C. M. Herr, N. Gu, S. Roudavski, M. A. Schnabel, *Circuit Bending, Breaking and Mending: Proceedings of the 16th International Conference on Computer-Aided Architectural Design Research in Asia,* 335-344.

LAST TRAIN TO TRANCENTRAL

From infrastructure to 'info'structure – a case study of embedding digital technology into existing public transport infrastructures.

TOM BARKER,[1] NICOLE GARDNER,[2] M. HANK HAEUSLER[3] and MARTIN TOMITSCH [4]
University of Technology, Sydney, Australia
1. tom.barker@uts.edu.au.edu, 2. nicole.gardner@uts.edu.au,
3. matthias.haeusler@uts.edu.au
4. University of Sydney, Sydney, Australia,
martin.tomitsch@sydney.edu.au

Abstract. The research presented in this paper is an investigation into how ubiquitous computing technologies can contribute to improving the quality of existing public transport environments through the integration of responsive technologies. The paper argues that given the significant challenges associated with transport infrastructure expansion including cost, disruption, energy use, and implementation periods augmenting existing transport environments offers alternate measures to manage demand and improve the user experience. The paper proposes improving transport environments by integrating smart, or responsive, digital information into the existing physical fabric in a coherent architectural and spatial context. This approach offers an opportunity to shift away from the static nature of public transport infrastructure to the dynamic notion of public transport 'info'structure. The research uses an architecture graduate studio as a foundation to investigate the objectives. The contribution of this paper is an investigation of ways in which digital technologies and networked communications can transform and augment public transport infrastructure, allowing new forms of intelligent, adaptive, interactive and self-aware architecture to be developed.

Keywords. Urban Informatics; media facades; public transport; responsive technologies; smart environments.

1. Introduction

Our vision is to improve existing transport environments by integrating smart, or responsive, digital information into their physical fabric with the purpose of improving the overall user experience in a coherent architectural and spatial context and managing increased patronage. Such an approach has the potential to reduce pressure on transport infrastructure at a period when public transport service provision is increasingly challenged by the continuing growth of Australia's population.

Given the significant challenges associated with transport infrastructure expansion including cost, disruption, energy use, and implementation periods the augmentation of existing transport environments offers alternate measures to manage demand and improve the user experience. Intelligent and responsive digital technologies, along with media displays and personal devices such as phones and smartcards, offer opportunities for creating user-centric timetables, public information, wayfinding and ticketing. For the scope of this research we define public transport environments (PTE) as multi modal transport interchanges in a high-density urban context. The aim of the research described in this paper is to identify and test technologies in terms of a central question to the research:

Can responsive technologies for user information allow improved passenger flow and a better customer experience in public transport environments?

To investigate this question we worked within a graduate studio as a foundation to investigate the capability to stream, screen and embed information in an existing public transport infrastructure. Some exemplary results of the studio are presented in the paper.

2. Background

The Economist Magazine's special report on smart systems (Economist, 2010) writes that:

> *The physical and the virtual worlds are converging, thanks to the proliferation of sensors, ubiquitous wireless networks and clever analytics software. Increasingly there will be two interconnected worlds: the real one and the digital reflection... and "Smart cities", in which more and more systems are connected, are multiplying... the number of [smart] applications is vast. Yet the most promising field for now may be physical infrastructures.*

Gardner notes three approaches to improving passenger flow within PTEs (Gardner et al, 2010): access to a transport service (physical and contextual), access to service frequency (operational and demand led), and access to information (commuter interface). The research area is predominantly on smart environments and Human-Computer Interaction (HCI) technology for the latter.

Relevant research includes: the architectural potential of digital technologies in the urban public realm and the study of urban experiences that use real-time and ubiquitous technology (Gardner et al, 2010); real-time information technologies to understand the relationships underlying urban spatial structure (Calabrese et al, 2007); public media screens as large scale interface for communicating information (Haeusler, 2009); and customer experience in the context of multiple media delivery platforms (Barker and Haeusler, 2010). For example, research has shown that obtaining accurate real-time timetabling and route information, such as estimated arrival times is essential for a positive user experience (Norman, 2007). Some cities around the globe are benefiting from radio frequency identification (RFID) ticketing as a common form of payment (Siu, 2008). Research has also been undertaken with regard to commuter stimuli barriers and sensory-overload (Geller, 1980); relations between real-time information; timetabling and willingness of non-transit users to use public transport (Casey, 2003); evaluations of the beneficial effects of at-stop real-time information displays (Dziekan, 2007); the benefit to people with cognitive disabilities in their use of public transport, enabling community integration, socialization, and independence (Carmien et al, 2005).

In the previous five years public transport use in all of Australia's capital cities has grown while trends for private car use have plateaued (BITRE, 2009). The Australian Bureau of Statistics forecasts a 38% increase in population size within Australian cities by 2026 (ABS, 2010). These statistics suggest significant changes ahead for private car and public transport use, which is set to significantly impact the environments in which these transport modes operate, the urban environment and public transport infrastructure. Research at the University of Sydney has shown that improving transport is a top transport concern for Australians (Institute of Transport and Logistics, 2010). This research suggests, there can be clear benefits in improving the existing environment without requiring large-scale infrastructural changes.

Travel quality is linked to all aspects of the customer's experience, including availability, intelligibility and accuracy of information relevant to the customer's specific transport needs, availability of choices, ticketing and payment mechanisms (Bunting, 2004). Providing the transit user with accurate information about timetabling, routing, and estimated arrival times is important for a positive user experience. Customers have responded well to new technologies such as Hong Kong's Octopus card payment system and Melbourne's Yarra Trams' real-time information, Tram Tracker.

Recent developments in information technologies such as large-scale screens, advanced sensors and networked communication, can transform everyday interaction with people and objects (Weiser, 1991). Personal devices such as smartphones help facilitate this. Responsive technologies are starting to be integrated into the urban environment, for example in the form of interactive building facades, with the aim of creating new urban experiences (Bullivant, 2006). The integration of *responsive technologies* with the ability to react or change usefully to user stimuli and needs in urban locations is termed *responsive environments* or *smart environments*, and the field is sometimes known as *urban informatics* (Foth, 2009).

3. Research explorations

The research hypothesis was tested through an architecture graduate studio. Students were tasked with investigating the capability to stream, screen and embed information within an existing public transport environment. The project context exists in multimodal public transport hubs, and the busy, aging Central Station in Sydney was our location for research experimentation. In the following section three exemplary projects are introduced and evaluated. The projects have been chosen as they address one or more of the main areas of investigation – Ticketing, way finding, public information (events, news, amongst others) and timetabling.

3.1. LEAD THE WAY

Wayfinding on a day-to-day basis as well as during emergency evacuations are crucial issues within stations. With high customer numbers circulating in station environments, the floor and wall surfaces can be obscured by pedestrian traffic and therefore not suitable for signage. The dynamic nature of station information such as train service, arrival and departure times and platform locations requires a flexible strategy such as digital screens. The project took these considerations on board and developed a design intervention based on an interactive ceiling system that allows illumination as well as dynamic wayfinding and information. The design intervention is proposed for the main Central station entrance ticketing concourse and spanning through the connecting underground passageways. A modular system is proposed and prototyped consisting of a repeated component. Each module is modelled as a translucent box shaped for the best visibility when seen whilst walking and compromises a series of RGB LED's controllable from a central computer. Four of these modules are connected to one piece creating a crosswork pattern. The crosses are then attached to the ceiling to form a grid like system. This configuration allows the display of arrows to point in various directions and therefore provides for flexible applications. On a day-to-day basis the installation would function as a wayfinding system guiding passengers to the correct platform by colour coding corresponding to the train network line colour. The illuminated arrows would begin to pulsate at a greater rate when a train is approaching the platform to inform passengers of arriving trains. Additionally, in the event of an emergency the lighting installation would display large arrows pointing towards the direction of the closest emergency exit. The implementation of the system allows for a false ceiling impression when seen in perspective but opens up the space when looking straight above.

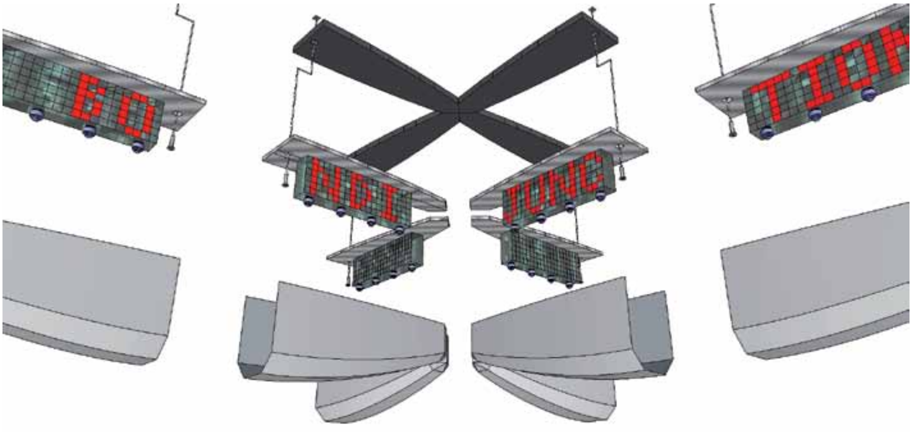

Figure 1. Exploded 3D view of lighting installation module © Christian Moi

3.2. INTELLIGENT TUNNEL

Public transport patronage is predicted to experience significant growth over the decades to come. ‘Intelligent tunnel’ took this assumption and the associated issue of passenger flows as inspiration for change. Based on the Fruin standard levels of service, an existing pedestrian tunnel was analysed using the Fruin calculation method and a processing script examining pedestrian movements. The research pinpointed several key peak period times and off peak period times in which the tunnel was barely occupied. Also noted were periods of time at which street buskers performed within the tunnel and whether these activities interfered with pedestrian traffic at peak times.

Figure 2. The existing tunnel transformed into an interactive, responsive environment © Vinh Nguyen

Based on these investigations the design intervention suggests two possible alterations: (1) a travelator to control the travel direction of the users while increasing their travelling speed and (2) fold out functions to utilise space during off peak times. The concept of a travelator is widely used in airport environments and can find similar application opportunities within public transport environments. The design intervention combined the proposed travelators with digital screens located parallel to the travelling direction, where software enables the content to travel at the same speed as the travelator and therefore identical speed for a stationary passenger. Fold out functions such cybercafé, bookstore or a stage for buskers are proposed to transform the space during the off peak times and activate the tunnel. Through this intervention the length of journey through the tunnel could be, psychologically, further reduced by giving the traveller intermediate stops, as well as improving security by introducing other activities.

3.3. FORWARD MOTION

This project addresses opportunities to improve journey times and wayfinding in and around Central station and the broader issue of fare evasion. Site analysis of the station precinct identified deficiencies in general amenity and inefficiencies in journey times from station entries to train platforms. In response to these issues, the project proposes a significant design intervention one of then addressing the issue of ticketing.

Figure 3. The 'shame' security system, a red marker indicates a fare evader © Oliver Petrie

The project concept is supported by the additional proposal for a new barrierless ticketing system and an alternate revenue protection strategy, the 'shame' security system. The 'shame' system consists of RFID embedded tickets that are detected by RFID antennas located in areas of the station floor and then tracked by an RFID radar system. A multi-touch sensor is also applied to the floor to detect customer footfall. The RFID Radar and RFID antennas are computer programmed to pinpoint and track those holding valid RFID embedded tickets and those that are not. Where the computer identifies a person without a valid ticket, LEDs embedded within the floor correspondingly display a red glow directly beneath the fare evader. The multitouch floor system would allow the red dot to then follow the fare evader. With a highly obvious red marker beneath the fare evader it would become very apparent to other customers and station staff of their indiscretion. The red light following the fare evader is likely to cause a degree of embarrassment or shame, thereby prompting this person to purchase a ticket and dissuading other customers from similar actions. The project employed a video game simulation tool 'Sandbox Editor' to test and develop the proposed design and evaluation of the final design demonstrated improved journey times

4. Discussion

Improving customer experience through human-computer interaction and the creation of smart environments for public transport is a rich and relevant research territory for innovation that offers alternatives to relieve the growing pressure on existing public transport infrastructure and improve the quality of life in an urban context.

The outcomes of the research described herein are design explorations with the potential to inform projects in loci at a range of scales and to demonstrate in a second iteration user-centric improvements of the interlinked transport infrastructure fit-out components, namely: timetables, public information, wayfinding and ticketing. Various public transport providers are making moves towards the integration of information technology. The design explorations presented in this paper demonstrate a way to wrap isolated technologies into a larger-scoped HCI-rich and responsive format that will deliver more fruitful and rewarding commuter interactions.

The three projects included herein, present innovative concepts such as:

- Coherent, architecturally designed and integrated smart spaces. Achieved within a whole to achieve legibility and avoid visual and spatial clutter such as the 'shame' security system when creating a barrier free ticketing system or in 'Lead the way' where information, wayfinding and illumination are combined in one ceiling system.
- A novel approach where existing public transport environments are enhanced for passenger movement and experience with without rebuilding the existing infrastructure. This was demonstrated in both 'Intelligent Tunnel' and 'Forward motion' either through a travelator where one can access information while moving or by removing barriers such as ticket gates.
- Extending the trend for affordable 'soft infrastructure'. The three featured student projects and others developed during the studio included features such as timetables and differential ticketing prices to optimise capacities avoid expenditure on high-cost 'hard infrastructures' like new tracks and signalling.
- Creating a socially inclusive public transport environment through improving the experience for all customers. The student projects considered the needs of various age groups and those with cognitive, physical or visual impairments, i.e. through large arrows on the ceiling pointing into the direction of travel as demonstrated in 'Lead the way'.
- Operating procedures for responsive technologies into public transport operating procedures. All projects included interactive technologies to create new ways of operating public transport services that differ from conventional passenger information systems.
- Enhance user experience: Projects like 'Intelligent Tunnel' with its use of responsive and user predictive technologies enabled passengers to reduce waiting times, avoid crowding and more confidently navigate the public transport networks. Simultaneously improves mobility- passenger flow and provides information access.

4. Next steps

With the graduate studio findings as a foundation, we are currently collaborating with industry partners to further investigate the underlying research question in three phases: Foundation, design and dissemination.

In order to gain further background knowledge we will investigate and analyse existing public transport environments both spatially and functionally. Here we aim to establish a taxonomy of public transport environment functional spaces, user movement and time-based activities; understand the requirements for location and time specific user information. Further we aim to fully review the literature, products and projects in the fields of HCI, computational technologies, and information display systems, and to collate and interpret relevant national and international projects in which digital HCI technologies have played a significant role in public transport environments. Based on these findings we seek to apply the impacts of digital technologies in terms of architectural-spatial integration and physical-digital infrastructure for efficiency of throughput, enhanced vibrancy, quality of place at Central Station in Sydney.

Based on the first foundation research phase we seek to establish a system designed in three iterations. Firstly, a system that can monitor and contextual respond to an individual. This system will be capable of proof-of-concept sensing human cues, gestures and inputs. Secondly, a system capable of sensing a wider range of human cues, gestures and inputs over a broad physical and temporal space. Finally, in consolidating the earlier work, introducing an e-ticket scenario, and undertake architectural and spatial integration of the system – including visual, functional, materials, durability and access criteria.

The last planned step includes dissemination with feedback and suggestions through a group of experts in a series of workshops, each coinciding with the latter part of a prototype stage to facilitate demonstration. The research should conclude in two recommendations. Firstly, technology recommendations, with technology and application evidence-based recommendations for implementing HCI technology in existing Australian public transport environments. Secondly, applied recommendation including a strategy to implement successful aspects of the research pilot projects in a rollout for other locations and consider options for further research work in the field with the industry partners.

References

ABS: 2008, *Population Projections, Australia, 2006 to 2101*. Australian Bureau of Statistics; available at: http://www.abs.gov.au/Ausstats/abs@.nsf/mf/3222.0

Barker T., and Haeusler M.: 2010, Achieving a designed customer experience across multiple delivery platforms: a telco perspective. *International Conference on New Media and Interactivity2010*, Istanbul, Turkey.

BITRE: 2009, *Australian Transport Statistics Yearbook 2009*. Bureau of Infrastructure, Transport and Regional Economics. Department of Infrastructure, Transport, Regional Development and Local Government. Canberra, Australia

Bullivant, L.: 2006, *Responsive Environments; architecture, art and design*. V&A Contemporaries, London.

Bunting, M.: 2004, *Making public transport work*. McGill-Queen's Press - MQUP.

Calabrese, F., Kloeckl, K. and Ratti, C.: 2007, Wikicity: Real-Time Location-Sensitive Tools for the City. *CUPUM 07 - 10th International Conference on Computers in Urban Planning and Urban Management*, Iguassu Falls, July 2007.

Carmien, S. et. al: 2005, Socio-Technical Environments Supporting People with Cognitive Disabilities Using Public Transportation. *ACM Transactions on Computer-Human Interaction*, Vol. 12, No. 2, June 2005, Pages 233–262.

Casey, C.: 2003, Real-time information: Now arriving. *Metro Magazine*, http://www.metro-magazine.com/Article/Story/2003/04/Real-Time-Information-Now-Arriving.aspx (Accessed Nov 8, 2009).

Diezkan, K. and Kottenhoff, K.: 2007, Dynamic at-stop real-time information displays for public transport: effects on customers. *Transportation Research Part A: Policy and Practice* Vol 41 Issue 6 pp. 489-501.

Economist Magazine: 2010, It's a smart world. Special report on smart systems. November 6th 2010.

Foth, M.: 2009, Urban Infomatics - The practice and promise of the real-time city. *Information Science Reference*, Hershey, USA.

Gardner, N., Haeusler M.H., and Tomitsch, M.: 2010, *Infostructure – A public transport research project*. Freerange Press, Christchurch, New Zealand.

Geller, D. M.: 1980, Responses to Urban Stimuli: A Balanced Approach. *Journal of Social Issues*, 36: 86–100

Haeusler, M. H.: 2009, *Media Facades – History, Technology, Content*. Avedition, Ludwigsburg. Germany.

Institute of Transport and Logistics: 2010, *Interfleet Transport Opinion Survey* (TOPS), The University of Sydney, Quarter 2, June 2010.

Korte, C.: 1980, Urban-Nonurban Differences in Social Behavior and Social Psychological Models of Urban Impact. *Journal of Social Issues*, 36: 29–51.

Norman, D.: 2007, The Design of Future Things. New York: Basic Books.

Siu, L.: 2008, Coercing Consensus: Unintended success of the Octopus electronic payment system, presented in the 6th International Conference on Politics and Information Systems, Technologies and Applications, Orlando, 29.6 – 2.7 2008.

Weiser, M.: 1991, *The computer for the 21st century*. Scientific American.