Institution: London South Bank University

Unit of Assessment: General Engineering

Title of case study: New voice alarm systems for underground stations developed through use of acoustic simulation techniques and novel engineering solutions.

1. Summary of the impact (indicative maximum 100 words)

This Case Study demonstrates how research has benefitted a commercial company (Telent Ltd), a public sector organisation (London Underground Ltd (LUL)) and the safety of staff and 1.4 billion passenger journeys.

The research enabled Telent to:

- Access scientific knowledge in acoustic modelling and engineering, saving the Company ~£500k;
- Deliver a Public Address/Voice Alarm (PA/VA) system into 74 underground stations on time, returning £300k net profit for the Company;
- Gain the maintenance contract worth £1.5M over 13 years;
- Gain additional contracts for installation of PA/VA systems in 3 further underground stations;
- Create 5 new posts during the project period including one permanent engineering position.

The new system also contributed to the revision of a BSI Standard (IEC BS EN 60268-16 2011).

2. Underpinning research (indicative maximum 500 words)

The Acoustic Research Group at London South Bank University (LSBU) has undertaken research into room acoustic computer simulation since 1993, and specifically, into non-diffuse enclosed spaces in public and industrial environments. Underground station platforms are an example of a non-diffuse enclosed space where speech intelligibility is of paramount importance both for service announcements and passenger safety.

This impact case study is underpinned by research carried out from 1993 to 2001 by Professor Bridget Shield (Professor of Acoustics, LSBU) and Dr Stephen Dance (Research Fellow, LSBU). It was funded mainly by grants from the EPSRC [GR/H82556/01, £100,729; 1993-6 and GR/L20894/01; £129,669, 1996-9].

Research into computer models for the prediction of sound in enclosed spaces led to the identification of novel algorithms and to an image-source code that could simulate sound pressure and predict the effects of interference on the sound field [1]. Further refinement of the model enhanced its ability to simulate and predict the effect of noise control techniques on temporal as well as spatial room acoustic parameters [2].

An alternative modelling technique for room acoustic computer simulation based upon ray-tracing demonstrated that where the treatment is located is just as important as how much absorption is fitted in the room [3]. This model was experimentally validated in a room configured in multiple ways to predict the effect of absorptive treatment on the temporal sound field. The findings from this study were recognised as having implications for reducing material and installation costs. A method to correct standardised absorption coefficients so that the data is consistently adjusted for use in computer modelling, specifically where absorption coefficients exceed one, was also developed.

The above mathematical models were further refined (1994-2001) to predict speech intelligibility and were targeted towards underground platform prediction [4], the primary differences between the respective models being multiple loudspeakers and curved surfaces, typically found in all underground transportation systems.

The accuracy of the above models was verified on London Underground Ltd platforms [4] and on the new Hong Kong Metro [5]. Innovative and practical VA system design guidelines were informed by these results.

To reduce the complexity of the simulations, a simplified modelling methodology was developed in 2003 [6] by Dr Stephen Dance. A web browser-based version was subsequently produced by Dr Dance (2009) under a Schultz Research Grant (Acoustical Society of America: US$3000 2008-9), the output from which provided tools for modelling any large enclosed space such as auditoria, classrooms, open plan offices, factories, atria, metro systems, arenas and sports stadia, as well as underground transport systems.

3. References to the research (indicative maximum of six references)

[1] S. Dance, J. Roberts, B. M. Shield. Computer prediction of sound distribution in enclosed spaces using an interference pressure model, Applied Acoustics, 44, 53-65, 1995. (Doi: 10.1016/0003-682X(94)P4419-7)

[2] S. Dance, B. M. Shield. The complete image-source method for the prediction of sound distribution in non-diffuse enclosed spaces, Journal of Sound and Vibration, 201(4), 473-489, 1997. (Doi: 10.1006/jsvi.1996.0770)

[3] S. Dance, B. M. Shield. The modelling of sound fields in enclosed spaces with absorbent room surfaces. Part II - Absorbent Panels, Applied Acoustics, 61(4), 373-384, 2000. (Doi: 10.1016/S0003-682X(00)00011-6)

[4] L. N. Yang, B. M. Shield, Development of a ray tracing computer model for the prediction of the sound field in long enclosures, Journal of Sound and Vibration, 229(1), 133-146, 2000. (Doi:10.1006/jsvi.1999.2477)

[5] L. N. Yang, B. M. Shield, The prediction of speech intelligibility in underground stations of rectangular cross section, J. Acoust. Soc. Am., 109, 266, 2001. (Doi: 10.1121/1.1329617)

[6] S. Dance, Minimal input models for sound level prediction in fitted enclosed spaces, Applied Acoustics, 63, 359-372, 2002. (Doi: 10.1016/S0003-682X(01)00046-9)

4. Details of the impact (indicative maximum 750 words)

This Impact Case Study relates to research that has had a beneficial economic impact on an international engineering company (Telent), led to an improved service provision for a public sector organisation (LUL) and made using stations on the London Underground safer for both LUL staff and the travelling public.

The 7/7 bombings on the London Underground in 2005 caused a reappraisal of evacuation standards and guidance. LUL issued new requirements (2006) for Public Address/Voice Alarm (PA/VA) systems to facilitate the efficient evacuation of stations. Particular emphasis was placed on electro-acoustic performance on deep platform stations as these are the most difficult and challenging to evacuate. In response to the new requirements, a major refurbishment of all PA/VA systems on London Underground was initiated by Transport for London (2006).

Telent (formerly Marconi) was awarded the contract (2006) to refurbish 74 stations on three underground lines (Jubilee, Northern and Piccadilly (JNP)). Telent recognised the need for specific technical expertise and selected the Acoustics Group at LSBU as their technical partner because of the Group’s reputation and expertise in acoustic modelling and specifically, in measuring and predicting performance of PA/VA systems in underground stations. The Head of Engineering (Metro) at Telent reported to independent consultants that Telent would not have been successful in this project without the support of LSBU [1, 2].

LSBU and Telent successfully applied for a Knowledge Transfer Partnership (KTP) award (2008-10; £187k) to facilitate their collaboration [3].

In 2010, Telent selected the resulting room acoustic modelling software based upon LSBU's research and further refined this through the KTP, to model the acoustics in complex underground stations, including the 74 stations. This led to the optimisation of PA/VA design parameters. The adoption of this model and approach resulted in significant time and development costs savings for the Company, estimated at £500k [1, 2].

During 2010-11, the final PA/VA designs produced by Telent and based upon the LSBU model were installed and commissioned by Telent engineers in the 74 underground stations. LUL had accepted all 74 installations by 2012. The gain on each of the 5000 associated loudspeakers was set at the design phase such that the load on each loudspeaker was minimised, saving an estimated 11 MWh of electricity (£2000/per year) in each deep sub-surface station (~35). The overall saving in electricity costs to LUL amounted to approximately £70k per annum [1, 2].

Telent considered LSBU's research to have been crucial in enabling it to deliver the system upgrade on time and to budget, and to avoid potentially steep penalty costs through late delivery. The PA/VA upgrade project has delivered a net profit of £300k to Telent. In addition, the Company has gained the maintenance contract for the new PA/VA system worth £1.5M. The Head of Engineering (Metro) at Telent has stated that, "We now have a PA system that provides far greater security to travellers on the Underground" [1, 2].

Telent has also successfully bid for further PA/VA installation projects at Whitechapel, Liverpool Street and Charing Cross stations. As a direct result of its success, Telent recruited 5 new professional level jobs during the project including one permanent job [1, 2]. In addition, Telent's technical team (6 staff) have received CPD training from LSBU in acoustics, the first within Telent Ltd, with two members of the team going on to gain Masters degrees from LSBU in 2011 [2].

The PA/VA system was found to be so improved that light classical music can be played in ticket halls. In 2012, for the first time, oral advertisements were delivered in underground stations e.g. featuring Boris Johnson promoting the London Olympics (July 2012), and Barbara Windsor on Poppy Day (November 2012) [4].

LSBU's research and the KTP outcomes have contributed to the development of a new speech intelligibility scale in the 2011 revision of the IEC BS EN 60268-16 Standard (4^{th} edition, 2011) [5]. In addition, the KTP Associate Luis Gomez-Agustina won the Institute of Acoustics, Peter Barnett Student Award 2013 as a result of this work [6]. Furthermore, since 2010, 1.4 billion passenger journeys have been made safer as a result of the improved PA/VA system on the London Underground [4].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[1] Report of independent consultants (The Innovation Partnership, 2013) – covers interview with Head of Engineering (Metro), Telent Ltd. Contact: Managing Director, The Innovation Partnership (tipl@innopartners.com).

[2] Contact: Head of Engineering (Metro), Telent Ltd.

[3] KTP 006293 Grant Award and Final Report – both available on request from LSBU.

[4] Contact: Head of Engineering (Tube Lines Ltd). NB: Tube Lines are the company which provide maintenance services for trains and infrastructure on the Jubilee, Northern and

Piccadilly lines)

[5] IEC BS EN 60268-16 - Sound system equipment: Objective rating of speech intelligibility by speech transmission index (4th edition, 2011).

[6] Institute of Acoustics, Peter Barnett Student Award 2013, www.ioa.org.uk/medals-and-awards. - Award to L Gomez-Agustina, KTP Associate on the Telent project.