Institution: The University of Edinburgh and Heriot-Watt University (Edinburgh Strategic Alliance)

Unit of Assessment: 13 (Architecture, Built Environment and Planning)

Title of case study:
Safer homes: From fire entry doors to high rise refuse hoppers

Period when the underpinning research was undertaken: 2002–2013

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:
Remo Pedreschi	Professor of Architectural Technology	1988–present

Period when the claimed impact occurred: 2016–2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Through Knowledge Transfer Partnership (KTP) funding and a sustained relationship with the specialist steel fabricator Martec Engineering, our research underpinned the development of new construction products, processes and practices that improved building occupants' security, safety and quality of life. Through laboratory and on-site experiments, theoretical studies, prototypes and designs, the following impacts were achieved:

- created new products that improved the safety of buildings and extended Martec Engineering's business performance, range, and market reach
- improved the efficiency and quality of Martec's manufacture and fabrication processes to be a market leader
- introduced Martec to new digital fabrication technologies
- increased the company's turnover and created 16 new jobs.

2. Underpinning research

All housing and buildings require fire door entry and exit systems which are robust, but also secure to prevent forced entry. This often reduces the range of materials used in construction, reduces glazing areas and requires wider and thicker door frames, to withstand various forces and prevent doors from warping and buckling under loading.

In 2014, Martec Engineering Ltd, one of the UK's leading SME companies for passive fire safety and architectural-engineering metalwork contractors, requested research support in expanding their customer base from social housing into commercial and institutional sectors, and specifically in relation to the design and development of robust door entry systems.

The project was funded by Innovate UK through a three-year Knowledge Transfer Partnership (KTP), which commenced in 2015 and would entail combining scientific research, detailed design, engineering product testing, studies into digital fabrication and market analysis. The project team involved architectural technologists and engineers and brought together a portfolio of previous work which could be applied to this project.

The underpinning research for this case study initially stemmed from a previous EPSRC project led by Pedreschi at the Edinburgh School of Architecture and Landscape Architecture (ESALA) in collaboration with Professor BP Sinha of the School of Engineering, that demonstrated the functionality of cold-formed steel structures for use in prefabricated housing, facades and building components. Funding for the project included support for an

impact workshop to demonstrate the application of the research in buildings and construction. Martec Engineering participated in the workshop leading to a sustained and productive research relationship that began with a TCS (Teaching Company Scheme, the pre-cursor to KTP) project 'Redesigning the Manufacturing Process' (2002-2004). Martec had worked extensively with cold-formed steel for fabricating doors, screens and facades, and were attracted by our combination of scientific and applied design research. The project focussed on research to improve the manufacture and performance of secure entry door systems and to achieve the nationally recognised security accreditation: Secured by Design (SBD).

The EPSRC research identified how technology from automotive manufacture could be transferred to building construction and engineering solutions [3.1, 3.2]. It was the first to show the effectiveness of clinching in cold-formed steel building systems, which is a means of joining two sheets of metal by a series of interlocked spot joints without bolts or welds. Our research then evolved towards a design focussed strategy investigating economical and sustainable construction methods, e.g., efficient steel/composite timber systems and form-active concrete structural elements and components [3.3], based on constructing and analysing full-scale prototypes, considering architectural form, construction and structural behaviour. The research involved close collaboration with the Steel Construction Institute [3.4, 3.5], the European Convention of Constructional Steelwork [3.6], and Scottish Enterprise, building on a legacy of research collaboration and product development with British Steel, the Concrete Centre, the Centre for Window and Cladding Technology, Metsec PLC, Watson Stonecraft Ltd, and Eckold GMBH. The research further demonstrated that innovative partnerships and technologies can improve manufacturing for construction in small to medium enterprises (SMEs) who have limited means to sustain their own research and development.

The 2015-2018 KTP with Martec 'Step Change in Manufacturing and Performance' was able to draw upon the knowledge and findings of the strength, structural capabilities, connections, clinching and applied forces of small steel framing elements [3.1-3.6]. In addition, the 2002-2004 TCS assisted the researchers in understanding the design for doors and product development requirements for Martec Engineering.

As a result, the research team were able to develop a robust alternative to the industry-standard electro-magnetic system of door restraint. During the project, extensive testing of the electro-magnetic locks at the UoE indicated a loss of robustness and reliability that hampered the development of the door system. Electro-magnetic locks are not normally suitable for a fire escape door, but the system, developed during the KTP, enables the door to be used as a fire escape, as it provides both secure access and escape. Tests were undertaken to evaluate the resistance to break-ins of external doors when fitted with different locks and frames. The resulting electro-mechanical design is stronger, more reliable and more sustainable, using less energy and significantly less steel than the standard system of door restraint. The new system uses 20% less steel than the standard system. These findings provoked Martec and the research team to re-think secure external door design engineering, with the potential to accommodate doors with large areas of glass and slimline frames. It also led Martec to re-think the design of other products, such as fire-rated refuse hoppers for multi-storey buildings. Using his expertise in applied research and design, Pedreschi supported Martec to prototype and test design variants, resulting in the company being able to manufacture their own refuse hoppers in-house rather than source these from a third party.

3. References to the research

[3.1] An experimental study of cold formed steel trusses using mechanical clinching. (2008) Pedreschi, R. F. and Sinha, B. P. Construction and Building Materials, Vol. 22, No. 5, pp921-931. https://doi.org/10.1016/j.conbuildmat.2006.12.014

[3.2] Predicting the shear strength of mechanical clinching in cold-formed steel structures. (2006) Pedreschi, R and Sinha, B.P. Journal of Materials in Civil Engineering, Vol. 18, No. 3, pp435-442 https://doi.org/10.1061/(ASCE)0899-1561(2006)18:3(435)

[3.3] Chandler, Alan, and Remo Pedreschi. 2007. *Fabric Formwork*. London: RIBA https://www.researchgate.net/publication/49290348_Fabric_Formwork

[3.4] Durability of light steel framing in residential applications. (2010) Lawson, R. M., Popo-Ola, S. O., Way, A., Heatley, T. & Pedreschi, R. Proceedings of the ICE - Construction Materials. 163, 2, pp109–121 https://doi.org/10.1680/coma.2010.163.2.109

[3.5] Developments in Cold Formed Steel Sections in Composite Applications for Residential Buildings**.** Pedreschi, R., Lawson, R.M., and Popo-Ola, S. O. (2008) Advances in Structural Engineering. Vol. 11. No 6, pp. 651–660 https://doi.org/10.1260/136943308787543603

[3.6] The Testing of Connections with Mechanical Fasteners in Steel Sheeting and Sections, No.124, (2009) *European Convention of Constructional Steelwork* Brussels, Prepared by Technical Working Group TWG 7.10, R Pedreschi chair of group. ISBN 92-9147-000-86 (Can be supplied by HEI on request)

4. Details of the impact

The underpinning research and KTP had a major impact on the reach, profitability and ethos of Martec recognised by a 'Certificate of Excellence' award (the highest rating) for the KTP by Innovate UK in 2019 [5.1] and its shortlisting as a Finalist for the Business Impact Award Category at the KTP Best of the Best Awards in 2020 [5.2].

Safer and Secure Buildings

Through the KTP, the research led to new products and safer buildings through:

A) a much-improved security door,
B) a safer two-hour fire-rated refuse hopper for multi-storey high-rise apartment buildings, by meeting the requirements of Secured by Design (via testing to STS 202 Level 2), as well as allowing means of escape performance to BS EN 179/BS EN 1125 [5.3].

Previous evaluation has shown that in areas where Secure By Design (SBD) doors and windows had been installed, attempted house breaking was reduced by 59%, and tenants reported that they felt safer and more secure [5.4, pp. 3, 10].

The innovative door system is also fully incorporated into the NBS National Building Information Modelling (BIM) Library for Autodesk Revit, providing both a UK and global reach for specifications [5.5]. Martec described the outcomes of the new door system developed with us as "*A strong, safe, user friendly alternative to magnetic locks. The three-point lock is fully consistent with door entry but is also EN179 compliant for escape routes. It does not require a constant electrical current to hold locked, meaning it is less expensive to run*" [5.6]. The new *Premier Vision* door system was released to market in April 2018, with 145 units sold to December 2020 [5.3] and is the only door in the UK that provides both accredited secure entry and safe egress [5.3]. Supported by our underpinning research and

knowledge [3.1-3.6] of steel frame systems, the thermal and security performance of the redesigned door system was described by Martec as "*industry leading*" [5.6].

Geographic reach, marketplace unique position and new global supply chains

As a result of the KTP and our underpinning research Martec's markets have seen a geographic as well as market and sector change, opening up opportunities in areas where they were not previously established. Having expanded into London, Martec is now working on its seventh significantly-sized London project, with a multitude of smaller ones and more large projects in the pipeline [5.2]. Developing new supply chains, facilitated by the new product designs, with two world leading suppliers has not only allowed Martec to provide new offerings; these relationships are creating sales opportunities through specifications, recommendations and shortlisting as trusted partners of these companies [5.2]. The products that Martec offers now differ greatly from those prior to the KTP and this development and transition has been facilitated by the background of the Associate and the development of new products during the KTP [5.2].

Martec's Design Manager stated in their 2019 KTP report that '*Post Grenfell this [system] is particularly valuable in apartments with only one principal exit'* and highlighted '*Premier Vision's unique position in the marketplace, in that it does not compromise on fire safety, means of escape, or security*' [5.7]. Martec also noted that they had received testimonials from clients citing examples in which the occupants of buildings with their electro-mechanical locks were able to exit during fire alarms and panic events, supporting their 'safer buildings approach'. These testimonials support their claim that Premier Vision products offer "*high security or entry control, the means of escape is never compromised*" [5.3].

Improved business performance

The research engendered new practices leading to improved business performance within Martec. The research and design led the company to create a design team in 2017, comprising a design manager and a design engineer. Unusually for a steel fabricator, Martec can now offer an integrated design approach to their clients. They confirm that this *"has had a major impact on our staff and company culture to the extent of everyone buying into the importance of engineering design and new products where everyone has an input"* [5.5]. The research team also developed an in-house facility at Martec for testing prototypes. A major element of the KTP was a fabrication study that led to the introduction of new software and a GBP60,000 investment in digital equipment. As a result, Martec's drawing office was integrated directly with the shop floor, leading to improved productivity and product quality and a reduction in fabrication errors [5.3]. This also provided a translational digital pathway to support Building-Information-Modelling (BIM) specification requirements for the new products to market [5.5].

New Refuse Hopper Products for Fire Security in High Rise Apartment Blocks

Clients often require Martec to supply refuse hoppers for multi-storey buildings (high rise blocks of apartments). Previously, the company bought certified fire-rated refuse hoppers from a third-party supplier but as a result of the KTP they have developed this in-house. By bringing manufacturing in-house, costs have been reduced and profitability has increased. By December 2020, the company has sold 3,200 units valued at GBP1.8 Million [5.3]. Martec stated "*The recent addition of Bin Hoppers to our range has proved to be a remarkable success and after our recent roll-out across the West Coast of Scotland we have decided to address the issue of Fire Security in High Rise Blocks across the UK*" [5.8]

Company Growth through Innovation

The benefits of the KTP and the door designs have brought value to the company. Martec sold GBP850,000 of Premier Vision products between April 2018 and July 2020. The new fire, window, door and façade systems produced by the company as a result of the KTP development, as well as the establishment of new supply chains and partners, have led to further growth, with direct increase in turnover starting during the KTP of GBP249,000 in 2017, GBP1,300,000 in 2018 and GBP1,600,000 in 2019 [5.3]. This has enabled Martec to increase productivity, employ new staff, add to the pool of expertise in the fabrication industry and create employment opportunities for young people. By March 2020, 16 new posts had been created, including the design manager and two designers, a compliance officer responsible for the fire-rated refuse hopper, four fabricators, two assemblers, and four trainees from a youth development programme [5.3]. These developments have underpinned successful new projects, including the renovation of Marr College in Troon, Scotland [5.3].

5. Sources to corroborate the impact

5.1 News article — Innovate UK rating of 'outstanding' and Certificate of Excellence for the KTP with Martec Engineering and the combination of architectural technology and engineering support behind the successful project, (13/02/2019).
https://www.eca.ed.ac.uk/news/full-marks-awarded-university-knowledge-exchange-team
5.2 KTP UK news. Finalist for KTP Best of the Best – Business Impact, (July, 2020).
https://www.ktp-uk.org/case-study/business-impact-finalist-martec-university-of-edinburgh-ktp-associate-keith-milne/
5.3 Testimonial from Design Manager, Martec Engineering Group.
5.4. Teedon et al, (2009) *Secured by Design Impact Evaluation Key Findings,* Evaluating Secured by Design door and window installations for crime prevention and community safety.
5.5 National Building Specification (NBS) National Building Information Modelling (BIM) Library object standard and National BIM Library listing for Premier Vision Doors.
https://www.nationalbimlibrary.com/en-gb/martec-engineering-group/premier-vision-single-door-side-panel-top-panel/?lo=en-GB
5.6 Martec Engineering website – describing key features of the new Premier Vision door
https://www.martecengineering.co.uk/products/premier-vision
5.7 Martec Engineering KTP report, 2019.
5.8 Martec Engineering website – describing the new refuse hopper features for high rise apartment blocks. https://www.martecengineering.co.uk/bin-hoppers