

**Imperial College London**  
**Department of Civil and Environmental Engineering**  
**EPSRC CDT in Sustainable Civil Engineering**

**PhD Studentship:**

**A systems engineering approach to off-site production: from requirements to customer solution**

**Supervisor:** [Professor Jennifer Whyte](#)

**Industry Partner:** [Laing O'Rourke](#)

This project considers construction as a manufacturing process. It takes systems engineering templates and processes and uses these to trace and inform the logic of decisions in integrated Design for Manufacture and Assembly (DfMA) processes from a systems perspective. The work will be conducted in close collaboration with Laing O'Rourke. It aims to improve the traceability of requirements through the development process into a customer solution in order to facilitate the development of new template design processes; to establish the information needed for verification; to reduce variability, and to understand the resilience/flexibility of the production process. It will map the whole process from the stakeholder identification and need elicitation process through the partitioning of designs, design processes using a product configurator; to the customer solution and aftercare. To facilitate the move to low-carbon civil engineering, each step of this process will also be evaluated in terms of carbon as well as costs and process efficiency. Different systems engineering templates will be compared, contrasted and evaluated in terms of the information required in construction as a manufacturing process and the adoption and barriers to adoption of systems approaches.

**Theoretical background**

Research on manufacturing, from a range of lean production and systems engineering perspectives, argues that understanding requirements and reducing variability are important precursors to optimising processes. This project draws on the significant traditions of research on production systems, systems engineering and innovation within Imperial College London, which include work on modular and off-site house-building, as well as aerospace and automotive industries. This project will develop new knowledge by using systems engineering templates and processes to map the DfMA production process. It starts from the classic systems engineering 'V' diagram, which articulates how planning for systems integration should inform and be informed by the system architecture. It will start out by evaluating a range of different approaches to practically understanding the logic of decisions and interdependencies within the processes, drawing on and if need be extending a recent review of modelling and simulation approaches (Agent-based; systems dynamics; economic (input-output based and computable general equilibrium); Network (topology or flow based) or computational (e.g. Petri-net and Bayesian) and situating a review of these

approaches in relation to prior methods used to evaluate processes associated with complex systems.

### **Aims and objectives**

The aim is to improve Design for Manufacture and Assembly (DfMA) processes through a systems engineering approach from requirements to customer solution.

The objectives are to:

1. Identify the stakeholders to the DfMA production process and practices for needs elicitation and requirements capture;
2. Develop a process map to trace the requirements through the DfMA production process;
3. Evaluate methods and theories for implementing a systems engineering approach to map the flows of information, resources and costs through DfMA production process;
4. Implement a prototype new approach to mapping these flows and the interconnections and resilience/flexibility of processes and activities; and
5. Impact practice by using the research to improve DfMA processes through research on the 'adoptability' of different systems engineering templates and processes.

### **Research methods**

1. *Refining research protocols:* The work will build on the classic systems engineering V diagram and recent reviews of modelling and simulation to develop protocols that focus empirical research that will start by evaluating the utility of different tools in improving DfMA practices. As background the researcher will conduct preliminary review of a) systems engineering and production templates and processes; and b) literature on decision-making in DfMA and logistics; and c) systems engineering approaches to requirements. Protocols will be agreed through preliminary discussions with Laing O'Rourke.
2. *Systems engineering approach to mapping key decisions:* The process map of decisions will be developed, collecting data to build and validate the map through interviews with Laing O'Rourke. It is expected that 3-5 construction projects that use DfMA will be chosen. It will map the process from requirements capture, partitioning of design, use of the product configurator, production, logistics and implications for systems integration, evaluating each step of this process in terms of carbon as well as costs and process efficiency;
3. *Using the process map to trace requirements:* The research will pay particular attention to stakeholder identification and needs elicitation approaches to capture implicit as well as explicit requirements; and using the process map developed in step 2 trace the requirement through the design process in a product configurator to the solution; establishing the information needed for verification.
4. *Understanding the resilience/flexibility of the process:* In relation to the requirements, the research will consider the impact of different perturbations to the production process on systems integration. This work will evaluate different options in relation to the availability and reliability of process information and the decisions that need to be made.
5. *Impact practice by using the research to improve DfMA processes:* work with industry partners to facilitate the development of new (or refined) template design processes. This

work will consider the 'adoptability' and compliance of processes and how information is formatted, stored and retrieved to support those processes.

### **Expected outcomes**

The intended outcome of this research are to improve DfMA processes through a systems engineering approach. By better understanding requirements and reducing variability it is anticipated that processes can be improved. The research is also intended to contribute to academic debates, with the research protocols developed to enable the outputs to be published in journals such as Transactions in Engineering Management; Automation in Construction; International Journal of Product Innovation; or ASCE Construction Engineering and Management. The research will also draw on and contribute to the work of International Council on Systems Engineering (INCOSE) and the Project Production Institute (PPI).

### **Eligibility and Funding**

Funding is available for applicants with settled UK status (see <https://www.epsrc.ac.uk/skills/students/help/eligibility/> for eligibility). The studentship offers a stipend of approximately £16,000 per annum (tax free) and covers fees at the UK/EU student rate for a period of four years.

The PhD candidate for this role should have a background in systems engineering, design engineering or civil engineering or and a knowledge or willingness to learn associated research methodologies. They will take the 'introduction to systems' class as part of the CDT first year. Imperial College London has a critical mass of research on production, systems engineering and innovation and this research project will benefit from and seek to make a contribution in this context. In particular, this project builds on the related ongoing empirical work by Marco Aurisicchio and Panagiotis Angeloudis and is associated with Theme 1 of the Centre for Systems Engineering and Innovation which is held in the Department.

### **Contact**

For informal enquires and to request more information, contact Professor Jennifer Whyte (<http://www3.imperial.ac.uk/people/j.whyte>)

This PhD studentship is co-funded by the EPSRC CDT in Sustainable Civil Engineering at Imperial College London:

(<http://www3.imperial.ac.uk/sustainablecivilengineering>)

### **Deadline**

Review of application is now in progress and will continue until suitable candidate is identified. The starting date for this PhD Studentship is 1<sup>st</sup> of October, 2018.