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Indicators for Promising Accessibility and Mobility Services

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Abstract: Cities are increasingly facing major transportation challenges, and new sustainable solutions are needed. New ICT-enabled services can be part of solving the problems, including both improving and finding new transportation services and providing digital access to different services. It is important to identify which services have the best potential for environmental benefits (e.g., travel reduction leading to lesser emissions), economic viability and spread. Such identification can be carried out with the help of indicators. This article uses four types of new accessibility services to test out a previously formulated set of indicators and suggest changes to make them more useful. Using common indicators for transportation and digital accessibility services seem to support collecting and condensing information about the services and simplifies understanding their benefits and challenges. However, a challenge for this approach is finding indicators that are both specific and broad enough to be useful.

Keywords: ICT; digitalization; societal change; sustainability; indicators

1. Introduction

Today, 53 percent of the world's population live in cities, and this number is expected to grow to 66 percent by 2050 [1]. Cities are therefore critical for global development and are key to realizing a sustainable future. Many cities have decided on ambitious goals for decreasing their energy use and reducing their climate emissions, often more ambitious than the national ones [2]. However, it remains a major challenge for the cities to tackle the negative environmental and climate impacts of transportation. For many European cities planned measures will not be sufficient in order to meet their environmental and climate goals [3,4]. Changes and transitions towards more radical alternatives are required and therefore innovative solutions need to be identified and implemented in order to meet the climate targets [5].

Information and communication technology (ICT) and digital innovations can make a difference in achieving global as well as local climate targets, and can help to make cities both smarter and more sustainable if they are placed in the right context (see e.g., Kramers et al. [6]). However, digital technology offers both possibilities and challenges when used as a tool for reaching climate targets. The main challenges consist of ICTs own carbon emissions [7], a problematic waste handling [8] and rebound effects [9]. Possibilities include potential to substitute travel and material goods with more resource-efficient digital alternatives, intensify use by sharing of resources, optimize use of different infrastructures, inform about effects and long-term changes of society [10].

Radical innovations represent a clear departure from existing practice and fundamental changes in technology only in terms of efficiency but also effectiveness compared to incremental innovations that represent minor improvements or simple adjustments in current technology [11]. The difference can be considered degrees of novel technology. Digitalization enables the emergence of radical service innovations, including in the field of accessibility and mobility ([12–14].

For traveling, the accessibility concept is often used for quantitative analysis to explain the ease of reaching one's destination. For the purpose of this paper, we look at accessibility not as a scale but as a singular phenomenon in line with Waters [15], who describes accessibility as "the ability of individuals to participate in necessary or desired activities for the wellbeing of humanity" (p. 29). Mobility, on the other hand, can be said to represent a movement in space. Accessibility is offered "as a service" (AaaS) when it does not require physical ownership or traveling but can be accessed (e.g., with the help of ICT) at one's current location. Likewise, mobility as a service (MaaS) is mobility that does not require individual ownership of a car (See e.g., Sochor et al. [16,17]). Digital platform technologies connect users and service providers and can offer combinations of services that reduce the demand for transportation and optimize the use of current infrastructures and vehicles [18].

There is widespread research in terms of exploration of different innovations in the transportation sector [19,20], and also tools developed with the aim to evaluate innovations in the field of mobility [21]. However, these are often explorative only or limited to feasibility studies [22]. On the other hand, impact studies are often focused on one type of service innovation or on one sustainability dimension.

In addition, influential scholars and institutions (see e.g., Banister [23–25]) and indicators (see e.g., Black et al. [26]) analyzing and evaluating various sustainable transportation measures, commonly fail to take the non-transport option of digital accessibility into account. As demand-side management measures are considered necessary if the environment and climate impacts of transportation are to reach a sustainable level [3], these digital options need to be considered and analyzed side-by-side with mobility providing services.

There is a need to understand new ICT enabled services to see if they have the potential to reduce transportation demand, transfer to an efficient mode of transportation and make use of the already built transportation infrastructure in a more efficient way. An earlier paper [13] suggests identifying promising services by examining them from three different perspectives:

(1) Is it more environmentally sustainable? Does it reduce negative impacts on the environment?
(2) Is it rewardable? Is value created for an organization? Does it make use of new sustainable business models?
(3) Is it attractive from a user perspective? How big is the spread among users?

This paper aims to test and, if needed, further develop the previously defined indicators in order to make them more useful for a future usage to identify such promising services. Hence, in this paper, we attempt to answer the following questions:

- Is using this approach and the suggested indicators feasible?
- To what extent does this approach support the identification of the most interesting services?
- What are the major benefits and challenges of using this approach and the suggested indicators?
- How could the approach and its indicators be improved to better fulfill its purpose?

2. Indicators for Sustainable Accessibility in Urban Areas

The following section explains the indicators from Kramers et al. [13]. These indicators were formulated through literature reviews.

2.1. Indicators for Environmental Impact

Traveling, with the exception of walking and bicycling, can generally be seen as less environmentally sustainable than remaining where one is [23,24,27–29]. Drawing from the discussions of accessibility and mobility in Section 2, it seems likely that this would be fulfilled with accessibility services. Digital accessibility can reduce the number of trips by bringing a service to one's current place, or to a location close to the user. It could also be achieved through "batching" household activities so that e.g., several errands can be run at once. This leads to fewer and/or shorter trips, which means a lesser environmental impact. As for the traveling that does take place, the environmental impact per traveled kilometer should be reduced.

All of the sources above mentioned the need to move away from private car use to achieve more sustainable forms of mobility. Simply using cars with a lower environmental impact per car and distance traveled is not enough, but the private car needs to be used less in favor of other more sustainable transportation modes. However, when cars are used, the vehicles should have lower emission per person and kilometer traveled [30], including all impacts from a life cycle perspective. Furthermore, another way of reducing the environmental impact is to use cars with a more optimal size for the purpose of their use [30].

The evaluation categories and indicators selected are presented in Table 1.

Table 1. Indicators for environmental impact.

Category	Indicator	Values
1. Reduce traveling overall	1.1. Number of trips	1.1.a. Digital accessibility—Yes/No 1.1.b. Encourages "batching" activities—Yes/No
	1.2. Distance of trips	1.2.a. Encourages neighborhood-based activities—Yes/No
2. Reduce environmental impact per traveled kilometer	2.1. Better modes of transport	2.1.a. Encourages shift to walking—Yes/Possibly/No 2.1.b. Encourages shift to biking—Yes/Possibly/No 2.1.c. Encourages shift to public transportation—Yes/Possibly/No
	2.2. Vehicles with lower emissions per kilometer traveled, including from a life cycle perspective	2.2.a. Number of users per car 2.2.b. Vehicle emissions during the use phase 2.2.c. Vehicle emissions during the production phase

2.2. Indicators for Viability and Business Value

The potential success of service innovations is dependent on their potential to create, capture, and deliver value for relevant stakeholders [31]. Combining literature streams from innovation, sustainable business, management, and marketing studies, five dimensions for identifying promising business models were selected:

(1) Value creation—What type of value the service creates. Here, a type of business that creates only technological value by introducing new environmental technology is not as sustainable as one that also creates social and economic value.

(2) Value capture—Realization of societal and economic profits. Profit models that are based on subscription are seen as more sustainable both for business and for the environment because they utilize resources better.

(3) Customer value offer—Value proposed for the customer. A customer value offer that is based on use rather than being product-oriented is more sustainable.

(4) Uniqueness—Competitive advantage enabled through a differentiation strategy. A business with high differentiation can have long-term effects on the transition industry. If it is based on focus or segmentation, it can just create more markets, which is not necessarily sustainable. Newness to the market/Innovativeness—The degree of familiarity that organizations, users, and industry have with a product or service [32] and distinguishing between different degrees of innovations is evidenced as critical [32,33]. A radical innovation is very interesting in the long run. An incremental innovation will take longer to shift industry and make a big impact.

However, it should be noted that determining business success is largely a subjective process and will vary for each business venture under consideration [34].

The business value indicators are presented in Table 2.

Table 2. Business value indicators.

Category	Indicator	Value
1. Value creation	1.1. Business model archetype	1.1.a. Technological (introduce new environmental technology) (Yes/No) 1.1.b. Social (Address social issues, low-income groups contexts, behavior change, value for stakeholders) (Yes/No) 1.1.c. Economic (change dominant organizational and economic paradigms underlying business activities) (Yes/No)
2. Value capture	2.1. Profit models	2.1.a. Selling (Yes/No) 2.1.b. Leasing (Yes/No) 2.1.c. Subscription (Yes/No) 2.1.d. Pay per use (Yes/No) 2.1.e. Non-profit (Yes/No)
3. Customer value offer (value proposition)	3.1. Mix of product/service (Hardware/software)	3.1.a. Product-oriented (Yes/No) 3.1.b. Use-oriented (Yes/No) 3.1.c. Result-oriented (Yes/No)
4. Uniqueness (competitive advantage)	4.1. Strategy	4.1.a. Cost leadership (Yes/No) 4.1.b. Differentiation (Yes/No) 4.1.c. Focus/Segmentation (Yes/No)
5. Type of innovation	5.1. Newness to the market	5.1.a. Radical innovation (Yes/No) 5.1.b. Really new innovation (Yes/No) 5.1.c. Discontinuous innovation (Yes/No) 5.1.d. Incremental innovation (Yes/No) 5.1.e. Imitative innovation (Yes/No)

2.3. Indicators for Use and Spread

For assessing the use and spread of a service innovation, three different indicators were selected; geographic distribution, adoption, and societal transition.

Geographic distribution tells us where the service is available on a country and city/municipal level and also in which urban context the service is located. Dependent on where in the urban region a certain service innovation is located it will lead to different effects.

Adoption is considered successful when the target group is using the service innovation and is measured by the number of users. Adoption can be focused on individuals, organizations, clusters within social networks and countries [35].

By the use of a socio-technical approach to transitions, it is possible through the multilevel perspective (MLP) [36] to analyze what societal transition that has occurred because of the service innovation.

According to MLP there are three separate levels where transition occur; Niche, Regime and Landscape. New service innovations are "Niches" that affect the current socio-technical system. At the micro level "Niches" act as incubator-rooms for radical novelties, they provide locations for learning processes on many dimensions such as technology, user preferences, regulation, symbolic meaning, infrastructure, and production systems. At the meso level "Regime" refers to the dominant practices, rules and technologies that provide stability and reinforce the current socio-technical system. At the macro-level, the socio-technical "Landscape" is a wider concept, which influences "Niche" and "Regime" dynamics. It includes not only the spatial structure but also the political ideologies, societal values, beliefs, concerns, the media landscape and macroeconomic trends [36]. "Landscape" can put pressure on and destabilize the "Regime", for example by the agreed climate goals and by the diffusion of ICT.

The indicators for Use and Spread are listed in Table 3.

Table 3. Indicators for use and spread.

Category	Indicator	Value
1. Geographic distribution	1. In what countries/cities/municipalities is the service available?	Name of country/city/municipality
	1.2. Type of city	1.2.a. Rising megacity (Yes/No) 1.2.b. Established megacity (Yes/No) 1.2.c. Car-dominated mature city (Yes/No) 1.2.d. Mature advanced city (Yes/No)
	1.3. Urban spread/localization—in which zones is the service available?	1.3.a. Zone 1—Central urban (Yes/No) 1.3.b. Zone 2—Inner suburbs (Yes/No) 1.3.c. Zone 3—Rural and outer suburbs (Yes/No) 1.3.d. Zone 3—Remote (Yes/No)
2. Adoption	2.1. How many registered users are there?	Number of registered users (quantity)
	2.2. How many actual users are there?	Total revenues (amount) Average revenue per user (ARPU) (amount)
3. Level of societal transition	3. What level of societal transition has occurred because of this service?	3.a. Niche 3.b. Regime 3.c. Landscape

3. Materials and Methods

3.1. Data Collection

The authors compiled a database with cases of ICT-based or ICT-supported services for accessibility and mobility. For each case, basic information was collected such as name, description, year founded, and place. The data about the services was collected from peer-reviewed journal articles selected between March and August 2017 and from websites. Cases were first identified in Sweden, followed by the Scandinavian region, Europe, and then across the world. The data collected was limited to innovations originating from the last two decades 1997-2018. The database contained approximately 200 identified cases from across the world.

3.2. Using the Indicators

The service innovations were evaluated using indicators from three different perspectives described in Section 2 [13]:

- Does it reduce negative impacts on the environment?
- Is it rewardable? Is value created for an organization?
- How widely is the service spread? How many users are there, what is the geographic distribution, and what level of societal transition has occurred?

In order to better understand how, and to what extent, these three key aspects could help us assess the collected cases of innovative services, the sets of indicators were tested on a selected number of cases in different service categories (Figure 1). The service categories were identified based on clusters that developed during the process of data collection. As more cases were added, patterns could be observed in terms of types of service. In the end, a few categories could be distinguished through clustering. The cases were selected based on them covering all of the service categories and all being part of trends with increasing market penetration and revenues. The selected cases are: Access without travel (web conferencing), Sharing spaces (co-working hubs), Sharing cars (transportation network services), and Sharing bicycles (dockless bike-sharing system). These cases were selected to try out the indicators and see what types of answers they would generate. Then, the indicators were re-formulated in a way that would cater to the problems encountered when using the first set of indicators.

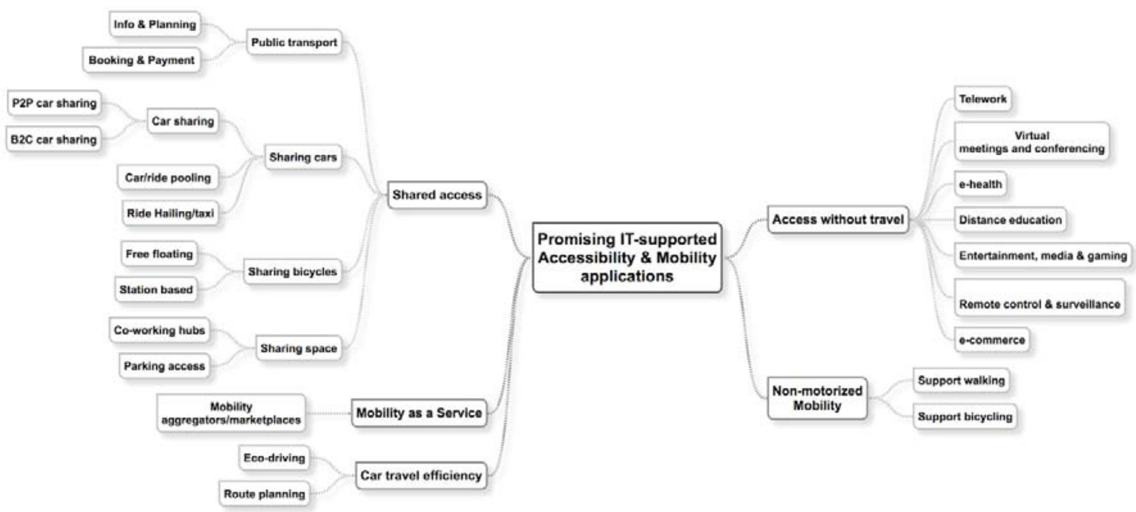

Figure 1. Description of each service category and levels 2–4.

4. ICT Services for Improved Sustainability in Accessibility

The different service categories that were found are (Figure 1):

- Access without travel
- Non-motorized travel modes
- Shared access
- Mobility as a service
- Car travel efficiency

This paper makes use of the following types of services in order to further develop the indicators before using them for their intended purpose:

- Access without travel—Virtual meetings
- Shared access—Sharing spaces—Co-working hubs
- Shared access—Sharing cars—Transportation network services
- Shared access—Sharing bicycles—Free-floating bicycle sharing systems

The intention is to eventually use the indicators to test all of the above-mentioned types of accessibility services for how promising they are.

4.1. ICT Services Supporting Access without Traveling

ICT changes the way we access different products and services, and, as a consequence, also our mobility patterns. The portfolio of services and societal functions that with the help of digital technology can be accessed remotely is rapidly expanding, and now includes access to work, health care, shopping, education, banking, entertainment, gaming, media, etc.

However, the use of these ICT-based services does not automatically lead to a drastic decrease in the demand for travel and transport. Nevertheless, by identifying and better understanding the different transportation implications of different ICT services, and analyzing how technical solutions, economic incentives, corporate and public policy can affect the outcome, may better facilitate the integration of ICT-based accessibility services into the "sustainable transportation toolkit".

Virtual Meetings

Virtual meetings are ICT-enabled services providing remote access to business meetings, seminars, consultations etc. and can thereby reduce the need for business travel.

In addition to audio- and video conferencing (H.323/SIP), web-conferencing (e.g., Skype for Business, Zoom, WebEx) is the most common form of virtual meetings. The different technologies are increasingly overlapping and merged together into what is technically referred to as unified communication.

Several organizations, many of them in the telecom and IT sectors, have reported significant reductions in business travel when investing in unified communications technology, with individual organizations reducing up to 70 percent of their business travel costs per capita through an increased use of virtual meetings [37]. Furthermore, 20 to 35 percent reduction in business travel is reported by different organizations [38]. About one-third of all virtual meetings replace business travel [14], but most of the meetings are new, complementary forms of communicating as discussed by Mokhtarian [39].

4.2. ICT to Support Shared Access

Shared access to resources is seen by many as a potential way to support sustainability [40]. Shared access or the sharing economy can be framed as: an economic opportunity; a more sustainable form of consumption; a pathway to a de-centralized, equitable and sustainable economy; creating unregulated marketplaces; reinforcing the neoliberal paradigm; and an incoherent field of innovation [41].

4.2.1. Sharing Spaces—Shared workspace/Co-working hub

Co-working hubs is a concept that has emerged over the last ten years as the opportunities to "work where you want" have increased with smartphones and laptops instead of fixed phones and desktop PCs. A co-working hub is a place that typically attracts startup companies and small and medium (SME) companies in city centers e.g., in Amsterdam (Spaces, [42]), Stockholm (United Spaces [43]) and New York (WeWork [44]). It provides a different level of memberships such as access to a drop-in flexible desk, a permanent desk and also a permanent room at the hub [45].

During our collection of data, it was found that most co-working hubs are located in city centers. If the co-working hub serves the neighborhood of a residential area, where people live, it can save the distance of trips. If co-working hubs are located close to residential areas, they can also lead to people changing to more energy efficient modes of transportation such as walking, bicycling, and using electric vehicles. The societal gain will be decreased pressure on the current infrastructure and possible by more livable suburbs. It has also a potential for cost effective premises.

4.2.2. Sharing Cars—Transportation Network Services

Sharing a car for going to a similar destination has long been promoted as a good way to utilize necessary car trips (see e.g., Fergusen [46]). But with digital technology and connectedness, many new different ways to share a car have arisen; from digitally supported versions of traditional carpooling to on-demand peer-to-peer varieties of a taxi and various hybrids. To distinguish them here, we use the overview by Shaheen et al. [47] together with other sources as referred to in the text.

Transportation network services refers to taxi-like ridesharing services like Uber [48] and Lyft [47,49,50]. They operate with the help of mobile phone applications. The mobile phone application allows for members to call for a driver who uses their own car and operates as a contractor rather than as an employee. Members can also use the app to pay for the ride, and the cost depends on real-time demand [47,50].

It has been debated what types of environmental effects this type of services may have. While e.g., Li et al. [51] see a tendency for Uber to lessen congestion in cities, the reasons for this effect remain unclear, as most of the literature they use to understand the phenomenon is focused on non-profit ride sharing or carpooling.

4.2.3. Sharing Bicycles—Free-Floating/Dockless Bicycles

During the last few years, bicycle sharing systems (bike-shares) have been gaining popularity in urban areas around the world. In many of these urban areas, they are a relatively new form of transportation [52]. With a few exceptions, most bike-shares are located in and around urban commercial or business centers. There are two typical system models: One where the bicycle is hired from a docking station and then returned to that or another (i.e., Nextbike [53]); and one dockless bike sharing system where bicycles can be placed more freely (i.e., Ofo [54]), but typically from crossroads in the area covered by the system [52]. Bike-shares are typically intended for relatively short trips and as a compliment to public transportation systems [55].

The dockless, or free-floating, bicycle sharing schemes have appeared in several places in the world. Perhaps the most prominent place is China where only two years after the first trails, they could count approximately 16 million bicycles in July 2017 and 106 million users in March 2018 [56]. The Chinese free-floating bike sharing systems also suffer from problems with unequal distribution of supply and demand, as well as malfunctioning bicycles risking to impede the use of the bike sharing system and after disuse occupying public space. Due to the relative newness of these types of systems, not a lot of empirical research has yet been carried out to understand their specific overall effects on travel behavior. However, Qiu and He [57] have estimated positive impacts from free-floating bike-sharing systems on energy use and the environment as well as the economy and public health.

5. Applying the Indicators on the Different Service Categories

The indicators were tested on different service categories. In the service category "Access without travel" the indicators were tested only on virtual meetings and more specifically web-conferencing (Section 4.1). In the service category "Shared Access," the indicators were tested on sharing spaces exemplified by co-working hubs (Section 4.2.1). Transportation network services exemplify sharing cars (Section 4.2.2). The dockless bike sharing systems exemplify sharing bicycles (Section 4.2.3). The options yes or no are evaluated with the help of literature, using results from other studies when applicable, and raw data when applicable. The results of the four tests are collected in Table 4.

Table 4. Using the sets of indicators to describe and assess four service innovation cases.

Environmental Performance Indicators			Services			
Category	**Indicator**	**Values**	**Virtual Meetings**	**Co-Working Hub**	**Transportation Network Service**	**Dockless Bike-Sharing System**
1. Reduce traveling overall	1.1. Number of trips	1.1.a. Digital Accessibility—Yes/No	Yes, virtual meetings can and do reduce the number of mainly business trips. The extent of the impact depends on organizational conditions and prevalent meeting culture. Travel substitution exceeds the generating effects. Similar effects on travel for e.g., health care and education/training.	No, co-working hubs are not better than other workplaces to reduce the number of trips.	No	No
		1.1.b. Encourages "batching" activities—Yes/No	No, virtual meetings allow the participants to meet without traveling,	Yes, the number of trips can be saved if the co-working hub is located in close proximity to other services or household activities.	No	Not directly
	1.2. Distance of trips	1.2.a. Encourages neighborhood-based activities—Yes/No	Yes, in some occasions, participants from one city meet at one location/studio and jointly participate in a virtual meeting there. In this way, only local and shorter trips are needed.	No, the co-working hubs found in the data collection are mainly found in city centers and not in residential areas.	Not specifically	Not directly
2. Reduce environmental impact per traveled kilometer	2.1. Better modes of transport	2.1.a. Encourages shift to walking—Yes/Possibly/No	Possibly, in the 1.2 case, the trips to a local gathering may be suitable for walking.	Possibly, if co-working hubs are located in close proximity to public transportation and if it's located close to residential areas.	Not directly, but may with decreased car ownership	Not directly
		2.1.b. Encourages shift to biking—Yes/Possibly/No	Possibly, in the 1.2 case, the trips to a local gathering may be suitable for biking.	Possibly, if the co-working hub is located close to bicycle lanes and also if it's located close to residential areas.	Not directly, but may with decreased car ownership	Yes, both directly through providing easy-access bikes and indirectly through improving attitudes toward bicycling
		2.1.c. Encourages shift to public transportation—Yes/Possibly/No	Possibly, in the 1.2 case, the trips to a local gathering may be suitable for public transportation.	Possibly, if it's located close to public transportation, it can encourage a shift to public transportation.	Not directly, but may with decreased car ownership	Not directly
	2.2. Vehicles with lower emissions per kilometer traveled, including from a life cycle perspective	2.2.a. Number of users per car	No, no car needed.	No impact	Yes	N/A
		2.2.b. Vehicle emissions during the use phase	No, no vehicle emissions. However, the equivalent climate impact of the information and communication technology (ICT) equipment use during virtual meetings is, from a life cycle perspective, orders of magnitudes less than the impact from the travel replaced.	No direct impact. Currently, vehicles using electricity as the only source of power have a very short range, and would therefore be useful in a scenario where co-working hubs serve the local neighborhood where people live.	Potentially, dependent on the fuel used.	N/A
		2.2.c. Vehicle emissions during production phase	No vehicle emissions. See 2.2.b.	No impact	No	N/A

Table 4. *Cont.*

Business Value Indicators			Services			
Category	**Indicator**	**Value**	**Web-Conferencing**	**Co-Working Hub**	**Transportation Network Service**	**Dockless Bike Sharing System**
1.Value creation	1.1. Business model archetype	1.1.a. Technological (introduce new environmental technology) (Yes/No)	No	No, co-working hubs make use of existing technologies, which means it is not a new environmental technology	No, built using existing technology: the business model is the innovation	Yes. The companies use the dockless bike-sharing system as a platform to launch other services. The dockless bike-sharing service itself has a traditional business model.
		1.1.b. Social (address social issues, low-income groups contexts, behavior change, value for stakeholders) (Yes/No)	No	Yes, a co-working hub can create value for both the users of the hub and society, e.g., the creation of stronger local communities and the integration of citizens living under different economic conditions.	Yes	Yes, it delivers functionality instead of ownership.
		1.1.c. Economic (change dominant organizational and economic paradigms underlying business activities) (Yes/No)	1.1.c. Yes, there is evidence that companies benefit economically by introducing web-conferencing solutions on a large scale in the company.	Yes, it will change the dominant organizational norm that people need to be at a specific workplace.	Yes	No, according to Daxue consulting [58]. However, it could also be argued that bike sharing could have a big impact on urban transportation if more infrastructure and ICT is integrated to make their access easy and simple.
2. Value capture	2.1. Profit models	2.1.a. Selling (Yes/No)	2.1.a. Yes, for businesses, but no for private persons	No, there's nothing to sell, since it's a sharing model.	No	No
		2.1.b. Leasing (Yes/No)	2.1.b. Yes	No	No	No
		2.1.c. Subscription (Yes/No)	2.1.c. Yes	Yes, there are different subscription models used in the different co-working hubs.	No	Sometimes
		2.1.d. Pay per use (Yes/No)	2.1.d. Yes	Yes, for some of the services in a co-working hub, a pay-per-use model is used.	Yes	Sometimes
		2.1.e. Non-profit (Yes/No)	2.1.e. No	Yes, co-working hubs are sometimes housed in a café or a library, where there are no fees charged for the use.	No	No
3. Customer value offer (value proposition)	3.1. Mix of Product/service (hardware/software)	3.1.a. Product-oriented (Yes/No)	3.1.a Yes, if the web-conferencing equipment is a shared resource.	No	No	No
		3.1.b. Use-oriented (Yes/No)	3.1.b. Yes, web-conferencing services are often offered as a service.	Yes	Yes	Yes
		3.1.c. Result-oriented (Yes/No)	3.1.c. Yes	No	No	No

Table 4. *Cont.*

Business Value Indicators			Services			
Category	**Indicator**	**Value**	**Web-Conferencing**	**Co-Working Hub**	**Transportation Network Service**	**Dockless Bike Sharing System**
4. Uniqueness (competitive advantage)	4.1. Strategy	4.1.a. Cost leadership (Yes/No)	4.1.a. Yes, if web conferencing is compared to travel, and especially long-distance travel.	No, currently it's not the price that is the main selling point for co-working hubs.	Not officially, but in practice	Yes
		4.1.b. Differentiation (Yes/No)	4.1.b. Yes, web conferencing solutions are targeting different customers; e.g., Adobe Connect is commonly used in universities and education, while Skype for Business is targeted towards businesses and public institutions (remm.se).	Yes, it's the community that comes with the hub.	Yes	Yes, it is a differentiation strategy with a type of ICT inbuilt technology for tracking and booking, inbuilt technology for locking, etc.
		4.1.c. Focus/Segmentation (Yes/No)	4.1.c. Yes, see above 4.1.b.	Yes, the focus is currently on small to medium-sized enterprises (SMEs) and startups.	No	No
5. Type of innovation	5.1. Newness to the market	5.1.a. Radical innovation (Yes/No)	5.1.a. No	No	Potentially	Yes, it uses platform technology to create network effects.
		5.1.b. Really new innovation (Yes/No)	5.1.b. No	No-except if it's localized in the outer regions of the residential areas.	Potentially	No
		5.1.c. Discontinuous innovation (Yes/No)	5.1.c. No as an ICT innovation, but yes when it leads to a shift from using different means of transportation to using ICT technologies.	No, not really a game-changer at first sight.	Potentially	Yes
Use/Spread Indicators			**Services**			
Category	**Indicator**	**Value**	**Web-Conferencing**	**Co-Working Hub**	**Transportation Network Service**	**Dockless Bike Sharing System**
1. Geographic distribution	1. In what countries/cities/municipalities is the service available?	Name of country/city/municipality	It is available globally, although not in locations without network access.	Co-working hubs are available globally in most cities of the world.	Many cities all over the world, although some cities and countries are re-formulating their laws to prevent these types of services. There are more in the United States (USA).	Bike-sharing is available in many parts of the world. However, the dockless bikes have launched relatively recently (2014) and therefore, there are still many cities without them.
	1.2. Type of city	1.2.a. Rising megacity (Yes/No)	1.2.a Yes	Yes, available in Nairobi, Kampala, and Jakarta.	Yes, available in e.g., Dhaka, Bangladesh	Yes
		1.2.b. Established megacity (Yes/No)	1.2.b Yes	Yes, cities such as New York.	Yes, available in e.g., Tokyo, Japan	Yes
		1.2.c. Car-dominated mature city (Yes/No)	1.2.c. Yes	Yes, in cities such as Detroit and Atlanta	Yes, strong in e.g., Los Angeles	Yes

Table 4. *Cont.*

Use/Spread Indicators			Services			
Category	**Indicator**	**Value**	**Web-Conferencing**	**Co-Working Hub**	**Transportation Network Service**	**Dockless Bike Sharing System**
		1.2.d. Mature advanced city (Yes/No)	1.2.d Yes	Yes, in cities such as Amsterdam and Stockholm	Yes, available in e.g., Amsterdam	Yes
	1.3. Urban spread/localization: in which zones are the service available?	1.3.a. Zone 1—Central Urban (Yes/No)	1.3.a. Yes	Yes, they are localized in city centers and hot tech spaces alike.	Yes	Yes
		1.3.b. Zone 2—Inner suburbs (Yes/No)	1.3.b. Yes	No, this type of service is currently not available in local nodes.	Yes	Yes
		1.3.c. Zone 3—Rural and outer suburbs (Yes/No)	1.3.c. Yes	No	Not always	No
		1.3.d. Zone 3—Remote (Yes/No)	1.3.d. Yes	Yes, ski resorts are one example of a remote place where co-working hubs currently are available.	Not normally, tends to be focused on cities and their surrounding areas	No
2. Adoption	2.1. How many registered users are there?	Number of registered users (quantity)	Skype has 300 million users monthly [59]	Approx. 1.27 million people worked in co-working hubs worldwide in 2017 [60].	For Uber alone, there are 75 million riders and three million drivers registered [48]	One example: Ofo (200 million users) [54]
	2.2. How many actual users are there?	Total revenues (amount)	Web conferencing market is USD 3.3 billion, growing at 6% annually [61].	In this particular case, the lowest level of subscription requires a payment, which means that the registered number of users is identical to the actual number of users.	According to Statista.com [62], ride-sharing, including online carpooling platforms, online platforms that let user book rides, and taxi companies that offer services through an app had a revenue of USD 60 billion in 2018.	The number of public-use bicycles available around the world has more than tripled between 2013–2016. By the end of 2016, nearly 2.3 million bikes were available to the public around the world, with 1.9 million of these located in China alone. With 430 bike-sharing programs, China is the clear frontrunner in terms of bike-sharing [63].
		Average revenue per user (ARPU) (amount)	The web conferencing market is projected to grow at an approximate Compound Annual Growth Rate of 10 percent annually from 2016 to 2024 [61].	Worldwide, there are an average of 129 members per co-working hub, and there are 15,500 co-working hubs globally [60].		
3. Level of societal transition	3. What level of societal transition has occurred because of this service?	3.a. Niche	3.1.a. Yes	Yes	Yes	Yes
		3.b. Regime	3.1.b. Partly, but there are still many cultural and organizational barriers before it can be used to its full potential.	No	No	No, for cities, there are a number of problems with the dockless bikes. Thousands of bikes are parked everywhere around the city, and many are not working because nobody takes care of them.
		3.c. Landscape	3.1.c. Yes, it is used to cut travel cost in many organizations, and also as an argument to reduce environmental impact.	No. There are still many institutional problems with a co-working hub for people employed in organizations other than smaller firms up to seven persons. Letting people work from where they want is not accepted by many larger firms. Many types of insurance do not cater to this type of solution. Also, who should pay for the extra cost that a service such as this will lead to?	Yes	No

6. Revising the Indicators

As the selected services were assessed and the environmental indicators were tested in practice, they showed promise as a framework for better understanding strong and weak points of MaaS and AaaS services. The services are described in a condensed and transparent way, facilitating comparison and visualizing synergies between different services. They also offer a common analysis framework for both more traditional mobility services and digital accessibility solutions together.

However, the indicators leave room for improvement. This chapter discusses some of the problems with the previously presented indicators with a starting point in the results of testing them. Thereafter, new versions with changes are suggested.

6.1. Revising the Environmental Impact Indicators

The experiences of testing the framework applying the four different services were as follows.

In the case of virtual meetings, both the assessment of whether a service reduces the number of trips and the assessment of reduced environmental impact per travelled kilometer bring up both indirect and direct impacts and differentiate between them. This motivates differentiating between direct and indirect effects also in the evaluation, for example by adding another column for indirect effects. Regarding assessment 2.2.b, it is also clear that the question regarding vehicle emissions may not only be relevant for vehicles, but for any kind of accessibility-enabling equipment. Another solution could be that we clarify efficient ICT as a pre-condition for the positive environmental impact of AaaS, as stated in question 1.1.a.

In the case of co-working hubs, 1.2.a discusses the actual impacts of co-working hubs where they are located today, rather than the effects in a perfected case. This motivates clarifying the purpose of the indicator. A suggestion could be that this is integrated within the indicator that discusses direct and indirect effects as above, e.g., by inviting the evaluator to list conditions for the effects.

In the case of transportation networks, this evaluation also shows a problem with differentiating between direct and indirect effect and a need for discussing conditions for optimal performance. For example, while transportation networks may have a direct negative impact on walking for that particular trip, if it lessens car ownership it may have an indirect positive impact. The evaluation also suggested that there is a need to differentiate between "number of users per vehicle while it is in use" and "number of users per vehicle including when it is not in use".

In the case of dockless bike sharing systems, almost all the indicators differentiate between direct and indirect effects. This suggests that these should be differentiated within the indicators themselves.

A problem that becomes evident in all the tests is that the indicators are partially, but not fully interdependent. If some indicators had been fully dependent on the others the indicators could have been formulated as a flowchart instead. However, while the questions regarding the mode of transportation are dependent on the answer to the question 1.1.a about whether or not the service provides access without travel, they are not dependent on the question about batching activities. However, the indicators do have an order that could be clarified.

A suggestion of revised environmental indicators is showed in Table 5.

6.2. Revising the Indicators for a Business Model

These indicators were closer to the revised literature and relatively straight forward in terms of what they assessed. As seen in Section 4, using these indicators was rather unproblematic. Eventually, no changes were considered necessary for the business models indicators.

6.3. Revising the Indicators for Use and Spread

When testing the indicators for use and spread the following observations were made:

The Urban Spread/Localization indicators proved to be useful since they highlight that many of the sharing services are only available in city centers, while they could be useful for the fulfillment of environmental and climate targets if they also were available in remote areas.

Table 5. Revised environmental indicators.

Category	Indicator	Values	Direct Effects, Including Conditions	Indirect Effects, Including Conditions
1. Reduce traveling overall	1.1. Number of trips	1.1.a. AaaS—Yes/No 1.1.b. Encourages "batching" activities—Yes/No	1.1.a. 1.1.b.	1.1.a. 1.1.b.
	1.2. Distance of trips	1.2.a. Encourages neighborhood-based activities—Yes/No	1.2.a.	1.2.a.
2. Mobility: reduce environmental impact per kilometer traveled	2.1. Better modes of transport	2.1.a. Encourages shift to walking—Yes/No 2.1.b. Encourages shift to biking—Yes/Possibly/No 2.1.c. Encourages shift to public transportation—Yes/Possibly/No	2.1.a. 2.1.b. 2.1.c.	2.1.a. 2.1.b. 2.1.c.
	2.2. Vehicle emissions	2.2.a. Number of users per vehicle when in use 2.2.b. Number of users per vehicle overall 2.2.c. Vehicle emissions during the use phase 2.2.d. Vehicle emissions during the production phase	2.2.a. 2.2.b. 2.2.c. 2.2.d.	2.2.a. 2.2.b. 2.2.c. 2.2.d.

The analyzed service innovations are all "Niches". They are however characterized by uncertainty because they have not yet resulted in best practices, rules of thumb and stable routines [36]. The destabilizing "Landscape" pressure on the "Regime" that is of interest in this article is the already agreed environmental goals. It is therefore of interest to know what "Regime" dimensions that have started to destabilize. Examples of "Regime" dimensions are: "Market, user preferences"; "Industry"; "Policy"; "Science"; "Culture"; and "Technology" [36]. The indicator 3. "Level of societal transition" has therefore been adjusted to the following structure: The dimension "Market, user preference" is represented by indicator 2. Adoption. The dimension "Policy" is divided into two Indicators; 3.1—Laws and 3.2—Regulations. Policies in this article should be seen in the context of the climate and environmental goals, asking whether there policies that need to be developed in order for the service to be able to fulfill these goals. The dimensions Technology and Culture are based on indicators developed by Kramers et al. 2014 [16]. Technology reflects if the technology used is existing (indicator 4.1.a) or new (indicator 4.1.b) to households. Culture reflects whether households are used to the service concept (indicator 5.1.a) or not (indicator 5.1.b) (i.e., because they already are used to other types of app-based services or if the service requires new knowledge that user doesn't have today). The Industry and Science regime dimensions are not yet covered by the indicators here. They need to be further developed.

The suggested revised indicators for spread are shown in Table 6.

Table 6. Revised indicators for spread.

Category	Indicator	Value
1. Geographic distribution	1. In what country/city/municipality is the service available?	Name of country/city/municipality
	1.2. Type of city	1.2.a. Rising megacity (Yes/No) 1.2.b. Established megacity (Yes/No) 1.2.c. Car-dominated mature city (Yes/No) 1.2.d. Mature advanced city (Yes/No)
	1.3. Urban spread/localization: in which zones is the service available?	1.3.a. Zone 1—Central Urban (Yes/No) 1.3.b. Zone 2—Inner Suburbs (Yes/No) 1.3.c. Zone 3—Rural and Outer Suburbs (Yes/No) 1.3.d. Zone 3—Remote (Yes/No)
2. Market/Adoption	2.1. How many registered users are there?	Number of registered users (quantity)
	2.2. How many actual users are there?	Total revenues (amount) Average revenue per user (ARPU) (amount)
3. Policy	3.1. Law	3.1.a. Is there a need for new laws because of the service? (Yes/No) 3.1.b Has the law changed because of the service? (Yes/No)
	3.2 Regulation	3.2.a. Is there a need for new regulation because of the service? (Yes/No) 3.2.b. Has regulations changed because of the service? (Yes/No)
4. Technology	4. Newness to the households	4.1.a. Is it an existing technology (Yes/No) 4.1.b. Is the technology new for households in the city (Yes/No)
5. Culture	5.1 Use of individuals	5.1.a. Is it an existing service concept(Yes/No) 5.2.b. Is the service concept new for households in the city (Yes/No)

7. Discussion

By testing the indicators their usefulness were evaluated. As several of the services showed potential for environmental benefits only under certain conditions, this could help stakeholders establishing such conditions and to design the services in ways that make them more environmentally beneficial, as well as a guiding principle for how to develop future services.

One of the challenges when formulating these types of indicators is to try to cover the complexity of the services' effects, including indirect and rebound effects. The indicators are qualitative to allow for reasoning regarding the effects, but that also means that they are more dependent on the person using them. Also, the services may have both positive and negative indirect effects that are not easily captured in an evaluation. Many of the digital accessibility services have a huge potential to substitute travel, but the potential is seldom fully materialized due to numerous counteracting factors. Furthermore, some of the services may have different effects when scaled up or dependent on how they are utilized. While the framework of analysis was expanded in order to capture some of this, the question of where to draw the boundaries of a service's effects remains hard to answer. Likewise, because of how interdependent the effects are, the indicators will unavoidably overlap or affect each other. As an example, if a service enables shorter trips, it is more likely that the user will choose to walk or bike to the destination rather than take the car, even if the service in question does not directly address modal choice. There is also an overlap between indicator types. For example, the environmental impact effect is dependent on societal transformation factors.

Another challenge is using quantitative data to compare different services. Black et al. [26] use the term "indicators" referring to quantifiable measures of performance, using them to e.g., evaluate transportation policies. However, in this case, it is not possible to securely quantify any differences in the areas our indicators are based in. Additionally, it is not their actual performance that is being assessed, but rather how promising they are. This means that our indicators only have to indicate potential and not actual performance.

When it comes to environmental performance and resource efficiency, the business model can have an impact. Subscription models make it possible to consume resources in a more efficient way. More people can share the same resource and use it more frequently. A subscription model can also contribute to the circular economy since there are benefits for the providing company to make products that last longer. In addition, a subscription model can lead to more revenues for a company compared to product sales. Selling a product gives only revenue one time, while a subscription model will generate revenues over many years. Combining a subscription model with the sharing of the resources will lead to the fact that the same product can generate revenues from several customers.

The Services Category Access without travel is per definition directly available globally, while mobility services which consist of both hardware (the vehicle) and software (the app), which makes them less widespread. There are certainly other barriers than the physical such as regulations, laws, and politics that sometimes makes it difficult to spread services even if they are software based. Many of the services identified in this study have very rapidly spread around the globe thanks to the fact that they are part of the platform economy and do not need to invest in equipment. They can instead lean on others' resources. Lyft and Uber are examples of this phenomenon.

It seems like city type does not influence where the services are available. They are already available almost everywhere. The urban spread indicator supports a greater variation; many of the services are only available in city centers. From an environmental point of view, for some types of innovation, it would be beneficial if they were also available in inner and outer suburbs.

Figures about the adoption rate in number of users were difficult to find. Therefore figures showing market value and annual growth rate were used. Many of the services have a very promising future according to the annual market growth rate.

Many of the services are niches, which still are in their early stages, meaning that there are barriers that need to be overcome at the "Regime" level. These barriers are everything from employment rules, norms, cultural and organizational barriers to questions on how to handle the countless numbers of bikes parked or left in every corner of the cities. At the "Landscape" level, many of the services benefit from the fact that governments around the world support the Agenda 2030 and the Sustainable Development Goals (SDGs) as well as other national, regional and local environmental targets. They see themselves as a solution to many of the problems.

The intended outcome of this research has been to facilitate the identification of promising ICT services with the potential to support more sustainable access and mobility in cities, by further developing a previously defined set of indicators. The next step will be using the renewed indicators for all the identified services in order to identify the most promising ones and formulate recommendations for what variations should be encouraged for better environmental performance.

8. Conclusions and Recommendation

This paper sets out to test and further develop a set of previously defined indicators, in order to make them more useful to identify promising services for sustainable mobility and accessibility.

Testing the indicators on four service innovation cases showed that it was possible and feasible to use them, and that the assessments helped identifying to what extent and under what conditions these services could contribute to more sustainable mobility and accessibility in urban areas. The approach used and the information gathered generates an extensive, multi-perspective description of different available options, providing the basis for a better understanding of each service innovation case, as well as offering the possibility to compare the different options. By looking at both accessibility and mobility as a service in the same context, there is an opportunity to find more optimized and combinations of solutions for future smart sustainable cities.

By testing the indicators, the need to change and to complement the indicators was also identified, and as a consequence, a number of changes of the environmental, spread and use of indicators have been suggested.

However, the test also revealed the challenge of collecting, interpreting and comparing the amount of data and information required for the indicators for each case, and then to compare this information on an aggregate level. Some indicators may have missing or uncertain data, and have to be based on estimations or assumptions. This calls for that the level of uncertainty should be indicated when using the indicators.

Moreover, when making a comparison of the indicators for e.g., the environmental performance of different cases, the difference in type and character of data and information provided makes a direct comparison between cases difficult. Therefore, making a ranking of various services, solely based on quantitative data in this set of indicators, may not be advisable.

Although the suggested approach has limitations, it could offer policy makers, market actors and researches a useful tool or "checklist", in whole or selected parts, when analyzing, comparing and taking informed decisions about different sustainable mobility and accessibility options in urban areas. If services are promising from an environmental perspective but have limitations in how they create value for a viable business and users' needs there might be a need for to highlight these opportunities. The services can be promoted through policies, innovation and development support as well as new business approaches. Further investigations of such services are needed.

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