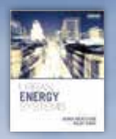
Other Centre related publications featured in this review:



Keirstead, J. & Shah, N. (2013)
Urban Energy Systems: An Integrated Approach.
Oxon, Routledge.

Imperial College London

LAING O'ROURKE

Laing O'Rourke Centre for Systems Engineering and Innovation

2013/14

For all enquiries relating to the Laing O'Rourke Centre of Systems Engineering and Innovation please contact the Laing O'Rourke Centre Administrator:

From September 2014 until June 2015 please contact:
Laura McKay
Centre Administrator
Tel: +44 (0)207 594 5995
Email: l.mckay@imperial.ac.uk

From July 2015 onwards, please contact:
Alexandra Williams
Centre Administrator
Tel: +44 (0)207 594 5995
Email: alexandra.williams@imperial.ac.uk

Laing O'Rourke Centre of Systems Engineering and Innovation
Room 437, Skempton Building
Imperial College London
South Kensington Campus
London SW7 2AZ
United Kingdom

Contents

Professor Jeff Magee
Dean of the Faculty
of Engineering

Professor David Fisk
Laing O'Rourke Professor
of Systems Engineering
and Centre Director

Professor Nick Buenfeld
Head of the Department
of Civil and Environmental
Engineering

Foreword

The Centre for Systems Engineering and Innovation was created following an agreement between Laing O'Rourke and Imperial College London, signed in October 2010, and is hosted within the Department of Civil and Environmental Engineering.

Large engineering projects are testing the art of bringing different systems together to form a coherent working whole. The need to acquire this skill has been a defining theme in the emerging work of the Centre. This began in the design of the Master's Course in Systems Engineering and Innovation which exposes students to systems engineering in all its forms across the different Departments of the Faculty of Engineering. But this year it has also steered our collaborations with others on campus in research and outreach.

Undoubtedly the highlight of the year for the Master's course was passing its CEng accreditation with flying colours. Thanks go to those who prepared our documentation, our assessors for their kind words, but above all the students who we were told gave such positive affirmation of the Course's value. Student Dissertations from our first cohort, all of whom graduated with Distinction, have resulted in well-received conference presentations, and we now have new Dissertation topics under study in such diverse fields as applying fuel cell systems to data centres, and introducing cyber security into Building Management Systems.

The Course was unusual in being designed from the outset for part-time study by students with real world experience. This year we opened a full-time one year alternative that doubles up the part-time course. Its 'test pilots' confess it is very challenging, but very worthwhile.

If urban systems were a thread in last year's report, cyber space and its threats have featured throughout this year. Presaged in a Centre Working Paper last year, the topic has since exploded as realisation has dawned that cyber security is as much a systems constraint as physical security. Working with Imperial's Institute for Security Science and Technology, the Centre has been involved in producing major publications on the impact of cyber security on modern intelligent buildings, and in the preparation of IET draft guidance. The emphasis throughout has been designing for resilience. This theme culminated in the Centre's Second Distinguished Lecture by Mike StJohn-Green to a packed audience '*Cybersecurity and the modern city – when our infrastructure goes online*'.

This document covers the period from April 2013 to March 2014. It highlights the Course, the research sponsored by the Centre and documents its increasing outreach activities.

April, 2014

Acknowledgements

The Centre would like to thank Professor David Gann CBE, who stepped down from the Laing O'Rourke Centre Board during June 2013 to focus on the post of Vice-President (Development and Innovation). Professor Gann has been involved with the Centre since its inception and his enthusiasm and wisdom have been invaluable to its success.

1.1 Centre timeline April 2013 – March 2014

2013

April

PhD Student Ms Sarah Noyé presents her paper *'Smart systems commissioning for energy efficient buildings'* at the CIBSE Technical Symposium.

Professor David Fisk speaks on green buildings and urban design at the New York Times *'Energy for Tomorrow – Building Sustainable Cities'* conference.

May

Professor Geoff Levermore, Institute of Energy and Sustainability, De Montfort University and MACE delivers his presentation *'Climate change, the IPCC, uncertainty and the built environment'* in the 2nd of the Centre's Lecture Series.

Professor Keith Clarke CBE presents his vision of what systems engineering can bring to engineering in the 3rd of the Centre's Lecture Series.

College Senate approve the full-time delivery of the Master's in Systems Engineering and Innovation.

June

Professor Fisk's paper *'Optimising heating systems structure using exergy branch and bound'* is accepted in the *Building Services Engineering Research and Technology (BSERT) Journal.*

College Senate approve the Laing O'Rourke Prize for Best Final Year Project. The prize is to be awarded to a final year undergraduate student in the Department of Civil and Environmental Engineering.

July

The Master's in Systems Engineering and Innovation Programme receives full Accreditation from the *Chartered Institute of Building Services Engineers (CIBSE)* and the *Engineering Council.*

Professor Washington Ochieng becomes Fellow of the Royal Academy of Engineering.

September

The first cohort of Master's in Systems Engineering and Innovation Students each pass with Distinction.

October

The Centre welcomes the first cohort of full-time Master's in Systems Engineering and Innovation students.

Ms Elizabeth Crow is announced as winner of the Laing O'Rourke Prize for Best Final Year Project during Commemoration Day, held at the Royal Albert Hall.

Master's Alumni Mr Michael Enstone and Ms Rhona Malcolm present as guest lecturers in the 5th and 6th of the Centre's Lecture Series.

November

Jean-Paul Vella, PhD Scholar joins the Centre.

2014

January

Professor Fisk gives evidence to the House of Commons Select Committee on Energy and Climate Change's inquiry into the effectiveness of the Low Carbon Innovation Co-ordination Group.

Master's Alumnus Mr Irek Starzyk presents as a guest lecturer in the 6th of the Centre's Lecture Series.

February

Professor Timo Hartmann, University of Twente, presents his ideas on *'Visualisation and simulation to support smart city engineering – towards a computer semiotic theory'* in the 7th of the Centre's Lecture Series.

March

The Centre hosts its second Annual Distinguished Lecture delivered by Mr Mike StJohn-Green, on *'Cybersecurity and the modern city – when our infrastructure goes online'.*

PhD Scholars, Marianna Micallef, Sarah Noyé and Jean-Paul Vella present at the Laing O'Rourke Doctoral Conference 2014 in Dartford.

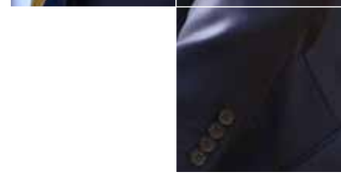
2

Master's in Systems Engineering and Innovation:
Introduction

The Centre is responsible for delivering the Master's programme in Systems Engineering and Innovation which is designed to develop the next generation of technology champions in modern complex engineering systems. The Course welcomes students who have already demonstrated competence and leadership in their field and who wish to extend their knowledge of systems, the broader application of systems thinking, and apply their learning successfully into the real world.

Dr Christian Onof
MSc Course Director

Konstantinos Karagiannis
Master's in Systems Engineering and Innovation student



2.1 Could your building catch a virus?
Measuring the impact of cyber security threats on Building Management Systems

Konstantinos Karagiannis is a Senior Mechanical Engineer and Consultant in the area of *Building Management Systems (BMS)*. Recently he has become the Technical Director of General Technology Ltd in Greece, leading the execution of BMS projects which include design, programming, testing and commissioning.

For his Master's Dissertation Konstantinos is investigating advanced cyber security technology and how it might be applied in BMS. "Today's fast-paced changing technology environment requires systems to be interconnected to a higher level. This increases their complexity, and inevitably, higher complexity comes along with higher vulnerability. Building Management Systems present a good example of these new security issues. In the near future, when BMS will integrate the building into the Smart Grid, cyber security of Building Management Systems will pose a challenge not only to the building but to a country's infrastructure," says Konstantinos.

The Dissertation template requires students to explore the systems implications of introducing a new technology into their field of professional expertise. "Before I started this research, cyber security had been a grey area to me and I didn't realise its paramount importance to BMS and the full potential of the commercial market. With the help of my supervisor Dr Deeph Chana, Deputy Director of the Institute of Security and Technology, I was plunged into the environment of cyber security. Along with Professor Fisk's guidance, I was able to identify the need for the innovation that my industry requires and the ways to achieve it," adds Konstantinos.

> "Overall, my experience as a full-time student has been a great journey in systems theory and its potential implementation in every aspect of engineering."
>
> **Konstantinos Karagiannis**

Konstantinos is also one of the first students to embark on the full-time delivery of the Course. "Overall, my experience as a full-time student has been a great journey in systems theory and its potential implementation in every aspect of engineering. After a few years in the BMS industry, I felt that I needed to participate in a Master's programme that will be market-orientated and which will introduce me to a different way of approaching and implementing innovation in an organisation. The Master's in Systems Engineering and Innovation Course addressed my interests and has taken my career development one step further. The holistic thinking approach uncovered in every case study used throughout the Course has given me the impression that I was doing an innovative MBA in engineering," concludes Konstantinos.

Konstantinos Karagiannis
Master's in Systems Engineering and Innovation student

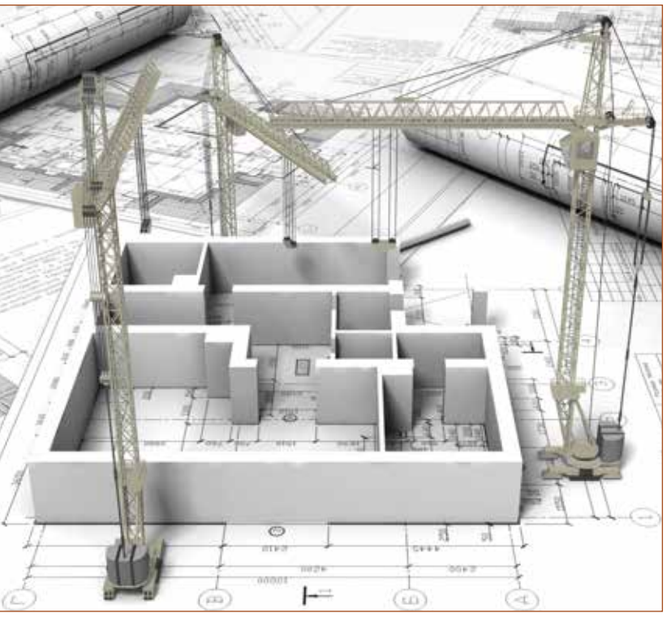
Andrew Ellwood
Master's in Systems and Innovation student

2

2.2 Tower crane optimisation

In conversation with Andrew Ellwood, a Master's in Systems Engineering and Innovation student and his supervisor, Dr Panagiotis Angeloudis

> "I've been able to take on a new role managing Innovation on a project within the Laing O'Rourke business."
>
> **Andrew Ellwood**



Above: Digitally 'placing' tower cranes during the design phase allows various scenarios to be evaluated.

Andrew Ellwood has been researching the use of optimisation methods in construction, with specific emphasis on the use of cranes with pre-manufactured elements.

Andrew's research into existing academic literature indicated that layout planning could be undertaken with optimisation tools to minimise the cost overhead of using tower cranes to install pre-manufactured elements, by placing the cranes in such a way to reduce time spent moving materials around the site. **Dr Panagiotis Angeloudis**, Andrew's supervisor, points out the current problem, "urban modern construction sites are highly congested. The outputs of Andrew's research will assist the construction industry in identifying optimal site layouts that maximise operational efficiency and ensure that schedules remain in check."

"There are a lack of optimisation models for the design of crane layouts that are mathematically sophisticated, yet applicable to practice. Given the wide range of parameters that need to be considered, this is not a simple problem to approach, let alone solve optimally," explains Panagiotis.

Throughout the course of his Dissertation, Andrew found that he managed to provide solutions to reduce workers' time spent on site. "Logistics planning often terminates at the site, and site layout planning is a highly conflicted balance of many factors," explains Andrew. "My research associates firm 'cost' figures with the location of tower cranes, therefore allowing objective analysis of crane placement to minimise the movement of materials on site."

The findings so far have the potential to benefit many industrial projects. "The current research indicates that lost productivity due to excess movement or inter-crane conflict could be minimised," says Andrew. His Master's research could act as the catalyst in ultimately reducing schedules and their risk, as well as decreasing the corresponding overhead costs.

A research project is not without its challenges, requiring students to use innovative and independent thinking within the time period of a Master's. Andrew says, "developing the optimisation model involved converting geometric algebra into computer code. The 'black-box' nature of the search algorithms made this a time-consuming activity." However, Panagiotis is sure that Andrew's industrial background, "ensured that the algorithm developed is grounded in reality, and will be ready to apply to his current projects."

There is another unexpected by-product of Andrew's research which also provides potential benefit to industry. "I was surprised to find how complicated a time-based model to optimise the construction sequence would be," Andrew reveals. "If sufficient data were available, this would be a valuable facility." There is the opportunity to build on this project, covering a greater area of research possibilities, and even create assets to improve the industry.

Support for students is an essential role of the Centre. Working alongside students to ensure their study experience is met with a capable back-up network is key. Andrew admits his Master's was not without its challenges. "Coping with the fast pace of lectures, and maintaining the difficult balance of work and study pressure has only been made possible for me because of the support I've received to overcome my dyslexia," he says. "Imperial's disability advice services are a credit to the College. Their support has helped me learn a great deal about myself."

Life after learning has opened more opportunities for Andrew, who had previously spent eight years as a Mechanical Project Engineer. Furthermore, Laing O'Rourke is active in acknowledging the work carried out by its Master's students. "I've been able to take on a new role managing Innovation on a project within the Laing O'Rourke business," says Andrew. "The innovation component of the Master's will clearly have had a bearing on this development, and offers encouragement that progressive organisations will value such a qualification."

"Working as Andrew's supervisor has been exciting," concludes Panagiotis. "His industrial experience and commitment to work on something that he can apply directly in Laing O'Rourke immediately after graduating ensures that the direction of the project remains in check and undiluted."

Edited by
Melanie Hargreaves
Administrative Assistant

Dr Panagiotis Angeloudis
Lecturer in Urban Engineering

> "Working as Andrew's supervisor has been exciting. His industrial experience and commitment to work on something that he can apply directly in Laing O'Rourke immediately after graduating, ensures that the direction of the project remains in check and undiluted."
>
> **Dr Panagiotis Angeloudis**

Matthew Brown
Master's in Systems and Innovation student

2.3 Increasing profits and improving design: a mechanical and electrical design platform using a systems approach

In conversation with Matthew Brown, Master's in Systems and Innovation student and his supervisor, Dr Marco Aurisicchio

> "I believe that the system proposed would improve a designer's efficiency, reducing design time, encouraging collaboration and minimising errors. Its implementation should encourage and improve the quality of BIM implementation."
>
> **Matthew Brown**

Using his experience in the industry and drawing on the systems thinking and innovation taught in the Master's, Matthew is investigating opportunities to improve the design development processes in the construction industry and argues that the most potential is revealed in the early design phases. His focus is on M&E building systems and the main point of his research is that despite the criticality of the decisions made in these phases, little support is available to engineers. In particular, Matthew maintains that there is a need to support system definition by encouraging system thinking and providing means to structure emerging system architecture to act as an enabler to Building Information Modelling (BIM). BIM is often heralded as the disruptive change, the next big thing that will cajole and enable the industry to move to model-based engineering, leaving behind its archaic document-based delivery process. But the adoption of BIM has been slow and used with varying levels of success.

Matthew's supervisor, **Dr Marco Aurisicchio**, says, "Matt envisions that a dedicated computer tool is needed, and that this should enable the definition of systems and system interfaces. The functionality of the tool goes beyond addressing these issues as it must also integrate design information, such as client requirements, store any relevant past design and standards information, and output plant schedules. Its implementation is expected to increase the quality of downstream processes."

The research undertaken to support this project has included the review of software tools used in adjacent industries, such as in IT and aerospace. For the management of the design process, tools such as the requirement management tool DOORS and the Systems Modeling Language (SysML) are used in the IT industry. No single existing tool in the market place is able to perform the required functionality of the proposed system, but there are significant aspects of these systems that the construction industry can learn from, and these are reflected in the specification for the proposed system.

Are you inspired to become a next generation systems engineer?

Full details regarding the Master's programme can be found on **page 32**

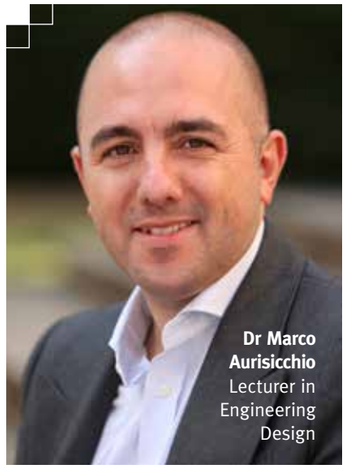
Once designed, the main features of the software will be to:

- Aid design process by encouraging system definition
- Provide a focus on system interfaces with interfaces to common systems interlinked
- Act as a means for capturing the specific client requirements, which can be linked to the design elements that satisfy these requirements
- Automatically generate plant schedules and plant interface schedules for inclusion within the written specifications
- Act as a library or database for the storage of standard specifications and past specifications
- Act as a library for lessons learnt, knowledge retention and useful tips

> "I was impressed by how Matt was able to ground his research aims into practical issues, and develop a comprehensive specification for a design support tool."
>
> **Dr Marco Aurisicchio**

"I believe that the system proposed would improve a designer's efficiency, reducing design time, encouraging collaboration and minimising errors. Its implementation should encourage and improve the quality of BIM implementation," says Matthew.
"In short the tool will be of primary benefit to design consultants with secondary benefits felt by BIM suppliers, and ultimately resulting in improved efficiency in the construction industry."

The main challenge in the research is in the design of a system that is simple and yet has sufficient functionality to achieve its objectives, whilst at the same time ensuring that the tool does not constrict designers' ability to innovate at this crucial stage of the project. "The problem of supporting the early phases of product development processes, where most innovation and free-thinking take place, is common to many industries," explains Marco.
"Computers have had limited success in providing effective aid because these processes are complex to automate. The tool proposed by Matt has the potential to translate into useful and effective support."



Dr Marco Aurisicchio
Lecturer in Engineering Design

Matthew comments further: "I have restricted my focus to the M&E industry (in terms of the tools application) but think that it would have merits in the architectural field as well. I think that more market research is required, involving a broader panel of designers in order to understand their frustrations with the current processes and their requirements for the proposed system."

Supervisors working with students on the Master's notice a different culture to other programmes.
"Working with students with industrial backgrounds and proven track records takes postgraduate education to an advanced level," says Marco.
"I was impressed by how Matt was able to ground his research aims into practical issues, and develop a comprehensive specification for a design support tool."

The merits of this Master's is also felt from a student perspective. "I do feel that the projects and the business decisions that I make have already benefited from the Course, from managing innovation and risk, to understanding the policy influences, to technology-specific knowledge. The Course has stretched me intellectually; it forces one to think more holistically, to focus on the user, the *meta system* and ultimately it makes you a better, more rounded engineer," concludes Matthew.

Edited by
Melanie Hargreaves
Administrative Assistant

3 Innovation

Professor G Anandalingam
Dean of Imperial College Business School

3.1 Innovation as systems thinking

In conversation with Professor G Anandalingam

Dean of Imperial College Business School

During autumn 2014 I was invited by the Centre to provide my first lecture at Imperial to the Master's in Systems Engineering and Innovation students and to the Centre guests.

Having initially been approached because of the important connection to the Business School, the Centre was also very interested in my previous experience as Chair of the Department of Systems Engineering at the University of Pennsylvania, United States. In my talk *'Systems Thinking and the Entrepreneurial Journey'* I wanted to share my thoughts on what I saw as the process of innovation using systems thinking. To relate this to the Master's programme, it was important to map out the journey from systems thinking, to systems engineering, to systems analysis.

Systems thinking, systems engineering and systems analysis – what do we mean?

Firstly we must try to understand what systems thinking is. To understand this, we must understand what it is not. Systems thinking is very different to the scientific method of thinking. The scientific method takes a problem as the whole sum of the parts, breaks down the sum into components, and analyses specific parts using models that we already have, whether it's in physics, mathematics, or chemistry. Once analysed, the parts are then built into a new subsystem before rebuilding this again to form a whole complex system in order to be analysed and understood fully. However, systems thinking takes a problem and embeds it into a more complex problem before it is analysed as a combined whole. Systems engineers analysing this combined whole may start by beginning to ask, *"what is the purpose, what is it we're trying to solve?"* To help answer this, systems engineers need to understand many environmental factors. They need to embed the systems into a more complex content before they can come up with better solutions. This is often seen as *system of systems* thinking. Once embedded in complex systems, the systems thinker is then able to identify, using systems analysis, the many tools which can be used to optimise different solutions aimed at solving large-scale problems. It is in the development of such tools that the systems thinker uses systems engineering. In turn, realising the whole, revealing the many problems and coming up with tools that can fix different solutions leads to innovation. Solving micro-problems as recognised in the scientific method does not lead to innovation.

In my earlier experience working for an established US telecommunication company, I was asked to solve a problem that they had in developing a global network. As a systems thinker I first asked what is it that they were trying to solve? Were they trying to design a network or to do something else? It transpired that they were trying to connect between US and the EU networks – they were not trying to design a whole network at all! By asking big picture questions you are able to work out what the real issues are. So the issue was really trying to find inter-connectivity between existing networks and through the use of tools, I was able to model and optimise the problems which led to an innovative solution to the problem. The first innovation was to focus on adding bandwidth rather than rebuilding a new network. There were many ways to add bandwidth and we could have used a close-minded approach and built the required capacity ourselves. At this point too, we decided to take a systems approach and look at all different alternatives and it turned out that the best solution was to acquire a small telecommunications company that was already operating in the EU. The process of systems thinking led to systems analysis, which led to systems engineering – the result was innovation!

Systems engineering and managerial innovation

The combination of systems thinking and having the tool kit of analytical thinking that is the core of engineering is extremely powerful and important for managers. I call this "true systems engineering". The traditional view of systems engineering is to think of building models with feedback loops and cybernetics, and also apply this methodology to engineering problems. This is not the modern view of systems engineering as articulated by C. West Churchman, Russell L. Ackoff et al.

The methodology of systems engineering is extremely useful for managerial decision making. Indeed, I would argue that very little managerial innovation happens without systems thinking and systems engineering.

Being an effective manager means that one needs to view an organisation as a system and manage it that way. Traditionally we have learned to manage an organisation by managing its separate pieces (sales, marketing, production, logistics, service etc.). Managing in this way always causes sub-optimisation, and parts of an organisation achieve their goals at the expense of the whole. Failures in cooperation, poor morale and conflicts in our organisations are symptoms, and their causes lie in the system. Training in teamwork or cooperation will only treat the symptoms. The causes usually remain.

A systems view of organisations leads to a different collection of problems to address. A systems view of an organisation starts from the outside-in. How does this organisation look to its customers? Who are its real stakeholders? How does the organisation look to its employees? How easy are we to do business with? How easy a place is it to work in? How does the industry view our company? Do we have a brand presence globally? And so on. This 'analysis' is called the 'As-Is' analysis.

The next step in systems thinking for managers is to ask the question, "If we leave the system the way it is, where will we end up in 5 years? 10 years?" This is called the 'As-It-Will-Be' analysis. The next step is systems design or one could call it organisational design. How should we change the system as a whole to make it better?

Changing the system means taking out things which have been limiting or damaging current performance. For example, removing activity measures, arbitrary targets and ceasing to manage performance through budgets, and changing structure and processes to enable them to better achieve their purpose. Managers will only take such radical action if and when they appreciate that their traditional means of control in fact give them less control: managing costs actually adds cost.

When the organisation is understood as a system, the inappropriateness of such practices becomes stark. It is a major source of motivation for action. Action means 'doing the right thing', putting in place the right 'system conditions' to ensure that performance is managed from a strong base of understanding.

Professor G Anandalingam
Dean of Imperial College Business School

Alexandra Williams
Centre Administrator

3

Professor Washington Ochieng
Professor in Positioning and Navigation Systems

Michael Enstone
Master's in Systems Engineering and Innovation Alumnus

3.2 Innovation
Smartphones in construction

Michael Enstone reports on how he has applied the skills he has learnt on the Course to develop a new productivity tool for Small Medium Enterprises (SME) in the construction industry.

"Originally I was to investigate how laser scanning might be used to inform designs in refurbishment projects. However, when I started the literature review I became interested in how low cost, low accuracy and high frequency measurements could improve quality in construction. Modern smartphones contain numerous sensors that proved to be an ideal platform for investigating these types of measurement," informs Michael.

"Having confirmed this research topic with my supervisor, Professor Washington Ochieng, I carried out more detailed investigations into the performance of the camera, GPS sensor, accelerometers and gyroscopes in modern smartphones. I also started to consider how the existing processes on construction sites might be improved by using the additional data that can be collected from a smartphone. I then looked at how smartphone applications could be used by a contractor or consultant to monitor progress on site. By utilising an existing process, I applied systems engineering thinking to create a way of collecting additional data without adding additional work for people on site. The idea was trialled with the help of one of my contractor colleagues who used the application on a smartphone to provide data for analysis," describes Michael.

"My conclusion was that smartphone cameras can produce high quality images for use in conjunction with advanced image processing algorithms to measure the progress of installation on site.

"Since leaving Imperial I have developed the smartphone monitoring concept into a product that is now available for Android smartphones. The application has a cloud-based collaboration hub to share the reports from the app with clients and other members of the construction team. The product is aimed at SME main contractors and consultants to provide a low cost way to improve site monitoring.

Looking to the future, I am currently developing an iPhone compatible version of the application. I am continuing to use the systems thinking in my everyday work and hope that this will lead to continued success in my career," concludes Michael.

Michael currently works as Project Manager and Team Leader for AECOM delivering building services engineering design. His Master's has provided the necessary skills to effectively manage and recognise innovation within his team and set him on course to his recent promotion to Associate Director.

Michael Enstone
Alumnus

> "My conclusion was that smartphone cameras can produce high quality images for use in conjunction with advanced image processing algorithms to measure the progress of installation on site."
>
> **Michael Enstone**

For more details of Michael's app please go to **www.simon-app.com**

4

PhD Research
Introduction

Professor David Fisk
Centre Director

The Centre provides a natural interface between Laing O'Rourke and the specialist expertise at Imperial. World class research enriches the quality of our teaching, provides a vital learning environment for students and advances the welfare of society. It is therefore natural that the Centre hosts research as part of its activities. Some of its associates are involved in industrial research and research funded by the Government's Technology Strategy Board. Under the Centre's founding agreement, Laing O'Rourke also supports PhD research in areas of common interest.

Faculty Building

Dr Robert Vollum
Imperial supervisor

4.1 Development of novel connection methods between precast concrete panels

Jean Paul Vella

Laing O'Rourke supervisors:
Dr John Stehle and Dr Andrew Jackson

When continuous reinforcement needs to be provided in cast in-situ concrete construction exceeding the lengths of individual reinforcement bars limited by production, transportation, or otherwise, splices need to be included.

These would normally be achieved by lapping separate reinforcing bars. However, these lap lengths can be even more than 1m, depending on several factors. When adopting these splices in precast concrete construction, the resulting joints to accommodate these lap lengths would be too large. A novel connection system has therefore been developed to greatly reduce joint widths between precast concrete slabs.

Above/right:
Explore Industrial Park

This project uses numerical analyses and experimental testing to carry out and verify the structural performance of the connection, in addition to developing simplified analytical models using the strut-and-tie method. Several factors are considered for the design of the connection, including: effects of confinement, stiffness, reliability, and behaviour under dynamic loading. The expected results from this research will lead to the development of a design-oriented analytical model for optimising the design of the connection system.

Dr Robert Vollum
Reader in Concrete Structures

PhD Research
4.2 Jean Paul Vella

Jean Paul graduated as an Architect and Civil Engineer from the University of Malta in 2010. He also has a Master's degree in General Structural Engineering from Imperial College London, in which he graduated with Distinction and achieved first place for the best concrete building design project.

Explore Industrial Park

In autumn 2013, Jean Paul was awarded a Laing O'Rourke PhD scholarship by the Centre. His research degree involves innovation in precast concrete structures, focusing on refining the design of a novel connection method between precast concrete panels developed by Laing O'Rourke.

The use of precast elements in concrete construction has become well-established owing to the benefits achieved through pre-manufacture and factory-controlled production, which include improvements in quality assurance, construction programmes and sustainability. However, particular attention should be given to the connections between separate precast elements, as these should be designed to transfer forces between precast elements, whilst ensuring strength and robustness of the structure.

Established methods are still used to connect individual precast concrete panels together. The choice of connection method is determined by the forces that need to be transferred from one precast concrete element to the other through the joint.

Laing O'Rourke are developing precast concrete products following the concept of Design for Manufacture and Assembly (DfMA) to provide higher quality and more efficient construction solutions than traditional methods. They have developed a novel form of connection between precast concrete slab panels utilising a variation of a lapped bar connection, such that a reduced lap length could be used in the cast-in-situ joint region, therefore decreasing the joint width. Slabs can be cast off-site in several sections under factory-controlled conditions, and minimal in-situ concrete is used during construction. The slabs are temporarily supported until the cast-in-situ joint gains sufficient strength. With this construction method, the use of conventional formwork and propping is drastically reduced, or totally eliminated, for regularly planned structures.

Initially, Laing O'Rourke determined the viability of their innovative proposal. However, further research was required to provide a more detailed theoretical framework. An initial visit to Laing O'Rourke's precast concrete factory facilitated a better understanding and appreciation of how products are manufactured and of the limitations that the manufacturing processes could have on design.

This research aims to further investigate the mechanical behaviour of this form of connection. A sound validation of this connection's structural adequacy will enable Laing O'Rourke to guide their clients towards this innovative system.

PhD Research
4.3 Marianna Micallef

Marianna Micallef graduated as an architect and civil engineer from the University of Malta in 2006 and has an MSc in Advanced Structural Engineering from Imperial College London.

Funded by Laing O'Rourke, Marianna is currently finishing her third year of her PhD. Her research focuses on crack control in water-resistant reinforced concrete (RC) walls with edge restraint and a combination of edge and end restraint.

Marianna presented her work orally at the 16th Young Researchers' Conference (YRC) on 5 March 2014, held at the King's Fund in London. This annual conference is organised by the Institution of Structural Engineers (IStructE), where nine researchers are chosen to give a 15 minute oral presentation, and another sixteen are selected to present a poster on their work. The conference is a result of the IStructE's initiative to develop consciousness of the importance of research in the advancement of structural engineering with young engineers. The YRC achieves this by connecting academia and the industry for the duration of the one-day conference, with Laing O'Rourke being one of the industry sponsors for this event.

The YRC is an excellent interaction opportunity for the presenters as it brings together researchers from leading UK universities. It provides a platform for research students in the final years of their studies to share their enthusiasm for structural engineering by contributing experiences and knowledge. Feedback was given by the judging panel of leading experts.

Marianna presented her work entitled 'Crack control in base-restrained RC walls'. She set the scene by discussing how restraint to movement in concrete leads to cracking and potential leakage in water-resistant RC walls with base restraint or combination of restraint, which is common in practice. Marianna highlighted the problem structural engineers face when designing reinforcement for crack-control for such walls. In particular, use of the current code of practice results in more onerous reinforcement requirements

Marianna Micallef (far right) and other colleagues from Imperial who also attended the Conference: (left to right) Jonathan Gosaye Fida, Fernando Madrazo-Aguirre and Claire Villette

to control crack widths, which has buildability and cost implications. She showed why more research is required and then focused on her own contribution, which aims at coming up with a method in which engineers can gain more confidence in predicting crack widths, by using both experimental work and a numerical modelling programme. She also presented her numerical modelling work using ADAPTIC, a non-linear finite-element analysis program developed by Professor Bassam Izzuddin, which is being used to investigate the influence of different parameters believed to influence crack widths, in addition to those parameters investigated in laboratory tests.

The Centre would like to congratulate Marianna on her progress and her success at being invited to the conference.

PhD Research

4.4 Sarah Noyé – The annual American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Winter Conference 2014

Laing O'Rourke scholars have many opportunities to increase their professional networks in the course of their studies. Sarah Noyé is a third year PhD student at the Laing O'Rourke Centre, who attended *The Annual American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Winter Conference 2014*, which was held in New York, to learn more about how the US approached the commissioning of buildings.

Sarah Noye's research focuses on reducing the gap between as designed and as operated building energy consumption using *Wireless Sensor Network (WSN)* to collect temporary, additional and continuously monitored data in an approach she has developed called Pop-Up Monitoring™.

New York and building energy

The ASHRAE conference together with its associated *Air conditioning, Heating and Refrigeration Exhibition* is the biggest international gathering of heating, ventilation and air conditioning (HVAC) professionals in the world. At the conference, Sarah had plenty of opportunities to meet with leading manufacturers, installers and academics. Speaking to exhibitors, Sarah found that energy prices in the US were still too low for energy to be a hot topic amongst uses. But *Building Energy Management Systems* were seen as important assets that enabled integrated monitoring of plant functioning and indoor air quality.

Sarah's research with Wireless Network Sensors raised a lot of interest with those she met, as the US building is predominantly still 'wired' when it comes to building control. Europe it seemed had a lead in the use of wireless technology. "However WSNs are likely to provide a cheaper opportunity to get hold of temporary or additional data, for post-occupancy commissioning, like in my research, or energy management or system retrofit," explains Sarah. "Requirements for close indoor control and low energy technology will drive this, where there is a market opportunity."

Sarah found that *commissioning* in the US was approached differently from the UK. It was a high level process consisting of systematic testing through a process called *Testing, Adjusting and Balancing*. "Both sides of the Atlantic have much to learn from each other's approaches," advises Sarah.

Sarah is CIBSE's student representative at the College and her final reflections were on ASHRAE itself. "ASHRAE is a community that dedicates time to improving the building services industry. What was encouraging and inspirational was to hear the Young Engineers in ASHRAE (YEA!) explain their volunteering in the different chapters of the organisation," concludes Sarah.

Above: The Ashrae conference 2014

> "ASHRAE is a community that dedicates time to improving the building services industry. What was encouraging and inspirational was to hear the Young Engineers in ASHRAE (YEA!) explain their volunteering in the different chapters of the organisation."
>
> **Sarah Noyé**

5

Outreach 5.1 Annual Distinguished Lecture

Cybersecurity and the modern city when our infrastructure goes online

Mike StJohn-Green

Professor Chris Hankin
Director of the Institute for Security Science and Technology

View the lecture **'Cybersecurity and the modern city – when our infrastructure goes online'** at www.youtube.com/watch?v=lorCRpcfqFU

Ensuring that systems are not only physically secure from harm, but cyber secure, has become a major issue in systems engineering.

This year's Laing O'Rourke Centre's Distinguished Lecture *'Cybersecurity and the modern city – when our infrastructure goes online'* was given by **Mike StJohn-Green**.

Mike was previously Deputy Director CESG within GCHQ and the Deputy Director in the Office of Cyber Security and Information Assurance in the Cabinet Office. The topic reflected the Centre's own involvement in cyber security analysis, including the IET Guidance on Cyber Security and Buildings, and its closer working with Imperial's Institute for Security Science and Technology (ISST). In conversation with **Professor Chris Hankin**, Director of the ISST, Mike elaborates his theme.

Systems engineering and cyber security

"The role of the systems engineer is central to the work on cyber security. The first point is about realisation, which makes the case for Chris's RITICS work regarding how to convey the cyber security risk to system owners. The systems engineer should tell the people who are commissioning and building their systems about risks. They may have to trade efficiency and cost savings to gain resilience, making the systems slightly more expensive. Two suppliers increase resilience, however a single supplier is more efficient. This is a trade-off between understanding and quantifying risk and then suggesting how much money businesses should invest in order to mitigate that risk. Only a systems engineer is well placed to understand this, to see the whole picture," says Mike.

Do metrics exist?

"We talk of wanting our critical infrastructure to be safe, secure and resilient, each word meaning something slightly different. Of these, I think safety has the most mature metrics, but even safety of critical infrastructure is difficult to measure. With cars you can measure accidents to see how often things go wrong, but in the case of critical infrastructure it is hard to adopt such a metric when we depend on the critical infrastructure to be available 99.9% of the time. Metrics based on errors or failures tend to be too sparse, and so you have to measure other areas, and this is fundamentally difficult," says Mike. "Turning to security or resilience, I don't know of universally recognised metrics," adds Mike, "but we can look at risk in order to understand more about security and resilience. I would also say that you've got to measure risk in business terms." Chris agrees with Mike on this point in that there are many challenges that we are currently faced with, particularly with cyber-physical systems. "The first challenge is how to translate between cyber threat and physical harm of that sort. The second is about translating cyber threat into business risk. The third challenge is about building interventions which could be made to make the systems better," says Chris.

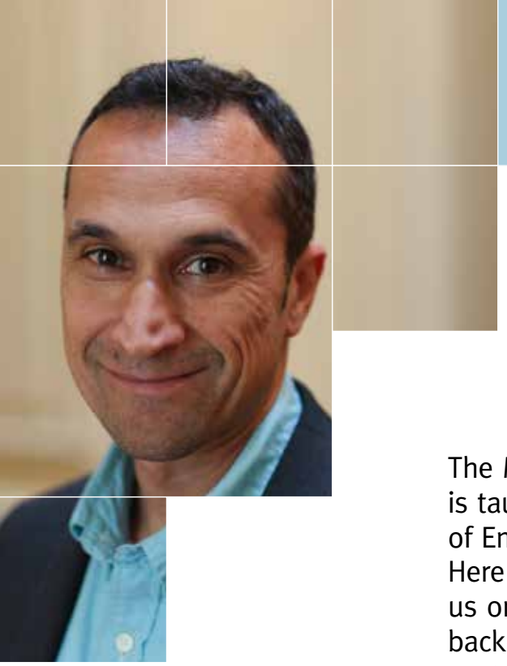
Safety without security?

Mike goes on to add that, "our expectation should not be that we must forever defend poorly constructed and operated systems: we should build systems that are more intrinsically resilient, safe and secure. I don't mean we should stop defending our existing systems; I mean to say, 'hey systems engineers, don't design a poor system which you would expect someone else to defend". There is already evidence that this is happening in the high safety cultures such as aerospace and transport, essentially in areas where there are safety concerns and where systems are reliant on a systems network. Nevertheless, my instinct says there are operational systems whose safety cases are invalidated because they are not secure in cyberspace. If the systems are not secure, then how are they safe?" Chris agrees with this point regarding the interplay between safety and security and highlights that the two communities both have more to learn on this.

Research

Yet do we have the necessary tools and techniques for the complex systems of systems in the Built Environment? "No, I don't think we have got there yet. We need different tools and techniques to deal with cyberspace systems that are unbounded in traditional physical terms. We need a different perspective, to flip the problem around to find a way to contain and measure the system. If this isn't achievable then we might think twice before building these very complex systems," concludes Mike.

Alexandra Williams
Centre Administrator



Professor Nilay Shah

Professor of Process Systems Engineering

Outreach 5.2 Research highlight

Urban Energy Systems – a systems engineering perspective

Dr James Keirstead and Professor Nilay Shah

The Master's in Systems Engineering and Innovation is taught by academics from across the Faculty of Engineering who are leaders in their field. Here Dr Keirstead and Professor Shah update us on their research, which also provides a background into their module *Optimising systems and networks: urban energy systems*.

"A systems engineering perspective provides valuable insight into the study of urban energy systems. In our recent book, *Urban Energy Systems: An Integrated Approach*, we use three systems concepts to help readers understand the potential for more efficient delivery of energy services in urban areas.

Cities are open systems, meaning that energy and materials can flow across their borders. For example, when trying to determine the carbon emissions arising from urban energy use, one must consider both the fuels directly combusted within the city boundaries, but also the indirect emissions associated with upstream processes, such as electricity generation and fuel refining. Electricity from a national grid is typically considered to have an average emissions factor representing a country's mix of fossil fuel and low carbon generating sources. However urban-specific solutions may include the generation of electricity from renewable energy or combined generation technologies, which could substantially reduce the emissions associated with electricity consumption. The analyst must therefore be clear about where the system boundary is drawn and appropriately account for flows in and out of the system.

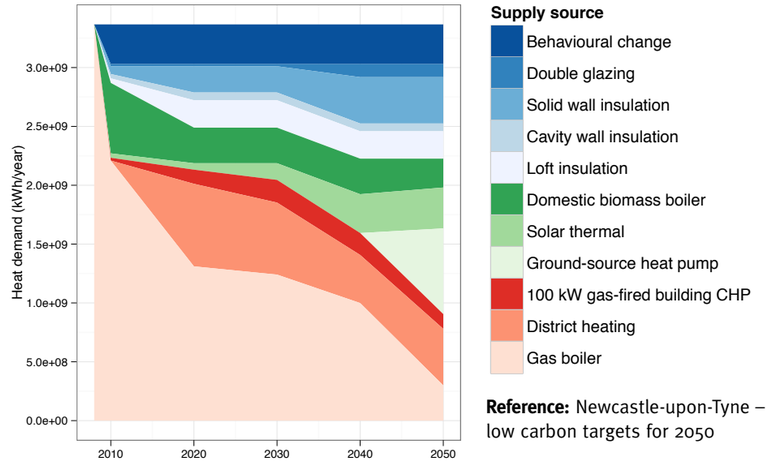
Urban energy infrastructures are also extremely long-lasting. Copenhagen, one of the world's most energy efficient cities, has an extensive district heating system that provides excellent emissions performance and energy efficiency. However, this infrastructure accumulated gradually over a 30-year period; it can't simply be installed overnight. Similarly, we have conducted an analysis of how Newcastle-upon-Tyne might meet its low carbon targets for 2050, using an optimisation model that accounts for the sequencing of investments over a long horizon. The results suggest that efficiency measures should be taken now, followed by a transition to low carbon energy systems in the medium-term, before transitioning to a long-term system powered by low carbon grid electricity.

Finally, the classic definition of a system as an assembly of components clearly applies to the case of urban energy systems, and studying these connections and system integration opportunities offers some of the greatest efficiency gains. From a technical perspective, our research has highlighted how multi-generation technologies, like combined heat and power, offer more efficient use of primary fuels. It also shows how the efficient design of urban bioenergy solutions requires an understanding of the myriad transportation, storage, and conversion processes that link raw fuel to final energy demand. But one can also take a wider view of systems integration and consider the social dimensions of urban energy systems: how do households use energy technologies? What is the role of policy makers, firms, and energy suppliers in delivering the low carbon cities of the future?

Technologies on their own will be insufficient, unless they are adopted within supportive social and economic systems.

These three systems engineering concepts: open system boundaries, long-term thinking, and systems integration, are therefore central to the study of urban energy systems."

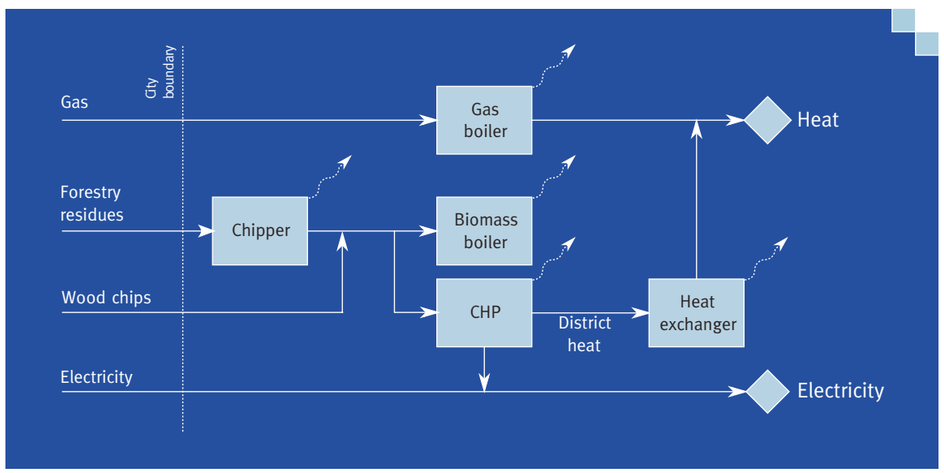
Dr James Keirstead
Lecturer



Reference: Newcastle-upon-Tyne – low carbon targets for 2050

Dr James Keirstead

Lecturer



Schematic showing how a combination of heat and power can offer more efficient use of primary fuels.

Irek Starzyk
Master's in Systems Engineering
and Innovation Alumnus

Outreach 5.3 Working Paper Series
Improving delivery of building services systems by implementing augmented and virtual reality technologies

The *Working Paper Series* provides a platform to debate current issues in systems engineering. The papers can be contributed by academics, PhD or MSc students associated with the Centre.

> "I have just learnt my paper has been accepted and I am looking forward to discussing its ideas with US and British experts at the meeting."
>
> **Irek Starzyk**

Irek Starzyk is a Chartered Engineer and a Design Manager at Crown House Technologies (part of the Laing O'Rourke group) with broad experience across disciplines in data centres, critical infrastructure industries, airports and more recently, renewables. Irek's research explored ways to use important innovative technologies, like virtual and augmented reality to improve design and collaboration within the construction industry. These technologies are already used in the manufacturing, aerospace and healthcare industries, and potentially could be very useful in the construction sector. Here Irek outlines his argument in a paper developing these ideas, which was accepted for presentation at the CIBSE/ASHRAE Technical Symposium to be held in Dublin in April 2014.

Visualisation of plantroom assembly processes by Irek Starzyk – Courtesy of the AMRC Virtual Reality Facility, Sheffield

"My Dissertation reviewed the existing scientific literature, reported my exploration of the technology in the context of installing mechanical and electrical engineering services and then drew conclusions. But if my ideas were to have a wider audience, a 20,000 word Dissertation is not ideal, which is why the Centre's *Working Paper Series* was.

"The point I wanted to get across was that some common problems associated with building services assembly and maintenance and the tight spaces in which engineers and technicians had to work had analogues in other industries. The computing power now available made it possible to use augmented reality and virtual reality software to reproduce full scale models that the engineering team could 'walk into' and work out the realisability of design before beginning construction.

Writing a Working Paper was great practice in condensing my argument into a short readable form. Working Papers are available on the Centre's webpage and provide an easy way to invite my peers to comment and make suggestions. Writing the paper was particularly useful to me in preparing to submit a paper to the 2014 ASHRAE/CIBSE Technical Symposium in Dublin. I have just learnt my paper has been accepted and I am looking forward to discussing its ideas with US and British experts at the meeting," says Irek.

Irek is now cooperating with leading world providers of *Augmented Reality Applications* such as *EON Reality* in order to implement this technology into the whole construction life cycle especially to improve *Facility Management* of buildings. "We need to be open for innovation, especially in the construction sector, because those who innovate own the future," concludes Irek.

Irek Starzyk
Alumnus

Outreach 5.4
From research to translation

Translation of research findings to business opportunities is central to engineering research. Fundamental to the Centre's role is facilitating an open dialogue between Imperial researchers and Laing O'Rourke colleagues. This year the Centre extended its outreach activities by inviting colleagues from Laing O'Rourke to review the potential for future collaboration during a research day held during early December 2013.

The day was attended by members of the Laing O'Rourke Engineering Excellence Group, key engineers from the Business' sections and academics from across the Faculty of Engineering, whose fields of expertise aligned with Laing O'Rourke's strategic interests. The event was chaired by **Professor John Polak**, Director of Research, Department of the Civil and Environmental Engineering.

With a focus on future translation, themes covered on the day included energy performance modelling, new materials and long-term asset investment and management. The event featured thirteen short presentations from Imperial on work at the cutting edge of world research, followed by an open discussion. Drs Angeloudis and Keirstead, associates of the Centre, explained their work on the optimisation of construction logistics and urban energy systems. Other topics included geothermal energy, nuclear power and research into steel and concrete structures. The key synergies that emerged suggesting areas of collaboration are to be reviewed quarterly.

Plans are underway to explore some of the outputs from the research day using various approaches. As a start, the Centre will set about running various workshops which will be attended by key individuals from both parties, and targeting the specific research and development themes from the Laing O'Rourke's R&D Strategy.

This year the College has been successfully awarded twelve of the one hundred and fifteen Engineering and Physical Sciences Research Council (EPSRC) Centres for Doctoral Training (CDT), eight of which are linked to the Faculty of Engineering. Of these, it is anticipated that the CDT in Sustainable Civil Engineering and the CDT in Nuclear Energy will provide a platform for future translation opportunities between Laing O'Rourke and the College.

The Centre looks forward to building this relationship further for the coming year.

Alexandra Williams
Centre Administrator

Professor John Polak
Director of Research,
Department of the Civil and Environmental Engineering

5

Outreach 5.5 Undergraduate recruitment

In conversation with Rachel Tonks, Education Network Manager, Laing O'Rourke

> "Given the improvement of the economy, the company is currently investing heavily into graduate recruitment. Current challenges include increasing competition who, like us, are looking to recruit the most able and driven engineering students."
>
> **Rachel Tonks**

Recruiter in Residence – 2013

The Centre works closely with Rachel Tonks, whose role involves recruiting graduate and sponsored students with an engineering background. From a company perspective, Rachel's role is very challenging.

By forming relationships with institutions such as Imperial, Laing O'Rourke is able to provide additional support, ensuring that all engineering students at Imperial are open to the best opportunities through Laing O'Rourke's Graduate and Sponsorship activities. These two programmes initiated by the company are advertised by the Centre in a series of recruitment roadshows such as the Recruiter in Residence and CV Drop in Clinics. Here, current students have the chance to meet Rachel, engineering leaders and Imperial alumni and to hear about the opportunities and experiences of working within the company. Along with other key benefits outlined below, those applicants who are successful on the sponsored programme may receive a bursary for the remaining years whilst they are a student at Imperial.

"To find a successful applicant, we are looking for students with a passion for engineering, a passion for construction and a passion to be part of the process. Furthermore, we are looking for someone with an energised outlook who wishes to be part of the building going up and leading to be being part of the end product," says Rachel. "We look to employ those individuals who wish to be a part of the legacy that the company is currently investing in. Successful applicants may work on iconic projects, such as the Crossrail project or may be involved with providing future solutions in energy, for example by working at the multi-billion Hinkley Point Nuclear Project."

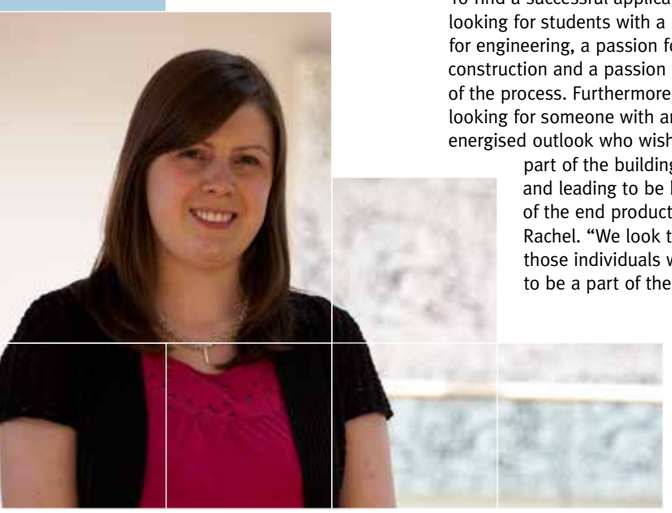
Successful applicants to the graduate programme will be able to work in a company whose real focus is on development and support. Throughout their careers they will also be encouraged to gain Chartered status.

The ethos of the company as promoted by Ray O'Rourke KBE, Chairman of Laing O'Rourke, is about investment. By investing in the right people and in innovation, the company leads the way in the future of research and development within the construction industry.

"Working at Laing O'Rourke, individuals are reminded of why they chose a degree in engineering," says Rachel. "As the economy grows we are continuing to work on major infrastructure projects in which we are constantly looking for ways to carry out construction differently. We are looking to build quicker, safer and better projects which show value to the client," concludes Rachel.

Alexandra Williams
Centre Administrator

Would you like to be a part of the future generation of engineers?
Look out for events advertised by the Centre.



Rachel Tonks
Education Network Manager, Laing O'Rourke

From left: Ed Labinski, Matt Fitch and Orestes Adamou at London Gateway Port – all Imperial Alumni and Laing O'Rourke Engineers

Outreach 5.6 Undergraduate outreach

The experience of a Graduate Engineer – **Matthew Fitch**

Department of Civil and Environmental Engineering Alumnus

Matthew Fitch, an Alumnus of Imperial with a degree in Civil Engineering, reports back on his experience to date since working for the company. He is currently working as a Section Engineer on 190 The Strand, in Central London.

"I started working for Laing O'Rourke after graduating from the College in 2011. I was a sponsored student whilst at Imperial, which gave me the opportunity to work on placements for eight weeks in the company each summer. During these placements I worked on some small scale sites (<£5m total value) to some of the largest in Europe (Heathrow Terminal 5 was approximately £5.6bn). This gave me a flavour of both infrastructure and traditional construction sites. Laing O'Rourke is a construction business that has very unique opportunities and diverse offerings.

Following graduation, I worked on London Gateway Port as part of a team that planned and delivered all of the under-services (over 16km of drainage systems and 300km of electric & communication cables). This project was delivered with the strictest environmental management policy in Europe.

I began my next role sixteen months later on secondment as the Performance and Partnerships Manager in the Engineering Excellence Group (EnExG), the Research and Development (R&D) team based at Head Office. Here I was able to make a real impact, from developing our internal R&D process to project managing collaborative projects with external partners, such as Arup, Atkins, BRE and Imperial.

Finishing my secondment, I quickly found myself back on site at the new Scottish Power HQ in Glasgow as a Section Engineer, where I trialled some of the newest innovations from the Engineering Excellence Group (EnEx.G), Laing O'Rourke's internal engineering specialist group, such as the installation of columns with the piles to eliminate the risks of working at height, and the erection of a section of the building that required no propping. In the industry, Laing O'Rourke leads the way in constantly changing how we work by challenging current operations to ensure that we are efficient, whilst adhering to a very high standard of health and safety."

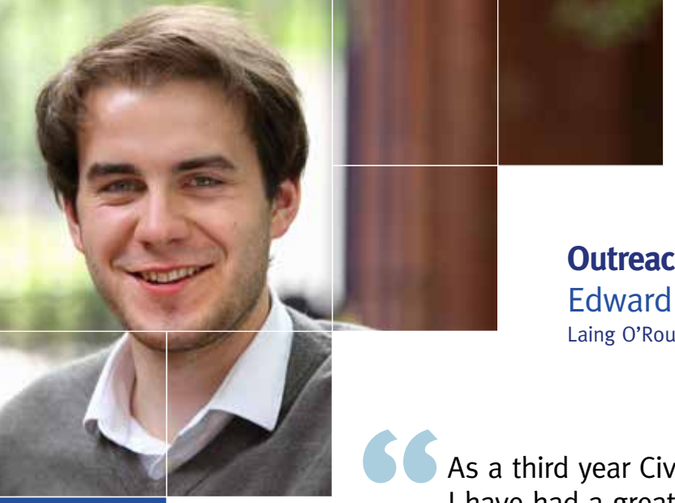
Laing O'Rourke's Graduate Development Programme is one of the best in the industry and is continuously improving, thanks to its team. There is a focus not only on one's personal development, but on building a team of graduates that know each other well and who have the ability to manage a company.

Matthew Fitch – Graduate Engineer

Overview of the current recruitment schemes advertised by Laing O'Rourke

Laing O'Rourke Recruitment Programmes	Deadline for applications	Stage 1	Stage 2	Stage 3
Sponsored students	*31 Dec 2014	Interview on Campus during spring term	Successful applicants are provided with a series of summer internships for a minimum of eight weeks each summer	Sponsored students are invited to apply to the Graduate Programme
Graduate recruitment	*Oct 2014 – Jan 2015	Interview on Campus early spring term	Successful applicants are invited to an Assessment Centre	Successful applicants join the company at the end of their studies

*Early application advisable for each of these programmes

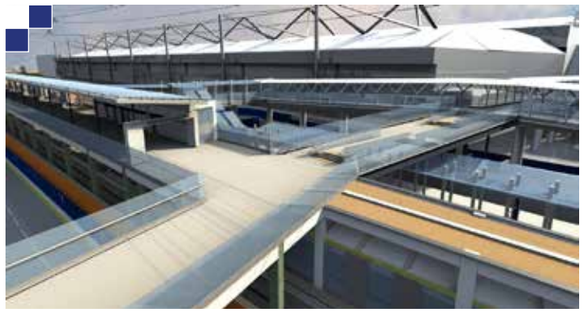


Outreach 5.7 Undergraduate outreach

Edward Courtnell

Laing O'Rourke Scholar

"As a third year Civil Engineering student at Imperial, I have had a great deal of exposure to the theoretical side of civil engineering. However, previous to my involvement with Laing O'Rourke, I had limited experience at putting this into practice and seeing designs come to fruition.



During my second year, I applied early in the winter term to Laing O'Rourke for a place on their scholarship programme. They were a company which stood out to me due to the innovative approach to engineering and construction they adopt on their projects.

After having my place on the scholarship programme confirmed during the spring term, I was given a summer placement on the Custom House Crossrail Project for a period of nine weeks. This project was particularly exciting since 80% of the components were to be pre-cast as part of a Design for Manufacture and Assembly agenda (DfMA). Despite not being there for the arrival and fitting of the pre-cast elements, I was able to get quite involved with the planning of construction activities and the engineering of temporary works. Due to the pre-cast nature of the station, the construction process for the station was significantly different to that which would be expected on other 'traditional' infrastructure projects, allowing me to experience the cutting edge in construction.

Above: BIM model of gantry crane used to lift pre-cast components

Top right: Finished Bridge 2 – rendered model of new crossing

At Custom House, I was given real responsibility and, towards the end of the placement, free rein over certain aspects of the project such as the design of a temporary bridge landing. This allowed me to stretch myself and further develop my management experience.
For example, alterations to the temporary bridge required effective communication with the different stakeholders and design consultants to reach a safe and efficient solution. Another challenging aspect of being a Scholar on the project included being responsible for a wide range of site activities and engineering tasks, while remaining safe on site and producing work to a high quality on a tight turnaround.

Being with Laing O'Rourke as a Scholar has given me an insight into what the industry of the future has to offer and has given me the opportunity to be part of a high profile project, confirming to me my ambition to join Laing O'Rourke and in particular, their Engineering Excellence group (EnEx.G)."

Edward Courtnell
Laing O'Rourke Scholar

Outreach 5.8 Undergraduate outreach

Jineesha Mehta

Laing O'Rourke Scholar

"I have just completed my third year of studying Civil Engineering at Imperial, and have been on the Laing O'Rourke scholarship scheme for a year. The scholarship scheme comes with opportunities such as a summer internship on exciting projects.

Above: William St Quarter

Above: On site at William St Quarter

During summer 2013, I spent eight weeks working on the William St Quarter project in Barking, Essex. William St Quarter is an affordable housing development for the Borough of Barking and Dagenham, with a value of £33m.

Working with Expanded, part of the Laing O'Rourke Group, I had the task of surveying works so that they were undertaken in the correct position and to a precise level. I gained further experience when writing up as-built surveys, maintaining concrete records and overall ensuring the continuation of the project. I was challenged by the sheer volume of checks behind every process, and at each stage of construction. Immediately I was given responsibility for duties, and worked directly with the site operatives to reach our goal.

Surveying allowed me to experience different on site activities, work with a wide range of people, and put our year one surveying module into context. The site fully encompassed the Laing O'Rourke Design for Manufacture and Assembly (DfMA) ethos and was a great site to learn on. I have thoroughly enjoyed my placement for this year and I am grateful for all the support I have been given by the Laing O'Rourke team."

Jineesha Mehta
Laing O'Rourke Scholar

Above: CGI showing what the William St Quarter development will look like when complete

Jineesha Mehta
Laing O'Rourke Scholar

6

Summary and overview

6.1 Key highlights April 2013 – March 2014

Professor David Fisk
Centre Director

The Centre's mission is to bring systems engineering to the built environment. We have continued the progress in the last report in engaging undergraduates in the work of Laing O'Rourke. Having proved our basic pedalogical model for the Master's Course and attained CEng accreditation, we have extended it to suitably qualified candidates to take on a one year full-time basis. We have also continued our popular *Laing O'Rourke Lecture Series* as part of our outreach engagement.

World class research remains at the heart of our mission at Imperial College London, and our two existing PhD students continue to shine with conference papers and awards. A third student has been added to the team this year. The virtue of thinking ahead is the driving force behind systems engineering techniques and we have aimed to make that a feature of both our emerging research portfolio and the issues we raise in our Working Papers and Master's Dissertations. Last year we hinted at the issue of cyber security, and by the time of this year's masterly lecture on cyber security and the modern city by Mike StJohn-Green, there was a howl of on-going media stories of hacking and espionage in industrial systems.

6.2 Looking ahead

Next year we will be celebrating the formal Graduation of our first cohort of Master's Graduates whose careers already seem to be going from strength to strength. It will also be the year in which our first cohort of full-time one year students will complete their course. We aim to support these ambassadors of systems engineering as much as we can as they spread the word.

Amongst our PhD students, Sarah Noyé will be presenting a paper at the prestigious ICEBO Conference, held this time in China. Our Laing O'Rourke Lecture series will include a discussion of the systems aspects of the smart grid by Gareth Evans, Head of the Engineering Profession at Ofgem, and one of the key participants in IET's exploration of the architecture of the grid of the future.

I would also like to welcome Laura Mckay who will take on the role of Centre Administrator from September until June 2015, covering for Alexandra Williams while she is on maternity leave.

Professor David Fisk
Centre Director

Alexandra Williams
Centre Administrator

Summary and overview
6.3 Master's in Systems Engineering and Innovation

The Master's programme is delivered part-time over two years or full-time over one year of which the academic year is split into three terms: autumn, spring and summer. Part-time students spend two weeks each term whilst full-time students spend four weeks each term at Imperial for intensive teaching. For part-time students, inter-sessional progress assignments are usually undertaken via distance learning. During the progression of the MSc, students will also complete a dissertation on a new innovative technology, and in conjunction with the Business School, devise a strategy to manage the successful application of the innovation.

2014-2016	**Programme dates for two year delivery** (Two weeks, usually* in the following months)			**Exam** (1 Day)
2014/15	October	January/February	May	June
2015/16	October	January/February	May	June
2014-2015	**Programme dates for one year delivery** (Four weeks, usually* in the following months)			**Exam** (2 Days)
2014/15	October	January/February	May	June

*Once enrolled, students are notified of actual term dates in advance

Each week will typically include in its programme:

- Lectures and seminars
- Workshops
- Presentations
- Group projects
- Individual meetings with supervisors

Entry requirements

- A minimum of an Upper Second Class Honours degree (or overseas equivalent) in an engineering or scientific subject would normally be required for entry to the programme.
- Industrial experience demonstrating outstanding leadership and innovation potential in their field. In addition to industrial experience and/ usually working towards Chartered Engineering status.

Learning outcomes

- 'Systems' as a much bigger idea than screwing parts together that fit. The student should now see systems thinking as something that pervades the understanding of everything that can be done in a complex world.
- The ability to recognise that global energy systems while changing rapidly have an underlying rationale that has deep implications for the selection of long life M&E building services.
- Confidence in the ability to demonstrate self-direction, originality and lack of risk aversion in tackling radically new engineering systems and concepts in M&E building services.
- Ability to evaluate critically the implications of new services application in areas such as networks, fuel cell and nuclear technology.
- Distinguishing between novelty and innovation and with that understanding able to lead an organisation to the forefront in systems innovation.
- The independent learning ability required for continuing professional development in systems and networks.

Programme themes

- Systems approaches in engineering: introduction and foundations
- Using a systems approach to analyse technologies and innovation
- Applying systems analysis to energy supply policy
- Data network systems models
- Process engineering design optimisation of large systems
- Systems approaches to safety reliability and resilience
- Whole systems design to decarbonise energy systems
- Power transmission and storage: integrating systems into energy supply
- Innovation and entrepreneurship

Assessment

Assessment of the Master's comprises two elements. The Master's is awarded to any student who achieves **both** of the following elements.

- 1 – Examination and Coursework, and
- 2 – Dissertation

To meet the requirements for the award of the degree, a candidate must achieve a minimum in each of the two elements of 50% overall. Furthermore, the Examination, Coursework and Dissertation assessment element are broken down into the following components:

1. Coursework – Two 2,000 word essays (full and part-time delivery)
2. Coursework – Two 1,000 word reports (full and part-time delivery)
3. One 3-hour examination at the end of June in Year 1 (part-time delivery)
4. One 3-hour examination at the end of June in Year 2 (part-time delivery)
5. Two 3-hour examinations during June in Year 1 (full-time delivery)
6. A 20,000 word dissertation

Students also undertake progress reports in the form of assignments or group work during the course of the programme. For part-time students, assignments and coursework assessments one and two listed above are taken via distance learning mode under the guidance of the programme lecturers.

Fees

Full details of programme fees can be found at **www.imperial.ac.uk/lorsystemscentre/msc/fees**

Applications

Applications for the 2014–16 part-time programme, reference **H26524** and full-time programme, reference **H265** should be made online **www.imperial.ac.uk/registry/admissions/howtoapplypg**

Please contact the Centre Administrator for advice on your eligibility and for any other enquiries. Early applications are encouraged.