

White Paper on Sustainable Transportation

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Connected Urban Development



**CONNECTED
URBANDEVELOPMENT**



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Introduction

The following three visions of sustainable public transportation were created by the MIT Mobile Experience Lab, Massachusetts Institute of Technology in collaboration with Cisco Systems, Inc. and the cities of Amsterdam, the Netherlands; Seoul, South Korea; and San Francisco, California.

Set five to ten years in the future, each scenario explores a variety of technologies and user experiences appropriate for the specific city, with the common goal of increasing public transportation use by enhancing services and making public transportation more attractive.

These scenarios were originally presented at the Connected Urban Development Conference in San Francisco in February 2008.

Sustainable Public Transportation

The main criteria for the Connected Urban Development project is to improve the sustainability of public transportation. While primarily focused on providing environmental benefits, the MIT Mobile Experience Lab was also interested in improving social and economic factors within sustainable public transportation. The Lab's approach encompassed two primary conditions: Information and Communications Technology (ICT) and social networking.

Information and Communications Technology (ICT)

While the nature of the Lab's partnership with Cisco immediately lent itself to seeking innovative, environmentally sustainable concepts utilizing ICT, the Mobile Experience Lab was also very interested in transforming the experience of using ICT solutions towards emphasizing a more human approach. By focusing on the social characteristics of ICT (such as empathy and personalization, as well as interaction and social networking), the Lab aims to make these already technically efficient and empowering solutions more attractive to users. Only by encouraging the adoption of these technologies can we begin to realize the large-scale environmental benefits that they promise to produce. After all, the most elegant solution is useless if nobody uses it!

Social Networking

Encouraging adoption of new ICT-based solutions can be accomplished by making the solution attractive, but social networks provide another significant motivator for adoption. These social networks can be existing, real-world networks such as families or coworkers, or ad-hoc virtual networks, such as online communities. Both types of social networks can be leveraged to achieve a common goal of sustaining participation and encouraging behavior change in participants.

Companies might encourage their employees to take public transportation or work remotely, collecting their employees' aggregated scores as the company's overall rating, which could then be compared to a rival company's score. Fostering competition between virtual and real-world social networks can encourage increased rates of adoption and motivation for continued participation.

However, leveraging these social networks is about more than simply reducing commute travel time or improving efficiency; initiatives which utilize social networks need to consider the experience as a fundamental component to their success or failure. For example, telecommuting may improve the quality of life for employees by reducing their commute, but one side effect of such an arrangement is that employees who often work from home are more likely to be passed over for a promotion compared to employees who are in the office every day. Social mores may be one factor in such a situation (the employee who comes to work may appear to be more dedicated), but technology such as video-conferencing or telepresence can help to alleviate some of these symptoms by making it easier to relate to remote workers. Instead of appearing as simply an email address, facilities such as telepresence enable remote workers to attend meetings as active participants in life-size circumstances.

Background

As part of this project's development process, the MIT Mobile Experience Lab ran a semester-long project with a class of students comprising a broad cross-section of MIT and Harvard, including the MIT Sloan School of Business, Harvard Graduate School of Design, and the MIT Department of Architecture and Planning. This interdisciplinary approach to the project brought a wealth of unique insights grounded in each student's particular background, experience, and research focus.

The Lab's partnership with Cisco Systems naturally led to a focus on the impact of ICT and networking technology on sustainable public transportation in particular, as well as its role in the broader issue of environmental sustainability. While the production of electronic products has a negative impact on environmental sustainability, the use of ICT has a potential for reversing this trend by, for example, improving the quality of remote communications and thereby reducing the need for business travel.

Additionally, each city had its own unique vision of the future and immediate needs. One of the challenges of this project for the Lab was to reconcile the long-term vision of the proposals with the pragmatic, near-term needs of the cities. Desk research helped to define the current state-of-the-art within each city, and the scenarios aimed to build upon each city's existing infrastructure and exploit planned technology implementations.

Amsterdam: The Personalized Public Bus

In the coming years, Amsterdam is expecting significant population growth in Almere, a nearby suburb. Infrastructure constraints along the route from Almere to Amsterdam mean that future capacity for private cars is very limited, particularly during commute hours. Our goal was to propose concepts which make public transportation an attractive, convincing alternative to private cars. Our target audience was commuters, with a technology- and trends-timeline of ten years in the future that also recognizes the ongoing development of a high speed, open fiber network in Almere.

The Amsterdam scenarios propose a number of innovations, each of which is described in more detail below: real-time travel planning, the majordomo bus, the open source bus, the personalized bus, and the customized bus.

Real-time Travel Planning

Two key elements to travel planning are to provide information that is easily accessible and easily digestible. Content can be delivered throughout the home using a variety of channels, such as embedded displays in furniture or ambient cues using lighting or sound. Along with news feeds, calendars, and agendas, transit information is given equal emphasis as part of the user's routine. Some of the elements taken into consideration include updates on bus reservations, traffic reports, scheduled construction, city events, weather conditions, and other factors which might impact a commute.



These factors are distilled into a set of commute recommendations by a personal travel assistant. While the user always has the option of drilling deeper into specific data sets, the default view provides a set of options that are tailored to the specific circumstances of the user. The options can be presented and ranked according to specific criteria, such as departure time or projected arrival time, making it easier for the user to quickly assess his or her options and make a decision.

The recommendations made by the personal travel assistant factor in personal preferences (commute duration, route, departure time) and real-time commute data (road conditions, weather, current capacity). The user can then select or modify a recommendation based on additional criteria such as the number of passengers projected to be on board, or to catch a bus with a friend. Over time, the personal travel assistant can learn a user's habits and preferences, and automatically integrate them into its recommendations.

Once the user selects a commute route and confirms his or her reservation, the system uses GPS on the bus and the user's mobile phone to coordinate boarding. Based on the location of the user and the bus, the system designates an ad-hoc pickup point where the bus and user arrive simultaneously. As both the bus and the user travel to the pickup point, they receive updates from the system about each others' progress. If either party encounters a delay, the system can dynamically re-allocate resources and direct the user to another pickup point, or arrange for another bus to make the pickup at a later time.

Strong optimization software powers both the travel recommendation system and the routing system, accounting for various factors within the system, including individual destinations and rate of travel, service pickup and delivery points, overall transit system status, and environmental factors such as weather or pollution. Data is gathered from a variety of governmental and private-party sources, and is combined with personal preferences of passengers to produce customized, highly relevant travel recommendations. Real-time updates boost rider confidence, as does the system's ability to recover from unexpected disruptions and coordinate alternate transit solutions.

Majordomo Bus

The majordomo bus acts on behalf of its riders to coordinate services which make their lives more efficient and convenient. Passengers can use a specialized service area on the bus to drop off mail and packages, deposit or collect dry cleaning, or pick up food or beverages. While promoting the bus as a centralized point for service delivery, this arrangement also helps to reduce the number of individual trips that passengers would normally need to make.



For example, riders can drop off their dry cleaning on the bus in the morning and arrange to pick it up on their bus in the evening. The bus acts as an aggregator of dry cleaning, ultimately coordinating a handoff of laundry with a partnering dry cleaning service. When ready for pickup, the bus system can act as a distribution network, with a bus picking up a load of dry cleaning that consists partly of deliveries for its passengers and partly of bulk deliveries for other buses. These bulk deliveries are left at way-stations for pickup by specific buses which then distribute the deliveries amongst their riders. Key to this service is coordinating buses with both passengers and deliveries so that they end up on the same bus.

The same type of system can accommodate the delivery of food, beverages, and other services. Passengers can make purchases in advance or while riding the bus, with the bus aggregating orders, collecting payments, and coordinating pickup from a partner service (e.g.: Starbucks), possibly in conjunction with picking up another passenger.

Payment for these services, as well as fare collection, is handled using Near Field Communication (NFC) or other contact-less payment systems, either as the payment mechanism or as an authentication method that enables electronic transactions. For example, a passenger would need to use their NFC-enabled phone to claim their dry cleaning from the lockers on the bus. Payment could be processed using the phone or by debiting an electronic account, but the physical presence of the NFC-based authentication adds a level of security to the transaction. As technology improves, contact-less payment systems could be replaced by multi-factor biometric authentication.

Open Source Bus

By providing an open platform for user participation and discussion, the Open Source Bus enables passengers to provide feedback to the bus system, interact with contextually-relevant content, engage in peer-to-peer discussions, and actively reconfigure the design of a bus to suit their particular needs.

By proactively soliciting feedback and suggestions from riders, the transit system can more effectively respond to everyday passenger needs. Feedback might include comments on service delivery or alerts about infrastructure issues such as potholes or graffiti. Passengers can also use this platform to determine what types of services are enabled and delivered through the bus system. By using crowd-sourcing to evolve its services, the system can ultimately deliver highly-relevant, high-quality services which address the specific needs of the community. This platform also enables the transit system to deliver service advisories and system information, and to propose and receive feedback on service changes.

The open source bus also allows passengers to communicate on a peer-to-peer (P2P) level, such as leaving messages for each other; real-time, bus-to-bus communication; or sharing ratings for local businesses. These ratings can be displayed in real-time as the bus passes the location, enabling opportunities for pushing place-sensitive information and location-specific advertising to passengers. Passengers could apply filters to this information, for example, choosing to be alerted whenever the bus passes a vegetarian restaurant with four or more stars. The format for displaying this information would normally be in a text-only



format, but retailers could perhaps pay to include more colorful graphics or descriptions.

By open-sourcing the design of the bus interior, passengers can contribute towards the creation of customized buses which provide distinct environments and promote specific kinds of activity. Similar to “quiet cars” found on trains today, where mobile phone usage is limited, customized buses are optimized for particular uses, such as business meetings, networking, families, sports clubs, or activities.

A bus customized for business meetings would have an interior dedicated for this purpose (tables, network connections, telepresence facilities, etc.), just as a bus customized for families would have playpens and seating for various heights, or a sports bus might be customized with the team’s livery and wide-screen TVs to watch the big game on the way home.

To promote the Work Bus, employers might offer employees time credits as incentives. Work done during the commute on the bus would thus count towards the overall work day. The combination of commute credits and productive working environments can help alleviate overall traffic congestion by encouraging commuters to stagger their departure times in the morning and evenings.

Personalized Bus

Next-generation internet routing technology in the form of IPv6 enables “internet everywhere”, where any object can access (and be accessed through) the internet, enabling smart devices which can load personal profiles stored on the network. These profiles can include specifications for physical objects, such as adjusting the height or pitch of a seat, or for populating screens with information, such as filling a public screen with a personal workspace.



Passengers can identify themselves to objects on the bus using contact-less technology such as NFC or RFID (Radio Frequency Identification). These objects can then reference the passenger’s personal profile stored on the network and adapt their functionality accordingly: seats can adjust their height, the ventilation system can adjust the temperature in your zone, or your agenda can be brought up on the embedded window display next to your seat.

The Personalized Bus can also note your interests and social networks, and highlight particular businesses or services which might appeal to you or that your friends have recommended. As the bus travels through the city, it can scan for and alert you to vegetarian restaurants which have

received ratings higher than four stars. Or highlight restaurants which your friends have recently visited and rated positively.

San Francisco: Connected Transportation

Our goal for San Francisco was to promote public transportation as an everyday mobility option, particularly for the elderly. We were also interested in exploring how to connect people with the city, with public transportation, and with each other. Our timeline was five years in the future, and our particular use-case dealt with an elderly woman traveling from her home to the hospital for a checkup and prescription refill.

The Passport

As a central part of the scenario, we developed the Passport application to deliver a number of different transit and lifestyle functionalities. This application runs on either a dedicated device or a generic mobile device, and delivers the following features and functionalities, which are described in detail below: personalized route planning, the green gauge, wearable urbanism, location-based social networking, personalized interaction with city services, and dynamic, intelligent traffic management.



The Passport application helps to make public transit an attractive choice for enabling everyday activities by providing an integrated payment system and easy-to-access transit information. The addition of GPS-based directions and personalized route planning, along with integration into everyday routines helps provides an improved level of relevance and personalization

For example, the ability to get directions to her home no matter where she is in the city helps alleviate Lucia's uncertainty surrounding the transit system, raising her confidence and increasing her independence. More importantly, the system can securely integrate her doctor's exercise recommendations into its transit options, for example, by increasing or decreasing walking distances in its recommendations. Aligning user needs and goals with the transit system develops public transportation as a platform for achieving those goals while contributing to improved environmental conditions within the city.

Personalized Route Planning

The Passport application's primary functionality is to connect the individual with the transit system. It does so by providing real-time information about bus arrival times and system delays, and by suggesting travel itineraries based on knowledge of the individual.

Based on the user's current location, the Passport application can suggest several options, calculating both the time it will take to walk to the bus stop and when the bus will arrive. The user can then make a decision whether he or she will be able to make it to the stop in time to catch the bus. These calculations take into account factors such as the overall system status, performance

along the particular bus line, the specific bus that will arrive, weather, traffic, city events, and planned works.

In addition to providing customized travel advice, the Passport application can integrate personal information into its calculations, such as health conditions or lifestyle goals set by the user or by their doctor. Taking these factors into consideration, the system can alter its recommendations to maximize or minimize walking, for example, in response to health conditions like diabetes or if the user is temporarily disabled with a broken leg.

In response to other factors, such as air pollution statistics or even the position of the sun, the system might recommend a reduced level of activity, or that you should walk on the shady side of the street to reduce exposure to UV radiation. In the evenings, the system could recommend routes which maximize streetlight exposure, or perhaps encourage taking an earlier bus which runs a longer route instead of waiting on the street for a bus running a later, more direct route.

Green Gauge

The Green Gauge acts as a kind of city health monitor and is located both inside and on the sides of buses. As a bus drives through the different districts of the city, it collects historical information (such as electricity usage) and real-time environmental data (the number of cars passed) about each district. This information is aggregated into a visualization that of colored bands which enables viewers to quickly assess the overall “health” of the city. Because buses drive different routes every day, each bus develops a unique pattern that helps shape the overall perception of the city’s environmental performance.



The goal of the Green Gauge is to diffuse awareness of the local environmental conditions throughout the community. The external Green Gauge enables members of the community to get a rough sense of how their city and their neighborhood is doing, using each bus as a kind of environmental thermometer or litmus paper. The interactive Green Gauge on the inside of the bus allows passengers to engage with the data and explore specific districts in more detail by browsing the bus’s route history and investigating specific data and trends.

Wearable Urbanism

The Passport application promotes a form of wearable urbanism, completely connecting the person with various services within the city, enabling more efficient service delivery and fostering collaboration between people and city services.

Wearable urbanism expands the current boundaries of service delivery past the physical environment. For example, patients can begin the hospital check-in process while still on the bus. When they arrive at the waiting room, they can proceed through an express checkin process, reducing their waiting time and improving service delivery. After their checkup, patients can opt to receive an update from the pharmacy when their prescription has been filled, freeing them to use their time more efficiently than if they had been waiting at the hospital.

By connecting passengers with city services on a more personalized basis, the Passport application enables direct communication and collaboration between people and city services. Users can alert the city to hazardous conditions within the system, provide demographic information which helps shape service delivery, and encourage the development of specific services and functionality within the bus system based on specific user needs.



Location-based Social Networking

Integrating location-based social networking into the transit system, enables the system to alert riders to friends on nearby buses and throughout the wider transportation network.

Access to this kind of coincidence information provides a unique social aspect to public transportation. Passengers waiting at a bus stop can either seek or avoid a ride with friends on arriving buses, providing another criteria for riders to use when deciding which bus to catch.

Social-networking information can also be used as a platform for urban gaming and as a basis for making place recommendations. For

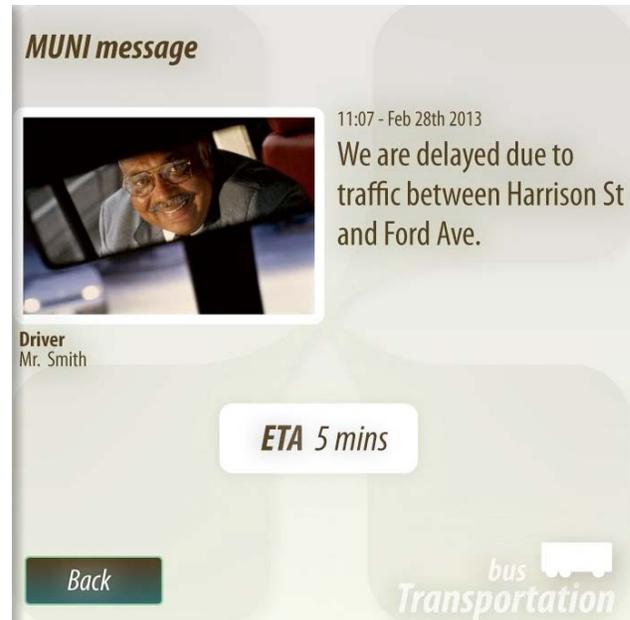


example, as your bus passes a restaurant, you might receive a copy of a review written by a friend. If the transit system were to provide an open API and encourage an “opt-in” culture for the social networking component, external developers could harness the location information to provide users with unique services and applications that the transit system itself might not develop on its own.

Personalized Interaction with City Services

Personalization of city services can take several forms. One option is to deliver trip and destination information, maps, and other travel information in multiple languages. Digital signage on a bus, for example, could adapt its displayed content based on language preferences stored in personal profiles associated with passengers’ electronic bus passes.

Another option is to enable passengers to directly communicate with either the drivers or transit representatives. Instead of a faceless system providing status updates at a bus stop, passengers can receive a personal update from the transit representative monitoring the line. Passengers can ask questions and interact with the representative, fostering a more human connection between passengers and service, and helping to improve the overall perception of public transportation.



Dynamic, Intelligent Traffic Management

In a city optimized for public transportation, buses may be given traffic-light priority through intersections. This means that as buses approach an intersection, the light will remain green longer to allow the bus to pass through. Giving traffic-light priority to buses helps to reduce pollution from acceleration and deceleration, provides passengers with a smoother ride, and improves reliability of the bus service.

If riders have access to real-time information through their Passport applications and other information outlets, the bus system gains flexibility in its service delivery. For example, the



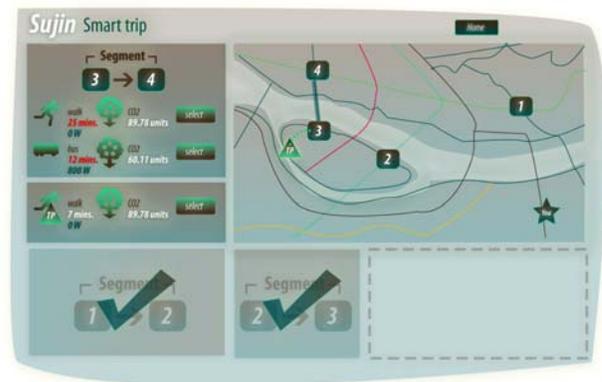
system can reroute a bus around an accident or construction and proactively alert passengers to the change.

Seoul: Informed Mobility with Options

Because Seoul is so technologically advanced compared to most cities around the world, the challenge facing the city is not in the collection of information but rather the delivery of it. While Seoul already offers many public and private information services for public transportation delivered over multiple channels (e.g.: SMS schedules), there is virtually no interoperability and no consistency in delivery. Our goal was to explore ways of effectively delivering personally-relevant information to people so they can make better transportation decisions. It is worth noting that although our timeline was five years out, Seoul's infrastructure enables very forward-looking concepts.

The Smart Trip Advisor

The Smart Trip Advisor is a version of the Personal Travel Assistant which helps people and passengers make informed travel decisions based on factors such as price, environmental impact, and time-to-destination. Specific trip segments within an itinerary are analyzed and presented with recommended transportation modes, along with an analysis of environmental, time, and financial impact. The user can match his or her priorities (time, money, CO₂) with the options listed by the system, or make changes on a more detailed, granular level.



By aggregating real-time and historical transit information from a variety of public sources (the subway system) and private sources (private bus lines), and personal information from an agenda (outlook calendar) or personal profile (accessibility or transit mode preferences), the Smart Trip Advisor can proactively generate a complete overview of a journey targeted towards a specific user. This journey overview incorporates a number of decision points which alert the user to multimodal options which may speed their journey or help reduce their environmental impact. For example, if traffic is predicted to be especially heavy between meetings, the system may recommend that a user stop at a public telepresence facility and hold her meeting remotely instead of holding the meeting in person.

Aggregate decisions made by a user with the Smart Trip Advisor can be represented through a personal green calculator that helps the user understand their personal impact on the city. Each option presented by the system can include environmental impact information which may influence a user's choices when creating a travel itinerary. Individual decisions made using the Smart Trip Advisor are then placed in context of a larger personal budget or goal, providing a common language with which to compare behavior with friends, family, and social networks at large.

By connecting a personal accounting system with a rewards system, cities, corporations, and institutions can provide incentives to users. A company like Samsung may sponsor an internal contest that recognizes and rewards employees who take public transportation. Individual employee performance can then be aggregated to produce an overall score for the company, which can then be compared against other companies to create team-based competitions. While such competition has immediate environmental benefit in the form of increased public transportation use and decreased use of personal vehicles, the longer-term benefits of competition include a persistent source of motivation for increased rates of adoption, and encouraging and sustaining behavior change.

Predictive Advice

By comparing real-time conditions with historical performance under similar conditions, the system can generate predictive recommendations for a particular journey. These estimates can incorporate data such as scheduled civic or sporting events; street closures and construction; accidents; environmental information such as weather, pollution, or seasonal variances; and current traffic volume. Collecting this information over time provides a foundation for the system to develop estimates of transit behavior in similar real-time conditions.



These estimates may vary depending on the time of day or the weather, and can assist in decision-making when optimizing trip itineraries, both for the current trip segment and for those later in the day. For example, the system might suggest waiting a half hour in the afternoon to avoid the worst traffic. Or if the weather is nice, it might recommend renting a bicycle to complete a journey.

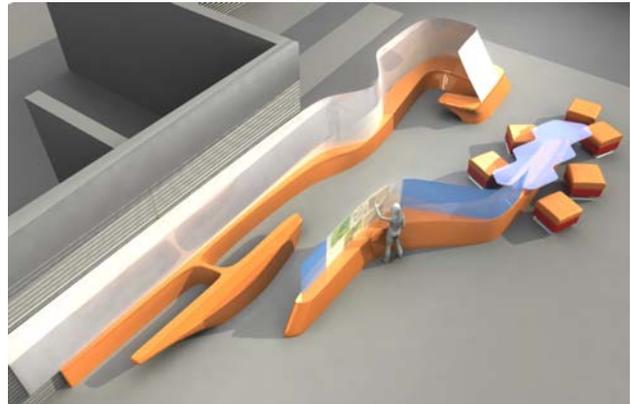
Including statistics about particular aspects of travel (travel time, CO₂ emissions, trip cost) helps both the system and the user to optimize trip itineraries based on particular goals. The suggestion to ride a bicycle in nice weather may be further influenced by the amount of CO₂ saved over a similar journey by car or bus.

The data used in these calculations is pulled from various sources utilizing a non-centralized information architecture. In this system, on-time information about a bus does not come from a data center but from the bus itself, or perhaps a router somewhere on the network.

Smart Urban Furniture

Smart urban furniture is a platform that extends accessibility for digital content into public spaces, creating a responsive city environment that allows citizens to access information through customized interfaces.

While a certain amount of transit information can be consumed through mobile and handheld devices, detailed planning with higher resolution information will likely require a physically larger screen and physical security measures to protect personal privacy. This perspective influenced the design of urban furniture in the subway system which allows users to retrieve their personal profiles from the network using a public access point. This access point enables a user to begin planning a trip on a mobile device or laptop, and then seamlessly access the same information through a high-resolution, public interface to complete detailed planning stages.



After approaching a screen embedded in the urban furniture, the user can use contactlessly log into their personal space using their mobile device and draw on the multi-touch screen to define the boundaries of their workspace. Directional sound, directional monitors, and sound cancellation technology provide physical security, which prevents passersby from viewing screen contents or overhearing conversations. Directional monitors enable the user to view content from a certain angle, while anyone outside of that viewing angle will see alternate images, such as advertising. Directional sound constrains audio to a specific zone, while sound cancellation can prevent eavesdropping through obfuscation or complete cancellation. Cameras embedded in the display can be used by users both for video conferencing and for monitoring personal space (for example, to see if someone is lurking behind them).

The urban furniture incorporates multi-touch tables and a private telepresence facility which adds an additional level of privacy for discussions. However, the physical design also provides a social space encouraging congregation and relaxation for those not using the electronic portion of the system.

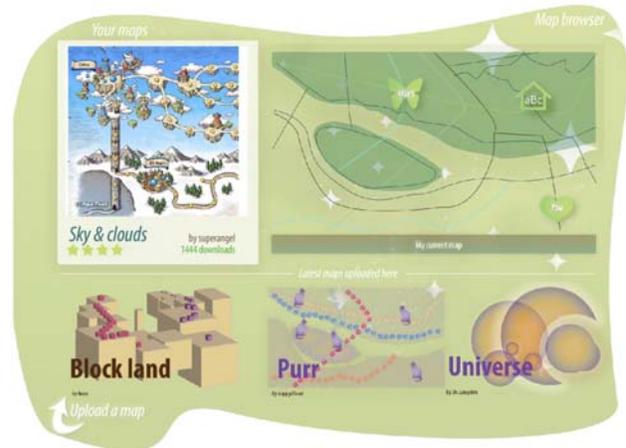
Customized Maps

Map information delivered through platforms such as the smart urban furniture incorporates two major concepts: personalization and customization.

Personalization means the system delivers information that is relevant to you. If you have a specific destination in mind, the map can focus its information delivery on points which are relevant to you, filtering out extraneous and potentially distracting or confusing information.

Customization means that the user has increased control over how the chosen information is presented. This capability serves two purposes: first, to represent information in a way that makes sense, is attractive, or is most useful to the user; the second, to enable personal expression through map templates.

Because screen-based maps are capable of changing their representation, it makes sense to cater to user needs when displaying map information. For example, the same map can be displayed in different languages based on who is viewing the map. Alternatively, a high-contrast version could be displayed for users with impaired vision.



Beyond the functional uses of customization lie more aesthetic goals. In the same way that ringtones signal identity and can be traded within communities, map templates could be used to encourage a culture of mapping that promotes two-way participation with transit data. Instead of consuming information as presented by the city, anyone can create a template which highlights different content or simply presents the same data in dramatically different styles.

Users could create personalized maps of the city which highlight stops based on the nice restaurants in the general vicinity. Other users might create a stylized, manga version of the subway map. This customization can be developed by individuals for their friends and social networks, or can be promoted by industry. Advertisers may create whimsical maps which represent the subway train as a hamburger, the stops as french fries, and the lines as ketchup, mustard, or other condiments.

Customized maps may be unique to physical locations; to download a custom map, you would need to visit the station which hosts that map template. This encourages exploration of the transit system while maintaining a unique character for each station that is developed by the community surrounding that station.

Credits:

This White Paper on Connected Urban Development is part of a research project on Connected Urban Development between MIT Mobile Experience Lab, Massachusetts Institute of Technology and Cisco Systems, Inc.

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For more information about Connected Urban Development, please visit the following websites:

<http://www.connectedurbandevlopment.org/>

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