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"Smart" Tools for Socially Sustainable Transport: A Review of Mobility Apps

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Abstract: In the smart city, information and communications technologies (ICTs) are proposed as solutions to urban challenges, including sustainability concerns. While sustainability commonly refers to economic and environmental dimensions, the concept also contains a social component. Our study asked how smartphone applications (apps) address social-sustainability challenges in urban transport, if at all. We focused on transport disadvantages experienced due to low income, physical disability, and language barriers. A review of 60 apps showed that transport apps respond to these equity and inclusion issues in two ways: (a) by employing a universal design in general-use apps, including cost-conscious features, and providing language options; and (b) by specifically developing smartphone apps for persons with disabilities. The article discusses the study by positioning it in the literature of smart cities as well as socially sustainable transport.

Keywords: smart transport tools; smart and sustainable; social-sustainability

1. Introduction

One of the primary concerns for urban areas in the 21st century is sustainability in using resources and in maintaining environmentally conscious approaches to urban development. While not explicitly under the umbrella of sustainability, cities attempt to address issues of equity and inclusion as well. In the advent of the smart city ("Places where information technology is combined with infrastructure, architecture, and everyday objects, and even our bodies to address social, economic, and environmental problems" [1]) and its potential in solving urban problems, specifically in encouraging efficiencies in urban infrastructure and services, cities have been increasingly incorporating smart technologies in their quest for sustainability. The important junction of smart technologies and sustainability has not been missed in the academic literature, where the current debate explores the relationship between information and communications technologies and the concept of sustainability [2,3].

In his seminal work on smart cities, Townsend [1] highlighted that the application of information technologies has proliferated in urban transportation systems more than in other urban planning subfields. The use of smart city technologies in transportation systems includes smartphone applications (apps) for various purposes, such as real-time transit information, measurement of carbon dioxide emissions, information about low-cost travel options, and navigation information for people with accessibility needs.

In the academic debate, smart cities are criticized for their focus on the economic and environmental dimensions of sustainability while disregarding social dimensions (see e.g., [4]). In addition, our literature review and document analysis (discussed in Section 4) indicated that, in the academic discourse, the joint mention of smart city and social sustainability (equity) was not significant. This can partly be explained through the evolution of sustainability from an environmental standpoint and its historic focus on the economy and environment. To gain a better understanding of the reality outside the academic literature regarding the application of smart technologies to social

sustainability, we conducted a survey of 60 smartphone transport apps to assess the features they offer in light of equity and inclusion. We share the findings in this paper.

The paper first provides a background on sustainability and sustainable planning while referring to the definition in the 1987 *Brundtland Report* and highlighting the lack of clarity in the definition and in the meaning of social sustainability. The next section examines urban sustainability and transport equity and inclusion by delving into what constitutes sustainable transport and the impact of transport on shaping communities. Planners and citizens alike are looking to smart technologies as tools for solving urban challenges. The concept of smart technologies is introduced in relation to sustainability followed by the role they play, if any, in socially sustainable transport. Findings from document analysis of academic literature are contrasted with the findings of our study, which we discuss along with the method of investigation and data collection used.

The overarching goal of the study is to contribute to research at the intersection of socially sustainable transport and technology. An objective of the paper is to bring forth issues of social sustainability in the smart discourse. In discussing the social aspect of sustainability in relation to an emerging technology, this paper will contribute to breaking the historical persistence of the focus of sustainability on the environment and economy only. The paper will also raise questions of equity and inclusion in urban transport and paint a realistic picture of the potential and limitations of smart technologies to contribute to these issues.

2. Sustainability and Sustainable Planning

Discourse on the topic of sustainability often references the vagueness of the concept and includes the frequently cited definition of the term put forth in 1987 by the well-known *Brundtland Report* [5]. According to the report, "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [6] (p. 291). It is widely accepted in the literature about sustainability that the "needs" mentioned in the report are threefold: economic, ecological, and social [7,8], while [9] lists four "needs": cultural, political, ecological, and economic. *Social* is a broad concept that includes both culture and politics; as such, the discussion in this paper will reference the three needs, which are commonly referred to as the 3Es (economy, environment, and equity).

The definition in the *Brundtland Report* has been adopted across various fields. It is especially relevant in urban planning; as [5] said, "Sustainability and planning have much in common" (p. 507). Planning commonly involves balancing competing needs, including those of future generations, which sustainable development stands to protect. Sustainable policies should include the preservation, maintenance, and strengthening of all communities and their overall quality of life through a variety of community services and infrastructures. The ethical principle of equity, particularly intergenerational equity, is central to the concept of sustainability.

Consistent in various perspectives on cities is that they play a part in creating sustainability [7–12]. Ensuring urban sustainability (which is the focus of our paper) then becomes of utmost importance. According to the European Environment Agency, one of the five goals that creates urban sustainability is "ensuring equal access to resources and services" [13]. This entails the provision of services and infrastructures to all members of the community, ensuring a level of affordability and access to service and removing barriers to service. Technology is expected to play an increasing role through initiatives that promote connectivity and ubiquitous data sharing. Leveraging these new resources to benefit underserved populations is one example of where social and technological dimensions can be better aligned.

3. Social Sustainability in Urban Transport

While economic growth remains essential, development must not only meet present concerns for growth, it must do so in a context that includes the long term safeguarding of social and environmental resources. Sustainability policies should include the preservation, maintenance, and strengthening

of all communities and their overall quality of life through a variety of services and infrastructures. This will require significant changes in planning, lifestyles, population growth, and especially in technology. Overall, the concept of social sustainability can be defined according to two points:

Intergenerational equity: the success of cities of the future will largely depend upon the legacy current cities leave on resources and the environment. Capital assets passed on to the next generation must be at least of equal value.

Social equity: implies a fair and equitable distribution of resources among the current generation. In terms of the built environment, the metropolitan area should provide a place of equal opportunity and not be an agent of segregation.

Plans for urban sustainability generally address transportation, housing, and employment and their effects on air quality, energy use, economic prosperity, and social equity. Recommended policies often include transit-oriented development; mixed-use developments; urban infill; brownfields redevelopment; more public transit use; active transportation; and better transportation information. This paper specifically examines social sustainability in transportation systems, as [14] say they have far-reaching effects in social and economic opportunities, including employment and prosperity, health and well-being, education, and access to information.

Transportation mobility promotes participation in most societies. The basic concept behind "sustainable transport" is to make transportation, land-use, and resource decisions in a manner that does not preclude transportation options for current or future generations or any segment of populations. This is an initiative that broadens the scope of transportation decisions so that economic, environmental quality, and social equity considerations are balanced in the short- and long-term [14]. At the national policy level, the concept of sustainability, including its applicability to communities, transportation, and the environment, is quickly emerging as a key issue. As mentioned, sustainability is a frequently used concept whose exact meaning is not well-established. A socially sustainable transport system is, among many things, one that:

- is affordable and saves travel costs, operates efficiently, offers a choice of transport mode, and supports a vibrant economy;
- is inclusive and provides options for persons of various abilities and financial as well as linguistic capabilities;
- ensures opportunities for meaningful public involvement in the transportation planning process, particularly for those communities that most directly feel the impact of projects or funding choices;
- distributes the benefits and burdens from transportation projects equally across all income levels and communities;
- provides high quality services—emphasizing access to economic opportunity and basic mobility—to all communities, but with an emphasis on transit-dependent populations; and
- equally prioritizes efforts both to revitalize poor and minority communities and to expand transportation infrastructure.

Community-based organizations and low-income and minority residents that seek to improve their communities are recognizing the significant role played by transportation in shaping local opportunities. Efforts to challenge inequitable transport policies have become increasingly sophisticated to encompass a broad range of related social impacts. In the advent of the smart city, urban planners, governments, and citizens consider smart solutions promising for solving urban challenges, including urban transport. Among these include incorporating information and communications technologies (ICTs) to improve the transport experience.

Rapid changes in technology and changing patterns in travel behavior are having significant impacts on urban transportation mobility. Because ease of movement within and between urban places is a critical element of social, economic, and environmental vitality, the evolution of complex systems for moving people, goods, and information is the focus of considerable global attention. Modal options in the future will be different from those we experience today, perhaps in unexpected ways. Cities will

seek to implement "intelligent", smart, and "sustainable" practices as they plan for and analyze the mobility needs of their populations. In the process, these practices will shape and reshape urban landscapes. History has shown that each era of transportation innovation has also coincided with cultural shifts.

4. The Intersection of Smart and Sustainable

According to [3], the intent of smart cities, which, as quoted previously, he defines "as places where information technology is combined with infrastructure, architecture, and everyday objects, and even our bodies" (p. 9) is to solve problems of the economy, environment, and those of social nature. This implies that the purpose of smart cities is inherently to attain sustainability by addressing its three dimensions. A slightly different sentiment is reflected by [4], who highlights that the smart concept merely encourages sustainable practices in the three dimensions of sustainability. However, the author argued that regardless of the advances to sustainable practices technology affords in all dimensions, socially sustainable considerations are not optimized by the smart city. Similarly, [15] state that one of the challenges smart cities face is in developing technologies that work in the interest of fairness and equity. This reflects that the introduction of smart in sustainability has followed the historical focus on the environment and economy. The same pattern is observed in the debate in academic literature on the intersection of smart and sustainability, i.e., less focus is given to the social dimension of sustainability.

While the integration of smart technologies (ICTs) and sustainability is gaining traction as a topic of discussion in the academic debate [2], we found in our study that there is still less focus in the academic debate on smart solutions that create social sustainability. Based on the results of an initial search using Google Scholar, we examined approximately 90 publications on topics of smart cities and technology, sustainability, and equity and inclusion. We focused on recent sources that would be more likely to draw together these themes or at least include each as components of contemporary urban discourse. We then performed a keyword frequency analysis of the selected documents, which resulted in 4100 mentions of smart or "technology"; 2197 mentions of "sustainability"; and 710 mentions of "equity" or "inclusion". This allowed us to assess the relative weight of these topics. The keyword analysis helped to identify documents that potentially included the three topics of interest (see Figure 1: Venn diagram of topics/keywords).
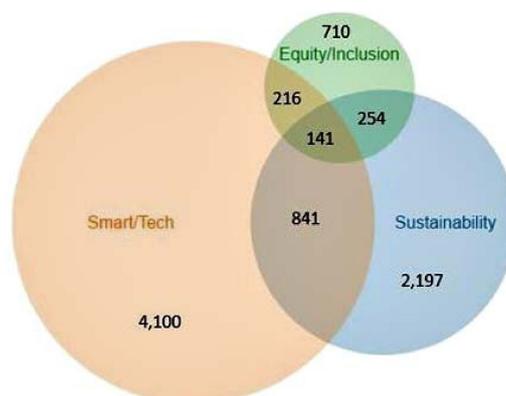
Figure 1. Document analysis and keyword co-mentions (note: numbers show the frequency of (co)mentions).

The keyword analysis identified 20 documents, which along with sustainability and smart cities (or technology) also mentioned equity or inclusion. As shown in Figure 1, there was a small number of mentions of equity or inclusion related to smart cities or sustainability. It is interesting to note in these cases how equity was being connected to sustainability and also to technological aspects of cities (i.e., smart cities). There are many perspectives, applications, and implications of the concept of equity. Among those included equity as part of the planning process, as inputs and also as outcomes.

Several authors acknowledged that social exclusion and inequity are critical problems to be addressed, see e.g., [16]. Technologies as part of "smart cities" are sometimes seen as having the potential to increase citizen engagement [17–19]. These notions are common among planners who see information and communications technologies as removing barriers from government and public interaction and information exchange.

Overall, the joint mentions of sustainability, technology, and equity fell into six general categories. These include citizen engagement, citizen involvement in governance and the planning process, digital divide/digital inclusion, detecting inequality and disadvantage, human and social capital, and general critiques about the ineffectiveness of technology in addressing social inequity. There is a notable void in the literature that explores the junction of technology and social sustainability, which is the focus of this article.

5. Smart Beyond the 2Es?

To gain a better understanding of the junction of technology and social sustainability, we designed a study that explores this junction outside of the academic literature. The study examined the application of information and communications technology (smart tools) in addressing a social dimension of sustainability in transport. In Section 3 we provide a list of what constitutes sustainable transport. For the purpose of the study, we focus on three issues in the list: travel cost saving, and access to transport for people of varying body abilities and language proficiency. We selected smartphone apps as the smart mobility tool of choice for this study as they have become ubiquitous in various aspects of urban living, with a high presence in transport-related functions. Smartphone apps are "software programs for mobile device operating systems..." [20] (p. 1) And their use for daily urban living is growing rapidly. In 2015, out of the 77% Americans who owned smartphones, 68% of them used apps, with 38% using 20 or more apps and 7% using 50 or more apps [21]. The app technology notably enables the shared economy through platforms such as Uber and Airbnb; provides social connectivity: Facebook and Twitter; assists navigation and travel: Waze and Google Maps; provides essential assistive information for visually impaired persons: BlindWays, BlindSquare; and so on. According to [22], by 2017 there will have been more than 268 billion app downloads. In the study, we asked: What role do mobility apps play, if at all, in making urban transport socially sustainable, i.e., equitable and inclusive in relation to cost, disability, and language barriers? To investigate the state-of-the-art, we examined 60 smartphone transport apps.

6. Data Collection and Research Method

6.1. Data Collection

We collected data by performing Google searches that are commonly used to find apps, and used keywords listed in Table 1.

Step 1 Using terms in Category-1 in Table 1 resulted in several apps for our collection on the first pages of each Google search. However, when using terms in Category-2, we included the first, second, and third pages of the Google search results to identify a sufficient number of apps. Our initial search resulted in a list of approximately 90 apps.

Step 2 The next step looked for these apps in the Apple Store and Google Play in the following manner: entering the name of the app in the Google search field. For example, to locate a download page for BlindSquare, we used "BlindSquare app" as a search term. Initially, we selected the Apple Store or Google Play download pages depending on which appeared first on the search result page but mostly on Apple Store for consistency and the information provided on language options which was not easily available in the Google Play download pages.

Step 3 Further exploration indicated that some of the apps were not available and did not have official websites as well, for example RideScout, Hopstop, and Way2ride. Regarding some apps, we found media accounts that reported they no longer existed. With other apps, we identified

that they were not exclusively for transport purposes but did have a transport component. These include Looptivity and GoKid. We excluded AccessMap, Ridershare, and Kangaride as they are not smartphone apps but are instead web-based platforms. The data used for this study constitutes a list of apps used for public transport, car sharing, carpooling, cycling, and walking. Most of the apps examined were for short, urban travel while a few of them were for longer-distance travel. Apps that have some component of travel, such as Looptivity, Cozi, Carpool Party, and Carpooler, were excluded in order to maintain consistency of the type of apps and the features for which they were assessed.

Table 1. Terms used in Google searches.

Category-1	Category-2
Transport apps	Transport apps for people with disability
Ridesharing apps	Transport app for the visually impaired
Ridesharing services	Transport apps for wheelchair users
Carpooling apps	Transport apps for low-income earners

App = smartphone application.

The above steps reduced the number of apps in our list to 60 (See Supplementary Materials for a list of apps and features).

6.2. Content Analysis

A key term content analysis was conducted on the descriptions of apps that are found on their respective official download pages from the Apple store, Google Play, and official websites. (In some cases, apps offered download options from their official websites directly, e.g., RollWithMe and Summon). Our research question asked how smart tools respond to social sustainability concerns resulting from low-income and physical and language barriers. In conducting content analyses to answer the question, we searched, in the description of the apps, for key terms referring to inclusivity and equitability concerns as listed in the left column in Table 2. Based on the terms used in the description, the apps were identified as offering one or more social-sustainability feature: (a) offering a cost-conscious feature; (b) containing an accessibility feature; and (c) providing language options or a combination of the three (see the Supplementary Materials for detailed information on each app).

Table 2. Content analysis key terms and actual terms used in app descriptions.

Content Analysis Key Term Reference	Actual Terms Used in App Descriptions
Cost	Save money, split cost, e.g., in Uber app
Wheelchair accessibility	Wheelchair accessible, e.g., in Wheely
Accessibility to vision impairment	Accessibility feature for blind users, e.g., in Tiramisu Transit
Accessibility to disability	Simplified comprehension, e.g., in abil.io
Availability of language options	Language options, e.g., in OneBusWay

The research method was used for the following reasons: convenience to access websites at any time, accuracy of information regarding the apps' features, and efficiency in time used to gather data. We see the sample size (60 apps) to be a potential limitation of our data. The next phase of research will include interviews with app developers, app users, city governments, and transport agencies to gather more and diverse data. The limitation in our research method includes the following items.

- Google searches conducted for this study took place on one computer. Replicating the search using the same terms in a different computer may not produce the same list of apps as Google search results may be specific to each Internet Protocol address and search history.
- We did not verify the functionality of the apps' features with users to compare with the official descriptions of the apps.

- In focusing on the descriptions available on download pages, the study might have missed features that the apps offer but were not mentioned on those pages.
- The Google searches conducted to identify apps used key terms in the English language. As such, the findings may be limited to English-speaking geographies.

7. Findings

Based on the approach described above, our analysis produced the following.

Google searches using generic terms, such as "transport apps", listed more on the first search page of results than using specific terms, such as "transport apps for the visually impaired": see Figure 2a. This may indicate the proportion of apps for general use compared to those that encourage social sustainability in transport. This was not unexpected considering the fact that populations with a transport disadvantage due to limited physical ability and language barriers are a minority and represent a smaller market for app developers. In the U.S., nearly 20% of the population have some form of disability [23].

The apps we examined fall into two different categories in terms of the type of function they provide. In the first category, the apps aggregate travel-related information to assist with navigation. Examples in this category include Google Maps, Bus Checker, Waze, and BlindSquare. The second category of apps enables travel service through car rental (e.g., Car2Go) or ridesharing services (e.g., Uber, Carma, and Curb).

Another finding is that apps serve two different users: the general public and persons with disabilities. The former group makes up most of the listed apps in our data and the later constitutes a quarter of the list. Of the 60 apps examined, 18% of them were accessibility apps, i.e., developed specifically for disability needs (Figure 2b). Of the 53 general-use apps, 21% had assistive features; for example, they included information about wheelchair accessibility or voice options for navigation. A language option was offered by 62%, varying from two to over fifteen language options (Figure 2c). Seventeen percent (17%) mentioned cost-conscious features (Figure 2d).

(a)   (b)

(c)   (d)
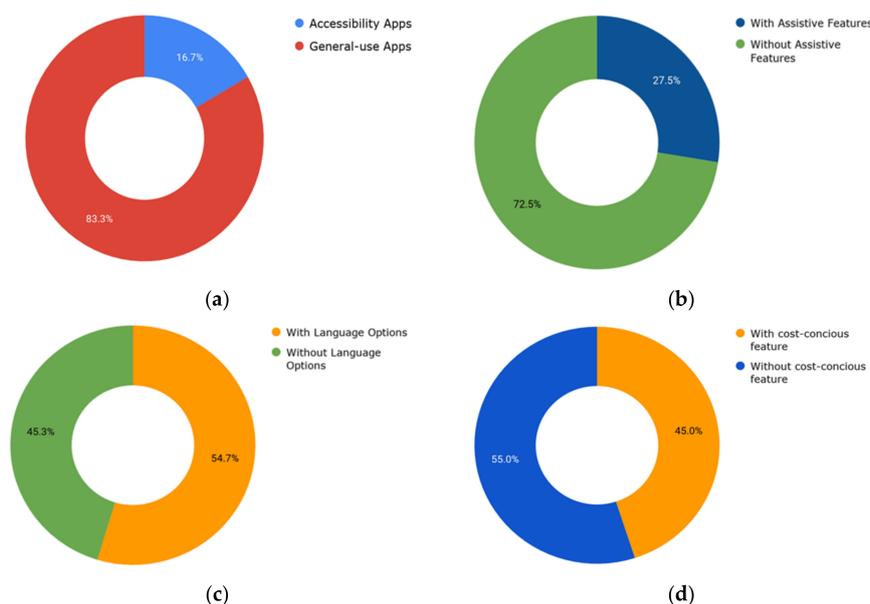
Figure 2. Findings from app analyses (**a**) Out of the 60 apps reviewed, 16.7% of them were accessibility apps and 83.3% were of general use (**b**) Percentage of general-use apps with and without assistive features (**c**) language options in all 60 apps (**d**) Apps with and without cost-conscious features.

8. Discussion

Based on our analyses, the apps responded to social sustainability in transport in two ways: (a) by employing a universal design in general-use apps, including cost-conscious features, and providing language options; and (b) by specifically developing smartphone apps for persons with disabilities. Our finding that some of the most used general-use apps, such as Waze, Uber, and Google Maps, incorporate accessibility features indicates two things: that accessibility is a consideration for smartphone app developers and that ICTs can be used for socially sustainable practices in transport. Apps such as Waze are used by millions in many countries around the world and as such provide service in various languages. As a result, their language options address potential barriers in cities that are linguistically diverse. Some of the apps provide features that enable cost-sharing or cost-splitting, indicating the technology's ability to respond to transport disadvantages that result from financial barriers.

The objective of our study was to gain a better understanding of the application of smart tools for the purpose of socially-sustainable transport. While our list of apps was not exhaustive, the findings of our study indicate that smartphone apps, as an ICT, may have the potential to address equity and inclusion issues and play a role in creating social sustainability in urban transport. However, this is not to imply that they are a solution to equity issues; rather, they are one of the several tools that can be used to address them. In addition, regardless of the technological capabilities, socio-economic factors affect technology use. In a report entitled *Technological Innovations in Transportation for People with Disabilities*, the U.S. Federal Highway Administration (FHA) stated that "Technological advancements could help to empower people with disabilities by addressing their mobility needs, but the benefits of such advancement have not yet reached this segment of the traveling public" [24]. The same demographics that can benefit from the technology have barriers to accessing it. Smart technologies have the ability to remedy a digital divide but they might create other forms of polarization [25]. References [26–28] highlighted the pronounced difference in smartphone ownership based on income, age, and disability, among other characteristics. A digital divide is clearly present and looks particularly to disadvantage those with disabilities or who earn a low income. In summary, seniors, persons with disability, and low-income earners have a lower rate of adopting technology in general and smartphones in particular than their peers in other demographics.

Access to emerging technologies affects the same demographics whose transport disadvantage could be alleviated using advancement in ICTs. To fully optimize mobility apps' potential in addressing social-sustainability challenges, socio-economic factors need to be addressed. In other words, it is important to recognize that the ability of smart city technologies to play a part in contributing to social sustainability in transport is dependent on other socio-economic factors. The author in [25] said that "New technologies have a tendency to polarize and divide at many levels and we need to explore how new forms of regulation at the level of urban and transport planning, and economic and community development, can be improved using future and emerging technologies" (p. 481). One way, he said, that this can be accomplished is by balancing efficiency and equity.

9. Further Research

We recognize that transport exclusion occurs as a result of other factors, including race, gender (safety issues for women), level of literacy (specifically, in immigrant communities from countries with a high illiteracy level), localities, and neighborhoods. In this study, we examined the use of technology (apps) to address social sustainability issues in transport by focusing on cost and physical and language barriers. Our study is one of the first to focus on technology (i.e., smartphone apps) related to transport need and assistance. We recognize the significant growth occurring in smart-city-, technology-, and transport-related research, which means the literature is growing daily and will need to be revisited. In addition, rapid changes in technology and app development mean that additional research is needed to keep pace with innovation. Therefore, our analysis represents a snapshot of the current state of the practice. Due to the novelty, we could not include a discussion or assessment of

policy dynamics, such as in the areas of persons with disabilities (e.g., the Americans with Disabilities Act in the U.S.), travel services, such as Uber, Lyft, and Via, as well as communications activities falling under regulations of various levels of government (e.g., the Federal Communications Commission in the U.S.). The growing body of research, changes in technology, and changes in policy represent opportunities for future research.

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