop short- and mid-term measures that contribute to achieving the shared long-term vision for the UTS.

The qualitative research approach employed in this study provided first-hand insights into the practical aspects of transitioning UTS. Combining the analysis of the "Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan" (Rupprecht Consult, 2019) with interviews conducted with UTS transition practitioners from diverse backgrounds has provided valuable insights into the utilisation of data in UTS transitions. Firstly, the study investigated the objectives of UTS transitions and analysed the governance approach through the TM framework. The primary objective of this thesis was to develop an overview of the different data sets required to implement UTS transitions. The DPP and data organisation frameworks were utilised to structure the results, which were further analysed within the TMA approach.

This research aligns with Litman's (2003) argument regarding the importance of collecting accurate data on accessibility to successfully transition UTS. It emphasises the need for a predictive and collaborative approach to develop strategies that align with the long-term vision for urban system transitions (Loorbach, 2010). Developing a shared vision for the UTS is an essential part of the transition process. Mid- and short-term tactics are needed to navigate the transition, and stakeholder collaboration plays a central role in successfully governing it.

Based on the conclusions drawn from this research, practitioners should be encouraged to prioritise the collection of data related to accessibility. Adequate resources should be allocated to support effectively gathering and utilising such data. Despite the time-consuming nature of assessing qualitative information, it is imperative for urban changemakers to overcome hesitation and take decisive action in transitioning UTS.

This thesis provides valuable insights and recommendations for policymakers, practitioners, and researchers in the field of UTS transitions, laying the groundwork for further exploration and advancement in this crucial area of study. However, future studies could explore what kinds of data other stakeholders propose and further investigate if practitioners are integrating accessibility assessments to successfully transition their UTS.

By investigating the transition of UTS, the research contributes to the broader debate on how to achieve sustainable cities, with a specific focus on UTS and the role of data within this context. The study offers an overview of the essential data sets identified and provides recommendations to facilitate UTS transitions for practitioners. It can assist urban practitioners in bridging the gap between planning and implementation through the effective use of data (Kalakou et al., 2021).

Based on this thesis, it can be concluded that urban practitioners are empowering transitions. However, it is important to acknowledge that despite the progress made, "There's still so much work to do" (Interview 6, 2023). We, as Sustainable Cities Engineers, should use this as a chance to navigate our future cities.

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