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Editorial

Claudia Eckert

Design Group, DDEM
The Open University
Milton Keynes, Walton Hall, MK7 6AA, UK
E-mail: C.M.Eckert@open.ac.uk

Marc Zolghadri*

IMS-Lab
Bordeaux University
351, Cours de la Liberation
33405 Talence Cedex, France
Fax: +33-5-4000-6644
E-mail: Marc.Zolghadri@ims-bordeaux.fr
*Corresponding author

Biograpical notes: Claudia Eckert is a Senior Lecturer in Design at the Open University and the former Assistant Director of the Engineering Design Centre in Cambridge, UK. Her research focuses on improving engineering design processes, engineering change management and comparing different design domains.

Marc Zolghadri works as an Associate Professor at Bordeaux University, France. His research interests include product development, coevolution of products and networks of partners, and design of extended products.

People have long been in awe of great technological works. They have admired tall ships, powerful trains, gleaming aircraft and fast cars; and have perceived these products as complex artefacts and triumphs of human achievement, but rarely did they think about what has been involved in designing, making and maintaining these objects. Explanations of these products are in terms of the physical principles that were employed and the way in which they work. The products are branded and marketed by what they can achieve and maybe by what they consume. The public perception is not totally dissimilar from the focus of academic research, which for a long time has concentrated on the engineering of the product – the technical, physical and scientific foundations that make these products work. Behind this a real understanding of the interconnected nature of product development is often hidden and many of the challenges of product development have long been unrecognised.

The sheer scale of large engineering projects is impressive in terms of the number of people involved, the number of components designed and the time scale of the projects. For example an aircraft has tens of thousands of components designed and developed by teams of thousands of engineers at the main aircraft manufacturer in conjunction

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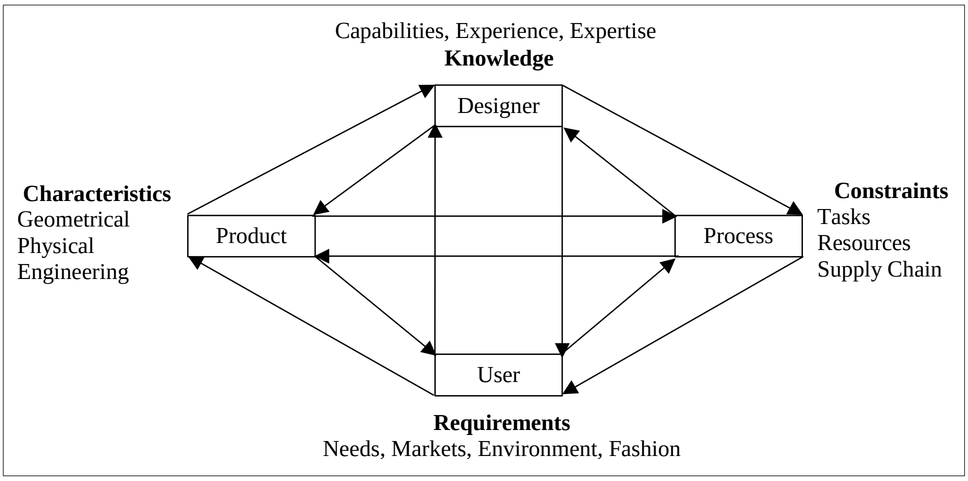
with a large supply chain over a period of about 5 to 10 years. Major components such as the avionics, the undercarriage or the engine are sourced from main first tier suppliers. These major components themselves are highly complex products with hundreds of components designed by large teams of people and long supply chains. For example, designers have commented in discussions that the design effort going into a jet engine is about 15 million person hours.

Figure 1, which is explained in more detail in Earl *et al.* (2005), shows the interrelation between different elements affecting the development of modern products. The technology itself is only one, very important, aspect of product development. A product is defined by its physical characteristics, but also by the elements that it shares with other products, through shared components, in product platforms, or shared elements of supply chains. The products are developed by people, who all bring their own experiences and expertise with them. Only a small faction of people is involved in the actual design of the components, many more are engaged in evaluating the product, preparing it for production, *etc.*, and of course in managing the complex processes that surround the development. The processes themselves are complex and bring together a very large number of tasks and stakeholders. They are heavily constraint by the requirements of the products and the practicalities of making these products in given time scales and budgets. Some of the requirements placed on the design of the product are derived directly from the users while others come from the wider market and the supply chain itself. Research has been directed at understanding how different elements of these complex interacting systems work and could be improved. For example much research is directed at modelling and simulating processes, where the question is addressed how processes can be described and analysed, so that their behaviour can be improved.

Figure 1 Interplaying factors in engineering design



Only recently some researchers have turned their attention to the relationships that exist between these different aspects of product development. For example looking at how the process by which a product is designed affects its characteristics and vice versa. The papers brought together in this special issue look at some these connections and address their relationships. The paper by Kinkel and Som reports on a survey of German manufacturing industry to identify why German industry has remained so successful in a competitive market, and highlights the enormous importance of R&D, which is often carried out in conjunction with partners at other companies or universities. There is a growing recognition of the importance to look carefully at the influence of all factors on engineering. For example the paper by Marle and Le Cardinal looks at the importance of the selection of people in the development processes and advocates to include people selection into the risk assessment of a development process, thereby combining soft people factors with hard technical issues.

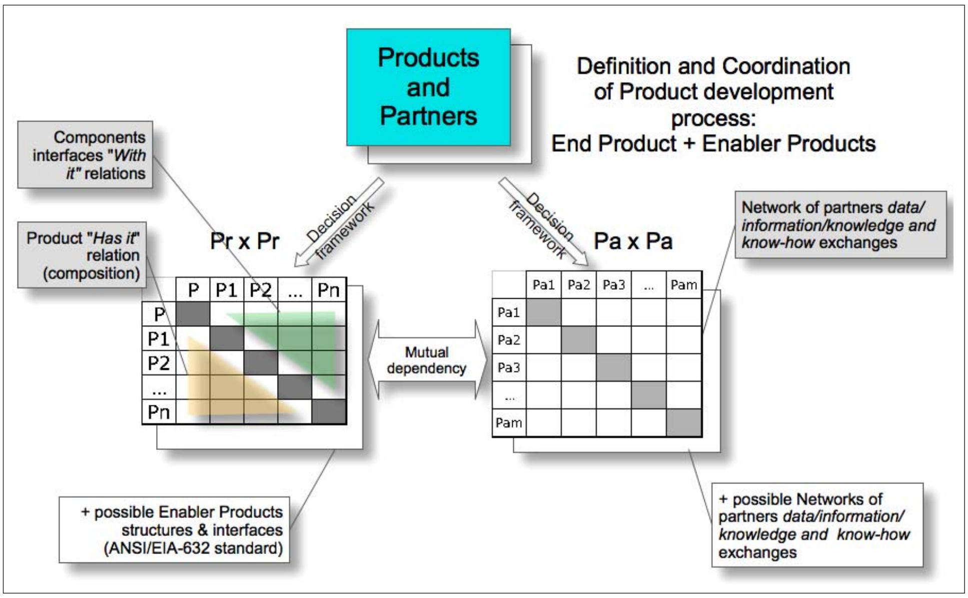
Throughout the development process a myriad of decisions need to be made, which concern this network of different factors. How these decisions are made in detail is still ill understood, as all participants need to juggle so many different considerations. This is very nicely illustrated in the paper by Ferioli *et al.* who look at the selection of ideas at the very beginning of the design process. Through an experiment they show how much early decision making is a combination of the rational application of carefully identified factors and intuition by experienced participants. Often experts can look at a design or a design situation and almost instantly know what to do. Without this ability to bring many factors together in an intuitive manner, people could not handle these complex processes. However, once a product has been designed intuition and tacit understanding are not enough to finish the process and expert use tests, computer simulations and mathematical models to evaluate their designs. The paper by Poncelin *et al.* is an example of design evaluation of product reliability based on a number of different factors.

Often it is not enough to look at a product in isolation, but in the context of other products with which it shares important factors. The people working on a project, often work on other projects at the same time and bring their understanding and also some of the problem across. The product itself often shares components with other products, so that changes to any of the products can propagate to different products. Process steps in production are both potentially hindered and enhanced by being shared with other products. Delays can propagate across products, but sharing process steps can also bring significant savings. The paper by Troussier *et al.* discusses the wider context of the entire supply chain of a product, which comes together to form a single virtual enterprise.

Figure 2 shows the connectedness of these different aspects of product development. Each of the papers picks up on different aspects of it. The product matrix shows the connectivity as a Design Structure Matrix (Browning, 2001) between different components and process steps. The partner matrix shows the project partners and the relationships between them. The products and the partners need to be coordinated and evolve over time. According to the ANSI-EIA632 standard (ANSI/EIA-632, 1998), an end-product process can be accompanied by enabling products, *i.e.*, products that are required for its design or production, but do not form a part of the final product.

Kinkel and Som analyse in their paper 'Internal and external R&D collaboration as drivers of the product innovativeness of the German mechanical engineering industry' the results of the 'European Manufacturing Survey 2006' with 1663 responses from different countries and industry sectors to understand the success of the Germany manufacturing industry, who specialises in complex often customised products. Over a quarter of the companies named innovation, technology and quality as their key differentiators, whereas price played a less significant role. As part of this research the companies highlighted the importance of research and development, both internally and with external partners, either other companies or universities and consultancies, who provide specific input. This paper demonstrates through a quantitative analysis the importance of developing supply chains throughout all phases of the life cycle process starting from R&D to production as well as the importance of running these processes effectively through approaches like simultaneous (concurrent) engineering.

Figure 2 Interconnections across the product development process (see online version for colours)



Marle and Le Cardinal argue in their paper 'Risk assessment method in project actor choice' that the selection of the people in new product development projects is a source of risk – and opportunity – that is often neglected in conventional views of risk. Usually risk analysis focuses on the execution of tasks during the development of the product or its life cycle, rather then the choices of the resources with which these are carried out. They highlight the importance of finding the right people to carry out tasks and analyse the ways in which problems can propagate across the network of tasks. They distinguish between the responsibilities for tasks and the ability to execute tasks and identify as sources of problem propagation inabilities in assigning technical and managerial roles, in supporting and endorsing the assigned roles, in managing assigned work packages and in being part of complex networks of people.

Troussier *et al.* argue in their paper 'Supplier-oriented and product life cycle management framework to support virtual organisations', that currently supply chains are put together and centred around the OEM, the original equipment manufacturer. Therefore PLM systems are structured according to OEM's needs and wishes. Instate they propose a bottom-up Global Supplier Network (GSN) approach, which enables information management of both the manufacturing equipment and its links with the OEM project. This involves active supply chain management and suitable PLM systems, which manage process and life-cycle data, in a way that fulfils the supplier needs. The

GSN is a virtual organisation, with clearly defined aims and new organisation models, which coordinate across suppliers and with the OEM. The paper proposes a framework to manage the supporting IT systems.

Ferioli *et al.* look at the very beginning of a product development process to the point when new ideas are generated and therefore need to be selected for further development, in their paper 'Understanding the rapid evaluation of innovative ideas in the early stages of design'. They report on the findings of an experiment, where a team of company experts was given to two hours to evaluate 138 ideas generated by student teams, which were presented to them in a standard format – a format similar to internal screening in the company. The experts employed a combination of objective criteria, like cost or technical feasibility, and subjective approaches. While they also used subjective criteria like the potential of market acceptance, which they state explicitly, they also just followed their impressions in 'feeling assessments' and made instant decisions for which no reason was given. They found that on average 'no' decisions were taken more quickly then acceptances and they spend the longest on 'may-be' decisions. The experts also spend more time on looking at ideas during the first 1/2 hours of the experiments then later, from which the authors conclude that the timing and relative position in the queue matters. In this rapid early selection manufacturing and supply chain issues were not considered explicitly, but would have been implicit in the expressed criteria.

Poncelin *et al.* again look in their paper on 'Design for electronic equipment reliability in complex systems' at the entire life cycle of a product, but this time from a reliability view point. Reliability is a very important aspect of the total cost of ownership of a product, which includes both the cost of making or purchasing the product, the running and maintenance cost and at the end the cost of recycling the product. This paper presents a mathematical optimisation model of reliability, which can inform design decisions, including diverse factors such as the technology or function supported or the operating conditions. Understanding the factors that influence reliability allows designers to make appropriate decisions in the design of the equipment, its components and operation environments through all phases of the design and production process. As such it can also support the selection of suitable suppliers. The paper concludes with a reflection on the challenges in introducing such a method into a company.

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