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Achieving Energy Savings by Intelligent Transportation Systems Investments in the Context of Smart Cities

Final Report for ESMAP-funded Project

“China: Wuhan Integrated Transport Development Project—Learning from Best International Practice in Smart Transport and Energy Efficiency: Applications to WITDP and Beyond”

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Executive Summary

Faced with the challenge of providing adequate transport services with limited resources, cities have, for several decades, been investing in Intelligent Transportation Systems (ITS). ITS utilize Information and Communications Technology (ICT) to make more efficient use of existing transport infrastructure with the aim of improving transport services and reducing congestion, accidents, and air pollution. In the past two decades, with the rapid advancement of ICT and intensive advocacy from big technology vendors, the concept of “smart cities” has gained great popularity and many cities have started to undertake a more holistic approach to improving urban services using technology in the name of smart city initiatives.

ITS investments are beginning to take place in the context of smart city initiatives in many cities around the world. Moreover, energy efficiency and emissions reduction are becoming essential rationales for smart city investments. It is important, therefore, to understand under what conditions investments in ITS in the context of smart cities produce energy savings.

In our study, we first reviewed relevant bodies of literature, including on smart cities, ITS, the linkages to benefits, especially energy savings, and the institutional and technological conditions that underlie these outcomes. Second, we conducted short case studies of smart mobility initiatives in Amsterdam, Barcelona, London, Madrid, New York City, San Francisco, Seoul, Singapore, Tokyo, and Vienna to determine the process, outcome, success factors, and lessons learned in deploying and operating these initiatives. And third, we conducted semi-structured and unstructured interviews with players in the smart cities field, including government officials, product and service providers, and local and global NGOs, as well as startup entrepreneurs. We sought their views on the conditions under which smart mobility products yield the best benefits.

We found that the smart cities context has transformed traditional ITS into “smart mobility” with three major characteristics: people-centric, data-driven, and powered by bottom-up innovation. These themes serve as the analytical framework for understanding how smart mobility investments lead to energy savings, and are discussed in detail in Section 2.

The comparison in the search for similarities among the case studies and interviews helped us develop a conceptual model—emphasizing cause and effect—of how ITS deployment and operation in the context of smart cities leads to energy savings. We argue that there are four main steps for ITS interventions in the smart cities context to achieve energy savings and that several institutional, technical, and physical conditions are required at each step. These four steps are: (1) a mobility problem is identified and a smart mobility solution is designed; (2) the solution is deployed and operated; (3) users use the solution and change their behavior accordingly; and (4) the smart mobility solution is scaled up and evolves over time. This conceptual model is presented in Section 3 with detailed discussions on institutional, technological, and physical conditions at each step in the model.

Section 4 focuses on energy savings with quantitative evidence of energy saving potential of ITS investments collected from literature and case studies. Energy savings are achieved when users change

their behavior and adopt smart mobility solutions: less travel, modal shift, and reduction of per-km energy consumption in the short term. Also, smart mobility solutions as an enabler could lead to other energy saving policies or initiatives, which would otherwise not be feasible. In the long term, the user's lifestyle could change, such as changes in vehicle ownership, location of job or residence, and activity pattern, which can lead to further energy savings.

Section 5 links the results of this study to the Wuhan Integrated Transport Development Project (WITDP) to be financed by the World Bank and explains how that knowledge has been incorporated into project design. Relevant institutional, technical, and physical conditions are checked at each step of the conceptual model for the specific case of Wuhan. To further explore the energy efficiency potential of Wuhan and to mainstream ITS and smart transport solutions as a source of achieving energy efficiency using results of this study, a TRACE analysis (a decision-support tool developed by ESMAP to help cities identify underperforming sectors in terms of energy efficiency and actions for energy efficiency intervention) was also completed as part of this research effort. This analysis focused on the passenger transport sector.

Finally, policy recommendations on the major conditions under which ITS investments in the context of smart cities achieve energy savings are summarized in Section 6. For cities in developing countries with lower motorization, less-developed infrastructure, less financial resources, and less institutional and technical capacity, our recommendations to achieve benefits from smart mobility investments are:

(1) Involve all public and private players in a collaborative and transparent setting. Financially-constrained cities in developing countries can take advantage of the resources from the private sector and citizens thanks to aligned interests in improving user experience. Collaboration and transparency is necessary not only for these low-cost innovative smart transport solutions to be developed, but also for building trust among all players for these solutions to be used, maintained, and scaled up in the long run.

(2) Develop the technical capacity to procure and monitor information services. For the innovative and usually technically complex smart transport solutions, developing cities with weak technical capacity face the risk of technology lock-in and capture by a powerful stakeholder (e.g., big technology provider) for excessive profit. Therefore, it is crucial for cities to develop minimum technical capacity to mitigate this risk when procuring and monitoring these services.

(3) Focus on basic infrastructure, including a coherent road network and basic traffic management measures. With less-developed existing infrastructure, developing cities have the opportunity to establish a coherent road network corresponding to land use and with basic traffic-management measures such as traffic lights, traffic signs, lane marking, zebra markings, and user education. Such a coherent road network is not only essential for meeting basic travel demand of the citizens (to avoid the paradox of high congestion at low-motorization level), but also strategically important to meet accessibility needs as the infrastructure and complementary policies guide future growth, thereby shaping future travel demand patterns.

Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials (US)
ANPR	Automatic Number Plate Recognition
API	Application Programming Interfaces
ARIB	Association of Radio Industries and Businesses (Japan)
ATC	Area Traffic Control
CCTV	Closed-Circuit Television
CEN 278	Committee de European Normalization (France)
CIO	Chief Information Officer
CTO	Chief Technology Officer
DfT	Department for Transport (UK)
ESMAP	Energy Sector Management Assistance Program
ETC	Electronic Toll Collection
FHWA	Federal Highway Administration (US)
FO	Fiber Optic
GIS	Geographic Information System
GTFS	General Transit Feed Specification
HAR	Highway Advisory Radio
ICT	Information and Communications Technology
IOT	Internet of Things
ITE	Institute of Transportation Engineer (US)
ITS	Intelligent Transportation Systems
ITSC	Information Technology Standards Committee (Europe)
KPI	Key Performance Indicators
LTA	Land Transport Authority (Singapore)
METI	Ministry of Economy, Trade and Industry (Japan)
MIB	Management Information Base
MIC	Ministry of Internal Affairs and Communications (Japan)
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
NEMA	National Electrical Manufacturers Association (US)
NPA	National Police Agency (Japan)
NMT	Non-Motorized Transport
NTCIP	National Transportation Communications for ITS Protocols (US)
OCIP	Open Communication Interface for road Traffic control (Germany)
PIU	Project Implementation Unit
PT	Public Transport
RFI	Request for Information
SARTRE	Safe Road Trains for the Environment (US)

SFMTA	San Francisco Municipal Transportation Authority (US)
SLA	Service Level Agreements
TfL	Transport for London (UK)
TNC	Transportation Network Company
TRACE	Tool for Rapid Assessment of City Energy (World Bank)
UDC	Urban Drive Control (Italy)
UGC	User Generated Content
UTMC	Urban Traffic Management Control (UK)
VICS	Vehicle Information and Communication System (Japan)
VKT	Vehicle Kilometers Traveled
VMS	Variable Message Sign
WITDP	Wuhan Integrated Transport Development Project
WMG	Wuhan Municipal Government
WPC	Wuhan Parking Corporation
WPMO	Wuhan Project Management Office
WTC	Wuhan Transportation Commission
WTDSRI	Wuhan Transport Development and Strategy Research Institute
WTMB	Wuhan Traffic Management Bureau

1. Introduction: ITS, smart cities, and energy savings

Faced with the challenge of providing adequate transport services with limited resources, cities have, for several decades, been investing in Intelligent Transportation Systems (ITS). ITS utilize Information and Communications Technology (ICT) to make more efficient use of existing transport infrastructure with the aim of improving transport services and reducing congestion, accidents, and air pollution. In the past two decades, with the rapid advancement of ICT and intensive advocacy from big technology vendors, the concept of “smart cities” has gained great popularity and many cities have started to undertake a more holistic approach to improving urban services using technology in the name of smart city initiatives.

Smart cities have proven to be more than just a buzzword or short-term hype. It is estimated that the size of the global smart cities market will grow from USD411 billion in 2014 to USD1,135 billion by 2019 [Markets and Markets (2015)]. Despite different focuses and definitions of the label “smart city” [see Albino et al. (2015) for a review], the core lies in the utilization of technology for the purpose of increasing the quality of life. Naturally, ITS become the essential application of “smart city” in the transportation sector as the “smart mobility” (or “smart transport”) component [Lombardi et al. (2011)]. ITS investments are beginning to take place in the context of smart city initiatives in many cities around the world. Moreover, energy efficiency and emissions reduction are becoming essential rationales for smart city investments. Indeed, energy saving (and/or greenhouse gas emissions reduction) is regarded as one major benefit and usually calculated in the cost benefit analysis [Newman-Askins et al. (2003) and Bertini et al. (2005)] to justify ITS investments.

Indeed, the transport sector is responsible for about one-fifth of total energy use worldwide [World Economic Forum (2011)], with the largest share in passenger road transport [World Energy Council (2011)]. However, transport in general and urban transport in particular are sectors in which it has proven difficult to cost-effectively reduce energy. Urban transport demand management, most of which is enabled by ITS, is regarded as a major solution to mitigate climate change [Creutzig et al. (2015)]. With environmental sustainability, i.e. energy reduction and climate change mitigation, becoming a more important rationale for ITS investments in the smart cities context, it is crucial to understand under what institutional and technological conditions the energy savings benefit is realized.

To answer the question of under what conditions ITS investments in the context of smart cities achieve energy savings we first reviewed relevant bodies of literature, including on smart cities, ITS, and the linkages to benefits, especially energy savings, and the institutional and technological conditions that underlie these outcomes. Second, we conducted short case studies of smart mobility initiatives in Amsterdam, Barcelona, London, Madrid, New York City, San Francisco, Seoul, Singapore, Tokyo, and Vienna to determine the process, outcome, success factors, and lessons learned in deploying and operating these initiatives. And third, we conducted semi-structured and unstructured interviews with players in the smart cities field, including government officials (including mayors, directors in relevant departments, technical staff etc.), product and service providers, and local and global NGOs, as well as startup

entrepreneurs. We sought their views on the conditions under which smart mobility products yield the best benefits.

Case cities were selected according to two criteria: (a) cover major well-recognized “smart cities” around the world to capture the international best practices; and (b) existing city (not built from scratch) that is medium to large in size so that the findings could be more useful for client cities of the World Bank. Smart mobility initiatives in case cities were explored through presentations, document reviews, panel discussions, interviews, as well as site visits during the period from November 2014 to December 2015. Additional cases and interviewees were obtained through interviewee references, and conference and exhibition attendance. The research team went through several rounds of theory-building exercises to let major themes emerge and establish an analytical framework. Findings from the mini case analyses as well as interviews of key players were then organized and the results summarized based on the framework.

We argue that three themes emerge that characterize the transformation of ITS in the context of smart cities—people-centric, data-driven, and powered by bottom-up innovation. Section 2 introduces these themes, which serve as the analytical framework to understand how smart mobility investments lead to energy savings. The comparison in the search for similarities among the case studies and interviews helped us develop a conceptual model—emphasizing cause and effect and presented in Section 3—of how ITS deployment and operation in the context of smart cities leads to energy saving benefits. This conceptual model is presented with detailed discussions of institutional, technological, and physical conditions at each step in the model. Section 4 focuses on energy savings with quantitative evidence of energy saving potential of ITS investments collected from literature and case studies. Section 5 links the results of this study to the Wuhan Integrated Transport Development Project and how the knowledge has been incorporated into project design. To further explore the energy efficiency potential of Wuhan and to mainstream ITS and smart transport solutions as a source of achieving energy efficiency using results of this study, a TRACE analysis was also completed as part of this research effort. This analysis focused on the passenger transport sector. Finally, policy recommendations on the major conditions under which ITS investments in the context of smart cities achieve energy savings are summarized in Section 6 with specific implications for cities in the developing countries.

2. From ITS to smart mobility

The evolution of the smart cities movement has transformed ITS into “smart mobility”—a series of transport initiatives that are integrated with broader city efforts aided by technology to improve livability, competitiveness, and sustainability. Smart mobility initiatives might be a new generation of traditional ITS investments. For example, a signaling system that could predict congestion and adjust traffic signal timings automatically versus fixed or pre-programmed settings of traditional signal control; real-time traffic information pushed to applications on users’ cell phones versus through variable message signs; demand-responsive pricing schemes for road, public transit, parking versus electronic toll with fixed pricing, etc.; or there could be totally new areas or new services traditional ITS were unable to provide,

such as multi-modal trip planning, real-time taxi-hailing and ride-sharing match, personalized incentives to nudge travel behavior, etc.

These “smart mobility” initiatives have three major characteristics. They are all: people-centric, data-driven, and powered by bottom-up innovations.

2.1 People-centric

Traditional ITS aim to improve system efficiency and focus on vehicles and vehicle flows. ITS in the smart cities age, on the other hand, aim to improve people’s travel experience and quality of life and therefore focus on users—people. A typical introduction to a “smart mobility” project would have a person (maybe with his/her cell phone) considering a wide range of mobility options as the lead role instead of cars driving in the streets and their never-ending need for improved traffic flows, as is the case for traditional ITS projects. Smart mobility aims to make users not just consumers of services, but also producers of such services—“prosumers”—who would “co-create” these mobility services with the government, operators, or other stakeholders. This people focus requires significant interaction with users to understand what people need and how they behave, and to provide users with personalized services. For example, in London, 30 percent of the Oyster card holders are registered and Transport for London (TfL) is able to send personalized alerts to these users via phone message or e-mail regarding potential disruption or delays specifically for the lines that the targeted user normally takes. TfL is also able to refund the user his/her fare automatically if the train or bus runs too late (based on pre-set criteria, e.g., 15 minutes) or implement other individualized interventions based on the person’s trip pattern.

The people-centric characteristic of smart mobility initiatives emphasizes the importance of problem identification and user evaluation—these solutions should respond to real people’s needs instead of showcasing technology. It also taps into the vast potential of public talent and user information, which could translate into valuable sources of data and potential revenue. The people-centric or user-centric characteristic also makes the alignment of interests possible for the public and private sectors—unlike the traditional ITS vendors who profit as long as the equipment and services are sold to the government, now making users happy becomes the new business model. All stakeholders have common interests to satisfy users’ needs as much as possible. People-centric brings tremendous challenges as well. People’s behaviors are complex, heterogeneous, and changing. Understanding and responding to user behavior is not easy. Fraud is also possible. More prominent is the privacy and security issue surrounding personalized information acquired and utilized by these smart mobility initiatives. Concerns over privacy and security might scare new users away or destroy the trust of existing users.

2.2 Data-driven

Traditional ITS have been collecting a large amount of data, but now data, especially big data, become the core business of smart cities. Besides the data traditional ITS collected through Closed Circuit Television (CCTV) cameras, sensors, and detectors installed on roads, gantries, and vehicles, smart mobility initiatives enjoy additional data sources such as real-time location of buses and taxis, location and records of mobile phones, smart cards, social networks, Internet view and click, shopping and credit

cards, and various other user-generated information. These data are “big” because they are generated real-time with location information by a large amount of sources. For example, Transport for London’s (TfL) iBus program produces 9,000 location data every second. These data are exponentially rich in information when integrated with other data sources and, therefore, have significantly more applications than the traditional ITS functions. Life in cities is being reshaped by better and faster flows of data [Saunders and Baeck (2015)]. Data start to become a new production factor, which drives productivity, innovation, and consumer surplus [Manyika et al. (2011)], although it can also be messy and manipulative [Greenfield (2013)].

With data collection, integration, analysis, and visualization ability enabled by rapid advancements of technology and algorithm, the information services provided to users are changing in a revolutionary way. Smart mobility initiatives use huge real-time and personalized datasets for “nowcasting”¹ what is happening at present and what is the best immediate action to take for individual users instead of “forecasting” how the system would work on an average peak hour using limited amount of data as traditional ITS did. The ability of “nowcasting” changes the infrastructure problem into an information problem [Mayer-Schönberger and Cukier (2013)], as less infrastructure is needed if it can be utilized more efficiently through better information. For example, a predictive signal system increases effective capacity of intersections; real-time trip planning helps users avoid congestion on roads or on public transport, reducing the peak-hour pressure on the system. Matching demand with supply, such as customized buses or taxi-hailing, could also reduce the needs for investment in additional capacity. The ability to collect and analyze big data, and disseminate to the public becomes the core competence for smart mobility applications to solve these problems.

2.3 Powered by bottom-up innovations

Unlike traditional ITS, which are mostly confined within the transport sector, smart city is a holistic approach that influences different aspects of people’s lives. It is precisely because ITS in the smart cities context are people-centric and data-driven that involving other sectors is necessary and feasible. While smart mobility tries to solve transport issues that are interconnected with land-use planning, housing, environment, energy, health, public security, economic development, and information technology, successful top-down implementation calls for collaboration and integration across sectors, which is extremely challenging given the commonly siloed structure of city governments.

On the other hand, the smart mobility market benefits from bottom-up innovations in the private sector. Unlike the traditional ITS market, which is dominated by large government procurement and therefore could suffer from both public sector inefficiency and proprietary technology lock-in, new ideas and applications of smart mobility initiatives are motivated and powered by citizens’ needs and private companies, more and more so by small startups. These innovations are fueled by data availability as the business model is based on the revenue-generating potential of the user base and data. Cities embrace these

¹ “Nowcasting: Big Data Predicts the Present.” *ITworld*, October 22, 2012. Available at <http://www.itworld.com/article/2719343/it-management/nowcasting-big-data-predicts-the-present.html>.

bottom-up innovations as they not only provide public services with lower costs to the city, but also bring high-quality jobs and vitality to the economy. One example is the collaboration between cities and the real-time crowdsourced navigation app Waze. Through the Connected Citizens Program, Waze users can get information from the city regarding construction, marathons, floods or anything else that can cause delays on the road. In return, Waze shares its real-time user-generated traffic data with participating cities so that they can respond to incidents and manage traffic better.

These bottom-up innovations bring jobs, low-cost public services, as well as competition, entrepreneurship, skill, and capacity to the labor market. However, they also bring disruption and regulatory challenges to the city. For example, Uber and other transportation network companies have shaken the traditional taxi industries in many cities and in some cases even caused conflicts. Cities are having a hard time finding the balance between encouraging innovation, and meeting citizens' demands, while keeping necessary control over public safety and social equity.

As is evident from the discussion above, people-centric, data-driven, and powered by bottom-up innovations are three characteristics that are intertwined and feed off each other. For example, open data and open-source initiatives are expanding the landscape of smart mobility taking advantage of all these three aspects: focus on user experience, people as consumers as well as producers of both data and applications (software and hardware), encouraging bottom-up innovations and nourishing community and entrepreneurship, leading to innovative initiatives such as the CitySDK initiative in Europe and the London Open Data Challenge Series.

Posing both opportunities and challenges, people-centric, data-driven, and powered by bottom-up innovations are key to understanding the conditions for ITS investments in the smart cities context, i.e. successfully implementing smart mobility solutions and achieving energy saving benefits.

3. How to successfully implement ITS investments in the smart cities context

It is possible to say that “all cities want to be smart.” For instance, India has plans to transform 100 cities into smart cities [World Bank (2015)] and China already has more than 500 smart city pilots.² Most of these initiatives have a smart transport component. However, implementing these smart mobility projects is not always successful—intended benefits are not achieved (and usually results are not even measured!). We will present the conceptual model in Section 3.1, and discuss in Section 3.2 what institutional, technical, and physical conditions are necessary to successfully implement ITS investments in the smart cities context at each step.

3.1 A conceptual model

We argue that there are four major steps for ITS interventions in the smart cities context to achieve energy savings (see Figure 1 which presents a stylized model):

² Xinhua net, 2015. http://news.xinhuanet.com/fortune/2015-06/27/c_1115742453.htm.

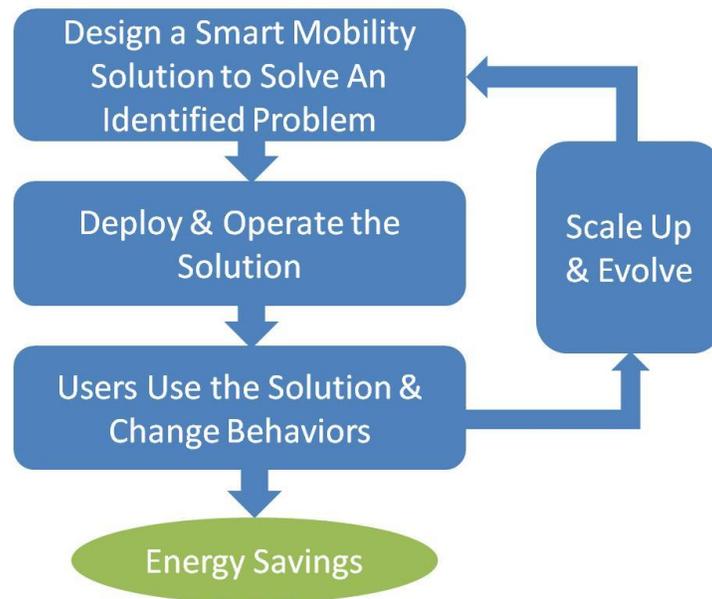
(1) A mobility problem is identified and a smart mobility solution is designed. Major problems associated with urban mobility—congestion, road accidents, and air pollution—all have energy implications. The key here is that the smart mobility solution is designed to solve an existing problem that people are concerned about, and is not a solution “looking for a problem.”

(2) The smart mobility solution is deployed and operated. The city needs to have the resources and capability to implement the solution and keep it running sustainably.

(3) Users use the solution and change their behavior accordingly. That transport service users are willing and able to use the application and change their behavior is the most important step. Users might travel less frequently, switch to a less energy-intensive mode, change to a less-congested route, change their departure time, or drive less aggressively. These behavioral changes translate into lower energy consumption.

(4) The smart mobility solution is scaled up and evolves over time. It is important for smart mobility solutions to be financially sustainable in the long run, taking advantage of the network externality and scale economy to maximize benefits. A healthy “ecosystem” of players also needs to be cultivated to enable learning and evolution in order to adapt to future changes.

Figure 1 Conceptual model for ITS investments in the smart cities context to achieve energy savings



3.2 Institutional, technical, and physical conditions for successful smart mobility investments

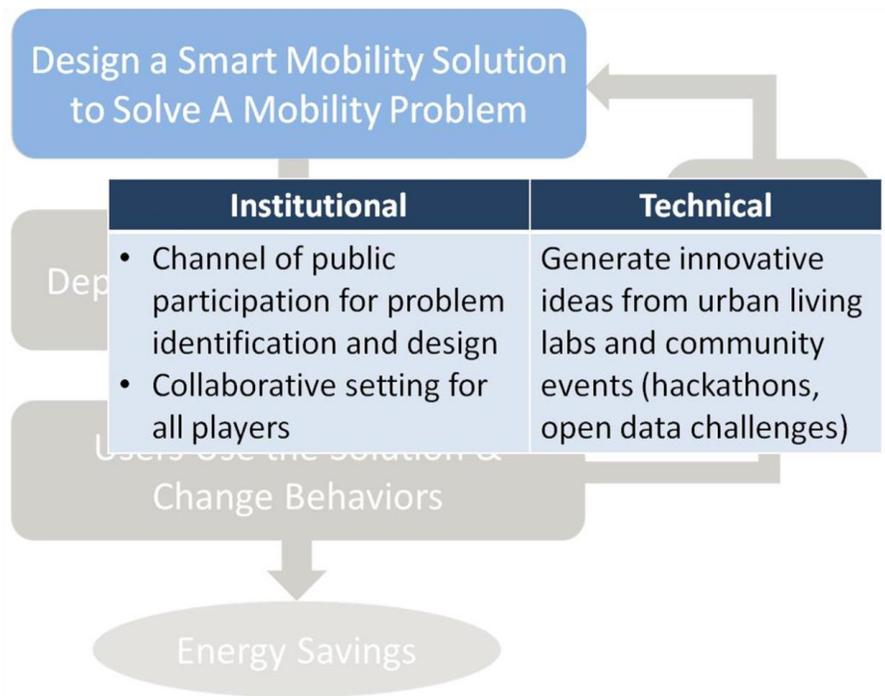
Smart mobility investments, or ITS investments in the smart cities context, are people-centric, data-driven, and powered by bottom-up innovations, as suggested by the framework presented in Section 2. These characteristics bring challenges as well as opportunities to implementation at each step in the

conceptual model. We will summarize what we have learned through research and past implementation experiences in different cities into three sets of conditions for each step: institutional conditions (including organizational, legal, and policy aspects), technical conditions (concerning technology and analytics), and physical conditions (infrastructure, equipment, and devices).

(1) A mobility problem is identified and a smart mobility solution is designed

As the use of ICT is the driving force of the smart cities movement and lies at the center of these initiatives, cities sometimes focus too much on investing in technology itself and neglect the real goal of improving the quality of people’s lives, resulting in the phenomenon of technology solutions “looking for a problem.” One criticism smart city initiatives commonly receive is their emphasis on the promotion of technology [Townsend (2013)]. However, as we discussed in Section 2.1, smart mobility should be people-centric. Investments made only for the sake of technology are seldom successful in achieving maximum benefits for the people because they are not set up to do so. Therefore, identifying a problem that people are concerned about is the key first step. Institutional conditions include a channel of public participation for problem identification and design, and a collaborative setting for all players. Seeking innovative ideas through urban living labs and community events such as hackathons and open-data challenges is highly beneficial at this step. See Figure 2 for a summary.

Figure 2 Conditions for Step 1: Mobility problem identified and smart mobility solution designed



Institutional conditions

Establishing channels to let the public voice their concerns seems to be the best way to identify problems. The governments in our case studies are generally proactive about reaching out to citizens. While technology enables easier communication channels, such as apps and social networks, traditional channels such as call centers, mail, or in person are still needed to include those who do not have Internet access. Many successful smart mobility initiatives are built along with e-government initiatives. For example, the Seoul Metropolitan Government implemented its Open Government 3.0 incorporating several channels for citizens to voice their concerns. Twenty-three percent of complaints are associated with transportation. The government has heard from citizens that low-income workers do not have access to public transport services late at night, taxis are expensive, and taxi drivers are sometimes reluctant to make the trip to a remote part of the city at night. Seoul implemented the Owl Bus initiative, utilizing cell phone call and message data made at night to determine demand and design a minimum level of bus service from midnight up to 5 a.m. This service was used by 629,752 passengers within the first 100 days [Sung et al. (2015)].

When searching for a smart mobility solution, a common phenomenon is that the city government is bombarded by private companies trying to sell their products and solutions. Public-private collaboration is very difficult when the government is resistant to the “sales pitch” while private companies are kept in the dark, unaware of the big picture. A truly collaborative setting is needed where all players can sit together and find a holistic solution to complex mobility problems in the city. This collaborative setting could be NGOs or industry associations. One good example is ITS Japan (formerly known as Vehicle, Road and Traffic Intelligence Society), an NGO that consists of less than 30 representatives from vehicle, infrastructure, and communication industries; private business corporations; and academia working together with the four government ministries—Ministry of Land, Infrastructure, Transport and Tourism (MLIT); National Police Agency (NPA); Ministry of Internal Affairs and Communications (MIC); and Ministry of Economy, Trade and Industry (METI)—and other agencies related to ITS. As per our findings, ITS Japan is one place where different ministries are talking to each other about the same issues, and real collaboration between public, private, and academia is taking place on identifying urgent problems, setting priorities, and proposing holistic solutions. A similar idea is the U.S.-based Smart Cities Council, an industry coalition promoting smart city solutions that offer a platform with opportunities to collaborate provided in the form of knowledge exchange, for example, studies, forums, and trainings. National and regional ITS societies play an important role across the lifecycle of smart mobility deployment. In our case studies, ITS societies in Asian cities show different characteristics from those in European cities. See Box 1 for more details.

Box 1 National ITS societies and organizations

National and regional ITS societies play a pivotal role not only in enabling collaboration between industry, the private sector, government, and academia but also in ensuring standardization of ITS equipment and communication protocols. As such, these tend to be rather centralized and top-down organizations. Creativity and innovation, while not stifled, is not usually engendered in these societies; rather they fulfil their main function to develop creative ideas, which have been generated elsewhere.

The case of ITS Japan illustrates this and showcases similar situations found in China, Singapore, and South Korea—as we found on our study tour of Asian cities. The case of ITS United Kingdom is a slightly different

model to the Asian one above. This society has more of a focus on the innovative stage of ITS. As we found on our study tour of European cities, this is also typical of such societies in the Netherlands and Spain, for example.

ITS Japan—A Typical Example of Asian ITS Societies

Japan was an early adopter of institutional arrangements to develop ITS in 1999 through ITS Japan. The objectives were to promote ITS through collaboration between industry, the private sector, government, and academia, and to standardize system architecture. Four central ministries report to the Japanese cabinet—the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the National Police Agency (NPA), the Ministry of Internal Affairs and Communication (MIC), and the Ministry of Economy, Trade and Industry (METI).

Nine development areas were identified: (1) car navigation (MLIT); (2) electronic toll collection (MLIT); (3) safe-driving assistance; (4) traffic control; (5) road management (MLIT); (6) public transport operation and management; (7) freight management; (8) pedestrian assistance; and (9) emergency vehicle management.

This is a centralized and top-down collaboration and while it could be argued that this might have stifled creativity, it has no doubt played a key role in enabling Japan to be at the forefront of: (1) in-car navigation systems developed by private companies, but with national standard compatibility; (2) a national Vehicle Information and Communication System (VICS) installed in over 50 percent of the country's 80 million cars; (3) roadside sensors called "ITS spots" that provide amongst other functions, dynamic route guidance, data collection, and advance warning of incidents; and (4) a nationwide ETC system, including smart route guidance and monitoring of freight vehicles.

Finally, Japan's ITS Info-Communications Forum focuses on standardizing ITS equipment and communications protocols. The MIC provides the framework to develop national technical standards; the Association of Radio Industries and Businesses (ARIB) evolves the standards through technical research; and the Forum prepares guidelines and disseminates these through ITS Japan and other organizations.

Other Asian countries, including Singapore, South Korea, and China have followed a similar centralized and top-down approach. In Singapore, ITS is the responsibility of the Land Transport Authority (LTA). In South Korea, ITS Korea was founded in 1999. ITS China was a later adopter, founded in 2007 under the Ministry of Science and Technology.

ITS United Kingdom – A Typical Example of European ITS Societies

ITS UK is a not-for-profit public/private sector association providing a forum for all organizations concerned with ITS. It works to bring the benefits that ITS can offer in terms of economic efficiency, transport safety, and environmental benefits to the United Kingdom—and at the same time expand the ITS market. The membership is wide, comprising over 150 UK organizations, including government departments, local authorities, the private sector, and academia.

Its focus on being a forum for ideas feeding the development of solutions and standards is different from societies in Asia that are directed more at the later stages of ITS development. ITS UK enables cutting edge ITS seminars and documentation, demonstrating best practice, and commissioning research unlikely otherwise to be commissioned on issues relevant to ITS deployment. This is more akin to a kind of "creative data lab" or a "brainstorming roundtable" than the Asian case.

For example, in recent years, ITS UK has focused on the development of autonomous vehicles, platooning, roadside sensors, narrowband communications, intelligent pedestrian crossings, and smart parking systems. However, this does not mean that the promotion, development, and standardization of ITS is neglected; rather, these functions are carried out by the Urban Traffic Management Control (UTMC) program by local authorities and the ITS industry.

The UTMC program, initiated in the early 1990s by the Department for Transport (DfT), is more comparable to Asian ITS societies yet its focus is broader and more insightful. It aims to: (1) achieve an effective, competitive marketplace, and avoid supplier "lock in"; (2) sustain technical innovation; (3) ensure that different local authorities align their demands on systems suppliers where practical; (4) ensure systems can exchange data quickly, simply, and cheaply. Its core is the UTMC Technical Specification based on simple values of: making use of

mainstream technology as far as practical, especially Internet protocols; setting standards where useful (but only where useful as the focus is on interfaces, leaving functional innovation to the creativity of suppliers); achieving development by consensus and not creating a technical dictatorship; and being open and readily available (UTMC specifications are free to access and free of charge).

Other European countries such as the Netherlands and Spain have followed this less centralized, more bottom-up approach in their ITS societies.

Technical conditions

Innovation is the key technical aspect at this stage. Cities are realizing the power of the citizen community and collaborations. Some cities establish civic innovation labs or urban living labs; some utilize events such as open-data challenges, hackathons, and innovation competitions to gain ideas for smart mobility solutions. Examples include the London Open Data Challenge Series, the Smart City Gran Concepción in Chile³, Smart Transport & Energy Hackathon in Berlin⁴, and many more. The London Open Data Challenge Series supports teams to develop products or services using open data for social challenges—as these social challenges might not have a market that encourages the private sector to develop them naturally [Nesta/Open Data Institute (2015)]. Some cities also use the “open by design” approach where data, source codes for software, as well as technical specifications or designs for hardware are open and shared to boost innovation.

Research has been done to show how hackathons facilitate public participation in providing innovative solutions to solve city problems [Zapico Lamela et al. (2013)].

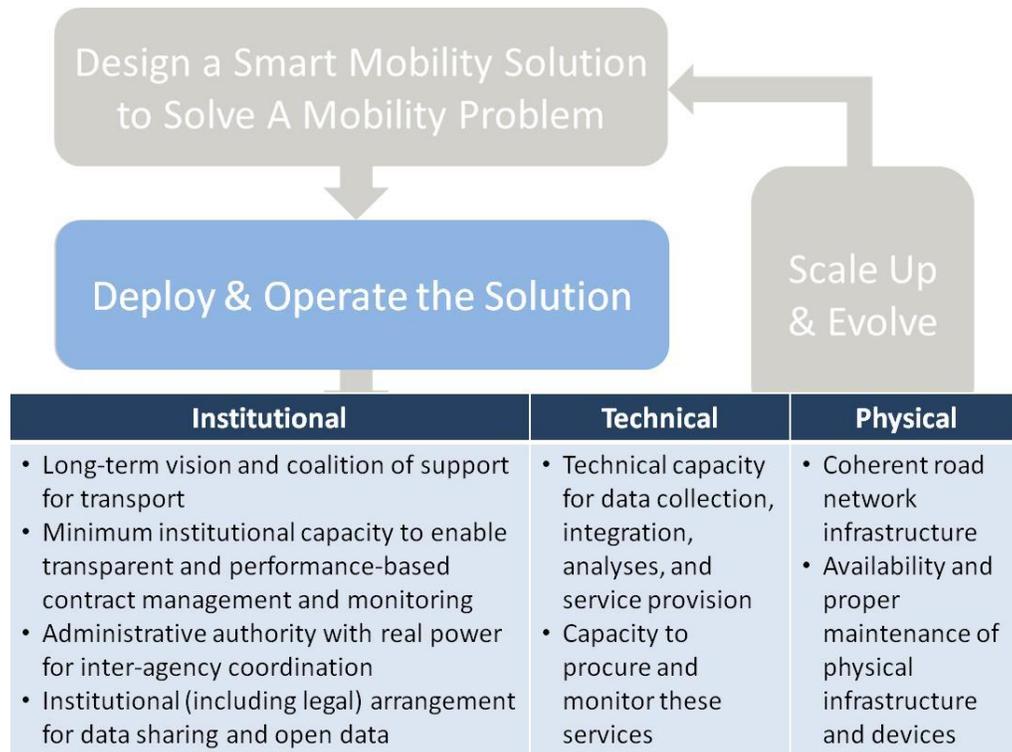
(2) The ITS solution is deployed and operated

This is the main implementation step for a smart mobility solution. The most-mentioned obstacles by our interviewees at this step include budget, data, and fragmented authority. To overcome these obstacles, a long-term vision and coalition of support for transport is needed. City government needs to have minimum institutional capacity to enable transparent and performance-based contract management and monitoring. An administrative authority with real power is also necessary for interagency coordination. Institutional (including legal) arrangements for data sharing and open data is also essential. Technical capacity is needed for data collection and integration, data analyses, and information service provision. If cities choose to use third-party providers, capacity is needed to procure and monitor these services. Physical conditions, including a coherent road network infrastructure as well as the availability of transport and ICT infrastructure and devices, are also important. See Figure 3 for a summary.

³ <http://innovatingcities.org/innovatingcities/chile/>.

⁴ <http://www.startupbootcamp.org/blog/2014/june/smart-transportation-energy-hackathon-2014.html>.

Figure 3 Conditions for Step 2: Deploy and operate the solution



Institutional conditions

Implementing smart mobility solutions is usually neither cheap nor easy. The city needs to have a long-term vision and “coalition of support” [Ardila-Gómez (2004)] for transport. A long-term vision is usually represented by a long-term transportation plan for the city. One good example is the City of Helsinki’s Vision 2025 “Mobility on Demand” plan.⁵ The city plans to provide citizens with a smartphone app that functions as both a journey planner and universal payment platform, knitting together every possible transport mode in the city, including subways, buses, ferries, car sharing, bike sharing etc. into a single personalized mobility package that is also updated in real time. This ultimate smart mobility solution proposal reflects Helsinki’s ambition, and the city has had political momentum to implement smaller solutions along the line, for example, Kutsuplus, an on-demand mini bus service that users could specify from a smartphone app. A champion is also frequently mentioned in our interviews as a condition for smart mobility deployment—for example, the Mayor of London, Boris Johnson, for the innovative solutions implemented by Transport for London (TfL), and the Mayor of Rio de Janeiro, Eduardo Paes, for implementing the City Operations Center, which gathers and displays data from multiple urban services ranging from public transport to garbage collection, among others.

Yet, even with a long-term vision, a coalition of support, and a champion in place, cities still need to have a minimum institutional capacity, including proper organizational structure, funding, and human

⁵ <https://www.hsl.fi/en/strategy>.

resources, to be able to ensure that the implementation of smart mobility initiatives is on track to realize the good vision and benefit the citizens. This institutional capacity of city agencies enables transparent and results-driven (performance-based) contract management and monitoring without which a powerful stakeholder (e.g., big technology provider) can capture the city for excessive profit [Ardila-Gómez (2004)].

A smart mobility project involves multiple sectors and siloed government structure. Fragmented authority is among the major obstacles to deploying and operating such a project. An authority with real administrative power is needed to facilitate the cooperation and integration of different agencies in the city. For example, many cities (e.g., Amsterdam, Barcelona, and Seoul) have a Chief Technology Officer (CTO) or Chief Information Officer (CIO) reporting directly to the mayor. This official has an independent finance/budget and wields power over all city agencies. This official can take the lead role in implementing smart mobility solutions without bureaucratic impediments, and can also facilitate learning, communication, and collaboration between different agencies and make city-level policies across sectors.

In order to integrate data from different sources, as required by most smart mobility solutions, there should be some institutional (including legal) arrangements for data sharing and open data. These arrangements include defining data ownership, the rights and liabilities of collecting, using, and sharing data depending on the type of data, including important aspects of privacy, security, and ethics. Some questions need to be answered to avoid potential conflicts of different parties. For example: Who can have access to the data and under what conditions? If data is wrong, who is liable? Who should benefit from the profits generated by data? What safety standard should apply corresponding to potential security risks? South Korea appears to be at the forefront of opening public data through legislation. Its Constitutional Court has ruled that access to information is a constitutional right. In 1996, it passed a freedom of information law; and in 2013, a new open-data law was enacted. This open-data law is the back bone for many smart city initiatives throughout the country. There are also examples of a step-by-step approach as sharing data is the first step of open data. For example, Amsterdam moves the open-data arrangement gradually by sharing data internally using the “Apps 4 civil servants” platform, external data sharing, and open data. For privately collected data, there is little experience and there is still debate on data ownership and rights. Usage is usually purchased, and information regarded as business secrets is difficult to obtain, such as car-sharing companies’ fleets or private parking companies’ real-time parking availability.

Technical conditions

The core technical condition at this step is all around data. Technical capacity is needed for data collection, data integration, data management, data analysis, and information service provision to implement the smart mobility solution.

Some data are collected through sensors, cameras, and field operators’ survey devices. Devices have errors and city officials in Barcelona said it is quite expensive to purchase software to correct these errors. Some data are collected through crowdsourcing becoming the so-called User Generated Content (UGC) (e.g., Waze and Moovit). Technical capacity is needed to integrate different sources of data. For example,

AutoNavi, a navigation software in China, uses real-time speed data collected by the company’s personnel using GPS and other devices, event extraction from Sina Weibo (a Twitter-like social network in China) tweets, as well as the software users’ GPS locations.⁶ Therefore, using the standardized data format and protocol is essential to reduce data integration costs. Also, adopting a common platform (such as CitySDK in Europe) for application development saves costs and increases interoperability.

Data collection and integration is now a flourishing market with thousands of startups, so-called data aggregators, providing these specialized services in the form of Application Programming Interfaces (APIs) through which software developers can write specific applications to use the data. Data analysis and information service provision also nurtures numerous startups specialized in developing and operating applications. If cities choose to open their data to take advantage of society’s productivity and innovation potential, technical capacity will be needed to maintain the open-data portal to manage the APIs with large volumes of calls. For example, New York City’s more than 1,300 open datasets are hosted by Socrata⁷, a private company that specializes in open-data portals and also hosts the World Bank’s open-data platform.

Most likely, cities do not have the technical capacity to do data integration, analysis, and information service provision in-house. It is suggested that cities publish data instead of managing APIs [Boyd (2014)] or develop applications that should be left to the specialized data aggregators, software developers, and system integrators. Cities then need to procure these services from a third party, therefore capacity is needed to procure startups and manage performance-based contracts, which in the case of information service are Service Level Agreements (SLAs). For example, the City of Madrid adopted a performance-based approach to manage its urban services provision. Regarding the huge amount of data generated in the urban system, the city chooses only to receive data that are useful—that which is linked to service quality indicators—to reduce the burden of data management. As smart mobility solutions are often innovative and technically complex, cities may not know the options available, not to mention the specifications. Therefore, more flexible procurement methods need to be adopted. For example, Copenhagen used a procurement method called “Competitive Dialogue,” a two-stage procurement process that allows cities to discuss with providers individually and identify and define the solutions (“dialogue phase”) before tendering [Burnett (2009)]. This requires the cities to have the capacity to clarify the needs, communicate with the private companies, and analyze and compare different technical solutions.

Box 2 below compares in detail different procurement options for ITS.

Box 2 Procurement of ITS

One of the main difficulties in preparing an ITS bid is when a technology supplier must act as the main contractor or belong to a joint venture, and where the ITS comprise a range of technologies such as ATC, CCTV, communications, etc. which are specialized and which may not be the specialty of the supplier.

Thus it is sometimes considered useful to use a system integrator when a number of disparate elements need to be combined for the overall solution (e.g. data transmission, CCTV, Variable Message Signs (VMS), Automatic Number Plate Recognition (ANPR), bus priority, etc.) These are companies that usually implement their own

⁶ <http://www.kingofcoders.com/viewNews.php?type=news&id=56336&number=94445285>.

⁷ <https://nycopendata.socrata.com/>.

specialized ITS application (such as an ATC system), but they are also able to incorporate ancillary subsystems that can be selected from internationally leading manufacturers. The ideal situation is one where the software developer and system integrator are one and the same. A system integrator can hold all of the subcontractors responsible and also help to resolve any issues upon installation.

System integrators can ensure functional specifications in an ITS bid to provide greater flexibility for innovation from different suppliers to assure competitiveness. However, functional specifications require clear evaluation criteria related to performance. They can also manage the Request for Information (RFI) from a potential supplier by providing bidders and suppliers a chance to better understand what is required.

A disadvantage can be a lack of application knowledge on traffic engineering and operations. Another disadvantage is the risk of conflict between the main ITS provider (say an ATC system or CCTV) and the system integrator regarding the sharing of responsibilities and technical risks.

For example, the table below summarizes ITS procurement options from World Bank case studies in Beirut, Cebu, and Mumbai, amongst others.

Bidding process	Description	Advantages	Disadvantages
Pre-qualification	Single-stage process requiring firms to prove expertise and experience before bidding	Assurance of reputable and capable bidders	Need to fix consortia very early in the process Cost of time that could be used with technical and financial bid
Two-stage	In the first stage, bidders demonstrate their ability to meet functional requirements. In the second stage, the most qualified bidders present their financial bids.	First technical filter allows concentration of evaluation efforts in financial and negotiation stages.	Cost of time that could be used with technical and financial bid
Single-stage	The above two steps are combined into one stage.	Shorter timescale with a two-envelope system, combined with a weighting system	Need for detailed specifications Risk of no market compliance Risk of having to evaluate too many bids in detail
IT variant of two-stage	In the first stage, a consultant will determine a city's ITS needs and draft functional specifications according to guidelines completed by the consultant. Firms are invited to demonstrate systems that adhere to functional specs. In the second stage, a specific specification is drafted. The bidders compete on equal footing for the same specification to find the least expensive way to provide the same service.	Solution(s) more focused on client's needs instead of suppliers' equipment offers More aspects than only equipment/systems requirements are taken into account from the beginning of the procurement process.	Initial process takes longer; however, this time is recovered in the long run

Training and education activities in collaboration with the private sector should be encouraged to increase in-house capacity and skills for the city to undertake smart mobility projects.

Physical conditions

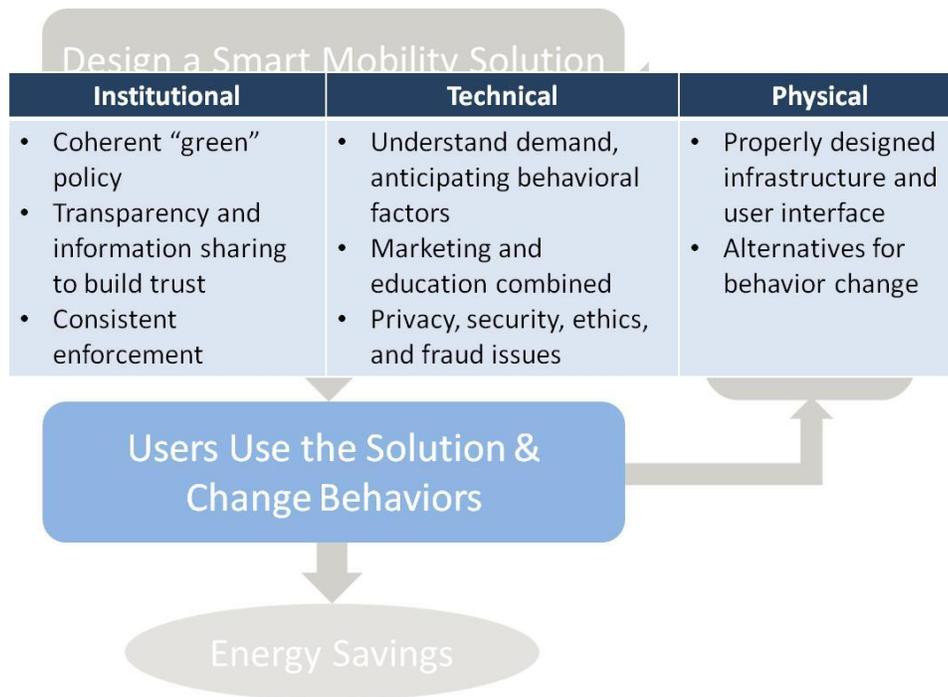
A coherent road network infrastructure (e.g., different types of functional road hierarchy) serves as the physical foundation for the ITS solutions to work. It would be costly to implement smart mobility solutions if the road network is dispersed, distant, and disconnected.

Other physical conditions are quite straightforward. Specific smart mobility application requires specific physical infrastructure to be in place for data collection (e.g., sensors, cameras, GPS device) and communication (e.g., Wi-Fi in the bus, electronic boards). All these physical infrastructure and devices need proper maintenance.

(3) Users use the solution and change their behavior accordingly

This is the most essential step in the conceptual model as users' behavioral changes result in energy savings. In our interviews, the challenge of changing user behavior is among the most mentioned obstacles to implementing smart mobility solutions. Korean Smart Card Co.'s T-money found the biggest challenge was getting users in Malaysia to adopt smart cards instead of using cash. In order for transport service users to be willing and able to use the smart mobility application, and then be willing and able to change their behavior—travel less, switch to less energy-intensive modes, change routes, change departure time, or drive with less stops—several conditions are needed. Institutionally, policy signals should be coherent leaning toward the “green” modes; transparency is necessary to build trust; and enforcement should be in place and consistent. Technically, demand should be understood correctly, anticipating behavioral factors; the public and private sector should be aligned to provide marketing and education; privacy, security, ethics, and fraud issues should also be considered. Physically, infrastructure and user interfaces should be properly designed considering the availability of user devices, and alternatives should be provided for users to change their behavior. See Figure 4 for a summary.

Figure 4 Conditions for Step 3: Using the solution and changing behaviors



Institutional conditions

Users’ behavior is influenced by multiple factors, including the transport services’ attributes. Cities can influence citizens’ travel choices with different policies. Therefore, policies need to be coherent, instead of contradictory, to direct users to favor less energy-intensive modes. For example, when a smart mobility initiative making public transport more convenient is implemented, users are more likely to use the solution and shift mode to public transport from cars if there are also policies restricting single-occupancy car use, such as parking restrictions or traffic-calming measures. If, however, other city policies encourage car use—for example, reduction in fuel tax, free parking, and higher speed limit—smart mobility applications aimed at encouraging pedestrians or cycling would be unable to influence users as intended.

Changing behavior is hard and users do not take risks if they don’t believe that they will benefit from the solution. Therefore, it is important for cities to encourage public participation throughout the design and implementation process. Cities need to be open and transparent, setting up channels to communicate with users on the intention, benefits, costs, timeline, and other attributes of the smart mobility solution. Being open and sharing information with users is especially important when there are bugs, mistakes, or incidents with the service provided, so that users do not lose trust. One example is in Rio de Janeiro during the protests that erupted in the summer of 2013 over the increase in public transport costs. Citizens were disappointed by the unavailability of real-time camera feeds of the city operation center and suspected cameras at protest locations were intentionally turned off. Officials at the operation center said

it was a technical difficulty due to high demand, but lack of transparency and communication could have led to public distrust.⁸ Enforcement should also be adequate and consistent, otherwise users lose trust.

Technical conditions

User behavior is localized. People living in different cities and communities, with different occupations, age, and gender, behave differently. Therefore, before implementing smart mobility solutions, demand study or even pilots should be done to understand user behavior. These behavioral factors should be considered and reflected in the solution design. For example, a smart parking application in China that sought to help drivers locate empty spaces found out only after it was rolled out that car drivers in Beijing have a tendency to stick to the parking location they usually use and are much less sensitive to price (some of them can have their parking expenses reimbursed by their employers) and availability than was originally assumed. Another important behavioral factor is the “rebound effect” [Greening et al. (2000)] in the energy efficiency literature or the “induced demand” [Downs (1962)] in the transport literature. The phenomenon is that when a smart mobility solution reduces congestion and makes travel more convenient, people will travel more and consume more energy. The existence of such a rebound effect was confirmed by many studies, but estimates of the magnitude vary. Studies show that the magnitude of the rebound effect increases with the level of congestion [Hymel et al. (2010)], but is generally modest. A recent review paper found that energy efficiency measures generally have rebound effects of 20 percent or less, and the 20 percent rebound also contributes to increased consumer amenities [Nadel (2012)].

Public as well as private players wish to see the smart mobility solution being used and benefits achieved. Therefore, the public and private sector should cooperate to influence users through the power of education and marketing, using methods such as campaigns, information boards, advertisements, financial incentives, promotion events, competitions, games, and utilization of social networks. Smart mobility initiatives should be innovative in attracting users. Being “data-rich” also enables many of these marketing and educational initiatives to be personalized. One example is the “Nudge Engines” developed by a startup called Urban Engines. The idea is to give small personalized rewards (could be cash, lottery tickets, fare discount or points for games) to incentivize commuters to “nudge” their travel behavior. For example, adjusting the departure time to travel on the metro at off-peak times therefore reducing congestion at peak travel times. Results from the transport pilots conducted in Bangalore, Stanford, and Singapore can be found in Prabhakar (2013).

As smart mobility solutions are “data-driven” with real-time and personalized data, privacy and security considerations might deter users. Users stop using similar services after security breaches as they see the risks. Most of our interviews showed that privacy and security concerns can be tackled using technology. Therefore, anonymization should be taken seriously and a network security specialist should be included in the team to make sure the risk of malicious attack is minimized.

⁸ <http://www.bbc.com/news/technology-22546490>.

Another issue is fraud. Fare evasion and misuse of smart card is not uncommon. Didi Kuaidi, the largest taxi-hailing application in China, claims to have more than 130 million users. However, it is not clear how many of these are real users, and how many are actually changing their behavior. The number of users and trips made each day using the application is mysterious because a portion of the trips are generated by “fraud bots”—apps developed on smartphones to take advantage of the cash incentives given to users for promotion purpose. A significant portion of real users only uses the application when there are promotional credits. It is hard to tell the behavioral change implications when those incentives are gone.

Physical conditions

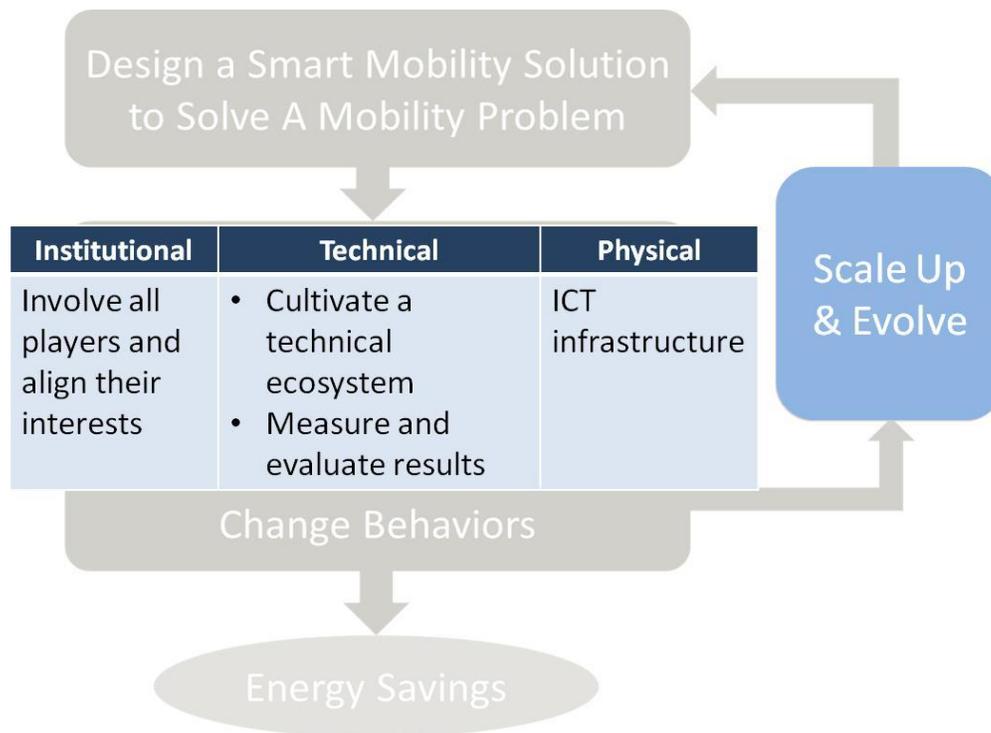
Infrastructure and user interfaces should be properly designed for easy and convenient use by users with due consideration given to users’ access to technology. For example, if the smartphone penetration rate is not very high among targeted users, smartphone apps on bus arrival time need to be complemented by traditional methods of communication, for example, electronic boards at bus stops; if Wi-Fi is not available inside the bus, screens and signs should be provided inside the vehicle where they can easily be seen.

The smart mobility solution will not be able to change people’s behavior if there is no other option available. For example, for a service that provides real-time traffic congestion information to drivers with the aim of changing drivers’ routing choice when the road is congested, an interconnected road network is needed to provide the driver with an alternative route leading to the same destination. When London implemented its congestion-charging scheme, alternatives were carefully studied with completely interconnected road networks, especially the ring roads and sufficient coverage of public transport services [Litman (2006)].

(4) The solution is scaled up and evolves over time

To maximize their benefits, smart mobility solutions need to be scaled up and evolve over time. Therefore, it is important for these solutions to be financially sustainable in the long run, taking advantage of the network externality (user and equipment penetration rate is one of the key parameters leading to maximum benefits) and scale economy (which is also exhibited in companies providing information services). It is beneficial for the city as a coordinator to involve all players and align their interests. Technically, a healthy “ecosystem” of players in the field needs to be cultivated with an evaluation mechanism to enable learning and evolution in order to adapt to future changes. Finally, existing ICT infrastructure can lower implementation costs, but ubiquitous high-speed broadband is not always necessary. See Figure 5 for a summary.

Figure 5 Conditions for Step 4: Scale up and evolve over time



Institutional conditions

All players in the smart mobility field want to gain more users and scale up. However, different players have different goals and agendas. In order to develop a sustainable business model for smart mobility solutions to scale up, it is important to involve all potential players (those who might benefit, as well as those who might be hurt) and align their interests. For example, a solution for street cleaning might benefit local business owners, local residents, as well as bus companies because garbage at the curb affects passengers’ boarding experience. Involving all players maximizes the potential funding and also mitigates the risk of future conflict.

City agencies have their own goals. For example, the transport management agency might put congestion reduction as a priority while traffic police focus on road safety. Users want better services with less costs; application developers want to accumulate user base, while some tech giant wants online payment data; NGOs have their own missions and agendas. It is actually not difficult to figure out the incentives and interests of all the players, therefore, it is feasible to find alignment. In many cases, cities or NGOs serve as the coordinator that aligns different interests into a sustainable business model because they have more coordination capacity. For example, Connekt, an NGO in the Netherlands, has a “Lean and Green” initiative to use technology to optimize freight routing and cargo combination in collaboration with different logistics companies to reduce greenhouse gas emissions in the freight sector. It was successfully scaled up to cover more and more companies because the initiative is aligned with the private companies’ main objective of saving fuel costs. Another example, *SFpark*, a project of the San Francisco

Municipal Transportation Authority (SFMTA), wasn't able to scale up to larger areas because there was no benefit-sharing mechanism (due to complex property rights issues), therefore, the solution was not financially sustainable.

Technical conditions

In order for the solutions to scale up and be able to learn to evolve, it is important to cultivate a “technical ecosystem” with products, experiences, skills, and a community that is conducive to learning. This ecosystem includes technology vendors and device manufacturers, solution providers, system integrators, data aggregators, data analysts, network designers, Internet security specialists, application developers, investors, and entrepreneurs. This ecosystem can be cultivated by open-data, hackathons, and knowledge-exchange events such as workshops, trainings, conferences, and forums. It will also benefit from standardization and collaboration efforts. One example is the CitySDK initiative in Europe. CitySDK is a “service development kit” implemented as a collection of standardized/harmonized APIs for smart city applications. For developers, it is easier to scale up to other cities due to better interoperability; it can also bring a greater variety of applications to cities and encourages cities to release similar datasets in similar formats.⁹ CitySDK users also form a community that works on similar projects and speaks the same language with a common platform for knowledge exchange.

Measuring and evaluating results is also key for learning and evolving. Transport for London (TfL) uses surveys and focus groups, both before and after the implementation of a solution, to evaluate public satisfaction. TfL also develops the system monitoring framework so that key performance indicators are monitored regularly and impacts of initiatives on these indicators (especially the journey time reliability) are evaluated consistently. Indeed, monitoring and evaluation appear as critical also because unless measured through a properly developed set of indicators, it is impossible to measure if the solution is actually improving the situation. City Protocol, a global collaborative innovation platform for smart cities solutions, is working toward an interoperable framework, including concept definition, common vocabulary for city data, and more importantly, a standardized cross-sectorial City Evaluation Framework consisting of a common set of indicators for cities to measure.¹⁰

⁹ <http://www.citysdk.eu/>.

¹⁰ <http://cityprotocol.org/>.

Box 3 ITS interfaces and interoperability

As ITS have evolved, the issue of interoperability and communication between different systems has become an issue. Of course, there is a need for standardization, open communication protocols, and data feeds so that different types of equipment from different suppliers can work together. However, this has been difficult to achieve over the years partly because technology is rapidly evolving and partly because of proprietary systems, and commercial sensitivity and protection of commercial assets.

Equipment suppliers are often at the forefront of innovation and development and it is natural that they would wish to protect their investment. On the other hand, there are benefits to be achieved from opening up proprietary systems.

In the technical specification of ITS it is crucial that communication and data exchange protocols are specified early on in the design process. However, as seen below, this is not always straightforward.

Communication protocols: Development of communications standards is normally a “negotiated process” with many vested interests (i.e. manufacturers, local authorities). Simply calling for a standard by a higher authority or a client is not enough; intelligent usage and enforcement are also required. An example is CEN 278 for DSRC (Dedicated Short Range Communications)—it has been a European standard for many years, but vendors developed proprietary or secret “profiles,” which have limited interoperability for years.

Another example is in the United States of America, where the National Transportation Communications for ITS Protocols (NTCIP) is a joint standardization project of American Association of State Highway and Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), and National Electrical Manufacturers Association (NEMA) with funding from the Federal Highway Administration (FHWA). Its aim is to standardize communication protocols between different manufacturers’ ITS systems and equipment—such as Area Traffic Control (ATC) equipment, CCTV, VMS, etc. NTCIP is currently becoming the default standard in China. Most North American manufacturers claim that their traffic control equipment are NTCIP compliant. In other parts of the world, manufacturers can address NTCIP requirements through their affiliation with other companies and/or are in the process of developing their own NTCIP-compliant products.

However, even NTCIP may still be far from becoming a universal standard in the industry. NTCIP allows for mandatory modules (Management Information Bases, or MIBs) and optional MIBs. The intent was that mandatory MIBs be used for standard functions and optional MIBs be used for enhancements, sometime proprietary. However, manufacturers have often opted to use optional proprietary MIBs to handle many standard functions. Because of this, NTCIP may not provide much interoperability.

Europe, on the other hand, has taken a different approach through a more collaborative approach, but based on national protocols, including the United Kingdom’s Urban Traffic Management and Control (UTMC) and Germany’s Open Communication Interface for road Traffic control (OCIT). The Information Technology Standards Committee (ITSC) specification supports a variety of existing and new access technologies and ITS applications. The term ITSC denotes communications protocols, related management, and additional functionality. It is arranged as a tool box as ITSC is independent of specific communication technologies and ITS applications. The ITSC architecture is intended to be an open-systems architecture—one that is not proprietary.

Data exchange—transfer protocols, APIs, data formats: For data exchange, there is a need for the development of standardized data transfer protocols in cooperation with the manufacturer of the ITS system. Again, this can and should be specified at the design stage, but care needs to be taken to avoid any skew towards a particular system or manufacturer even at this early stage of functional specification. Another key element here, in addition to the hardware, is the interaction with the software. This is generally considered to be best done through Application Programming Interfaces (APIs); these are software routines with functionalities that are independent of the hardware and of the system, and they can provide a program, such as a trip planner or bus times, for example, to enable more efficient and seamless trips. Supporting APIs are the data formats and while there is less of a need for standardization here (as the API can manipulate the data feed), it is certainly beneficial to evolve more standardized datasets such as the General Transit Feed Specification (GTFS), which defines a common format for PT schedules and associated geographic information.

Physical conditions

Having good ICT infrastructure is important to scale up smart mobility solutions. For example, the Seoul Metropolitan Government owns most telecommunications infrastructure such as the fiber optic lines along the subway and expressways. Seoul, therefore, was able to roll out major data-intensive initiatives without worrying about bandwidth. The Barcelona City Council also owns most of the fiber optic network in the city and enjoys low maintenance costs for many smart city initiatives. Therefore, the City Council ordered that whenever civil work happens—for example, construction of subway tunnels and waste systems—it has to leave room for communication infrastructure. However, high-speed broadband is not necessary to take advantage of technology. For example, despite having limited broadband connectivity (both mobile and fixed), Nairobi was able to develop two of the most innovative platforms used in 2G environments—M-PESA, the world’s largest mobile payment platform, and Ushahidi, a crowdsourcing platform [Mulas (2014)].

Box 4 Broadband or narrowband?

Both broadband and narrowband communications are vital for successful deployment of ITS. Cities with a legacy of early ITS deployment, such as Barcelona and Copenhagen, have benefitted from the early installation of a fiber optic (FO) broadband network, typically below ground. Emerging cities in China typically install FO above ground; and this has also often been the case in Japan and South Korea.

Broadband is a robust technology that provides the framework for mobile phone (cell phone) applications through on-site Wi-Fi. If there is already a broadband network, then it is likely to be worthwhile to maintain or upgrade this depending on the cost.

However, technology evolves rapidly, and narrowband is becoming most cost effective, particular for roadside sensors. Typically, narrowband can be deployed quickly citywide as it does not use Wi-Fi but uses the radio spectrum and radio technology. Narrowband has already been deployed to control smart lighting and parking sensors. If narrowband evolves successfully and if costs reduce, there is a case for considering this as an alternative to broadband.

It is hard to present advice to individual cities without detailed knowledge of their specific needs and infrastructure. Suffice to say that emerging cities should examine the potential to benefit from the “latecomer’s advantage” and should evaluate both technologies.

4. How energy savings are achieved by ITS investments in the smart cities context

There have been several commonly used models for understanding energy consumption (greenhouse gas emissions) in the transport sector. The “ASIF framework” breaks transport energy use down into activity, modal share, and energy intensities [Schipper et al. (2000)]. Others organize mitigation approaches into behavior (number of vehicles), design (distance traveled), and technology (emission/energy per vehicle-distance traveled) [Wright and Fulton (2005)]. A more recent “ASIF2” paradigm and its variances summarize mitigation measures into avoid, shift, improve, and finance [Dalkmann and Brannigan (2007)]. All models are actually pretty similar and straightforward. Considering that the intervention in focus is ITS investments in the smart cities context, which are “people-centric,” not pure vehicle or

communication technology nor policy or regulatory interventions such as vehicle standard or fuel price, this study emphasizes the energy savings through users' behavioral change.

We can see from the conceptual model presented in the previous section that energy savings are achieved through users' behavior changes resulting from using the smart mobility solutions (Step 3). These behavioral changes can be grouped into three categories based on their results: (i) less travel (reduction in total vehicle-distance travelled), (ii) modal shift (users switch to a less energy-intensive mode), and (iii) reduction of per-km energy consumption (fewer stops, faster speed) in the short term. Smart mobility solutions as an enabler could also lead to other energy-saving policies or initiatives, which would otherwise not be feasible. In the long term, users' lifestyles could change and changes in vehicle ownership, work location, residential location, and activity pattern can lead to further energy savings.

4.1 The short-term effect

(i) Less travel

Smart mobility solutions could reduce vehicle-distance traveled in many ways. For example, a taxi-hailing app matches a taxi driver's location and routes with real-time demand so that drivers do not need to drive around looking for passengers. Car-sharing and carpooling could combine two trips into one thereby reducing vehicle travel.

Smart-parking apps help drivers easily find available parking spaces. It was estimated that *SFpark* reduced vehicle-distance travelled by cars in search for on-street parking spaces by 50 percent [Millard-Ball et al. (2014)]. Real-time communication with the traveler about road conditions, accidents, and construction could reduce travel time as travelers pick better routes and avoid cruising.

(ii) Modal shift

When the use of smart mobility applications increases the attractiveness of a less energy-intensive ("greener") mode such as public transport, biking, or walking, users might switch from private cars to the greener mode. For example, applications such as multimodal trip planners (e.g., Moovit and Citymapper), public transport information (e.g., NextBus and MyTransport Singapore), and bike-sharing that either decrease the money and time costs, increase comfort and satisfaction, add enjoyment, or change people's perception and attitude, all have the potential to encourage users to switch modes. One study showed that mobile real-time information reduces not only the perceived wait time, but also the actual wait time experienced by transit riders. Data of OneBusAway transit traveler information system in Seattle reduced users' actual wait time by two minutes and an additional 0.7 minutes for perceived wait time [Watkins et al. (2011)]. Studies show that people are more satisfied with public transport with real-time bus information services and people are willing to pay 19 percent to 24 percent more over their bus fares for the information provision [Papaioannou et al. (1996); Politis et al. (2010)], and that real-time bus information increases bus ridership [Tang and Thakuriah (2012)]. One study done in city of Thessaloniki,

Greece, showed that 20 percent of users make more trips as a consequence of the information system, and 24 percent of these new trips would have been made by car [Politis et al. (2010)].

(iii) Reduction of energy per vehicle-distance traveled

Traditional ITS measures, for example, adaptive signal control, ramp metering, and vehicle platooning, save energy by smoothing traffic flow and improving fuel efficiency. Smart mobility solutions that reduce congestion (including those targeting road accident detection that shorten the time of congestion caused by accidents) could also result in smoother traffic flow and increase the average speed thereby increasing fuel efficiency for most vehicles. Eco-driving solutions promote a driving style characterized by accelerating slowly, cruising at more moderate speeds, avoiding sudden braking, and idling less, as well as selecting routes that allow more of this sort of driving [Lovejoy et al. (2013)]. One experiment of providing real-time fuel efficiency information on the dashboard to drivers showed 2.9 percent average improvement in fuel efficiency [Kurani et al. (2013)]. An experiment in Taiwan showed that cash rewards (NT\$5 per liter fuel saved) given to bus drivers increased fleet average fuel economy by more than 10 percent [Lai (2015)]. The variable speed limit experiment in Madrid showed a local reduction of about 2 percent in fuel consumption due to less stop time and reduced average positive acceleration.

More examples of energy saving potentials are summarized in Table 1, which includes some traditional ITS interventions because similar studies for recently developed smart mobility interventions were extremely scarce and very few estimates are available.

Caution should be taken to use or reference the results from the literature. Some of these studies suffer from methodological caveats as many factors influencing behaviors are difficult to control. Neglecting selection bias is especially common in the eco-driving literature. These estimates might also be subject to “publication bias” as studies that show negative or insignificant results are less likely to be published and the significance of the published studies is overestimated. The actual effect, therefore, might be much smaller.

Table 1 Examples of energy saving estimates of ITS investments

Behavior change	More examples, including some traditional ITS interventions
Less travel	<ul style="list-style-type: none"> • Car sharing reduced Vehicle Kilometers Traveled (VKT) overall by about a quarter to a third among those who have participated [Martin et al. (2011)]. • Dynamic message signs and Highway Advisory Radio (HAR) reduced 66,000 vehicle miles driven to 99,000 vehicle miles driven in the Grand Canyon National Park. • Stockholm congestion charging reduces VKT by 14 percent. • Milan congestion charging reduces VKT by 14 percent. • A shift to accident insurance per mile (PAYD), rather than in a lump sum, would reduce driven kilometers by 8 percent. • Planning systems in taxi companies in Taiwan reduce fuel consumption by 16 percent. • Integrating traveler information with traffic and incident management systems in Seattle, Washington, could lower fuel consumption by 0.8 percent.
Modal shift	<ul style="list-style-type: none"> • Personalized travel planning system in Nagoya, Japan, helps commuters choose environmentally friendly routes and modes, and reduces carbon dioxide emissions by 20 percent.
Reduction of energy per vehicle-distance traveled	<ul style="list-style-type: none"> • The E-ZPass electronic toll collection system on the New Jersey Turnpike is estimated to save 1.2 million gallons of fuel each year. • Signal system in Richmond, Virginia, reduced fuel consumption 10 percent to 12 percent; 13 percent in Los Angeles; coordinated signal timing on the arterial network in Syracuse, New York, reduced total fuel consumption by 9 percent to 13 percent. • A transit signal priority system in Southampton, England, reduced bus fuel consumption by 13 percent; Helsinki, Finland, reduced by 3.6 percent. • An adaptive signal timing in Gresham, Oregon, in 2007 saves over 74,000 gallons of fuel every year. • Adaptive signal control systems in two corridors in Colorado reduced fuel consumption by 2 percent to 7 percent. • In some EU cities, Adaptive Cruise Control reduces an average fuel consumption of 5 percent. • Smart Motorways (variable speed limits and flexible shoulder access) reduced fuel consumption by 4 percent in the United Kingdom. • SPECS cameras for speed enforcement in the United Kingdom achieved 11.3 percent fuel savings. • Platooning in EU motorways generates fuel savings of 8 percent to 11 percent. • The Safe Road Trains for the Environment (SARTRE) project demonstrated up to 16 percent reduction in fuel consumption with vehicle platooning. • Urban drive control (UDC) systems in Torino, Italy, traffic light approach control (TLC) reduced fuel consumption by 8.3 percent to 13.8 percent. • Intelligent speed control applications can reduce fuel consumption by 10 percent to 20 percent without drastically affecting overall travel times. • In the European Union, fuel-consumption/energy-use indicator generates fuel savings at an average of 5 percent. • In Sweden, drivers educated in eco-driving had 7 percent lower fuel consumption than conventional drivers. In Gothenburg, a similar study for distribution-truck drivers shows that after education in eco-driving, fuel consumption decreased by 17 percent. Experiments in Madrid, Spain, and Turin, Italy, showed 13 percent to 15 percent reduction in fuel consumption. • Incident detection, adaptive signal control, and transit signal priority implemented on the Atlanta Smart Corridor reduced fuel consumption by 34 percent across all peak periods.

Source: US DOT ITS Benefits Database; ICT-emissions, 2015¹¹; ITS UK, 2013¹²; Klunder, 2009; Vaidyanathan, 2014.

¹¹ <http://www.itsbenefits.its.dot.gov/>.

¹² <http://www.its-uk.org.uk>.

4.2 Enabling effect

Smart mobility interventions could also be an enabler for implementing other interventions or policies due to their ability to collect and analyze real-time and personalized data. Parking schemes, road-pricing schemes, public transport pricing and subsidies, special mobility service provision, other enforcement and education measures, all can be on-demand, targeted, customized, and adaptive in real time. These initiatives and policies enabled by ITS investments in the smart cities context would achieve energy savings via both technology and behavior changes.

4.3 The long-term effect

In the long run, smart mobility solutions might change people's lifestyles. While ride-sharing is able to combine trips leading to less travel, it is still unclear how newly emerged Transportation Network Companies (TNCs) such as Uber, Lyft, GrabTaxi, and EasyTaxi that provide ride-sourcing services would change people's travel behaviors and what the aggregate impact would be on energy use. However, in the long term, it is plausible that with more mobility options, and much more convenient transport services provided in the city through smart mobility solutions, there is less incentive for people to own private cars (like the on-demand mobility vision in Helsinki). For example, four years after the introduction of City CarShare in the San Francisco Bay Area in California, 29 percent of CarShare members had gotten rid of one or more cars [Cervero (2007)]. Although there are no relevant studies, observations in some cities in China showed that ride-sourcing apps and their variances (car-rental, shuttle services, chauffeur services, and delivery services) are making private car ownership less and less attractive for people, especially the younger generations. Lifestyle change might also include the locations of work and residence as well as activity patterns. With more people preferring to live in dense urban centers, travel demand is less. As more people use public transport, bikes, and walk to get around, there are fewer private vehicles so cities do not need to build more infrastructure such as roads and parking. Energy savings are thus achieved in the long run.

5. Applications to a Bank-financed project: Wuhan Integrated Transport Development Project

Table 2 summarizes the key themes and conditions for successful implementation of smart mobility initiatives at each step as discussed in the previous sections. In this section we apply the main findings of the research to the Bank-financed Wuhan Integrated Transport Development Project (WITDP, 148294). The Board of Directors of the World Bank on February 26, 2016, approved this project, which is currently under implementation in the cities of Wuhan and Anlu in Hubei province in China. Wuhan has a population of close 10.3 million and Anlu 0.6 million. Both are located in the Wuhan Metropolitan Region that has in total close to 30.9 million inhabitants. In addition, the team also carried out a Tool for Rapid Assessment of City Energy (TRACE) analysis for the city of Wuhan.¹³

¹³ See <http://www.worldbank.org/projects/P148294?lang=en>.

Table 2 Summary of key themes and conditions for successful implementation of smart mobility initiatives

Step	Key themes	Institutional conditions	Technical conditions	Physical conditions
1. A mobility problem is identified and a smart mobility solution is designed.	<p>People-centric</p> <p>Avoid an ITS solution looking for a problem</p> <p>Innovation</p>	<p>A channel of public participation for problem identification and design comprising apps, social networks, e-government and traditional channels such as call centers, mail, and in person.</p> <p>A collaborative setting for all players embracing public/private partnerships as well as academia.</p>	<p>Seek innovative ideas through urban living labs and community events such as hackathons and open-data challenges.</p> <p>Enable private sector involvement</p>	
2. The ITS solution is deployed and operated.	<p>City champion</p> <p>Long-term vision</p> <p>Data sharing</p>	<p>A long-term vision and coalition of support for transport.</p> <p>Minimum institutional capacity to enable transparent and performance-based contract management and monitoring.</p> <p>An administrative authority with real power for interagency coordination.</p> <p>Institutional (including legal) arrangements for data sharing and open data.</p>	<p>Technical capacity for data collection and integration, data analyses, and information service provision.</p> <p>Standardized data format</p> <p>If cities choose to use third-party providers, capacity is needed to procure and monitor these services.</p>	<p>A coherent road network infrastructure.</p> <p>Availability of transport and ICT infrastructure and devices</p> <p>Infrastructure and hardware such as sensors for collecting data</p>
3. Users use the solution and change their behavior accordingly.	<p>Energy savings</p> <p>Behavior change</p>	<p>Coherent green policy</p> <p>Transparency and information sharing to build trust</p> <p>Public participation</p> <p>Consistent enforcement</p>	<p>Understand demand and anticipate behavioral factors</p> <p>Marketing and education combined</p> <p>Public/private partnerships</p> <p>Privacy, security, ethical and fraud issues</p>	<p>Properly designed infrastructure and user interface</p> <p>Alternatives for behavior change</p>
4. The solution is scaled up and evolves over time.	<p>Evaluation and monitoring</p>	<p>Involve all players and align their interests</p>	<p>Cultivate a technical ecosystem</p> <p>Measure and evaluate results</p>	<p>ICT infrastructure</p>

5.1 Project background and scope

Wuhan has already invested in Intelligent Transport Systems (ITS) and built the foundations for “smart” transport planning, management, and monitoring. In recent years, Wuhan city agencies have implemented systems that include: (a) Area Traffic Control (ATC) signals; (b) CCTV traffic-monitoring cameras; (c) e-police enforcement cameras; (d) a traffic guidance system; (e) public bus monitoring and dispatch systems; (f) a “floating-car” taxi-monitoring system; (g) bridge-and-tunnel electronic toll-collection (ETC) systems; (h) a highway toll-collection system; and (i) a public transport-monitoring system using smart cards. In addition, mobile, including mobile broadband (3G/4G), penetration is widespread in Wuhan, with extensive use of social media, which offers a strong foundation for the provision of access to transport data and information through smartphone apps as well. The added value of the investments under this project will be to utilize the substantial data, which have been gathered and processed strategically and efficiently, to inform transport network design, operational planning, and management, as well as system performance monitoring by the municipal government and system users. Therefore, significant focus is placed on “analytics” and “smart” evidence-based decision making.

A key step at this stage is the integration of and data capture from Wuhan’s multiple ITS components and modules. Separate agencies manage these modules without standardization or interoperability, and data or information sharing has been limited.¹⁴ Analyses undertaken are also disaggregated, thus limiting their benefits and applicability. The project offers an excellent opportunity to apply cutting-edge technologies to increase data capture (e.g., a variety of sensors/monitoring equipment—“Internet of Things” [IOT]); analytical tools and techniques to handle large data volumes (“big data/analytics”); and cloud computing to facilitate the more effective and efficient sharing of information-system infrastructure and resources. Non-compatible legacy systems will be progressively phased out and superseded by a unified portal. Developing such a “one-stop” portal for all of Wuhan’s ITS and associated systems will facilitate more widespread access to data and information and provide powerful tools for analysis and decision making.

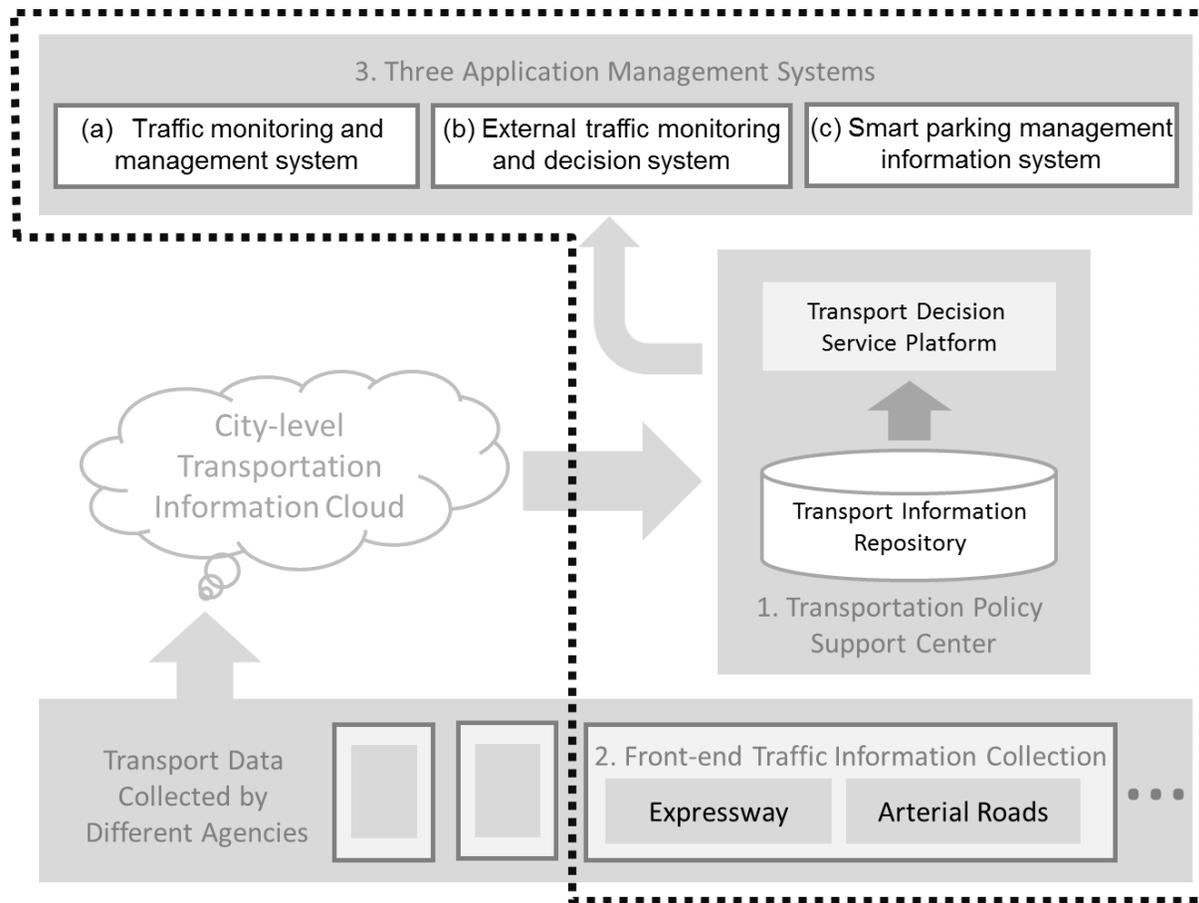
Use of cloud computing (shared services) can help make infrastructure more scalable for end users by enabling elastic capacity planning for individual participating agencies. Cloud computing will support and encourage the adoption of standardization and sharing of ICT services across Wuhan Municipal Government (WMG) agencies responsible for transport and urban planning. The ability to use virtual servers, virtual storage, and virtual networking should also result in much lower capital expenditure for establishing the overall cloud computing infrastructure.

¹⁴ Existing operational ITS are operated by three agencies under the municipality: the traffic police operate coordinated traffic signals, e-police enforcement, and traffic guidance systems; the bus company operates bus monitoring, dispatch, and passenger information systems; and the Urban Road and Bridge Management Center operates electronic toll collection on bridges, tunnels, and highways. These were developed independently because they had different objectives and functions: traffic operations and enforcement; bus operations; and toll collection. This is fairly standard in most cities, even developed ones, and it is only very recently that cities are beginning to integrate these functions. In Wuhan, there have been no previous attempts to integrate these systems.

WMG decided to use a large-scale commercial cloud service for the integration of all transportation-related data from different agencies by establishing the city-level transport information cloud. Based on data security consideration and special needs of local agencies, this project will set up a transport information repository: a smaller-scale data center housed in Wuhan is the Wuhan Transport Development and Strategy Research Institute (WTDSRI). This repository will have raw and processed data feeds from the city-level transport information cloud, and will provide local data backup and data services for the two platforms hosted in the center. In other words, the city-level transport information cloud will be the hub for the storage, integration, and sharing of all transport-related data in Wuhan. The local transport information repository will complement the cloud and play two strategic roles: data backup, and hosting the decision service platform and basic data and research platform to support the government's transportation policymaking. WTDSRI is an institute specialized in transportation planning and policy research. It is considered ideal for managing the Transport Policy Support Center.

The city-level transport information cloud and the local Transport Policy Support Center (with integrated transport data from all sources) can provide high-quality data and analytical services to different agencies to help them improve management and planning, and provide better transport services to residents. The intelligent comprehensive traffic management system to be developed for the Wuhan Traffic Management Bureau (WTMB) will improve operations, reduce congestion, and monitor road conditions, command and dispatch, and traffic signal control. The integrated transportation information system developed for the Wuhan Transportation Commission (WTC) will improve operations and management of in- and out-of-city traffic, with data integrated from urban railways, waterways, intercity roads, airlines, urban buses, subways and taxis, and will support the coordinated monitoring and management of all modes. The smart-parking management information system for the Wuhan Parking Corporation (WPC) will integrate on-street, off-street, and public parking information in the city, and will provide real-time availability monitoring, hierarchy parking guidance, electronic payment, customized booking, and searching services for residents. The project will emphasize capacity building—both technical and institutional—for the sustainable operations of these systems.

Figure 6 Stylized representation of Wuhan ITS component of the WITDP



5.2 Knowledge incorporated in project design

Several key lessons learned from international best practices include: smart cities thrive with public participation and engagement, and classic “top-down” approaches need to be strengthened with “bottom-up” perspectives; governments need to have at least minimal technical and institutional capacity to be able to procure and manage performance-based contracts; open data are beneficial with consideration of privacy and security; and standardization and system interoperability are essential. The design of the WITDP considers and incorporates these lessons. Specifically, following the four essential steps in the conceptual model:

Step (1): A mobility problem is identified and a smart mobility solution is designed. Institutional conditions include establishing channels of public participation for problem identification and design. The project took advantage of the existing e-government initiative in Wuhan and utilized also the resources of “Wuhan’s Citizen’s Home” (the “one-stop” center for Wuhan citizens to get administrative approval, public services, and information from government agencies established in 2012) as channels of public participation and information dissemination.

Step (2): The smart mobility solution is deployed and operated. One of the institutional conditions is that an authority with real administrative power is needed to facilitate the cooperation and integration of different agencies in the city. In the Wuhan case, this condition is realized by a very strong city government leadership—the Wuhan “Internet+” Action Committee (WIAC)—that was established by the Wuhan Municipal Government (WMG) in July 2015 to provide overall leadership, strategic guidance and institutional coordination for all smart city initiatives in Wuhan, including the Wuhan component of this project. WIAC, housed in the WMG’s Internet and Information Office, is headed by the municipal party secretary and has the mayor as vice director. WIAC reviews, approves, and coordinates the implementation of all smart city projects in Wuhan. Wuhan Project Management Office (WPMO) will report to WIAC with relevant project information when strategic guidance and coordination from WMG are necessary.

There is also great emphasis on the minimum technical capacity to procure and monitor information services. The Wuhan ITS component of the WITDP promotes data integration and data format standardization, and also proposes a schedule to open data gradually with technical, privacy, and security considerations. Therefore, the Project Implementation Unit (PIU) for the Wuhan ITS component is the Wuhan Transport Development and Strategy Research Institute (WTDSRI), which has the highest technical capacity in transportation data analysis and research. All other subcomponents will also be implemented by agencies with the highest technical capacity in their respective areas. Capacity-building activities designed under the project will focus on system implementation and operation.

Step (3): Users use the solution and change their behavior accordingly. Lessons show that institutionally, policy signals should be coherent leaning toward the “green” modes. In the WITDP, the expectation is that the smart mobility solutions planned for Wuhan will be used by users that range from the mayor and other decision makers, to planners, users of public transport, and pedestrians, among others. The project contemplates several “platforms” that will provide information according to the needs of each of these users. In addition, the project also contemplates open-data initiatives to allow developers of applications to maximize the use of the data generated by the “platforms.”

In addition, the design for the Anlu parts of the WITDP built upon lessons learned in Wuhan—which has had two previous projects financed by the World Bank—and from other Bank-financed urban transport projects in China. In addition, Anlu expressed a desire to follow a green growth trajectory by laying the foundation for a public transport and Non-Motorized Transport (NMT) system that is an efficient alternative to cars. Technical assistance activities to be financed by the WITDP for Anlu are also designed around this ambition—on urban transport strategy and planning, road safety, parking policy, and non-motorized transport—to make sure coherent policy signals are sent to the users in Anlu.

Physically, the Anlu part of the project focuses on infrastructure investments in its transport system to improve public transport through integrated corridors—a comprehensive approach that improves the entire corridor by giving priority to public transport and NMT—as well as additional sidewalk improvements. These integrated infrastructure investments improve the connectivity of road network, provide basic traffic management measures, and improve public transport and NMT services, which not

only lay the infrastructure foundations for smart mobility solutions, but also provide users with alternatives for “green” behavioral changes.

Finally, Step (4): The smart mobility solution is scaled up and evolves over time. Financially and technically-constrained cities in developing countries can take advantage of resources from the private sector and citizens thanks to aligned interests in improving user experience. In the Wuhan ITS component of the project, WMG established a long-term partnership with a private company by using its large-scale commercial cloud service for the integration of all transportation-related data from different agencies to establish the city-level transport information cloud. Measuring and evaluating results is also important for learning and evolving. The team has put great effort into working with its counterpart to design the project’s Monitoring and Evaluation (M&E) framework so that impacts on final beneficiaries are demonstrated through Specific, Measureable, Attainable, Relevant, and Time-bound (SMART) indicators for learning and evolving purposes, and both cities’ capacity for measuring and evaluating results are also strengthened.

5.3 TRACE analysis for Wuhan

While the lessons learned from international best practices in the conditions for successful implementation of smart transport solutions are incorporated into project design, the lessons learned on how and how much energy savings are achieved by smart transport solutions could be used to strengthen the recommendations made to Wuhan for the purpose of energy efficiency. The team developed these recommendations using the Tool for Rapid Assessment of City Energy (TRACE) analysis.

TRACE is a decision-support tool to help cities identify underperforming sectors in terms of energy efficiency by comparing them to peer cities, evaluating improvement and cost-saving potential, and prioritizing sectors and actions for energy efficiency intervention.¹⁵

The team utilized the TRACE tool to evaluate potential energy savings and provide energy efficiency recommendations to the urban transport sector in Wuhan. The TRACE tool was designed to help prioritize energy savings across six sectors—passenger transport, municipal buildings, water and wastewater, street lighting, solid waste, and power and heat. It consists of three principal modules:

- (1) Energy benchmarking: Compares Key Performance Indicators (KPIs) across peer cities such as percentage modal split for Non-Motorized Transport (NMT), which covers cycling and walking;
- (2) Sector prioritization: Identifies sectors that offer the greatest energy cost savings potential; and
- (3) Intervention selection: Provides “tried and tested” energy efficiency solutions.

For this study, the passenger transport sector was prioritized and interventions were explored using the TRACE tool to facilitate the linked World Bank loan project to identify energy efficiency in Wuhan. During the course of the preparation of the WITDP, the project team visited Wuhan and conducted

¹⁵ <http://esmap.org/TRACE>.

interviews with officials from a broad range of city agencies to collect energy use information for the city as well as for the transport sector. The data was then fed into the TRACE tool to conduct the current energy use benchmarking with other cities in the TRACE database. The initial energy saving potential was then estimated according to the benchmark results as well as the level of the city's control over transport sector authorities. Finally, recommendations were provided based on the energy saving evaluation and the city database. The initial energy saving potential, assets, and infrastructure, with detailed information on each of the strategies, are also provided.

The energy benchmarking finds that Wuhan has:

- Relatively high citywide primary electricity consumption per capita;
- Relatively high citywide energy consumption per capita;
- Low average length of high-capacity transit routes per 1,000 people;
- High private transport energy consumption; and
- Total transport energy use per capita, public transport energy consumption, and public transport mode split ranks in the middle when compared with peer cities.

According to the diagnostic results, it is estimated that potentially 31 percent can be saved in public transport energy costs and 20.2 percent in private vehicles' energy costs.

Based on Wuhan's specific situation, the TRACE tool provided the following recommendations for energy savings in the transport sector. As discussed in Section 4, all these recommendations achieve energy savings through less travel, modal shift, and reduction of per-km energy consumption in the short term. Smart mobility solutions, which as an enabler could lead to other energy-saving policies or initiatives that would otherwise not be feasible, are not in the "solution base" of TRACE. Some of the interventions achieve energy efficiency by long-term users' lifestyle changes—such as changes in vehicle ownership, work location, residential location, and activity pattern.

- **Enforcement of vehicle emissions standards**

Enforcement of vehicle emissions standards not only improves local air quality, it leads to lower fuel consumption. Energy saving is achieved through reduction of per-km energy consumption. Vehicle emissions standards may be implemented through mandatory regular emissions checks. The higher the vehicle emissions standard, the less fuel the vehicle is likely to consume and the higher the reductions in the emission of fine particles, nitrogen dioxide, ozone, CO₂, and other pollutants. Lower emissions result in better air quality and a lower risk of respiratory diseases associated with air pollution.

- **Traffic-flow optimization**

Traffic can be positively managed to ensure the most efficient operation of the transport system. Management techniques and Intelligent Transport Systems (ITS) will seek to minimize distance travelled between origin and destination, minimize the number of vehicle stops, ensure the efficient flow of traffic, and encourage multiple-occupancy vehicle travel. The strategy will encourage efficient use of vehicles and minimize journey lengths and vehicle stops, thereby reducing fuel use.

- **Public transport development**

Develop or improve the public transport system and take steps to increase its accessibility and use. Energy saving is achieved through modal shift. Public transport achieves lower emissions per capita than private cars and has the potential to provide an equitable transport network. A reduction in the number of private vehicles in circulation can lower emissions and improve air quality.

- **Non-motorized transport modes**

Energy saving is achieved through modal shift. Non-motorized transport modes have zero operational fuel consumption and require low capital costs for implementation. In addition to improving the health of users, their use reduces noise pollution and improves air quality. The benefits include improved air quality, lower operating costs for users and providers, and lower infrastructure requirements. However, it should be noted that in Chinese cities the term “Non-Motorized Vehicle (NMV)” covers electric bicycles (E-bikes) and their numbers have risen substantially since motorcycles were banned in many urban areas. Vehicle registration data for Wuhan in 2012 shows E-bikes at 0.7 million and bicycles at 1.17 million. In Wuhan in 2008, E-bikes comprised 13 percent of the trip modal split with bicycles comprising only 7 percent.¹⁶

- **Parking-restraint measures**

Energy saving is achieved through modal shift and long-term lifestyle change. Restricting parking can discourage car use and provide an incentive to use more sustainable modes of transport, including public transport. Removing vehicles from circulation reduces fuel use and the effects of congestion.

- **Traffic restraint measures**

Energy saving is achieved through less travel, modal shift, and long-term lifestyle change. Discouraging potential drivers from using their cars can lead to fewer cars in circulation. This can encourage people to use alternative modes, which in turn will increase their viability (increased public transport patronage, for example). Removing vehicles from circulation reduces fuel use and the need for road space.

- **Congestion charging**

Energy saving is achieved through less travel, modal shift, and long-term lifestyle change. Congestion charging restrains access by selected vehicle types, usually private cars, into large urban areas during congested times of the day. The aim is usually to discourage work-based commuting trips into a defined urban area. Measures range from complete restriction to discouragement through charging to incentive pricing for low-emission vehicles in low-emission zones. It is a market-based mechanism for influencing driver behavior that looks to capture the “external cost” of vehicle travel during congested periods of the day.

- **Travel planning**

¹⁶ Wuhan Municipal Engineering Design and Research Institute (WMEDRI), 2009.

This is one example of smart transport solutions. Energy saving is achieved through less travel, modal shift, and reduction of energy per vehicle-distance traveled. Informing drivers about alternative modes of transport and sharing resources with other drivers leads to fewer cars being used and more trips on public transport. Removing vehicles from circulation reduces fuel consumption and increases the viability and efficiency of public transport.

- **Awareness-raising campaigns**

Public education and training campaigns can increase the public’s awareness and understanding of the benefits of energy efficiency and help change attitudes. Energy saving is achieved through modal shift and long-term lifestyle change. Providing information on easy ways to be more energy efficient can help modify citizen behavior and contribute to overall energy savings. The key benefits are more energy efficient behavior by residents leading to reduced energy consumption within the city. For example, encouraging people to leave their car at home and take transit instead, or promoting walking for short trips. Indirect benefits include reduced pressure on energy infrastructure, reduced carbon emissions, and better air quality.

The above recommendations can build upon the ongoing programs carried out by the city, and some of them can also be combined with the linked WITDP that is financed by the World Bank. A full report on how the TRACE tool was applied to Wuhan was prepared and is an ancillary document to this report.¹⁷

6. Conclusions

We first present the conclusions derived from international best practices and then we use the example of applying these conclusions to the WITDP to craft conclusions for other client cities of the World Bank.

6.1 Lessons learned from international best practices

Compared to traditional ITS investments, the smart cities context has transformed ITS into “smart mobility” with three major characteristics: people-centric, data-driven, and powered by bottom-up innovations. These three characteristics bring both opportunities and challenges and are key to understanding the conditions for smart mobility solutions to be successfully implemented and achieve energy saving benefits.

We argue that there are four major steps for ITS interventions in the smart cities context to achieve energy savings. These are:

Step (1): A mobility problem is identified and a smart mobility solution is designed. Institutional conditions include establishing channels of public participation for problem identification and design, and finding a collaborative setting for all players. Seeking innovative ideas through community events such as hackathons and open-data challenges is highly beneficial at this step.

¹⁷ See “City Energy Efficiency Report: Transport Sector Wuhan.” August, 2015.

Step (2): The smart mobility solution is deployed and operated. A long-term vision and coalition of support for transport is needed. City government needs to have institutional minimum capacity to enable transparent and performance-based contract management and monitoring. An administrative authority with real power is also necessary for inter-agency coordination. Institutional (including legal) arrangements for data sharing and open data is essential as well. Technical capacity is needed for data collection and integration, data analyses, and information service provision. If cities choose to use third-party providers, capacity is needed to procure these services.

Step (3): Users use the solution and change their behavior accordingly. These behavioral changes translate into less energy consumed. Institutionally, policy signals should be coherent leaning toward the “green” modes; transparency is necessary to build trust; and enforcement should be in place and consistent. Technically, demand should be understood correctly, anticipating behavioral factors; public and private sectors should cooperate to provide marketing and education; privacy, security, and fraud issues should also be considered. Physically, infrastructure and user interfaces should be properly designed considering the availability of user devices; alternatives should be provided for users’ behavior change.

Finally, Step (4): The smart mobility solution is scaled up and evolves over time. It is beneficial for the city as a coordinator to involve all players and align their interests. Technically, a healthy “ecosystem” of players in the field needs to be cultivated and results measured for evaluation to enable learning.

Energy savings are achieved through users’ behavior changes resulting from using the smart mobility solutions: less travel, modal shift, and reduction of per-km energy consumption in the short term. Also, smart mobility solutions as an enabler could lead to other energy-saving policies or initiatives that would otherwise not be feasible. In the long term, user’s lifestyles could change—such as changes in vehicle ownership, work location, residential location, and activity pattern—and this can lead to further energy savings.

6.2 Implications for developing countries

Compared to cities in developed countries with the best international practices in smart mobility—discussed in previous sections—cities in developing countries tend to have: (1) lower motorization level, but high growth rate and higher congestion levels; (2) less-developed existing infrastructure; (3) less financial resources for both capital investment and operation and maintenance expenses [Ardila-Gomez and Ortegón-Sánchez (2016)]; and (4) lower institutional and technical capacity. In the context of the smart cities movement, where traditional ITS transform into more people-centric, data-driven “smart mobility” powered by bottom-up innovations, cities in developing countries face both leapfrog opportunities and also challenges in institutional, technical, and physical aspects. Learning from this study, in order to achieve benefits from smart transport investments, developing cities should:

(1) Involve all public and private players in a collaborative and transparent setting. Financially-constrained cities in developing countries can take advantage of the resources from the private sector and citizens thanks to aligned interests in improving user experience. Collaboration and transparency

is necessary not only for these low-cost innovative smart transport solutions to be developed, but also for building trust among all players for these solutions to be used, maintained, and scaled up in the long run.

(2) Develop the technical capacity to procure and monitor information services. For innovative and usually technically complex smart transport solutions, developing cities with weak technical capacity face the risk of technology lock-in and capture by a powerful stakeholder (e.g., big technology provider) for excessive profit. Therefore, it is crucial for cities to develop minimum technical capacity to mitigate this risk when procuring and monitoring these services.

(3) Focus on basic infrastructure, including a coherent road network and basic traffic management measures. With less-developed existing infrastructure, developing cities have the opportunity to establish a coherent road network corresponding to land use and with basic traffic-management measures such as traffic lights, traffic signs, lane markings, zebra markings, and user education.¹⁸ Such a coherent road network is not only essential for meeting basic travel demand of the citizens (to avoid the paradox of high congestion at low-motorization level), but also strategically important to meet accessibility needs as the infrastructure and complementary policies guide future growth, thereby shaping future travel demand patterns.

The challenge for cities in developing countries is, therefore, to be able to leapfrog by developing the necessary capacity to carry out the four major steps for smart mobility interventions to yield positive results. Institutional capacity, indeed, emerged in the analysis as a key constituent of these four steps. Yet cities in developing countries frequently lack the capacity to properly manage a basic traffic light network. Congestion in these cities is very high despite low levels of motorization and seemingly enough roads. This point was vividly illustrated on the ESMAP-funded study tour to Barcelona with Chinese government officials. During discussions, the key point that was made was that car ownership in Barcelona was 600 cars per 1,000 inhabitants whereas in Wuhan that figure was around 200 cars per 1,000 inhabitants. Yet car traffic flowed in Barcelona whereas it was jammed in Wuhan. Barcelona also had lots of pedestrian and bicycle traffic. The Chinese officials hoped that smart mobility solutions could be implemented not only in megacities like Wuhan, but also in smaller cities like Anlu where the smart solutions could help all road users, especially bus passengers, cyclists, and pedestrians to achieve an outcome similar to Barcelona's. Indeed, the implementation of the WITDP in Wuhan and Anlu will allow testing of the conclusions reached in this research effort and hopefully achieve better mobility and the resulting energy savings.

¹⁸ The Triple E approach—Engineering, Education, and Enforcement—encompasses the essential approach for sound traffic management because the urban transport system is complex and needs sound engineering to solve many problems. In addition, users need to be permanently educated about traffic regulations and good behavior. Finally, authorities need to enforce regulations. The Triple E approach therefore offers a comprehensive approach to adequately manage the urban transport system.

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