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Internal and External Involvements in Integrated Product Development: A Two-Step Clustering Approach

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Abstract

The term Integrated Product Development (IPD) has been introduced as a focus for cross-disciplinary research and can have several forms, or manifestations, with regard to the existing disciplines such as concurrent engineering and design for manufacturing. Of central importance to IPD is the interpretation of the term "integration", particularly with regard to internal and external elements. However, there is not yet an explicit understanding of an appropriate degree of integration, or involvement, with respect to its different forms, that can assure successful implementation of IPD frameworks in practice. Through a review and clustering of the literature, this paper aims to address this challenge.

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Keywords: Integrated Product Development; New Product Development; Concurrent Engineering; Design for Manufacturing; Engineering Design; Literature Review; Process Modelling; Clustering Analysis

1. Preliminary

The term Integrated Product Development (IPD) is associated with improvement and management of New Product Development (NPD) processes through standardization. Over the past decades, due to its multi-disciplinary essence, it has been interchangeably used with other manifestations of process improvement and management, such as Concurrent Engineering (CE) and Design for Manufacturing (DFM).

In addition, along with the increase in complexity of NPD processes as well as such advancement in developing more sophisticated methods, tools, and techniques, there have been appeared multiple interpretations of the term "integration" in IPD. This has resulted in the emergence of topics such as Integrated Product-Process Systems, Integrated Product-Service Systems, Integrated Product Teams, Cloud-based Design and Manufacturing and Collaborative and Distributed Design. As a result, depending on the performance objectives, each of these aspects comes with a different combination and degree of involvement of traditional NPD elements (e.g., customer, design, manufacturing, assembly and supplier).

Therefore, an emerging debate in the research community is that of understanding what is the appropriate degree of involvement of modeling in IPD frameworks, with respect to the internal or external elements, that can assure successful implementation of IPD in practice?

The topic is fundamentally important in the context of IPD modeling since, on the one hand, there are many suggestions in the literature to involve the major NPD elements *as early as possible* during design and planning. On the other hand, others argue that these elements should be kept in mind *as much as possible* during design and planning. However, the reality of IPD modeling and implementation reveals that full integration (involvement) is not always achievable in practice due, for example, to the huge amount of mutual and often conflicting dependencies among stakeholders. Hence, there should always be a compromise between degree of involvement of internal or external factors (complexity of an IPD configuration) and the efficiency of its implementation.

The main contribution of this paper is to address the above debate, through reviewing, clustering, and analysis of the relevant literature with the aim to propose a common ground for the configuration of future IPD efforts. Our specific

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objectives are to understand: (1) which are the most relevant publications in the literature with respect to each IPD manifestation; (2) to what extent multiple internal and external involvements of NPD have been addressed in the literature; (3) which are the most influential sources of involvement that should be more prominent; (4) which kind of models in the literature are more appropriate for involving particular elements; and (5) what can be learned from the diversity of previous research in IPD in general.

To satisfy the above objectives, an extensive search of the literature was undertaken to find a sufficient amount of publications pertaining to each IPD manifestation (Section 2). The repository of publications was then reviewed, with attention on involving the internal (related to the product, process, organization, etc.) and external (related to suppliers, customers, partners, competitors, etc.) elements of NPD process and with regard to the different manifestations of IPD (Section 3). Using the functionality of SPSS® software, a two-step procedure was applied to cluster the publications based on their similarity in addressing the same range of NPD elements (Section 4). The paper finally concludes with a discussion of the findings and some remarks for future modeling directions (Section 5).

2. Research methodology

The literature of IPD is dispersed and contributes many facets. As a result, a step-by-step procedure was followed to narrow down the search criteria and collect a sufficient and representative set of publications:

1. A parallel search of Scopus, Engineering Village and Google Scholar with a set of 10 keywords, including Concurrent Engineering, Integrated Product Development, Design for Manufacturing, Product Development, Integrated Design, New Product Development, Integrated Product, Engineering Design, Product-Service Systems and Modern Project Management, within the scope of the past ten years (from early 2006 to the end of 2015). The goal was to find such advancements in modelling IPD.
2. A review of emerging titles and abstracts to determine if the found paper was somehow concerned with any kind of internal or external integration in PDP.
3. On ongoing filtering of a master list against the scope of the paper. In doing so, many papers were eliminated from the list, due to: (1) language of the paper was not in English; (2) it was a conference paper and later matured as a journal paper; (3) it was not possible to get the full-text; and (4) the paper was a duplicate.

Overall, 108 references were found, with a contribution of the order of 2030 citations in total (based on Google Scholar, up to 30 April 2016). The full-texts were downloaded to the Mendeley® platform and used for review and analysis. The composition of the publications is presented in Figure 1. Of the 108 papers, 79 were from journals and the remaining 29 were from conference proceedings.

In comparison to previous reviews (e.g., [1], [2], [3], [4]), the paper has a broader perspective of IPD modeling and covers not only multiple aspects of research in IPD but also its associated disciplines such as CE and DFX. This more comprehensive scope is intended to lead to a better understanding of the transformation of patterns and values over the years and consequently, enables the drawing of a picture of future IPD models.

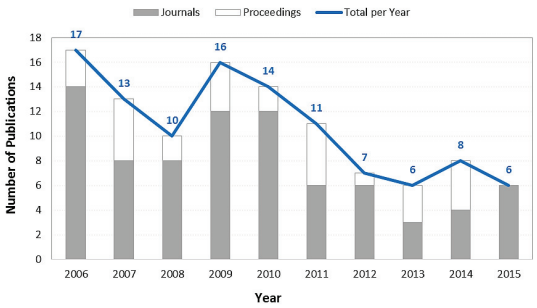

Figure 1. Year-wise distribution of publications based on their type

3. Literature review

The literature of IPD modeling has always been concerned with an ongoing debate around several aspects pertaining to its multiple forms (manifestations), successful implementation and configuration (structure). As far as this is related to the scope of this paper, the references were first classified based on their perspective on the term IPD and then studied based on their richness in addressing internal and external elements of the NPD process.

3.1. Multiple manifestations of IPD

Depending on the characteristics of performance objectives, scope of influencing and degree of involvement (integration), IPD has been viewed from so different ways in the literature and modelled using different sets of methodologies, tools, and techniques, nevertheless all of which have been concerned with as such integrating *as early as possible* and *as much as possible*. Two dominant groups of approaches emerged as the result, namely CE and DFX.

Accordingly, the references were grouped into three research themes: (1) CE, including any models within the domain of concurrent and simultaneous engineering; (2) DFX, including the models that believed the consequent phases of a product lifecycle should proactively be considered early during design, e.g., design for manufacturing and assembly, design for quality -cost, design for sustainability, design for environment, etc.; and (3) Other IPDs, including the models that identified IPD as an independent management style and also approaches that had different interpretations of the term *integration* (see Par.2 in Section 1). The year-wise frequency of these themes is presented in Figure 2.

Attempts were made to collect the samples pertaining to each theme big enough to make the clustering and analysis reasonable and also to cover multiple forms of IPD as much as