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The Impact of Cultural Change: A Transdisciplinary Engineering Case Study

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Abstract. Engineering Change Management (ECM) is a complex process requiring transdisciplinary working across the entire business and product lifecycle. Core to achieving successful transdisciplinary working are collaborative teams focusing on a common goal. However, much of the research and studies presented tend to be academic in nature and often focused on education and health, with a small number of papers providing industrial engineering examples. In this paper, we present an Engineering Change Management case study of a small UK-based automotive business and reflect on the importance of a transdisciplinary engineering approach. We place focus on the importance of social sciences, people and culture, in gaining success i.e. a people-focused approach to ECM. We hypothesized that by using a transdisciplinary approach where people and culture were key, we could accelerate the Engineering Change Management process. Within this paper, we introduce ECM and Quick Release's role in assisting companies with their engineering change management processes. This is followed by a summary of the case study context and the two-phased approach to the analysis; Diagnostic (Phase 1) and Acceleration sprint (Phase 2). The results of the case study estimated a process throughput increase of a factor of three and a reduction in ECM process time from a 64-day average to approximately 22 days. This eliminated a potential 8-week program delay, valued at over £5 million in engineering costs alone for the case study company.

Keywords. Engineering Change Management, ECM, Culture, Transdisciplinary, Business Process, Efficiency, Automotive

Introduction

Within the context of Engineering Change Management (ECM), it is quoted in the literature that approximately 30% of engineers' time is spent on non-value add activities such as avoidable engineering changes and associated administrative work [1-4]. This inefficient use of engineers' time, alongside a multitude of cross-functional stakeholders such as purchasing, finance, manufacturing, logistics, and senior management, results in significant process costs associated with change. A study conducted in 2005 found that the average cost of a late design change in a large German automotive OEM was approximately €20,000-50,000 [5].

There is a significant gap between literature and industry experience on this topic. The dominant themes from the literature are focused on process mechanics and system optimisation as the key areas in which best practice efforts should target. Though the literature often touches on the 'people' aspects of ECM, this often lacks depth and

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evidence. Hamraz et al. [6] highlight this in a comprehensive literature review of 427 academic publications, of which only nine were classified as 'people orientated', two as 'Organisational issues', and no category was assigned to 'Data' or data focused themes.

Quick Release (QR) is an engineering management consulting business specialising in Product Data Management (PDM) and business processes, with 20 years experience in the automotive sector. QR leverages this wealth of experience to apply industry best practice within their projects. QR has worked in collaboration with the University of Bath to optimise QR's methodology for ECM. Over QR's 20 years of industry experience, the business has tailored its approach based on the recurring challenges identified across its client base. QR approaches business process projects by addressing four key areas: People, Process, System and Data. Whilst these are common focus areas in academia, QR often focuses on 'People' and 'Data', given these areas are often underdeveloped or overlooked within automotive businesses, as reflected in ECM academic literature [6]. In doing so, QR aim to incorporate transdisciplinary principles [7] within ECM. Transdisciplinary approaches have focused on case studies such as education [8], and healthcare [9], and more recently investigating whether data science can be the means to assist in transdisciplinary working [10]. In this case study we hypothesize that, by complimenting technical best practices with a transdisciplinary approach where people and culture are key, ECM process efficiency can be improved measurably. To quantify the improvements attributed to the adoption of a transdisciplinary approach, no investment or changes were made to the system architecture or process itself.

In this paper, a two-phase case study was conducted in a small UK-based automotive manufacturer, with the aim to test the hypothesis that using a transdisciplinary approach where the social science of culture and people were key, we could accelerate the ECM process. Phase 1 consisted of a Diagnostic activity, followed by an implementation phase. The latter phase took the format of an 'acceleration sprint' during which 'People' focused changes were employed to meet a defined objective within a set time constraint: All high-priority change requests processed and implemented (within the enterprise system) within six weeks.

Figure 1 outlines the approach taken for both phases. For Phase 1 (Diagnostic) an Exploratory Sequential Mixed Method approach was taken. The results of this phase informed the acceleration phase, having identified the core issues within the ECM landscape, and benchmarked the Key Performance Indicators (KPIs) against which value add could be quantified. The acceleration phase employed Kotter's Model and Lean methodologies to drive and embed rapid cultural change in the business, with the aim to accelerate throughput and achieve the objective set by the business.

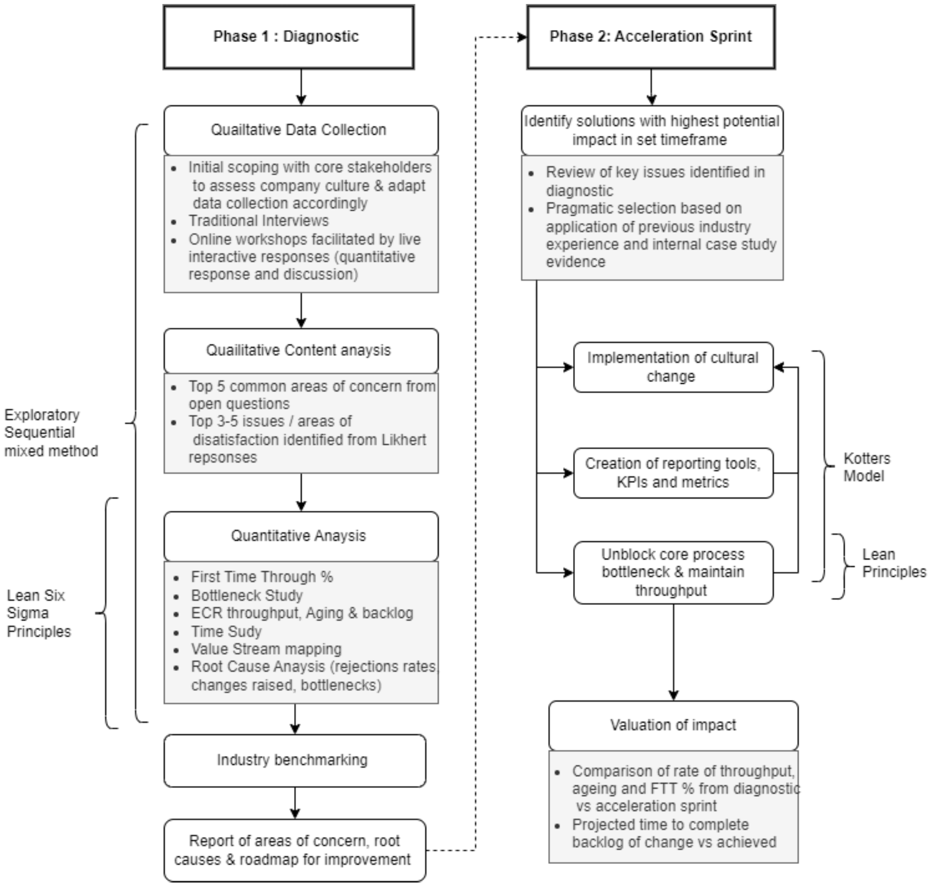

Figure 1. Methodologies applied to the Diagnostic and Accelerate phase of the case study.

1. Case Study Context

This case study took place in a small UK-based automotive business. The project was split into two distinct parts: Diagnostic and Acceleration. The first phase comprised of an 8-week diagnostic of the ECM landscape. The objective of Phase 1 was to assess and benchmark the current state of ECM and provide the business with a roadmap of recommendations to improve process efficiency. Due to the timing of this project in relation to the COVID-19 pandemic, this phase was conducted remotely. Analysis and recommendations included a curated roadmap of 'now, near and far' changes to implement across People, Process, Systems and Data. This included pragmatic, short-term interval control solutions to manage the current data in the change backlog, and optimisation of the end-to-end process long term.

Following the diagnostic, the QR team were contracted to run a 6-week process improvement sprint, with the aim to 'accelerate' the rate of change throughput to meet a commercially crucial gateway deadline. This phase was conducted onsite, though a large proportion of the client team worked remotely for the duration. The success criterion for the sprint was to clear the backlog and current active high-priority change prior to the commercial gateway deadline.

2. Diagnostic (Phase 1)

Due to the time and budget constraints of the diagnostic, an exploratory sequential mixed method was used [7]. Such constraints are reflective of typical industry evaluation activities, hence companies such as QR have adopted streamlined methodologies to maximise output within set times, budget, and resource limitations. This mixed-method approach combines both qualitative and quantitative data collection and analysis. Due to time constraints, a pragmatic approach was taken, starting with qualitative analysis, which in turn allowed for focused analysis of the dataset once available. The dataset consisted of an export of the change log from the ECM system, which included all recorded details of the changes themselves, and associated metadata.

2.1. Qualitative exploration

Initial conversations with project sponsors in the Program Management department were held to identify key process stakeholders and gain an initial high-level insight into the perceived issues and inefficiencies. These discussions also revealed that, although not considered to be a direct cause of process inefficiency, cross-functional communication was poor, with the consequences of this concentrated on the engineering teams. As a result, it was noted that an emotional response from this department was likely. The methodology and tools used to gather the initial qualitative response were selected carefully to maximize useful output without stifling idea and opinion generation.

Workshops were conducted with Engineering (five functional groups), Purchasing, Finance and Manufacturing, to gather insight into the perceived key issues from those who interact with the process daily. For the engineering teams, each of which had up to 10 participants, an interactive presentation tool, “Menti” was used. This allowed participants to respond to both open and closed questions in a written format, encouraging constructive feedback. This in turn stimulated productive, relevant discussion and helped alleviate tension. For the remaining departments, classic interview-style questions and open discussion were used to optimize time and QR resource use. A total of 32 questions were asked, with the same questions covered in Menti and interviews. Examples of closed questions answered via a Likert scale[2]:

To what extent do you agree:

- *I get enough support from cross-functional teams (Purchasing, Manufacturing, Finance etc.)*
- *I have sufficient visibility of release/change metrics.*
- *There is effective cascade of Change Management related information, deadlines, and priorities from the senior leadership team.*

[2] A commonly used psychometric tool that measures opinions of individuals towards a specific topic or subject. A five-point scale was used for respondents to indicate the extent to which they agree or disagree with a particular statement, i.e. Strongly agree, Agree, Neutral, Disagree, Strongly Disagree.

Examples of some interview questions included:

- *How much time do you spend searching or waiting for data per week?*
- *How much time do you spend attending nonvalue add meetings per week?*
- *What priority do you assign ECM tasks?*
- *Can you identify any bottlenecks in the current workflow?*
- *Are you aware of target completion timings and Service Level Agreements with different departments?*

2.2. Quantitative data analysis

Based on feedback from interviews and workshops, a time study analysis was conducted across all relevant stakeholder departments. Stakeholder estimation was selected as the method of data collection. Although less accurate than a recorded time study, this method allowed for greater participation, was perceived as less intrusive by the client, and was best suited to the remote working environment. Value stream mapping [11], bottleneck analysis [12] and ageing analysis [13] were conducted on a data extract from the ECM system. 1287 data points were analysed. All data points were included for root cause and First time Through[3] (FTT) analysis. 99 data points were removed from process timing analysis due to being incomplete (withdrawn from system prior to approval).

2.3. Results

The core points of failure within the operation of the ECM process were found to be communication and collaboration based. The top three issues identified were:

1. Lack of governance structure and program planning.
2. Allocation of responsibility across departments.
3. Process bottlenecked by ineffective meetings and poor data quality.

Top-down communication was identified as a key issue. Poor communication of decisions including product definition resulted in poor Gateway adherence, causing confusion and lack of a common, measurable goal. This eliminated any sense of urgency at the delivery level, and thus any drive for continuous improvement. This lack of transparency upstream hindered efforts to employ data-driven program planning which in turn created a 'reactive' culture amongst key stakeholders of ECM, further fuelling a lack of gateway adherence, resulting in a higher risk of program delays.
A lack of change management operational leadership resulted in administrative and operational burden falling on a resource constrained engineering department. Consequently, the engineering department was perceived by the rest of the business to be responsible and accountable for all stages of the process. This was worsened by poor data visibility, creating an onus on engineering to track and report the status of change across all departments. This, in conjunction with remote, siloed work practices, was identified as a key root cause of blame culture in the business. This created an environment in which cross-functional collaboration was executed poorly. Up to 77% of engineers' time was

[3] First Time Through (FTT) is measured as the percentage of items that are approved without rejection or rework required over a defined time period for a specific process or stage within a process. Also known as Right First Time (RFT).

spent on non-technical tasks at the later stage of the program due to poor delegation of tasks and responsibilities. Figure 2 shows the time study results across three phases of the development program, highlighting the increasing burden ECM and associated process responsibilities had on engineers as the backlog of Change Requests increased thought the program. On average, engineers were expected to attend up to 10 hours of change review meetings per week per program, with many engineers working on two programs simultaneously. Undisciplined, ineffective meetings further slowed the process and fostered a blame culture. Change meetings largely consisted of providing non-value add updates, as a result of poor data visibility and lack of trust in available data. The annual cost of engineering resource inefficiency in the latter stages of the development cycle was estimated to be £2.7 million, based on a team of 50 engineers.

Poor data quality accounted for 67% of rejections at approval, with process confusion cited as accounting for 27% of those rejected items. In both cases, the core root causes were poor training, overly complex process documentation, minimal cross-functional engineering practices and ineffective communication with stakeholders. Furthermore, the overall business culture created an environment in which the engineering teams did not feel empowered to raise these issues to senior management in a constructive manner, inhibiting continuous improvement efforts.

The root causes analysis indicates cultural factors are a significant cause of inefficiency in the ECM process. In contrast, the literature often only refers to cultural considerations in passing [2, 4, 6]. Instead, focus is largely placed on maturity assessments of design methodology, process mechanics and enterprise system architecture [4, 14]. The lack of consideration for cultural factors in assessment templates contributes to the knowledge gap in this area, particularly regarding the measurable impact social and cultural factors have on the efficiency of ECM. The diagnostic results from this case study highlight the importance of varied assessment methods that leverage both quantitative evaluation of the process and systems, and qualitative insight from stakeholders across the business regarding culture and communication.

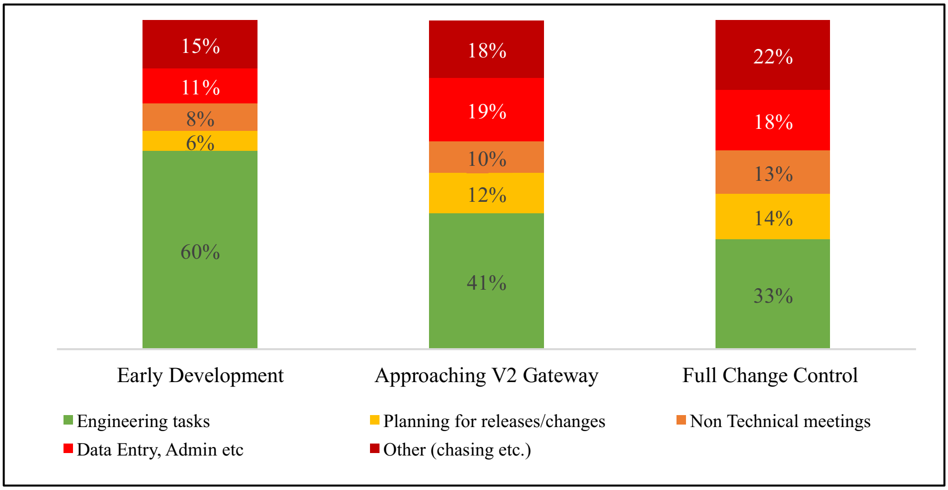

Figure 2. Stacked bar chart showing time analysis breakdown for the engineering team across three program stages. Diagnostic and sprint occurred during the later stage of the program, labelled as 'Full Change Control'.

3. Acceleration Sprint (Phase 2)

As highlighted in Phase 1, 'People' related challenges dominated the top issues identified by the diagnostic analysis. Quantitative analysis indicated this with the root causes of many process and data issues connected to poor communication, training, or people management. Due to the time constraints and specific success criteria set by the client, not all recommendations could be implemented. The People and supporting Data recommendations were selected as the core focus for the sprint. This was a pragmatic selection, as these changes could be implemented rapidly by integrating the QR team within the client operations, required no additional investment from the client, and had the potential to have an immediate value add impact. This enabled a more rapid culture shift, as members of the delivery team could operationalise changes immediately, eliminating training and adjustment periods for roles in which QR temporarily occupied. The methodologies adopted utilised the core concepts of Lean and Kotter's 8-step change model[4] [15].

The QR team initiated the sprint by clearly communicating the objective and KPI used to measure success. This created a time-bound sense of urgency and unified the multi-disciplinary team in a common goal. Progress against this KPI was reported daily across all teams, communicating short-term wins (e.g., daily/weekly targets) and enforcing the longer-term objective and progression towards this.

To create a 'guiding coalition', the QR team was embedded within the client management team, taking roles as program and change management coordinators. Meeting structure and culture was addressed with high priority. QR team members ran core Change Management meetings, adopting Lean methodologies to maximise productivity and reduce process cost by running leaner meetings to contain required parties only. Best practice was applied to ensure agendas and actions were data driven and non-value add contributions such as status updates were eliminated. The change to a neutral facilitator also aided the cultural shift away from blame culture and non-value add content and further aided the sense of urgency to achieve the common goal of processing all change by the Launch deadline.

Another root cause of ineffectiveness identified was the remote working culture. Whilst this had worked well initially for an established program, this became an issue as the business moved into the latter stages of the new program. Poor visibility and meeting culture resulted in ineffective communication channels and siloing of cross-functional teams. As the business culturally struggled to enforce onsite presence, QR introduced a 'dial in' policy, encouraging a digital 'desk to desk' environment, whereby individuals were regularly dialled into meetings as required and asked to leave when the relevant discussion had been concluded. This helped unblock issues quicker, and reduced blame culture, particularly between cross-functional teams [10]. To embed this in the business, the QR members who were integrated within the client teams communicated the vision behind this policy, and adopted it in core program meetings. Prior communication of

[4] Kotters model consists of 8 core steps: (i) Establishing a Sense of Urgency (ii) Creating a Guiding Coalition (iii) Developing a Vision and Strategy (iv) Communicating the Change Vision (v) Empowering Employees for Broad-Based Action (vi) Generating Short-Term Wins (vii) Consolidating Gains and Producing More Change (viii) Anchoring New Approaches in the Organization's Culture

intent reduced the risk of the client team perceiving this to be rude or intrusive, helping embed this practice swiftly and as intended.

Data visibility was addressed by consolidating and centralising all required data into a single repository, which in turn was used as the single source of truth for running daily KPI metrics, generating meeting agendas, and producing weekly progress reports for senior management. This improved the quality of data reporting, unified the cross-functional teams and reduced the margin for blame. A key data block identified was drawing data quality. Drawing FTT metrics and bottleneck analysis indicated that poor quality drawings were a key rate limiting step in the ECM process. Though this was categorised as a data quality issue, the root cause of this was poor communication between the data check team, the engineering team, and program management. A Lean approach was used to minimise waste and improve process flow. The QR team created a checklist and basic training documentation in collaboration with the data check team. Training and documentation were delivered to the engineering team, with a helpline email set up to direct questions away from the resource constrained data check team. All drawings were directed via a QR inbox for screening before being forwarded to the data check team. Though this added an interim step to the process, it placed emphasis and responsibility on the engineers to quality check their work before submitting to the process, allowing the resource constrained data check team to increase throughput. Metrics illustrating the weekly improvement in FTT for drawing checks were circulated alongside progress towards the overall objective. In addition to creating a sense of ‘quick wins’, this helped consolidate the changes made, as the benefits were tangible and measurable to the process stakeholders.

3.1. Results

Process throughput increased by a factor of three, as highlighted in Figure 3. Overall, the ECM process time was reduced from a 64-day average to approximately 22 days. Extrapolating completion rate prior to the sprint shows that time to process the backlog of change reduced by up to 8 weeks, saving an estimated £5 million in engineering resource alone by preventing a 2-month delay late in the program. Figure 3 shows this increase in completion rate from week 26 onwards. Figure 3 also highlights the immediate and sustained impact of the cultural shift achieved by embedding a ‘guiding coalition’ to drive urgency and steer working practices.

The backlog of drawings was reduced from 104 with a queue time of 35 days, to consistently less than 20, with a backlog queue of 3 days by the end of the sprint. Complimenting this, the FTT from engineering rose from a monthly average of 34.6% to 58.1%, achieving 90% in the final week of the sprint, illustrating consolidated gains week on week during the sprint.

The results highlighted were achieved with zero investment or changes to the ECM process or the supporting enterprise systems. Instead, the results achieved were driven by a change in culture, communication, and data visibility, which in turn improved data quality and issue resolution. This supports the hypothesis that, using a transdisciplinary approach where the social science of culture and people are key, the ECM process can be accelerated. The measurable value of a transdisciplinary approach to ECM, as demonstrated by this case study, helps address a gap in the current literature regarding the cost-benefits of investing in cultural change within the context of improving ECM. This gap must be addressed to empower businesses to invest in cultural change.

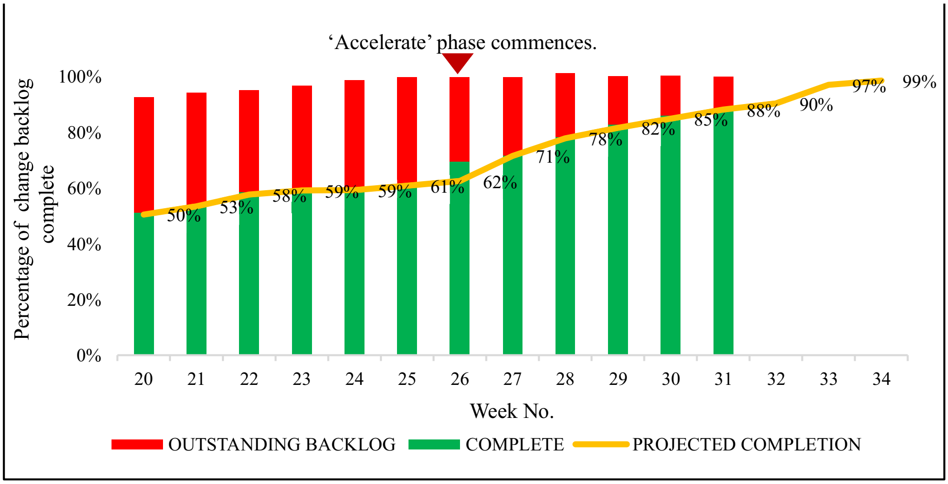

Figure 3: Bar Chart indicating completion status per week. Red indicated outstanding changes to be processed. The yellow line highlights the projected completion curve, based on data gathered from engineers to predict processing lead time and provide data-driven weekly targets.

4. Conclusion

This paper reports the results obtained from a two-phase, industry-based case study investigating the impact 'People' orientated characteristics of ECM, including company culture, communication and working practices, have on process efficiency.

Phase 1 highlights that culture and related organisational issues were identified as the root causes of significant inefficiencies in the case study. This finding is contrary to the focus on process logic, system architecture and engineering design tools found in the literature. During the diagnostic, initial social and cultural observations were used to tailor the study to the business to ensure the qualitative data collection received adequate participation while minimising potential influence from emotional reactions. Such considerations are largely absent from current literature, which typically use rigid maturity assessments focused on process, systems, and design process. Consequently, cultural and social factors are often overlooked and under-valued as areas for opportunity and continuous improvement.

Phase 2 consisted of a six-week sprint, in which the findings of Phase 1 were addressed. A team of industry experts created a shift in cultural change within the ECM landscape, applying Kotter's model and Lean Methodologies. Comparing data from both phases, the results of Phase 2 show a reduction in process time from a 64-day average to approximately 22 days. This eliminated a potential 8-week program delay, valued at over £5 million in engineering costs alone. This was achieved without process or system changes.

The measurable results of this case study support the hypothesis that using a transdisciplinary approach, with a focus on culture and people, can accelerate the engineering change management process. The significant cost saving outlined in this case study, achieved with zero investment in the existing process or supporting IT systems, highlights the potential productivity increase that can be achieved via cultural and organisational change, and thus the value transdisciplinary research can offer to the engineering sector in the ECM space. Addressing the knowledge gap concerning the impact of cultural factors in ECM is key to enable businesses to justify investment in the adoption of a transdisciplinary approach within the ECM space.

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References

[1] N. Iakymenko et al., Status of engineering change management in the engineer-to-order production environment: insights from a multiple case study. *International Journal of Production Research*, 2020, Vol. 58(15), pp. 4506-4528.

[2] E. Fricke et al., Coping with changes: Causes, findings, and strategies, *Systems Engineering*, 2000, Vol. 3(4), pp. 169-179.

[3] V. Quintana et al., Re-engineering the Engineering Change Management process for a drawingless environment, *Computers in Industry*, 2012, Vol. 63(1), pp. 79-90.

[4] J. Tavčar, I. Demšar, and J. Duhovnik, Engineering change management maturity assessment model with lean criteria for automotive supply chain. *Journal of Engineering Design*, 2018, Vol. 29(45), pp. 235-257.

[5] A. Wasmer, G. Staub and R.W. Vroom, An industry approach to shared, cross-organisational engineering change handling - The road towards standards for product data processing. *Computer-Aided Design*, 2011, Vol. 43(5), pp. 533-545.

[6] B. Hamraz, N.H.M. Caldwell, and P.J. Clarkson, A Holistic Categorization Framework for Literature on Engineering Change Management. *Systems Engineering*, 2013, Vol. 16(4), pp. 473-505.

[7] S. Lattanzio, L. Newnes, G. Parry and A. Nassehi, Concepts of Transdisciplinary Engineering: A Transdisciplinary Landscape, *International Journal of Agile Systems and Management*, 2021, Vol. 14, no. 2 , pp. 292-312.

[8] A. Ertas, *Transdisciplinary engineering design process*. First edition, Wiley, Hoboken, 2018.

[9] D.J. Roux, et al., Transdisciplinary research for systemic change: who to learn with, what to learn about and how to learn. *Sustainability science*, 2017, 12(5), pp. 711-726.

[10] H. Sarah, H. Heather and F. Dean, Developing a Transdisciplinary Team Using Online Data Science Training and a Real-World Case Study on the Pandemic, COVID-19. *Transdisciplinary Journal of Engineering & Science*, 2023, 14.

[11] M. Rother, J. Shook, *Learning to see: value-stream mapping to create value and eliminate muda*. Version 1.4., Lean Enterprise Institute, Cambridge, 2003.

[12] S. Lee, Assessment of process improvement from organizational change. *Information & Management*, Vol. 45, Issue 5, July 2008, pp. 270-280.

[13] A. Pulkkinen, P. Huhtala, S.P. Leino, J.P. Anttila and, V.V. Vainio, Characterising the Industrial Context of Engineering Change Management. In: Bouras, A., Eynard, B., Foufou, S., Thoben, KD. (eds.) *Product Lifecycle Management in the Era of Internet of Things. PLM 2015. IFIP Advances in Information and Communication Technology*, Vol 467, 2016, Springer, Cham. https://doi.org/10.1007/978-3-319-33111-9_56.

[14] S.H. Storbjerg, T.D. Brunoe, and K. Nielsen, Towards an engineering change management maturity grid. *Journal of Engineering Design*, 2016, 27(4-6), pp. 361-389.

[15] J.P. Kotter, Leading Change: Why Transformation Efforts Fail, *Harvard Business Review*, 1995, 73(2), pp. 59-68.