The design of a framework for managing resilient manufacturing systems

Supervisors:

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Project Description:

The design and management of a manufacturing system such as for automotive manufacturing can be highly complex, especially when such systems produce sets of products or a product with many components and subsystems. Also, the supply network and production/operation processes of these products can be interconnected in highly complex ways. Resilience is an essential dimension of a manufacturing system's capability, but its inclusion increases the resultant complexity of the system and the effort of that need to manage the system. Therefore, improving the resilience of a manufacturing system while maintaining productivity, quality and, profitability is challenging.

The concept of resilience is a relatively new concept in manufacturing systems, and the work on the design and implementation of resilient manufacturing systems is limited (Madni and Jackson 2009, Jin and Gu 2016). Resilience can refer to adaptability, reconfigurability and flexibility (Bhamra, Dani et al. 2011, Ivanov 2020, Bag, Gupta et al. 2021) along with many other terms. Still, it is not clear how these terms are defined, implemented and quantified, and their impact measured when applied to manufacturing systems.

In general, the concept of resilience is closely related to a system's capability to return to a stable state after a disruption (Madni and Jackson 2009, Bhamra, Dani et al. 2011). However, the design of a resilient system is much broader than just recovering and returning to the previous state. According to (Madni and Jackson 2009), "resilience is a multi-faceted capability of a complex system that encompasses avoiding, absorbing, adapting to, and recovering from disruptions". Resilience system design is a proactive approach that enables the system to avoid disruption through anticipation, survive through withstanding and recovery, and grow through adaptation (Madni and Jackson 2009). The adaptability of a

system can be a mechanism for achieving resilience (Fiksel 2003, Bhamra, Dani et al. 2011). To achieve adaptability to unexpected changes, a system needs to be reconfigurable in form (i.e., structure) or available capacity (Madni and Jackson 2009). Therefore, reconfigurability becomes important in designing a resilient system.

The reconfigurable manufacturing system (RMS) concept was introduced by Dr Koren in the mid-1990s to meet the challenges of unpredictable market changes due to globalisation, including rapidly varying product demand and frequent introduction of new products (Koren, Heisel et al. 1999, Koren, Gu et al. 2018). This concept is relatively new and mainly focuses on the production capacity, e.g. machines, layouts and production process planning, limiting the opportunities to improve resilience by making appropriate design decisions (Kusiak 2020).

Resilience needs to be managed in both product design and operation phases. Three areas, product design, supply chain, and production, would need to be considered in harmony to make the system efficient. A synergistic approach will be needed to combine resilience with conventional attributes such as productivity, reliability, and quality. To note a system can be regarded as with three key interlinked elements: product (what is designed and manufactured), process (how the design and manufacturing activities are organised, for example, workflow, process flow and associated equipment and materials) and people (as a resource that performs the activities).

This project aims to support the management of a resilient manufacturing system by developing a framework that will integrate three areas of product design, supply chain design and production process design. The focus of the research is:

- Identifying the key factors to define matrices for the new resilient manufacturing system
- Developing a new framework for managing resilience for this system
- Virtually modelling and simulating for evaluating alternative solutions and finding optimal or satisfactory solutions.

Proposed methodology

The proposed methodology is based on case studies to explore and identify key factors and associated variables from industrial settings. This will include a mixed-method approach starting with 'experimental' simulation to assess how variables behave and are related. These simulations will help establish the framework, which will be validated using case studies (more about this research methodology can be found in, for example, Yin (2009) and Bell, Bryman et al. (2018))

The student is will be based on the Department of People and Organisations, Business School, but will also be working in an interdisciplinary team with the Design and Technology department.

About the Supervisors:

Dr Khadija Tahera researches product development, manufacturing and operation management, focusing on improving processes in collaboration with industries to establish best practices. Her recent publications and doctoral supervision concentrate on new product development and production process improvement through case studies, modelling and simulation.

Dr Björn Claes is Senior Lecturer in Operations Management. His research interests are related to the behavioural aspects in operations and supply chain management and in business processes in general. His work has been published in journals such as Human Resource Management, Journal of Enterprise Information Management, Prometheus, Supply Chain Forum, International Journal of Physical Distribution & Logistics Management, among others.

Dr Christopher Earl, Emeritus Professor, School of Engineering and Innovation, has researched Design and Manufacturing Processes in several projects, currently co-investigating on EPSRC' Design Configuration Spaces' (2018-2022) at Leeds University (Schools of Engineering, Business and Computing).

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