Editorial: integrated product development and system engineering

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1 Introduction

New product development is central to the prosperity and even survival of product manufacturers. However, the world of new product development is becoming increasingly challenging. With the intensifying competition of today's markets, product manufacturers are striving to develop their products with better performance, higher quality, and lower cost within a shortened product development cycle. At the same time, changing and diverging customer tastes are creating greater demands for product variety, and mass markets are being replaced by fragmented, niche markets. Technology advances are providing new tools and approaches to product development. However, they also pose new challenges in terms of identifying proper uses and supporting infrastructures. Finally, globalisation is opening up new markets, global labour forces and global manufacturing bases. Given this dynamic environment, we believe that studying how to develop products in an effective and efficient manner remains one of the most important endeavours in product innovation research. This belief led us to propose and edit this special issue dedicated to the intersection of Integrated Product Development (IPD) and System Engineering (SE) concepts.

The term 'Integrated Product Development' is surely one of the most ubiquitous in business today. Different users of the phrase often attach different meanings to it. Indeed, as we sifted through the responses to our call for papers for this issue we discovered two broad perspectives represented by two different groups. At the product engineering level, 'Integrated Product Development' is often used to connote the concurrent consideration of interdependencies among different engineering disciplines such as mechanical, hydraulic, electric/electronic, and software. In this context, IPD refers to efforts aimed at establishing an effective product development process in which all these different disciplines are integrated to achieve the optimal performance for the overall product. Analyses at this level centre on product specifications, functional synthesis, and design trade-offs.

At a broader business level, managers tend to use IPD as an umbrella term for efforts to concurrently address and synthesise information from market research, product planning, product engineering, manufacturing, procurement, supply, and support functions. Business-level IPD also considers the impacts of a given product development effort in regard to long-range business plans, profitability, team formation and function, regulation and environment consideration, and societal changes.

'System Engineering' is a set of activities and processes that interact to achieve predetermined performance objective. SE is an approach that fits the requirements of the 'Integrated Product Development' very well. In product development, 'System Engineering' defines a structured process that proceeds from concept design to product production using an interdisciplinary approach focused on defining customer needs and expectations early in the development cycle, then proceeding with design synthesis and system validation. This systematic effort integrates all the disciplines and specialty groups, and considers both the business and the technical needs of all customers with the goal of providing a quality product that meets user needs.

Our 'Call for Papers' invited prospective authors to submit papers that addressed IPD from either systems engineering or broader business perspectives. In total, we received 16 paper submissions in response to the 'Call for Papers.' The papers addressed a mix of tools and techniques for IPD as well as theoretical elements of IPD. Each paper was blind-reviewed by two subject experts including one academic researcher and one industrial practitioner. Based on the review comments from subject experts and our own reviews of the papers, we conditionally accepted five papers pending required modifications, we notified the authors of another five papers to resubmit revised papers for further review, and we rejected the remaining six papers. After a second iteration of reviews, we decided to accept a total of eight papers for inclusion in this issue. These eight papers provide excellent coverage of both practical and academic considerations of the elements of 'Integrated Product Development' and 'System Engineering' discussed above.

2 Overview of the papers included in this issue

This special issue brings together articles reflecting different views of IPD and SE. Several of the articles describe tools and techniques; others illustrate how IPD approaches are related to product development speed, design quality (product performance), and customer satisfaction. All of the papers point out unique challenges and implementation issues associated with successful IPD.

In the first paper, 'Exploring New Product Innovation Types and Performance: The Roles of Project Leadership, Functional Influences, and Design Integration', M. Swink explores the varying impacts of the three areas of integrative project management on project performance in incremental, architectural, and radical NPD projects.

The three important project management aspects are project leadership, functional influences, and design integration techniques. Swink reports the results of a multivariate analysis of survey data for a broad cross-section of NPD projects in manufacturing industries. The results suggest that the importance of various integration approaches and tools do vary across different NPD project types. The research concludes that NPD project managers would benefit from recognising and acting upon different levels and types of uncertainties associated with different types of NPD. Further, this paper points out the need and importance of future research to develop and advance our understanding of contingencies that may apply to IPD approaches.

Breakthrough products often have more complex built-in technology and functionality than their traditional counterparts. Since most customers do not have prior experience with breakthrough products, they usually spend more significant time, money, and/or effort in learning their innovative features. In the paper 'Time-To-Value, Customer Learning, and the Development of Breakthrough Products', C. Chen and H. Noori develop a conceptual framework to analyse the impacts of time-to-value on post-purchase customer learning and the development of breakthrough products from an integrative perspective of design and marketing. They develop a mixed-influence function inspired by psychological research and case studies to model the learning process undertaken by customers and to derive some useful guidelines for new product development. Their analysis shows that time-to-value has significant impacts on customer satisfaction and the success of a breakthrough product. For example, a customer may choose to terminate the learning process before a product's entire embedded value is realised in order to maximise its utility. To avoid such an unwanted consequence, the authors suggest that product developers should take into consideration the timing aspect of customer learning in formulating strategies for new product design. The authors also list several useful guidelines and strategies that can be used to manage the development of breakthrough products marketing strategies for improving the probability that consumers will embrace the breakthrough products. The paper delivers an excellent example of how rigorous mathematical modelling might be applied to integrate marketing and product design concerns for breakthrough products.

As markets and technology change, time-based competitors create integrative product development practices that reduce response-time and enhance customisation capabilities. Such time-based product development practices (TBPDP) often involve computer-mediated knowledge work, enabled by end-user computing capabilities. In the paper 'Level of end-user computing moderates the impact of Time-Based Product Development Practices on performance', P.J. Rondeau, M.A. Vonderembse, T.S. Ragu-Nathan and M. Cao develop a theoretical framework that describes relationships among TBPDP, performance, and end-user computing. Data collected from manufacturing managers and executives are statistically analysed. The results support the claim that end-user computing skill and end-user involvement moderate the impact of TBPDP on performance. As end-user skill and end-user involvement increase, the effect of TBPDP on performance becomes stronger. End-user skill and involvement in Information System development are essential in distributed data processing activities like TBPDP. This climate enhances creativity, knowledge sharing, and continuous learning.

In the next paper, 'A Multi-Purpose Hand-Tool Development: Implementation of a Collaborative Design Process in Aerospace Industry', B. Kayis and K. Hoang present their research associated with the successful development of a new multi-purpose hand tool in the aerospace industry. The collaborative design, development and implementation approach using the concept of 'real users as active partners', was identified as the key success factor for the high acceptance of the new product among users. Comparing to the prevailing practice of 'design for X' (DFX) where 'X' is various product life-cycle concerns, such as manufacturability, recycleability, serviceability, etc., the authors suggest that the approach of 'collaboration with extended enterprise' is composed of multiple parties in multiple locations focusing on collaborative design, or 'design with X', where 'X' refers to constituents of the extended enterprise. The challenges identified by the authors in the implementation of the collaborative design approach are to raise an awareness for a better, safer, and productive working environment; to build a supportive culture and transparency in operations; to have a collective objective and project goal; to exchange ideas on a continual basis; and to increase both individual's and the team's knowledge.

Customers' expectations are constantly changing due to the volatile marketing environment. Shortening product life cycle is an important issue to be addressed and its achievement requires a good collaborative environment for the product development process. However, collaboration is often hampered by limited information and communication systems. In the paper 'A Generic Model to Support Rapid Product Development: An XML Schema Approach', C.M.K. Lee, H.C.W. Lau, K.M. Yu, and W.H. Ip present a technical approach to providing a universal product information exchange standard. The proposed 'Product Information Markup Language' enables data exchange between traditional relational databases and knowledge bases, thus allowing knowledge management tools to access, manipulate, and exchange product data formatted with XML. In providing these capabilities the proposed system helps designers identify and respond to design interdependencies that might otherwise go unnoticed.

In the paper, 'A Case Study of Vehicle Cooling System Optimisation through System Engineering', R.A. Wade presents a detailed example of applying system engineering principles in vehicle cooling system design. The challenges in implementing system engineering principles, the author identifies, are that organisational learning that led to programme changes before project completion impeded the new product development process and mutually exclusive requirements, inhibited the system integration process and could have forced the system to operate in conditions known to lead to failure. The other challenges faced in correcting the system issue included working with independent organisation structures, tight programme timing, and changing evaluation methodology. The author points out that system engineering tools such as Parameter Diagrams and Limit Diagrams helped guide decisions on the programme. The application of system engineering principles led to organisational learning that improved the capability and confidence of the entire organisation, and the Chief Engineer guided the team to prevent design iteration and look at improved subsystem requirements. An optimised design solution, which satisfied all subsystems and established a robust cooling system design, was found. This paper presents an excellent example of how system engineering can be used in product development to resolve conflicted requirements, manage programme progress, and, therefore, enhance product development performance.

In the paper, 'Multidisciplinary Design Optimisation of Elastomeric Mounting Systems in Automotive Vehicles', Z. Ma and C. Qi present a design optimisation problem with multidisciplinary objectives for a general purpose elastomeric mounting system (EMS). The multidisciplinary design objectives include quasi-static, dynamic and stability targets. Reliability assessment of the optimum design is also conducted in order to consider uncertainties of the system parameters due to the manufacturing and assembling variations. Design optimisation of a real vessel-mounting system in an innovative concept vehicle is used as an example to demonstrate the feasibility of the approach developed. While the paper deals specifically with the design of elastomeric mounting systems, the introduced problem formulation and solution approach could be generalised to other design challenges that have similar problem structures. The paper represents an exemplary research work addressing design optimisation with multidisciplinary objectives.

Mechanical fatigue subject to external and inertia transient loads in the service life of mechanical systems often leads to structural failure due to accumulated damage. A structural durability analysis that predicts the fatigue life of mechanical components subject to dynamic stresses and strains is a computer-intensive, multidisciplinary simulation process, since it requires the integration of several computer-aided engineering tools and large amounts of data communication and computation. In the paper 'Structural Durability Design Optimisation and Its Reliability Assessment', B.D. Youn, K.K. Choi, and J. Tang develop an integrated CAD-based computer-aided engineering process to effectively carry out design optimisation for structural durability, yielding a manufacturable, durable, and cost-effective product. In addition, a reliability analysis is executed to assess the reliability of the deterministic optimal design.

3 Future research

Although the selected eight papers included in this issue provide a relatively broad coverage of 'Integrated Product Development' and 'System Engineering' issues, many other issues remain. We believe that research of IPD at the business level needs to include many other relatively unaddressed issues such as product finance, human resource requirements, and regulatory considerations. Further, efforts to bring together the concentrated engineering-focused research of system engineering processes along with broader business level integration research should yield great insights into the development and application of IPD processes. In sum, IPD includes both technical problems and business interactions. Research that recognises both of these perspectives will yield more complete 'design solutions' and development processes that are sustainable and amenable to organisational and behavioural constraints.

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