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Design Elements Of Corporate Functions In The Trade-Off Between Efficient Goal Achievement And Prevention Of Disturbance Impacts

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Abstract

In the context of sustainable management, organizational resilience is gaining importance. Manufacturing companies are increasingly exposed to external disturbances. At the same time, corporate functions today are usually geared towards efficient execution. A positioning in this trade-off between efficient achievement of goals and the prevention of impacts of disturbances is necessary. Crisis-resistant product development is of particular importance, as innovative products offer a promising opportunity to create competitive advantages and thus secure the company's existence or even enable a company to increase its market share in the event of a crisis. Based on a literature review and its structured consolidation, this paper presents design elements of product development for positioning in this trade-off. The overall dimensions of the design elements are strategy, organization, resources, product, as well as project management. The approach is transferable to other corporate functions.

Keywords

Design Elements; Resilience; Efficiency; Manufacturing Companies; Product Development

1. Introduction

The topic of sustainability has risen in importance and popularity, with manufacturing companies increasingly incorporating sustainable management and sustainable product development into their operational practices [1–3]. The recent COVID-19 pandemic has shown that organizational resilience is also crucial, highlighting its contribution to sustainable management [4]. However, businesses frequently overlook resilience in favour of efficiency. General management heuristics do not recognize creating transparency regarding uncertainties and related risks as a top concern. As a result, businesses struggle to strike a sensible balance between risk and return while making development decisions. [5] Therefore, it is vital for an organization to position itself and its corporate functions appropriately in this trade-off between efficient goal achievement and mitigating the effects of disturbances. Accordingly, the question arises: How can a company position itself in this trade-off between efficiency and resilience?

The corporate function of product development is essential to increase organizational resilience in manufacturing companies because it opens the doors to new innovative products and enables product-side adaptation to changing circumstances. This helps a company to create an edge over its competitors and increase its market share or even capture a new market segment. [6] Product development is a complex corporate function and thus can best be described using a variety of meaningful design elements. With the help of these design elements and their characteristics, organizations can perform evaluations to better position themselves in the conflicting goals. However, there is currently no comprehensive overview of the

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design elements that can be referred to. Hence, this paper aims to provide an overview of the design elements that make up product development.

As part of this work, a thorough systematic literature review and consolidation have been conducted to find the design elements as well as their superordinate dimensions. The design elements are clustered and assigned to one of the following dimensions: Strategy, organization, resources, product, and project management.

This introduction is followed by the fundamentals relevant for the paper in the second section. The steps of the methodology employed for this paper are described in the third section. An overview of the results is presented in the fourth section. The extracted design elements are listed with a brief description and an allocation to the respective dimension. Finally, the conclusion with the scope of further research is presented.

2. Fundamentals

This section presents the relevant basic concepts for this paper. It includes brief descriptions of product development, systematic literature review, Design Structure Matrix (DSM), and Idicula-Gutierrez-Thebeau-Algorithm-plus (IGTA-plus).

2.1 Product Development

Product development is an interdisciplinary process within a company that aims to create an innovative product for the market. The process starts by defining the initial objectives and requirements for the product, which are continuously improved and constantly adjusted. [7] Product development is a significant corporate function because the design and creation of products help organizations potentially gain an advantage over their competitors. Moreover, it helps corporations to diversify, adapt, and even reinvent themselves according to the changing markets and technological conditions. [8]

Product development can be explained in two ways. On the one hand, it is a process that controls the operations of development projects as well as how the individuals and teams engaged behave. It is possible to distinguish between sequential, iterative, and hybrid processes. [7] On the other hand, product development is defined as an organizational division that outlines the layout of the required workplaces. It consists of dividing product development into subsystems and assigning tasks to each of the subsystems [9]. [10,2] Furthermore, the product development process can be divided into different phases, such as the concept phase, the development and verification phase, as well as the planning and development of production processes phase [11].

2.2 Systematic Literature Review

A systematic literature review (SLR) is required to make the process of finding relevant articles, papers, and books organized and efficient. Figure 1 shows the most common steps for conducting a SLR despite the differences in various procedures. Literature reviews are categorized into four sections based on the main objective of the review: describe, test, extend, and critique. This paper falls into the extend category as the current literature has been reviewed to extract information and derive design elements of product development. There are different methodologies to conduct a SLR developed by various authors. [12] Therefore, a systematic approach based on [12] is developed to proceed with the literature review in this research project. The approach is described in the third section of this paper.

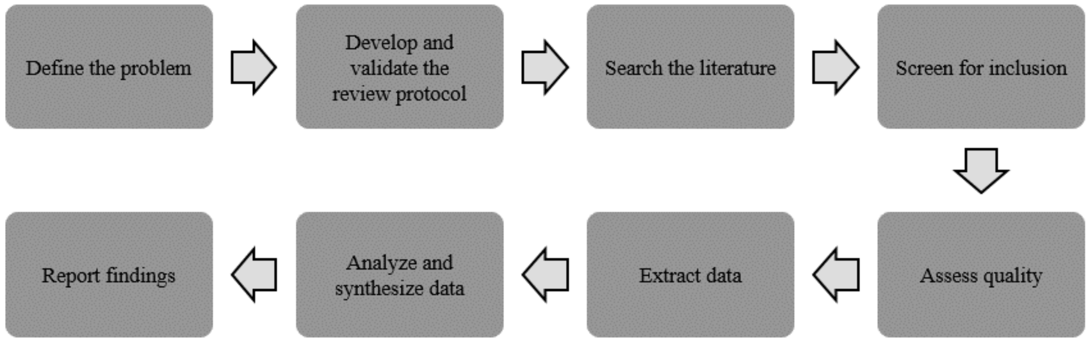

Figure 1: Process of systematic literature review [12]

2.3 DSM and IGTA-plus

As shown in Figure 1, one of the necessary steps of a literature review is the analysis and synthesis, which, in the context of this work, is the consolidation of the extracted data. This also requires a systematic approach, whereby DSM and IGTA-plus are the methodical procedures applied to facilitate this consolidation process.

DSM is a widely used tool for modelling, offering a straightforward, consolidated, and visual representation of a complex framework that encourages innovative solutions to challenges involving decomposition and integration. [13] A DSM is essentially a square matrix where the system elements are listed along the horizontal as well as the vertical axis. The off-diagonal cells of a DSM demonstrate relationships between the system elements, such as dependencies, interactions, interfaces, etc. [14]

[13] lists different types of DSMs. For the purpose of this work, an efficient representation of product development is necessary. Therefore, component-based DSM is the most suitable. A component-based DSM is particularly useful when system architectures are modelled based on the components and/or the subsystems and their relationships [13]. This kind of DSM is filled using the binary system in which a cell is marked if there is a relationship or an interaction between the elements. However, the binary system does not provide any information about the extent as well as the direction of the relation. [15]

With the help of a DSM, the components can be clustered into multiple categories. Although manual clustering can be performed, it is inconvenient for bigger problems. Consequently, computer algorithms are developed to fulfil this task. One such algorithm is the IGTA-plus [16], which is built upon the foundations of the IGTA [18,17,19]. IGTA is designed to find optimal groups by minimizing the overall interactions between clusters while simultaneously maximizing the interactions within clusters. This is achieved by shifting the individual components from one cluster to another. The algorithm assigns costs to all the interactions. The costs of the interactions within a cluster are weighted lower than the costs of the interactions between different clusters. As a result, the algorithm finds an optimal cluster for a component by minimizing the total cost. IGTA-plus is a significant improvement over the original algorithm in terms of the computational speed and the quality of the solutions. [16]

3. Methodology

The objective of this paper is to identify the design elements that describe the corporate function of product development. Figure 2 shows the procedure adopted in this project, which includes conducting a SLR based on [12].

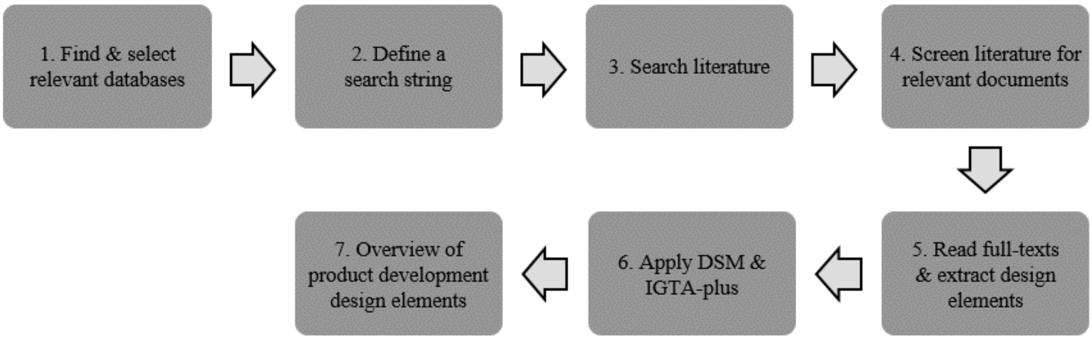

Figure 2: Methodological procedure for deriving design elements of product development

The first step is to find the relevant databases to search the literature. As a part of this project, a list of well-known databases is compiled, taking the database-information system of RWTH Aachen University into consideration [20]. The databases are then inspected based on the volume of literature, the availability of engineering literature in English or German, and the possibility of applying filters on the results. After looking at all the databases, Scopus and Web of Science are deemed relevant for the purpose of this work because of their unique capacity to aggregate results from various other databases, thereby enhancing the comprehensiveness of the data acquisition process, and their user-friendly interfaces. In order to find significant publications, it is necessary to define a search string for the literature search in the second stage of the methodology (see Figure 3). The defined search string includes terms in both English and German. Additionally, Boolean operators (i.e., "AND" and "OR"), as well as the wildcard (i.e., "*"), are used to formulate an appropriate string. The operator "AND" finds the documents that contain all terms connected by it, whereas "OR" finds documents that contain at least one of the connected terms. Therefore, it is often used for synonyms in a search string. The wildcard "*" is used to include the different forms of a word. For instance, "strateg*" would provide results containing words such as strategy, strategize, strategic, etc.

(produktentwicklung OR "product development") AND (gestalt* OR design* OR innovat* OR faktor* OR factor* OR konfigur* OR configur* OR organis* OR organiz* OR manag* OR steuer* OR regel* OR control* OR strateg* OR einstell* OR align* OR adjust* OR orient* OR optim*)

Figure 3: Search string for literature search

The results from both databases are sorted by relevance and citations, and the top results are taken into consideration for screening. Screening starts by removing all the duplicates in the results. A team of researchers independently executes parallel analyses of the titles and abstracts to filter out irrelevant publications. Subsequently, the full texts of the relevant publications are collected. However, it is imperative to note that not all full-texts are accessible or available, rendering them ineligible for inclusion in the ensuing review. Furthermore, the book [21] is included for the full-text evaluation, given its status as a foundational resource for teaching product development at RWTH Aachen University. Figure 4 illustrates the important steps of the systematic literature review, which constitute the third, fourth, and fifth steps of the overall methodology.

Scopus and Web of Science deliver 2881 and 1550 results, respectively, which contain the terms from the defined search string in their title. Given the practical constraints and time limitations associated with examining the entire pool of results, only the top 200 publications sorted by relevance and citation are selected from each database. Therefore, 800 of the total generated results are considered for screening. In the subsequent phase, a rigorous screening and assessment process is undertaken, encompassing the examination of the titles, abstracts, and full texts of the results, and those that do not align with the research objectives are systematically excluded from consideration. Consequently, a refined selection of 57 publications is deemed suitable to extract design elements of product development.

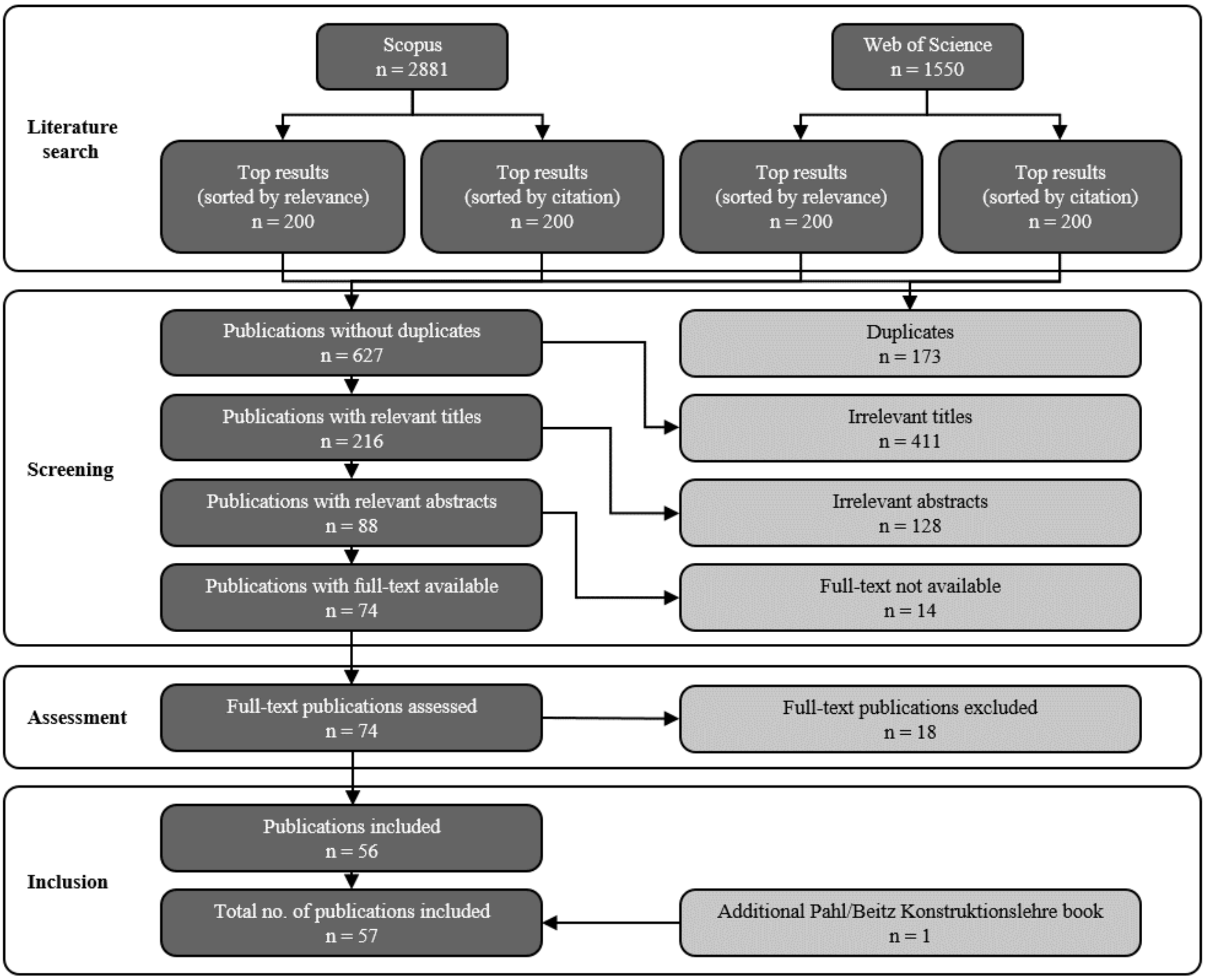

Figure 4: Systematic literature review based on [12]

After the first evaluation of the relevant publications, 195 design elements of product development are extracted from the available literature. Subsequently, all the duplicates and the design elements that are aspects of other design elements are excluded. As a result, 157 of the initial 195 design elements are removed. Further consolidation is essential to remove design elements that, though not blatantly identical, exhibit significant overlaps with other design elements. Both DSM and IGTA-plus are used to assist with this consolidation in the sixth step of the methodological procedure. DSM plays a pivotal role in streamlining the process of establishing linkages among the design elements. The IGTA-plus algorithm is subsequently used to group the design elements by utilising these links inside the DSM, which leads to the establishment of numerous distinct clusters. The remaining 38 design elements are inserted into a DSM, and the cells are filled based on the similarity between the design elements. IGTA-plus uses this DSM to analyse and group the design elements with the most similarity. The algorithm offers various adjustable parameters that influence the outcomes. Notably, one of the most decisive parameters is denoted as "pow_cc," which plays a significant role in determining the cost allocation associated with the size of clusters during the computation of the "Total Cost." A higher value assigned to this parameter corresponds to an increased cost attributed to larger clusters, consequently favouring the formation of numerous smaller clusters comprised of fewer design elements. In the present work, the parameter is set to “2” because it delivers an appropriate number of clusters in comparison to other values. As a result, nine design elements are taken out of further consideration based on their similarity to other design elements within the same cluster.

In the next step, the remaining 29 design elements are to be clustered into multiple dimensions. A new DSM is generated using these final design elements and is evaluated with a focus on content relatedness rather than mere similarity. IGTA-plus is applied again to determine the optimal groups by clustering the design elements. The groups of design elements are discussed and named by the group of researchers. Each group of design elements is known as a dimension of product development.

4. Results

This section presents the results that are obtained by conducting the described systematic literature review, and represents the final step of the overall methodology. Table 1 displays the design elements as well as the dimensions they are assigned to. A brief description of the design elements is also provided.

Table 1: Dimensions and design elements of product development

Dimension	Design Element	Description
Strategy	Innovation type	Addresses whether gradual improvements of an existing product are made or a completely new product is developed [22]
	Trigger of product development	Addresses the alignment to market pull or technology push [23]
	Design flexibility	Addresses the company's openness to new technologies and product development risks [24,25]
	Innovation openness	Addresses the extent to which a company applies open innovation [26]
	Sourcing strategy	Addresses the extent to which the company outsources tasks and resources [27]
	Portfolio management risk aversion	Addresses whether a company has a lot of large and high-risk projects or smaller and lower-risk projects [28]
Organization	Decision making	Addresses the degree of centrality of decision making [29]
	Development process	Addresses the structure and flexibility of the development process [22]
	Degree of cross-functionality	Addresses the degree of cross-functionality of teams in product development [30]
	Specialization of the employees	Addresses the balance between generalists and specialists in product development [31]
	Customer and supplier integration	Addresses the integration of customer requirements and suppliers into product development [30]
	Senior management involvement	Addresses the extent to which a company's managers are involved in projects and bear personal responsibility [28,32]
	Internal control system	Addresses the internal evaluation of employees and managers in product development [33]
	Training of employees	Addresses the methods used for further training of the employees [21,31]

Dimension	Design Element	Description
Organization	Global presence	Addresses the international diversification of product development [34]
Resources	Knowledge structure	Addresses the structure and storage of knowledge [21,31]
	Resources allocation	Addresses the allocation of personnel, materials and monetary resources in product development [28]
	Resources flexibility	Addresses the sharing or relocating of resources when necessary due to changing circumstances [35]
Product	Product category	Addresses whether the product is developed as an investment product or a consumer product [36]
	Product variety	Addresses the planned number of product variants [37]
	Product modularity	Addresses the degree of modularity of a product [30]
	Design for X	Addresses the determination of the favoured Design for X approach [38]
	No. of units	Addresses the planned number of units to be produced [21]
	Product durability	Addresses the planned durability of a product [21]
	Updateability	Addresses the updateability of products after manufacturing [21]
Project management	Project duration	Addresses the duration of a product development project [28]
	Project selection	Addresses the factors based on which a project is selected [39]
	Upfront feasibility	Addresses the steps that take place before the actual product development begins [40]
	Focus on simulation and testing	Addresses the use of simulations or rapid prototyping methods to test the products [32]

5. Conclusion

Many companies give high significance to efficient performance. However, focusing just on efficient execution makes a company vulnerable to disturbances. Manufacturing companies are realizing the importance of introducing organizational resilience. Therefore, in the context of sustainable management, a company must be prepared for external as well as internal disturbances and position itself effectively in this trade-off between being efficient and being resilient. One of the key aspects to increase organizational resilience is the corporate function of product development.

Since product development is a complex corporate function, it can be described meaningfully using design elements. Design elements provide an overview of the scope of a corporate function that can be aligned by management. Companies can use the design elements to position themselves in the trade-off between conflicting goals. As part of this work, 29 design elements are derived by conducting an extensive literature review. Subsequently, the design elements are clustered into the five major dimensions of strategy, organization, resources, product, and project management. Furthermore, the methodology introduced in this paper for deriving product development design elements holds wider applicability. It can be easily adapted to extract design elements of other corporate functions.

The presented topic is currently being researched as part of a doctoral thesis at the Chair of Production Engineering of the Laboratory for Machine Tools and Production Engineering WZL at RWTH Aachen University. The results of this paper will be applied in industry working groups and consulting projects to ensure their feasibility in industrial applications. The next step is assuring the comprehensiveness of the formulated design elements. For this purpose, interviews are being conducted with experts in the field of product development. In addition, it is essential to operationalize each design element by specifying its key characteristics. In the broader context of enhancing organizational resilience within manufacturing companies, the identification of corporate function goals and the recognition of internal and external disturbances are of paramount significance for strategic orientations. As an integral component of this research endeavour, methodologies are being developed to facilitate the identification of corporate function goals, as well as both internal and external disturbances. Additionally, an approach is under development to determine the interdependencies among corporate function design elements, goals, and disturbances. This holistic framework aims to empower companies with the strategic insights necessary to enhance their resilience while concurrently achieving their corporate goals efficiently.

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Biography

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