

Institution: Edinburgh Napier University		
Unit of Assessment: UoA13 – Architecture, Built Environment and Planning		
Title of case study: Influencing global housing sound insulation standards and innovative products		
Period when the underpinning research was undertaken: 2001 to 2015		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
R. Sean Smith	Professor and Director of the Institute for Sustainable Construction	Oct 2000 to May 2020
Richard Mackenzie	Director of the Building Performance Centre	2004 - ongoing
Period when the claimed impact occurred: August 2013 to April 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words) <p>Sound insulation research by Edinburgh Napier has led to multiple impacts such as influencing changes to international sound insulation ISO criteria. New building standards developed led to the highest sound insulation standards globally for multi-storey housing. New technical designs have been used in 580,000 new homes across the UK with asset values of GBP110billion. Innovative acoustic products from waste streams have been developed leading to industry sector 'world firsts', achieving gold level sustainability, high sound insulation performance, improving quality of life and reducing landfill. International license agreement for new product was formed with a global multinational partner through co-authored patent leading to new manufactured products in the UK.</p>		
2. Underpinning research (indicative maximum 500 words) <p>High levels of sound insulation in housing are of critical importance to reducing annoyance, sleep disturbance and providing a better quality of life. Napier's Institute for Sustainable Construction and Building Performance Centre have led sound insulation research both for new products and building standards in the UK and internationally led by Professor Sean Smith and Richard Mackenzie.</p> <p>In 2001 the Scottish Executive funded [P1] the Napier team, led by Smith, to review housing and sound insulation in Scotland as Napier had the UK's most detailed on-site test performance database. The findings demonstrated that design and product modifications to future housing build systems could deliver higher sound insulation standards encompassing a range of low, mid and high sound frequencies [O1]. In 2001-03 some countries were considering amending their building regulations for more emphasis towards low frequency sound insulation. The Napier team then recalculated the impacts of the proposed changes using the [P1] data analysis. The findings in 2003 [O2] indicated the difficulty of addressing all frequencies if a new future ISO criteria focused primarily on low frequencies.</p> <p>In 2007 the Napier team focused on potential future changes to ISO 717 sound insulation criteria standards or harmonisation of acoustic criteria [O3]. This identified that heavy and lightweight core building structures would be differently affected and there would be a 'ceiling limit' for low frequency focused adjustments, at the detriment of sound insulation for normal living noise</p>		

frequencies. During 2006-08 the Napier research team, led by Mackenzie were funded [P2] by Scottish Government to lead the development of the new building standards for Scotland, Section 5:Noise [O4]. The research identified that setting the criteria at a specific level could avoid using low frequency correction factors and still achieve high levels of sound insulation.

As a result of [O1-O4] Smith was invited (2009-13) to lead one of the three working groups for COST Action TU0901 to assess sound insulation performance, construction types [P3] and develop a harmonized sound insulation approach across a partnership involving 32 countries. Key findings from this work were the issue of low frequencies and the resultant 'limited' modal responses for small rooms and the uncertainty for measurement accuracy [O6]. Small rooms restrict the number of acoustic modes that can form within the volume dimensions and as a result the less acoustic modes per frequency band the greater the variation in what the microphones can detect. This increases uncertainty in the on-site test sound insulation results can negatively impact the regulatory process for compliance and accurate reporting of products and construction performance.

In 2010 following changes to Part L of the energy efficiency building regulations requiring separating wall cavities to be fully filled, Robust Details funded Napier [P4] to assess the implications of both roll and blown fibre insulations on acoustic frequency performance. The Napier study demonstrated that whilst there was a slight reduction due to fibres overall both product types could be utilised within future construction specifications.

During 2009-13 Smith led the Low Carbon Building Technologies Gateway and undertook a review on behalf of 2G Environmental and British rigid foam industry body (BRUFMA) and supported by public body Zero Waste Scotland to investigate low, mid and high frequency response for rigid foam waste streams [P5]. A significant majority of thermal rigid insulation board 'off-cuts' were going to landfill. The findings identified a novel acoustic performance benefit due to the acoustic tortuosity factor (caused by shredded 'green crumb' waste particles).

In 2014 Smith was invited on behalf of Eurogypsum to undertake a review of draft proposed changes to international standard ISO 717 [P6] [O5]. The proposed changes would alter the regulatory criteria for sound insulation globally. His report findings illustrated this could lead to an increase in noise complaints and the recommendation would be to not adopt this new criteria approach.

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

[O3] and [O6] have been peer reviewed; [O6] has been cited 16 times since publication.

[O1] Smith, R.S., Mackenzie R.G, Mackenzie R.K. and Waters Fuller, T. (2001) Review of housing and sound insulation, Scottish Executive report.

<https://www.napier.ac.uk/~media/worktribe/output-274928/smith2pdf.pdf>

[O2] Mackenzie, R., & Smith, R.S. (2003). The implications of ISO 717 spectrum adaption terms for residential dwellings. Proceedings of the Institute of Acoustics, 25, Cambridge, UK.

<https://www.napier.ac.uk/~media/worktribe/output-267718/implicationsofiso717adaptiontermspdf>

[O3] Smith, R.S., Macdonald, R., Lurcock, D., & Mackenzie, R. (2007). Airborne sound transmission, ISO 140 and influence of ISO 717-1 spectrum adaptation terms. Proceedings of the 19th International Congress on Acoustics, Madrid, Spain, 2007.

http://www.sea-acustica.es/WEB_ICA_07/fchrs/papers/rba-07-029.pdf

[O4] Smith, R.S., Wood, J., & MacKenzie, R. (2008). Design of separating constructions that are resistant to the transmission of noise. Part 1 - main report to Scottish Government.

Can be supplied by HEI on request.

[O5] Smith R.S. (2014) Review and synthesis of ISO 717 airborne sound insulation criteria. Eurogypsum. Industry report E4965. 38 pages.

<https://www.napier.ac.uk/~media/worktribe/output-1146381/review-and-synthesis-of-iso-717-airborne-sound-insulation>

[O6] Machimbarrena, M., Monteiro, C. R. A., Pedersoli, S., Johansson, R., & Smith, R.S. (2015). Uncertainty determination of in-situ airborne sound insulation measurements. *Applied Acoustics*, 89, (199-210). [doi:10.1016/j.apacoust.2014.09.018](https://doi.org/10.1016/j.apacoust.2014.09.018). ISSN 0003-682X.

Funded projects

[P1] Review of housing and sound insulation in Scottish domestic construction. Funded by the Scottish Executive. (2001) £9,900. (PI) R.S. Smith; (Co-PI) R.G. Mackenzie

[P2] Review of Section 5: Noise (previously Part H) Scottish Building Standards Agency. (2007-8). £30,000. (PI) R.G Mackenzie; (Co-PI) R.S. Smith

[P3] COST Action TU0901 network. Harmonization of European Standards. (2009-2013). UK lead R.S. Smith.

[P4] Technical acoustic assessment of fully filling separating masonry cavity walls with roll or particle fill mineral wool insulation. Funded by Robust Details Ltd. (2010) £6,000. (PI) R.S. Smith.

[P5] Investigation into rigid foam waste materials for cavity fill (2012-13). £10,000 Funders Zero Waste Scotland and in-kind 2G Environmental and BRUFMA. Also supported by the Low Carbon Building Technologies Gateway led by Edinburgh Napier University.

[P6] Review and synthesis of ISO 717 airborne sound insulation criteria. Eurogypsum Trade Body. (2013-14). £15,000. (PI) R.S. Smith.

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

The impact of this research over the REF period has been multi-factor and includes:

- delivering **globally world leading building standards for sound insulation**;
- contributing to the **stoppage of a proposed draft ISO international standard** which would have resulted in a worse sound insulation criteria, and reduced quality of life for building occupants;
- developing **'world first'** acoustic products from thermal insulation landfill waste streams;
- industry adoption of acoustic specifications for sound insulation products in the development of **580,000 new homes** across the UK with a **combined asset value of GBP110billion**.

New sound insulation standards

The outputs [O1, O2, O3] on frequency spectra and construction influenced the report on new sound insulation standards and recommendations to government [O4]. This report [O4] was then accepted following public consultation by the government. The new Section 5: Noise building standards was delayed for full implementation to all sites, due to the economic downturn and legacy warrants. From October 2013 **all new housing sites in Scotland** were required to build to the new technical domestic standards, which included the Section 5: Noise requirements [C1] developed by Napier's research team. The Napier research applied to sound insulation standards and design guidance for all walls and floors for houses and apartments. During the period 2014-15 to 2018-19, **90,000 homes were built in Scotland to these new standards** [C2]. Taking the average new build house price since 2014, this equates to at least **GBP13 billion of assets**, which have been designed and built in Scotland to the Napier wall and floor construction specifications and criteria set within these standards.

World Leading Sound Insulation Standards and Compliance

One of the key outputs of the EU COST Action TU0901 [P3] was the comparison of all countries which undertook on-site sound insulation testing and their regulatory sound insulation compliance criteria. For Scotland the Napier led new sound insulation standards were found in 2014 to have the **world's highest regulatory level for airborne sound insulation for multi-storey housing** (i.e. apartments) [C3].

Influencing ISO 717 – International Standards

The 2014 report by Smith for Eurogypsum [O5], which also incorporated the early research findings of [O6] identified that the proposed draft changes for ISO 717 sound insulation criteria

would, if adopted, significantly affect the quality of life and lead to more noise complaints. In addition, the proposal would require companies to undertake extensive new testing of all acoustic products. Companies which are members of Eurogypsum have a turnover of over EUR7.5 billion, operate 200 factories and employ 28,000 staff. As such the draft ISO proposal would also impact on their and many other sector companies future business operations. Smith's report was distributed to the ISO working group prior to the Berlin ISO meeting in April 2014 and **the ISO draft changes were halted**. The UK representative at the Berlin ISO decision meeting reported to Smith, *"your report was the first to encapsulate all of the arguments and key technical facts. Many countries supported your arguments ...the proposed changes to ISO 717 for extending to low frequencies has been cancelled.... your report added sufficient weight to the debate such that it ensured that there was no significant room to permit counter arguments"* [C4].

New Innovative Products

Utilising the knowledge from [O1-O3], Smith's research investigating converting rigid foam waste streams into recycled shredded 'green crumb', [P5] led to enhanced sound insulation performance and new insights to acoustic material benefits. The test were undertaken at the Building Performance Test Centre in Fife, part of the Napier University acoustic test facilities. In March 2015, the British rigid foam insulation trade body (formerly BRUFMA), who supported the project to reduce landfill stated the **application of such waste materials into acoustic products** as a sector **"world first" and achieved Gold level, the highest level for sustainability** [C5]. Government agency co-funder of the project Zero Waste Scotland stated *"that this work supports and offers an important means of diverting a valuable construction material from landfill, giving it a longer life, and improving resource efficiency"* [C6].

Licensing to Global Company & Manufactured in UK

Smith's research [O1-O4] led to a new PhD project to investigate multi-frequency response of resilient ceiling bars and ceiling hangers with early career researcher Su Shenzhi. The outcomes of this research led to a **new international industry partnership** with Illinois Tool Works (ITW) which **operates in 55 countries** [C7] resulting in a **license agreement** and **granted patent in 2017** [C7]. The new resilient ceiling hanger **increases sound insulation performance**, provides a **dedicated cavity zone for future low carbon building services**, and has a pre-installed easy fix approach, **improving health & safety for site operatives** when working at ceiling heights, compared to traditional ceiling fixings [C8]. **The product is manufactured in the UK.**

Acoustic Solutions aligned to Energy Efficiency

The technical compatibility research for Robust Details [P4] combining thermal and acoustic performance of fibre based insulations for separating walls led to the full incorporation of this approach for all masonry robust detail designs. As each attached house or apartment built with robust detail specifications is registered on a national database it is possible to track which acoustic specification (Robust Detail construction) is registered. Since August 2013 to April 2020 over **490,000 new attached homes have been registered and built** [C9] using Smith's masonry separating wall and outer wall specifications, incorporated into a combined **asset value of over GBP98 billion** (using average new build house prices).

In summary:

- **90,000 new homes built in Scotland** using the research underpinned Scottish building regulations and guidance constructions, and
- **490,000 homes** where industry adopted the research underpinned robust detail acoustic-energy solution technical specifications in England & Wales, resulting in a total of
- **580,000 homes being built incorporating the research findings, in a combined pan-UK asset value of GBP110billion.**

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

[C1] Letter from Scottish government to local authorities instructing full implementation of the new Scottish Domestic Technical Handbook Standards, from 1st October, which incorporating Section 5:Noise – developed by Napier research team, (29th Sept 2013)

[C2] Statistics for new Scottish housebuilding, showing over 90,000 new homes built during 2014-15 to 2018-19, which required to meet the new Section 5: Noise design guidance and criteria developed by Napier research team (Scottish Government May, 2020)

[C3] International comparison table of 35 countries showing Scotland with the highest airborne sound insulation for multi-storey housing (EU published report - 2014)

[C4] Feedback from the UK representative on the draft ISO 717 committee Berlin decision and the impact of Smith's Eurogypsum report (email - 2014).

[C5] Statement from CEO of industry trade body BRUFMA on the new waste products being an industry sector 'world first'. (Industry trade body web page - 2016)

[C6] Impact of project and attainment of Gold level sustainability performance. Innovation case study (Zero Waste Scotland – 2014)

[C7] Granted patent (22nd Feb 2017) for new resilient ceiling system involving global company ITW and Edinburgh Napier researchers, Smith and Shenzhi (2017)

[C8] Letter from ITW-Cullen on the benefits of the new acoustic hanger ceiling system for performance, low carbon system integrations and health & safety

[C9] Robust Details stating the number of new homes registered in the UK incorporating Smith's assessment and recommendations: totalling 493,485 new homes. (Letter from company chairman, May, 2020)