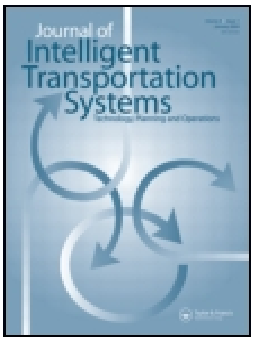

Journal of Intelligent Transportation Systems
Technology, Planning, and Operations

ISSN: 1547-2450 (Print) 1547-2442 (Online) Journal homepage: http://www.tandfonline.com/loi/gits20

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To cite this article: Achille Fonzone, Jan-Dirk Schmöcker & Francesco Viti (2016) New services, new travelers, old models? Directions to pioneer public transport models in the era of big data, Journal of Intelligent Transportation Systems, 20:4, 311-315, DOI: 10.1080/15472450.2016.1190553

To link to this article: http://dx.doi.org/10.1080/15472450.2016.1190553

Accepted author version posted online: 23 May 2016.
Published online: 23 May 2016.

JOURNAL OF INTELLIGENT TRANSPORTATION SYSTEMS
2016, VOL. 20, NO. 4, 311–315
http://dx.doi.org/10.1080/15472450.2016.1190553

EDITORIAL

New services, new travelers, old models? Directions to pioneer public transport models in the era of big data

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ARTICLE HISTORY Received 18 April 2016; Accepted 13 May 2016

Public transport in the era of big data

The ubiquitous availability of information is arguably the distinctive feature of the 21st-century developed world. The organization of flows affects our lives increasingly more than the organization of spaces. However, even in the digital era, not everything is digital. Therefore, high-quality transportation systems are still a crucial asset for our contemporary network society (Castells, 2010).

Information and communication technology (ICT) is radically changing our concept of mobility, causing a shift from the regime of the automobiles to the regime of multi-mobilities, where travelers can easily swap between physical and virtual mobility and traveling is not alternative to doing something else (Lyons, 2014). The traditional "system-based" demand, in which travelers buy tickets for specific means of transport, progressively gives way to a new "service-based" demand, where travelers purchase bundles of mobility services defined by different levels of waiting time, reliability, comfort, and price. Private cars become less important. Millennials, the prevailing cohort of travelers in the not-so-distant futures, like public transport because it offers opportunities for digital socialization and work. Besides more reliability, they ask for user-friendly real-time information and provision of WiFi (Sakaria & Stehfest, 2013). Sharing information, as well as sharing resources, seems to be the characteristic of the future mobility. As a consequence, the definition of "public" transport is also evolving. Public does not mean owned or regulated by a public body any longer: A few clicks in the Uber website and your car becomes a taxi; register with BlaBlaCar and you start providing a service to the general public. Public transport is not necessarily mass transport, either: Santander bikes in London and bikes and cars of any sharing scheme in the world are evidently public but they can only move one or very few persons per trip.

Real-time information (RTI), increasingly accessible at small or no (economic and cognitive) cost from everywhere at any time, is the life blood that keeps these new forms of public transport in motion. In the last decades, transport agencies and operators have implemented automatic systems to track vehicles, count passengers, and smooth ticketing transactions and boarding process. The data collected by such systems, initially used only to increase the efficiency of management and operations, has become the raw material to generate information for the passengers. In the United States, almost half of the large agencies disseminate real-time information on service arrival through their own website, and one-third through an app and/or Google Transit (American Public Transportation Association, 2013). Real-time information, possibly elaborated by journey planners, makes the systems more visible to passengers and thus, if the supply system is sufficiently complex, it widens the user choice sets. The capillary dissemination enabled by the pervasive diffusion of smartphones and WiFi technology has crucially increased the potential impact of RTI. Smartphones have also transformed the role of passengers: Similar to what is happening in the public transport industry where travelers are no longer only consumers but also providers of mobility, nowadays passengers have become passive (through their global positioning systems [GPS], Bluetooth, and WiFi footprints) and active (through their interactions via new social media and networks, such as blogs, Twitter, Facebook; or through apps like Citymapper) system sensors. However, the information shared by passengers is often unstructured and not complete, and this reduces the value to operators and passengers.

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Big data and the Internet-of-Things (IoT) are destined to revolutionize the way public transport will be able to adapt to travelers' mobility needs, and will optimize transit planning, scheduling, and operations. Consideration of the possibilities generated by ubiquitous real-time information and the more detailed description of the system components provided by big data calls for a new generation of public transport models. Collecting and promoting advances in models to predict passenger flows in the era of big data was one of the aims of the COST Action TU1004 "Modelling Public Transport Passenger Flows in the Era of ITS." The COST Action has recently published a book with a chapter concerning the use of new data (Fonzone, Bordagaray, Rodriguez, & Postorino, 2016). However, we soon realized that passenger flow models are still far from capturing the characteristics of the new public transport systems with the level of sophistication enabled by big data. The call for papers of this special issue was an attempt to nudge the academia in this sense.

What information means to smart travelers

With the increasing amount of information as well as travel modes available to travelers, decision-making processes are also changing. Instead of looking up a schedule and then planning one's time management around the available services, such constraints might be far relaxed. Table 1 shows that ubiquitous information such as that available through smart phones may impact travelers during all stages of their journey. Before, a traveler would preselect a certain stop and certain service, whereas now the decision can become much more dynamic, in that a traveler, after finishing his or her activities, can "on the spot" decide the best service from a variety of stops and services, given the current time and possible disruptions in the service. This can generate benefits both to individual passengers in terms of journey time, and to the system as a whole in terms of more even distribution of flows, as illustrated in Fonzone and Schmöcker (2014) with an example network. Further, at the stop, instead of idly waiting, the traveler is in a position to dynamically reasses his or her choices. Once on board the traveler might also react to service disruption messages or crowding on board and change route so that he or she might alight earlier or later than originally (i.e., at time of boarding) intended. Furthermore, the traveler's schedule might become dynamic itself. That is, incoming messages from contacts (possibly in conjunction with traffic conditions) might make the traveler reconsider his or her original plans and change not only route but also destination. Finally, previously a traveler would have to inform him- or herself at the alighting point about whether the traveler's planned connections to his or her final destination would still be available/attractive depending on possible delays, whereas now the connected and informed traveler can make such revisions already on board and, for example, order a taxi on board if it is rainy or the service has been running late.

We note though that clearly also travelers without ubiquitous real-time information can make "strategic" route choices. That is, based on timetable knowledge and past experiences, travelers might develop strategies to cope with events unfolding during a journey. Travelers might learn that at some stops it is not worth waiting for their preferred, fast connection and it is better to take any service bringing them closer to their destination as on average such an adaptive strategy will minimize their travel time. This is in fact the classic example of a hyperpath. What ubiquitous real-time information adds is a dynamic element to the strategy. In classic transit assignment models based on "optimal strategies" as in Spiess and Florian (1989) travelers choose a static strategy such as "choose whichever line comes first from an attractive set," whereas now travelers can dynamically adapt their choice set.

As this discussion shows, whether and how the effects of ubiquitous information described in Table 1 are in fact important will depend on how strategic users without this information behave and how they utilize the additional dynamic information. This in turn will depend on how accurate and dynamic the available information is, as well as the structure and reliability of the public transportation system itself. In small and medium-sized cities often the widening of choice sets described in Table 1 might not be an important issue as there are for most routes not many attractive options to choose from. This means that

Table 1. Effects of ICT and ITS on decisions during different stages of a journey.

Travel stage	Uninformed, unfamiliar traveler	Commuter; local dynamic information	Ubiquitous info (smartphone)
Before departure	Look up timetable, select stop and departure time	Select stop and dep. time, possibly complex alternatives and more complex strategies	
At stop	Wait for service	Possibly consider more connections	+ Possibly consider changing stop
On board	No decision	Possibly adjust alighting point	+ Possibly change destination
At alighting point	Stick to plan or make an effort to obtain new information	Possibly revise and coordinate plans; e.g., adjust pickup	

the behavioral impact of ubiquitous real-time information is expected to be larger where the networks are denser and the services more frequent, as well as for trips performed at a regional scale. Further, clearly in cities such as Metro Manila, where traffic conditions are so unreliable that arrival time predictions are often only vague guesses, information provision via smartphones during journeys and rearranging schedules have become an indispensable tool for many travelers to be, at least to some degree, "time efficient." In other countries, such as Japan, where public transport is generally reliable, dynamic ubiquitous information might still be important before departure to find the best connection once the end of an activity is known. During the journey, in reliable conditions the need to consult travel information or one's contacts to update one's schedule will be reduced. Hence, the need for dynamic information and the lack of transportation system reliability are usually to some degree "correlated" and create a conflict: In cities with less reliable transportation systems, accurate information will be harder to get but is more needed by travelers.

What information means to smart services

The giant leaps offered by information and communication technologies (ICT) provide ample opportunities for public transport providers and managers to improve their services, by reducing the overall costs and more importantly by offering solutions that are more reflecting the customers' needs.

Advanced public transport systems traditionally rely on three main technological innovations in telematics: automatic vehicle location (AVL), automatic passenger counts (APC), and advanced fare collection (AFC) systems. AVL helps in tracking and tracing the position of the vehicles on the network, while APC provide an estimate of the numbers of passengers boarding in a vehicle and alighting it. Finally, AFC offers smart ticketing solutions and enables efficient transferring between (multimodal) services. In addition, it completes the information on passenger flows with data regarding the time at which users enter or exit a station (or get on and off a vehicle), and transfer from one operator to another. These technologies are considered standard data sources, as they have been used to improve performance and operations of transit systems for more than a decade (Furth, Hemily, Muller, & Strathman, 2006). Nevertheless, their adoption in practice is not as widespread as one might expect, with often only large, innovative metropolitan areas having invested in these technologies for service/operations planning, and scheduling, line management, and real-time operational control of public transport systems. Although AVL has always been regarded as more suitable for real-time operational control applications, APC and AFC bring additional benefits as they may provide insight into the demand distribution in the network, and hence the actual passenger flow patterns (Wilson & Hemily, 2016).

Incorporating passenger flow data in real-time transit operations, together with more realistic transit assignment models, which consider the effect of real-time information on travelers' choice strategies, enables public transportation (PT) providers/operators to build up design and management solutions that are more responsive to the actual use of the transit network capacity. In addition, with the advent of dynamic short-range communication technologies, a new revolution is characterizing public transport services, with the name cooperative intelligent transportation systems (C-ITS). Potential gains are, for instance, in fleet management and transit signal priority (TSP). Real-time provision of signal phase and time (SPaT) information from traffic signal controllers is one of the most promising technologies, which, when integrated with vehicle-to-vehicle communication between PT vehicles, will allow more efficient platooning at signals, thus overall increasing the total throughput of transit systems (Seredynski, Khadraoui, & Viti, 2015). A future potential application will allow adjusting PT operational speeds and holding strategies in real time, depending on the information on signal timings, which are likely to dynamically change and in some case be in conflict with the planned schedule of PT vehicles. In these applications, passenger flows can be used to define different priority levels based on the transported number of passengers in real time, or to apply holding strategies with the goal of jointly reducing the number of stops at signals and the bunching effect at stops and stations.

What information means to transport modelers

In the previous sections, we tried to give an overview of how advancements in ICT are empowering both travelers and PT services.

ICT offers great opportunities not only for having an enhanced vision of transit services in real time, but also for incorporating users' data and mobility patterns, which will enable one to know more about, and model, activity-travel behavior of transit passengers.

The amount and the variety of the collected data have attracted the attention of the public transport planners and modelers besides that of system controllers and passengers. The scope and the feasibility of transport planning have to be understood in a world that can be swiftly revolutionized by catalysts hard to predict and control, like Uber. Modelers have to face the challenge of the

demand for very fast predictions, which can support real-time operation control. In this context, academics and practitioners in the sector of (public) transport modeling are driven to draw their attention to data, with the hope that they prove as useful as they promise to be. The content and the granularity of the available big data may give the decisive impetus to promote the usage of activity-based demand modeling, but this may also improve the quality of the results of the four-stage approach, for instance, by casting light on stochastic phenomena (both on the supply side, e.g., headway distributions, and on the demand side, e.g., the arrivals of passengers at stops) that before could be hardly observed on a large scale.

To exploit the potentials of big data, new analytics approaches are being developed that feed smarter decision support services for both transit users and service providers. From a research perspective, this is favoring the development and is increasing the interest in data-driven modeling approaches. There is then a common discussion in the transport research forum on whether traditional model-based approaches will be needed in the future. The objective difficulty of calibrating flow models, which are by necessity simple and coarse representations of real decision-making processes, may indeed suggest a future requiem to be plausible for their application to managing situations that are not excessively exceptional. Nevertheless, data-driven approaches will hardly be suitable for network planning and design and for evaluating the impact of new services, as they will always provide an accurate representation of the actual system, but will hardly be able to explore scenarios that are not represented in past data.

This issue and beyond

In advocacy of the relevance of modeling passenger flows in the era of ITS, the article by Cats and Loutos (2016), published in an earlier issue of *Journal of Intelligent Transportation Systems*, shows how RTI data can be used for evaluating the performance of real-world operational systems. In that, the paper attempts to assess the value of RTI for the service operators. Particular attention is drawn in the study to the importance of information reliability and its impact on expected waiting times both from the passengers and from the operators' perspective.

This issue contains three additional original works on this topic. The importance of modeling passengers' decision-making processes in the context of RTI is the main research motivation in Nuzzolo, Crisalli, Comi, and Rosati (2016), where a new mesoscopic transit assignment model has been presented, which considers explicitly real-time prediction of on-board passenger numbers and crowding of PT services. The paper of Leahy, Batley, and Chen (2016) takes advantage of new smart card data to quantify service reliability. This approach is argued to provide more insight to reveal travelers' preferences and, in combination with traditional choice modeling methods, can be used to estimate a value of reliability. Combination of stated and revealed preference data is also the approach adopted by Carrel, Mishalani, Sangupta, and Walker (2016) to provide a measure of satisfaction for public transport passengers, which can be used to identify and prioritize effective management measures to adapt public transport services to the mobility needs of the transit riders.

We finally note that the introduction of public transport ICT and ITS solutions does pose significant challenges beyond operational issues and modeling passenger flows. Technological issues and challenges discussed in the article in this special section appear to be sometimes less of a problem than legislative and organizational issues. Further, how far users are willing to accept technological developments and change their behavior in line with arguments brought forward in this editorial appears to be an under-researched topic. As one contribution related to this, this journal issue also includes the article by Cheng and Chen (2016), which discusses ways to encourage the uptake of smart cards among public transport passengers.

A comprehensive discussion of the research needs in the field of public transport passenger flow models can be found in the already-mentioned book of the COST Action, in particular in the chapter "Research Topics on Transit Modelling" (Leurent & Andreasson, 2016).

Acknowledgments

This special-focus section is based upon work from COST Action TU1004, "Modelling Public Transport Passenger Flows in the Era of ITS," supported by COST (European Cooperation in Science and Technology).

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