Digital Applications in Urban Public Transport: a Comparative Analysis of Shared and Sustainable on-demand transport solutions in Germany and Greece

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Abstract

Digital applications are transforming the functioning of cities, proposing solutions to urban challenges. Digital transport solutions have become a representative example of the implementation of sustainable mobility strategies in cities. This research focuses in the case of on-demand Ridepooling and aims to investigate whether on-demand Ridepooling is a sustainable urban mobility solution. Can on-demand Ridepooling contribute to the sustainable development of urban areas and can it really provide solutions to the urban mobility challenges cities face today? What is a sustainable mobility solution and how is it measured? These are the driving questions of this research, that presents an interdisciplinary comparative assessment of on-demand Ridepooling in Germany and Greece. Unique operational data of on-demand Ridepooling in Germany are published for the first time. Operations are predicted and simulated for Greece, where on- demand Ridepooling doesn't exist yet. Moreover, significant literature review on sustainable mobility indicators is presented. The relation of on-demand Ridepooling to the three pillars of urban sustainable development is examined. Furthermore, a selection of interviews with key stakeholders, planners, and transport experts provides unique insights regarding the differentiated paths those two countries are following in shared transport solutions. Finally, policy recommendations are extracted, regarding a) the applicability of digital shared mobility solutions, such as on-demand Ridepooling and b) the synergies between public policies and market forces in order to achieve effective and sustainable mobility solutions for the urban ecosystem.

1. Introduction

Movement is a core evolutionary necessity as far as survival on Earth is concerned (Darwin, 2009). All micro - and macro - organisms need to directly or indirectly move to survive and reproduce themselves (Ibid.). Movement is a prerequisite for the development and maintenance of cells, associated with the fulfillment of basic needs, survival, and prosperity. The science of Biology explains principally that in order for a cell to maintain itself, robust movement is required from the cell's compartments (Alberts *et al.*, 2014). Biology's principles and learnings about organizational structures can be a useful model for understanding the subjective creations of human beings. Those subjective creations are the urban environments, the cities, that human beings create to reside in. Cities are like cells, and human citizens are the compartments of those urban constellations. Likewise, with cells, in order for a city to efficiently function, maintain and prosper, a sustainable and efficient mobility system is needed. This mobility system can be identified as the public transport (PT) system that every city has, enabling public movement for its citizens.

In the spotlight of the 4th Industrial Revolution (Schwab, 2018) with digitalization in the forefront, new technological innovations influence the urban economy, society and environment, as well as enhance the power of the internet and the virtual space, transforming the everyday urban life (Bálint, 2016). As mobility is a core part of the urban life, mobility itself undergoes a revolution as well, driven by the digitalization process and the Sharing Economy (Zhang, 2017).

At the same time urban environments are being challenged by tenacious forces, such as population growth, urbanization, car centricity and subsequently CO_2 and NO_x emissions, traffic congestion and scarcity of public urban space. Those forces ring the alarming bells of change on how urban mobility is organized today. The principle of sustainability shines positively above them, as the rescuing shift, as the guideline that could drive solutions (United Nations, 2018).

As on-demand shared mobility solutions emerge as a potential solution to the urban mobility challenges (International Transport Forum, 2017), this paper is devoted to on-demand publicly operated Ridepooling. The research is driven by the questions of a) whether on-demand Ridepooling is a sustainable mobility solution b) how the service should be operated and c) which are the barriers and enabling factors for a city to implement on-demand Ridepooling. In order to answer those questions and find out if on-demand Ridepooling can provide a sustainable solution to the urban mobility challenges cities face, the paper presents a comparative analysis of how the existing service is operating in Germany and why and how could it potentially operate in Greece. Berlin is compared to Athens, and Munich is compared to Thessaloniki. Additionally, a significant literature review of sustainable mobility indicators is presented, to validate the answer. The answers to the questions, are summarized into final policy recommendations. Last but not least, the last section concludes with further open questions and implications of on-demand Ridepooling, that remain open to future research.

2. Urban Mobility and Challenges

Mobility is a core function of life in cities, and it plays a fundamental role in the economy, the urban environment, and the society itself, as it shapes the access, the quality and the status of those pillars. Subsequently, the quality of urban mobility enables the possibilities and opportunities of each citizen and defines their everyday life. Moreover, as urban movement is connected to freedom (Walker, 2011), the quality of urban mobility seen in PT networks defines to an extend the quality and equity of freedom citizens can enjoy.

Parallel to human development and evolution, as cities are the "cells" that host humans, they experience changes as well. Compared to the past, cities today undergo alterations, that give birth to multiple challenges (Walker, 2011), such as population growth and urbanization. The United Nations underline that population growth between 2007 and 2050 will doubled itself, reaching 6,7 billion in 2050 (United Nations, 2008). Moreover, intense urbanization is existing worldwide, where in 2018, 55% of the world population was living in urban areas and is expected to be increased to 68% by 2050. (United Nations, 2018). In the European context in

2018, 74% of the European population resided in urban areas, expecting to reach 84% by 2050 (United Nations, Department of Economic and Social Affairs, 2014). Moreover, up to 85 % of Europe's GDP was generated in urban areas (European Commission, 2019), indicating the profound economic importance and the dependence of the EU economic development and growth on urban areas.

Consequently, agglomeration in cities will impose challenges and entails changes in the way public recourses, such as urban mobility, are planned and distributed. Noland and Polak state, that due to the growth of cities in population and land use, increasing pressure is being placed on the reliability of urban transportation systems (Noland and Polak, 2002). Questions such as, *how will cities deal with the increasing citizens number, in terms of mobility?* and *how will cities face the new complex transport challenge?* arise.

In today's growing urban reality, another factor has been adding challenges since the last four decades: the private passenger car. A symbol of freedom in the 70's, the holy grail of private transport, for which cities were built around to in the 20^{th} century (Patsouri, 2019).

However, today the car is identified as core reason of multiple problems and costs cities face. Bakogiannis et al. explain the direct and indirect costs of motorized vehicles for both individuals and society, including obesity, fatalities, air pollution, congestion, road construction and purchase and maintenance of a private car (Bakogiannis *et al.*, 2016). In Europe the external costs of individual motorized transport are able to reach up to the 8% of the national GDP (Ibid.). Even if car ownership is a costly case, since 1960 worldwide vehicle ownership has been unanimously increasing (Dargay *et al.*, 2007).

More specific, CO_2 and NO_x emissions are produced by cars polluting the urban atmosphere. In the United States, 30 % of all greenhouse gas emissions are connected to transportation (Chestnut and Mason, 2019), while the European Commission announced in 2009 that road transport is causing 40% of Europe's CO_2 emissions and urban traffic is causing 70% of other air pollutants such as NO_x and PM10 (Bakogiannis *et al.*, 2016). It is worth noting that since the establishment of the automobile back in the 2^{nd} Industrial Revolution, today car traffic has increased tenfold, when cycling and PT have seen hardly any growth (Litman, 2018).

Moreover as Peñalosa underlines, private passenger cars entail inequitable distribution of public space between private passenger car users and pedestrians (Peñalosa, 2013), indicating the equity issues on public space that cars impose.

At the same time, the high demand on earth resources that fuel cars, contradicts the scarcity of those resources (United Nations, 2012), and is unsustainable to satisfy. The seriousness of this topic, as well as the dependence on fuels and cars that the economy and society have, can be also underlined in the social imbalances and strikes, that specific tax alterations on fuels can produce. The recent 2018, social and political movement of the "Yellow Vest" in France, is exemplary example on this topic (Kar-Gupta, 2019).

Today, the need of thinking differently on public mobility, is more urgent that ever. It entails a different attitude, than the one that also produced all those mobility challenges that cities face today. For example, research shows that increasing the hard infrastructure of highways in cities, is not resolving the problem of traffic congestion, but on the contrary it is contributing even more to congestion (Handy, 2015). It is obvious that outdated solutions from the past decades cannot resolve any longer the urban mobility problems of today, and new perspectives need to bring innovative solutions.

Reflecting upon the urban challenges, the principle of sustainability shines positively above them, as the rescuing shift that could orchestrate solutions to a sound urban development (United Nations, 2018). Defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987), sustainability is composed by three pillars; the economy, the environment and the society (United Nations, 2014), that interact in urban environments.

3. Shared and Digital Mobility

At the same time, in the aftermath of the financial and economic crisis of 2008, which 11 years ago struck the globe, significant new trends in the global economy, have made their appearance. One of those trends concerns ownership and collaborative consumption. Under the emerging need of thrifty spending connected to the global economic recession of 2008 (Cohen and Kietzmann, 2014), a new generation of *homo economicus* (Oxford Dictionaries, 2019) is created that replaces possession and ownership, with consumption and management (Stahel, 2015). The fundamentals of a new-born economy, the Sharing Economy (Bálint, 2016) are set, affecting the way citizens transact in all aspects of urban life.

As mobility is a core part of the urban life with its PT network in the front line, a shared mobility revolution is taking place in cities today (Zhang, 2017). Modes of shared mobility are becoming more and more appealing, posing a potential solution to the complex problems cities face today. Shaheen et all. indicate that recently "socio-economic forces coupled with advancements in technology, social networking, location-based services, wireless services, and cloud technologies are contributing to the growth of shared and on-demand mobility" (Shaheen, Cohen and Bayen, 2018). In the 4th Industrial Revolution; the epoch of digitalization (Schwab, 2018), shared mobility absorbs technological improvements (Cohen and Kietzmann, 2014). Such improvements include the mobile geolocation technology that enables on-demand mobility requests.

Shared mobility includes multiple modes such as Carpooling, Carsharing, Bikesharing and more (Cohen and Kietzmann, 2014). Shared mobility also includes Ridehailing/Ridesharing with its controversial background on selective profitable operations that have raised cannibalization concerns and unfair competition to public mobility. The mission of the non-profitable unanimous PT coverage contradicts the Ridehailing private business model that needs to be profitable to exist (Patsouri, 2019). Shared mobility also includes the mode of on-demand Ridepooling, defined as the operating transport service, where passengers are sharing journeys in a shuttle and the vehicle's route is defined by a dynamic intelligent algorithm that matches the on-demand ride requests of travelers (König, Bonus and Grippenkoven, 2018). The current research focuses on publicly operated on-demand Ridepooling, that is being tested in German cities, in the name of minimizing private passenger cars and creating a modern, resilient and simultaneously flexible PT system (Ibid). However, *is the experimental on-demand Ridepooling truly a sustainable mobility solution? To what extend can on-demand Ridepooling contribute on combating the multiple challenges cities face today?*

4. Sustainable Mobility

Focusing in the analysis of whether on-demand Ridepooling is sustainable, this paper translates sustainability into urban mobility. Litman, at Figure 4.1. illustrates the objectives of sustainability, that pay into sustainable transportation (Litman, 2018). The objectives are categorized under the three pillars of sustainability; economy, society and environment, with sustainable mobility paying into all three pillars. From an economic perspective, a shift to sustainable mobility can provide savings up to 70 trillion $ by 2050, when considering all transport costs and losses due to traffic congestion (including vehicles, fuels, and operational expenses) (Sustainable Mobility for All, 2017). From an environmental and social perspective, the Helsinki study from OECD underlines that "better and more equitable access to opportunities, improved (public) service quality and a reduction of CO2 emission" can be achieved by on-demand shared mobility (International Transport Forum, 2017).

Quantifying sustainable mobility, the paper presents a literature review on Sustainable Mobility Indicators and Metrics. The literature review is set as a referred baseline, in order to investigate whether on-demand Ridepooling is a sustainable urban mobility solution, to urban challenges.

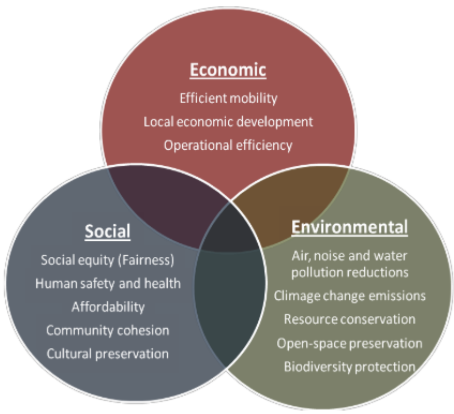

Figure. 4.1. The Sustainable Transport Objectives (Litman, 2018).

On a high-level, Table 4.1. presents Litman's guidelines and indicators on how sustainable goals are translated in transport planning (Litman, 2018). The sustainability goals are divided in four categories; the economy, the society, the environment and the governance. Economic development, economic productivity, community development, health and equity, climate stability, pollution and public space seem to be the most important targets, shaping what a mobility solution needs to take into consideration to be sustainable.

Table. 4.1. The Transport Planning Objectives of Sustainability.

Sustainability Goals	Transport Planning Objectives							
	Transport Diversity	System Integration	Affordability	Resource (energy and land) Efficiency	Demand Management (efficient pricing & prioritization)	Land Use Accessibility (smart growth)	Cost Effective Operations	Comprehensive and Inclusive Planning
Economic productivity	✓	✓		✓	✓	✓	✓	
Economic development	✓	✓	✓	✓	✓	✓		✓
Energy efficiency	✓	✓		✓	✓	✓		
Affordability	✓	✓	✓	✓	✓	✓		
Operational efficiency					✓		✓	✓
Equity / Fairness	✓	✓	✓		✓	✓		
Safety, security and health	✓	✓	✓	✓	✓	✓		✓
Community development	✓	✓	✓	✓	✓	✓		✓
Heritage protection	✓			✓	✓	✓		✓
Climate stability	✓	✓	✓	✓	✓	✓		
Air pollution prevention	✓	✓	✓	✓	✓	✓		
Noise prevention	✓			✓				
Water pollution	✓	✓	✓	✓	✓	✓		✓
Openspace preservation	✓	✓	✓		✓	✓		✓
Good planning								✓
Efficient Pricing				✓	✓		✓	

Sustainable goals paying into transport planning objectives (Litman, 2018).

Litman also connects the analysis of sustainable transport goals to performance indicators (Ibid.). Table 4.2. illustrates this relation, where for the four categories of Economy, Environment, Society and Governance, measurable indicators are extracted, that can quantify the sustainable transport goals.

Table. 4.2. The Transport Planning Objectives of Sustainability and their Performance Indicators.

Sustainability Goals	Objectives	Performance Indicators
I. Economic		
Economic productivity	Transport system efficiency. Transport system integration. Maximize accessibility. Efficient pricing and incentives.	• Per capita GDP and income. • Portion of budgets devoted to transport. • Per capita congestion delay. • Efficient pricing (road, parking, insurance, fuel, etc). • Efficient prioritization of facilities (roads and parking).
Economic development	Economic and business development	• Access to education and employment opportunities. • Support for local industries.
Energy efficiency	Minimize energy costs, particularly petroleum imports.	• Per capita transport energy consumption • Per capita use of imported fuels.
Affordability	All residents can afford access to basic (essential) services and activities.	• Availability and quality of affordable modes (walking, cycling, ridesharing and public transport). • Portion of low-income households that spend more than 20% of budgets on transport.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	• Performance audit results. • Service delivery unit costs compared with peers. • Service quality.
II. Social		
Equity / fairness	Transport system accommodates all users, including those with disabilities, low incomes, and other constraints.	• Transport system diversity. • Portion of destinations accessible by people with disabilities and low incomes.
Safety, security and health	Minimize risk of crashes and assaults, and support physical fitness.	• Per capita traffic casualty (injury and death) rates. • Traveler crime and assault rates. • Human exposure to harmful pollutants. • Portion of travel by walking and cycling.
Community development	Help create inclusive and attractive communities. Support community cohesion.	• Land use mix. • Walkability and bikability • Quality of road and street environments.
Cultural heritage preservation	Respect and protect cultural heritage. Support cultural activities.	• Preservation of cultural resources and traditions. • Responsiveness to traditional communities.
III. Environmental		
Climate protectin	Reduce global warming emissions Mitigate climate change impacts	• Per capita emissions of global air pollutants (CO_2, CFCs, CH_4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce exposure to harmful pollutants.	• Per capita emissions of local air pollutants (PM, VOCs, NOx, CO, etc.). • Air quality standards and management plans.
Prevent noise pollution	Minimize traffic noise exposure	• Traffic noise levels
Protect water quality and minimize hydrological damages	Minimize water pollution. Minimize impervious surface area.	• Per capita fuel consumption. • Management of used oil, leaks and stormwater. • Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage more compact development. Preserve high quality habitat.	• Per capita land devoted to transport facilities. • Support for smart growth development. • Policies to protect high value farmlands and habitat.
IV. Good Governance and Planning		
Integrated, comprehensive and inclusive planning	Planning process efficiency. Integrated and comprehensive analysis. Strong citizen engagement. Lease-cost planning (the most overall beneficial policies and projects are implemented).	• Clearly defined goals, objectives and indicators. • Availability of planning information and documents. • Portion of population engaged in planning decisions. • Range of objectives, impacts and options considered. • Transport funds can be spent on alternative modes and demand management if most beneficial overall.

Performance indicators measuring sustainable transportation (Litman, 2018).

Moving forward, to a second analysis of Sustainable Transport Indicator, Table 4.3. presents the Index of Sustainable Urban Mobility (I_SUM) by Da Silva et al. Sustainable Transport Indicators have been identified, based on specific domains and themes, influential for sustainability (Da Silva et al, 2010). Here, the major domains that get translated into Sustainable Transport Indicators are; accessibility, social inclusiveness, polluting emissions, political management, infrastructure and non-motorized modes.

Table 4.3. The sustainable urban mobility indicators that form the I_SUM (Index of Sustainable Urban Mobility).

	I_SUM	
DOMAINS	**THEMES**	**INDICATORS**
ACCESSIBILITY	Accessibility to transport systems	Accessibility to transit Public transportation for users with special needs Transport expenses
	Universal accessibility	Street crossings adapted to users with special needs Accessibility to open spaces Parking spaces to users with special needs Accessibility to public buildings Accessibility to essential services
	Physical barriers	Urban fragmentation
	Legislation for users with special needs	Actions towards universal accessibility
ENVIRON. ASPECTS	Control of environmental impacts	CO Emissions CO_2 Emissions Population exposed to traffic noise Studies of environmental impacts
	Natural resources	Fuel consumption Use of clean energy and alternative fuels
SOCIAL ASPECTS	Support to the citizens	Information available to the population
	Social inclusion	Vertical equity (income)
	Education and active citizenship	Education for sustainable development
	Public participation	Participation in decision-taking
	Quality of life	Quality of life
POLITICAL ASPECTS	Integration of political actions	Integration of different government levels Public-private partnerships
	Acquisition and management of resources	Acquisition of resources Investments in transport systems Distribution of resources (public x private) Distribution of resources (motorized x non-motorized)
	Urban mobility policy	Urban mobility policy
TRANSPORT INFRA.	Provision and maintenance of transport infrastructure	Density of the street network Paved streets Maintenance expenditures in transport infrastructure Streets signaling
	Distribution of transport infrastructure	Transit lanes
NON-MOTORIZED MODES	Bicycle transportation	Length and connectivity of cycleways Bicycle fleet Facilities for bicycle parking
	Non-motorized modes	Pathways for pedestrians Streets with sidewalks
	Trips reduction	Travel distance Travel time Number of trips Measures to reduce motorized traffic

The indicators that construct the I_SUM. Each indicator is connected to themes, influential for sustainability and to identified domains (Da Silva et al, 2010).

Moving further to a third technical set of Sustainable Mobility Indicators, Chestnut and Mason published in 2019 a study for the Institute for Transportation and Development Policy (ITDP) on Sustainable Mobility indicators. The indicators were classified in three categories; a) proximity to transport, b) access to opportunity and c) city characteristics (Chestnut and Mason, 2019). Each of those three categories, have subcategories that are quantitative explained. The paper has collected the material of the ITDP publication at Table 4.4., illustrating the above 3 main indicators with their subcategories.

Table. 4.4. Indicators for Sustainable Mobility.

Category of Indicator	Sustainable Mobility Indicators		
a) Proximity to transport	**People near rapid transport**= indicator measures % of the population that is within a half-kilometer walk or a max10-minute bike ride (on restricted protected bike lines) of a rapid transit station, a proxy for accessibility to destinations, illustrates the relationship between population distribution and the coverage of rapid transit services. **This indicator can show where people are not currently served by rapid transport.**	**People near frequent transport** = measures the % of the population within a 500-meter walk or a max10-minute bike ride (on restricted protected bike lines) of frequent transit service. **The indicator shows the reliable transport coverage to access destinations.**	-
	Job near rapid transport = measures the % of jobs that are within a max 10-minute bike ride or walk of a rapid transit station	**Job near frequent transport**= measures the % of jobs in the city located within a 10-minute journey of a frequent transit stop	-
	Low income households near to rapid transport = measures the % of population that makes less than 20.000 USD a year that lives within about a 10-min bike ride or walk of a rapid transit station. **The indicator measures the equity in a transit system**	**Low income households near frequent transport** = investigates the equity of a transport system while serving a city, it measures the % of people near frequent transit (referring to the total population) and the % of low-income households near frequent transit and compares them.	.
b) Accessibility to opportunity	**Access to jobs by sustainable transport (60 and 30 minutes)** Access to Jobs by Sustainable Transit can be defined as the average number of jobs that can be reached from a census tract within 30 or 60 minutes on a weekday morning at 8 a.m. Using an ArcGIS based software for the city's spatial analysis, the city is visualized by polygons representing census tracts. This indicator in this analysis is weightented by the total population, as access to jobs refers to population as a whole.	**Access to low-skill jobs by sustainable transport (60 and 30 minutes)** Access to Low-skilled jobs by Sustainable Transit can be defined as the average number of low-skilled jobs that can be reached from a census tract within 30 or 60 minutes on a weekday morning at 8 a.m. This indicator is weightented by the number of workers with less than a high school education.	**Access to people by sustainable transport (60 minutes)** Access to People by Sustainable Transit can be defined as the average number of people that can be reached from a census tract within 30 or 60 minutes (on a weekday morning at 8 a.m). While the spatial analysis is visualized in the ArcGIS based software, population can be counted for all census tracts of the operating are.
c) City characteristics	**Block density** Is defined as the number of blocks per square kilometer of the urban area.	**Weighted residential density** Calculated for each census tract and then multiplied, calculated for the whole city area	**Sustainable transport mode share** A measurement of behavior among travelers in a city. Identifies cities with higher rates of sustainable transport use

The classification of Sustainable Mobility indicators by Chestnut and Mason, for the ITDP (Chestnut and Mason, 2019). The indicators promote the understanding and measurement of sustainable urban mobility. Table created by the author.

5. Comparing on-demand Ridepooling to the Sustainable Mobility Indicators

The paper attempts to compare on-demand Ridepooling to the sustainable mobility indicators provided by the presented literature review. For this comparison, this research uses the on-demand Ridepooling definition and indicators that door2door GmbH is using to bring on-demand Ridepooling on the streets of Germany. With the kind courtesy of door2door GmbH on offering their data, specific and measurable demand and supply indicators are provided describing the on-demand Ridepooling service.

On-demand Ridepooling is the current research, is enabled through the collaboration of the public and private sector, where door2door GmbH sells to PT companies, the Ridepooling product. Part of the product, is also the so-called "Insights" platform, serving as a mobility analytics software based on geographical information systems (GIS). The system is used for the planning and simulation of on-demand Ridepooling, onboarding and visualizing first of all the static public transport schedules of a city. Demand and supply mobility indicators in the software, describe this public mobility reality of a city. Once an operating scenario for on-demand Ridepooling is chosen, "Insights" simulates dynamically on-demand Ridepooling operations.

Focusing on the wished comparison with the Sustainable Mobility Indicators from the literature review, the demand and supply indicators for on-demand Ridepooling from "Insights" indicators are the following;

Supply Indicators:

a) Walking Accessibility = How easy is to reach a form of PT within 5 minutes (indicator measured in stations)
b) Public Transport Coverage = The area covered within 15 minutes using PT (indicator measured in km^2)
c) Frequency = How often PT departs from this area (indicator measured in departures)

Demand Indicators:

a) Population Density = The number of inhabitants per km^2
b) Public Transport Searches = The number of searches related to this area made through trip planning apps
c) Ridepooling Searches = The amount of Ridepooling searches related to this area made through Ridepooling apps (data provided by door2door's operations)
d) Predicted Searches = The number of predicted Ridepooling searches for a specific urban area, based on an algorithm that balances accordingly existing on-demand data from Berlin
e) Car Journeys = The number of journeys made by car from or to this area (data provided by external partners)
f) Mobile Phone Movement = The number of journeys recorded by mobile phones from or to this area (data provided by external partners)

Figures 5.1. and 5.2. illustrate analytically the supply and demand indicators of on-demand Ridepooling, used by door2door GmbH.

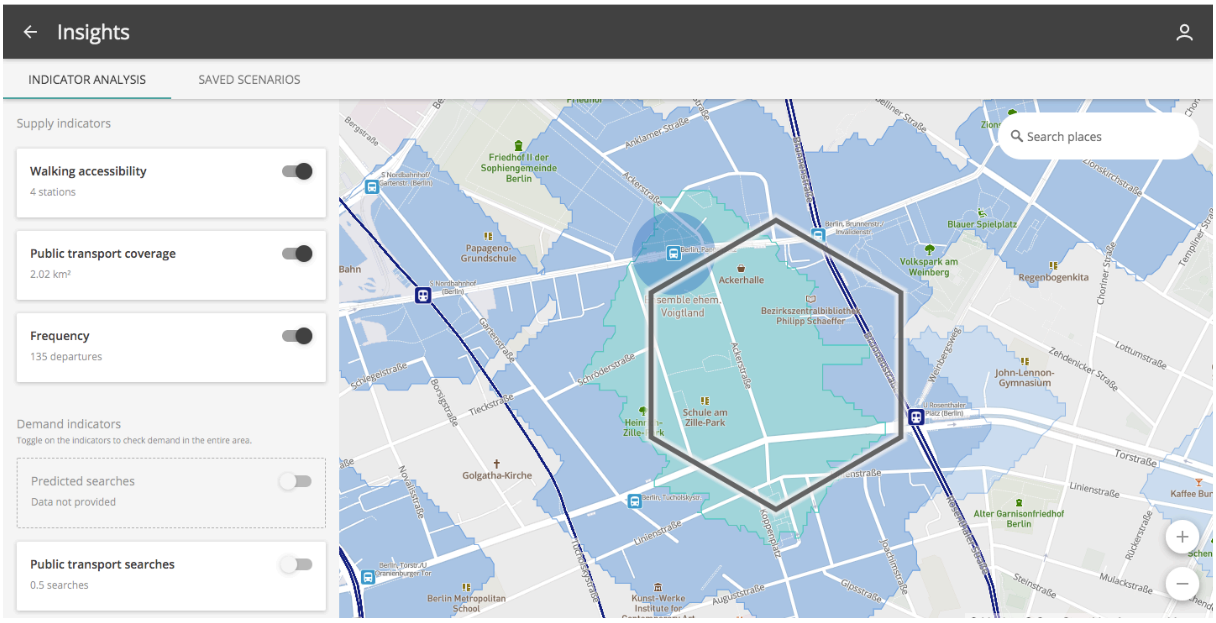

Figure 5.1. The supply indicators used for the planning of on-demand Ridepooling at door2door GmbH, through the "Insights" software. All three supply indicators are enabled, coloring with green the walking accessibility and with blue the public transport coverage. The 5 and 15 minutes timeframes accordingly, are calculated from the center of the chosen hexagon cell. The indicator of frequency is illustrated by the blue circle. Courtesy of door2door GmbH.

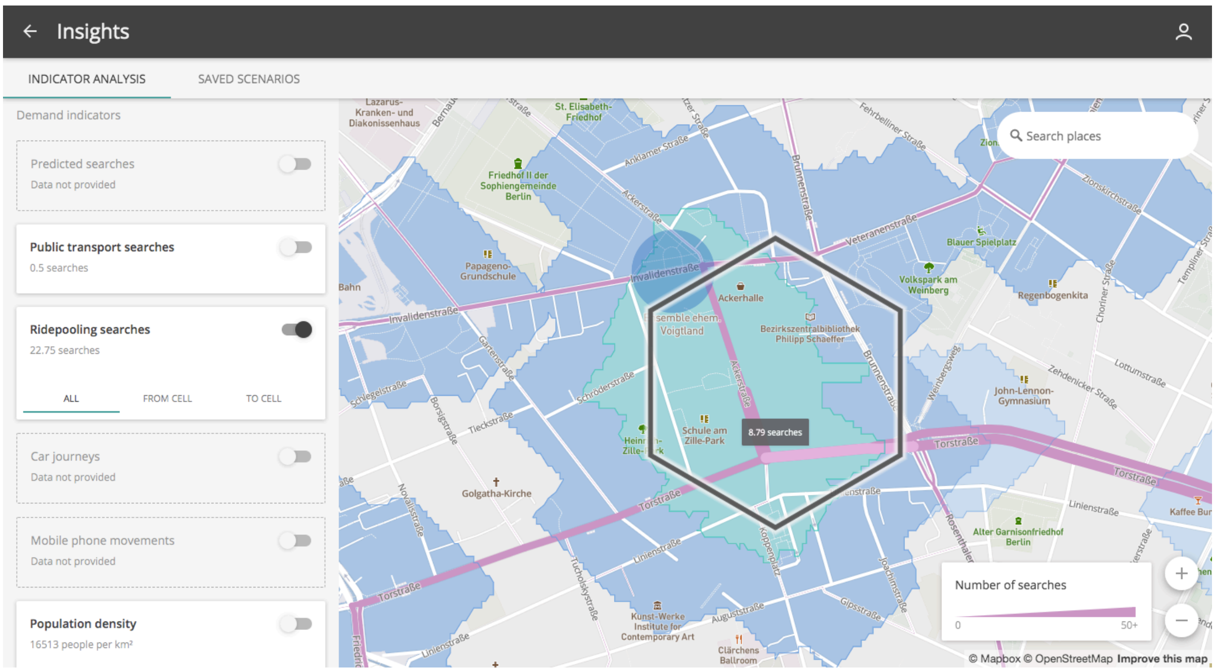

Figure 5.2. The demand indicators of on-demand Ridepooling at door2door GmbH, through the "Insights" software. The Ridepooling searches indicator is enabled, illustrating with pink lines the demand for Ridepooling routes. At the same time the supply indicators are enabled, coloring with green the walking accessibility and with blue the public transport coverage, with their 5 and 15 minutes timeframes calculated when starting inside the chosen hexagon cell. The supply indicator of frequency is illustrated by the blue circle. Courtesy of door2door GmbH.

Summarizing, the on-demand Ridepooling indicators, include an analysis of accessibility, frequency and coverage, indicators that also appear in all the Sustainable Mobility Indicators presented in the literature review (Figure 4.1. and Tables 4.1, 4.2, 4.3.). More specific, the time framed indicators of accessibility and coverage for on-demand Ridepooling, are in line and even score shorter times than the ITDP sets in its Sustainable Mobility Indicators in Table 4.4. Moreover, on-demand Ridepooling takes into account the indicator density, which appears in the third part of the technical Sustainable Mobility Indicators by ITDP in Table 4.4.

The decrease of CO_2 emissions and other air pollutants, have a significant place in the Sustainable Mobility indicators, as presented in the literature review at Table 4.2., 4.3., and 4.4. Based on the Helsinki study by OECD, the use of on-demand shared mobility, entails the wished reduction of CO_2 emission (International Transport Forum, 2017).
Moreover, the topics of public space and equity, appear in the literature review, as part of the Sustainable Mobility objectives at Table 4.1. The Lisbon and Helsinki studies, indicate that on-demand shared or autonomous mobility can offer equitable access to opportunities and provide new space due to the removal of 9 out of 10 cars from the streets (International Transport Forum, 2015) (International Transport Forum, 2017).

Based on the above analysis, we can therefore conclude that the objectives and indicators that plan and describe on-demand Ridepooling, are in line with the standards set in the presented literature review of the Sustainable Mobility Indicators.

6. On-demand Ridepooling in Germany

Germany is the most populated EU Member State (eurostat, 2018), with almost 83 million people (Destatis, 2018b). Germany also has the highest GDP in the EU, equal to 3.386.000.000 billion Euro for 2018, equal to the 21% of the whole EU GDP (Eurostat, 2018). This translates into a GDP per capita of 40.843 thousand Euro (Destatis, 2018c), 10.000 Euro higher than the median EU citizen (Eurostat, 2018).

Germany's economic leading power is accompanied by a high passenger car centricity. In 2018 Germany counted 47.1 million passenger cars (Kraftfahrt-Bundesamt, 2019), which divided by the country's aforenoted population equals to a private passenger car motorization rate of 57%.

In 2016 Germany scored first in EU on new registered passenger cars, from which more than half (53,1%) where petrol powered and only 2% where powered with alternative fuels (eurostat, 2019). For the sake of comparison, Germany scores far too low on passenger cars with alternative fuels, when other countries score way better, such as Poland with 8,2% and Norway 16,9% (Ibid.).

Car centricity in Germany resembles also another important fact for this research and that is the automobile sector. Germany has one of the economical strongest car industries and manufactures, being 2,5 times bigger than the European average automobile sector and almost three times bigger than the national German food and beverage industry (Transport and Environment, 2018). In 2018 the sector counted 1.75 million employees equal to about the 4% of the national labor force (Destatis, 2018a) and in 2016, the sector generated an economic output of 134.9 billion Euro, corresponding to a 4.7 % of the gross value added in Germany (Ibid.).

The economic importance of the automotive sector in Germany, is translated also to a very strong lobbying power, that acts for the prosperity of the German automotive industry, influencing strongly the national and European politics and economics. In specific, the German Automobile Industry Association (VDA) (VDA, 2018) has been accused for exercising unhealthy political influence to the European Commission proposals and target goals that try to regulate car CO_2 emissions (Transport and Environment, 2018). German transport experts, advocating for sustainable mobility and PT enhancement, verify the influence that the automobile sector has, against their work (Patsouri, 2019). Therefore, it can be concluded that tackling car centricity and all the urban problems it brings along in German cities, is a complex issue.

However, there have been several German cities of all sizes, that have taken the challenge of minimizing private passenger car usage and are experimenting with an alternative mobility solution in their streets. Table 6.1. presents German cities that embrace and operate publicly on-demand Ridepooling, through their cooperation with private software provider companies.

Table. 6.1. Ridepooling in Germany

German City	***Public Transport Operator (PTO)***	***Ridepooling Software Company***	***Ridepooling Brand***	***Year of Release***
Berlin	BVG (Berliner Verkehrsbetriebe)	ViaVan Technologies B.V	BerlKönig [a]	2018 [a]
Munich	MVG (Münchner Verkehrsgesellschaft mbH)	door2door GmbH	IsarTiger [b]	2018 [b]
Hamburg	VHH (Verkehrsbetriebe Hamburg-Holstein GmbH)	ioki GmbH	ioki Hamburg [c]	2018 [c]
Stuttgart	SSB (Stuttgarter Straßenbahnen AG)	moovel Group GmbH	SSB Flex [d]	2018 [d]
Duisburg	DVG (Duisburger Verkehrsgesellschaft AG)	door2door GmbH	myBUS [e]	2017 [e]
Freyung	Town of Freyung* *Local government partners with "Prager Reisen" Local Operator	door2door GmbH	freYfahrt [f]	2018 [f]

German cities, where on-demand Ridepooling is operated as a public transport mode. The second table column presents the PTO of the city and the third column presents the Ridepooling software company that collaborates each time with the city's PTO, to provide the Ridepooling technology. The fourth table column presents the name of the Ridepooling Brand, available for citizens. Data taken from: [a] (BerlKönig, 2019); [b](MVG, 2018); [c] (VHH, 2018); [d] (moovel Group GmbH, 2018); [e] (door2door GmbH, 2019c); [f] (door2door GmbH, 2019b).

6.1. The use case of Berlin

Berlin is the capital of Germany, being the most populous city in Germany with 3.748.148 residents (Amt für Statistik Berlin-Brandenburg, 2019). The city spreads across 891 km^2, in 12 boroughs, with a population density of 4.055 residents per km^2 (Amt für Statistik Berlin Brandenbourg, 2018). Presenting a short mobility background for the city, Berlin counted 1.195.100 million registered private passenger cars in 2017 (Ibid.) and 8.138 registered taxis in 2018 (Statista, 2018). It is remarkable that Berliners spend 154 hours and 1.340 Euro per year due to traffic congestion (INRIX, 2019).

In September 2018, BVG, the PT operator company in Berlin, launched on-demand Ridepooling under the brand of BerlKönig, through a collaboration with the private provider ViaVan (BerlKönig, 2019). The service owned by BVG, operates publicly in the whole city of Berlin, on a 24/7 basis and a free-floating system of virtual stops. The vision of the operator is to "provide affordable, shared and environmentally friendly rides" that offer the comfort of a private car, but are almost cheap as a bus (Ibid.). The goal of the service is to minimize individual motor vehicles by providing drivers with a public alternative. Passenger can book rides, by downloading the mobile application of the service, which in February 2019 counted 90.000 registered customers (Stresse, 2019). Furthermore, the BerlKönig service includes wheelchair accessible vehicles promoting social inclusiveness (BerlKönig, 2019) and more than half of its vehicle fleet (68 vehicles) is fully electric promoting environmental mobility (Stresse, 2019). The fleet of the service is aiming to have 300 fully electric vehicles by 2020, increasing its 132 total vehicles that were licensed for its launch in 2018 (Stresse, 2019). Moreover, looking at how passengers embrace the service in Berlin, it was published that the average maximum usability of the vehicles at peak times has been 70% (Ibid.)

Evaluating the success story of the BerlKönig, the service has been criticized for cannibalizing the preexisting traditional PT modes and potentially adding more traffic on the streets (Šustr, 2019). In specific, members of the German coalition government, such as Tino Schopf, have been questioning the meaningfulness of the service (Stresse, 2019), being operated in central districts of the city, where PT has relatively no service gaps (Šustr, 2019). What is for sure, is that the service is evaluating its debut experimenting service, figuring out best practices, in line with its vision (Stresse, 2019). A vision of minimizing the environmental impact of transport.

Based in the aforenoted analysis of the sustainable mobility indicators, the current research is not able to drive more specified conclusions on the sustainability of the BerlKönig on-demand Ridepooling service. This is due to the fact that no core indicators describing the service were available, to be compared with the sustainable mobility indicators bibliography.

6.2. The use case of Munich

Munich is the third biggest city of Germany, with a flourishing economy, generating 31% of the GDP of the Bavarian State (München Betriebs-GmbH & Co. KG, 2015). Munich's employed citizens are in average the wealthiest of the county, with a GDP per working person of 98.041 Euro, 39 % higher than the national average in Germany (Ibid.). Demographically, Munich spreads over an area of 310,70 km_2, in 25 boroughs (München Betriebs Portal GmbH & Co. KG, 2019b). In 2018 Munich's population was calculated 1.542.211 (München Betriebs Portal GmbH & Co. KG, 2018) with 4.963 people residing per km2 (Mstatistik München Betriebs Portal GmbH & Co. KG, 2018b).

At the same time, Munich's population is growing in a high pace (München Betriebs Portal GmbH & Co. KG, 2019a), also due to the city's prosperous economy and society that attracts many new coming citizens. The city's urban growth though, poses a challenge to the planned city transport. As transport experts in Munich explain, the transport network of Munich operates to its best capacity every day, but needs to adjust to the new needs that the city's growth is imposing (Patsouri, 2019).

Presenting a short mobility background profile for Munich, in 2018 the city counted 716.246 registered private passenger cars (Mstatistik München Betriebs Portal GmbH & Co. KG, 2018a) and 3.336 registered taxis in (Statista, 2018). It is remarkable to mention that Munich citizens spend 154 hours and 1.340 Euro per year due to traffic congestion (INRIX, 2019). Compared to Berlin that is almost 3 times larger, congestion costs for Munich are very close to the ones of Berlin, indicating the intensity of the congestion problem in Munich. Already in 2015, MVG, the PT company in Munich, stated that “in the city center (of Munich) traffic is at its limit” (MVG, 2015).

Munich is also a highly motorized city, with almost half of its 1,5 million citizens owing a car. In the last 8 years, a yearly increase of more than 20% on newly registered passenger cars was calculated (Mstatistik München Betriebs Portal GmbH & Co. KG, 2018a). Combined by the fact that cars, spend most of their time parked (Figure 6.1.), the constant increase of passenger cars in Munich intensifies the city’s urban challenges.

It is clear, that under the forces of population growth, PT capacity problem and the private car centricity that poses space and emission issues, Munich is facing a mobility problem. At the same time, the PT network shall not lag behind the demographical changes the city experiences, given the fact that those changes happen faster than the implementation of hard infrastructure extensions of the PT network (Patsouri, 2019). In these scenery, the city’s PT is challenged to provide mobility solutions for Munich.

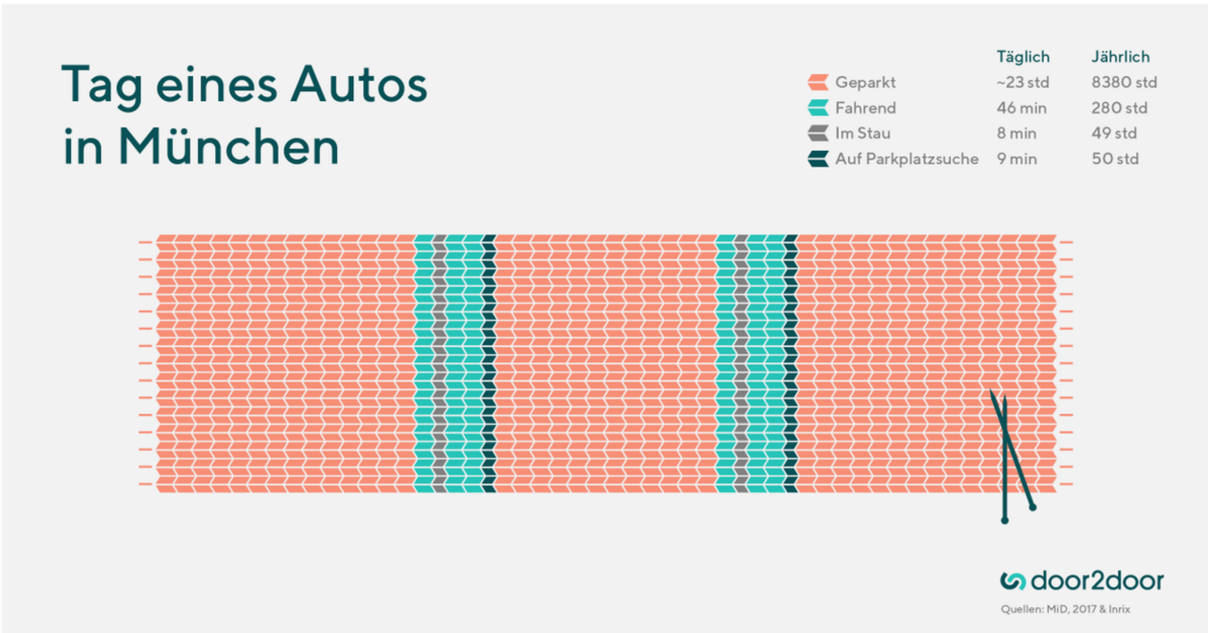

Figure. 6.1. The Day of a Car in Munich at 2017. In Munich, a car spends most of its “life” being immobile. A car is 96% of its time parked, 3% of its time driven and 0,5% of its time in traffic or searching for a parking place. Courtesy of door2door GmbH.

Embracing that challenge, MVG, Munich’s PTO, launched in May 2018 on-demand Ridepooling for the city of Munich. Under the product brand of IsarTiger (MVG, 2018), a new PT mode was added to the city’s PT network. The service was brought on the street thought the public-private collaboration of MVG and door2doorGmbH, the private company providing the on-demand Ridepooling software. As MVG explains, the driving goal of the city, is to offer such a robust and simultaneously flexible PT system, that will cross out the need of private passenger car usage in Munich (Patsouri, 2019).

Passengers of the on-demand Ridepooling service can be picked up from physical fixed stops that they have to proceed to and can be dropped out to any “free” stop of their wish (MVG, 2018). The operating IsarTiger area covers almost 150km^2 expanding from the inner city of Munich and as MVG explains, the area was chosen strategically as one of the most heterogenous ones, representative for Munich's economic and social diversity (Patsouri, 2019). The service operates 3 times a week, in an average of 8 hours. (MVG, 2018)

On the costs of the service, MVG explains, that on-demand Ridepooling will not bring any profits as a service, but it is possible for the service to realistically equal its costs (Patsouri, 2019). As MVG has calculated, 6 requests per hour of 2–5 km each, are needed, for the IsarTiger to cover its costs of paying the driver's labor and the automobile costs (Ibid.) In July 2019, the service will expand, to include 100 times more potential users than it has today in its testing operating area (Ibid.)

On the environmental aspects of the service, the IsarTiger shuttles operate with bio-natural gas, which emits less CO_2 than other gas sources, making the IsarTiger 80% eco-friendlier than diesel or petrol cars (MVG, 2018).

Moreover, Andreas Steinbeißer Head of Marketing in MVG and Project Manager of the IsarTiger, explains that MVG and IsarTiger are concerned about the cannibalization effects that on-demand shared mobility can produce to existing PT networks (Patsouri, 2019). Therefore, the IsarTiger operates only as a first-last mile solution. In specific, the service acts as an interconnected route of 2-5 km distances to and from public transport or to direct end stations. The IsarTiger is not crossing the city from one side to another (Ibid.).

Additionally, in the future, operations that serve as feeder cases, feeding passengers to end stations of the S-bahn (city rapid railway) that connect the city center to the outskirts of Munich, are planned (Ibid.). Those future plans have also the vision to substitute costly bus lines that citizens do not use due to various inefficient reasons. As Steinbeißer explains, Munich compared to Berlin, is a tight city and due to space constrains, bus lines are not always planned in a user friendly or flexible way, leading to private passenger car usage (Ibid.).

At this point, unique Key Performance Indicators (KPIs) of the IsarTiger service are provided with the courtesy of MVG and door2door. The presented data are published for the first time. The provided performance metrics describe; total passengers transported, availability, vehicle productivity and booking frequency from the same users.

Starting from the total passengers transported, the IsarTiger, during the first 4 months of 2019 almost doubled its transported passengers, underlining that passengers are embracing and trusting on-demand Ridepooling in Munich. More specifically, the IsarTiger counted in total 454 passengers in January 2019, 652 in February 2019, peaking to its record in March 2019 with 975 passengers and an increase of 45,54% in comparison with the previous month. The high number of passengers was maintained in April 2019 as well, with 921 passengers.
Secondly, the average availability rate of the IsarTiger for the first four months of 2019 was 94%, ranging always from a 89,9% to 98%. The availability rate describes the total amount of ride requests being accepted by the system, when compared to the total amount of requests.
Thirdly, the average vehicle productivity per hour is presented, illustrating how many passengers per vehicle per hour got pooled. Between January and April 2019, the average vehicle productivity scored an increase of 23,4%. The 1,44 pooled passengers per hour per vehicle in January, reached the 1,88 pooled passengers per hour per vehicle in April. This increase underlines that the sharing vehicles capacities are being utilized, realizing the vision of pooling people together, in the effort of minimizing single passenger car trips in the city.

A fourth indicator describing the on demand Ridepooling operation in Munich is the booking frequency. The indicator describes the average number of bookings per user per month. This indicator provides once more information about the trust and usability passengers show to the service. In January 2019 the same user would book on average 2,18 rides per month, in February 2019, on average 2,64 rides and in March 2019 on average 2,83 rides. This illustrates an increase of 30% of the IsarTiger booking frequency in the first three months of 2019.

The data presented for those four indicators convey the message that on-demand Ridepooling is growing steadily in Munich. More specific, the increase of the total passengers transported and the booking frequency, reflect the popularity and positive perception on-demand Ridepooling is receiving from Munich active passengers. At the same time the increases of the vehicle productivity and availability indicators show that MVG is taking seriously the escalation of the service, offering a robust on-demand Ridepooling system that responds to the increasing demand for PT in Munich.

Concluding, based on the presentation of the sustainable mobility indicators and their comparison to the on-demand Ridepooling indicators from doo2door GmbH, the IsarTiger has at its disposal the right indicators to plan a sustainable on-demand Ridepooling. More specific, the IsarTiger has the potential to operate under the standards of Sustainable Mobility, set by the international bibliography. With this potential, the IsarTiger can truly contribute on minimizing the CO2 emissions and the traffic congestion, by motivating citizens to leave behind their private passenger car and free up the urban streets. Moreover, the IsarTiger can increase social inclusiveness, access to opportunity and equity on public mobility, by filling the existing gabs of the PT network. Moreover, as explained with the right operating scenarios, cannibalization of other PT modes can be avoided. At the same time a true enhancement of the PT capabilities and of the quality coverage can be achieved.
Finally, as Steinbeißer states, sustainability is the driving force and the high-level goal that exists in MVG and should exist above all PT systems (Patsouri, 2019).

7. On-demand Ridepooling in Greece

Moving forward after the German cases, this paper examines the potential application of on-demand Ridepooling in Greece. The analysis is presented in comparison to Germany.

Greece is populated by 11.124.603 million (Worldometers, 2019), a number 7,5 times smaller than the German population. In 2009, Greece was struck with one of the most severe fiscal and sovereign crisis, leading the country to a full-blown recession (Matsaganis, 2013). The results of this crisis unfold in the big fall the Greek GDP marks in the next 10 years (World Bank Group, 2019), scoring 184.713.600 mill. Euro for 2018, equal to a GDP per capita of 17.200 Euro per citizen (Eurostat, 2018).

Today, the crises has intensified the risk of a long-lasting poverty and inequality in Greece, due to its development and management (Kaplanoglou and Rapanos, 2018). As on-demand Ridepooling can offer access to opportunity and strengthen equity in the urban life, we could argue that on-demand Ridepooling could minimize the intensified inequality resulting from the crises.

Looking at the demography of the country, 79.0 % of the population resides in urban areas (Worldometers, 2019), indicating a high urbanization in Greece.

At the same time, Greece is also a highly motorized country, with 5.249.135 million private passenger cars (ΕΛΣΤΑΤ, 2018). When divide by the aforenoted country's population, a passenger car motorization rate of almost 50% can be extracted. Compared to Germany's passenger car motorization rate of 57%, to the costs of passenger cars, and to Germany's way bigger GDP than Greece's, Greece private passenger car "obsession" is strongly underlined.

7.1. The potential use case of Athens

Athens is the biggest city and the capital of Greece with a population of 3.154.152 people residing in the broader area of Athens in 2019 (World Population Review, 2019a). Athens has one of the highest densities in Europe with 17.040 residents per km^2 (Ibid.), being surpassed in some districts like Kallithea and Nea Smyrni with more than 20.000 residents per km^2 (CIESIN, 2018).

Athens is also a highly motorized city, depending on private passenger cars. In 2018 out of the total passenger cars in Greece, 55% of them were registered in the broader area of Athens (ΕΛΣΤΑΤ, 2018). This indicates the insane concentration of cars in Athens, if we consider that more than half of the total passenger cars in Greece, are concentrated in the 2,8% of the country's territory, which is the broader area of Athens (ΕΛΣΤΑΤ, 2019).

The urban area of Athens includes 40 districts (ΠΕΠ Αττικής 2014-2020, 2019) and as calculated expands in 411,107 km2 (Patsouri, 2019). Compared to Berlin, both capitals have similar populations residing in their urban complexes. However, based on the presented data, Athens expands in an urban territory almost half of the Berlin one, with almost double population density. Considering also the similar passenger car motorization rates of Greece and Germany, we can understand that the mobility reality on the street, especially on the traffic congestion factor, can be twice worse for Athens, when compared to Berlin.

Moreover, the problematic urban reality of Athens, affecting also negatively urban mobility, can be underlined in the statement of the Environmental Strategical Analysis of the city state, where it is explained that "the urban area of Athens is suffering from increasing non-planned residential extension, severe transportation problems, constant urbanization, lack of urban green and of free public spaces" (ΠΕΠ Αττικής 2014-2020, 2019).

Following the above analysis, pain point areas of PT in Athens where identified, and for those on-demand Ridepooling was simulated (Patsouri, 2019). In specific, the city center is not suggested for on-demand Ridepooling, as due to the efficient PT coverage there, it is speculated that the service would increase congestion and cannibalize the existing PT network. Subsequently, the choice of the areas, was based on known inefficiencies and gaps of the public network, that urge Athenians to use their private passenger car. On-demand Ridepooling was simulated and the demand of the service was predicted, based on real demand data from Berlin that were balanced based on the Athenian urban characteristics. The software used, was provided by the courtesy of door2door GmbH.

Figure 7.1., 7.2. and 7.3. illustrate how on-demand Ridepooling could look like, in order to demotivate private passenger car usage in the spotlight of poor PT coverage. Provided the general transport feed specification data (GTFS) for the Athens public transport schedules, the "Insights" software based on geographical information systems (GIS), visualizes the public

transport reality in the city. The following Figures are extracted from the “Insights” software, as explained at section 5.

Figure 7.1. refers to the Zografou area where the campus of the National and Kapodistrian University of Athens is located. PT has been identified as undersupplied with no flexibility in the bus schedules, as shown in the indicators in the left. The Figure illustrates with pale pink lines the predicted demand of on-demand Ridepooling, pointed out by the red arrows. Figure 7.2. illustrates the PT reality of Psychiko, a wealthy area, where the population density is low and efficiently and flexible PT exists only in the main highway of the area, leaving the chosen residential areas around the illustrated hexagon in the faith of private passenger car usage. Figure 7.3. illustrate the mobility situation of chosen areas in Politeia and Ekali, two wealthy areas of the northern Athens, where PT as illustrated does not serve the areas and citizens rely completely on private passenger car. All four areas of Zografou, Psychiko, Politeia and Ekali are strongly proposed for on-demand Ridepooling.

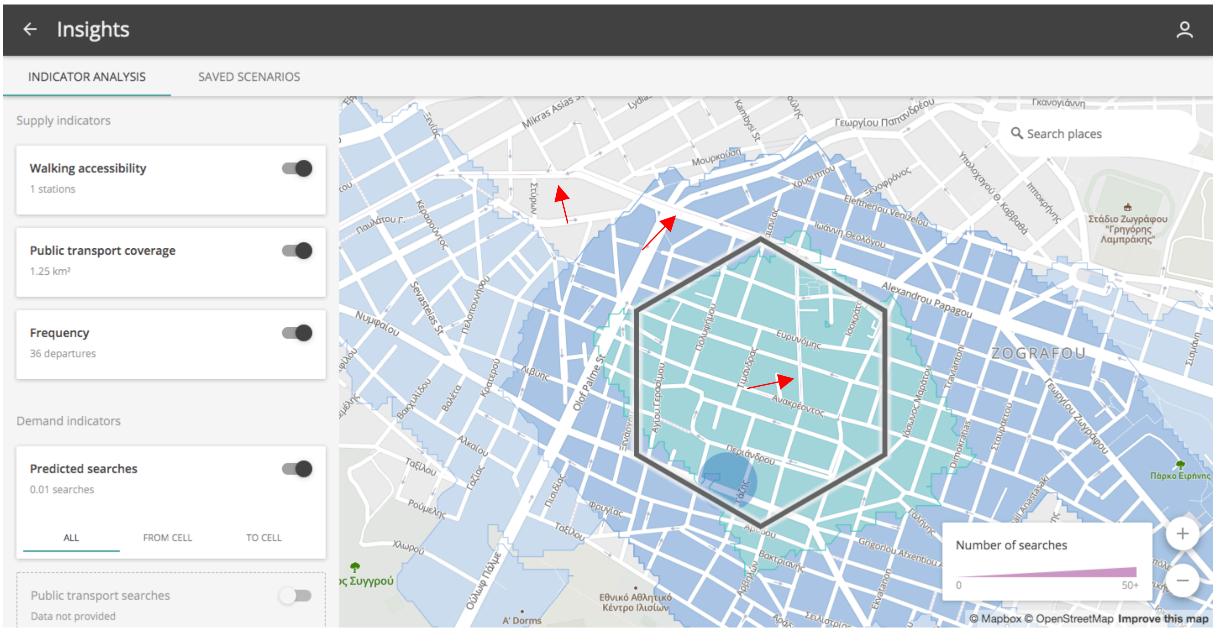

Figure 7.1. Predicted demand of on-demand Ridepooling for Zografou area, in Athens. The red arrows point out the pale pink lines of the service. Courtesy of door2door GmbH.

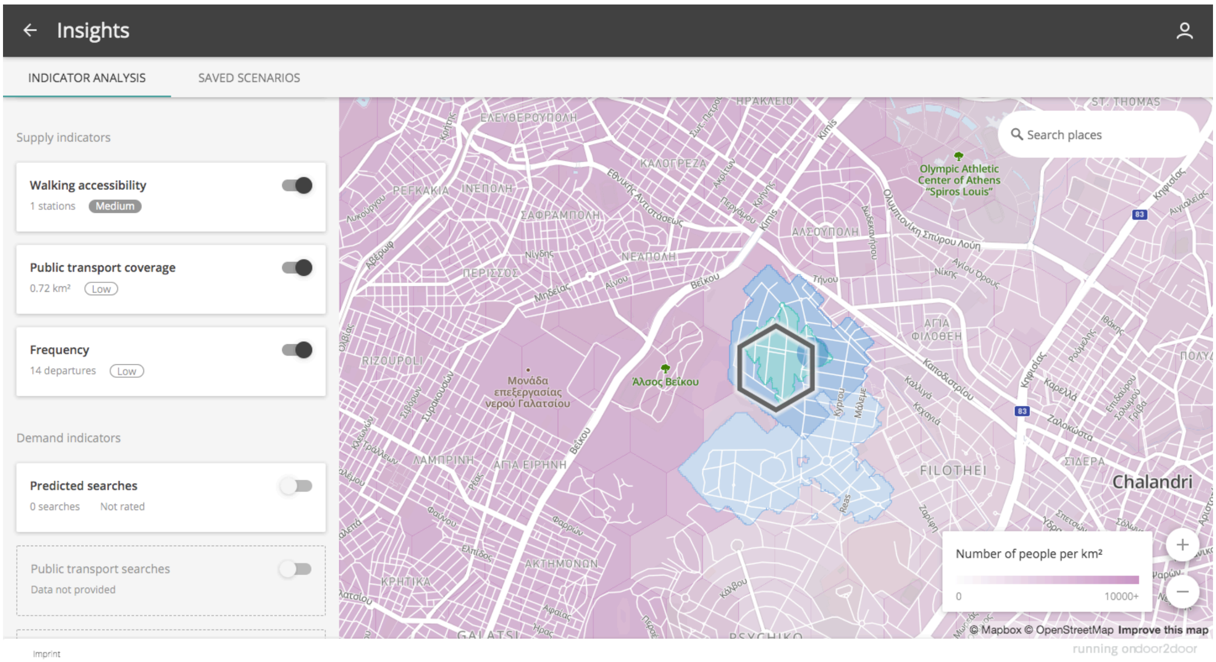

Figure 7.2. The public transport reality of Psychiko, in Athens. PT supply is ranked as low, as shown in the indicators on the left. This reality urges citizens to use their private passenger car. Courtesy of door2door GmbH.

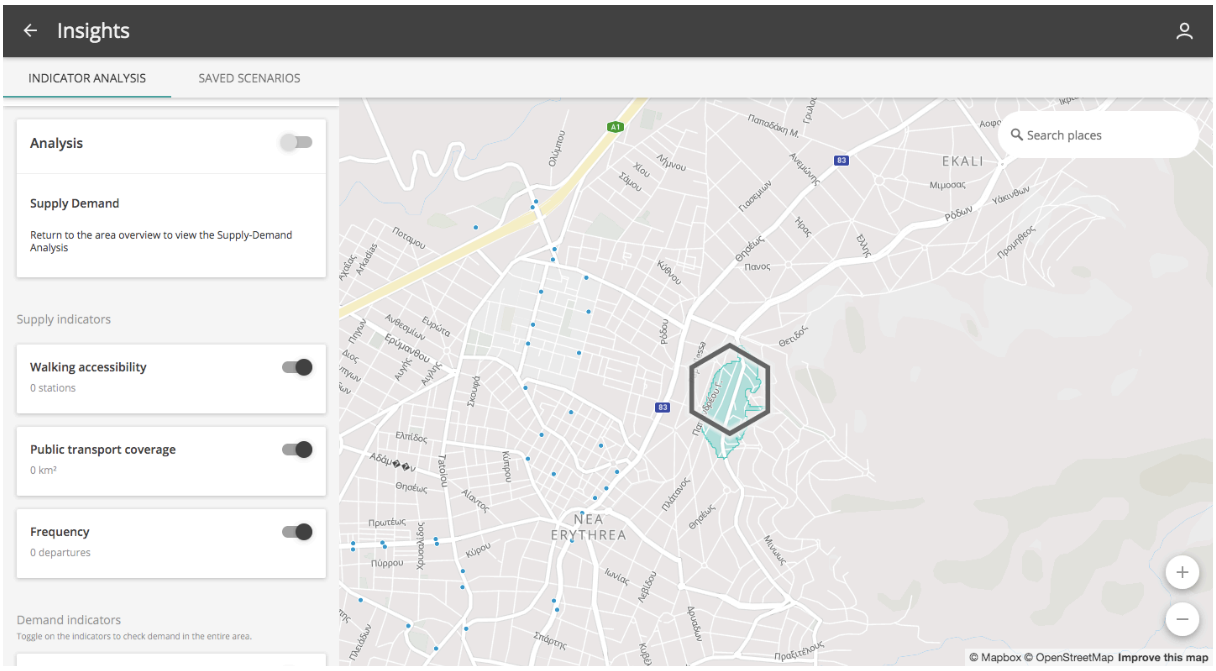

Figure 7.3. The public transport reality of Politeia and Ekali, in Athens. PT does not supply the chosen areas, as shown in the indicators on the left. This reality urges citizens to use their private passenger car. The blue dots illustrate the bus line that does not cover the areas. Courtesy of door2door GmbH.

7.2. The potential use case of Thessaloniki

Thessaloniki is the second biggest city in Greece. The urban complex of Thessaloniki has 895,915 residents (CIESIN, 2018), with a population density of 7.100 residents per km^2 (World Population Review, 2019b), reaching however in central areas like in Ampelokipi 21.925 residents per km^2 (CIESIN, 2018). It has been calculated that the urban complex expands in an area of 132,349 km^2 (Patsouri, 2019) in 7 boroughs (Ανδρικοπούλου and Καυκαλάς, 2015).

In comparison to Munich, Thessaloniki is almost 3 times smaller in size and 2 times smaller in population, as it can be derived by the presented data of this paper. The two cities, operate almost the same amount of bus lines, with Thessaloniki having 80 bus lines (Ο.Α.Σ.Θ., 2012a) and Munich 90 bus lines (Münchner Verkehrsgesellschaft mbH,2018). It should be also noted, that the Thessaloniki PT mix, is comparted only by busses (Ο.Α.Σ.Θ., 2012b), whereas Munich offers a variety of metro, tram, city rapid railway and bus choices (MVG, 2019).

Thessaloniki can be also characterized as Munich, by urban spatial narrowness. As Munich has been dealing with inefficiencies in some bus lines, due to urban space constrains (Patsouri, 2019), the same situation can be assumed for Thessaloniki that unfolds in a " narrow strip" of land from the north to the south.

For the urban mobility reality of Thessaloniki, it was identified that bus lines do not connect efficiently specific districts directly to each other, such as in the case of neighboring district Kalamaria and Pulaia. When a passenger car journey from one to another may take 5 minutes, a bus journey may take more than 20 minutes, due to detour and bad connection of the two neighboring districts. Therefore, citizens often prefer car, over the bus. This is also intensified by the fact that some bus lines expand in radial lines from the city center to the districts, without any connection among the districts themselves. Figure 7.4. illustrates poor connection in Pulaia and Figure 7.5. illustrates the predicted demand of on-demand Ridepooling for Pulaia and Kalamaria. Moreover, it has been identified that the edges of the city, are also not connected with an optimal way to each other, where connections include time consuming bus line changes and waiting times. Given the fact that the city is not large to cross, citizens prefer to cross districts through the city by private passenger car within 15 minutes, rather than taking the PT that may take up to 60 minutes for the same journey.
Figure 7.6. illustrates the PT reality in the area of Panorama in the southern part of the Thessaloniki urban complex. As shown, PT is not serving the area, which means that citizens rely completely on private passenger cars. Figure 7.7. predicts the demand of on-demand Ridepooling for the southern part of the city, serving Panorama and Pulaia. Figure 7.8. illustrates the specific use case of the demand of on-demand Ridepooling for the Mediterranean Cosmos commercial mall, part of southern Thessaloniki as well.

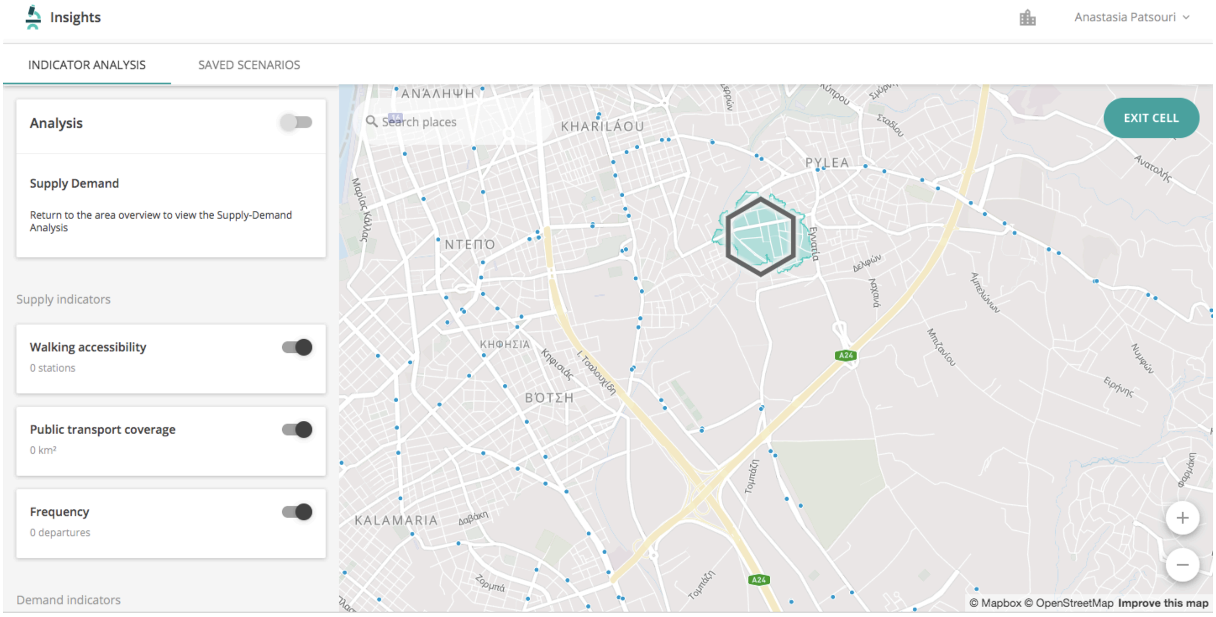

Figure 7.4. The public transport reality of Pulaia, in Thessaloniki. Apart from the fact that Pulaia does not have optimal PT coverage (indicators scoring 0 on the left), Pulaia is also not connected directly to Kalamaria by PT. The blue dots illustrate the basic bus coverage of Pulaia, that does not connect to Kalamaria neighbor borough, but instead detours it. As a result, a distance of 5 minutes may take 20 minutes. Citizens are urged to use their private passenger cars instead. Courtesy of door2door GmbH.

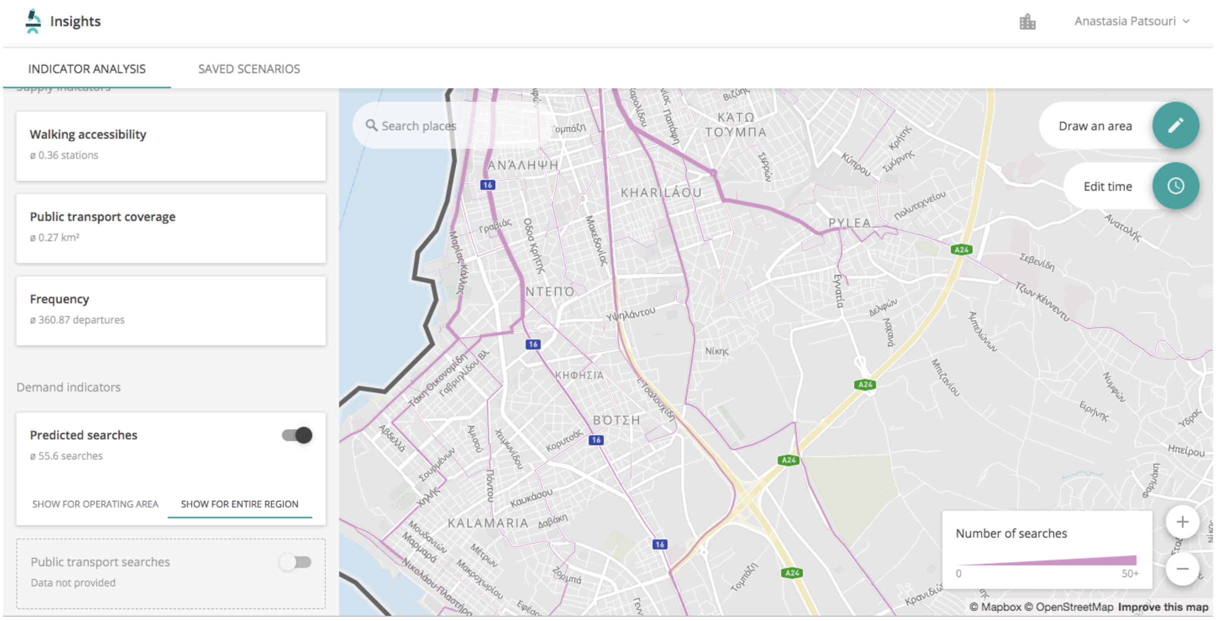

Figure 7.5. Predicted demand of on-demand Ridepooling for Pulaia and Kalamaria, in Thessaloniki. The pink lines illustrate the demand of the service. Main idea is to connect the two boroughs with each other directly. Courtesy of door2door GmbH.

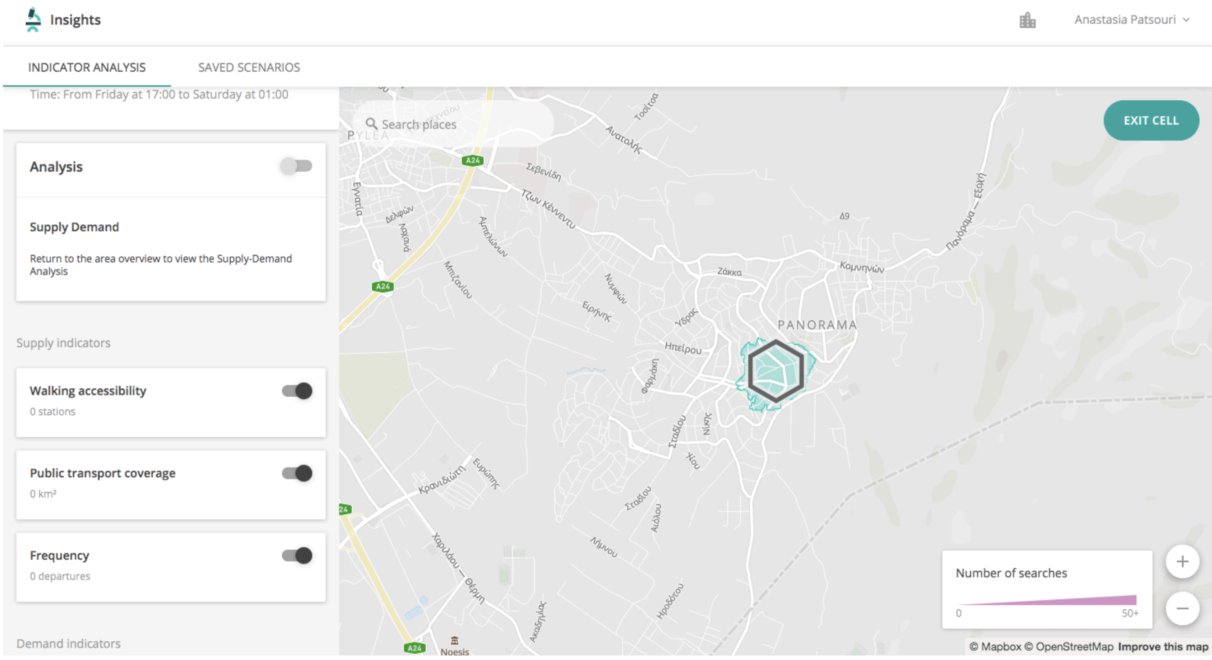

Figure 7.6. The PT reality in Panorama, Thessaloniki. PT is not serving the area, which means that citizens rely completely on private passenger cars. Courtesy of door2door GmbH.

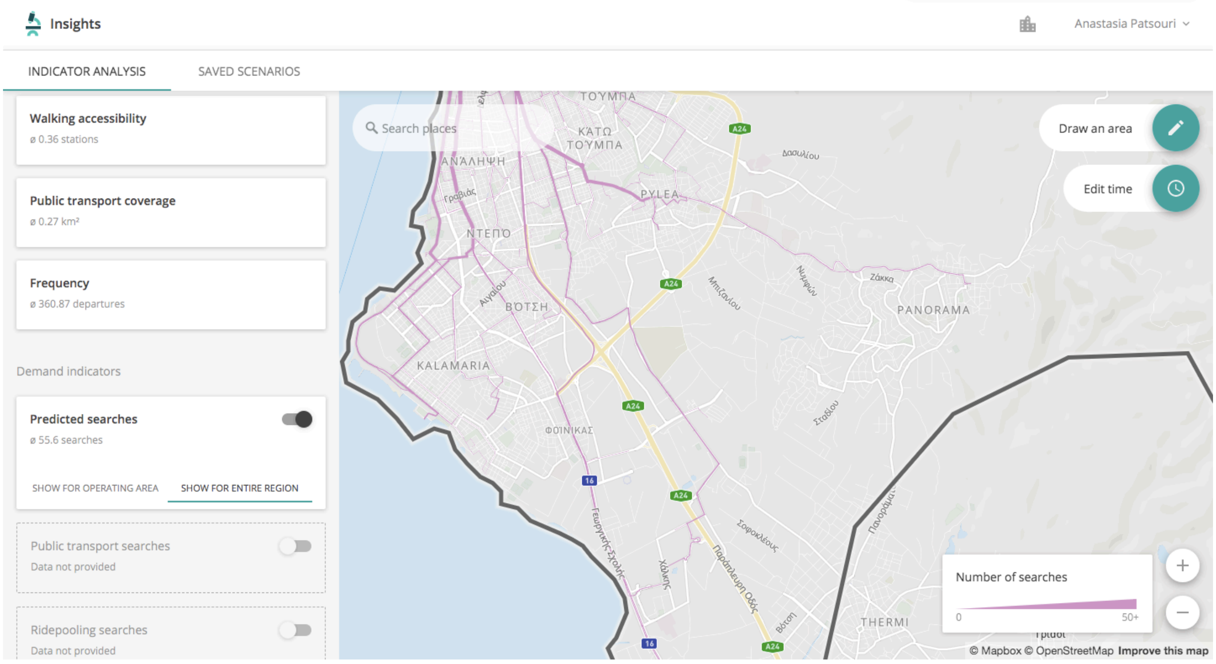

Figure 7.7. Predicted demand of on-demand Ridepooling for Pulaia connecting to Panorama, in Thessaloniki. Panorama is not connected to the PT network, as shown in Figure 7.6. The pink lines of the figure illustrate the predicted demand for the service. Courtesy of door2door GmbH.

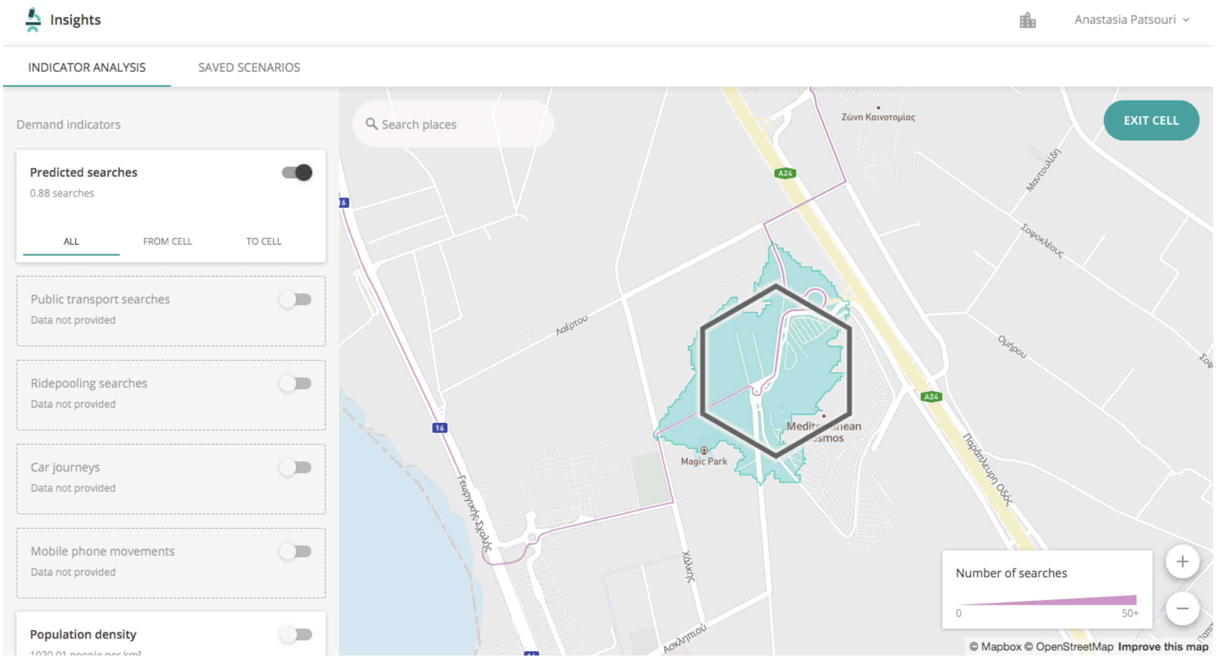

Figure 7.8. Predicted demand of on-demand Ridepooling for the Mediterranean Cosmos commercial mall, in Thessaloniki. The pink lines illustrate the demand of the service. Main idea is to connect the mall to PT in a more flexible manner. Courtesy of door2door GmbH.

8. Policy Recommendations

Following the above comparative analysis of on-demand Ridepooling in Germany and Greece, as well as the previous Sustainable Mobility Indicators analysis, this paper presents policy recommendations and guidelines, on on-demand Ridepooling best practices and applicabilities. The policy recommendations are extracted from a presented analysis of barriers and enabling factors, in regard to on-demand Ridepooling implementations.

Starting from the factors that enable on-demand Ridepooling, transport experts from the public and the private sector underline the essence of stakeholder inclusiveness (Patsouri, 2019). From their experience launching on-demand Ridepooling in various European cities, the transport experts highlight that on-demand Ridepooling can be publicly launched in a city, only when there is political unanimity amongst all affected stakeholders (Patsouri, 2019). Stakeholders for on-demand Ridepooling may include different levels of political authorities that affect transport decision making in a city and taxi organizations that can potentially participate in the service. Table 8.1. illustrates an overview of the stakeholder groups typically involved in transport projects.

Table. 8.1. The typical stakeholder groups involved in transport projects.

Typical stakeholder groups involved in transport projects (based on GUIDEMAPS)			
Government / Authorities	**Businesses / Operators**	**Communities / Local Neighbourhoods**	**Others**
Local authorities	Transport operators/ providers	National environmental NGOs	Research institutions
Neighbouring cities	Transport consultants	Motorist associations	Universities
Local transport authority	Car sharing companies	Trade unions	Training institutions
Traffic police	Bicycle rental operators	Media	Experts from other cities
Other local transport bodies	Other mobility providers	Local authority Forums	Foundations
Other local authority bodies	National business associations	Local community organisations	
Politicians	Major employers	Local interest groups	
Other decision-makers	Private financiers	Cycle/walking groups	
Partnering organisations	International/national business	Public transport user groups	
Project managers	Regional/local business	Transport users	
Professional staff	Local business associations	Citizens	
Emergency services	Small businesses	Visitors	
Health & safety executives	Retailers	Citizens in neighbouring cities	
European Union	Utility services [e.g. electric, telecoms]	Disabled people	
Ministry of transport	Engineers/contractors	Landowners	
Other national ministries		Transport staff	
Regional government		Parents/children	
		Older people	

The stakeholder groups as defined by the Sustainable Urban Mobility Plans (SUMPs) (European Commission, 2013).

A second important enabling factor for on-demand Ridepooling concerns the involvement of the public sector. The Lisbon study from OECD, underlines the important regulatory role authorities play, in the realization of shared urban mobility (International Transport Forum, 2015). In specific the regulatory role of the public sector is vital on guiding the developments of shared mobility in cities, but also in some cases maintaining market barriers (Ibid.). Transport experts from door2door GmbH also underline that the active participation of the public sectors is significant, for a sound operation on the streets (Patsouri, 2019). As Steinbeißer from MVG explains, the public sector shall have a loud voice on on-demand Ridepooling in order to compete with the expanding private sector, that does not necessary have the mission of offering mobility equitably (Patsouri, 2019). One of the core principles of PT is the concepts of geographic equity (Walker, 2008), where PT shall operate in both dense and non-dense areas, serving as much citizens as it can. Steinbeißer explains that private mobility operators need to run profitable services, in order to sustain their business models, and therefore choose to operate only where profit may exist (Patsouri, 2019). Prof. Vlastos also explains that public mobility is the one that takes the challenge of operating under non-profitable states to serve all areas, in the name of equity on PT (Ibid.). Therefore, we can conclude that the goal of profit from the private sector is contradicting the goal of equity from the public sector, producing a conflict of interest. Moreover, the selective private operation strategies of "cherry picking" on profitable urban areas, usually leads to operations on central dense areas. Steinbeißer explains that those central dense areas, usually already face traffic congestion, and as the independent private operators are not intergraded to the PT system, oversupply of transport and worsening of traffic are produced (Ibid.).

It can be therefore advised, that for an equitable transport system, including on-demand Ridepooling, the involvement of the public sector is vital. Enabling this involvement, the schemes of private – public collaborations can be very valuable, for the public sector to be in the front line of new shared mobility solutions. Moreover, the public sector can benefit from the private sector, as innovation and technical knowledge can flow from the private sector to the public one. The presented IsarTiger and BerlKönig services, in Munich and Berlin, are representative examples of this fruitful collaboration on the "know how to" bring on-demand Ridepooling on the streets. In this collaboration, the operational and private passenger data remain under public ownership. Public ownership is crucial as it protects the data away from misuse and purposeful profit, given the fact that data may often be object of unhealthy hoarding for the private sector.

Moreover, as underlined in the scientific community, integrated transport planning, can act as an a effective tool for changing travel behavior (Milakis, 2006), (Bakogiannis *et al.*, 2016). Therefore, the PT operators play also an educative role on introducing on-demand Ridepooling to passengers, in an intergraded manner, that does not contribute to the urban mobility problems.

Furthermore, on the aspects that enable a sound on-demand Ridepooling system, the Helsinki study from OECD underlines that benefits from on-demand shared mobility, can be enabled under specific operational frameworks (International Transport Forum, 2017). As analyzed in section 6.2., on-demand Ridepooling should avoid cannibalizing existing PT networks. The idea of a first-last mile operation of on-demand Ridepooling, as part of a multimodal journey, is a good example of a non-cannibalizing service. Therefore, integration to the existing public system is foreseen as a healthy practice for on-demand Ridepooling. At the same time as analyzed in section 6.2., the recommended operational scenarios for on-demand Ridepooling, may include the substitution of costly bus lines that citizens do not use due to various inefficient urban planning reasons or the feeder case of feeding passengers to end stations of rapid railway, connecting the outskirts to the central PT network.

On the potential cannibalization issue shared mobility may have on preexisting PT, a variation of the price of on-demand Ridepooling according to the operating area, could avoid the effect of cannibalization (Patsouri, 2019). As already discussed, on-demand Ridepooling wants to motivate citizens to stop using their private passenger car, but does not want that citizens start to use only on-demand Ridepooling instead of preexisting PT. The price of the service may therefore drive citizens' behavior and choice. Potentially the service could be pricier if operating in central areas to motivate car users to give up their car, and cheaper if operating in areas where there are no other public mobility choices. After all, MVG in Munich and BVG in Berlin, price on-demand Ridepooling higher than PT and cheaper than a taxi (MVG, 2018) (BerlKönig, 2019).

On the contrary to the analysis of factors that enable sound on-demand Ridepooling operations, there are also factors that act as barriers. Those barriers need to be taken into consideration when planning on-demand Ridepooling in a city, in order to overcome or manage them successfully.

Firstly, PT operators and companies, may have two problematic characteristics that act as barriers for implementing new mobility solutions; aversion to innovation and understaffed teams (Patsouri, 2019). Those two characteristics, especially seen in cases of smaller German PT operators (Ibid.), do not allow PT networks to develop and incorporate new mobility solutions. Skepticism about new technological innovation and aversion to technological development, can be detrimental for on-demand Ridepooling. Moreover, when PT companies face shortages in their human resources, undertaking new projects such as on-demand Ridepooling operations is not feasible.

Secondly, political forces such as the automobile lobby, may also be detrimental to the implementation of new public shared mobility solutions. Analyzed also at section 6., MVG explains that often the political influence the German automobile industry has in politics, is so powerful that it is able to attract a higher attention from the government, absorbing a much higher amount of public subsidies, leaving the PT operators underfinanced (Ibid.). Moreover, political forces appear as barriers also in the case of political instability and changing governments. As Transport Expert Kokkinos explains for the case of Greece, his efforts on implementing shared mobility in Athens in the 1980s where erased by the opposite government that was established in the early 1980s, in the middle of his project (Ibid.). Moreover, the topic of local regulation falls also under the political forces, that may challenge on-demand Ridepooling. Old PT Laws in force that do not foresee new platform-based digital mobility services such as on-demand Ridepooling, need to be taken into consideration (Patsouri, 2019).

Thirdly, culture is considered to be another factor crucial for the success of on-demand Ridepooling, as transport experts Mentz, Prof. Vlastos and Kokkinos underline (Patsouri, 2019). For the case of Greece, Prof. Vlastos highlights that the mentality citizens have on shared transport and private passenger cars, is crucial for the adoption of on-demand Ridepooling. Moreover, Kokkinos underlines that the aversive mentality on sharing vehicles, due to social status reasons, can be detrimental to any ambitious project on shared urban mobility (Ibid.).

Concluding on the factors that may challenge on-demand Ridepooling, poor digitalization may be a barrier for a city to implement on-demand Ridepooling. Based on the analysis of existing operations in Germany, digitalization plays an important enabling role for on-demand Ridepooling, as the service is based on software tools that operate digitally. Referring to the Digital Economy and Society Index (DESI) for Greece and Germany in 2018, Greece is scoring the penultimate position amongst the 28 EU on digital performance competitiveness, whereas Germany surpasses Greece by 20 percentage points, being higher than the EU average (European Commission, 2018). Germany's high DESI underlines the digital development the country has and can be connected to the numerous German cases of on-demand Ridepooling in the last two years (Table 6.1). Comparing to Greece's very low DESI and to the fact that on-demand Ridepooling in Greece does not exist today (Patsouri, 2019), we can conclude that low digitalization is not easing the implementation of digital mobility solutions, like in the case of on-demand Ridepooling.

9. Conclusions

On-demand Ridepooling has been attracting much attention in today's urban environments.
In the spotlight of the sharing economy, the digitalization process and the urban mobility challenges cities face today, some cities embrace on-demand Ridepooling operations.
The paper concludes positively on the sustainability aspects of on-demand Ridepooling, as a shared transport mode that can be in line with the sustainable urban mobility standards of the bibliography. Sections 5 and 6.2. analyze how the objectives and indicators that plan on-demand Ridepooling are matching the Sustainable Mobility Indicators presented at Table 4.1., 4.2., 4.3. and 4.4. Additionally, the interdisciplinary and comparative approach of the paper, identifies key factors that enable the sustainable operation of the service and form policy recommendations. Those recommendations that allow a sustainable and sound on-demand Ridepooling that strengthnes PT, include the factors of; integration, private – public collaboration, operation scenarios of first-last mile / feeder cases, price differentiation of the service, stakeholder inclusiveness and public sector orchestration of the on-demand Ridepooling service. Considering the challenging factors that need to be addressed; political influence, PT regulations, culture and mentality, digitalization level and aversiveness to innovation, can act detrimental to a successful service implementation.
Finally, from an economic point of view, on-demand Ridepooling appears to sustain itself as a service and can be implemented in short timeframes, when compared to hard PT infrastructure projects (Patsouri, 2019). Given the fact that urban mobility challenges demand urgent solutions, sound on-demand Ridepooling appears capable to be part of them.
From a social point of view, on-demand Ridepooling seems capable to minimize crisis results such inequality and poverty, by increasing access to opportunity and people, and public space equity.
Future research will focus on the numerical and long-term effects of on-demand Ridepooling on the micro and macro economy of an urban city, to drive even more precise policy on the topic. Additionally, as today empirical data concerning passenger's appraisal are limited (König, Bonus and Grippenkoven, 2018), future research can target passenger behavior to better comprehend the incentives behind transport choices. Then, the goal of incentivizing citizens to switch from their private passenger car, to sustainable public transport can be achieved. Thus, the vision of minimizing the number of cars troubling urban space would be realized, and sustainable mobility modes would be able to combat the urban mobility challenges that cities face today.

10. References

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