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USE OF A STRUCTURED ENGINEERING DESIGN PROCESS IN EXPANDING MARKETS OF SME'S

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ABSTRACT
EGPR (European Global Product Realisation) is an undergraduate group design project for final year engineering students at City University. The learning outcomes of this project are to equip students with the necessary skills to approach real design problems in a systematic way using a structured engineering design process. It is understood by the participating students that this process can increase the ability of companies to expand their existing market share by identifying possible niches through novel designs of their existing product line. Many Small and Medium Enterprises (SME) yet fail to implement such an approach in daily practice. In order to learn the engineering design process through an application in industry, the EGPR team conducted a design exercise aimed at creating conceptual designs of fencing systems with the objective of expanding the market of their UK based industrial partner. Various methods for specifying suitable functions to conceptualise upon were used and compared. Although the scale of the students' work was not sufficiently large and time was too short to assess the commercial value of the designs, we feel the work is of value for the 'platform' it provides for a proactive approach to meeting customer requirements.

Keywords: European global product realization, structured design process, expanding market share, proactive approach

1 INTRODUCTION

The use of the engineering design process is a very important principle for unbiased idea generation and product creation. The design process may be performed in several different ways. These range from the "standard" approach as referred to in Pahl et al [1] which emphasises structure over intuition, all the way to value engineering and analysis focusing on cost reduction and value enhancement. In any case, design processes provides a strong platform for 'out-of-the-box' thinking by structuring the idea generation process through different tools as, for example, the functional model and the morphological chart.

The team of students at City University preparing for the EGPR course [2] undertook a project with an industrial partner in order to learn about the application of the engineering design process in a real life situation. The idea was to assist an industrial partner in improving their existing product range to target a previously unexploited market. The industrial partner informed the team that current design methods used in the company were dependent mostly on direct contact with customer and ad hoc application leading usually to small modifications of existing design solutions. Such a development process can significantly increase costs and required man-hours mostly as the consequence of ever changing customer requirements or poor communication during the contracting and development phase. It can even lead to loss of a contract if existing products fail to attract customer interest or the customer requirements are more readily met elsewhere. It is argued that customer retention and market share is enhanced by taking a long term business view through use of the structured engineering design process. Although immediate cost and structural changes are likely to occur, the new approach can ultimately yield an improvement in performance through innovation and market demand anticipation.

Even though the design process presents the potential for significant product optimization and idea generation, there are indications that the process is not widely adopted and specifically neglected by SME's, as defined in [3] . Experience suggests that it is due to two factors: 1) Organisational inertia and 2) Resource intensity. When asked, our industrial partner company called Jacksons' Fencing the UK leader in providing domestic and industrial fencing systems, confirmed that "lack of manpower" and "lack of time" were the primary factors for not introducing such a process in practice. Previous research in SME's has also identified this obstacle. For example, Hudson et al [4] concluded that the general failure of implementation of their SME's performance measurement system was a result of it being perceived as "too resource intensive".

On the other side, the company management may find several other reasons for adopting a structured design approach. The engineering design process takes the long-term view by providing a platform for product extraction aimed at demand anticipation and generation of novel designs. It is argued that the short term gain of simply reacting to market directions, rather than the long term approach required for anticipating them, is detrimental to potential growth [5] . The importance of demand anticipation is emphasised through the vast amount of literature focusing on the link between innovation and business performance [6] and other researchers who refer to innovation as a key driver of business performance in industrialised countries [7] . The success of Apple's 'i' series of products may be taken as another example of the immense potential of market demand anticipation, innovation and engineering design to business growth, as reflected in Apple's stock price growth in the past several years [8] . The case for the long term outlook is further argued through examples of the replacement of short term growth with a long term growth outlook in Chinese entrepreneurs [9] and of corporate reputation preservation (which may often conflict with short term interests) correlating with profits [10] .

2 BACKGROUND

City University operates a design program under the name of European Global Product Realization to give students an experience in working on an industry commissioned design project [2] . The university collaborates with about half a dozen other universities from around Europe in working across a virtual platform throughout the course of the project in order to deliver on a design problem as set by an industrial partner from the same country as the year's host university. The program takes place across 4 months in the second teaching term with activities ranging from problem definition to prototype delivery. However, in the first term an independent project is generally taken up by City University in order to give students first-hand experience in working for industry. For that project, City's EGPR team was tasked with the creation of a "barrier system" for an industrial partner in order to penetrate non-native product markets. The partner specializes in bespoke and up-market fencing solutions and is a prominent and growing player in a market worth approximately £1bn [11] . The partner had identified a lucrative segment of the fencing market with the potential for significant growth in the presence of suitable products, which it had traditionally neglected due to a policy of targeting only the upper market range of products. The team was briefed on the company's requirements on a visit to the university and given ten weeks to employ the engineering design process. A set of conceptual designs were to be delivered in order to develop suitable designs for possible future commercial deployment.

3 METHODOLOGY

The group did not initially have a preferred approach in tackling the given problem, so it decided to adopt the structured engineering design process detailed in Pahl et al [1] . The standard approach described in the literature comprises of the utilization of a number of tools:

1. The process began by identifying the problem, which in this case was: "*Designing a fencing system that would fit the quality-centric business model of the industrial partner, while also remaining flexible enough to cater to the partner's desire to gain market share in the lower-cost range of fencing products*".
2. The process continued by developing an extensive objectives tree. In Figure 1, the top hierarchic level is observed.

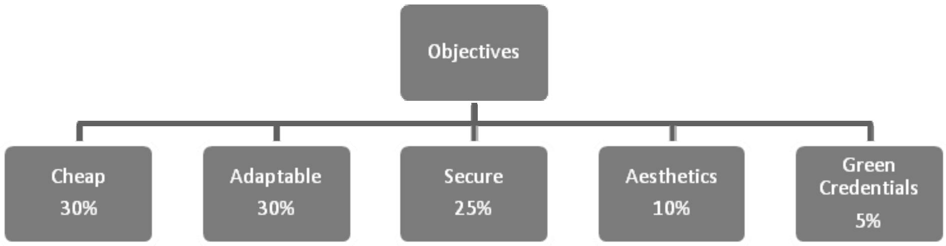

Figure 1. Top level of Objectives tree

3. To derive the system's functions, three different approaches were conducted: Value analysis/engineering, Functional model and Failure Mode and Effects Analysis (FMEA). The approach adopted and the details of the output from each tool can be found described in depth by Halai et al [12] .
4. Consequently, the research phase of the project is concluded by the QFD matrix which was derived by combining the customer requirements from the objectives tree and inputs of engineering characteristics from all three methods described in [12] . Divergence from the standard QFD described in literature appeared when comparing the potential product with competitors. Instead of analysing competing companies as in Pahl et al [1] , analysis of competing fence types was deemed more suitable.
5. Based on the results obtained by the above methods, the group constructed the Requirements List. The Requirements List was continually updated throughout the process in order to provide an up-to-date list of the necessary criteria the concepts must fulfil.
6. Abstraction was used to solve the problem of fixation and conventional ideas by broadening the problem formulation, identifying the essential problems from the requirements list and facilitating the functions structure.
7. Finally, the morphological chart was used for systematic solution generation.

In order to illustrate how the above process aided in the extraction of the final concepts, two of these are shown in Figure 2.

The research showed that the customer was looking for high adaptability of the fencing system, the importance of which was quantified in the objectives tree with a weighting of 30%. The developed functional model clearly indicated functions that could affect the system's adaptability. For example, the load transmission from the panel to the beam is affected by the connectors which in turn have an impact on the system's adaptability.

The engineering characteristics were extracted from the functional model and put into the QFD showing the strength of the connectors, terrain angle and number of parts in each connection to contribute to the adaptability of the whole structure. The morphological chart was then devised with a set of solutions to fulfil the functional requirements. For example, the connecting system had 7 total solutions, of which one was selected for concept variant 2 and another in concept variant 3, as shown in Figure 2.

Given the simplicity of the construction all concept variants were seen to satisfy the main criteria of cost and adaptability. The concepts were then checked for coherency and optimized, then presented to the industrial partner's management team.

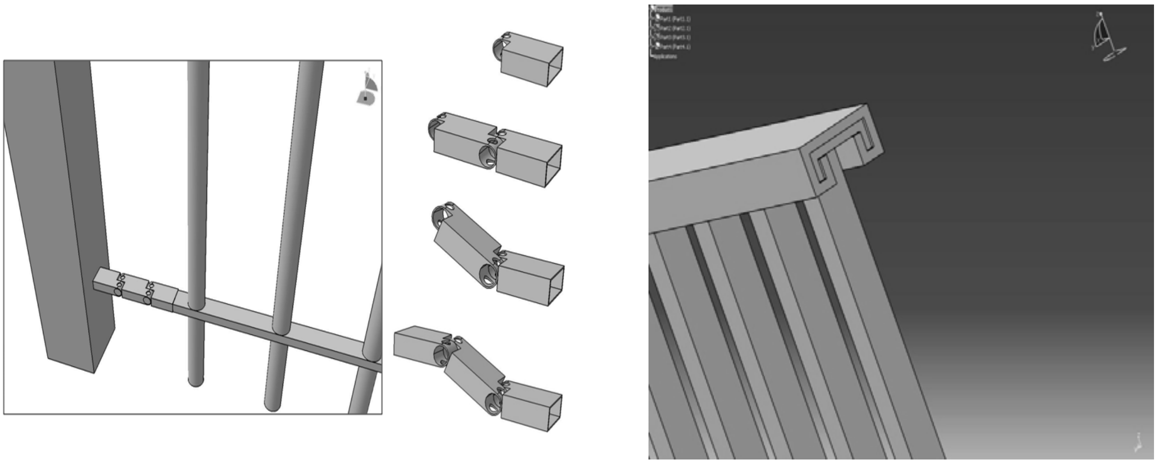

Figure 2. Concept variants 2 (left) and 3 (right)

Having derived the concept variants a qualitative analysis was performed in order to determine the most suitable concept for the given task. A grading criterion was used to assess each solution on its technical and economic feasibility. The grading criterion allowed for comparison of the extracted solutions to existing competing products. After analysing each concept based on its economic and technical characteristics, it was determined that Concept 2 was the equivalent of the Barbican range of fencing systems which was one of the key competing products, as illustrated in Figure 3. The cost difference between all compared concept variants was small, but Concept variant 3 showed significantly better technical performance than other solutions and outperformed both main competitors, the Barbican and the Palisade fencing system. Concept variant 3 (shown in Figure 2) was therefore selected as the best overall performer.

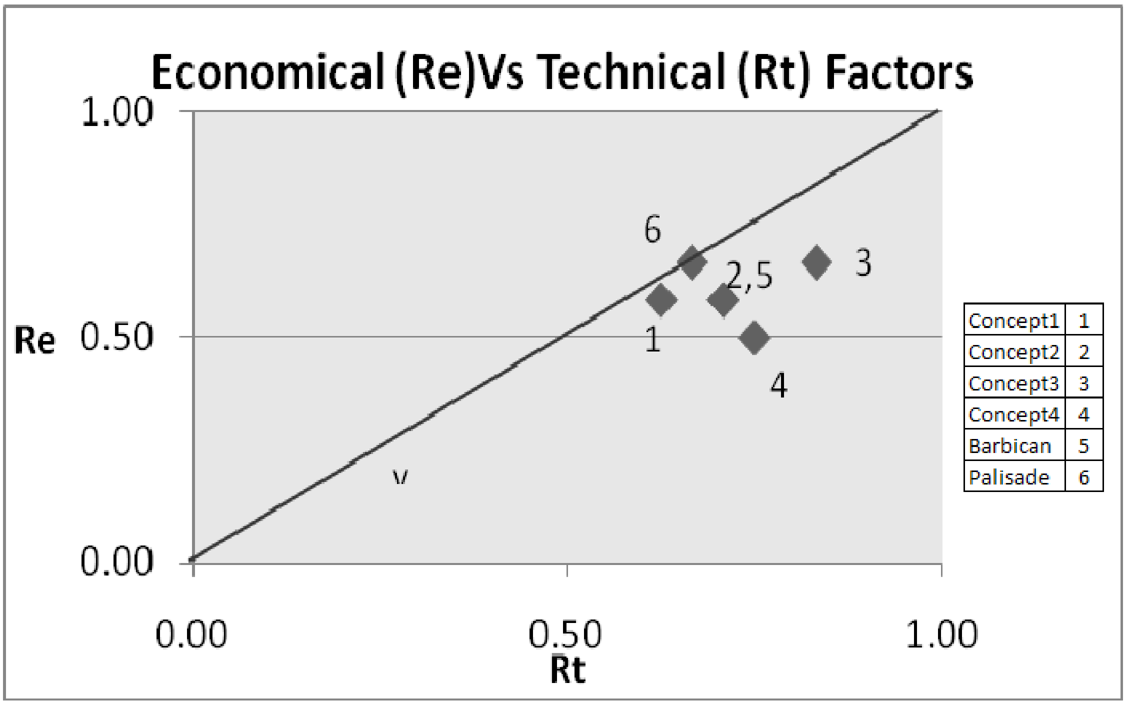

Figure 3. Economic Technical Analysis

4 DISCUSSION

The industrial partner has indicated that its current design procedures are reactive and are dependent on their customer approaching them and specifying the design framework. One of the problems with such an approach is that miscommunication between the two parties can easily result in poor reception of customer requirements. Since the process is non-systematic, previous efforts may become irrelevant to the new requirements, resulting in significant delays to product delivery with the undesirable possibility of a complete redesign of the product. For example, in a recent case the partner's customer requested just an increase in the opening angle of existing electrical gate. However, the company had to completely redesign the gate mechanism to make it open to the increased maximum angle, demonstrating the potential inefficiency of the applied design process. Although the proposed engineering design process cannot eliminate all problems in frequently changing customer requirements and is not always self sufficient and does not eliminate "ad hoc" solutions, it does provide the platform to navigate through the thought process more easily. If customer requirements change throughout the process, the team can simply return to the tools and change the parameters to reflect the new requirements. After gathering experience with use of the process, the team may also be able to more efficiently address future design problems by virtue of experience of common problems and solutions in past tasks. Although the reapplication of old solutions is presented as a potential efficiency gain, it is imperative to maintain creativity and innovation in order to make best use of the design process. To that end, it may be suggested that the company divert resources from design to research and development after realization that the point of diminishing returns in brainstorming has been reached. It is also worth mentioning that the process can help to specify customer requirements at the very beginning of the process and even narrow them down to a specific area which will spark customer interest in applying alternative solutions to existing products.

Customers who could see a desired product or design which potentially fulfils their requirements would be more likely to approach the manufacturer and seek a tailored solution based on novel design principles. The customer and the company therefore both benefit. The customer receives the required product in the shortest time with a minimum number of alterations. The process helps to reduce communication errors and improve product delivery time. The company reduces excess cost incurred by inefficient communication and ad hoc design. The product portfolio is therefore expanded, while sales are increased through consolidation of market share resulting from increased interest from potential customers. The students acknowledge that such an approach may be initially capital intensive. It would thus require that the company have a sufficient equity cushion, or have sufficient credit lines. SME's may operate with smaller cash flows and be subjected to greater interest charges. The decision to take such an approach does therefore ultimately depend on the company's financial ability to resist the initial blow from adoption of this procedure.

5 CONCLUSION

A structured design process allows for out-of-the-box thinking, producing a platform for innovative design solutions. The reactive design policy generally carried out by SME's, including our industrial partner, restricts the ability of the company to forecast market needs as it pursues a purely immediate and short-term agenda. On the other hand, innovative and proactive designs facilitated by a structured design process have the potential to expand market share by addressing and anticipating market demand prior to significant shifts in market direction. The final solution presented to the company was well received and new to the portfolio. Though simple, the design highlights how thinking outside the conventional company culture can lead to design breakthroughs. Although the structured design process is a powerful tool in providing innovative solutions, the nature of established practice in an organization's culture and the resources required to adopt such process prevented our industrial partner and indeed many SME's from implementing it fully. The company recognised that application of such a process may in the long term result in more efficient design and provide a platform for greater innovation.

There are two possible paths to the adoption of the design process. One is to employ an in-house design team and continually use the process to extract new designs. The problem with such an approach is that design teams may succumb to an organization's established practice and therefore make the same assumptions that prevent innovative solutions. The suggestion was given that some of the company's resources be diverted to research in order to maintain innovation and creativity. The alternative solution is to outsource design requirements to a dedicated design team, for example an academic team like City University's EGPR. Outsourcing however, comes at potentially significant cost and the company has less control over the quality and suitability of the final solutions. It is therefore necessary for the company to perform a cost-benefit analysis to determine which approach is most suitable to their needs. To that end, future research should also be performed to establish relationship between a systematic design approach and business performance. It would then be possible to measure and therefore make an informed decision on whether adoption of the process will lead to reasonable returns.

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