Towards a New Framework for Product Development

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Abstract

In the mid-1980s, Andreasen and Hein first described their model of Integrated Product Development. Many Danish companies quickly embraced the principles of integrated product development and adapted the model to their specific business and product context. However, there is concern amongst many Danish companies that Integrated Product Development no longer provides a sufficient way of describing industry's product development activity. More specifically, five of these companies have supported a programme of research activities at the Technical University of Denmark, which seeks to develop a new framework for product development. This paper will describe the research approach being taken, present some initial findings, and outline a vision of a new working approach to product development.

Introduction

The concept of Integrated Product Development (IPD) was created by Andreasen and Hein [1] during the 1980's, and has acted as a guide to industry ever since. IPD highlighted the need to concurrently address the product, production and market situations when developing products, and provided a structured framework for product design. The focus of IPD was to develop good business outcomes via a process that began from the recognition of needs.

On evaluating the original IPD model, we see that IPD was, in essence, a definition of professional behaviour in product development. IPD was a new paradigm of co-ordinated strategies, which combined design with the roles of marketing and production. Boe and Hein [2] state that the most important aspects of IPD were that it:

- provided a context for Engineering Design;
- linked the product development process to the goal of optimising business;
- provided a generic map of the product development process; and
- gave words and graphics to some important 'laws of nature' of product development.

Following its introduction, Danish industry was quickly exposed to IPD in several ways:

- a two-year campaign by the Federation of Danish Mechanical Engineering and Metalworking Industries;

- various meetings, seminars and courses carried out by the Institute for Product Development (IPU); and
- employment of graduates of the Technical University of Denmark (DTU) who had specialised in integrated product development and were champions of its principles;

The benefits reported by the companies who were early adopters of IPD include [2]:

- a reduction in product development lead-time;
- increased ability to reduce cost and quality problems;
- increased ability to meet customer demands; and
- less rework and fewer major loop-backs in the product development process.

However, in the fifteen years since the first articulation of IPD, the social context and the commercial and technological environment in which manufacturing industries exist has changed. Today, we would be very surprised to learn of any reputable manufacturing enterprise that has not responded to the challenges of IPD and see the benefits reported by those early adopters as targets for their own product development processes.

But during that period, we also know that the practices of those early adopters have moved beyond the original model. These companies are competing in rapidly changing markets and business environments, whilst developing increasingly more complex product and process technologies. We consider that some of the causes for these changes are:

- product quality developing to very high levels and becoming an accepted norm rather than a competitive lever;
- differences in expectation, interpretation and perception of quality between the customer and the company (and furthermore internally within the company) are causing a number of gaps, leading to low competitive edge;
- environmental concerns being translated into a range of product design efforts, and re-shaping the direction of industry development;
- products becoming technologically more complex and combining technologies that were previously left as discrete solutions (e.g. mechatronic products);
- the introduction of the concept of product families, where many products share the same basic architecture and certain base-components, but have an array of end-variants, to provide a continued product range;
- the further development of the product family concept to the activity of modular design, where the product is not only capable of being a family member, but also up-gradeable, easily repairable, and interchangeable;
- a significant shift in the way that products can be defined, due to the fact that they increasingly come as a package of hardware, software and services – industry is increasingly regarding the physical artefact (the former definition of a product) as carrier to the growing range of services that they provide;
- globalisation and uncertainty induces companies to create new product concepts and self define new or niche markets; and
- the need for companies to find another means of competition – time, cost, quality, flexibility, (and to a certain extent, environment) have all been key competitive dimensions for industry over the past twenty years, all of which satisfy the customer's basic needs/desires. Industry is seeking the next competitive dimension.

These issues are driving Danish industry to find a framework for product development that can cope with these many aspects. We consider that the original IPD model is no longer an adequate solution because it does not truly reflect modern product development practice in many manufacturing companies. This paper describes the challenge of creating a new product development framework, which both represents and guides industry in its systematic approach to creating new, innovative products.

2 The Search for a New Framework for Product Development

2.1 The P* research programme

The search for a new framework for product development to succeed IPD has been stimulated by five Danish companies: Bang & Olufsen, Danfoss, Nokia, Foss Electric and Oticon. These five companies, together with the Department of Control & Engineering Design at DTU, have established and are now supporting a research programme named P* (Product Development Programme). Initiated in 1998, this programme aims to provide deep insight into the needs and interests of Danish industry. Based upon emerging theory and scoping studies carried out in the P* companies, a number of issues have been identified, which are not currently covered by integrating models of product development.

The following eight themes crystallise the areas of significant importance to the P* companies (a more complete discussion of these topics by the authors can be found in [3]):

- life cycle oriented design and the universal virtues;
- product structuring (e.g. platforms, modular engineering);
- integration of technical disciplines (e.g. mechatronics);
- environmental issues;
- product quality;
- the role of IT in product development processes;
- human-machine interaction; and
- innovation.

2.2 Project PD2000

The progeny of the P* programme is a series of activities called PD2000. Figure 1 shows the critical elements of this P* project. Initial activities have included a review of international results to determine the 'state-of-the-art' of product development, an investigation of mechatronic design in the five P* companies, and a short study tour to the UK. The main elements of the PD2000 project are:

- a series of one-day workshops;
- insight reports;
- questionnaires; and
- interviews in industry.

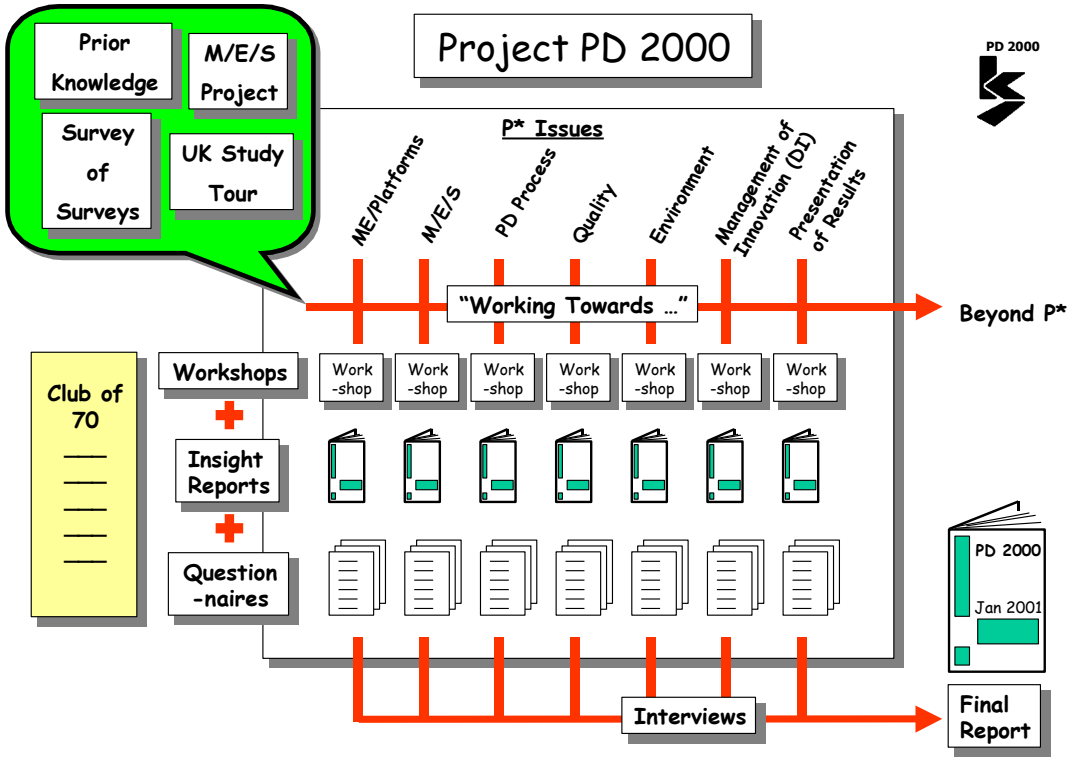

Figure 1: PD2000 - a series of activities supporting the P* programme

The one-day workshops focus upon one specific aspect of interest to the P* programme. The workshops are open to Danish industry and are generally attended by personnel responsible for the topic of discussion. We have identified a "Club of 70", which is a list of professional engineers who have an active interest in identifying a new framework for product development, and who are specialists or stakeholders in at least one of the themes. Selected members from the Club of 70 make up the participants for the workshops. Presentations by invited researchers and specialist guests are arranged to complement those given by industrialists. The workshop is hypothesis driven and goal orientated, inasmuch as we have predetermined ideas that we wish to validate by the end of the workshop. Most of the time is allocated to discussion, during which participants are asked to share their own experiences and be prepared to present their own examples, models, hypotheses, or results. The overall aim of each workshop is to obtain insight in to the current practices of Danish industry, seek insight into future trends, identify research needs, and validate hypotheses about product development theories, models, and tools. Each workshop is reviewed and evaluated, structuring the results against existing design research theories, models or known results. Follow-up interviews with industrialists enable clarification of specific issues, provide deeper insight and partially validate the results.

“Insight Reports” address the specific topics of interest to the P* programme. Each report has a "stand-alone" format, enabling it to be read independently of the others. However, they have a common structure that includes a review of collected research results; observations about Danish industry acquired from the workshops, interviews and other sources; insights in to current and emerging practices, identification of best practices, methods and tools; and the identification of future research needs. The purpose of each report is to communicate our

findings to readers and stimulate feedback and discussion. Consequently, each report includes a self-diagnostic questionnaire to establish the level of agreement with the results reported. The goal is to validate our insights by testing them in a wider cross-section of the manufacturing and design research communities.

As a consequence of the initial activities, the workshops, the insights reports, questionnaires, and interviews we aim to identify the phenomena that represent a new framework for product development. It will be characterised by real experiences, international results, and the collective insight of industrialists and researchers. It will be validated amongst the industrial and research communities, and based upon a strong foundation on design theory, methods and tools.

3 Progress with PD2000 and Initial Observations of Danish Industry

The PD2000 project is only partially complete. Many of the workshops have taken place and the process of writing the insight reports has begun. The first two reports, which consider product development from a company perspective, have been drafted and distributed to the P* companies for evaluation. Questionnaires have been included in the reports, but no formal process of collecting responses has been initiated. However, we are able to discuss some of our initial observations of the small sample of Danish companies active in the PD2000 project to date and consider the implications for a new product development framework.

3.1 The Product Development Activity

All the companies we have worked with on the PD2000 project are product developers, creating products either on a business-to-business basis or for consumer markets. All would be classified as "original equipment manufacturers". They design and develop products in-house, continue to have a high content of manufacture and assembly in-house, and undertake novel research and development in core technologies. All the companies have international sales and some operate globally. Consequently, the product development activity is important to all these companies, and without exception they all recognise its impact on the business.

Multi-disciplinary teams carry out product development projects, but we observe that different strategies are used to organise personnel. All organisation structures are based upon a matrix between functions and projects, but it is how individuals are deployed that differs. In some cases, individuals from different functions are permanently allocated to just one PD project for its duration. In others, individuals are allocated to several projects at once. In another, the "spaghetti organisation" allows a person the freedom to choose in which projects they participate. Yet another approach is to re-organise the PD team, changing personnel according to the phase of the PD process, i.e. different teams for concept and detailing.

However, whilst PD teams are multi-disciplinary in their organisation, the personnel involved tend to be those directly associated with the principal product development activities, e.g. engineering, production, marketing. We have little evidence that other stakeholders, e.g. production workers, service personnel, suppliers, end-users, are repeatedly involved in PD teams. A traditional design approach, where designers act as agents on behalf of all the

stakeholders, seems prevalent, but we have observed some encouraging examples of more mature working approaches:

- a furniture company who employ a teacher in a team designing novel school equipment;
- designers of medical equipment spending time in a hospital observing the operation of their devices in the true context of use; and
- usability studies of on-site service and maintenance operations.

The companies report that they have high confidence in their ability in detail design and use of computer tools, but they see the necessity to fulfil customer's needs more precisely and are increasingly putting more focus upon the product planning and conceptual design stages.

With respect to suppliers and their involvement in PD teams, the approach taken by most of the companies seems traditional with quite immature relationships with suppliers reported. The overall impression given is that design expertise is resident in the manufacturers and the specialist expertise of suppliers may only be utilised during detailing - supplier involvement at the concept stage is not evident. Similarly, co-operation with competitors is minimal - the exception here being to agree upon industry sector standards. Consequently, the companies tend to act independently and are highly reliant upon using their own resources to develop new and innovative products and processes. More importantly, because they do not create alliances they are unable to significantly influence the business environment, in which they work, and are vulnerable to external change. For example, nearly all the companies in our sample produce mechatronic products with a significant content of software, yet they have little or no influence upon new and future software standards. However, often they must provide devices that can interface to other proprietary hardware and software.

Where there are close relationships with the customer or a supplier, it is usually with respect to quality assurance and environmental control. One company, a pharmaceutical company, reports that they work very closely with both suppliers and customers to ensure the complete product life cycle meets their exacting quality assurance and environmental impact goals. As a consequence, they have effectively taken on the burden of defining, specifying, implementing and managing both quality and the environment for the complete value chain.

3.2 Product Structuring

The sample of Danish manufacturers that we have observed is particularly interested in the modularisation of its products and the creation of product families based upon platforms. The arguments for this product structuring approach are:

- platforms enable cost-effective production of product variants, allowing customers to obtain high quality products of near individual specification;
- platforms utilise similarities of function and solution (even reuse), avoiding unnecessary work, reducing risk, maintaining quality assurance and enabling faster and better product development; and
- platforms reduce complexity by decomposing the structure into independent units (modules), allowing better perception and understanding of the product structure.

Initially, modularisation and standardisation were means for stable markets and products. Today the challenge is to create platforms that allow flexibility and agility in product

definition. Visible platforms are shown to the customer, who benefits from a product family with many different variants in the marketplace. Invisible platforms help the organisation to be flexible, save money and to leave a basis upon which to become innovative in the future. However, there are limits to the approach: the same platform can only be added a finite number of times, due to the psychological needs of the customer to see 'new' products. The difference between traditional design carryover and platform strategy seems to be the management of knowledge related to the platform's issue (e.g. functionality and properties). Platforms could be perceived as limiting creativity in product design, yet in fact the level of creativity is freed from areas of danger and low interest to areas where the uniqueness of each variant is manifest.

Platforms require separate product development processes in which the platform is defined and all subsequent product variants are anticipated. Consequently, the platform has to be designed to integrate with design solutions, which have not yet been generated in detail (Figure 2). The challenge for research is to be able to explain the phenomenon of platform thinking and modularity and to relate the product structure to the technical and business goals of the organisation, customers and other stakeholders.

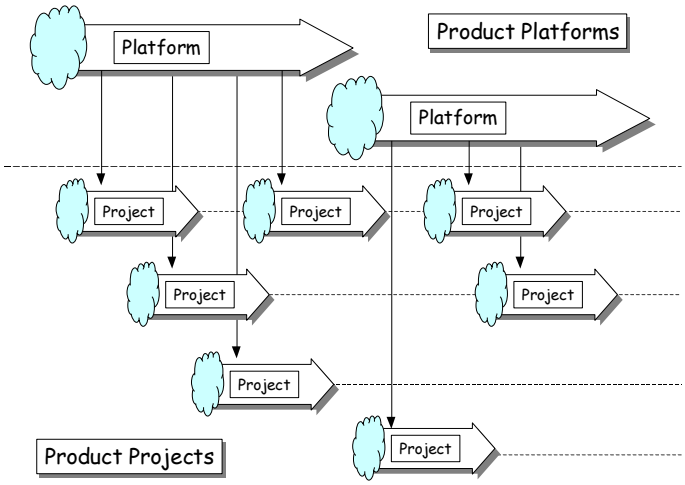

Figure 2 - Product development of platforms and platform variants

The necessity to create products with greater functionality, higher levels of performance and flexibility in operation has led most of our sample of manufacturers to adopt mechanical/electrical/software solutions. The mechatronic nature of the products has also presented some interesting observations. For example, at the concept stage, mechatronic solutions provide many options for fulfilling a function and designers seem to have difficulty "cutting the cake", i.e. deciding how and when to distribute functions between the different disciplines. Also, we perceive that mechanical and electrical design is often allowed to dominate the choice of solutions and that software is used for control and refinement of system behaviour. Consequently, software development often starts late in the design process. Yet it is known that software takes a long time to create and verify, and that it provides immense flexibility for configuring the performance and behaviour of the whole system (not only in the factory but also during its life in service). We also observe that whenever alternative solutions are sought from each discipline, whichever solution appears first is usually adopted. Consequently, we conclude that mechatronic design solutions are often *evolved* rather than *planned*.

3.3 Quality, Innovation & Environment

Product quality and innovation is high on the agenda of all our sample companies as their competitive advantage in based upon creating high quality, technically innovative products. However, when we delve deeper into the activities of the PD teams it becomes evident that "life cycle thinking" is weak and product quality is very much determined by the experience and expertise of the designers. For example, there is very little evidence of quality methods, e.g. QFD, being used to plan the fulfilment of customer's requirements and there is often a limited consideration of other stakeholders' needs, e.g. service, production. We observe that PD teams often have little or no formal contact with their customers and so have no feedback about what they really think about their products. Consequently, the designers are often "blind" to their customer's real needs.

To date, the tactic employed by most of the companies is to utilise experienced engineering designers, with a track record of product success, to lead the PD teams. These experienced designers, who can be either from within the company or external consultants with a good knowledge of the company's products, are expected to define the quality goals. Encouragingly, the companies seem aware of their inadequacies in this respect and are making efforts to introduce more methodical quality related methods, e.g. FMEA (which already is in frequent use), and develop a quality culture in the PD teams.

All the companies in our small sample innovate in the technological domain by undertaking research and development in core technologies. They all focus on developing novel core technologies, however, as discussed previously, the independent status of most of the sample companies limits the resources available to maintain a leading-edge position. The companies believe they have an "innovation culture" because new product ideas often come from personnel in the company, but these ideas tend to be variants of existing products. We believe the companies have a narrow understanding of innovation principles and that more could be achieved if they were to look at innovation in other aspects of their business. Innovation is possible at various levels of the product development process, or it could change the whole business strategy and definition of core business. For example, by taking greater responsibility of the whole product life cycle, a company can move up the value chain and enhance their products to become "total solutions".

Environmental issues have been on the agenda for some time now, but tend to come in waves, depending on industry sector and culture. In Europe, national, European or international (ISO) standards and regulations make it increasingly difficult (legally and economically) for companies to drop below agreed acceptable environmental levels. However, there is still a large gap between the present activities of industry and the targets of sustainability, laid out on a global level in the Bruntland Report [4]. We observe that our sample companies tend to suffer from a lack of overview and that eco-design is still managed from a reactive, rather than pro-active stance. The opportunity to innovate and create competitive advantage through eco-design is not fully appreciated by most, yet where companies have been pro-active they are reporting significant cost savings and enhancement of the brand reputation. Whilst we believe that the discipline of quality and innovation theory provide a framework for managing eco-design in product development, one company in our sample was emphatic that they had no intention of repeating the mistakes made when quality assurance systems were first introduced.

4. Vision of a new working approach to product development

From our observations, we see product life oriented design as the backbone of any new framework for product development. Product life thinking enables companies to take an insightful approach to quality, environmental issues, innovation, and product structuring. The growing complexity of product development clearly requires a new working approach that can cope with product variety; integration of complex technologies; extended product development practices; and the necessity to compete in a global marketplace.

We observe that there is a greater necessity to focus on the early stages of product development, where the strategy is defined and the requirements for the product are set. We note that the downstream product development activities (e.g. embodiment and detailing) have well-defined procedures, enabling a systematic approach to their execution. Consequently, we perceive that the activities of the product development process can be divided, allowing different working practices, which will take place in two different types of environment. These we call the 'war-room' and the 'machine-room'.

The war-room/machine-room vision provides a flexible approach to product development, maintaining overview throughout the project, whilst adopting the best of current practices. The war-room is used for strategic activities: specifying goals; controlling unification of requirements between stakeholders; seeing the consequences of one life phase requirement upon another (dispositions); identifying the supporting product life systems; and agreeing upon the 'guiding stars' for innovative product concepts, synthesis and review.

The war-room is an environment that will foster dialogue and creativity amongst the team. Display boards will provide the focal point of the working area. The multi-board concept [5] is a proposal for supporting life cycle oriented design, which we believe, overcomes many of the weaknesses observed with current design practice and enables the team to fully represent multiple-stakeholder criteria and ensure design effort is focused on product quality. It will help develop a life cycle oriented mindset amongst all members of the product development team and enable the team to share a common understanding of who all the stakeholders are, what their needs are, and what functions, qualities and properties the product must have. The multi-board display allows for the comparison and evaluation of the alternative concepts against all life cycle needs, and appropriate choices can be made for more detailed design development in the machine-room. Product design proposals can be properly adjusted to integrate fully with the project goals, synthesis can be co-ordinated on a continual basis throughout the project, decisions can be made with a full awareness of the life cycle consequences, and emerging results documented by modification of the multi-boards.

The routine, procedural and well-defined tasks of product development occur in the machine-room. After cutting the cake, these tasks can be distributed through the extended product enterprise (i.e. into the supply chain). Computer-based activities and processes are at the heart of the machine-room. Many product development processes are already carried out using these means, and the trend is that more will follow. The technology will save time during development, enhance the number of prototype alternatives that can be assessed, whilst cutting development costs. Consequently, product developers will gain more time and resources for the strategic activities of the war-room. The results emerging from the machine-room will be continually fed to the war-room, where their consequences will be evaluated and controlled.

5. Towards a new product development framework

The purpose of a product development framework should be to create vision, guidance and contributions towards an understanding and methodology, which should lead industry to higher competitive ability and efficiency. We consider the issues highlighted in Section 4 to be essential ingredients of a new framework. Our goal is to create a framework, which can carry types, procedures, models and methods for industrial product development, focusing on the understanding, insight, values and motivation of individuals.

To achieve this aim, we require consolidation of theory, research results and industry practice. This paper has highlighted the areas of significant importance to industry, which will form the basis of a new framework for product development. There is clearly a challenge in enhancing and co-ordinating these areas of research significance, in order to unite them in a single framework. The purpose of the PD2000 project is to support our quest for this goal and we believe we are making good progress towards our objective.

We believe that a new product development framework will enable industry to create products and solutions that will continue to satisfy the increasing demands of its customers, whilst being sympathetic to the demands of society at large.

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