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Wiener Linien in the context of Smart City Vienna, Austria

Master Thesis submitted in fulfillment of the Degree

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in Management

Submitted to Dr. Daniel Dan

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AFFIDAVIT

I hereby affirm that this Master's Thesis represents my own written work and that I have used no sources and aids other than those indicated. All passages quoted from publications or paraphrased from these sources are properly cited and attributed.

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ABSTRACT

Public transportation plays a crucial part in smart cities' urban sustainable design and development. The city of Vienna, which was defined as a “smart city” in the Smart City Wien Framework Strategies, starting from the year 2014, has adopted important sustainable agendas and guidelines to facilitate the change from a former private-motorized dependent mobility, towards an expanded usage of a state-of-art public transportation (Karjalainen & Juhola, 2019). Also, it aims to focus on other multimodal mobility solutions as well, such as first and last mile mobility (bike sharing, car sharing) and active modes of mobility within the city (Wiener Stadtwerke, 2021).

The outlined policies at European Union, national and local level can accelerate the development of the Viennese urban public transportation and combat today's climate change challenges that especially demand for innovative, long-term views to ensure the highest quality of life. With the adoption of the Austrian Mobility Master Plan 2030 and Smart City Wien Framework Strategy 2019-2050, the city of Vienna has identified the parameters for these goals. Establishing objectives for the years 2030 and 2050, strategies are created on a long-term direction framework. These long-term perspectives allow for the mapping out of "development pathways" over legislative timespans, thereby providing the basis for long-range courses of action (City of Vienna, 2019).

Moving on to the concept of “smart city”, it will be defined how Vienna provides a technological framework for mobility optimization, not just of economic productivity and efficiency but also to maximize the happiness of the inhabitants. To increase their well-being, the smart city concept enables digitalization technologies such as Artificial Intelligence, Deep Learning, Internet of Things etc. It is a vision of building a technology-oriented city, to create an urban environment in which smart phones, embedded sensors, cameras, and so on, all work together harmoniously for the well-being of society and individuals. A smart city is clearly built from an internet-connected perspective, aiming to retransform urban spaces, including an old one like Vienna. In this context, the smart city not only improves, but reshapes the role of public transportation as infrastructure service by optimizing connectivity based on real-time data. Therefore, public transportation is a part of the system composed of other elements such as buildings, education, healthcare, government (Radu, 2020).

However, the concept of smart city is controversial. Some see this vision of smart cities or cyber cities as utopic, because they are presented as an ideally perfect place. However, to some it is a “surveillance city”. As the smart city concept is in the Schumpetarian sense of word causing a “creative disruption” (Năsulea & Mic, 2018), it involves not only things such as smart utility meters, intelligent traffic signals, etc., but also e-government. E-government provides citizens the facility to contact the government directly via an app to report an issue, education and health

interconnected through data into a holistic system, it is no wonder that some people are more cautious about believing into such an idyllic perfect vision of modern life (Radu, 2020).

The scepticism comes because smart cities are fueled by data coming also from people (Giest, 2017), including their biometric data. “Big data” is used to create algorithms that help predicting behaviour. This issue will be analysed taking a particular attention to privacy. Data give a competitive advantage in targeted ads creating a possible distortion in the market competition. As the technology evolves faster than regulation, it is important that for the two sides, all involved stakeholders have to find solutions that would be transparent, protect people’s privacy, especially their Personal Identifiable Information while allowing for the fair use of the data (Ibrahim, El-Zaart, & Adams, 2018).

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WL = Wiener Linien

PT = Public Transportation

WLB = Wienerlokalbahnen

WS = Wiener Stadtwerke

GHG = Greenhouse Gas

UN = United Nations

SDGs = Sustainable Development Goals

EU = European Union

EC = European Commission

SC = Smart City

ICT = Information and Communication Technology

SCWFS = Smart City Wien Framework Strategy

SCSI = Smart City Strategy Index

SM = Smart Mobility

PMT = Private Motorized Transportation

AIT = Austrian Institute of Technology

KFV = Austrian Road Safety Board

CVD = Clean Vehicles Directive

IoT = Internet of Things

ML = Machine Learning

PII = Personal Identifiable Information

PTSIL = Public Transport Sustainability Indicator List

1 INTRODUCTION

The aim of the paper is to answer the three main research questions. First, it provides an analysis for all of them by using Natural Language Processing tools. Furthermore, it presents the "smart city" concept as applicable to Vienna and the role that urban public transportation, especially Wiener Linien, plays in it. The urban spatial development, digitalization plan and interconnection with and within the public transportation are part of the Smart City Framework's 2019-2050 goals and are integrated in Vienna's smart optimization strategy. Based on the aim of the paper, following main research question arises: *"What is the interconnection between Wiener Linien and the "Smart City" concept?"*

The second research question is structured as following: *"How do policy makers aim to shape the future of Wiener Linien through directives, regulations, plans and financing?"* Therefore, the paper analyses the development plan leading to a sustainable and efficient urban public mobility based on public policy, financing and sustainable development goals. Here, the areas of emphasis are the sustainability mandates for transportation in reducing the carbon footprint and saving scarce resources. It examines factors about Wiener Linien such as corporate structure and players/stakeholders, performance indicators, ridership and finances (subsidies). The goal is to show how Wiener Linien fits in the European Union's and national mandate to promote a sustainable solution for transportation.

Third, the paper analyses the relevance of data collection especially the one gathered from passengers through Wiener Linien's app, WienMobil. Thus, the third research question: *"What opportunities and challenges arise from the collection and use of passenger data?"* refers to the role and applicability of "Big Data", which is a delicate topic, debated between the technological world and the privacy advocates. On the one hand, data are described by some as the "new gold" due to their infinite possibilities to transform modern life and on the other hand, there are raising concerns about how personal data are collected, stored, transmitted and used by companies, governments and third parties.

2 LITERATURE REVIEW

The literature review revolves around a broad theoretical introduction of the main topics: public transportation, smart city and data collection. Definitions, public policies, financial statements, development frameworks etc. with respect to Wiener Linien GmbH & Co. and the city of Vienna, Austria, will be granulated for a better understanding of the long-term oriented development plan for the Viennese community.

2.1 Public Transportation

Preliminary distinctions and limitations of this chapter are that Wiener Linien GmbH & Co KG (hereafter WL) is Vienna's leading "public transportation" (hereafter PT) operator in Vienna. There are other companies providing PT in Vienna that will not be analysed in this paper, such as Wiener Localbahnen (hereafter WLB), also a subsidiary of Wiener Stadtwerke (hereafter WS) or private entities. Along with WL, it is 100% publicly-owned by Wiener Stadtwerke, which is directly under the ownership of the City of Vienna (Wiener Stadtwerke, 2021). The analysis is limited to local urban passenger transportation only, excluding freight, cargo or passenger transport outside of Vienna, even if offered by WL. It does not analyse individual micro mobility per se even though it may reference it occasionally, such as shared mobility services (e.g. city-bikes, e-scooters and cars) for individual use as part of first and last mile mobility.

The term PT refers to the multitude of collective modes of passenger transport services on land that are made available to the "general public on a non-discriminatory and continuous basis" (Hirschhorn & Veeneman, 2021), offered by WL in Vienna. PT is designed based on predetermined lines/routes, as well as on established and announced timetables and frequencies. The access to this services depend on the payment of prescribed fares (Hirschhorn & Veeneman, 2021) or possession of a pass (Wiener Linien, 2021). Synonym terms are "public transit, mass transit" (Litman, 2022). In this large sense, the term "public" in "public transportation" is linked to the usage of the service and not to the "ownership nature of the transport operator" (Hirschhorn & Veeneman, 2021).

2.1.1 Public Transportation: Definitions

PT may be thought as a compound economic and socio-technical system, because in order to work efficiently, PT has to ensure the interplay of apparently disparate components, such as technology, finance, infrastructure and individual or collaborative actors with the aim to deliver a key societal need, passenger transportation (Hirschhorn & Veeneman, 2021). The involved actors in PT can be very diverse such as "politicians and public officials, operators, managers, drivers, users and non-users" (Bevir, 2013). The cooperation between all actors cannot be taken for granted, because they hold different visions of reality, have different interests and opinions of how PT should work and different preferences of what role it should fulfil (Bevir, 2013).

According to Bevir (2013), governance plays an important role in investigating and understanding the needs of society and to implement norms and instruments to pursue the interests of all actors (Bevir, 2013). The goal of governance should be to enhance the cooperation between various entities and to improve the decision-making for better outcomes through the following components: policy, polity and politics (Treib, Bahr, & Falkner, 2007). First, the policy component suggest the motifs of implementing policies. They should be bi-partisan and serve the interests of society and the public at large while protecting the environment. Second, the polity component refers to the identifiable groups and regulatory structure that impacts actors. Third, the politics component refers to the influence and power of the political actors. The connection of these 3 components to PT is crucial for establishing a strong collaboration between all actors, to set the "roles and responsibilities" among them and to design the potential "policies and services" that PT will implement (Hirschhorn & Veeneman, 2021).

2.1.2 Analytical Framework of the 3 Dimensions of Sustainable Development in PT

One of the most accepted definitions of sustainable development comes from the Brundtland Commission (1991) and its report Our Common Future: "…development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". Another definition of sustainable development is "improving the quality of human living within the carrying capacity of the supporting eco-system" (IUCN/UNEP/WWF, 1991).

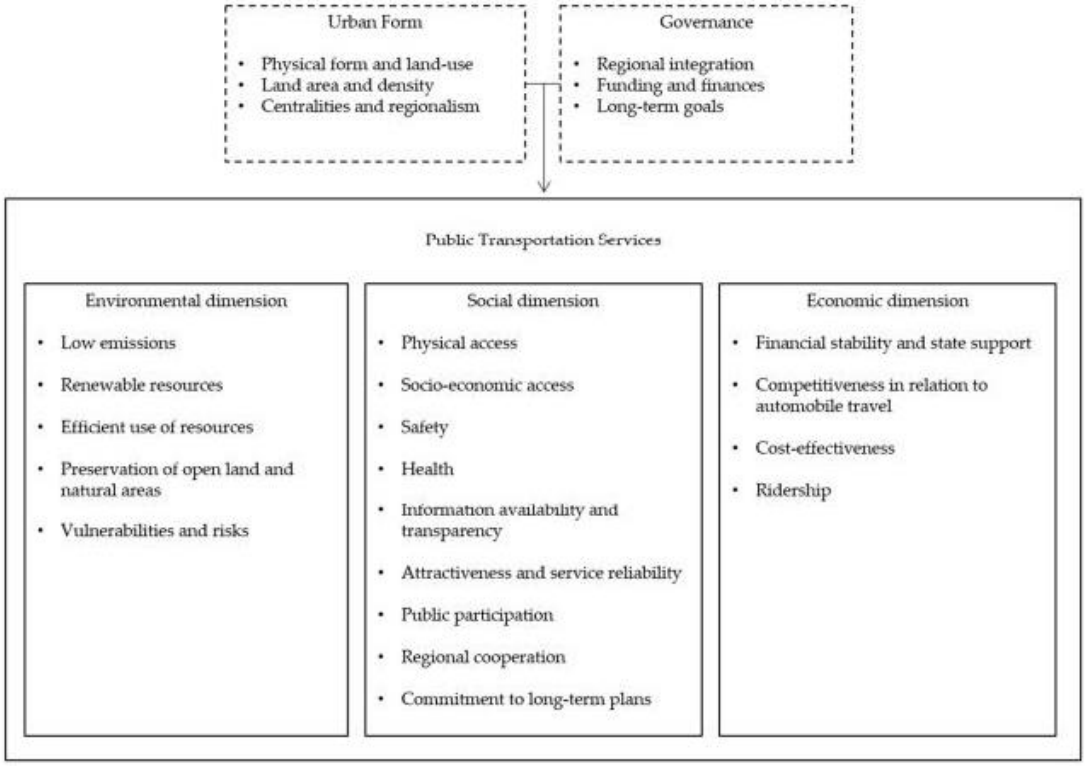
Sustainability in PT is one part of the general sustainability mandates coming from the European Union as result of climate change and the need to eliminate carbon footprint. It is a policy goal in a rapidly urbanizing world (United Nations, 2014) with cities and transportation authorities pledging their support for it (Banister, 2000), including the city of Vienna, because it leads to greenhouse gas (hereafter GHG) emission reductions causing fewer negative externalities when compared to private modes of motorized transportation.

According to the United Nations (hereafter UN), sustainable transportation guidelines have been established and "accessibility, affordability, emissions, safety, and equity, alongside increased congestion and travel times in urban areas" are particular features highlighted in the literature (Karjalainen & Juhola, 2019).

The three dimensions of sustainability: the social, economic, and environmental dimension, are perceived as the foundation of sustainable transportation in both policy and scientific literature (Karjalainen & Juhola, 2019). The analytical framework of the three dimensions of sustainable development (Figure 1) synthesizes existing literature as part of the core component PT services. It presents the core aspects of the functionality setting of public transportation services, considering the conditions of urban form and governance. Each component of this framework shares

a different view. The associated elements linked with their core component create the foundation of the Public Transportation Sustainability Indicator List (hereafter PTSIL) (Karjalainen & Juhola, 2019).

FIGURE 1. PTSIL ANALYTICAL FRAMEWORK



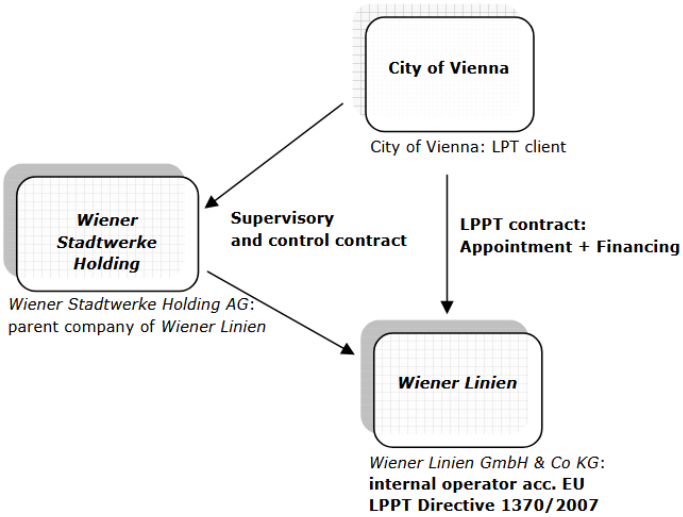
SOURCE: (KARJALAINEN & JUHOLA, 2019)

2.2 The Viennese Urban Public Transportation: Wiener Linien GmbH & Co KG

In this chapter, the highlighted PT division in Vienna (Wiener Stadtwerke, 2021) consists of two subsidiaries, WL and WLB and is 100% publicly-owned by WS, which is directly under the ownership of the city of Vienna (Figure 2) (Kostal, Michalitsch, & Obermann, 2014). According to official reports of WS, WL is directly responsible for the operation of trams, buses, underground metro lines and "it carries out a wide range of traffic management functions including service and interval scheduling, route and stop planning for all transport modes, sales and marketing, and operational control" (Wiener Stadtwerke, 2020). Also, WL is responsible for providing maintenance of the PT's infrastructure and fleet units (Wiener Stadtwerke, 2020).

The City of Vienna, which is not just a municipality but a federal state as well, is de jure and de facto responsible for the local PT in Vienna (based on Art. 10 the Federation has the power of legislation and execution in area of transportation) (COR, 2018). According to Kostal, Michalitsch and Obermann (2014), even though the big decisions about investment, management, etc., are still taken by these 3 key players, they are bound together by their goal of furthering the public interest of welfare in LPT (Kostal, Michalitsch, & Obermann, 2014).

FIGURE 2. THE THREE KEY ACTORS DIAGRAM



SOURCE: (KOSTAL, MICHALITSCH, & OBERMANN, 2014)

WS's total number of employees was 15,131, as of 2020. WL represents around 60% of the total number of employees, which is around 8,700, making it the subsidiary with the most employees within WS (Wiener Stadtwerke, 2021). Moreover, WL's employees are working 24/7 in a year, in order to provide reliable and accurate transportation for all passengers (Wiener Linien, 2021).

WL is responsible for around 180 underground metro, bus and tram lines. The underground network stretches on 83 kilometres (Wiener Linien, 2021) with 5 functional underground lines and one under construction (U2xU5) (Wiener Linien, 2021). The tram network consists of 29 tramway lines (Knoflacher, Frey, & Leth, 2018) and reaches to around 220 kilometres, making it the sixth-largest in the world, while the bus 127 bus lines network (Knoflacher, Frey, & Leth, 2018) covers around 850 kilometres (Wiener Linien, 2021). Nevertheless, 97.3% of Vienna's urban population lives within 500m or less from an underground metro station or suburban train stop and also 300m or less from another public transportation stop (Knoflacher, Frey, & Leth, 2018). The focus on multimodal mobility brings together first and last mile solutions, such as WL's car-sharing service, launched in 2018 that can be used via WienMobil app. Also it offers a

bike-sharing service fleet of around 3000 bikes (Wiener Linien, 2022). Other mobility solutions in partnership with WL are: E-moped sharing services, as well as taxi services and e-scooters (Wiener Linien, 2022). This allows WL to provide an integrated and very attractive PT to the community and to push for the shift for sustainable and energy-efficient mobility solutions (Wiener Stadtwerke, 2021). Moreover, the e-scooter provider TIER in partnership with WL, belongs into the micro-mobility transport option in the category of very light, low-occupancy vehicles. E-scooters make use of digital technology as they are rented and activated simply by using WienMobil app (Wiener Linien, 2022). They are "dockless", meaning they are available for shared use to customers on a short-term basis without the need to use permanent, fixed locations where rides must begin and end. They lack a fixed home location and may be dropped off and picked up from certain locations in the service area (Moreau, et al., 2020). It is debatable if e-scooters are sustainable or not, however they provide important first-and-last mile services connecting to PT services in Vienna (Wiener Linien, 2022). Barbara Laa and Ulrich Leth (2020) are quite pessimistic in their study about the role this transportation method could play in promoting sustainability. They believe that on the contrary, users, who otherwise would be walking, biking or taking PT, use e-scooter not only to their own but also to the environment's detriment (Laa & Leth, 2020). Even though the TU Vienna's study casts doubt on the sustainability claims of e-scooter, another study involving Laa and Emberger (TU Vienna) in cooperation with Moran (from the UC Berkley) states that in Vienna, PT should have a collaborative relationship with the shared e-scooter companies providing access to first and last mile for passengers. PT should "provide oversight over the spatial dynamics of scooter-sharing, such as by establishing incentives to ensure outlying and/or transit-poor neighbourhoods are not excluded, and via basic disclosure of geofences for the benefit of riders, transit planners, and trip-planning or wayfinding applications" (Moran, Laa, & Emberger, 2020).

According to official reports of WL (Wiener Linien, 2021), around 2.6 million passengers are using each day the Wiener Linien network and WL's public vehicles cover a distance of 214,000 kilometres per day. This highlights that around 961 million passengers have used WL's PT network in a year. The total number of WL's annual pass holders (852,000), have surpassed for the fourth time in the row the total number of vehicles registered in Vienna (by 143,000 in 2019) (Wiener Linien, 2021).

WL's goal is to provide the most efficient and sustainable means of transportation. As of 2020, 38% of all passenger trips are recorded using the PT and this percentage will potentially increase through WL's development plans and policies that will be implemented in the near future (Wiener Linien, 2021). Moreover, the walkability of Vienna represents 28% of people's mobility preference, who replaced their car for walking. The car usage represents 27% of Vienna's transport structure and will potentially diminish due to the Sustainable Development Goals (hereafter SDGs), Mobility Master Plan 2030 and other public policies and strategies that pursue the reduction of CO2 to zero in the near future (Wiener Linien, 2021).

2.2.1 WS's and WL's Annual Report 2021: Financial Statements

Key subsidiaries under the control of WS are Wiener Netze GmbH (energy grids), Wien Energy GmbH (energy), Wiener Linien GmbH & Co (transport) Bestattung GmbH und Friedhöfe GmbH (funeral services and cemeteries), WIPARK Garagen GmbH (car parks) (Wiener Stadtwerke, n.d.).

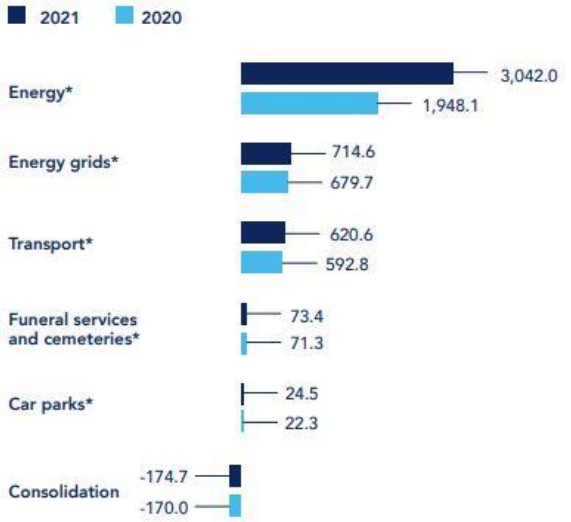
According to WS Financial Report as of 31. December 2021, the group's total assets have been valued at €20.362 billion, a 47% increase compared to the previous year 2020 (Wiener Stadtwerke, 2021). Table 1 highlights the most recent consolidated statement for profit and loss that compares the years 2021 with 2020. As of 2021, the group's total registered revenue was €4.3 billion, a €1.156 billion increase from the previous year. However, the adjusted profit was €282 million, which represents a €1 million decrease compared to 2020. The revenue parameter by division is defined in Figure 3. Hence, WL reported €592.8 million in revenues in 2020, while in 2020, revenues increased by €27.8 million and resulted a total of €620.6 million. In Table 1 is considered "*" as "adjusted for a foreign procurement right and other one-off or rare expenses and income" and "**" as "in addition to adjusted EBITDA effects, adjusted for effects of impairment tests and other one-off or rare financial expenses and income" (Wiener Stadtwerke, 2021).

TABLE 1. CONSOLIDATED PROFIT/LOSS STATEMENT OF WS BETWEEN 2020 AND 2021.

EUR m	2020	2021	Year-on-year change +/-	Year-on-year change +/- %
Revenue	3,144	**4,300**	1,156	37
Other income	630	**669**	40	6
Raw material, consumables and services used	-1,424	**-2,547**	-1,122	-79
Personnel expenses	-919	**-1,129**	-210	-23
Other operating expenses	-581	**-690**	-109	-19
Net gains on investments accounted for using the equity method	38	**13**	-25	-65
EBITDA	**888**	**618**	**-270**	**-30**
Depreciation and amortisation	-307	**-333**	-27	-9
Impairment losses and reversals	84	**-2**	-85	-102
Operating profit (EBIT)	**665**	**283**	**-383**	**-57**
Finance income	61	**83**	22	37
Finance costs	-85	**-69**	17	20
Financial result	**-25**	**15**	**39**	**160**
Earnings before tax (EBT)	**641**	**298**	**-343**	**-54**
Current tax expense	-1	**8**	9	n. a.
Profit for the year	**640**	**306**	**-334**	**-52**
Adjusted EBITDA*	**616**	**593**	**-23**	**-4**
Adjusted profit for the year**	**283**	**282**	**-1**	**-0**

SOURCE: (WIENER STADTWERKE, 2021)

FIGURE 3. REVENUE IN MIL. €, ACCORDING TO WS DIVISIONAL BREAKDOWN BEFORE CONSOLIDATION AS OF 2020 AND 2021



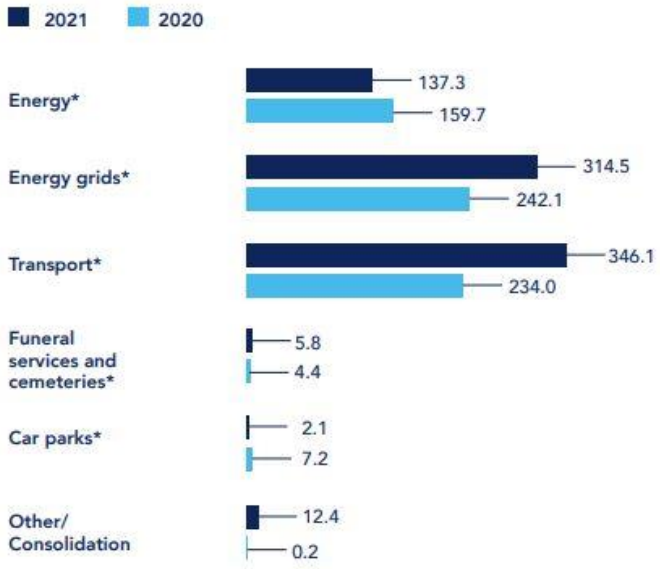
SOURCE: (WIENER STADTWERKE, 2021)

Nevertheless, WL's revenue streams are accounted from ticket/pass sales, rental services for bike-sharing and car-sharing, rental of spaces for small and medium-sized businesses and advertisement within the PT infrastructure and more. According to WL's PT financial structure, that came in effect January 1, 2017, around 60% is considered WL's self-financing capability (Wiener Linien, 2017), while the rest is perceived as WS's financial contributions to subsidize various services for WL's continuous functionality (Wiener Stadtwerke, 2020). The funding contract between WL and WS has been agreed on a 15-year length, due 2032. "Under these arrangements, investment finance takes the form of capital grants, and the remainder of the money required for operations is covered by compensation from the City of Vienna to the company for its public service obligations. The capital grants include amounts received by the City of Vienna from the Austrian federal government as subsidies for underground construction projects and as allocations for investment in public transport (section 20 Finanzausgleichsgesetz, Austrian Fiscal Equalization Act). In addition, income from payroll taxes is transferred to the company in the form of capital grants for underground line construction" (Wiener Stadtwerke, 2020).

For example, according to the general terms and business conditions, as of 2016, student tickets are also subsidized on a monthly and semester basis by WS (Wiener Linien, 2016). Such investments are crucial, in order to increase the demand for PT, enhance public safety and public health, reduce WL's production costs, stimulate and advance urban land consumption, and promote affordable and sustainable means of transport. Therefore, dysfunctional agglomeration within the city is avoided and key elements of the three dimensions of sustainable development (economic, environmental and social), are achieved (Karjalainen & Juhola, 2019).

As of the 2017 financial structure, €500 million will be invested for the development of transportation infrastructure (Wiener Linien, 2017). In 2020, the gross investments accounted as €1.757 billion in total, of which €212.3 million were granted. In 2021, WS registered a €1.007 billion investment, of which €334 million were granted. Therefore, the total net investment in 2021 has been reported as €672 million, a decrease of €873 million compared to 2020. Consequently, according to Figure 4, WL reported €234 million have been invested in properties, plants, equipment and intangible assets in 2020, while in 2021, investments increased by €112.1 million resulting €346.1 million in total (Wiener Stadtwerke, 2021). Roughly one third of WL's total investment, excluding financial assets, was attributed for the underground network expansion (Wiener Stadtwerke, 2020). As of 2020, this comprised the extension of the U2xU5 line, the modernization of the U4 and the replacement of obsolete trams (Wiener Stadtwerke, 2020).

FIGURE 4. INVESTMENTS ACCORDING TO THE DIVISIONAL BREAKDOWN BEFORE CONSOLIDATION AS OF 2020 AND 2021



SOURCE: (WIENER STADTWERKE, 2021)

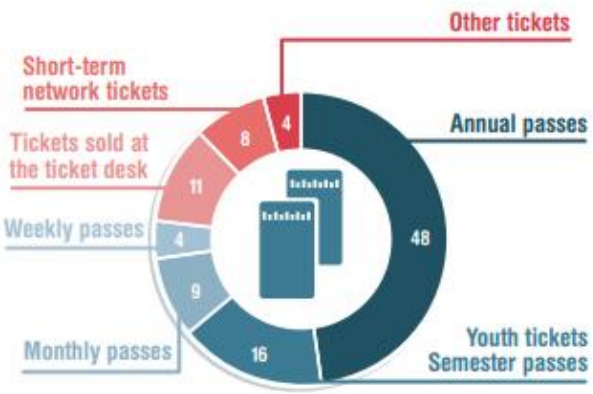
Tickets and passes (Wiener Linien, 2021) represent the major revenue stream for WL. "The fare represents a fixed consideration and is governed by the current tariff regulations". Moreover, earnings from "single, multi-journey, and limited-time, single-route tickets are recognized when they are sold, even if they are not validated until later" (Wiener Stadtwerke, 2020). Thus, Table 2 represents the complete overview of the PT tickets, offered by WL, as of July 1, 2020 (Wiener Linien, 2020). Figure 5 highlights the revenue by ticket type in 2019 (Wiener Linien, 2019). One popular ticket is the annual pass, offered for €365 (which represents a cost of €1 per day. It is no wonder that it provides 48% of the revenue as it is very affordable.

TABLE 2. OVERVIEW OF TICKET SELECTION. 4 DIFFERENT CHANNELS ALLOW PT USERS TO ACQUIRE SPECIFIC TICKETS

	By standard post	Online ticket shop	Mobile online ticket shop	WienMobil
Annual pass		x		
Annual pass for senior citizens		x		
Top youth pass		x	x	x
Youth pass		x	x	x
Semester pass with principle place of residence in Vienna		x	x	x
Semester pass		x	x	x
Summer holidays monthly pass		x	x	x
Monthly pass	x	x	x	x
8-day ticket	x			
Weekly pass	x	x	x	x
72 hours Vienna	x	x	x	x
48 hours Vienna	x	x	x	x
24 hours Vienna	x	x	x	x
Day ticket		x	x	x
Single trip Vienna	x		x	x
Single trip Vienna reduced	x		x	x
Single trip Vienna senior citizen	x		x	x
2 trips Vienna	x			
2 trips Vienna reduced	x			
Senior citizen for 2 trips Vienna	x			
Vienna City Card		x	x	x
EASY CityPass Vienna		x	x	x
QUEER CityPass Vienna		x	x	x
Admission ticket for Remise transport museum, full price, adult		x		
Admission ticket for Remise transport museum, reduced price, adult		x		
Admission ticket for Remise transport museum, full price, youth		x		
Admission ticket for Remise transport museum, reduced price, youth		x		

SOURCE: (WIENER LINIEN, 2020)

FIGURE 5. REVENUE STREAM BY TYPE IN %, ACCORDING TO AVAILABLE SELECTION OF TICKETS, AS OF 2019.



SOURCE: (WIENER LINIEN, 2019)

2.2.2 Austria's Mobility Master Plan 2030: Purpose, Strategy and Public Policy

Mobility is essential to improve the quality of life and to foster economic growth. The transportation sector's efforts to combat climate change by reversing the upward trend in carbon emissions will need precise frameworks and complex implementation strategies. Thus, Austria's Mobility Master Plan 2030 published in 2021 by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK, 2021) proposes strategies for transitioning, transforming and improving the transportation sector, as well as considerably increasing the percentage of eco-mobility in transportation modes, such as: walking and cycling, shared mobility and PT (BMK, 2021).

Austria's Mobility Master Plan 2030 aligns with the government's commitment to achieve climate neutrality by 2040 and to switch to 100% energy from renewable sources by 2030 (European Parliament, 2021), according to Austria's energy and climate #mission2030 strategy adopted on May 28, 2018 (BMNT, 2019) and the Renewable Expansion Act passed in the National Parliament on July 7, 2021 (European Union, 2021). The climate neutrality transition was initially promoted in 2014, before the entry into force in the Paris Agreement in 2015 (European Union, 2021), where all European Union (hereafter EU) member states agreed for the implementation and to be achieved by 2050. Also, these objectives correlate with EU's Green Deal, approved by the European Commission (hereafter EC) on January 14, 2020 (European Commission, 2019).

Austria's progressive plan to successfully achieve climate-neutrality by 2040, one decade before the due date (European Parliament, 2021), demonstrates that the ambitious Mobility Master Plan 2030 will necessitate a shift in the way legislative frameworks are developed and to emphasize innovation. The following two core components are considered: First, mobility regulations targeted towards solving the future challenges of the transition are imperative, in order to achieve the planned state-of-art standards. Second, the introduction of innovative climate protection awareness programs into transportation regulations, jointly with existing policies will have to be evaluated to ensure the compliance to Mobility Master Plan's climate neutrality goals. The harmonization of these regulatory requirements will lead to an effective implementation of the framework's standards (BMK, 2021). First, mobility regulations targeted towards solving the future challenges of the transition are imperative, in order to achieve the planned state-of-art standards. Second, the introduction of innovative climate protection awareness programs into transportation regulations, jointly with existing policies will have to be evaluated to ensure the compliance to Mobility Master Plan's climate neutrality goals. The harmonization of these regulatory requirements will lead to an effective implementation of the framework's standards (BMK, 2021).

2.2.3 Incentives for Mobility Transition towards the use of PT

To Vienna's outstanding quality of life, WL is contributing immensely by operating the city's PT system. According to sustainability press releases of WL, the goals are to decarbonize PT and lower the energy consumption, while resources are used efficiently for the development of a better mobility selection of urban PT. “It is the combination of many small steps that makes a sustainable future possible”, which directly leads to a higher quality of life (Wiener Linien, 2022).

Future mobility solutions could be developed efficiently if the public sector, in cooperation with the private and scientific sector agree to exchange knowledge. Early mobility education, promotion of modern transport services and communication of potential outcomes are essential actions to be considered. Moreover, the involvement of the association networks, such as Austrian Association of Cities and Towns, the Austrian Association of Municipalities and Austrian Association for Public and Social Economy are crucial to raise awareness and to understand mobility behaviour (BMK, 2021).

Furthermore, the urban spatial structure influences the importance of PT by considering the dispersion of places where people invest time in traveling. The volume and mean of transportation required to cover these travel distances are determined by the transportation infrastructure. "Modern, resource-saving land-use planning will transform structures over the long term," with the goal to decrease the overall private-motorized transportation demand. In other words, "urban sprawl" could potentially shape our future mobility needs and it is crucial to implement climate-friendly land-use planning and transportation regulations that shift from the use of private-motorized transportation and promote sustainable mobility solutions, such as active mobility and PT (BMK, 2021). More details with regard to the urban spatial development of the city will be presented in chapter 2.4.

A back-casting model, based on the combination of avoiding, shifting and improving mobility solutions has been one of the starting points for the Mobility Master Plan 2030. The analysis of Austria’s mobility modal split, which reverses the trend from private-motorized mobility towards PT and active mobility is defined in Table 3 and Table 4, the former referring to the modal split in passenger transport by distance travelled, while the latter referring to the modal split by passenger transport by route. Table 3 shows that a decrease of private-motorized transport will be shifted towards PT and active mobility by 2040 in Austria. Table 4 presents that a decrease of private-motorized transport will be shifted towards PT and active mobility, such as the use of bikes and walking by 2040 in Austria. Moreover, Figure 6 represents the modal split by transportation mode as of 2018 and potentially in 2040 (BMK, 2021). Thus, as of 2021, WL managed to contribute to a 38% PT modal split, while 28% was active mobility and 27% was private-motorized transport (Wiener Linien, 2021). Compared to the Mobility Master Plan’s 2030, in Austria from 2018, Vienna can be considered a pioneer in promoting eco-friendly mobility (BMK, 2021).

TABLE 3. MODAL SPLIT IN PASSENGER TRANSPORT BY DISTANCE TRAVELLED FROM 2018 TILL 2040.

	2018	2040
Private motorised transport	70 %	54 %
Public transport	27 %	40 %
Active mobility	3 %	6 %

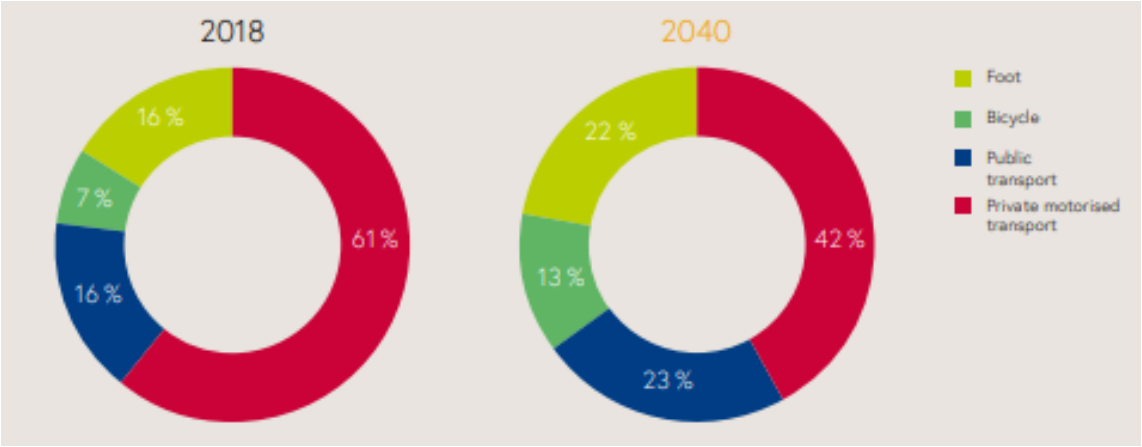
SOURCE: (BMK, 2021)

TABLE 4. MODAL SPLIT IN PASSENGER TRANSPORT BY ROUTE FROM 2018 TILL 2040.

	2018	2040
Private motorised transport	61 %	42 %
Public transport	16 %	23 %
Active mobility	23 %	35 %
Thereof bicycle	7 %	13 %
Thereof foot	16 %	22 %

SOURCE: (BMK, 2021)

FIGURE 6. EVOLUTION OF MODAL SPLIT IN PASSENGER TRANSPORT BY MODE FROM 2018 TILL 2040.

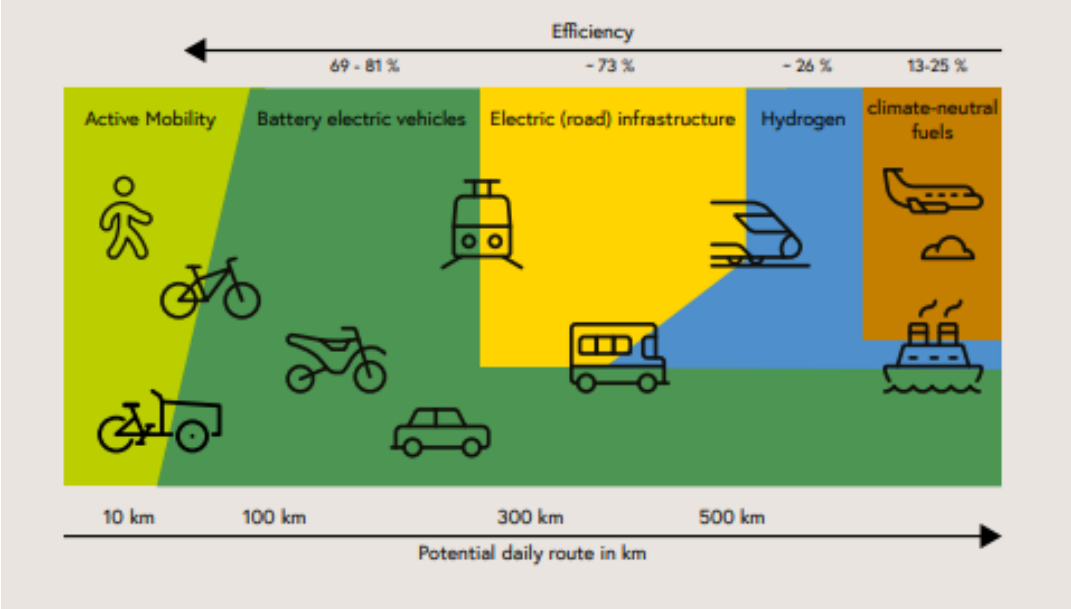


SOURCE: (BMK, 2021)

Figure 7 represents the mobility options applied in Austria's transportation sector. It is pivotal that efficiency has to be maximized, as each transportation mean has to comply with the sustainable, decarbonized mobility plan for the future. In order to do so, the Mobility Master Plan 2030 highlights the need for optimal infrastructure, technological progress and maximization of

capacity utilization in the transport (BMK, 2021). As of Figure 7, it can be identified that PT has an immense potential for the future if electrified or with batteries. However, for short routes, active mobility is leading the trend (BMK, 2021).

FIGURE 7. EXISTING TRANSPORTATION MEANS, CATEGORIZED BY THEIR EFFICIENCY AND POTENTIAL DISTANCE TO BE COVERED IN A DAY



SOURCE: (BMK, 2021)

2.2.4 Limitations of Austria's Mobility Master Plan 2030: SDGs and Green Financing

The UN established the 2030 Agenda for SDGs in 2015, which includes 17 SDGs. 193 Member States adopted this set of global goals to emphasize economic, environmental and social well-being. The Austrian government has likewise agreed to meet these goals. Nevertheless, the Mobility Master Plan 2030 is one of the most important pillars of the SDGs to be achieved for the mobility sector, in Austria (BMK, 2021).

Economic instruments, in conjunction to monetary policy measures, are crucial in establishing incentives for environmental-friendly technologies and sustainable transport. As a result, eco-friendly behaviour will be gradually pushed, as well as cost truth, which includes environmental costs. To effectively reduce carbon emissions in the transportation sector and attain climate neutrality by 2040, a well-balanced policy mix is required. Moreover, the failure to achieve these climate targets will involve significant economic costs in addition to negative environmental and social effects (BMK, 2021). As of now in 2022, the Austrian government is paying a yearly

fee of around €1 billion “in costs related to damage from weather and climate change”, according to Mobility Master Plan 2030 reports. In 2030, the costs could increase to €1.5 billion and potentially more than €2 billion for the year 2050 (Steininger, et al., 2020). Austria’s commitment to reduce CO2 emissions is bound to its agreed international obligations. Not respecting these obligations will lead into acquiring at undisclosed costs further emissions allowances (BMK, 2021).

The adoption of a CO2 pricing instrument is one of the most well-established economic mechanisms. This can be accomplished by the implementation of both taxation and emissions trading system (BMK, 2021). According to the Organization for Economic Co-operation and Development, trading systems are classified into two types: "cap-and-trade systems" and "baseline-and-credit systems." A cap-and-trade system establishes an upper limit on emissions, where emission licenses could either be auctioned out or distributed based on particular parameters for free. However, no predetermined limit on emissions is set under a baseline-and-credit system. Polluters can earn credits, if they decrease their emissions more than they otherwise are compelled to. Credits could therefore be sold to those "who need them to comply with regulations they are subject to" (OECD, n.d.). The EU's Green Deal in conjunction with the ambitious climate targets goals have also sparked debate over the inclusion of new industries in Europe's emissions trading system, such as one of the largest polluting sectors, transportation. Incentives for investment can be attracted through the integration of tax reliefs, state aids, social insurance reductions, reimbursements and redistribution of additional tax revenues (BMK, 2021). Thus, Austria’s Green Finance Agenda highlights the strategic plan to include the mobility and financial sector to promote innovative mechanism for development (e.g. green leasing, green labelling, green bonds, green crowdfunding, green finance programmes) (BMK, 2021).

2.3 The Concept of Smart City

The concept of Smart City (hereafter SC) has reached global popularity in the past decade amongst research institutes, governments, organizations and multinationals. However, there is no universal understanding of what being “smart” exactly means (Echebarria, Barrutia, & Aguado-Moralejo, 2021)The definition of SC is a "work-in-progress" (Ibrahim, El-Zaart, & Adams, 2018), even though many cities around the world have been granted or have self-proclaimed as “smart”. Frequently used synonyms in the literature are “digital” or “intelligent” city. The literature considers that the major distinction between the SC and digital or intelligent cities is the prominence of the human element in the former (Kutty, et al., 2022).

2.3.1 Characteristics of SC

It has been said that SCs are the "engines of global prosperity and innovation" (Kutty, et al., 2022). SC is seen as a solution to problems such as rising urban populations, pollution and effects of climate change. SC will achieve the goal through digitalization. It has been compared to the

Schumpetarian disruptive technology because it challenges the status quo through “creative destruction” (Năsulea & Mic, 2018). Even though there is no clear cut definition of SC, here are some of the characteristics and goals of SC as espoused by the proponents of the concept:

I. Applying information and communication technology (hereafter ICT). The concept of SC is resonating around the fundamental idea of applying ICT within the operation system of a city (Radu, 2020). ICT considers two main aspects: "the physical-technological aspect and the human-social aspect" (Bibri & Krogstie, 2017). This "dichotomy landscape" echoes with the combination of human capital, social capital and ICT, in order to promote a sustainable economic growth, “enhance local prosperity and competitiveness” (Paskaleva, 2009) and improve quality of life and urban well-being (Capdevila & Zarlenga, 2015).
II. Creating a holistic system by looking at the big picture rather than separate parts. Key characteristics of a SC blueprint are designed in terms of infrastructure, economy, society, environment, and governance (Radu, 2020). SC is a city with accessible and secure ICT system, reliable and efficient infrastructure, prosperous economy, inclusive and equal society, resilient and sustainable environment and engaged and transparent governance (Huiying, Liyin, & Yitian, 2022). What is hoped to be achieved with the SC is to use modern technologies with the goal to optimize, integrate, and efficiently enhance services such as the PT (Camero & Alba, 2019) in order to help people live a happier life, having a higher standard of living, greater equality, greater involvement and benefiting from a more diversified culture (Beretta, 2018).
III. Leading to create a progressive system led by people (Radu, 2020). SC involves smart governance, which promotes the participation of citizen in political life. The human aspects of SC: smart living, pursues to improve the quality of life, while smart people interconnect the social and human capital (Giffinger, Fertner, Kramar, & Meijers, 2007).
IV. Protecting the environment and saving scarce resources. According to the authors, a city is smart if it is devoted to adopt a smart economy, which stands for competitiveness, smart environment and refers to protection of natural resources (Giffinger, Fertner, Kramar, & Meijers, 2007).

2.3.2 SC Implementation Challenges

As ambitious as the goals of SC are, transposing them in real life is sometimes more problematic. Therefore, some reasons are:

I. Lack of resources: Solutions usually require extensive and time-consuming planning for which the city officials may lack the time, knowledge and resources to implement. SC solutions frequently involve immense costs, unclear returns on investment, and lengthy repayment timeframes (Radu, 2020).

II. As various stakeholders hold various interests, there is a need to focus on key priorities in order to harmonize their interests and garner their support (Ibrahim, El-Zaart, & Adams, 2018).
III. The attempt to stabilize unsustainable and inefficient development patterns with ICT-centred initiatives frequently face uncertainty, as tech-driven SC focuses on such high goals that do not inherently provide sustainability, making development models obsolete in the long run (Ibrahim, El-Zaart, & Adams, 2018).
IV. While excessive regulation may hinder innovation, SC implementation demands nevertheless a legal framework to regulate the utilization of new and complex technologies, including the use of real-time data, which is seen that a key to improve the city's environmental outcomes (Ibrahim, El-Zaart, & Adams, 2018).
V. The majority of intelligent solutions are new and untested on actual processes (Ibrahim, El-Zaart, & Adams, 2018).
VI. Resistance to change: Some stakeholders may not fully comprehend and accept the benefits of SC solutions, and perceive them with uncertainty, which complicates the adoption into the market. Vienna however appears to have overcome such issues due to coordinated effective communication during the implementation of projects (Roland Berger, 2019).

2.3.3 Smart City Wien Framework 2019 – 2050

A number of cities, including Vienna, have focused on the above mentioned criteria to become "smarter" and to not only build a competitive advantage (Sharifi, 2020), but also to apply the three interconnected dimensions of sustainable development through the use of ICT (Anthopoulos, 2019). "Vienna is a city that is constantly able to reinvent itself and develop innovative solutions to enable sustainable future development; and at the same time a city that remains true to its basic values, attaching the same importance to social inclusion and quality of life for all residents as it does to climate and environment objectives" (City of Vienna, 2019).

Vienna City Hall established the Smart City Wien-Framework Strategy (hereafter SCWFS) in 2014, a long-term project that seeks to convert Vienna into the world's most sustainable, liveable, and progressive city by 2050. This plan was designed through bringing together a multitude of stakeholder procedures in which the city government, academic institutions, private sector and civil society expressed their vision towards the future of Vienna (City of Vienna, 2019). In order to achieve the strategic objectives, such as to provide the highest quality of life levels and resilience, the collaboration of all stakeholders is crucial. Besides that, from a cross-sectorial perspective, uniting all stakeholders that have conflicting agendas is one of the greatest challenge (Guilherme, Camboim, Zawislak, & Amarante, 2019).

Smart City Wien Agency is an autonomous organization that provides the local government with external support regarding concept execution, as well as links between all significant projects of

the City of Vienna that develop the implementation of the SCWFS plan. The agency's primary responsibilities includes the networking of individuals and groups, to develop governance mechanisms and to support the decision-making and implementation of the framework (Guilherme, Camboim, Zawislak, & Amarante, 2019).

The first comprehensive monitoring of the SCWFS was conducted in 2017 as Vienna established new international standards. The monitoring procedure revealed that Vienna was on track to achieve several of its self-established goals while indicating areas where further effort is necessary to achieve some key objectives. Also it identified specific areas in which some goals need to be revised. The revised findings were integrated into the updated version of the framework, which is Smart City Wien Framework 2019-2050 (City of Vienna, 2019).

In December 2019, Vienna City Council adopted the updated version of the framework from 2014 and was called "Smart City Wien Framework Strategy 2019 – 2050, Vienna's Strategy for Sustainable Development" (City of Vienna, 2019). In the newest version, City of Vienna has set the following meaning for a SC: "In Vienna, "smart" is defined as combining innovations and new technological and digital capabilities, climate action and resource conservation, high social standards and possibilities into a vision that inspires and motivates people to change" (City of Vienna, 2019).

Following local and international agreements have been decided to be incorporated into the SCWFS's new vision (City of Vienna, 2019): "Transforming our world: the 2030 Agenda for Sustainable Development" adopted by the UN in September 2015, focuses on the 17 SDGs as a plan of action for the planet, people and prosperity (United Nations, 2015). Also, the "Paris Agreement", adopted by the UN, in December 2015 has the goals to limit global warming and reduce GHG emissions (United Nations, 2015). Moreover, the "2030 climate and energy framework" adopted by the EC in October 2014, promotes the minimum reduction of 40% of GHG emissions and focuses on the production of minimum 32% of renewable energy and energy efficiency (European Commission, 2014). Another international agreement is the new "EU Circular Economy Action Plan" adopted by the EC in March 2020, with the ultimate goal to foster the transition towards circular economy (European Commission, 2020). Other highly important national agreements are "National Energy and Climate Plan for Austria" and "#mission 2030" (BMNT, 2019), where the former promotes GHG emissions reduction by 36% by 2030 and the latter targets 100% renewable electricity to be produced by 2030 (City of Vienna, 2019).

The agreements and national policies mentioned above stand as the foundation of the SCWFS and represent a manifest towards global issues, such as the impact of growing cities, emerging developments in digitalization and technology, and resource utilization costs (City of Vienna, 2019). Vienna offers a plethora of development programs (e.g. STEP2025, Klima Smart City Strategie Wien 2022 (City of Vienna, 2022), SCWFS (City of Vienna, 2019) and many more) aimed to guarantee the city's long-term success to provide the highest quality of life and innovation levels,

as well as to maximize the conservation of natural resources and to ensure resilience for which the SCWFS serves as an umbrella strategy that unites them (City of Vienna, 2019).

The evaluation of SCWFS shows that currently, Vienna meets the adequate basis of incorporating the principle of sustainability (Yigitcanlar, Han, & Kamruzzaman, 2019). However, as of now, achievements' effects are still unknown and immense level of versatility and learning capability are demanded (City of Vienna, 2019). Due to the fast pace of global changes frequent reviews and revisions are required in order to provide the most efficient framework to achieve the long-term goals. (City of Vienna, 2019).

2.3.4 Vienna's Success as a City: The smartest, greenest and most livable in the world

Top ranking entities have voted Vienna as the "Smartest" by Roland Berger Studies for the years 2017 and 2019 (City of Vienna, 2021), "Most Liveable" by Mercer Studies from 2009 to 2019, designating it as the best for several years consecutively (City of Vienna, 2021) and "Greenest" by Resonance Consultancy Study in 2020 (Chris, 2020) city in the world. These superlatives are interconnected with the "smart city" concept, being the new power to create liveability and greenness. WL's contribution will be highlighted as one of the main drivers behind Vienna's thriving performance (City of Vienna, 2022).

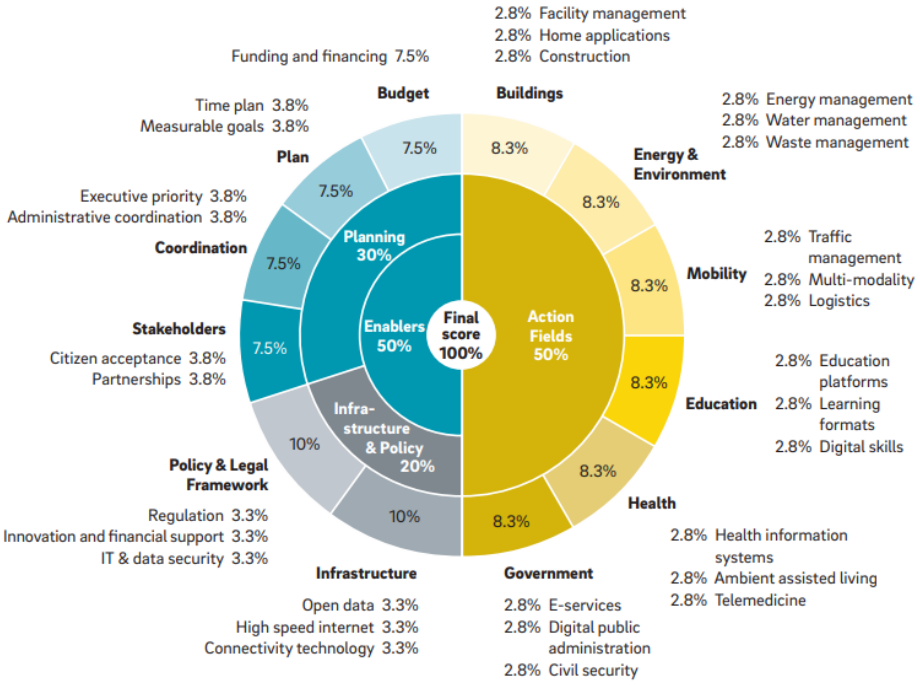
2.3.4.1 Vienna – The Smartest City

Particularly honouring to Vienna is the characterization coming from the 2 Roland Berger studies dated 2017 and 2019. The 2017 Berger study analyses how cities around the world are embracing the digital revolution. With 74 points out of 100 in 2017 and 2019, Vienna is "the smartest of the smart" because it "has a well-structured smart city strategy" (Roland Berger, 2019). The average score in 2017 was 37/100, while in 2019 it was 41/100. In granting the title "smartest" the study used the following Mathematics: The cities were indexed based on 3 criteria of evaluation called action fields, planning, and infrastructure and policy. "Action fields" are the "scope of the applications and services that make up the overall smart city strategy" (Roland Berger, 2019). According to the study, action fields weighted 50% in final evaluation, while strategic planning 30% and the infrastructure and policy 20%. As part of the "action field", the analysis of transportation counted as 16.6% from of the score (Roland Berger, 2019).

The 2019 Roland Berger's study analyses the Smart City Strategy Index (hereafter SCSI) because "without a strategic approach to integrate, coordinate and organize these solutions, Smart Cities will never reach their full potential". This index "measures the comprehensiveness and ambition of urban centres against the key ingredients of a Smart City" and provides solutions to governments how to overcome implementation challenges of SC solutions. According to UN, out of 500 cities with over one million population around the world, only 49 have published an official SC development plan. The previous index from 2017 analysed only 87 cities, while in 2019, 153 cities were taken in consideration for being the smartest cities in the world. In 2017, as well as

in 2019, Vienna has been chosen as the smartest city in the world (Roland Berger, 2019). Figure 8 shows criteria that been considered to achieve the highest performing SC in the world.

FIGURE 8. DISTRIBUTION OF POINTS ACCORDING TO PLANNING, INFRASTRUCTURE AND POLICY AND ACTION FIELDS CRITERIA



SOURCE: (ROLAND BERGER, 2019)

2.3.4.2 Vienna – The Most Livable City

The city of Vienna has been ranked for 10 consecutive times, from 2009 to 2019, as the most liveable city in the world in the Mercer Quality of Living Survey (City of Vienna, 2021). Mercer's survey is based on 39 criteria that "compares the political, social and economic climate, medical care, education, and infrastructural conditions such as public transport, power and water supply" of 450 cities worldwide (City of Vienna, 2021). The information is collected from public and independent institutions, as well as from expats in Vienna. However, the roots of Vienna's top position in the global competition are much older than the history of Mercer studies and the last few decades of analysed transportation system (City of Vienna, 2021).

2.3.4.3 Vienna – The Greenest City

On 50th anniversary of Earth Day April 22, 2020, Resonance Consultancy published a study of the world's greenest cities and Vienna ranked first. 50 of the most visited cities, based on Tripadvisor's total amount of reviews, have been considered in this study, including Vienna. Following

criteria has been selected for the world's greenest city title: availability of public green spaces, consumption of renewable energy, usage of PT to go to work, air pollution levels, consumption of water, walkability, recycling facilities and capacity of composting, and number of local farmer markets (Chris, 2020).

2.4 Urban Land-Use: The Interconnection between WL's Smart PT Services and SC

Even though Smart Mobility (hereafter SM) is just one of the areas that contribute to the SC implementation it is, nonetheless, of a crucial importance. However its implementation is also challenging just like the SC in part, due to various interests of the stakeholders holding different visions (Bevir, 2013).

SM is viewed as a "slice of the Smart City", encompassing all the components mentioned in earlier chapters. As a result, SM is a multidimensional topic that pursues to deliver a diverse set of advantages for all SC stakeholders. Furthermore, a successful, SM system in a city employs all the transportation characteristics outlined in earlier chapters, which constitute the SC of Vienna: digital city, green city and knowledge city (Benevolo, Dameri, & D'Auria, 2016).

Smart Mobility is influenced by the urban spatial infrastructure. As a result, Vienna adopts attractive strategies and a diverse variety of measures to promote cycling, walking, PT or "eco-mobility", as the primary means of transport inside the city, and integrates their networks for optimal efficiency. Affordable transportation for all segments of the population makes it even more appealing. Walking and cycling are further examples of physical mobility that encourage a healthier lifestyle, because for every journey that people do not use their car, it represents a win for the city (City of Vienna, 2019). In parallel with the advancement of "eco-mobility" infrastructure, adequate actions are being adopted to reduce the demand for private motorized transportation (hereafter PMT). This mix of "push and pull" elements, developed and integrated within the structure of policies, guarantees that the goals could be achieved. The findings of the first SCWFS review indicate the need for continuous innovation (City of Vienna, 2019).

Urban sprawl is one of the most significant external factors. "The distribution of places where people spend their time and the transport infrastructure" (City of Vienna, 2019) measures the preferred means of transportation and the needed volume to cover the demand. Therefore, the mobility needs have a direct impact on the urban spatial structure and environmental-friendly land-use planning. Transportation guidelines, as well as the government's financial implications are incredibly important to "create urban settlement structures that prevent" the use of PMT and shift mobility to sustainable means of transport, such as active mobility and PT (City of Vienna, 2019). Austria has a high urban sprawl, meaning that the actual regulation for land-use planning must be improved. The Austrian Spatial Development Concept (ÖROK) has the role

to set objectives for the land-use projects with the governmental participation being key for success (BMK, 2021).

According to Austria's Mobility Master Plan 2030, the city of Vienna, as well as other cities and regions of Austria are planning to improve the structure of urban settlements and to promote environmental mobility through following decisions (BMK, 2021): to create "cities" with no more than 15 minute travel distances, also called "15 minute cities", (City of Vienna, 2022) as well as to reallocate and make more attractive public spaces (e.g. town centres, green spaces). Also, it aims to improve the traffic and parking condition, as well as to ban or restrict PMT entry in certain areas. Multimodal mobility will be promoted, due to lack of parking spaces within the cities and climate-neutrality goals. Moreover, active mobility and PT will be the most beneficial means of transport, especially on short distances. Also, "virtual mobility and digitalization can also be used to limit travel" (BMK, 2021).

2.4.1 Recent Major Innovation and Infrastructure Upgrades conducted by WL in SC Vienna

Since by 2030 it is predicted that Vienna will be home to approximately two million people, PT will need to keep up with this rapid growth. Economic progress demands flexible transportation which eases access to resources and trade markets. (Rassafi & Vaziri, 2013). A reliable mode of transportation is required, one that minimizes the negative consequences of congestion and resource depletion, achieving success without compromising "the ability of future generations to fulfil their needs" (Bamwesigye & Hlavackova, 2019). SC revolves around finding intelligent techniques that concentrate on people's demands and interests in economic prosperity looking "at the long-term element of economic development and quality of lifestyle of people living in cities". The goal is to provide citizens with better and more efficient public services that are also affordable and long-term oriented (Malasek, 2016).

2.4.1.1 New transportation routes/improvements: U2xU5 public transport expansion

The U2xU5 intersection will cover a significant route in the inner-city metro network as a follow-up to major urban development initiatives like the U2 extension to the "city within a city" Aspern, the smartest suburb area in Vienna. Especially at peak times, WL pursues to ensure adequate space and conditions, so that passengers can efficiently use PT services. Therefore, the U2xU5 investment upgrade worth €100 million will bring following benefits to the Viennese community (Wiener Linien, 2021):

I. More convenience, due to higher transport capacity, as well as higher comfort level (Wiener Linien, 2021).
II. More e-mobility, leading to a 50% share of PT is considered (Wiener Linien, 2021).
III. The intervals will be shorter, more connections will be available and therefore, more annual passes will be acquired (Wiener Linien, 2021).

IV. Around 1700 full-time jobs will be created through the €100 million investment (Wiener Linien, 2021).
V. In 2021, tram stations were renovated that intersected the U2xU5 stations (Wiener Stadtwerke, 2020).
VI. Additionally, 18 Bombardier Flexity type D low-floor carriages were added to the tram fleet in Vienna, by the end of 2021 (Wiener Stadtwerke, 2020).

2.4.1.2 The U4 modernisation project

The modernization of U4 underground metro line, also called "NEU4" is considered "the largest modernisation project in the history of Vienna's underground network". The €335 million investment by WL and WS will improve the functionality of U4 and it includes the renovation of tracks, metro tunnel, stations. "Additional track connections will also make it possible to change tracks in the event of disruptions, helping to improve the reliability of the U4's operations". Started in spring 2014, the project is due 2024 (Wiener Linien, 2022).

2.4.1.3 auto.Bus Seestadt

According to Günter Steinbauer, Managing Director of Wiener Linien, "autonomous driving is a megatrend with the potential to change cities for good. As a public transport provider, we will be at the forefront of this." The auto.Bus – Seestadt project strived to enhance autonomous mobility, but also to raise the efficiency and overall functionality of driverless transportation in Vienna with two autonomous buses provided by Navya (Wiener Linien, 2022).

The testing two kilometres circular bus route was in Seestadt under genuine scenarios - including 10 stops, timetables and passengers. The Federal Ministry of Transport, Innovation and Technology was providing financial support for the auto.Bus – Seestadt research project as part of the "Mobility of the Future" program, developed by WL, Austrian Institute of Technology (hereafter AIT), Austrian Road Safety Board (hereafter KFV), TÜV Austria, Siemens Mobility and Navya (Wiener Linien, 2022).

However, after more than three years of testing started in April 2018, the project ended on June 30, 2021. Furthermore, on July 18, 2019 a pedestrian suffered minor injuries after colliding with one of the busses. It has been found out, that it was caused by the inattention of the pedestrian that was using its phone and headphones, while crossing the street. On one hand, the bus was in that testing phase not driverless, but on the other hand, the sensors might not have reacted fast enough, to avoid the unexpected collision (Wiener Linien, 2022).

2.4.1.4 Clean Vehicles Directive (CVD)

The Clean Vehicles Directive (hereafter CVD) was implemented in August 2, 2021 and was approved in the EU Parliament. It involves the following criteria:

I. The public purchase of "clean and energy-efficient road vehicles", as well as mandatory quotas for the acquisition of buses with alternative drive mode (Wiener Stadtwerke, 2020).
II. By the end of 2025, at least 45 percent of new buses fleet acquired by WL must be powered by alternative driving, according to CVD (Wiener Stadtwerke, 2020).
III. A fleet of 62 battery-electric buses and 10 hydrogen-powered buses was planned for 2021 to meet the first quota (Wiener Stadtwerke, 2020).
IV. A new procurement for electric minibuses about the operating on lines 2A and 3A since 2013 is scheduled in 2024. Nevertheless, on line 39A, ten hydrogen-powered buses will be deployed by 2023 (Wiener Stadtwerke, 2020).

2.4.1.5 Wiener Linien - Greener Linien Initiative

The motto “Wiener Linien sind Greener Linien”, translated to “Wiener Linien is Greener Linien” stands for WL’s concern regarding the environmental protection and sustainable development (Wiener Linien, 2022). This initiative resulted in implementing local projects, such as:

I. The replacement of “all of the old fluorescent lighting in vehicles and stations” with a consumption of 1.6GWh to energy-efficient LED lamps, in 2020 (Wiener Stadtwerke, 2020).
II. Also in 2020, the TÜV Austria Science Prize award-winning project “The Brake Energy” integrated in U2 underground station Hardegasse collected 3GWh/year of energy from the metro’s breaking system and managed to supply escalators, lifts and lights in the station (Wiener Stadtwerke, 2020). The breaking system was implemented in Altes Landgut station and Ober St. Veit that can transmits 4.5 GWh electricity into the work of the stations (Wiener Stadtwerke, 2021).
III. In 2019, on the roof of Ottakring underground station, around 360 m² of photovoltaic films that generate 62,000 kWh/year of solar power to power escalators, lifts and lights have been implemented via the program Interreg Central Europe and is due 2022 (Wiener Stadtwerke, 2020).
IV. A depot for electric buses in Siebenhirten is in plans to be built as well as a hydrogen refuelling point in Leopoldau (Wiener Stadtwerke, 2020).
V. A new, green bus shelter was built in the proximity of the parliament (Wiener Stadtwerke, 2020).
VI. Building bee hives for 2 million bees in Leopoldau (Wiener Linien, 2022).

2.4.2 Other plans in Vienna: A city within a city - Vienna's Urban Lakeside Smart City Aspern

Besides the already integrated neighbourhoods, "Autofreie Siedlung Floridsdorf" that is car-free since more than 20 years, and bicycle-oriented "BikeCity" Nordbahnhof, Aspern – Vienna's Urban Lakeside is the most expansive urban, implemented in the 22nd district of Vienna (Knoflacher, Frey, & Leth, 2018).

Considered as the city of the 21st century by its developer Wien 3420 AG, owned by GELUP GmbH, a subsidiary of Vienna Business Agency, Aspern has been conceived as a "city within a city" concept and stands as well as a model for other modern urban initiatives in the suburb area of Eastern Vienna, Seestadt (City of Vienna, 2014). As a result of the development of this new smart suburb, its residents will be able to live in recently constructed homes that have been designed according to sustainable principles (Anthopoulos, 2019). "The project has a prime location at the centre of the economic growth region CENTROPE, right on the Vienna-Bratislava axis: Bratislava's central station can be reached within 28 minutes and Vienna airport within 15 minutes". Also, Vienna's city centre can be reached within 25 minutes (City of Vienna, 2014).

With a total cost of €5 billion and a total area site of 240 hectares, the construction of the project started in 2010 (Vienna Business Agency, n.d.), and 2 years later, the first companies started moving in. The first phase of construction was done by 2018. The second phase is due 2024, while the third phase is due 2030 (Aspern Seestadt, 2018). "Until the year 2028, 20,000 workplaces and 10,500 apartments for 20,000 residents will be built" (Knoflacher, Frey, & Leth, 2018).

The U2 underground line extension efficiently connects the centre of Vienna with Aspern, which has been a key characteristic of the development plan. Moreover, according to the city authorities of Aspern, seven other buses are interconnected with the neighbourhood. "The mobility options will increase as Seestadt grows: an Austrian Federal Railways (ÖBB) station is planned at Aspern Nord, and a tram link is likewise in the pipeline." Since multimodal mobility is a priority for Aspern, current transport network targets are as following: 40% of the transportation to be offered by PT, 40% through active modes and the rest by car (Aspern Seestadt, n.d.).

For the entire Urban Lakeside project, 0.7 parking spots per housing unit can be enforced due to the overall development plan. The amount of public parking available has been drastically reduced in the interest of improving the quality of life for everyone and ensuring that all facilities are open to everyone. Part of the savings from garage building are reinvested to assist sustainable modes of transportation (Knoflacher, Frey, & Leth, 2018).

2.5 Implementation Challenges and Ethics: Limitations of Data Collection and Data Privacy of PT passengers

"Big Data" was championed as the "new gold" due to its infinite possibilities to transform modern life. Amongst the uses, Big Data is most heralded for is to be a mechanism that helps governments solve issues such as reducing the carbon footprint by optimizing transportation (Lorinc, 2018). Vienna is famous for being the "smartest city" (Roland Berger, 2019), therefore this concept encompasses various levels of the city existence including transportation, smart buildings and government services allowing for interconnectivity fueled by Big Data. It also includes Internet of Things (hereafter IoT) technology, "physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment," from smart sensors and smart mobility, through connected vehicles (Gartner, n.d.).

Digitalization combined with IoT, the latest developments in wireless technologies, the low-cost and widespread usage of sensors, the increased use personal devices all are generating enormous amounts of structured and unstructured data. Analysing it through data mining and analytics, it transforms the raw numbers and amorphous material into patterns that are used for predictions of needs. This increased connectivity by improving urban mobility and preserving scarce resources as planners can better to grasp the needs of riders allocate resources better (Torre-Bastida, et al., 2018).

Additionally, it increases connectivity, reducing waiting time between rides. For WL, the real-time streaming of the data makes possible to control traffic signals, transmit the information from sensors placed inside PT vehicles that are counting riders flow. The sensors may come from GPS navigators, mobile phones apps or Social Media (e.g. geo-located tweets, Google Analytics), offering data about customers' location and timing, leading to detection of mobility patterns that are going to be used for prediction (Torre-Bastida, et al., 2018).

2.5.1 The 5 Vs Characteristics of Big Data and their Relevance in Public Urban Transportation

While Big Data lacks a precise definition, it refers to collecting of large volumes of high-velocity, heterogeneous, data sets by using advanced techniques and models to store, retrieve, manage, process, and analyse what was captured. One definition was given by Gartner: "Big Data is high volume, high velocity and/or high variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization" (Gartner, n.d.). This famous definition by Gartner consists of the initial 3 Vs that have been expanded to at least 5 Vs (Gartner, n.d.):

2.5.1.1 Volume

Volume means the huge amount of data that are generated continuously from millions of devices and applications. Public transportation agencies themselves generate substantial amounts of data as part of their daily operations. Some examples are: Automatic Vehicle Location systems track the positions of buses, trains collect a constant stream of information including passenger counting systems mounted on transit vehicles record how many people get on and off at each stop (Nagaraj, Gururaj, Swathi, & Hu, 2022). Fare collection systems record trips taken, transfers, and travel patterns among transit users. Other sources of data are not automatically created but entered by agency employees: time tracking, absenteeism data, safety incidents, and other employment data, etc. ”On average, some 2.6 million passengers per day use the Wiener Linien network, for which our public transport vehicles cover a distance of 214,000 kilometres – the same distance as orbiting the earth 5 times. In total, some 961 million passengers used the Wiener Linien network” (Wiener Linien, 2021).

2.5.1.2 Velocity

Velocity refers to the fast generation and transmission of data. The flow of data was helped by advance in technology such as the fiber optic cables. Technology allows for ticketing and tolling transactions that use smart cards to be reported in real- time (Clarke, n.a.).

2.5.1.3 Variety

Variety refers to the diverse data forms with structured and unstructured content such as text, image, multimedia content, audio, video, sensor data etc. In public transportation, variety of data is generated as trains' telemetry collects information about crew members and passengers as well, about things like energy consumption (e.g. data were collected about energy consumption from tracks operating under different conditions, to see how energy may be reduced while maintaining comfort for passengers and crew). WL collects from riders both at the ticket shop as well as through the mobile app WienMobil (Wiener Linien, 2021), a whole “garden variety” of data including as:

I. Name, email address, date of birth, address, and telephone number, one may assume that this information can profile the riders by sorting them by age, the residence can give insides into how wealthy/poor a rider is, etc. (Wiener Linien, 2021).
II. “The positional data, assigning users an age category (utilizing 10-year increments), device metadata (i.e. mobile phone type, operating system, version of the operating system, app version), route queries, and bookings. Data can be anonymized and processed to obtain statistical and analytical information to optimize mobility.” Consent can be taken back by if the user is deactivating his/her profile. However, the likelihood and effectiveness of it seem very unlikely or highly useless since data already may have been used or migrated (Wiener Linien, 2021).

III. By using the WienMobil feedback function, inquiries and any photos riders might have sent as well as their device meta data (mobile phone type, operating system, version of the operating system, app version) will all be processed. However, Wiener Linien allows that the rider may be able to delete the device metadata in their feedback section (Wiener Linien, 2021).

IV. With each purchase of a WL product, regardless of whether rider has created an account or not, the data provided will be stored (first and last name, academic degree, date of birth, email address, residential address and/or billing address, telephone number) (Wiener Linien, 2021).

V. If using the "annual season ticket service" in the online ticket shop a photo and the bank details will also be stored for the annual season ticket holder (Wiener Linien, 2021).

VI. When purchase tickets for students, the matriculation number and the name of the university enrolled in will also be stored (Wiener Linien, 2021).

VII. To be able to maintain the connection to the rider's device Wiener Linien will store the IP address and the device's metadata (Wiener Linien, 2021).

2.5.1.4 Veracity

Veracity means the trustworthiness or reliability of the data. The substantial amounts of data have to be organized accordingly, to produce accurate datasets before the analysis process. The quality of data is less important than the understanding that can be found in it, "as there are discrepancies in all the data collected. The necessity to deal with inaccurate and ambiguous data is an important aspect of Big Data that is being addressed by tools developed for mining of unreliable data" (Ortelio, 2018).

2.5.1.5 Value

Value refers to the information extracted from the amorphous data captured which makes it possible for business to monetize it. For Big Data to be valuable it must be accurate and reliable a process accomplished through data analytics. This process is expensive and therefore many companies cannot afford state of the art tools needed, paying for savvy people who can bring the analytics know how. Therefore companies who collected the data must either sell it for marketing purposes, or discard it minimizing the risk of loss (Faroukhi, El Alaoui, Gahi, & Amine, 2020).

2.5.2 Relevant technologies used to make Big Data valuable

From a technological point of view, predictive analytics is used to forecast the future based on past and actual behaviour and by drawing inferences based on a regressive algorithm. Machine Learning (hereafter ML) is a tool used in this technology. In PT, past and actual data regarding the fleet's routes are analysed, with the aim to (a) discover frequently occurring patterns about

fleet's performance and to (b) make prediction on the fleet's performance (e.g., early, on time, and/or late). This helps planning to increase efficiency (Balbina, et al., 2020).

Technically, Big Data can be just bits and bytes, amorphous and meaningless, but through AI machines being fed, "cleaned " or transformed, data machines can "learn" to draw inferences and patterns that estimate future outcomes. Transportation algorithms can be created by analysing traffic data and public transport vehicle data through the application of machine learning techniques, which need vast amounts of data to reveal complex patterns.

Patterns can be used to minimize service disruptions by analysing passenger behaviour allowing the adjustment of transport lines to prioritize high demand areas and rush hours following predictive patterns (Newman, Hargroves, & Stantic, 2017). For learning to be effective, there is a need for a lot of data as a learning model trained on a limited or irrelevant dataset would lead to ineffectiveness. In the PT system deep learning is an emerging technology.

More attention is given to the self-driving private automobile. Deep learning algorithms in transportation fall into the category of unsupervised algorithms, meaning learning of patterns occurs from untagged data (Nagaraj, Gururaj, Swathi, & Hu, 2022). "Autonomous driving has reached also Wiener Linien as two small, self-driving electric busses are operating at Seestadt Wien. These unique test conditions allow them to train to gain experience in autonomous driving in city traffic" (Vienna Region, 2021).

2.5.3 Ethical Concerns

Some of the ethical concerns are about privacy, access to and ownership of the Big Data. Privacy is a fundamental EU right benefiting only natural persons (not companies). The European Union enacted the General Data Protection and Privacy (GDPR 2016/679) to increase the individuals' control over their data. GDPR defines Personal Identifiable Information (hereafter PII) as information relating to an *"identified or identifiable natural person"* (GDPR, 2021). For organizations subject to the GDPR, there are two broad categories of compliance: data protection and data privacy. GDPR defines data protection as" keeping data safe from unauthorized access." Data privacy is "empowering users to make their own decisions about who can process their data" (European Union, 2016).

WL is collecting PII subject to GDPR providing data riders give "explicit consent." WL collects "your personal data, specifically name, address, contact data, contract, invoicing, usage and consumption data, commercial indicators, customer contact behaviour and response behaviour for the purpose of ensuring data quality, consistency and up-to-dateness, as well as for the purpose of new product development, the categorization of customers in groups and subsequent marketing in respect of the delivery of products and services in the energy, telecommunication, building management, IT, funeral and mobility" (Wiener Linien, 2021).

Data migration and external date misuse or hacking can lead to privacy violations. WL for example migrates data collected to businesses involved from transportation, education etc. all the way to the cemetery industry. In the case of the WienMobil application, data are shared with Google Firebase for continuously improving the service and usability (Wiener Linien, 2021).

Tracking occurs when online users are followed, their online behaviour is recorded and stored to gain insights about their interests, habits, and profile them for sending targeted or personalized ads. One may be browsing a trusted website while invisibly followed by trackers from other websites that are collecting data with purpose to repackage it and sell it to the profiled user. Mobile phone tracking can occur through: displaying ads in an app based on user data collected from other apps, sharing device location data with data brokers, sharing information with third parties that can use the information to retarget the user in other apps, placing a third party SDK (Software Development Kit) in the app: using a third party SDK that repurposes the data it collects from the mobile app to enable targeted add from other developers' app advertisements, push notifications (SDK's created by Google for example have additional features that can be installed in apps to provide analytics, data about application activity, and monetization) (Leith & Farrell, 2021).

The WL website states that "Firebase is used to collect information…transmitted to Google… we cannot exclude that the usage data is transmitted to Google LLC in the USA or is transmitted by Google sub processors in third countries (pursuant to Article 45 or Article 46(2) GDPR). Wiener Linien is not able to draw conclusions about a specific user" (Wiener Linien, 2021). Also, WL riders may be targeted through marketing campaigns. "Marketing includes, but is not limited to, direct marketing via electronic means or other media such as mailings, emails, text messages/multimedia messaging services or phone calls" (Wiener Linien, 2021).

Privacy is a cherished right and therefore, GDPR requires PII protection through anonymization of the data. It can be done through encryption, hashing, generalization, pseudonymization and perturbation by removing the PII. However, anonymization is not fool proof and if de-identified datasets are matched to other datasets or other information, it is possible that individuals can be re-identified especially if cross-referenced with other sources of related data as a necessary process to ascertain the reliability without which data are not valuable (Rooney, 2018).

However, WL states that "no personalisation or linking with your user data takes place" during data transfer. Anonymization is however a great middle ground, because if performed correctly could allow companies to utilize datasets for research and development purposes without compromising the privacy of their customers and running the risk of being sued if consent is lacking or was not properly done (Wiener Linien, 2021).

Minimization of data retention and use limitation - GDPR requires that a data controller should limit the collection of personal information to what is directly relevant and necessary to accomplish a specified purpose. When data are no longer needed it should be discarded to minimize the risk of loss. WL states the purposes for which the data will be used and it does provide some mechanisms for deletion by removing consent (Wiener Linien, 2021).

Transparency and control mean explaining sufficiently to the public how the data will be used and explaining the data practices by not abusing the trust given to handle it. WL states: "Subject to your express consent your personal information, namely name, address, contact information, contract, billing, usage and consumption data, business indicators, customer contact behaviour and response behaviour will be transmitted exclusively within the Wiener Stadtwerke Group to the following companies to ensure data quality, consistency and currentness for the purposes of new product development, the classification of customers into groups, and subsequent marketing concerning the provision of products and services in the energy, telecommunications, building management, IT, funeral, and mobility sectors both during and after the termination of the respective contract" (Wiener Linien, 2021).

Riders are informed that they will be segmented/profiled and targeted for marketing based on PII for selling to them products ranging from mobility services all the way across the whole spectrum ending with funeral services. Even though WL bases its practice on "express consent" (Wiener Linien, 2021), it is doubtful that most riders are educated enough to know what this means and what their options are. The marketing duration may be even the termination of the contract. Even though the disclosure provides transparency, the only control is the unlikely occurrence that a rider will come and remove the consent already given. Riders should have the possibility to see all the data collected about them and the inferences drawn from it (Jevinger & Persson, 2019). This may be very problematic if meanwhile the data are located in the US or other third countries outside the EU authority.

Big Data ownership is another ethical issue**.** Since its value was assessed as "gold" or a new factor of production, its ownership should be equitable so that public at large should be enriched. Presently most likely to benefit from it are multinationals: Google, Facebook, Amazon, etc. They contribute little to local economies as they are headquartered many times in tax havens (Farny, Franz, Gerhartinger, & Lunzer, 2015). The ownership can last forever. E.g. riders give WL consent not only to collect the above PII information from them but also to store it for eternity (Wiener Linien, 2021).

The winners of the Big Data endless possibilities are multinationals like Google, Amazon, etc., who already have the resources and know how to transform the data into information through data mining programs needed for reliable predictions. Building effective data infrastructure requires resources but governments can help to remove barriers to entry into this new field by adopting measures such as forcing the Big Data owners to open it up under certain conditions,

levelling the playing field by creating business opportunities through subsidies for smaller companies, creating collaboration opportunities, to prevent monopolization of the new “gold” in the hands of the few (Ortelio, 2018). As more people become aware that they are practically prevented from making money from their own data there is a need for policy makers to intervene by making it more accessible, while technology must become smarter by needing less data by learning to make better use of the already existing data models (Ortelio, 2018).

The following chapter will present the methodology of the master thesis, followed by an analysis and visual representation of the findings. Lastly, recommendations and future research will be addressed.

3 METHODOLOGY

This chapter of the paper will emphasize a thorough understanding of the applied research methods. The most appropriate research method that would be a good fit to the master thesis will be the mixed method approach. As the main goal of the study is to analyze and evaluate the interconnection between Wiener Linien and the "Smart City" concept, a qualitative work based on interviews with experts from Wiener Linien GmbH & Co will be conducted, backed by a quantitative method of text-based analytics of the interviews, followed by a qualitative approach to analyze and present the scenario's results (Muskat, Blackman, & Muskat, 2012).

3.1 Selection of methodology

To better understand the methodological approaches adopted in this paper, this chapter acts as a preamble to present the chosen research methods. As the collected secondary data for assessing the literature research was especially important in the initial part of writing the master thesis, it continued to also enhance the findings in the methodology phase, as well as to develop the qualitative work of expert interviews. “While secondary data analysis is a flexible approach and can be utilized in several ways, it is also an empirical exercise with procedural and evaluative steps, just as there are in collecting and evaluating primary data” (Johnston, 2014). According to Creswell (2014), “qualitative research is interpretative research; the inquirer is typically involved in a sustained and intensive experience with participants. This introduces a range of strategic, ethical, and personal issues into the qualitative research process” (Creswell, 2014).

The primary data collection through a structured expert interview is key in setting the “protocol for recording information” (Creswell, 2014). The type of mixed method used in this master thesis is exploratory sequential mixed methods, because it enables the researcher to start with a qualitative approach, in this case expert interviews, and therefore to collect and analyse the obtained data for the next phase (Creswell, 2014). It is then followed by the quantitative work, which is the text-based analytics of the collected data (Welbers, Van Atteveldt, & Benoit, 2017). According to Pang and Lee (2008), the text analysis, also called opinion mining, “deals with the computational treatment of opinion and subjectivity in text” (Pang & Lee, 2008). As data are key in assessing validity of the research, “the data analysis should reflect the statistical tests and not be underreported,” to avoid biased results. To interpret the collected data, coding in R programming language will be implemented, to create a graphical visualisation and to draw correlations, similitudes and frequencies of the words found in the protocol with recorded information. Nevertheless, Creswell described in 2003 that “a mixed methods design is useful to capture the best of both quantitative and qualitative approaches”, especially if the subject is new and it has “not been addressed with a certain sample” (Creswell, 2003).

3.2 Expert Interviews

3.2.1 Objectives of Expert Interviews

Expert interviews represent a very meaningful technique for methodological analysis. The conducted expert interviews in this master thesis have the main objective to obtain data on a more comprehensive level, such as valuable key insights from the fields of public transportation, multimodal mobility, and smart city development, and therefore to answer the paper's research questions. Assessing an exploratory expert interview approach is important because important because it "aims at the structured and comprehensive collection of expert knowledge in order to achieve a high level of data comparability" (Döringer, 2021). According to Van Audenhove and Donders (2019), a processual knowledge technique is pursued, because "process knowledge captures knowledge that is based on practical experience and the institutional context of actions. In this sense, process knowledge emerges due to the position of the person in a process and comprises knowledge about interactions, routines, or social practices" (Donders & Van Audenhove, 2019). Therefore, the expertise in the field of the interviewees and their knowledge have a crucial role in the validity of the data, that is why a careful selection of the interviewees must be done.

3.2.2 Structure and Design of Expert Interviews

Open-ended, fixed questions were the most appropriate for conducting the structured expert interviews, to allow experts to express their opinion with respect to the questions and to increase reliability, credibility and validity, as well as to reduce bias. "Combining an open narrative beginning with a more structured interview section enables the researcher to remain receptive towards the gathered information, as it encourages the interviewees to describe individual perspectives, to clarify previous statements, and to revise misguided assumptions of the interviewer" (Döringer, 2021). By doing this, the foundation of the upcoming phases is built and as mentioned above, a text analysis approach will be proceeded afterwards, to create not only a visual representation of the findings, but also to build a better understanding with respect to the collected data.

The first part of the interview pursued to create an overview of the company Wiener Linien GmbH & Co, considered in this master thesis as the only public transportation provider in Vienna. Interviewees have been asked how they would describe Wiener Linien, from their personal point of view and if the company is ahead or behind on its sustainable goals. Their perception is important because it offers an overall image of the company's role and future-oriented mission to improve the quality of life of the Viennese community.

The second part of the interview focused on how the multimodal solutions of Wiener Linien interconnect with the Viennese community. Interviewees have been requested to elaborate

what they think it should be prioritized at Wiener Linien to develop Vienna as a "smart city," as well as how they could therefore convince Viennese people to give up on their car use inside the city. Then, interviewees have been asked how Wiener Linien could become an even more attractive option for mobility in Vienna, especially through Wiener Linien's promoted mobility solutions. The next question was based on how they see the future of Wiener Linien's shared mobility fleet competing with local established players.

The third part of the interview referred to the data privacy and data collection strategy implemented at Wiener Linien. Interviewees have been asked to elaborate if they are concerned for data being leaked to other companies and if it could be used as a competitive advantage against Wiener Linien. Moreover, they were asked if Wiener Linien's quantitative data collection, referring to passenger data, sensors data etc, would be sufficient for improving Wiener Linien's efficiency or if there are also qualitative features that could to be considered.

The fourth and last part of the interview cover the expert's description and interviewees were asked how long their experience in the field is, expressed in years.

3.2.3 Sampling of Expert Interviews

The expert interviews were conducted via Teams with a duration between 30 and 60 minutes, consisting of the 4 parts mentioned above. According to Creswell (2014), "The free-flowing, conversational characteristic of videoconferencing most closely compares with face-to-face dialogue" (Creswell, 2014). A total number of 11 experts, all from Wiener Linien GmbH & Co, with experience ranging from 3 to 20 years have participated to the interviews. However, one interviewee preferred to offer a written response to the addressed questions, while other 2 experts preferred not to have an audio-recorded interview. The interviewees identities have been completely anonymized, meaning that the job title and name have not been disclosed, as well as any other personal information.

As part of the expert interview process, interviewees were asked for permission for being recorded via Teams, so that the interviewer could subsequently analyze all the responses as genuinely as possible. Very few questions were not able to be thoroughly explored because of the company's internal policies, even though all interviewees made a significant effort to offer as much information as possible. The most important findings from these interviews will be analyzed in the following chapters. In Appendix 1, the questionnaire is attached with all the addressed interview questions.

3.2.4 Limitations

To be comprehensive, it must be stated that this thesis has several limits that were discovered during the methodological investigation. One of the obstacles was the available online information when organizing the literature review, as very few research papers were published with

respect to this topic or similar. Regarding the conducted expert interviews, an important challenge was the sample size, which consisted of 11 interviewees and varied in terms of industry backgrounds and years of experience at Wiener Linien GmbH & Co. In addition, a larger amount of experts would have shared even more valuable insights that would contribute to the methodological analysis of the thesis. Therefore, consistency and homogeneity can be perceived as potential limitations, based on the volume of information disclosed.

4 ANALYSIS AND VISUAL REPRESENTATION OF FINDINGS

The complete protocol of information recording, converted into a text file of all interviewee's answers will be implemented into R software, in order create a visual representation and better understanding of their personal perspectives. As mentioned above, the literature review and the careful selection of methodology approaches represent a major step, to extract key findings of this analysis. The findings will portrait the conclusion in chapter 6, which will particularly focus on answering the paper's research questions.

4.1 Data Collection

The first phase of the automatic text analytics is to collect the text from the conducted interviews, which is also considered the dataset for the thesis. However, the preprocessing of the text is a fundamental step, with the "aim to make the inputs to a given analysis less complex in a way that does not adversely affect the interpretability or substantive conclusions of the subsequent model" (Denny & Spirling, 2017). Text preprocessing is typically overlooked and underreported in text mining studies, despite its importance (Fokkens, et al., 2013). According to Grimmer and Stewart (2013), "the most consequential, and shocking, step we will take is to discard the order in which words occur in documents. We will use the "bag of words," model where order does not inform our analyses" (Grimmer & Stewart, 2013). The preprocessing phase considers following important operations: white space removal, transformation of all characters to lowercase, specification of language and stopwords removal, punctuation removal, number removal and reduction of inflectional forms (Grimmer & Stewart, 2013). Nevertheless," we refer to the population of texts to be analysed as the corpus and a collection of these as corpora. Some methods will work better on diverse types of tasks or documents of different lengths, but most methods begin in the same way with a series of pre-processing steps to reduce the awe-inspiring diversity of language to a manageable set of features" (Grimmer & Stewart, 2013). All the above mentioned operations will be briefly described as following:

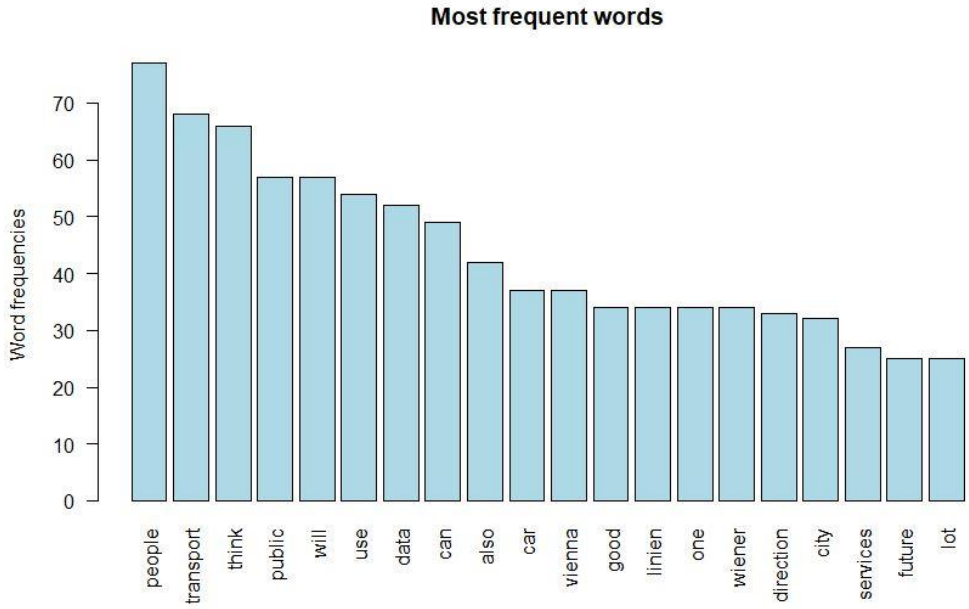
1. White space removal. The removal of white spaces is important, because they do not add value, but unnecessary increased volume to the dataset.
2. Transformation of all characters to lowercase. Since a word written in lower or upper case has the same meaning in English, "it would seem odd to count them as two separate word types for the sake of corpus analysis. However, there are some instances where a word with the same spelling may have two different meanings that are distinguished via capitalization, such as personal names" (Denny & Spirling, 2017).
3. Specification of language and stopwords removal. "After tokenizing the text, the researcher is left with a vector of mostly meaningful tokens representing each document. However, some words, often referred to as "stop words", are unlikely to convey much information" (Denny & Spirling, 2017), such as the terms "the", "and" etc..

4. Punctuation removal. The punctuation is considered uninformative in this analysis and based on the pre-processing approach, it is considered useless (Denny & Spirling, 2017).
5. Numbers removal. Numbers, as well do not add value to this analysis and are considered uninformative (Denny & Spirling, 2017).
6. Reduction of inflectional forms. According to Grimmer and Stewart (2013), in order to reduce the inflectional forms and dimensionality, stemming and lemmatization are considered (Grimmer & Stewart, 2013). "Stemming reduces the complexity by mapping words that refer to the same basic concept to a single root", while lemmatization "seeks to reduce words to their base forms". Moreover, "the critical difference is that a lemmatizer uses context and dictionaries to help discover" the base form of the particular word. Nevertheless, they are not applied both, it is either one or the other but never stemming and lemmatization together (Grimmer & Stewart, 2013).

4.2 Word Frequency

The successful completition of the pre-processing phase enables the "Word Frequency" analysis that assesses which words were used the most in the conducted expert interviews. The aim of this analysis is to offer an insight with respect to the most addressed words, organized in decreasing order, the first one being the most popular. According to the computed model, the most frequently used 20 words will be presented in Figure 9.

FIGURE 9. MOST FREQUENT WORDS PLOT



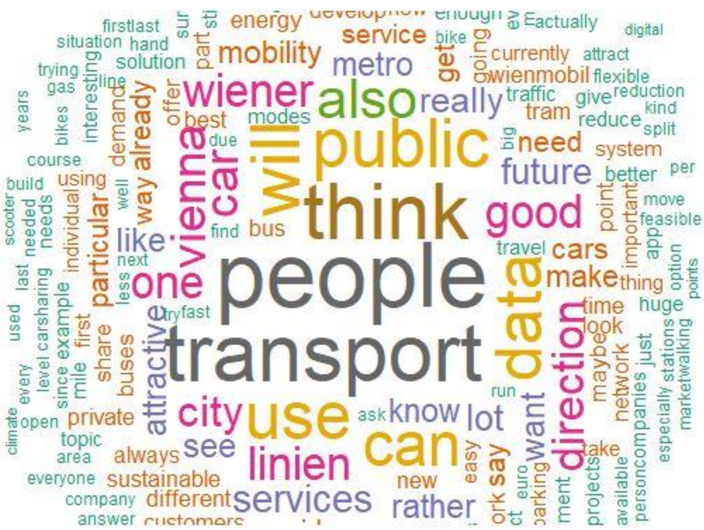
SOURCE: AUTHOR'S OWN PLOT

It can be observed in Figure 9 that the most frequent word used is “people”, followed by key terms, such as “transport”, “public”, “data” etc., with slightly fewer frequencies. In the top 20 list, following very relevant words can be also identified: “car”, “vienna”, “good”, “linien”, “wiener”, “city”, “services”, “future” etc.

4.3 Wordcloud

The wordcloud technique is also used to provide a visual representation of the most frequently occurring words in the dataset. According to Kwartler (2017), “the wordcloud function takes a vector of terms, and then a term frequency vector” from the established dataset (Kwartler, 2017). Because in the dataset words are potentially related to each other, in the worldcloud words are self-explanatory and independent. Moreover, “this word cloud is an example of a non-insightful visual”, because the 20 most frequent words were already known (Kwartler, 2017). Immense corpora are minimized to the most frequently occurring words by using such synthetization method. Word frequency and font size are correlated, meaning that words with larger fonts have occurred more frequently, whereas smaller fonts have been called with fewer frequency, as displayed in Figure 10. This static model portrays words as independent variables, with no potential indication of correlation that might exist between them. The highlighted words were mostly mentioned by interviewees during their interview. Furthermore, positive opinions are implied by adjectives such as: "good", “attractive,” “best,” “available,” “flexible,” “sustainable,” “easy” etc. (Kwartler, 2017).

FIGURE 10. WORDCLOUD OF MOST FREQUENT WORDS FROM THE DATASET



SOURCE: AUTHOR’S OWN VISUALIZATION

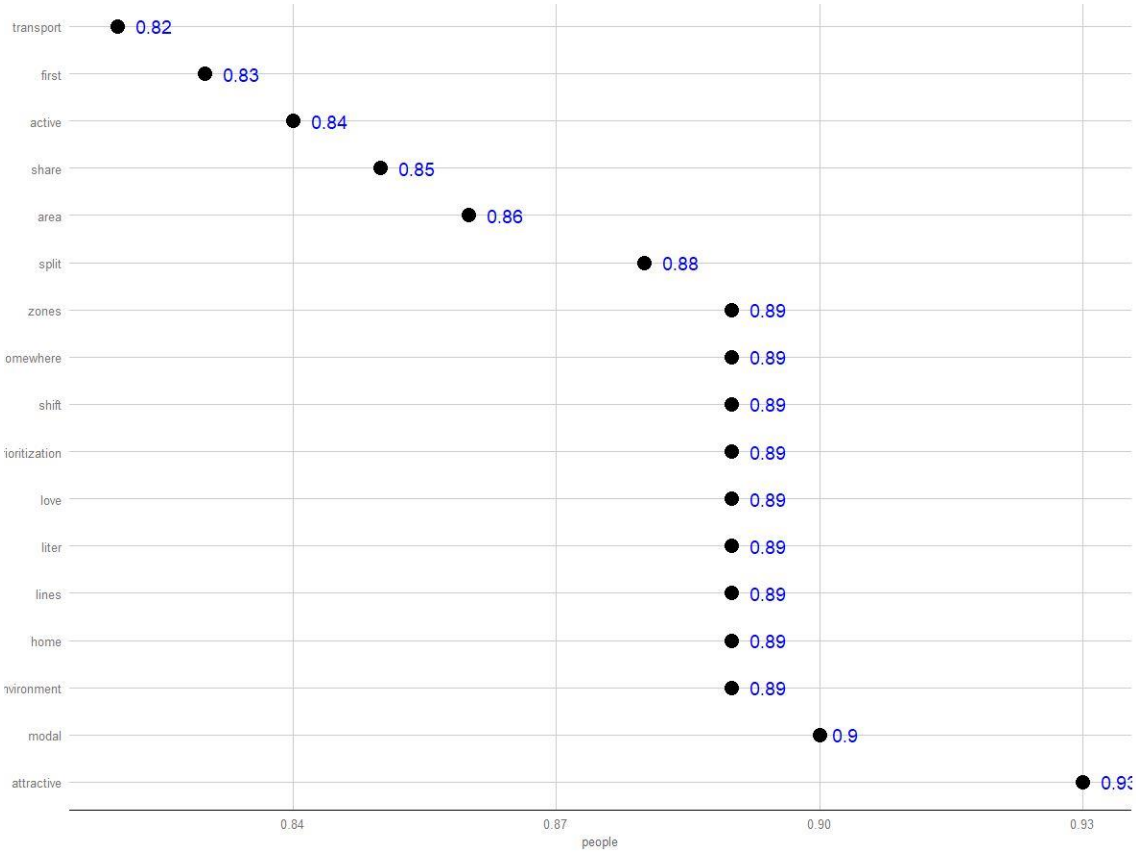
4.4 Word Correlation

According to Kwartler (2017), "text mining's association is similar to the statistical concept of correlation. That is to say, as the frequency of a single word occurs, how correlated or associated is it with another word" (Kwartler, 2017). The word correlation approach shows the correlation between words and the frequency with which they appear together in a single sentence or phrase. However, to simplify the analysis, only high correlations of over .80, have been selected. Due to the very large amount of words that could potentially appear in the same sentence together, it would create a very agglomerated visual representation, making Figure 11 and Figure 12 impossible to read. Since the words "people" and "transport" are very close to each other in terms of word frequency, a word correlation analysis will be elaborated for both of them below.

On one hand, Figure 11 presents high correlations of words, related to the term "people". The word "attractive" has a .93 correlation with the term "people", which means that these two words have been very often addressed together in the same sentence during the interviews. More precisely, "attractive" refers to the mobility solutions as a service provided by Wiener Linien GmbH & Co, that can be offered to the "people" in Vienna. "Attractive" is considered to have positive meaning, that in this context would bring important benefits to the community.

Furthermore, the term "modal" has also a very high correlation with "people", directly referring to the various mobility solutions promoted in the city of Vienna and the existing mobility split that separates different means of transport. Another very important aspect that correlates with the word "people", is based on the "environment", followed by "home". Public transportation is crucial for the development of Vienna's communities, both in key "zones"/"area(s)", such as the city centre or suburbs where people consider it as "home". The sustainable factor that is related to the term "environment" is set at a very high priority for the future development on mobility in Vienna, being also one of the most important targets in Vienna's frameworks for the SC implementation concept. That's why a "shift" towards a higher multimodal "split" is considered as a "prioritization" in WL's agenda. Also the word "active" has a very high correlation, suggesting that "active" mobility is strongly correlated with the term "people".

FIGURE 11. "PEOPLE" – WORD CORRELATION ANALYSIS

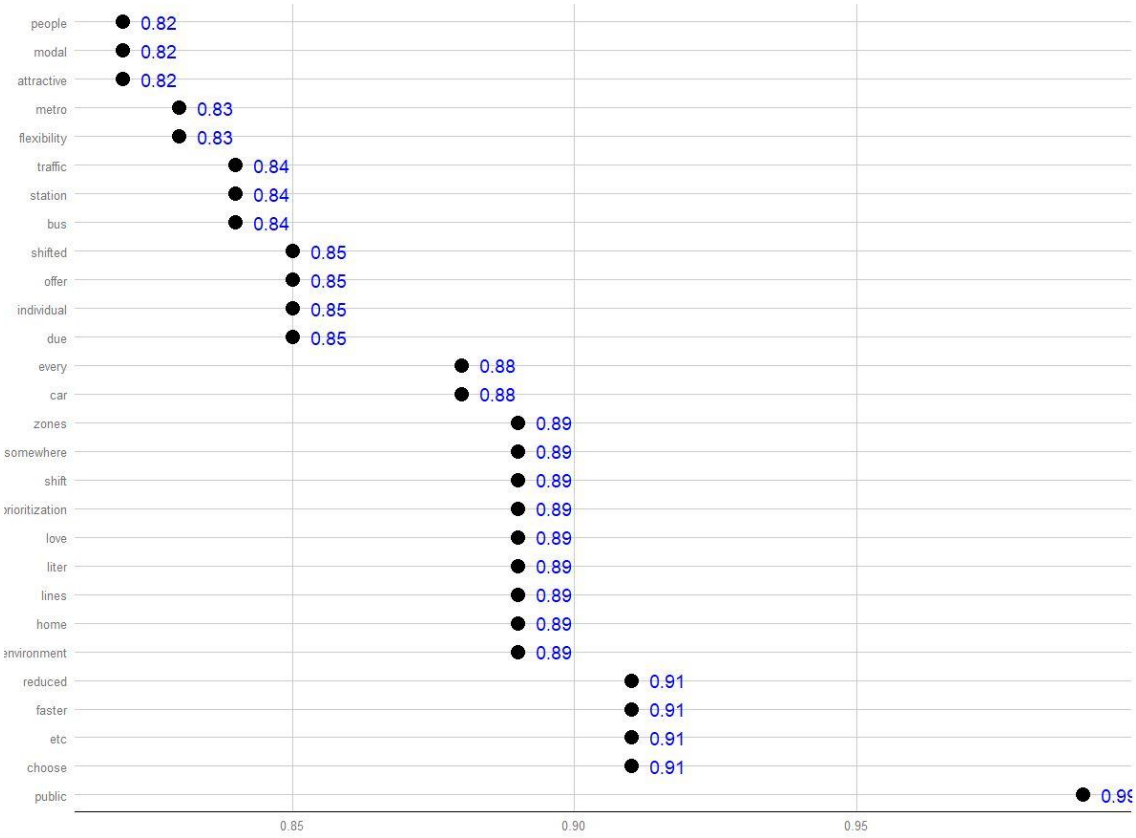


SOURCE: AUTHOR'S OWN COMPUTED VISUAL REPRESENTATION

On the other hand, Figure 12 presents as well a high word correlations of over .80, with respect to "transport". A correlation of .99 is represented by the word "public", since these two words are complementing each other. The second highest association comes from the word "choose" that refers to the opportunity that people in Vienna have, which is to have reliable, affordable, and available solutions for the multimodal mobility in the city. The word "faster," as well as "attractive" and even "love" refers to the top quality and well-organized services that WL offers, and that people highly appreciate and consider as a crucial need for their life balance.

Also in this case, the word "environment" is strongly related to "transportation," since WL promotes state-of-art sustainable mobility solutions, offering "flexibility" when using its services. Since "bus" and "metro" are high performing fleets under Wiener Liniens' control, they "prioritize" to "shift," or "reduce" the "individual" "car" usage inside the city towards more environmental-friendly mobility solutions, such as the first and last mile mobility.

FIGURE 12. "TRANSPORT" – WORD CORRELATION ANALYSIS



SOURCE: AUTHOR'S OWN COMPUTED VISUAL REPRESENTATION

4.5 K-Means Clustering

According to Isabella and Srinivasan (2018), "K-Means is an unsupervised machine-learning algorithm for clustering. This algorithm groups the data based on the similarity between them. Unsupervised Learning means that there is no predictable output and the groups are created based on their similar properties" (Isabella & Srinivasan, 2018). Clustering is a data classification approach that divides data into clusters, such as groups or classes based on the degree of similarity between the data components within each cluster, as opposed to the degree of similarity between data items within other cluster (Isabella & Srinivasan, 2018). Nevertheless, clusters can be understood as "connected regions of a multidimensional space containing a relatively high density of points, separated from other such regions by a region containing a relatively low density of points (Ayramo & Karkkainen, 2006)".

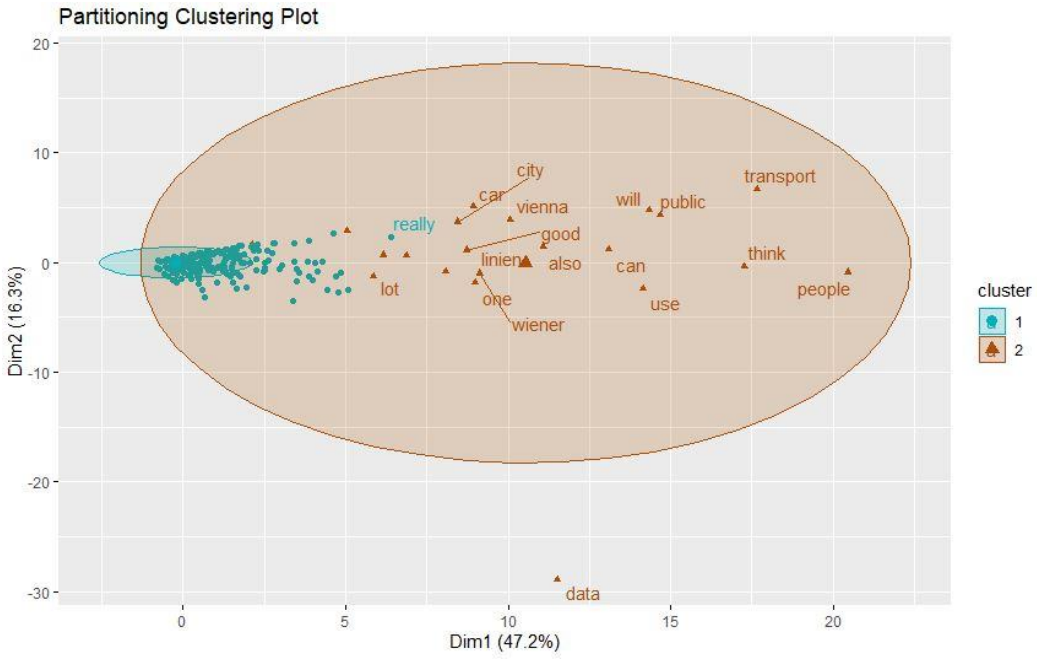
A precise number of clusters might be easy to guess in some cases, but in other cases it is difficult to assess. One of the most popular clustering methods "Partitioning Clustering" will be used in the following analysis, because this technique "first creates an initial set of k partitions, where

parameter k is the number of partitions to construct" (Velmurugan & Santhanam, 2011). Additionally, K stands for the number of clusters that could be implemented into the dataset. However, the algorithm might not find the most suitable number of clusters, especially when working with immense datasets (Velmurugan & Santhanam, 2011), because it uses a fast and simple algorithm. Thus, the flexibility offered in analyzing the text by the partitioning-based clustering approach is based on "iterative relocation of data points between clusters" (Ayramo & Karkkainen, 2006). According to Ayramo and Karkkainen (2006), this iterative relocation algorithms "minimize a given clustering criterion by iteratively relocating data points between clusters until a (locally) optimal partition is attained". Two negative aspects that are considered in this method are rearranging the dataset would potentially offer dissimilar solutions and it has a high sensitivity to outliers.

As of Figure 13, the computed output of clusters is 2. The existing words within the clusters have been randomly assigned from the dataset. Also, it aligns the dataset to the closest cluster to the center with respect to the calculated Euclidean distance. However, since the shape of the clusters in not spherical or round, the algorithm is not very precise. The challenge to find a perfect amount of clusters, as well as a dataset large enough to contribute to the algorithm determine the output of the cluster, as seen below.

We may wonder which method is optimal and could potentially generate the ideal number of clusters of observations. Many tools and packages exist to help researchers compare datasets, but the experience in the field is pivotal, since it is necessary to know what your dataset is and how it is organized. Cluster 1's most prominent words are for example "technology", "tram", "unique", "metro", "safe", "regulations", "scooter", "passenger", "network", "taxi", "flexible", "micromobility", "bus", "carsharing", "cheaper", "bike", "walking", "costefficient", "climate-friendly", "hydrogen", "hupfer", "electric", "available", "comfortable", "collaboration" etc. The second cluster has the following most prominent words: "wiener", "linien", "public", "transport", "vienna", "people" etc. One outlier to the dataset can be considered the word "data", which belongs to cluster 2.

FIGURE 13. PARTITIONING CLUSTERING PLOT.



SOURCE: AUTHOR'S OWN COMPUTED VISUAL REPRESENTATION

4.6 Affinity Propagation Clustering

According to Frey and Dueck (2007), "clustering data by identifying a subset of representative examples is important for processing" several types of data. They implemented the concept of "exemplars," which "can be found by randomly choosing an initial subset of data points and then iteratively refining it, but this works well only if that initial choice is close to a good solution" (Frey & Dueck, 2007). As a comparison with the K-Means method, which was mentioned in the previous chapter, K-Means "is sensitive to the initial random selection of exemplars, and does not necessarily select the best representation of clusters" (Huffer & Graham, 2018).

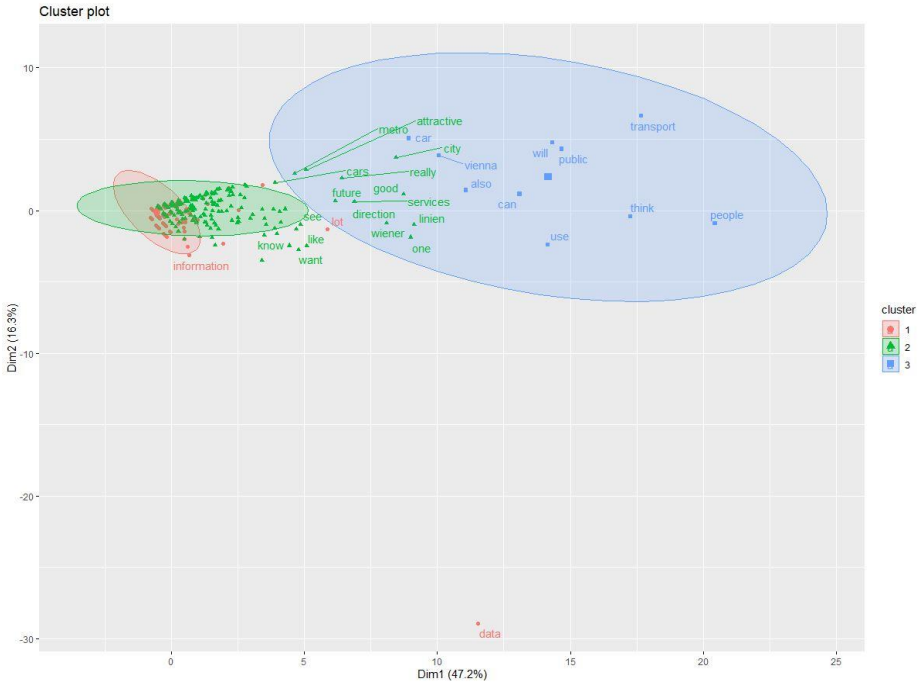
Within the affinity propagation clustering, every component can be viewed as an exemplar and a message system is linking them all together to form clusters. The data can be of any shape and density compared to the previous clustering algorithm. The optimal number of clusters is also automatically calculated.

As of Figure 14, a word is computed to describe each "exemplar" cluster, which is a meaningful in illustrating the clusters. That word is defining the whole elements within the cluster. The examples of this scenario are as following: the first cluster exemplar is described as "achieved," while the second cluster as "imagine" and the third cluster exemplar is defined as "public". First exemplar's elements describe technologies, as well as environmental and economic aspects.

Following key words are part of it: “technology,” “strategy,” “modernization,” “modalsplit,” “optimal,” “sustainability,” “reduction,” “neutrality” etc. The second exemplar defines future implications with respect to mobility solutions and required resources. Following key words were used: “alternative,” “attractive,” “autonomous,” “comfortable,” “digital,” “flexibility,” “hydrogen,” “bikesharing,” “carsharing,” “scooter,” “shift,” “walking,” “wienmobil” etc. The third exemplar describes key elements of the public transportation, as well as the community’s perception with respect to it. Following key words are defined: “people,” “public,” “transport,” “Vienna” etc. The first and second exemplar have similarities within their cluster elements, but also the second and third exemplar share similar concepts.

A major advantage of affinity propagation is that the number of exemplars does not need to be set in advance of the experiment. "Instead, the appropriate number of exemplars emerges from the message passing method and depends on the input exemplar preferences". Therefore, the model selection can be automated based on the prior specification of how desirable "each point is as an exemplar" (Frey & Dueck, 2007).

FIGURE 14. AFFINITY PROPAGATION CLUSTERING



SOURCE: AUTHOR’S OWN COMPUTED VISUAL REPRESENTATION

5 RECOMMENDATIONS AND FUTURE RESEARCH

The fact that the most frequently word in the interviews was “people”, this means that the WL’s duty is to serve the people and their well-being, making them happy and to reach their destination safe and comfortable. The overall perception of PT in Vienna is extremely high due to the state-of-art services offered. However, to increase the modal split towards the usage of public transportation, more financial investments and more projects will have to be planned into WL’s agenda. Also, it is important that better use of collected data is made, because according to the interviews, this could be a game changer in assessing the efficiency of PT and better understanding the people’s needs when they use WL’s services.

Future research could also include the opinion of experts from other public and private institutions, as well as authorities that could potentially have key insights with respect to PT, multimodal mobility solutions and the concept of smart city of Vienna. Also, a research approach in form of a survey towards urban PT users could present valuable information towards the quality and comfort level, as well as reliability and availability of the actual services, but also of future services, especially after the implementation of the modern fleet of vehicles and multimodal solutions, modernization of infrastructure projects and key partnerships by Wiener Linien GmbH & Co.

6 CONCLUSION AND FINDINGS

While the concept of SC is not clearly defined, it has already changed the urban landscape forever. Some characteristics and reasons for its adoption involve the use of technology to increase efficiency in the use of land, road, buildings, and assets usage to improve efficiency and make better use of scarce resource. The term "walkability" means how people can move around inside the city without having to get into their car. The SC concept uses urban PT to create a "liveable community" in the sense of a place where transportation is coordinated to offer a reduced car usage split for people and to access adequate, affordable, and environmentally sustainable pollution free, inner-city mobility.

According to the conducted interviews, WL has existed long before SC came along as the veins and arteries of the urban Vienna, moving its people through its fleet at an unbeatable price. In the era of SC, WL has adjusted remarkably building connectivity and alliances with unlikely partners like e-scooters, constantly looking for innovation and being more than a cheaper alternative to the private mobility. Based on the text analysis of the interviews, the main research question *"what is the interconnection between Wiener Linien and the "Smart City" concept?"* suggests that presently, the demand for PT in Vienna is remarkably high and soon, urban PT will collaborate with automated and connected vehicles, as well as electric and hydrogen powered vehicles, that will offer riders even more advantages and better travel experiences.

Moreover, future investments in infrastructure projects, partnerships and sustainable vehicle fleet upgrades will make WL an even more attractive solution for the SC of Vienna. According to the interviewees, not only that the traditional means of transport have to be interconnected within the city, but also future shared-mobility solutions. That could potentially have a very high positive impact in the sustainable development and availability of PT and therefore it has to be as well implemented. As the interviewees mostly referred to the first and last mile solutions to be a game changer, the text analytics approach shows that there is a very high correlation between traditional means of PT and multimodal mobility, such as bikes, e-scooters and car-sharing services. Thus, they will have the capacity to interconnect the suburban areas of Vienna with the city centre in a highly efficient, reliable, comfortable way that all passengers will benefit from and therefore could substantially reduce the car usage in the city. Findings show that it is very difficult to reduce the car usage to 0%, since cars offer the inhabitants important benefits as well, such as high level of comfort, flexibility and privacy. However, the less cars in the city, the better for the environment of the city of Vienna. Also, the city infrastructure of Vienna does not offer a similar space dedicated for micro-mobility solutions as for car-users. That's why the future planning of Vienna's infrastructure has to further consider the integration of multimodal mobility and to promote innovative and sustainable means of transport.

Based on the conducted interviews, the second research question *"how do policy makers aim to shape the future of Wiener Linien through directives, regulations, plans and financing?"* suggests that PT will have to offer more than being a cheaper alternative to the private-motorized vehicles, but to offer a higher availability, reliability, efficiency, and mobility solutions. Moreover, to achieve the proposed sustainability goals, it is crucial not only for WL, but also for the city of Vienna. The discussed sustainable development plans at local, national and EU level offer a pivotal growth opportunity for PT. Thus, for sure it will not be easy as the "self-driving" cars are also laying claim to being environmentally sustainable. However, WL will find an alternative to integrate with them once they become a reality and continue to build long-term promises that will improve the well-being of the Viennese community, as well as for other incoming people.

In accordance with the text analytics approach, there is a very high correlation between the environment, the people and the transportation. Observations within the affinity propagation clusters show that technologies and resources play an important role in the development of PT within the SC of Vienna. Interviewees consider that to achieve the proposed strategic objectives, such as to provide the highest quality of life levels and resilience, the collaboration of all stakeholders is crucial. To make the PT more attractive, interviewees mentioned that in the long run, WL has to constantly develop its infrastructure and quality of services, offer a multitude of transportation modes at a reasonable price that will stay highly competitive compared to other mobility providers, to promote active mobility solutions and first and last mile solutions, to raise awareness of the potential consequences of climate change and to provide all passengers a travel experience from A to B in the best possible way. This could make for example the private-motorized mobility less attractive and because of the city's lack of parking spaces and high-performing PT, people will believe that PT is ultimately the better option. If the continuous use of private-motorized cars is not reduced, the climate neutrality goals and the reduction of carbon footprint according to the proposed strategic plans will not be possible.

In accordance to the interviewees, the last research question "w*hat opportunities and challenges arise from the collection and use of passenger data?"* suggests that there are still issues and opportunities to be ironed out including the ethical handling of the PII through the app. "Big Data" was championed as the "new gold" due to its infinite possibilities to transform modern life. By relying on real-time analytics and Big Data, WL's business can drive performance by taking more accurate decisions that increase productivity and improve lives. In the PT arena, Big Data provides real time key information to evaluate, plan and improve urban PT systems. However, there are challenges due to the scalability of data, its variety and velocity of its changes that make it difficult to harness it into valuable information without considerable mistakes and risks. The algorithms are not always accurate and too often the data is misused.

As specified by the interviewees, WL has a very strict policy of how data are stored, used and protected in conformity to national level regulations and GDPR at EU level. WL uses various ways to collect data and to better understand how passengers are using its network. However, there

are also blind spots when analysing the passenger's journey, because WL does not have the necessary service to do that. For example, which routes passengers are using or will use in the future, why they are moving in a specific direction and what activities they are going to have, what their needs are etc. Thus, WL is open for innovation and oriented to enhance the travel experiences in the best way possible for local passengers, as well as for incoming people in Vienna. Data are always valuable, but it is more important to analyze what is generated with it and what outcomes it has for the customers. If WL could access the complete journey of the passengers, in conformity with all required regulations, then the future mobility services will offer much better travel experiences.

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APPENDICES

Appendix 1: Expert Interview Questions

First Part: Wiener Linien's Description

1. How would you describe Wiener Linien?

2. Do you think that Wiener Linien is ahead/behind on its sustainable goals?

Second Part: Interconnected Public Mobility

1. What do you think should be prioritized at Wiener Linien to develop Vienna as a "smart city"?

2. What would convince Viennese people to give up on their car use inside the city?

3. How can Wiener Linien become an even more attractive option for mobility in Vienna?

4. How do you see the future of Wiener Linien's shared mobility fleet competing with local established players?

Third Part: Data Privacy and Data Collection

1. Are you concerned for data being leaked to other companies and that it could be used as competitive advantage against Wiener Linien?

2. Is Wiener Linien's quantitative data collection (passenger's, sensors etc.) sufficient for improving Wiener Linien's efficiency or are there also qualitative features that have to be considered?

Fourth Part: Expert's Description

1. How long is your experience in your field, express it in years to the nearest year?