Combining Design Thinking and Systems Engineering to Improve Customer Outcomes

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Biography

Brandon is a PhD student at the University of the West of England studying the implementation of user centred design methods in large engineering organisations; in particular with design thinking and systems engineering methods. Previous to this he completed his MEng in Aerospace Engineering at UWE, Bristol.

Overview

The field of engineering is a major contributor to the economic stability and growth of the UK and other economies. Therefore, the efficient operation of engineering companies and firms is vital. However, design projects undertaken by large engineering organisations are often beset with a number of problems and constraints that stem from the decision-making process and design process that have been selected. This PhD aims to investigate whether the design processes of design thinking and systems engineering can be combined. This would lead to better customer outcomes and reduced time to market, and thus remove the problems often found in large engineering organisations to improve the overall operational efficiency. The overarching research methodology used in this investigation will be action research and is likely to be predominantly qualitative in nature as it has been found that it is very difficult to establish quantitative metrics for design.

Keywords

Design Thinking; Systems Engineering; User Centred Design; Large Engineering Organisation; Qualitative Research; Design Process

Background

In 2022, the engineering sector is predicted to contribute £608.1 billion GDP to the UK economy and is expected to employ around 5.8 million people. Contributions from the engineering sector in 2014 equated to 27.1% of the total UK GDP (Centre for Economics and Business Research, 2015). Therefore, the efficient operation of engineering companies and firms is vital to sustain the economy. However, design projects undertaken by large engineering organisations (LEOs) are beset with a number of problems and constraints that include technological, economic and political factors. The cause of many of these problems is related to the design process undertaken in LEOs and the decision-making process that has resulted from the design process selection; this research investigates alternative design processes as a means through which to improve the delivery of projects in LEOs and the potential for development for inventive solutions to very complex problems.

The Traditional Engineering (TE) design process shows that as a design develops and gets closer to production; the costs incurred for changing any aspect of the design increases dramatically. As a project progresses, the design becomes more fixed and project artefacts such as technical drawings, prototypes and manufacturing techniques are created, meaning that changes to the design of the part itself has implications for other work that has already been conducted thus far. Systems Engineering (SE) is a design process that was developed to reduce the probability of changes occurring later in the design process as SE aims to ensure that the implementation that has been selected is suitable for the stakeholder needs. SE directly contradicts TE techniques as it focusses on the design of an entire system and its subsystems, by considering the wider context, to resolve the stakeholder needs, whereas TE focusses predominantly on individual components and individual component design. In SE, a system is considered in its simplest form to be a set of parts that work together to resolve a design requirement (Cloutier, Baldwin and Alice, 2015:19).

Monat and Gannon (2018) identified case studies for which the systems engineering process was not effective. Analysis identified four rationale; ‘failure’ to identify environmental factors, ‘failure’ to understand that the problem could not be solved simply using technological innovation but requires other considerations (economic, political or sociological as examples), ‘failure’ to address interactions between the systems components that are either planned or unplanned and ‘failure’ to recognise that the product is part of a user experience system so that the product fails to be useable.

This research proposes that principles of Design Thinking (DT) can be utilised to address these 'failures'.

Razzouk and Shute (2012:1) defines Design Thinking (DT) as '*an analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback and redesign*'. Design thinking is seen as an interdisciplinary tool that takes a pragmatic approach to design and considers human needs as the centre of the design process (Brenner, Uebernickel and Abrell, 2016). As such it introduces a design toolbox that focusses on the in-depth investigation of the customers wants and needs prior to the design, development and prototyping stages. One example of this is found in requirements generation; SE processes will base their requirements from the perceived wants of the consumers generated by the key project stakeholders and will deliver a product or service based solely off of these requirements. In contrast DT techniques will actively aim to identify who the consumer is, what the consumer truly needs, and how the end result may be created with an entirely user centred focus in mind. At every stage the identified consumers are consulted about how they believe that the product or service may benefit them and how they perceive it to be flawed.

DT techniques focus on the overall user experience, ensuring that the needs of the end user are identified early. Importantly, DT techniques help shift the design of a product from a marketable item to a resolution for a customer problem. As DT puts more emphasis on considering the potential consumers and the scenarios that the solution may be implemented (Seidel and Fixson, 2013), it generates a holistic understanding of a problem that will include all external factors when creating a solution.

DT has been selected in this context over other design processes as the strengths of design thinking compliment the weaknesses of systems engineering. This is especially true in situations whereby the problem considered is very complex, or wicked, and potentially has a number of different factors causing the issue and thus potentially has a number of complex solutions. However other human centred design approaches were considered for this project; one of which was Agile for its flexibility and the ability to create products rapidly. This was not chosen for this investigation due to the emphasis it places on the frequent development of software which is something that will simply not be possible on the types of projects that are being undertaken with the sponsor.

Therefore this project aims to identify the opportunities and barriers in blending design thinking into a systems engineering design process within an LEO. In particular, this project aims to develop a design process that yields better customer satisfaction and reduced time to market for complex and innovative products without stifling the creativity of a design team. As the success of a project is directly linked to the effectiveness of the design carried out and its suitability for a consumer, this research is incredibly important in the current economic climate to give LEOs the tools required to provide an effective service to their consumers and to aid in the development of novel ideas for very complex problems.

This project will consider the work of Carlgren, Elmquist and Rauth (2016), who conducted a series of interviews with 31 senior members of staff in large organisations that had used design thinking for at least five years to identify what the barriers were to adopting this design process. They found that the challenges of implementing design thinking were actually linked to the characteristics of the theory itself; a misfit with existing processes and structures, the resulting ideas and concepts being difficult to implement, the value of design thinking is difficult to prove, the design thinking principles or mindset clash with the organisational culture, the existing power dynamics are threatened, the skills needed to use design thinking are hard to acquire and the communication style required is

different from the norm. Interestingly this suggests that issues around achieving implementation are not solely with design thinking as a concept but will actually focus more around the cohesion of the company structure and culture.

Several investigations conducted into the applications of design thinking processes (Mabogunje, Sonalkar and Leifer, 2016; Plattner, Meinel and Leifer, 2012; Seidel and Fixson, 2013 and Blizzard et al, 2012) have found that it is very difficult to 'measure' the effects of design as the concept of design has no real measurable variables or KPI's. In this context design refers to the generation of a product or service that fulfils the needs of a given consumer and so this trend suggests that it is difficult to compare one product to another if both were aiming to fulfil the same role.

Research Questions

The research question identified is as follows;

1. What are the opportunities and barriers in integrating design thinking within the systems engineering process of a large, established company?

Research Methodology

This investigation aims to use a single case study methodology to answer its research questions. This is because the resources allocated to the project have clear, distinct boundaries and the sponsorship with an external engineering organisation includes the ability to conduct research within their operations. Therefore, the researcher will be involved directly with the LEO and its current, ongoing projects.

As this is the case there are two prevailing theories that shall be considered as a part of this methodology; action research and theory for change. Action research, when discussed with the aim of generating change, can be referred to in its simplest form as the introduction and manipulation of interventions that can be monitored over a period of time in order to generate a required result (Payne and Payne, 2004:9). Theory of change however will be considered more heavily as the framework for this investigation, as this theory proposes that change can be planned based off of the perceived causality of an issue and tackled by creating implementations that will resolve these root causes. Figure 1 shows the preliminary outcomes framework which considers all of the themes outlined thus far from literature and aims to identify actions that can be chained together to resolve the research question for this investigation.

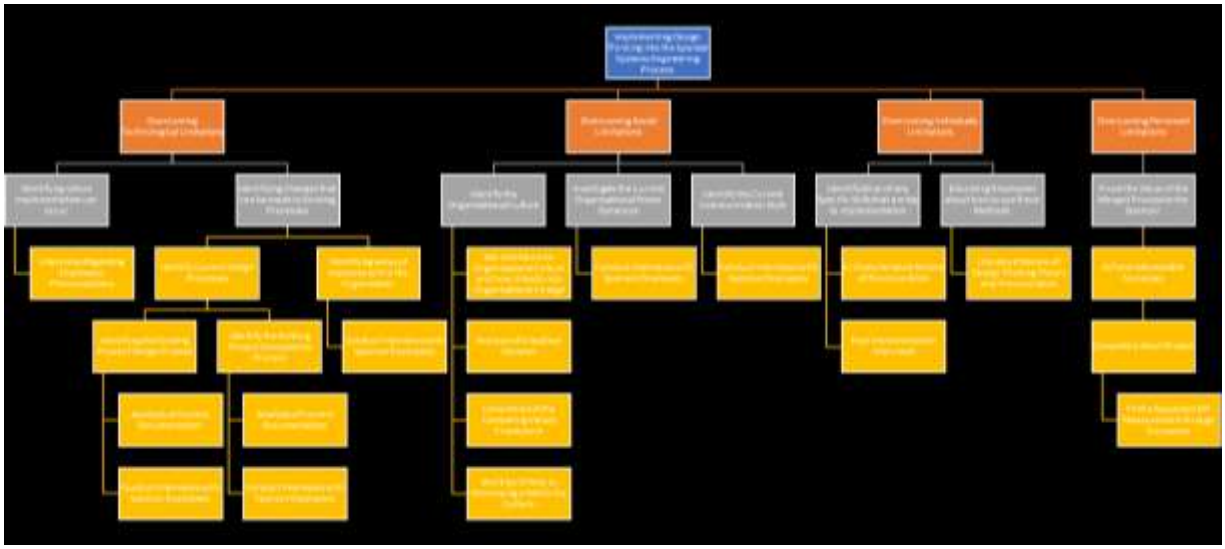

Figure 1 - Preliminary Outcomes Framework

In this investigation participants will be professionals working in the engineering or engineering management profession as they are the users of the teams that will be affected as a part of this implementation and thus they will provide the greatest insight into the opportunities and barriers that may be found. Participants will be selected predominantly from the sponsor company. This is likely to limit the available sample size for interviews due to participant suitability and willingness to take part. However, minimum sample sizes shall be calculated for any interview investigation undertaken and considerations made for the type of sampling and available resources at any given time (Payne and Payne, 2004:205). This is to potentially include participants of differing levels of seniority and shall vary based on the investigative and data analysis methods that have been determined.

This project has been identified to be predominantly qualitative in nature due to the work of Mabogunje, Sonalkar and Leifer, 2016; Plattner, Meinel and Leifer, 2012; Seidel and Fixson, 2013 and Blizzard et al, 2012 as they have found that it is very difficult to establish quantitative metrics for design. Therefore, the research methods used predominantly in this project will be unstructured interviews, semi-structured interviews, post workshop feedback surveys and in-depth reviews of existing literature. These were selected based off of the perceived resources available and the intricacies of the necessary data to answer each section of the main research question at each stage. A simplified research methodology plan has been created below to demonstrate the general direction that the project is expected to take.

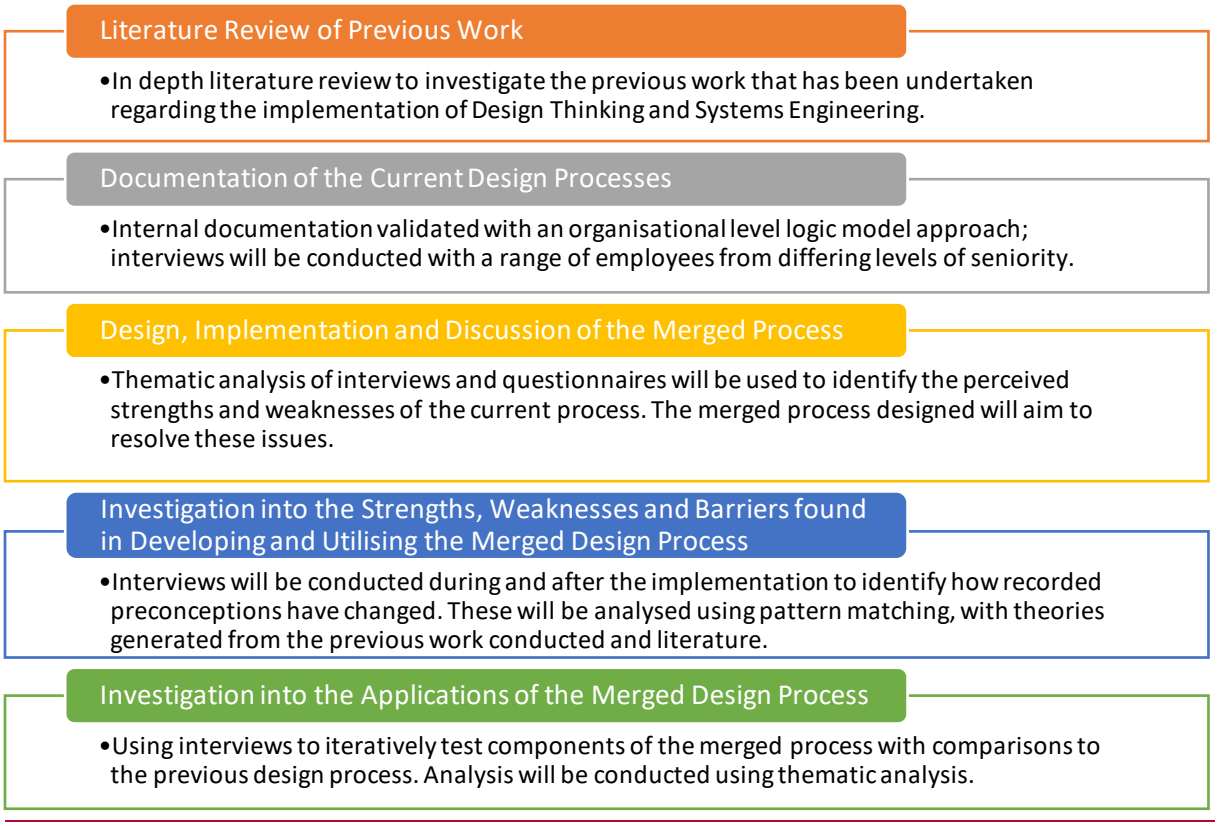

Figure 2 - Research Methodology Plan

Due to the current influences of the COVID-19 pandemic this research will also investigate the aspects of the merged design process that can be completed within a remote working environment. Under normal circumstances this could be shown to represent a globally distributed design team that are all aiming to work together on the same project or alternatively, it could reflect a company culture where remote working is accepted as a part of the organisational structure that a design team might have. Regardless, an emphasis will be placed on investigating how design thinking and systems engineering can operate in these contexts and the kinds of tools and techniques that are required to effectively achieve design outcomes.

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References

Abdussamad, Juwaeriah. 2014. "Applying Systems Thinking to Examine and Reduce Dependency on Food Banks." *Interdisciplinary Description of Complex Systems* 12 (1): 99–107. https://doi.org/10.7906/indecs.12.1.7.

Bahill, Terry, and William Chapman. 1994. "Understanding Systems Engineering Through Case Studies" I (I): 145–54.

Bhooshan, Shajay. 2017. "Parametric Design Thinking: A Case-Study of Practice-Embedded Architectural Research." *Design Studies* 52 (September): 115–43. https://doi.org/10.1016/j.destud.2017.05.003.

Blizzard, Jackie, Leidy Klotz, Alok Pradhan, and Michael Dukes. 2012. "Introducing Whole-Systems Design to First-Year Engineering Students with Case Studies." *International Journal of Sustainability in Higher Education* 13 (2): 177–96. https://doi.org/10.1108/14676371211211854.

Brenner, Walter, Falk Uebernickel, and Thomas Abrell. 2016. *Design Thinking as Mindset, Process, and Toolbox: Experiences from Research and Teaching at the University of St.Gallen*. *Design Thinking for Innovation: Research and Practice*. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-319-26100-3_1.

Buchanan, Richard. 1992. "Wicked Problems in Design Thinking." *Design Issues* 8 (2): 5. https://doi.org/10.2307/1511637.

Carlgren, Lisa, Maria Elmquist, and Ingo Rauth. 2016. "The Challenges of Using Design Thinking in Industry – Experiences from Five Large Firms." *Creativity and Innovation Management* 25 (3): 344–62. https://doi.org/10.1111/caim.12176.

Centre for Economics and Business Research. 2015. "The Contribution of Engineering to the UK Economy - A Report for EngineeringUK." *A Report for EngineeringUK*, no. January.

Clarke, Victoria, and Virginia Braun. 2017. "Thematic Analysis." *Journal of Positive Psychology* 12 (3): 297–98. https://doi.org/10.1080/17439760.2016.1262613.

Cloutier, Robert, Clifton Baldwin, and Mary Bone Alice. 2015. *Systems Engineering Simplified*. *Systems Engineering Simplified*. London: CRC Press. https://doi.org/10.1201/b18018.

Dorst, Kees. 2011. "The Core of 'design Thinking' and Its Application." *Design Studies* 32 (6): 521–32. https://doi.org/10.1016/j.destud.2011.07.006.

Douglass, Bruce Powel. 2015. *Agile Systems Engineering*. *Agile Systems Engineering*. Oxford: Elsevier Inc. https://doi.org/10.1016/C2014-0-02102-8.

Du, Junpeng, Shikai Jing, and Jihong Liu. 2012. "Creating Shared Design Thinking Process for Collaborative Design." *Journal of Network and Computer Applications* 35 (1): 111–20. https://doi.org/10.1016/j.jnca.2011.02.014.

Dym, Clive, Alice Agogino, Ozgur Eris, Daniel Frey, and Larry Leifer. 2005. "Engineering Design Thinking, Teaching, and Learning." Journal of Engineering Education. 2005.

Kossiakoff, Alexander. 2011. "Systems Engineering : Principles and Practice." Edited by Alexander Kossiakoff. Hoboken, N.J.: Hoboken, N.J.: Wiley-Interscience.

Mabogunje, Ade, Neeraj Sonalkar, and Larry Leifer. 2016. "Design Thinking: A New Foundational Science for Engineering." *International Journal of Engineering Education* 32 (3): 1540–56.

Martin, Roger, and Jim Euchner. 2019. *Design Thinking: A Guide to Creative Problem Solving for Everyone*. *Harvard Business Review*. https://doi.org/10.5437/08956308X5503003.

Monat, Jamie, and Thomas Gannon. 2018. "Applying Systems Thinking to Engineering and Design." *Systems* 6 (3): 34. https://doi.org/10.3390/systems6030034.

Mubin, Omar, Mauricio Novoa, and Abdullah Al Mahmud. 2017. "Infusing Technology Driven Design Thinking in Industrial Design Education: A Case Study." *Interactive Technology and Smart Education* 14 (3): 216–29. https://doi.org/10.1108/ITSE-01-2017-0008.

Muijs, Daniel. 2011. "Experimental and Quasi Experimental Research." In *Doing Quantitative Research in Education with SPSS*, 13–33. London: SAGE Publications, Ltd. https://doi.org/https://dx.doi.org/10.4135/9781849209014.

Muijs, Daniel. 2011. *Doing Quantitative Research in Education with SPSS*. *Doing Quantitative Research in Education with SPSS*. London: SAGE Publications, Ltd. https://doi.org/10.4135/9781849209014.

Payne, Geoff, and Judy Payne. 2004. *Key Concepts in Social Research*. Trowbridge, Wilture: SAGE Publications.

Plattner, Hasso, Christoph Meinel, and Larry Leifer. 2016. *Design Thinking Research: Making Design Thinking Foundational*. *Design Thinking Research: Making Design Thinking Foundational*. Springer International Publishing. https://doi.org/10.1007/978-3-319-19641-1.

Plattner, Hasso, Christoph Meinel, and Larry Leifer. 2018. *Design Thinking Research*. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-319-60967-6_14.

Plattner, Hasso, Christoph Meinel, and Larry Leifer. 2012. *Design Thinking Research*. *Design Thinking Research: Studying Co-Creation in Practice*. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-21643-5_1.

Razzouk, Rim, and Valerie Shute. 2012. "What Is Design Thinking and Why Is It Important?" *Review of Educational Research* 82 (3): 330–48. https://doi.org/10.3102/0034654312457429.

Seidel, Victor, and Sebastian Fixson. 2013. "Adopting Design Thinking in Novice Multidisciplinary Teams: The Application and Limits of Design Methods and Reflexive Practices." *Journal of Product Innovation Management* 30 (SUPPL 1): 19–33. https://doi.org/10.1111/jpim.12061.

Shilakov, Vadym. 2019. "Sample Size for Usability Study. Part 1. About Nielsen and Probability." UX Planet. December 19, 2019. https://uxplanet.org/sample-size-for-usability-study-part-1-about-nielsen-and-probability-efffecdbfa95.

Stickdorn, Marc, Adam Lawrence, Markus Hormess, and Jakob Schneider. 2012. *This Is Service Design Thinking*. Amsterdam: BIS Publishers.

Thienen, Julia Petra Ariane Von, Christoph Meinel, and Giovanni Emanuele Corazza. 2017. "A Short Theory of Failure." *Electronic Colloquium on Design Thinking Research*, no. September: 1–5. http://www.ecdtr.hpi-web.de/report/2017/001/.

Urquhart, Cathy, Hans Lehmann, and Michael D. Myers. 2009. "Putting the 'Theory' Back into Grounded Theory: Guidelines for Grounded Theory Studies in Information Systems." *Information Systems Journal* 20 (4): 357–81. https://doi.org/10.1111/j.1365-2575.2009.00328.x.

Vaughan, William. 2015. "Systems Engineering." *Concurrent Engineering in the 21st Century: Foundations, Developments and Challenges* 8: 221–54. https://doi.org/10.1007/978-3-319-13776-6_9.

Yin, Robert K. 2014. *Case Study Research : Design and Methods*. Fifth. California: SAGE Publications.

Appendices

Appendix 1 - Table of Figures