Tracing a path to knowledge? Indicative user impacts of introducing a public transport map in Dhaka, Bangladesh

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Abstract

The smartphone exemplifies the rhetorical smart city movement. This paper examines one potential use of smartphone technology – mapping public transportation services in a megacity of the Global South. We examine the potential user impacts of introducing a smartphone-generated and analog-delivered schematic bus map in Dhaka, Bangladesh. After distributing the map, we used a web-based survey to investigate impacts on users' knowledge, as measured by their stated understanding, navigation, and perceptions of the system. While a small and biased sample, the results suggest that the map fills a knowledge gap, provides useful and valued information, and may stimulate "exploration" of the city and its bus system.

JEL codes: R41; O22; O33; O29

Key words: Urban Public Transportation; Map Usage; Semi-Formal Systems; Applied Technology; User Impacts; Dhaka, Bangladesh

Introduction

Cities in the early 21st Century face an unprecedented range of opportunities and challenges related to the spread of technologies, natural resource constraints, global economic integration, intra- and inter-urban inequities, etc. Relative to past eras, many cities find themselves more deeply enmeshed in a new mix of local- and global-driven forces, particularly due to increased material, economic, and social flows which are restructuring market and governance relationships (Young et al., 2006; van der Ploeg and Poelhekke, 2008). In examining urban environmental transitions, Marcotullio (2005) suggests these forces are collapsing, compressing and telescoping urban conditions, causing them to happen at lower levels of income, more rapidly, and with greater overlap.

In many cities of the Global South, transportation systems epitomize this phenomenon. Borrowing from Marcotullio (2005), we can characterize much of the Global South's metropolitan mobility systems as "telescoping" eras, with a simultaneously strong presence of "new" and "old" vehicular technologies (from cycle-rickshaws to automobiles; e.g., Delhi [Pucher et al., 2005]), urban forms (from dense traditional neighborhoods to modern "towers-in-the-park"; e.g., Shanghai [Pan et al., 2009]), and service technologies and related organizational structures (from state-owned subways to owner-operated para-transit; e.g., Mexico City [Stokenberga and Schipper, 2012]). Inserted into such *milieus*, comes the ill-defined, global "smart city" movement, the ongoing revolution in information and communication technologies (ICTs) which potentiates new means of planning and managing infrastructures and services and empowering citizens (Hollands, 2008; Allwinkle and Cruickshank, 2011). ICT technologies hold great promise for urban mobility, arguably ushering in a new era of seamless shared services, vehicular-infrastructure communications, and autonomous vehicles.

This paper explores a blend of traditional and “smart city”-related mobility service technologies in the urban Global South, as manifest in a relatively pedestrian information product: a paper map. Paralleling the emergence of the smart city potential, challenges to traditional map-making have emerged in recent years, including multiple, interactive, and animated presentation capabilities; an emphasis on exploration over presentation, recognizing the transient nature of the information mapped; and a move towards the user-cartographer, enabled by web-based technologies, etc. (Crampton, 2001). If the “real” smart city is about using ICTs to better deploy knowledge for city planning, development and use, examining the rhetoric through a traditional knowledge product, a map, may be revealing.

Our empirical setting is one of the world’s most challenging megacities, Dhaka, Bangladesh and its public transport, comprised of a fragmented, loosely organized, and weakly regulated system of approximately 7,000 buses and minibuses (Olsson and Thynell, 2004; Poole, 2011). The example capitalizes on a technology epitomizing the smart city rhetoric, the smartphone: a portable, high-powered personal computing, communication, and sensing device with data and Internet connectivity and a host of applications and sensors from high resolution cameras to global positioning systems (GPS). Inspired by Hollands’ (2008) “smart city” vision, our interest is in examining how the smartphone can be deployed to empower people in their urban environment. Towards this end, we used the technology to generate data to develop a new information source in Dhaka: its first publicly available public transport map. This paper provides a very initial user knowledge impact assessment of introducing this map, an analog information product of a smart city artifact.

The following section introduces public transportation and the role of user information, specifically maps in the Global North and South. The third section briefly reviews trends in mobile telephony in the Global South and their implications for urban mobility. The fourth section introduces the empirical setting, describes the technology used to generate the Dhaka bus map and the method employed to assess the map's impacts, and provides a preliminary assessment of the user impacts of introducing the map. The final section concludes.

Public transport, information and user knowledge

Public transport (PT) refers to a range of travel modes available to any passenger, who does not have an ownership stake in the vehicle. This definition includes a broad spectrum of services (e.g., taxis, pedicabs, minibuses, fixed-route buses, commuter rail) owned by the public or private sectors, and operated under varying degrees of service "formality." A large share of urban PT in the Global South operates in the informal or semi-formal realms, where the public sector holds less control over planning, management, operations, fare and ticketing systems, and licensing and contract enforcement (Cervero and Golub, 2007). In such systems, the institutional organization falls to the private operators themselves, as they often organize into route associations (or similar structures), through which owners and operators typically pay dues in exchange for operating privileges and other support (e.g., Eros, et al., 2014). Authorities divest themselves of organizational and financial burdens, but also lose transparency, as they often have little access to information on key service characteristics, such as routes, drivers, frequencies, and demand. One can imagine, then, that the more informal the transit system, the higher the likelihood of poor information being available on that system.

Public Transport User Information

For the user, important dimensions of PT information include: type, delivery method, and timing. PT users may want to know schedules, routes, stops, travel times, prices, reliability, and current conditions. Users may obtain information from their own experiences, other users, system operators/staff, printed maps, call centers, the internet, text-based trip planners, map-based trip planners, and real-time updates to mobile devices.

Theoretically, providing high-quality service information will affect travelers' ability to access and understand the system (Hall, 1983), increasing awareness of travel options and assisting in trip implementation (Lyons, 2006). Better information can reduce real and/or perceived wait times and improve predictability of total travel time, system usability, sense of personal security, and overall knowledge of system extent (accessibility of origins and destinations). Passenger satisfaction levels may improve (Ferris et al, 2010). Over time, system ridership may increase, as users become more aware of public transport-accessible destinations (and make more trips), and/or shift to public transportation for trips previously made by other modes (Abdel-Aty, et al., 1996). Overall perceptions about a city may also improve (Freksa, 1999). In an increasing number of places, mobile tracking devices (e.g., GPS), information digitization, the so-called "open data movement" (e.g., Janssen, et al., 2012), and new forms of communication media and devices are being combined to fundamentally shift the way users learn about, choose from, and navigate PT offerings.

PT Mobility Knowledge from Maps

In the Global North, maps represent one of the most traditional forms of PT information delivery. Considered "a base of knowledge instrumental for supporting information processing" and spatial problem-solving (Casakin et al., 2000; p. 56), maps represent an information source that can enhance passengers' ability to navigate an urban transportation system (Avelar, 2008). PT maps are typically "schematic," in that they do not strictly adhere to spatial and other constraints, but aim to enable easy derivation of key aspects, such as routes (Freksa, 1999). Guo (2011) suggests that maps inform users' choice of origin/destination, mode, and path, but that few studies have examined maps' impact on travel decisions. Research tends to focus on three areas: comprehension, wayfinding, and perception.

Regarding *comprehension*, studies have evaluated users' understanding of public transport systems, focusing primarily on map design elements such as: the importance of graphics for New York City's subway map and signs (Bronzaft *et al.*, 1976); user difficulties in understanding maps with highly detailed street representation (Garland *et al.*, 1979); and user preferences for paper versus on-line maps and for attributes (e.g., labels) for on-line delivery approaches (Law and Sung,2003). *Wayfinding* studies, drawing from research on spatial cognition and cognitive mapping (e.g., Lynch, 1960), focus on maps' impacts upon individuals' perception, understanding, and manipulation of space (Casakin et al., 2000) and therefore ability to navigate from one location to another. Hall (1983) timed new university students taking PT to a nearby library; those with maps reached their destination faster than those without PT information and those with maps alone were faster than those given maps and schedules. Dzeikan (2008) examined the effects of urban PT maps on newcomers' experiences with, and initial impressions of, PT systems in their new environments, finding that knowledge of a new PT system depends on previous experience and that "good" maps provide foundational information upon which higher-level knowledge such as routes and line numbers can be built. Hochmair (2009) tested, via on-line survey, different map designs for Vienna's PT system, finding that geometric representation (e.g., distances presented) matters and that time-related information (i.e., frequencies or service headways) increased map effectiveness for unfamiliar users. Guo (2011) investigated route choices on London's Underground, using actual travel paths (access, transfer, egress stations) for more than 250,000 underground trips; he finds that presented map distances matter (similar to Hochmair), suggesting that passengers trust the map more than their own experiences, and that map representations (of, e.g., transfer stations) may affect user decisions.

Less research has evaluated transit maps' impacts upon individuals' *perceptions* of the city itself and PT organizations. Degani (2013) claims that the London Underground (LUL) map, initially designed in 1931, "is considered by many to be the most celebrated graphic design of the 20th century," which has become "an essential guide to London" (p. 14). Vertesi (2008) concurs, suggesting the map is an iconic symbol of the city. Through a mix of methods – including interviews with LUL staff and a variety of Londoners – Vertesi finds that, beyond serving as a PT navigation and wayfinding tool, the LUL map is a "graphical user interface to the city" (p. 25). At a broader level, maps – being a form of knowledge and power – represent control of space, expansion of social systems, and some administration/supervision (Harley, 1988). In this sense, the absence of a public transport map, even when PT vehicles are ubiquitous, is potently symbolic.

PT Maps in the Global South

In much of the urban Global South, especially where informal or semi-formal PT dominates, usable schematic PT maps or other information for users are rare (Avelar, 2008). In such systems, information channels tend to be in-person, asking a friend or acquaintance, a street vendor, the bus-ticket vendor, or the driver himself.

Perhaps partly due to the informal nature of PT information provision in the Global South, the literature reveals few studies on PT information comprehension, wayfinding, and perception. Avelar and Allard (2009) tested 18 users' interpretations of various map design features after the complete restructuring of Santiago de Chile's PT system; the assessment revealed the importance of landmarks – such as hospitals, parks, and shopping malls – to navigation and wayfinding. Thienmongkil and Waring (2012), in examining the design of a PT map for Khon Kaen, Thailand, argue that the design standard of most graphical variables in maps is based on Western cultures, which differ from Thai and Khon Kaen cultures, particularly regarding individual cognitive learning and the process of interpretations. Therefore, stakeholder knowledge was incorporated into the map; with follow-up usability tests indicating high levels of satisfaction in terms of comprehension, visible efficiency, and visual appeal.

The Chilean and Thai studies hint at what we might guess: culture matters. The process of creating a schematic transit map involves distortion, restoration, codification, and cognition (Guo 2011). Each of these processes requires value-laden decisions that can enhance or limit a map's communication abilities and, ultimately, its usability for different purposes and to different audiences (Hochmair 2009). Cultures may vary, however, in the ways in which they think about and move through space. For example, Soh and Smith-Jackson's (2004) wayfinding study indicated that cultural difference was a significant predictor of total time deviated from the route. Landmarks, street names, lines, and text may play varying roles in assisting individuals with perception and wayfinding. Better understanding cultural distinctions could aid in developing more usable tools for navigation in different contexts.

Cultural influences on wayfinding may also arise because travel priorities are affected by social conventions and structures, gender roles, values, ideologies, and religion. Such elements vary *within* a given urban area, producing variations in values of travel time and reliability (Small et al., 2005), the relative burdens due to poverty, gender and location (e.g., Salon and Gulyani, 2010), inter-relations among behaviors, attitudes and intentions (Zhao, 2011), the role of habits (Gardner, 2009), etc. Differences *across* urban areas thus almost certainly exist, which may impact wayfinding priorities, such as time, burden, crowding, transfers, safety, and so on. The needs for, desires for, and availability of information for a person seeking to take the subway across Manhattan differ than for someone seeking to catch a *matatu* (minibus) across Nairobi. We may not know what information to present, nor how. But, due to a range of factors – such as institutional capability, industrial structure, resource availability – we might not even have information to provide. Advances in mobile telephony, however, pose ready to rapidly change this situation.

Mobile technologies, information, and mobility

Mobile devices present an opportunity to collect, process, and disseminate information from people in even the poorest and remotest areas of the world. Urban mobile phone ownership is greatly increasing across the Global South, as is Internet availability, although penetration rates of both vary considerably (Table 1). Internet-capable phones, including both smartphones and multi-media phones, are also increasingly common.

[Table 1 here]

Because of their ubiquity, portability, and sensing capabilities mobile phones can be a great source of data about individuals' mobility demand (e.g., González, et al., 2008; Cottrill, et al., 2013). At the same time, they provide an information-delivery platform on which many kinds of tools and services can be built to enhance mobility services and the user experience.

Already in the Global South, a range of mobility-related mobile phone applications have emerged focusing on, for example, safe taxis in Buenos Aires, rickshaw fare verification in Mumbai, and SMS-based bus route guidance in Nairobi. In these contexts, smartphone apps have also been gaining traction for data collection. For PT data collection, the potential is great. Consider two cities, Mexico City and New York City; ignoring their broader metropolitan areas, the cities, proper, have comparable populations, approximately 8 million persons. The large majority of New York City's bus service is provided by a public agency, MTA, operating approximately 3,800 buses (NTD, 2013). Generating route, stop, and performance data on such a service is centralized and real-time feeds are made relatively easy through existing GPS equipment on the agency-operated buses. In the Mexico City case, however, the majority of PT trips are served by private minibuses, some 30,000 vehicles in 121 different route associations, with little regulatory oversight and poor information (Eros et al, 2014). Generating codified, user-oriented information on such a system, to provide something even as simple as a route map, much less as sophisticated as real-time service information, presents a major organizational and financial challenge.

To confront this challenge, academics, agencies, NGOs and others have begun experimenting with smartphones as a means of collecting data on, and mapping, privately operated and atomized PT services, like minibuses, in places like Mexico City, Dhaka, Manila, and Nairobi (Eros et al, 2014; Klopp et al., 2014). At least in the Dhaka case, this work has resulted in the city's first widely available PT map.

Research Questions and Approach

The rapid emergence of increasingly powerful mobile sensing and computing devices in megacities with little PT information readily available presents an interesting experimental opportunity. While paper maps may represent "old-fashioned" analog PT information in cities of the Global North, they represent a relatively new type of information source in semi-formal PT-dominated cities from the Global South. Unlike Dzeikan (2008) who investigates how newcomers to a city utilize existing PT maps to become more informed users, we take the inverse approach, examining how existing residents react to the introduction of a PT map as a new information source. We aim to answer, tentatively and indicatively, a number of questions related to if and how this new form of PT information can bring knowledge-based value to the users:

- Comprehension. Can a newly introduced PT map be understood? What elements make it understandable? That is, does it create potential knowledge?
- Wayfinding. Is the new knowledge from the introduction of a PT map executable? That is, does it actually help navigation in the system? Might it increase the likelihood of exploring new parts of the city?

- Perceptions. Does the introduction of a PT map change individuals' perceptions of the PT service in the city?

We attempt to answer these questions using the introduction of a PT map in Dhaka and assessing, preliminarily, impacts on users. Specifically, using smartphone-based technology we mapped the city's PT services; developed and disseminated a paper map of those services; conducted a convenience sample among recipients of the map; and, applied various statistical models using the survey results.

Empirical Setting

Background

Metropolitan Dhaka is one of the most rapidly growing megacities, expected to reach 22-25 million people by 2020, which would make it the world's fourth largest city (City Mayors, 2012).[1] The economic and political capital of Bangladesh, Dhaka is also the world's highest density large city; at 550 persons per hectare, its built-up area density exceeds Hong Kong's (Angel, et al, 2011). Average annual household income in the city is approximately US$2,220 (in 2010), roughly $300 more than the national average (BBS, 2011). By the government's own measure, approximately 18% of Dhaka's urban residents are "moderate poor," measured relative to expenditures for a basic food basket and "non-food" allowance; the national-level urban Gini coefficient, 0.45, suggests high income inequality (BBS, 2011). Despite the relative poverty, Dhaka's urban households have high access to electricity (96%) and mobile telephony (87%, suggesting land-line "leapfrogging" has already taken place as just 5% of households have regular telephones); access to computer and email remain low, however, at 10% and 5%, respectively, in 2010 (BBS, 2011).

Dhaka's density and limited space for new transport infrastructure has produced high congestion levels, despite the country having one of the lowest rates of private car ownership in the world (World Bank, 2014). The city's mobility remains highly human powered: reportedly, 63% of trips in the city are by foot, 20% by cycle-rickshaw, and 1% by bike, while just 10% are by bus, 3% by car, and 2% by auto-rickshaw (Hossain and Susilo, 2011). According to a 2004 household survey, the average bus trip was 15-16 km. A recent survey of 425 work commuters found an average bus trip distance of 8 km and 110 minutes, implying an average speed of under 5 km per hour; the average fare for such a trip (in 2011) was 24 Taka (US$0.31) (Nasrin et al., 2012).

Bus service remains fragmented and loosely organized. More than 60 companies operate 95% of the 7,000 buses and minibuses on an unknown number of total routes in the city, with weak service and fare regulation (Olsson and Thynell, 2004; Poole, 2011). The government directly provides only 5% of PT services, although six different government agencies have a hand in planning, operating, regulating, coordinating, enforcing and/or contracting the city's bus operations (World Bank, 2009). Ineffective regulation and little accountability have led to persistently poor quality buses, low service standards, high pollution, over-crowding, on-street competition for passengers, little adherence to schedules, and weak fare control (World Bank, 2009). Problematic outcomes include high accident rates (Mannan and Karim, 1999), vehicle over-crowding and negative impacts on comfort, safety, and security (Katz and Rahman, 2010). These conditions exacerbate inequities; for example, evidence suggests that crowding often inhibits older adults, women and children from boarding buses during rush hour (Rahman and Nahrin, 2012). For religious reasons and fear of crime, women are also disinclined to use male-dominated public transport modes; among motorized alternatives, women are less likely to choose the bus (Hossain and Susilo, 2011).

In terms of the role of PT information among Dhaka's residents, route maps and schedules are non-existent (Mahmud et al, 2008). Rahman and Nahrin (2012) interviewed users on 5 major bus routes in the city; 45% of the respondents mentioned they lacked adequate information on bus services. JICA (2010) surveyed bus passengers at 6 bus terminals and stops, finding that 85% of users were not satisfied with the levels of information available. Enam and Choudhury (2011) find women are less likely to consider the bus as a travel choice and hypothesize that this is, in part, because they have less information on PT routes (a lack of information coming partially from less PT usage for the reasons stated above). On the other hand, Enam and Choudhury (2011) find that people have a higher relative likelihood of including PT in their choice sets for educational and work trips, perhaps an indication of how users accumulate PT knowledge through routine trip-making. In the end, informal channels represent the only way for users to gather information on Dhaka's bus system, since Dhaka does not have an updated, complete, publicly available map.

Map Development Method

In early 2012, we launched an initiative to test the viability of smartphone-based technologies to improve mobility conditions and services in Dhaka. We developed three simple Android-based smartphone applications which enabled the user to record the bus route trajectory, perform on-board counts of male and female passengers, and conduct rapid on-board user surveys. Pilots, conducted in January and March 2012, showed the basic technological viability, as applied to two major routes in the city. Eight volunteers from a partner NGO completed 270 one-way trips on buses plying these routes at different times of day, beginning and ending at different points. The resulting route portraits included vehicle speeds, route adherence, and crowding levels and their variation at different times of day. In addition, 1,014 onboard surveys were administered, revealing insights such as bus rider satisfaction levels and their correspondence with time, place and crowding.

Dhaka's high density and congestion levels, together with its relatively sparse road network (approximately 8% of the city's area is covered by streets; UNEP, 2006), actually combined to make the city an opportune place to test the app, from a technical perspective. The app, as designed for the Dhaka deployment using MIT App Inventor (appinventor.mit.edu), often encountered problems related to irregular data upload frequencies and poor locational sensitivity. The limited functionality also constrained the abilities to run background tasks, so that certain functions constantly overrode others. This complicated locational accuracy since the app often could not accurately estimate the phone location through Android's preset location call function before being interrupted by the user when, for example, conducting ridership counts or on-board surveys.

In a city with a denser, more intricate road network and/or with higher travel speeds, the technological issues may have seriously hampered the ability to discern bus locations and routes. In this sense, we benefited from Dhaka's slow traffic and sparse road network; the irregularities in locational uploads did not preclude ex-post identification of the route since vehicle movements tended to be slow enough, and route alternatives few enough, to make the route easily discernible.

Building on the pilot, in January 2013, the team initiated an attempt to develop a complete map of the city's bus system. To gain initial feedback about the value of a physical bus map, we used the data from the 2012 fieldwork to prepare maps of the two routes, with landmarks, neighborhoods, and major bus stops identified. Two maps were created, both with text in Bangla: one including text describing the landmarks, stops and neighborhoods, and a second featuring text, icons, and images representing the landmarks. Team members presented these initial maps to individuals waiting at major intersections and bus stops in Dhaka to gauge general perceived usefulness, design preferences (e.g., images/icons versus names), and potential user groups.

At the same time, a team of NGO volunteers, with a revised version of the Android app, strategically rode buses to geo-tag vehicle movements on all major bus routes in Dhaka. These data were then used as the basis for developing a schematic bus map, incorporating the design suggestions derived from the on-the-street interviews. Figure 1 shows the map relative to an available Dhaka street map, and a Google Maps image. The schematic map covers an approximate area of 145 km^2 and shows major arterials, waterbodies, select major urban reference points (Dhaka Zoo, National Assembly, Old Dhaka, etc.), and high-level nodes in the traffic network. Place names are marked in English and Bangla. Bus lines are color-coded and correspond to a legend on the back of the map which gives the origin, destination, and bus company for each route (Figure 2). From when data collection started in January, it took a total of five months to produce the final, ready-to-print version of the map.

[Figures 1 and 2 here]

Assessing the Map

In May 2013, we printed 5,000 paper bus maps and distributed them to university campuses and major public spaces in Dhaka. We focused on university students as the trial audience for two reasons: a large share of students use bus services for transportation, and students have higher-than-average access to the internet. The latter was important due to the sampling approach employed in an attempt to initially assess the impact of the map distribution. The nature of the convenience-based sample make this assessment very preliminary, providing initial evidence and a framework for future assessments.

Sampling Approach and Results

The paper maps included an HTML address for a Facebook page and a message requesting recipients go online to complete a 15-question survey. Approximately 40% of Bangladeshi internet users use Facebook; and, while the national penetration rate is less than 2% (MMG, 2013), Facebook usage is reasonably high among university students. Resource constraints inhibited implementation of a probabilistic sampling method and, thus, reduce the external validity of the results.

Over the period June 5 to July 15, 2013, 109 individuals completed the Facebook survey. Table 2 presents the results. Unsurprisingly, given the sampling approach, the results reveal a strong bias: the respondents were primarily male (92%), university students (41%) or graduates (47%), ranging between 22 and 35 years of age (65%).[2] The results are clearly not representative of the target population nor generalizable; resource constraints also inhibited more sophisticated stated preference experimental design, which further limits the possibility to estimate the structure of user preferences. Nonetheless, the findings still provide initial indications of the map impacts and suggest a framework for a more rigorous assessment in Dhaka and/or other places where technology-enabled PT map generation is feasible.

The data suggest a notable lack of transportation information in Dhaka. The sample consisted of frequent bus users, with 63% of respondents reporting taking the bus four or more times per week. However, only 14% reported having sufficient information to navigate the bus system. Of the remaining individuals, 62% ask questions of the ticket seller or the bus driver, and 23% ask a chai (tea) seller at the bus stop. Familiarity with PT maps was low: 61% had never seen a public transportation map of any kind, for any city. Nevertheless, the vast majority (83%) of respondents were able to locate their typical bus route on the map, indicating comprehension and at least partially validating the map's accuracy.

86% of respondents indicated that the paper bus map would be a better source of transportation information than their current source. The vast majority stated that the map would make it easier for them to navigate Dhaka's transportation system (92%), that they were more likely to take a different bus (91%), and that they were more likely to visit a part of the city to which they had not previously travelled (85%). Consistent with these results, most respondents reported some willingness to pay for the product (78%), with the majority willing to pay between US$0.13 and US$0.38, in the range of an average work trip bus fare in 2011 (Nasrin et al., 2012).

[Table 2 here]

Relationships Between Individuals' Characteristics and PT Knowledge Gain

In spite of the small and biased sample, we specified and estimated some indicative models, intending to discern some of the individual characteristics related to our questions about comprehension, wayfinding and perceptions. Appendix 1 presents the model approaches and results.

Regarding *comprehension*, we examine the respondents stated preferences for what would make the map easier to understand (Table A1). The respondents' tastes are relatively heterogeneous regarding preferences for map attributes (see Table 2) and the model results reveal little possibility to explain this variation among the variables we have for this sample. This suggests an effective map in Dhaka may need to have multiple representative approaches, at minimal naming landmarks and neighborhoods. Having previously seen a PT map does not influence respondents' preferences. Respondents with university degrees are less likely to prefer landmark-oriented maps in favor of street and neighborhood names.

Turning to the question of *wayfinding*, Table 2 shows an apparently strong positive effect of the map on respondents' stated ability to find their way in the city and willingness to "explore by bus", that is take a new bus route and/or take a bus to a non-typical destination. The model results provide some additional indicative insights (Table A2). Respondents who could find their typical bus route on the map and judged the map to be more useful than their current information source (e.g., the ticket seller) are more likely to think that this map will make it easier for them to find their way in the city. The improved wayfinding capability may lead to more exploration. In terms of likelihood of taking a new bus route, respondents' previous exposure to PT maps and judging of the map to be better than their previous preferred information source increase the stated likelihood of exploration (taking new route and going to new destination). Comprehension (indicated by being able to find current bus route) increases respondents' stated likelihood of taking a new bus route. Finally, the youngest group of respondents, under 22 years old, had a higher stated likelihood of going to new parts of the city by bus, a potentially interesting and important finding of PT maps serving to increase the opportunity space for the city's "next generation."

Willingness to pay provides additional indication of the PT map's enhanced wayfinding value (Table A3). Respondents who are male, primarily depend on information from ticket sellers, and/or are between 22 and 35 years old are willing to pay something for the map. Beyond that, those respondents who have previously seen a map, and who are modestly frequent bus users state a willingness to pay somewhat high values for the map. The latter result is interesting and intuitive; the map appears to be of particular value not to those who use the bus system regularly, nor very infrequently, but a few times per week.

Finally, we turn to the question of possible effects of the PT map on *perception* of Dhaka's bus system, by examining the stated observation as to whether the respondents view the service as better, the same, or worse than previously thought (Table A4). Respondents who have previously seen a PT map indicate that the map shows them that the bus system is worse than they previously thought, as do those who typically get their information from a street tea seller (chai wallah). These results are potentially interesting – perhaps having previously seen a PT map (say for the London Tube) makes respondents consider the extent of the Dhaka system to be inadequate. On the other hand, those respondents getting their info from the chai wallah perhaps previously had an optimistic "vision" of the system captured from informants on the street. Those with the least experience with the bus system (few bus) actually find the system to be better after seeing the map, a potentially important effect for attracting users to PT in the city. Male respondents are more likely to have the same perception of the bus system as before seeing the map, while women are more likely to see the bus system as better than previously thought. This latter result is also potentially important and consistent with the apparent effect of the map on infrequent users. Finally, younger working age adult respondents are less likely to consider the bus system as better, possibly indicating a particular expectation level among this cohort.

Discussion and Conclusions

The "smart city" movement should be about using data to generate information that becomes useful knowledge towards the public good. The smartphone is the quintessential smart city instrument: putting computing, sensing and communication power into citizens' hands as they use the city. A basic question is whether the smartphone can lead to knowledge enabling people to develop, pursue, demand, and/or regulate the services and infrastructures necessary to survive and thrive in our urbanizing world. Will the smart city rhetoric live up to its hype? In this paper we preliminarily evaluate a modest example of how smart city-related technology, the smartphone, can be harnessed to generate information that a wide range of citizens can act on immediately: a schematic paper PT map.

Theoretically, a PT map can increase users' comprehension of, improve their ability to navigate, and change their perceptions about the system. We attempted to detect these effects by surveying users who received a paper copy of the map. Despite being based on a small and biased sample, and thus not generalizable beyond those who chose to respond to the on-line survey, our attempt to assess the introduction of a PT map in Dhaka provides a first step towards, and precedent for, understanding enhanced PT information's potential for providing useful knowledge.

The results suggest that: consistent with prior evidence, the great majority of respondents have inadequate information on the city's bus system; the generated PT map was widely deemed usable and useful (relative to current information sources) and may stimulate "exploration" of the city and its bus system; and, most respondents would be willing to pay for such a map, the majority in a range comparable to current bus fares. The apparently heterogeneous preferences for what a useful map should represent (e.g., naming neighborhoods, landmarks) suggest that testing actual user navigational capabilities with different forms of representation may be important.

Previous exposure to PT maps and ability to comprehend the map are associated with an increased likelihood of respondents' "exploring" the city and its bus system, as is being young (under 22 years old). Over time, the map may open up new areas of the city, previously unknown or effectively unreachable to residents. As Dhaka's road system can be chaotic, residents may fail to realize the proximity of certain locations they do not frequent simply because they are unaware of particular PT connections and spatial arrangements. The map may enable these residents (as well as newcomers to the city) to better understand Dhaka's spatial potential. While requiring a broader and more rigorous assessment, a "market" for a PT map apparently exists; respondents who are male, young adults and currently depend on the ticket seller as an information source indicated a willingness to pay something for the map, while those who are occasional weekly users of the system and/or have previously seen a PT map state a willingness to pay over 40 Taka (US$0.60) for the map, twice the average work trip bus fare (in 20110. The map had mixed effects on respondents' overall perceptions of Dhaka's bus system; very infrequent users of the system and women reported perceiving the bus system to be better than previously thought; young adult respondents are less likely to consider the system better upon viewing the map.

This initial exploration of the user effects of introducing a PT map in Dhaka provides a first step in understanding how improved PT information leads to better knowledge of the system. Additional work could focus on expanding the representativeness of the sample, which would likely require moving it out of a web-based platform. Such work could also test actual effects on comprehension and wayfinding by, for example, observing actual use of the map information in trip execution and/or new trip generation, testing alternative means of representing relevant information, and testing different types of information (e.g., trip times, crowding levels, user satisfaction levels, and perceptions of safety and security). The suite of smartphone apps we tested as part of this map development show the ability to collect such information; the demand for, and means of delivery of, such information in Dhaka and elsewhere remain to be examined. Accounting for different information needs according to gender seems particularly important in the Dhaka case, as it likely is in other parts of South Asia (e.g., Campbell, 2013). Ensuring the map's accuracy and that it remains up-to-date in light of Dhaka's relatively dynamic bus system will also be important – a crowdsourced approach utilizing the apps we have developed may be possible.

Obviating the need for a paper map, moving entirely to digital forms of information delivery, seems consistent with the "smart city" rhetoric and our underlying data collection approach enables such a pathway. A smartphone-based trip planner recently debuted in Dhaka for the Windows Phone platform; the route information feeding the app was reportedly developed by collecting the information, analog style, from among users and ticket vendors.[3] We have put the bus route information we collected into the General Transit Feed Specification (GTFS)[4] format and the GTFS feed publication is pending; that should enhance the possibilities for updating and feeding the information into various delivery media. Ultimately, understanding the value of paper maps, versus digital maps, versus digital trip planning services (from SMS to smartphone-based apps) requires further research, particularly in places like Dhaka where PT information access, legibility, and comprehension could have important equity effects, either enhancing "inclusion" or exacerbating "exclusion."

The Dhaka case also holds relevance for other cities around the globe. The majority of PT in the urban Global South is provided by semi-formal paratransit services. While reliable figures are scarce, available evidence indicates that paratransit accounts for over 50% of public transportation trips in many cities (e.g. Cairo, Mexico City), over 75% in others (e.g. Abidjan, Caracas, Lagos, Manila, Nairobi), and close to 100% in still others (e.g. Bamako, Dar es Salaam, Kampala, Kigali) (Eros et al. 2014). As similar experiences with smartphone-enabled PT information gathering and delivery in the Global South take place (e.g., Eros et al, 2014; Klopp et al, 2014), examining the demands for, and use of, PT information by users in different contexts may be revealing. We have provided an example of how this information can be turned into potentially useful knowledge among PT users; our initial framework and analytical approach will hopefully enable other cities low on the PT service information spectrum to design knowledge products for users and evaluate the impacts upon such users.

Finally, it would be worth understanding how the influences of such information generation and provision may extend beyond direct user effects. Might such information services accelerate system reforms, enhance regulatory capacity and/or change industrial relations in the semi-formal PT industry? After learning of the map, authorities in Dhaka contacted our team with interest in deploying the technology to provide real-time tracking capabilities on the government-provided services, a project currently under development. In the longer term, more information on the system might lead to enhanced pressure, and capacity, to regulate and reform the system, breaking an impasse that has been difficult to overcome in Dhaka (World Bank, 2009) and elsewhere in the Global South. Clearly a large research agenda remains.

Endnotes

1. As in many metropolitan areas around the world, jurisdictional, statistical, and planning definitions of the Dhaka Metropolitan Area do not always align.

2. Directly comparable statistics for Dhaka are unavailable; 20-35 year olds comprise just 26% of urban Bangladeshis (BBS, 2011), only 24% of 14-24 year olds in Dhaka attend higher education institutions (JICA, 2010); just 3% of the nation's 25+ have completed tertiary education (World Bank, 2014). The much lower representation of women in our

sample at least partly reflects the lower share of women with some tertiary education in Bangladesh; just 30% of enrolled university students in 2012 were women (MOE, 2012).

3. Information on the PT information gathering comes from personal communication with Swagata Prateek, NerdCats, on 29 November, 2013; the app is available here (as of 14 August, 2014): http://www.windowsphone.com/en-bd/store/app/bus-map-dhaka/3795f088-028a-4958-bea6-a2d0eb243bd9.

4. GTFS, and its real-time extension, GTFS-RT, is the standard format through which PT operators and regulators have been making their data available to independent software developers, web-site providers and others to allow PT information delivery in a range of digital formats and delivery media.

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Table 1. *Internet, Mobile Phone, and Smart Phone Penetration Rates – Select Countries.*

Country	Population (2012 Est.)	Internet (% Pop.)	Mobile Phone Penetration	Smartphones (2013)	Smartphone (% Pop.)
LATIN AMERICA					
Brazil	193,946,886	45.6%	124%	70,000,000	36%
Mexico	114,975,404	36.5 %	82%	21,000,000	18%
ASIA					
Bangladesh	161,083,804	5.0%	56%		
India	1,205,073,612	11.4%	72%	67,000,000	5.6%
Malaysia	29,179,952	60.7%	127%	15,000,000	51%
Philippines	103,775,002	32.4%	99%	19,000,000	18%
AFRICA					
Egypt	83,688,164	35.6%	101%	10,000,000	12%
South Africa	48,810,427	17.4%	127%	14,000,000	29%
NORTH AMERICA					
United States	313,847,465	78.1%	93%	219,000,000	70%

Sources: Internet penetration rates from MMG (2013); mobile phone penetration from ITU (2013); smart phone numbers from KPCB (2013); penetration rates estimated from given information.

Table 2. *Descriptive statistics from on-line survey of Dhaka bus map users.*

Question (variable name)	Possible Responses	Number Responses	% non-null response
Have you seen a public transportation map like this before, for any city?			
(seen map)	Yes	41	39%
	No	65	61%
Can you find the bus route that you typically most frequently use on this map?			
(find route)	Yes	81	83%
	No	17	17%
What would make this map easier to understand?			
(names of neighborhood)	Showing the names of the neighborhoods	25	24%
(names of landmarks)	Showing the names of landmarks	35	34%
(pictures of landmarks)	Showing pictures of landmarks	29	28%
(names of streets)	Showing the names of streets	14	14%
How often do you take a bus?			
(one bus/week)	Once a week	3	3%
(two-three bus/week)	Two or three days a week	20	21%
(four+bus/week)	Four days or more a week	61	63%
(few bus)	A few times a month	13	13%
Will this map make it easier for you to find your way in the city?			
(easier to find way)	Yes	93	92%
	No	8	8%
Seeing this map, you would say that:			
(bus better)	I think that Dhaka's bus system is better than I previously thought	33	35%
(bus same)	I feel the same about the bus system as I did before I saw the map	52	56%
(bus worse)	I think that Dhaka's bus system is worse than I previously thought	8	9%
With this map, are you more likely to take a bus route you have never taken before?			
(take new route)	Yes	91	91%
	No	9	9%
With this map, are you more likely to take the bus to a part of Dhaka that you normally do not travel to by bus?			
(new destination)	Yes	85	85%
	No	15	15%
What is your best source for information about the bus system in Dhaka? Select one answer.			
(have info)	I already have all the information I need to take the bus	14	14%
(ticket seller)	The ticket seller	50	51%
(chai wallah)	The chai wallah (tea-seller) near the bus stop	23	23%
(bus driver)	The bus driver	11	11%
Is this map more useful than the information source you picked in the previous question?			
(map better)	Yes	81	86%
	No	13	14%

(Table Continues)

Table 2 (cont'd).

Question (variable name)	Possible Responses	Number Responses	% non-null response
How much would you be willing to pay for a map like this? Pick the highest amount you consider possible.			
	Nothing	23	21%
	10 Taka (US$0.13)	28	26%
(willing to pay)	20 Taka (US$0.25)	13	12%
	30 Taka (US$0.38)	14	14%
	40 Taka (US$0.59)	2	2%
	50 Taka (US$0.63)	22	20%
	100 Taka (US$1.26)	6	6%
What is your gender?			
(male)	Male	95	92%
	Female	8	8%
What is your age?			
(under 22)	Under 22 years	33	32%
(22-35)	22 - 35 years	66	65%
(36-50)	36 - 50 years	3	3%
What is the highest level of education you have completed?			
(primary)	Primary School	1	1%
(secondary)	Secondary school	9	10%
(university)	I am currently a university student	36	41%
(postuniv)	University	41	47%

Figure 1. *A paper version of Dhaka's Street map (left), the bus map developed and distributed (center) and a Google Map of Dhaka's main streets and urban area (right)*. *Sources*: http://www.mayerdak.com/homeland/ (left) ©2013 Google • Cnes/Spot Image, DigitalGlobe, Landsat • Imagery Feb 10, 2013 (right).

Figure 2. *Back side of the Dhaka schematic bus map, displaying major routes, terminal stations, and operating companies*.

Appendix

In our multivariate analysis, we tested both logit and probit models. While some evidence suggests that ordered probit might be more appropriate given the small sample size (Ye & Lord, 2013), given the nature of our inherently biased data set and the modest differences in the estimation results across the two estimation approaches, we present logit here. Due to the small sample size, we report results significant at p=0.10 or lower.

Table A1 presents the results of the multinomial logit model of respondents' preferences for four different map attributes. Table A2 presents binary logit models of stated wayfinding effects.

[Table A1 here]

[Table A2 here]

For *willingness to pay*, we estimate a generalized ordered logit model. A typical ordered logit model imposes the proportional odds assumption, meaning that the explanatory variables have the same effect on the odds that the dependent variable is above any dividing point (in the distribution determining the probability of the ordered outcome). The generalized ordered logit model relaxes this proportional odds assumption "by allowing the effects of the explanatory variables to vary with the point where the categories of the dependent variable are dichotomized" (Fu, 1998; p. 27). The Brant test of parallel regression assumption on willingness to pay, provided evidence that the parallel regression assumption was violated, supporting the generalized model. Few responses in particular categories can, however, be problematic for the generalized ordered logit (Fu, 1998), so we combine the willingness to pay values (in Table 2) into three categories: nothing, low (10-30 Taka; US$0.13-0.38), and high (40-100 Taka; US$0.59-1.26). Generalized ordered logit results also have relatively straightforward interpretability. The coefficients under "pay low" correspond to the dividing point between those willing to pay nothing and pay 10-30 Taka; the coefficients under "pay high" correspond to the dividing point between those willing to pay 40-100 Taka and 10-30 Taka (Table A3).

[Table A3 here]

Finally, Table A4 presents a generalized ordered logit model of the map effects on respondents' perceptions of Dhaka's bus service.

[Table A4 here]

Appendix References

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Table A1. *Multinomial logit model results of respondents' stated preferences for map attributes.*

Variables	Names of neighborhood		Names of landmarks		Pictures of landmarks		Names of Streets
	β	Z Stat	β	Z stats	β	Z Stat	
seen map	-1.17	-1.61	-0.83	-1.23	-.024	-0.33	reference
map better	-1.50 *	-1.70	0.07	0.07	0.13	0.13	
postuniv	-0.90	-1.21	-1.64*	-2.34	-1.87*	-2.58	

N= 103; Log(L) = -126.54; Pseudo R^2= 0.08

Note: * indicates significant at >90% confidence.

Table A2. *Binary logit models for stated wayfinding effects.*

Variables	Take New Route			New Destination			Easier to Find Way		
	β	Z Stat	Odds Ratio	β	Z Stat	Odds Ratio	β	Z Stat	Odds Ratio
seen map	1.18*	1.64	3.26	2.48*	3.00	11.91			
find route	1.11*	1.82	3.05				2.52*	3.07	12.39
map better	2.03*	3.40	7.63	1.91*	3.08	6.75	3.09 *	3.49	22.06
under 22				3.10*	2.80	22.23			
N	109			109			109		
Log(L)	-37.27			-37.94			-21.98		
Pseudo R^2	0.24			0.34			0.42		

Note: * indicates coefficients that are significant at the 10% level or greater.

Table A3. *Generalized ordered logit models for stated willingness to pay for map.*

Variables	Pay Low (10-30 Taka) (US$0.13-0.38)		Pay High (40-100 Taka) (US$0.59-1.26)		Pay Nothing
	β	Z Stat	β	Z Stat	
seen map	0.46	0.46	0.92*	1.99	reference
two-three bus	0.61	0.75	1.21*	2.19	
ticket seller	1.57*	2.52	0.08	0.17	
male	2.20*	2.76	1.56	1.40	
22-35	1.15*	2.03	0.44	0.90	

N= 109; Log(L) = -94.57; Pseudo R^2= 0.15

Notes: * indicates significant at >90% confidence; non-response values (5) were treated as willing to pay “nothing.”

Table A4. *Generalized ordered logit models of respondents' perception of bus service.*

Variables	Bus Same		Bus Better		Bus Worse
	β	Z-Stat	β	Z-Stat	
seen map	-1.78*	-1.80	0.20	0.40	reference
find route	1.77*	1.78	0.25	0.45	
few bus	17.79	0.00	1.27*	1.88	
chai wallah	-2.85*	-2.70	0.36	0.62	
male	2.72*	1.66	-2.04*	-2.38	
22-35	1.00	1.16	-1.19*	-2.38	

N=93; Log(L) = -69.81; Pseudo R^2= 0.17

Notes: * indicates significant at >90% confidence; 16 observations omitted due to non-response on dependent variable.