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The Proposal of a Shared Mobility City Index to Support Investment Decision Making for Carsharing

S. Murr, S. Phillips

***Abstract*—**One of the biggest challenges entering a market with a carsharing or any other shared mobility (SM) service is sound investment decision-making. To support this process, the authors think that a city index evaluating different criteria is necessary. The goal of such an index is to benchmark cities along a set of external measures to answer the main two challenges: financially viability and the understanding of its specific requirements.

The authors have consulted several shared mobility projects and industry experts to create such a Shared Mobility City Index (SMCI). The current proposal of the SMCI consists of 11 individual index measures: general data (demographics, geography, climate and city culture), shared mobility landscape (current SM providers, public transit options, commuting patterns and driving culture) and political vision and goals (vision of the Mayor, sustainability plan, bylaws/tenders supporting SM).

To evaluate the suitability of the index, 16 cities on the East Coast of North America were selected and secondary research was conducted. The main sources of this study were census data, organisational records, independent press releases and informational websites. Only non-academic sources where used because the relevant data for the chosen cities is not published in academia.

Applying the index measures to the selected cities resulted in three major findings. Firstly, density (city area divided by number of inhabitants) is not an indicator for the number of SM services offered: the city with the lowest density has five bike and carsharing options. Secondly, there is a direct correlation between commuting patterns and how many shared mobility services are offered. New York, Toronto and Washington DC have the highest public transit ridership and the most shared mobility providers. Lastly, except one, all surveyed cities support shared mobility with their sustainability plan.

The current version of the shared mobility index is proving a practical tool to evaluate cities, and to understand functional, political, social and environmental considerations. More cities will have to be evaluated to refine the criteria further. However, the current version of the index can be used to assess cities on their suitability for shared mobility services and will assist investors deciding which city is a financially viable market.

***Keywords*—**Carsharing, transportation, urban planning, shared mobility city index.

I. Introduction

CARSHARING has grown tremendously in the past few years and is predicted continuing to do so in the next decades. Susan Shaheen and Adam Cohen of the Berkley Institute have done a remarkable amount of work in the past few years and investigated carsharing growth potential by analyzing industry data [1]. Yet there has been very little research on what the pre-requisites are to make a city successful for a carshare operator.

All attendants at the carsharing conference in Vancouver in October 2015 agreed that cities have a large influence on how successful shared mobility is [2]. However, there has been very little academic or systematic research into what the key criteria are to determine when and if a city would be a viable market. The only research the authors are aware of, is the innovative city index whose recommendation is around the integration of technology into public transit [3], and a newly published study by SUMC (Shared Use Mobility Center) that attempts to answer the questions what the potential for shared mobility is in a particular region, and how to best tap into it [4]. Nevertheless, the authors think that there is still no consistent approach to both support shared mobility operators to assess cities on their suitability for shared mobility services, and to serve cities as benchmark tool how attractive they are for shared mobility providers. To alleviate this, the authors believe a city index evaluating different criteria is necessary. They have chosen a set of five different external measures to investigate financially viability of a potential shared mobility operator and the understanding of its pre-requirements. Thus, the authors have created a Shared Mobility City Index (SMCI). They have consulted several shared mobility projects and industry experts to guide them through this process.

II. Methodology

A. Selecting Key Index Measures

To assess a city for shared mobility, three major areas have been identified to be important for research: General data of the city, the existing shared mobility and transportation landscape, and the current political vision and goals of the city.

General data includes of demographics, geographical data, the climate and an overview of the culture of the city. Demographics include the size of the area the city covers, the number of inhabitants of that area and the density of the city, which is calculated by dividing the area size by the number of inhabitants. For geographical data, a geographical map provides distinctive characteristics that would be of importance for a shared mobility provider. Similarly, the climate chart offers insights on seasonal weather. Lastly, a city culture gives background information on the likes and dislikes of the population of that city.

Sigrun Murr was with Royal Roads University, Victoria, BC, V9B 5Y2. She is now with movmi Shared Transportation Services Inc, Vancouver, BC V6G 1Z3 CA (phone: +1 604 441 6612; e-mail: sigrun@movmi.net).

Sandra Phillips was with University of Zurich, Zurich, ZH, 8006. She is the founder of movmi Shared Transportation Services Inc, Vancouver, BC V6G 1Z3 CA (phone: +1 778 708 1845; e-mail: sandra@movmi.net).

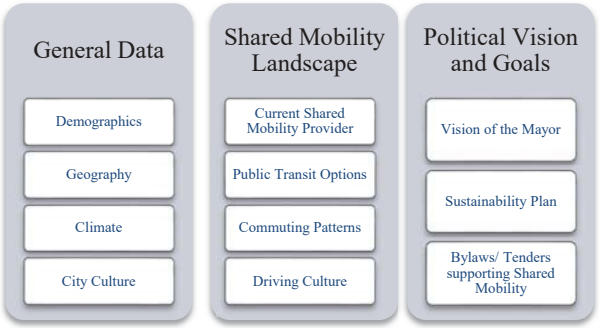

Fig. 1 Overview of SMCI Index Criteria

Shared Mobility and Transportations landscape provides firstly information on the current shared mobility providers, how long they have been in operation in that city, what kind of service they offer and, if available, vehicle and member data. Secondly it offers information on the available public transit options, the types and number of services they offer and the daily ridership. Commuting patterns, drawn from census data, are giving insights on number of people driving to work, using public transit or a bicycle and the average commuting time and distance. Distinctive features regarding the driving culture of the city, if present, give further insights in the transportation landscape.

Political Vision and Goals of the city includes information of the current mayor and the mayor's vision. A sustainability plan, if one is in place, is an indicator if shared mobility is supported in any capacity. Furthermore, some cities have bylaws or tenders supporting shared mobility or plan to implement them in the near future.

B. Selecting 16 Cities

To validate if the selected index measures are indeed a true indicator for successful shared mobility assessment, 16 cities were chosen to test the hypothesis. The cities were selected based on the following criteria:

- They have to be on the East Coast of North America,
- At least one shared mobility provider has to be present,
- A minimum of 100,000 inhabitants should live within its city area.

Table I shows a list of the 16 selected cities, their number of carshare and bikeshare providers (if any), as well as the number of inhabitants and their density, which is the area of the city divided by the number of inhabitants. Cities where assessed for size according to the following classification:

- XL = Over 1.6 Million Inhabitants
- L = 500,000 to 1.6 Mil
- M= 200,000 to 500,000
- S = Under 200,000

TABLE I
OVERVIEW OF SHARED MOBILITY IN 16 NORTH AMERICAN CITIES

City	# Inhabitants	/ km2	Carsharing	Bikesharing	Country	/ km2
Ann Arbor	113,934	1,580.70	2	1	US	1,580.70
Atlanta	447,841	1,306.00	0	0	US	1,306.00
Chicago	2,695,598	4,447.40	0	1	US	4,447.40
Detroit	680,250	1,985.00	0	0	US	1,985.00
Jacksonville	821,784	424.80	2	0	US	424.80
Kitchener	219,153	1,602.10	2	2	CA	1,602.10
London	366,151	870.60	3	0	CA	870.60
Miami	399,457	4,299.60	3	1	US	4,299.60
Montreal	1,649,519	4,517.60	2	1	CA	4,517.60
New York City	8,491,079	10,756.00	4	1	US	10,756.00
Ottawa	883,391	316.60	3	2	CA	316.60
Philadelphia	1,560,297	4,492.40	2	1	US	4,492.40
Tampa	347,645	1,146.70	2	2	US	1,146.70
Toronto	2,615,060	4,149.50	4	1	CA	4,149.50
Washington, DC	658,893	4,065.00	5	1	US	4,065.00
Waterloo	98,780	1,520.70	2	1	CA	1,520.70

C. Researching Key Measures for Selected Cities

Demographics: To assess each city on a very generalized level, general data and Google maps were used to evaluate Geography and Topography of each city.

The authors collected for each city data on the city size (the number of inhabitants), the city area in square miles, and the density, which is the city size divided by the number of inhabitants. This data was collected from publicly available data and census pages from the United States of America (U.S.A.) and from Canada. Additionally, specific geographical information was researched for each city, mainly in regards to traffic. For example, if bridges, tunnels or a specifically hilly geography would have impacts on the existing traffic flow.

Climate: The climate of the selected cities is described using the Köppen climate classification. This classification is based on the empirical relationship between climate and vegetation and provides an efficient way to describe climatic conditions defined by temperature and precipitation and their seasonality with a single metric. More details on this classification can be found in Appendix A.

City culture: Assessing city culture is not easy to do from afar. The authors have opted to look at key messages from economic development and tourism groups, as both groups

have a wealth of local connections and information available.

Commuting Patterns: Canadian and US census data were used for transportation and commuting patterns. These data are publicly available although they usually are from a few years back, when the last census data was collected. For Canada the last census was done in 2011, for the U.S.A. the most recent available date is from 2010.

Existing Shared Mobility: Researching exact numbers for each shared mobility provider per city proved to be difficult. Not all providers publish their data on member and vehicle numbers. Susan Shaheen has done studies on carsharing [5] but unfortunately the data available to her for this study are not available to the public – her date is only available in aggregated form, not for each individual mobility operator. Hence, the authors decided to interview industry experts as well supplement data with publicly available operator data.

Political Vision and Sustainability plan: It is standard practice for political leaders in North America to detail their vision in plans that are publicly available. The authors have consulted and reviewed the sustainability plan, as well as carsharing and parking regulation for each selected city.

III. Analysis and Key Findings

A. General Data

Size and Density: The selected cities vary in size (number of inhabitants), with New York City, Chicago and Toronto being the biggest cities (XL), and Ann Arbor and Waterloo the smallest (S). Density of a city is calculated by dividing the number of inhabitants by square mile of the city area. Ottawa for example is a large city, but its large city area makes it less dense than New York City, which small city area combined with a large number of inhabitants makes it the densest city of this report.

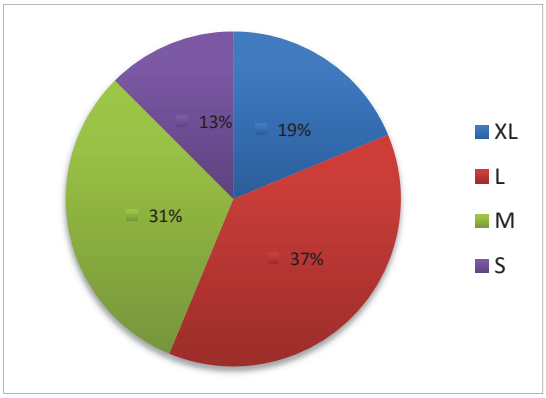

Fig. 2 Size of selected cities

Geography: Most cities are flat or only slightly hilly (Ann Arbor and Detroit). None of the selected cities has road tolls but many of the historically larger cities have been built close to waterways, often rivers. This means there are bottlenecks when there are bridges that could impact traffic and commuting times. Atlanta is a special case as it has three major interstate highways converging, forming the so-called Downtown Connector through the middle of the city. They carry more than 340,000 vehicles per day, making it one of the ten most congested segments of interstate highway in the U.S.A [6].

Chicago has bike lanes through almost all major veins in the city, as well as many smaller streets that are highly frequented by bikes during summer.

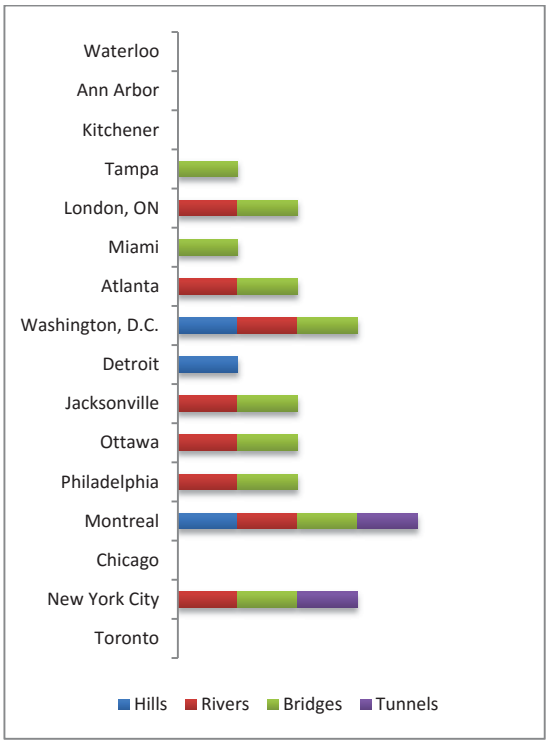

Fig. 3 Hills, Rivers, Bridges and Tunnels of selected cities

Climate: Out of the 16 selected cities, nine cities classify as humid continental (Dfa and Dfb), six are classified as humid subtropical (Cfa) with Miami being the only city in the tropical monsoon classification (Am). The humid continental climate (Dfa and Dfb) consists of warm to hot (and often humid) summers and (sometimes severely) cold winters. Cities like Chicago and Toronto are known for heavy snowfalls in winter, which can make biking, driving and in particular the use of electric cars challenging. Too hot summers tend to prevent people from using bikes as means of transportation as they do not want to arrive at their destination sweated. The humid subtropical climate (Cfa) has usually hot and humid summers with mild to cool winters. New York City falls into this climate unlike the rest of its state (which is Dfa climate), as the city is an urban heat island with temperatures 5-7 degrees Fahrenheit (3-4 degrees Celsius) warmer overnight than surrounding areas. The tropical monsoon climate (Am) has monthly mean temperatures above 18 degrees Celsius in every month of the year and features wet and dry seasons.

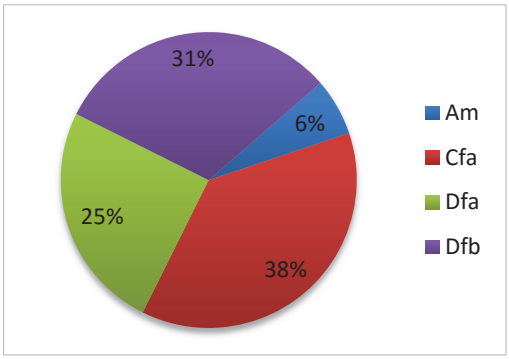

Fig. 4 Köppen Climate of selected cities

B. Shared Mobility Landscape

Current Shared Mobility Provider - Carshare: 11 out of the 16 surveyed cities have station-based systems for shared mobility. car2go as free-float car share provider is only present in five of the selected cities. In New York, car2go is still in the preliminary testing phase in Brooklyn and it is the only city where car2go does not have dedicated spots in the downtown core (Manhattan) and users need to pay for parking [7]. The biggest station-based provider is Zipcar, which can be found in every surveyed city except Montreal. Eight cities have Enterprise Car Share and four had Hertz 24/7. Both Hertz 24/7 and Enterprise Car Share combine their rental car options with a sharing model and offer a variety of vehicle types. They are able to optimize their utilization by shifting their rental vehicles to carsharing options when rental demand is low. Nevertheless, both require return of the car at the same station. Hertz 24/7 ceased operations at the beginning of 2015 [8]. Further eight cities have independent station-based providers. The situation of Waterloo and Kitchener in Canada is unique among the surveyed cities, as both cities are so close together that they share a community car share provider [9].

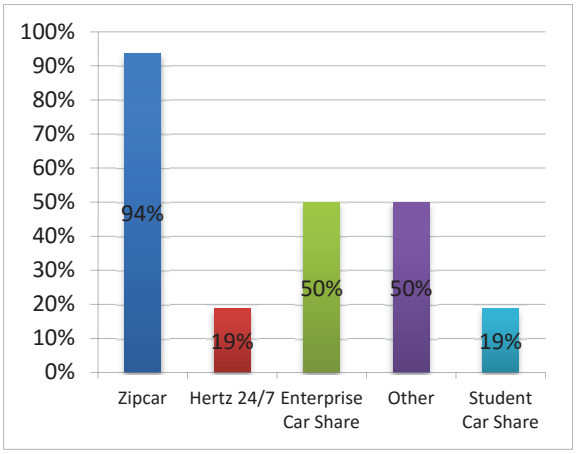

Fig. 5 Station based carshare

Bikeshare: 14 out of the 16 surveyed cities have a bikeshare provider, with Ottawa and Tampa the only cities with two bikeshare providers. The cities without bikeshare are: Atlanta, Detroit and Jacksonville in U.S.A. and London, Ontario in Canada. There is no information on plans for a bikeshare for Atlanta, or London, Ontario. The city of Detroit was granted $1 million in Transportation Alternatives Program funding for 2016 through the Federal Highway Administration. Detroit will use that to start a bike share program to be launched possibly as early as 2016 and is currently looking for potential vendors [10]. Jacksonville in Florida announced plans for a bikeshare in 2013 and as of 2014 published reports of a development in a new housing community [11]. However, current information on the development process could not be found.

All bike share providers are station-based but offer the option to return the bike at a different hub. Notably except are Tampa and, since 2015, VeloGo in Ottawa, where bikes are equipped with a GPS sensor and can be returned at any bike rack within the city. VeloGo in Ottawa charges an additional fee for not returning the bike to a hub [12].

C. Public Transit Options, Commuting Patterns and Driving Culture

In all selected cities the majority of commutes are done by car from the suburbs to the business core. The only exception is New York City, which is the only city with a 24/7 public transit. Its highly used public transit makes New York the most energy efficient city in North America. Also in Washington D.C. about 30% of the population commutes by public transit, which results in about one million trips each weekday on its Metro. This makes it the second-busiest rapid transit system in the country and has in addition the nation's sixth-largest bus system. Miami has Florida's highest transit ridership as about 17% of Miamians use transit on a daily basis.

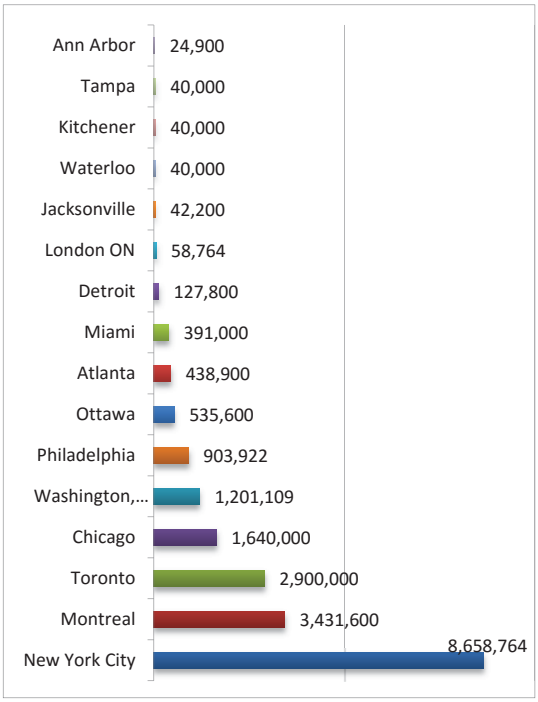

Fig. 6 Average daily ridership on public transit

Toronto, the small Canadian sister of New York, has the third most heavily used urban mass transit system in North America, after the New York City Transit Authority and Mexico City Metro. Montreal has the sixth busiest commuter rail system in North America after New York City, Chicago, Boston, Philadelphia, and Toronto. Nevertheless, still over 65% of the population in the U.S.A. commutes by vehicle.

Driving Culture: Despite the fact that most people commute (or perhaps because of it), many North American cities are among the worst for traffic or accidents. Washington is ranked as one of the top 10 of the worst cities for driving in the U.S.A. due to confusing traffic patterns and congested roads during rush hour. Philadelphia is close behind due to bad street conditions and many street accidents [13]. Miami is the two-time winner of the Rudest Drivers in America contest [14] and, like Detroit, is also known for bumper-to-bumper traffic and ignorance of traffic rules and lights. Even small Tampa has a bad reputation: it is annually listed as the deadliest city for pedestrians and bicyclists, with car drivers often described as rude and angry [15].

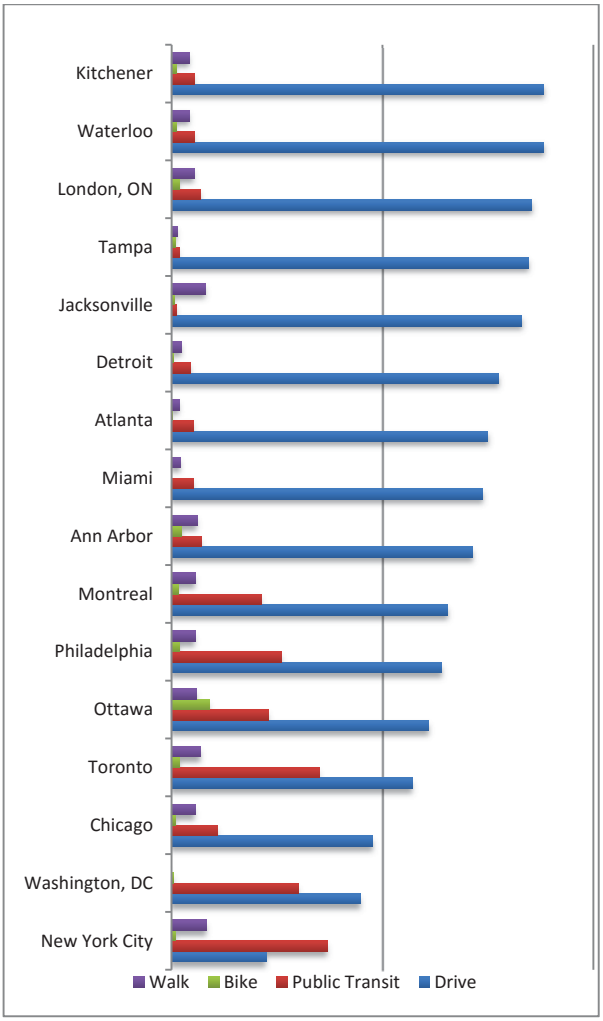

Fig. 7 Commuting Patterns of selected cities

D.Political Vision and Goals

The vision of the mayor influences the sustainability plan significantly. The authors have done a thorough review of all 16 cities and their sustainability plans and found that a good indicator if a Mayor supports alternative modes of transportation were Green House Gas emissions (GHG) reduction measures. Except Jacksonville, all surveyed cities have a sustainability plan in place. Some cities have specific goals but most cities do not define numbers in their goals towards sustainability.

Washington wants to reduce their GHG 50% by 2032. It also lists additional specific numbers in reducing waste and increasing transportation options as well as announces specifically to expand car-sharing programs to low-income residents using financial tools [16].

New York [17], Miami [18], and Atlanta [11] plan to reduce their GHG 80% by 2050.

Toronto wants to reduce their GHG 30% by 2020 [19], Montreal defines 30% GHG reduction in 2020 compared to 1990 [20], while Ottawa identifies their goal to reduce the GHG emissions per capita 20% until 2024 [21].

Philadelphia had a plan to reduce GHG 20% by 2015 [22] and is currently on a new plan (Philadelphia 2035), which does not provide specific numbers.

Every other city in this report states that it wants to reduce GHG, use energy more efficiently and provides plans and recommendations on how to achieve that, but does not provide measures or metrics of success.

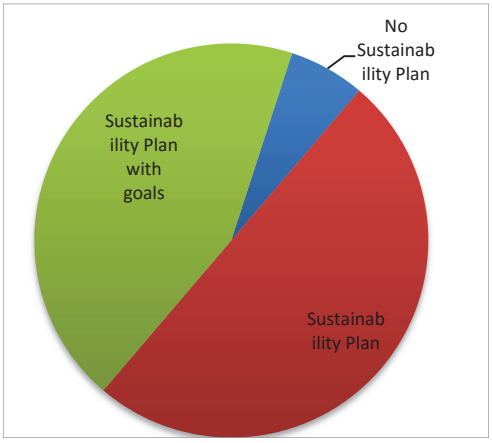

Fig. 8 Sustainability plan of selected cities

Bylaws or tenders supporting shared mobility: Montreal is one of the few cities with an open tender in the fall (2015) for electric car share providers, with new criteria for all future tenders. This tender requires at least four seats and a range of 150 km. It is not clear at this point what this will mean for car2go, as their SMART cars only have two seats [23].

Philadelphia has bylaws supporting carsharing since 2012, since then a new zoning code required developers to provide at least one dedicated parking spot for car-share services (like Zipcar) for every 100 residential units or 100,000 square feet of office space. The code also included carsharing incentives

for developers, giving them the option to reduce the overall number of parking spots if more dedicated car-share spots were created. Additionally, Philadelphia allows carsharing companies to obtain permits from the Parking Authority for street-level spaces at significant reduced rate compared to regular parking fees [24].

IV. Ranking the Cities on the Index

While all key index measures where researched for each of the 16 selected cities, after a first qualitative analysis of the different areas the authors decided to refine the initial proposal of the index for the ranking of the cities.

The key index measures where reduced to four selected areas are:

- Urban Density
- Commuting Patterns
- Sustainability Plan
- Shared Mobility Services

In order to rank the cities, for density and commuting patterns the "best in class" method was chosen to distribute points. It is a well-known method to benchmark the highest current performance in any given area. For the other two criteria points were distributed up to a maximum of 10.

The qualitative analysis showed that density is not an indicator for the number of shared mobility services offered; the city with the lowest density has 5 shared mobility options. This goes against the notion that a city needs high density, otherwise people would not use shared mobility services. This is why the authors decided to distribute weights among the criteria to build a final ranking of the 16 selected cities.

The selected weighting of each criterion was chosen to be:

- 6%: Urban Density
- 30%: Commuting Patterns
- 34%: Sustainability Plan
- 30%: Shared Mobility Services

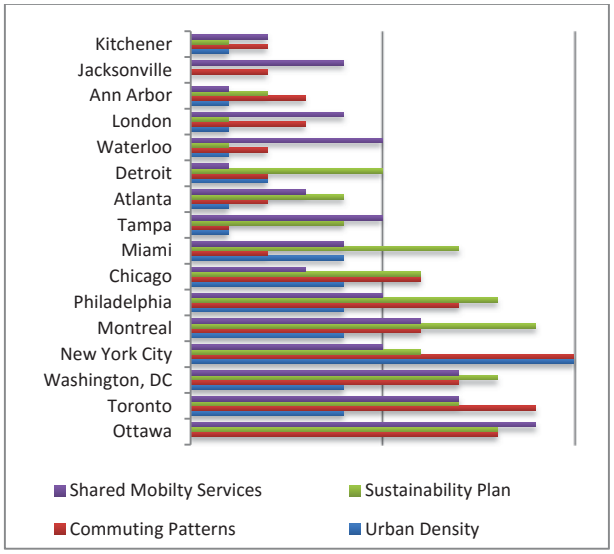

Fig. 9 Scoring the selected cities on the proposed index

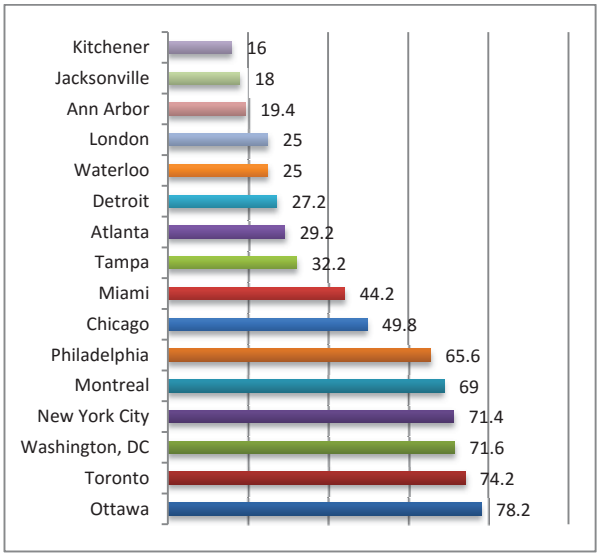

Fig. 10 Scoring the selected cities on the proposed index

V. Discussion

The SMCI proved to be a useful tool not only for cities to assess their suitability for alternative mobility offers that support their residents, but also supports shared mobility operators in their decision making and market development efforts. However, the report provided some surprising findings, contrary to what the authors expected to be the results. Density proved not to be an indicator of variety and number of offered shared mobility services in a city. These findings support the theory that Feigon posed, too - that density in fact is not an indicator for successful shared mobility in a city [3, p. 42]. Furthermore, there seems to be a direct correlation between regulatory framework, political vision and the success of shared mobility providers in a city.

Based on the ranking and evaluation of the SMCI, Ottawa provides fertile ground to launch shared mobility mainly as political support is in place, there is a strong public transit network and a variety of shared mobility options. Any new entrants to the market will profit from the political support and educational groundwork that the other shared mobility providers have already done. On the other hand, a city like New York that scores high on density and commuting patterns (which means it has a low ratio of vehicle commuters) is only on place five. This is mainly due to lack of political support for new mobility options, particularly free-floating carsharing. This is in fact a conscious choice by the city as they are concerned about scarce curb space and want to maximize curb access for shoppers, visitors, and deliveries. Additionally, New York boasts one of the best transportation network and terrible traffic congestion, which are major disadvantages for free-floating carsharing services.

Last but not least, small cities such as Kitchener, Ann Arbor or Jacksonville rank very low on the SMCI. It appears that in all three cities there is very little support and awareness on a city level when it comes to sustainability plans, visions or parking regulations needed for shared mobility. It may also

indicate that the shared mobility need for these smaller communities are different than the ones for larger cities. A further assessment of this theory will be needed.

The importance of evaluating cities along a set rule of criteria cannot be underestimated.

From a city-perspective, the proposed index will assist cities interested in attracting shared mobility providers and operators. It gives an unbiased evaluation and ranking of the city and shows clearly which areas need support from a city level. The surprising findings about density and New York's particular challenge around curb space, led the authors to the conclusion that an additional criterion is needed to take space limitations of a city into consideration. It is yet to be decided what a good key measure is to understand space limitations of a city.

It is understood that the index measures of the general data are mostly out of a cities direct control. The city will have some influence regarding the city culture and demographics, but general geography and climate are out of human control.

From a shared-mobility-provider-perspective, launching a shared mobility system is tied to a large upfront capital investment and choosing a city that is not ready, supports or is in need of such a solution may result in the service being closed due to financial losses.

VI. Conclusion

Based on the rapid growth and demand of shared mobility, and a scarcity of valuable information both on the side of a city and on the side of a shared mobility provider, the authors created a shared mobility city index. This index ranks each surveyed city on key measures consisting of: density, commuting patterns, sustainability plan, and existing shared mobility services.

The proposed index would give a city an idea which areas could be improved if they want to attract more shared mobility providers, as well as it would give potential shared mobility providers an idea if a city is worth considering to invest for expansion. The authors tested the proposed index on 16 selected cities.

The most interesting finding of applying the selected measures of the proposed city index to cities was that the density of a city apparently has less influence on shared mobility than thought. Ottawa in Canada is the least dense city of the 16 selected cities but has the most shared mobility providers. Furthermore, it became also apparent that researching the political environment is of utmost interest, as New York City for example looks to be very attractive on almost all measures for shared mobility, but looking deep into the political environment, it becomes apparent that the city is not very interested in attracting more shared mobility providers. These findings lead to the conclusion that the proposed shared mobility index can be a great tool to support shared mobility providers in their decision making process of whether to invest in that city, or not, but also clearly needs further refinement.

Appendix

A. Köppen Climate Classification

The climate of the selected cities is described using the Köppen climate classification. This classification is based on the empirical relationship between climate and vegetation and provides an efficient way to describe climatic conditions defined by temperature and precipitation and their seasonality with a single metric.

Because climatic conditions identified by the Köppen classification are ecologically relevant, it has been widely used to map geographic distribution of long term climate and associated ecosystem conditions.

1. Humid Continental Climate:

A humid continental climate (Köppen prefix D and a third letter of a or b) is typified by large seasonal temperature differences, with warm to hot (and often humid) summers and cold (sometimes severely cold) winters. Precipitation is usually well distributed through the year. The definition of this climate regarding temperature is as follows: the mean temperature of the coldest month must be below −3 °C (26.6 °F) and there must be at least four months whose mean temperatures are at or above 10 °C (50 °F). In addition, the location in question must not be semi-arid or arid.

Under Köppen, the following variants of this climate are possible. The climate regime uses a three-letter code, beginning with the letter D. Otherwise,

The second letter

- f : Does not meet either of the alternative specifications.
- s : A dry summer — the driest summer month has at most 30 millimetres (1.18 in) of rainfall and has at most 1⁄3 the precipitation of the wettest winter month.
- w : A dry winter — the driest winter month has at most one-tenth of the precipitation found in the wettest summer month.
- The third letter
- a : Warmest month averages above 22 °C (71.6 °F)
- b : Does not meet the requirements for a, but there still are at least four months above 10 °C (50 °F).

2. Humid Subtropical Climate:

A humid subtropical climate (Köppen climate classification Cfa or Cwa) is a zone of subtropical climate characterised by hot, usually humid summers and mild to cool winters. Under the Köppen climate definition, this category of climate type covers a broad range of attributes, especially in terms of winter temperatures. Under the modern Trewartha climate classification, most of the climates that have eight or more months with a mean temperature of 10 °C (50 °F) are warm to hot much of the year with mild winters.

The Köppen definition of this climate is for the coldest month's mean temperature to be between −3 °C (26.6 °F) and 18 °C (64.4 °F), and the warmest month to be above 22 °C (71.6 °F). Some climatologists prefer to use 0 °C (32 °F) as the lower bound for the coldest month's mean temperature. It is either accompanied with a dry winter (Köppen: w) — or has no distinguished dry season (Köppen: f)

3. Tropical Monsoon Climate:

Tropical monsoon climate, occasionally also known as a tropical wet climate or tropical monsoon and trade-wind littoral climate in climate classification, is a relatively rare type of climate that corresponds to the Köppen climate classification category "Am".

Tropical monsoon climates have monthly mean temperatures above 18 °C in every month of the year and feature wet and dry seasons, as Tropical savanna climates do. Unlike tropical savanna climates however, a tropical monsoon climate's driest month sees less than 60 mm of precipitation but more than (100 − [total annual precipitation {mm}/25]). Also a tropical monsoon climate tends to see less variance in temperatures during the course of the year than a tropical savanna climate. This climate has a driest month which nearly always occurs at or soon after the "winter" solstice for that side of the equator.

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