Industrial Design Structure: a straightforward organizational integration of DFSS and QFD in a new industry and market reality

Published Version:
Industrial Design Structure: a straightforward organizational integration of DFSS and QFD in a new industry and market reality / Frizziero L.; Leon-Cardenas C.; Galie G.; Liverani A.. - In: THE TQM JOURNAL. - ISSN 1754-2731. - ELETTRONICO. - 35:2(2023), pp. 1-23. [10.1108/TQM-11-2021-0314]

Availability:
This version is available at: https://hdl.handle.net/11585/912374.4 since: 2023-01-23

Published:
DOI: http://doi.org/10.1108/TQM-11-2021-0314

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Industrial Design Structure: a straightforward organizational integration of DFSS and QFD in a new industry and market reality

Received 10 November 2021
Revised 7 March 2022
5 July 2022
Accepted 31 August 2022

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Abstract

Purpose – The aim of this research is to enlighten the methodology model of Industrial Design Structure (IDeS) that integrates the internal and external customer feedback embodied both in methods of quality function deployment (QFD) and as basis of design for six sigma (DFSS) steps to systematically bring the information across the entire organization, saving overall product development time and resources.

Design/methodology/approach – The paper describes the state of the art enlightened to establish the disadvantages and challenges of other methods taken into consideration in the study like QFD and DFSS that, together with the need of companies to react fast to changes they need to straightforwardly implement product development information across all departments, leading to a mass customization infrastructure. Several application trials of this methodology have been cited.

Findings – The IDeS method has established to been able to integrate other well-known methodologies to gather technical specifications starting from voice of customers (VOCs) like QFD that served to canalize the generalist approach of define, measure, analyze, design and verify (DMADV) of DFSS in order to reach into a larger share of the organization and englobe by following the overall product design steps of an industrial project.

Research limitations/implications – The research approach chosen for this document presents the concept of a methodology ought to operate most internal branches in a company driven by product design requirements and guidelines. Therefore, researchers are encouraged to develop further studies on the IDeS method are required in order to adapt this methodology to specific management tools that would help to ease information gathering for immediate analysis and modification.

Practical implications – The paper implicates that a need to interchange information systematically across all subdivisions in the organization, as brisk response to VOC reactions is needed to thrive in the market nowadays, leading to a fast product customization scene. However, the industry is heading into adopting an individual customer-centered product conceptualization ought to be driven by design as a key for individualizing an object. Afterward by taking this concept broadly and adopting it would lead to implement a company organization that would be directly affected by the customer's input.

Social implications – The methodology described aims to enable organizations to portray fast and accurate product prototyping, by exploiting technologies from Industry 4.0.

Originality/value – This concept proposes a method to canalize the implementation of DFSS by using the DMADV approach, whilst assessing the challenges of adaptation and keeping up with cultural pace that impacts the behavior of buying and consumption and moreover implementing a seamless communication within all departments in the organization to share the development progress and change requests by using similar information technology tools. This would imply important savings in resources, whilst delivering quality products to the society.

Keywords IDeS, DFSS, QFD, Six sigma, Engineering, Quality, Industrial design

Paper type Conceptual paper

1. Introduction

The aim of this study is to establish the potential that Industrial Design Structure (IDeS) methodology builds up for shaping the development phases of industrial projects, by creating a link between the design section across the rest of the company organization, integrating execution tools from design for six sigma (DFSS) product development, together with exploiting the big data, Internet of Things and high bandwidth connectivity from the Industry 4.0 technology. This approach proves to be the best for delivering products and services ought to be focused on the customer demand and continuous evolution of such increased use of digital tools across all branches of the industry, from product conception and feasibility analysis, design consistency assessment, virtual and physical prototyping and until quality control tools. Adaptability of the shared data is required to be unfolded to other organization departments, enabling to take inputs from all stakeholders involved, from product conception toward production, quality control and logistics, and the correct implementation of such is of great importance in order to throw a high-quality product that would be economically feasible to the organization.

Since early organization structure guidelines established by Mintzberg (1989) outlined that the technical core was listed as one of the key elements for establishing an organization's know-how, the same of which has to be in a seamless feedback with other main units of the organization, enabling it to communicate with main technical and administrative support staff that would connect directly to the management responsibleness, as seen in Figure 1 organizations proved to be more effective if they provide an environment that transmits enough feedback to the technical core, reaching a balance between technology and process development. Although this core must deal with great complexity, uncertainty and interdependence, accurate feedback to this area is needed from the top management in order to know in a better way about important change requirements in technology and know-how that would determine important variations in the organization itself. The society impacts technology choice (Luderer *et al.*, 2019; Mintzberg, 1981).

Additionally, Kohli and Jaworski (1990) introduced the idea of organizing the structure by focusing solely on customer satisfaction; that switch would mean organizations to focus in the market orientation theory. Successive studies from Ramani and Kumar (2008) and DiRomualdo *et al.* (2018) expanded the later model by suggesting interactive cycles to reach to guide organizations to drive the changes. Nonetheless, it is not easy to build an organization entirely oriented to input from customers; this approach would depend on a reliant integration between customers or market analysis with most of the business processes (Latyshova *et al.*, 2015). Eventually, companies have driven through expanding the customer knowledge analysis with the help of modern data analytics tools to discover the evolution of the most profitable customers and new areas for future market product introductions. This involves the need to enable each area of the organization to accurately understand customer-related data. Consequently, an organization could attract and retain the most valuable portion of the market by creating value to the customer; this would directly impact on the entire chain created to generate value, as later approaches on social responsibility (Ali *et al.*, 2020).

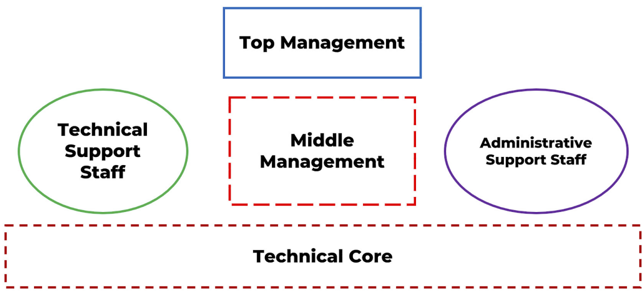

Figure 1.
The main entities of an organization

Statement was confirmed also by Narver and Slater (1990), Powell and Bartolome (2020) and Seno *et al.* (2019) who also underline the importance of taking into account each stakeholder across the entire value chain creation for better results in a cross functional organization.

Moreover, as market behavior shown to head toward choosing individualized products, companies are moving for adopting a strategic opportunity of switching to customer-driven processes by creating new procedures that adopt the will of every customer (Jørgensen, 2009; Medini *et al.*, 2019). Other analysis by Alt *et al.* (2019), Neneh (2018) and Oyner and Latyshova (2009) established that nowadays the volatility of the customer behavior turned the individual customer orientation concept in a more objective way for market analysis, and differentiating or customizing a product or service is useful to even get extra information about the customer maximum necessities. Therefore, increased data analysis capacity in tools from Industry 4.0 have enabled companies to develop complex evaluations to gather as much detailed information (Perez *et al.*, 2018) that can give out the optimal solutions to the challenges solved with the integration of tools for manufacturing 4.0 (Figure 2).

However, dedicated manufacturing 4.0 technologies (Lin *et al.*, 2018), aided with artificial intelligence (Balamurugan *et al.*, 2019) gave the opportunity to exploit high data bandwidths in order to optimize information sharing across all the organization, giving the stage to new era manufacturing sequence, in which digital technologies are present seamlessly across the entire development process, namely circular manufacturing (Delpla *et al.*, 2022), from the early conception of customer-oriented targets (Ahmed *et al.*, 2021), initial 3D drawing and digital prototyping (Lazorík, 2021), until the ultimate automation and manufacturing with additive manufacturing technologies using Internet of Things (Ashima *et al.*, 2021; Parmar *et al.*, 2022) (Figure 3) and quality control (Dutta *et al.*, 2021; Silva *et al.*, 2021) solutions of which offer midterm cost-effectiveness (Shivajee *et al.*, 2019).

2. Theoretical framework

2.1 Quality Function Deployment (QFD)

QFD is a structured method ought to define customer needs and requirements and then translating into specific plans to create a product that meet those needs. This methodology, created in Japan in late 1960s by Professors Shigeru Mizuno and Yoji Akao (Akao, 2014), is among the best-known approaches to translate the "voice of the customer" into customer needs and requirements; this tool is well-known and used in design for six sigma to gather the product requirements straightforwardly.

The QFD method displayed on Figure 4 starts with a basic, six questions' process (who, what, where, when, why and how) that are used in order to determine the elements in the

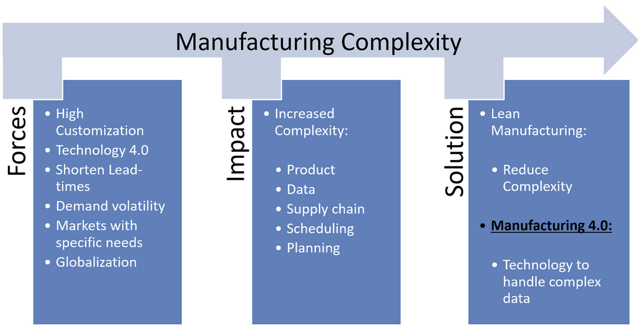

Figure 2.
Manufacturing complexity assessment

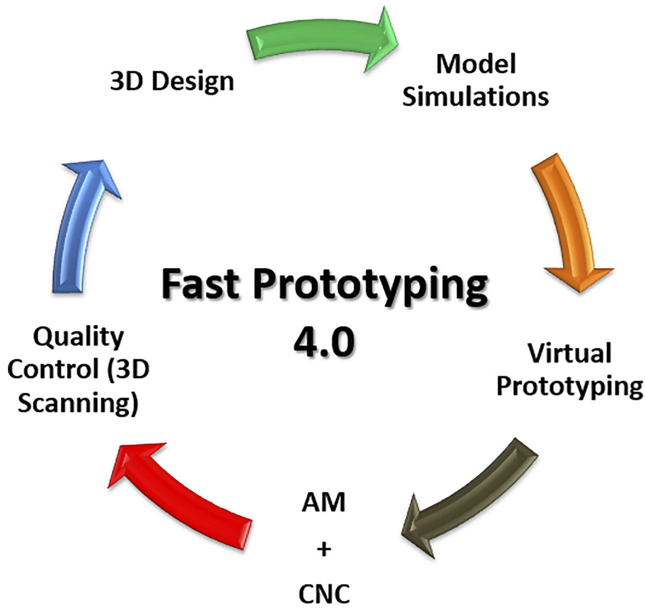

Figure 3.
Manufacturing 4.0 technologies in product development

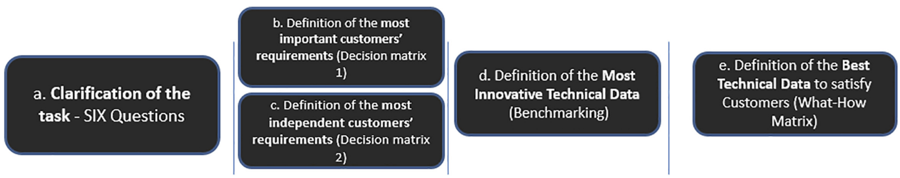

Figure 4.
Six main steps for the QFD method

decision matrixes, depending on the accurate customer segmentation, by which technical specifications are obtained based on the results gathered of the decision matrixes and the benchmarking analysis. QFD guidelines have been widely adapted to product development in most industries (Erdil and Arani, 2019) from information technologies (Ping *et al.*, 2020) toward the food industry (Vanany *et al.*, 2019), service quality (Adiandari *et al.*, 2020) and chemicals (Gandara *et al.*, 2019) until medical services (Hasibuan *et al.*, 2019). As of today, the QFD method is still a very straightforward approach to improve business practices, by analyzing the potential markets to operate, as well as customer lifestyles and technology. Modern QFD is developed according to the new ISO 16355 standard that underlines interaction with today's information technologies to better reach customer satisfaction (Mazur and Belt, 2017). QFD output would be a customer-centered technical specification.

2.2 Design for six sigma (DFSS)

This methodology, as defined by Baker (2003) and widely studied thanks to its great adaptability to most production industries (Gijo *et al.*, 2021) that could be individually fit to convenience for product development (Bidikar *et al.*, 2021), design process, improved specifications (Su and Su, 2019) and internal process improvement (Shojaie and Kahedi, 2019; Pai *et al.*, 2018) or as a business process management method related to traditional six sigma (Yang *et al.*, 2018; Madhani, 2021). This approach, introduced by Motorola engineers in the mid-1980s led to a process driven to continuous improvement and afterward has been widely diffused across most industries, from engineering, energy management, electronics development until finance and marketing. This methodology could be implemented through the sequence process of *define– measure– analyze–design–verify* (DMADV), as outlined by Baptista *et al.* (2020), Cartagena Méndez (2021) and Li *et al.* (2018) among others and shown in Figure 5. Whereas the second approach given by *define–measure–analyze–improve–control* (DMAIC) (Jamil *et al.*, 2020; Soundararajan and Janardhan Reddy, 2019; Prashar, 2020; Shipa *et al.*, 2021) is aimed to improve products or processes at six sigma quality levels; therefore, a product or service has to be created beforehand (Selvi and Majumdar, 2014). Previous product research exercises applying the DMADV sequence in diverse industry sectors such as electronic devices (Purushothaman and Ahmad, 2022), home appliances (Bidikar *et al.*, 2021) and transportation (Rajendran and Popfinger, 2022). Therefore, DFSS final output by using the DMADV approach would be a customer-centered product concept, as findings of such are reported in Figure 6. However, DFSS lacks the knowledge of adaptation and must focus in keeping up with people's cultural shifting that impacts the behavior of buying and consumption (Nurcahyanie *et al.*, 2020); it must be flexible enough to deal with rapidly changing environments (Antony *et al.*, 2017);. another research outlined the high level of e-waste generated in the last generation, so a critical need to update the process is needed (Echegaray, 2016).

2.3 Conceptual framework – Industrial Design Structure (IDeS)

The conception of product development has evolved drastically in the last 15 years with the introduction of technology-driven advanced design tools ought to speed up overall time to

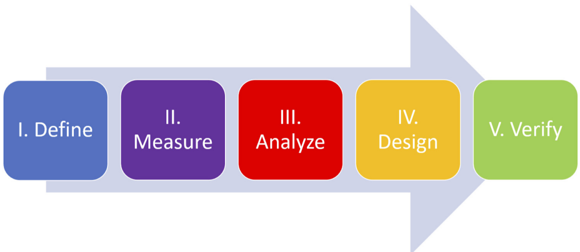

Figure 5.
DFSS sequence process of DMADV

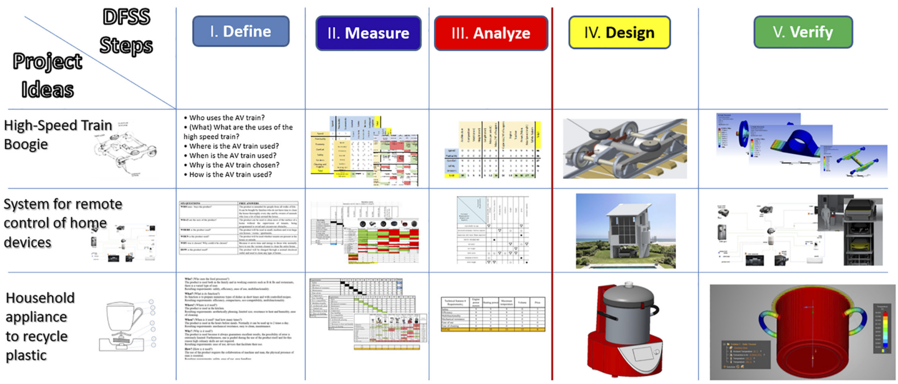

Figure 6.
Project development using DFSS sequence

market. Therefore, high adaptability in early stages in product design processes is critically needed where most important decisions are made to the product functionality, quality, manufacturability, cost and environmental performance (Gu *et al.*, 2004), followed by various studies ought to prove the standpoint of design, as the main driver to better deal with known and unknown changes (Han *et al.*, 2020; Lv *et al.*, 2018) toward sustainable solutions (Cong *et al.*, 2020b), in addition to open architecture products toward a circular economy solution (Mesa *et al.*, 2019), using Industry 4.0 (Fu and Liang, 2020) (Cong *et al.*, 2020a; Kerin and Pham, 2020) later establishing the concept of design thinking (Liedtka, 2018), as a tool to drive innovation centered on the human behavior (Jaskyte and Liedtka, 2022), as a strategic management approach (Sandro, 2021) and as an implementation approach within large businesses (Tomlinson, 2018). Not surprisingly, companies have been following a new product implementation strategy in recent years. The original approach to the project was historically referred to as “Stage-Gate”, such that at the end of each design phase a series of project status checks and validations (milestones) were performed. This is therefore a series of activities arranged in a time series. Today, companies prefer to align the various project phases as temporally as possible, from design and planning to prototyping and manufacturing process fine-tuning, so that any economic, logistical or functional issues related to the process can emerge from the early stages of its development.

Thereafter, is the proposal of the IDeS structure to develop products aiming to organize all steps involved in the management of industrial projects across the whole company organization. This method draws a guideline for best efficiency in rapid product development by exploiting Industry 4.0 tools for data analysis and 3D computer-aided design (CAD), computer-aided manufacturing (CAM) and computer-aided engineering (CAE) technologies that are demonstrated to be exploited for achieving accurate, fast product prototypes (Frizziero *et al.*, 2022). Its strength lies in the fact that the entire product development activity is schematized according to a set of rigorous and efficient methodologies, so that small companies that lack individual roles for experts in the context of markets, engineering and business, can understand how to use the tools introduced with Industry 4.0 to accurately bring new products useful to consumers and capable to bring the innovation that is most valuable to the consumer.

The method establishes the creation of continuous feedback links between the design structure with the other departments related to product development across the organization. Likewise, the main three macro phases of this concept are exposed in Figure 7 summarizing the entire industrial product design processes (setup, development and production). Consequently, the main IDeS output is a customer-centered, technical and demand-wise secured product design company organization. This is obtained by structuring the organization transversally with quick adaptation in today’s industrial challenges and being able to train new professionals into the skills required for obtaining good results with manufacturing 4.0 in the company, obtained by joining

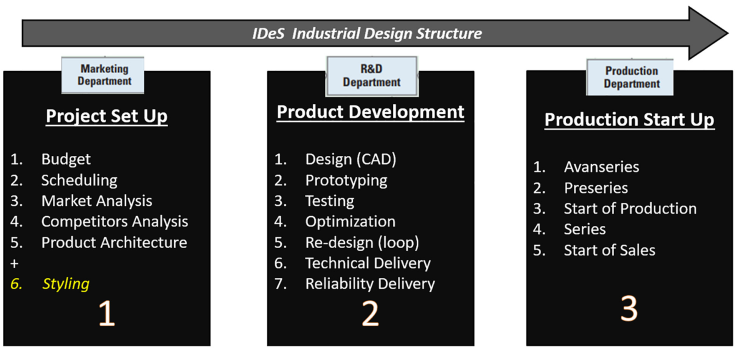

Figure 7.
IDeS methodology for product and process design

all organization departments from product developers to manufacturing and quality control areas. In the end, this information would switch an organization's effectiveness in maximizing consumer profitability (Burton and Obel, 2018) from the traditional, known methodologies centered in product effectiveness, as previously introduced by Maas (2000); this evolution has to be carried over the entire value chain (Volkov *et al.*, 2018) until redefining the sales structure (Thaichon *et al.*, 2018) therefore establishing a modern organization structure that would interactively update the knowledge of customer behavior and the evolving to understand the demand of specific requirements that would deliver exclusive value to its users.

The implementation of the IDeS method has been discussed and demonstrated in early product design research findings carried out by the affiliated institution of the authors that proposed this methodology as an innovative organization method for product development by providing product prototypes for different industry sectors ranging from the mobility solutions (Frizziero *et al.*, 2022), marine (Frizziero *et al.*, 2021) until medical (Frizziero *et al.*, 2019) examples of which are seen in Figure 8.

Additionally, the scheme shown in Figure 9 summarizes all stages of IDeS, the main technologies related to them and the tools applied. The work divided among the three main categories (project setup, product development and production start-up) is simultaneously deployed and continuously updated. Problems that might arise throughout the project are studied at the outset to speed up the timelines as much as possible and partial overlap between the various stages is sought as far as possible to increase efficiency by decreasing time and enabling dialogue for sharing errors, problems and solutions.

The first phase, called project setup, is leaded by the Marketing Department; this encompasses the list of activities shown in the diagram, and each activity makes use of specific technologies, constantly changing, going to stimulate research in finding and if necessary, developing the solutions that allow for greater overall efficiency, for example, shown in the image is the Gantt chart, benchmarking as a competitor analysis and various product architecture development methodologies such as QFD or Stylistic design engineering (SDE) regarding to product style and design. The next process is product development. This phase is mainly the responsibility of the R&D Department and includes the seven main stages shown in the figure above. The first of these phases shown is that of CAD that includes the use of some specific software for the purpose, mainly 2D and 3D modeling, examples of which are listed among the most widely used similar with the prototyping phase that makes use of the most advanced digital construction technologies available at the time and adopted as needed, with the ultimate goal of obtaining a technical viable prototype, ready to be evaluated as needed. By using the latest technologies, it is also possible to work on a virtualization of the product,

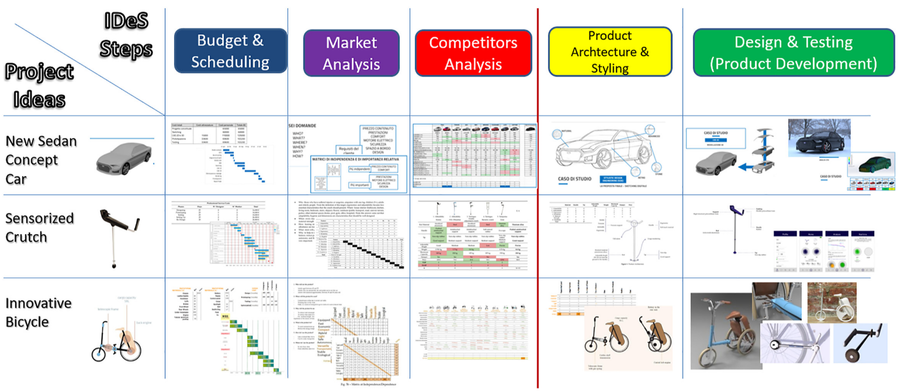

Figure 8.
Project development using IDeS sequence

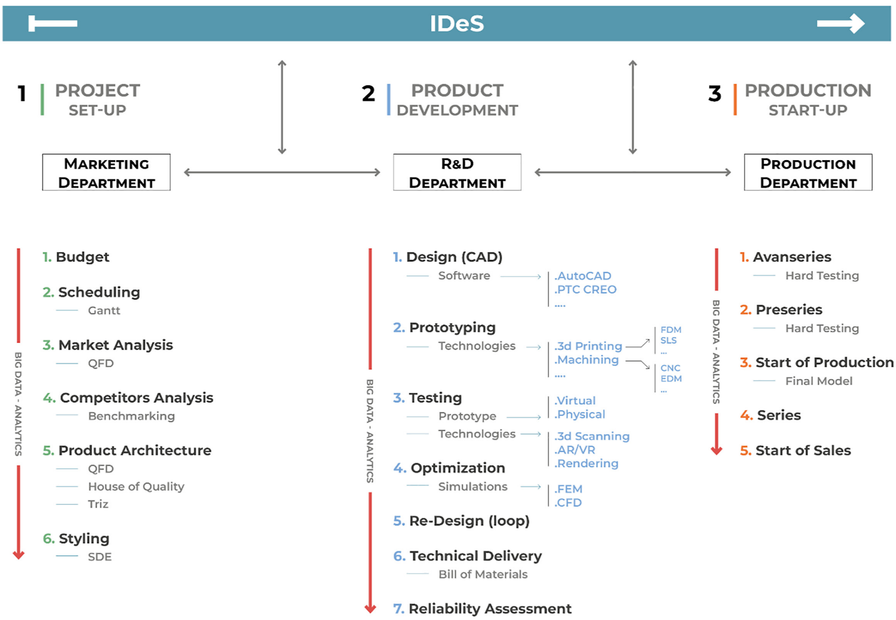

Figure 9.
IDES method deployment: tool overview

through the creation of virtual prototypes that allow the evaluation of specific aspects, avoiding, when possible, the realization of physical models except when strictly necessary, so as to contract the timeframe, decrease the economic expenditure and the environmental impact resulting from the realization of many prototypes destined to be destroyed, often in 1:1 scale leading to the testing phase. Because of the previous step, testing can be carried out either virtually or physically. In the first mode, it is possible, in addition to carrying out the appropriate structural simulations, to go in for form checks and simulations of the product's functionality, so that the bulk of the findings can be made on the virtual model and errors and problems corrected in real time, arriving at testing on the physical model with already a good experience on the product and making it as quick and efficient as possible. This loop continues until it is finished and then proceeds to production start-up. In this last phase all tests and checks are carried out on prototype models that are gradually becoming more definitive and closer to what will be the series version of the final model, so that we can finally proceed to the preparation and start-up of the production chain and market entry.

3. Research methodology

One of the types of DFSS, as mentioned early in Figure 5, is that referred to by DMADV. This approach is given to achieve six sigma quality standards in the creation of a product. Therefore, a correlation was found within the tools applied across DMADV processes (Wang *et al.*, 2016; Mouaky *et al.*, 2018) and the tools applied across IDeS structure.

(1) Integration of QFD into DFSS

Even though the six sigma approach has become the key method used to improve business processes and problem-solving, a well-engineered implementation process according to each own company's nature is required to guarantee the success of DFSS (Brue and Launsby, 2003; Dias *et al.*, 2020); various studies of successfulness of DFSS by Ericsson *et al.* (2009) and Swarbrick (2018) concluded that companies very often have their own procedures to develop the work tasks, so there is a need of creating structures and tools within the concept that could adapt the implementation of DFSS to most individual situations (Dias *et al.*, 2020). Subsequently, the main steps of QFD are known to be defined as a customer deployment tool by DFSS (Baptista *et al.*, 2020). This tool is widely used to evidence the voice of customer (VOC) data; therefore, the six questions are used in products (Johnson *et al.*, 2006) and services (Purushothaman and Ahmad, 2022) in the Define phase, as well as Measure towards both Decision Matrixes and Benchmarking, and using the What-How Matrix with Analyze. Synthesis of such integration could be seen in Figure 10.

Mainly speaking, QFD is the tool used by DFSS to help companies to gather VOC-sourced technical specifications and built the house of quality (HOQ) (Deshpande, 2016; Wang *et al.*, 2020), the process aimed to ensure an adaptive integration across DFSS during project definition, measuring and analysis areas for most industrial sectors, as shown in Figure 11.

Other research findings were about QFD application into DFSS in different industry sectors by means of complex-shaped mold design and manufacturing by Fatahillah *et al.* (2022) and Karasan *et al.* (2022), a conception of a green transportation vehicles (Cronemyr and Huge-Brodin, 2021; Rampal *et al.*, 2022; Giacobone and Mincolelli, 2020), until design methodologies improvement (Vimal *et al.*, 2021) and services improvement (Chan *et al.*, 2021).

(2) DFSS integration into IDeS

A right leadership approach enriched by the proper infrastructure must be supported by a straightforward strategic planning and managerial development. Many organizations have been deploying DFSS to build six sigma momentums in the area of design and development for their products and processes (Yoon and Byun, 2012), as evidences were found about major budget and schedule run over in applied systems. DFSS guidelines must play a key role in product design and research in order to achieve process sustainability (Gijo *et al.*, 2021; Ferryanto, 2008). In this way, IDeS methodology offers the capability of embracing the

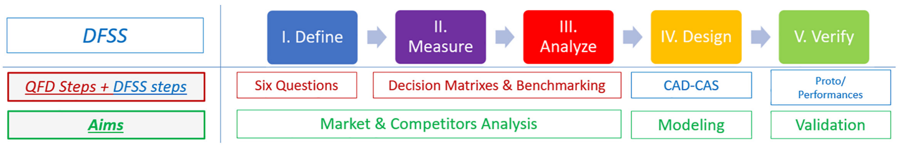

Figure 10. QFD vs DFSS: synthesis of the methods' integration

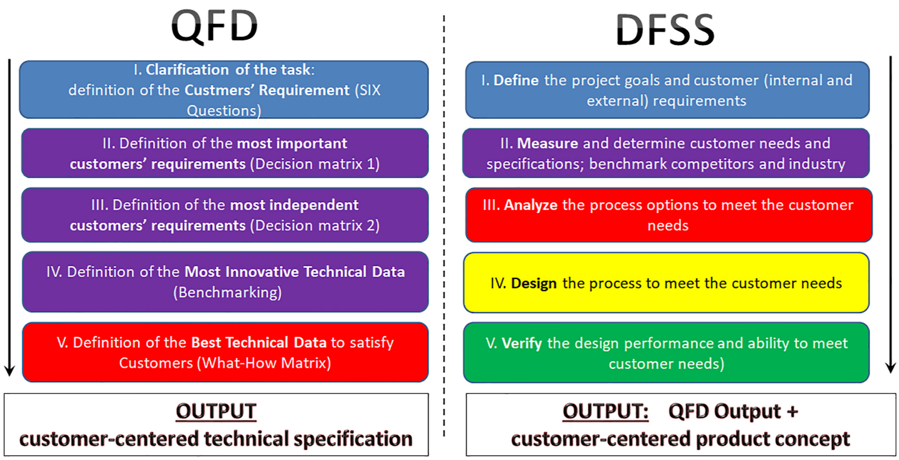

Figure 11. Outline: integration of QFD into DFSS

support of a major part of the organization, sharing information to reduce waste and internal bureaucracy time, whilst helping them to systematically grow into sustainability (Ericsson *et al.*, 2009).

In addition, the HOQ tool from DFSS has been used to assess the ultimate need to outline a method for product development, in line with benchmarking of existing research from Cooper (2019), Kang *et al.* (2018) and Setti *et al.* (2021) in the example shown in Figure 12. This tool aims to find out the customer requirements of a product, based on a QFD method.

Therefore, DFSS DMADV steps could be channeled, complemented with guidelines from lean productivity (Ikumapayi *et al.*, 2020) and correlated in Figure 13, to be integrated into the proposed IDeS methodology across its main three phases as seen in Figure 14, in which a complete coherence of using the DFSS methods into a wide organizational methodology could be also noticed.

Moreover, Figure 13 showed in detail, the list of the tools used by DMADV on IDeS the same that ought to be applied, partial or totally equal to the tools used by the proposed IDeS method. The similarity on the inputs, output characteristics and target process outputs resulting of the tools of DFSS.

However, DFSS roles can originate challenges in an organization according to a six sigma point of view given the fact that product development tasks that are distributed over the entire organization from a product concept are not usually conceived at an expertise level (process driven) rather than an idealistic model (Cooper, 2019). Moreover, at an operations management level, or better said, the processes of production and logistics are also key infrastructure elements in today's organizations in order to get a holistic understanding of the decisions made in the previous phases (Reche *et al.*, 2020). Researchers have outlined the benefits of applying DFSS methods adding up to Industry 4.0 technologies (Sallati *et al.*, 2019; de Medeiros *et al.*, 2018), and that could also be used internally to efficiently share important,

			Functional Requirements										Customer Competitive Assessment			
		Direction of Improvement	▲	◻	▲	▲	▲	▲	▲	▼	▲	▲				
Relative Weight	Customer Importance	Customer Requirements	Convenience	Differentiation	Coordination	Hardware + Software	Data Analysis	Stylish design	Attention to detail	Product Development Time	Flexibility	Top Quality Level	Our Method	Method 1	Method 2	Method 3
13%	9	Cost Effective	●	●	▽	▽	▽	▽	●	●	○	●	4	1	3	3
9%	6	Customization	●	●	▽	▽	●	●	●	●	▽	●	3	1	1	2
10%	7	Coordination	○	▽	●	○	●	▽	○	●	○	●	3	2	1	2
9%	6	Technology	●	▽	○	●	●	○	○	○	▽	○	3	1	3	2
6%	4	Smart	▽	▽	●	○	●	▽	▽	○	○	▽	1	1	3	2
6%	4	Creativity	▽	●	▽	●	▽	●	●	▽	○	▽	4	1	1	1
13%	9	Market Driven - VoC oriented	○	▽	●	●	●	○	●	●	▽	●	3	3	3	3
13%	9	Time saving	●	●	●	●	●	▽	▽	●	▽	●	3	1	2	2
9%	6	Adaptability	●	▽	▽	○	▽	●	▽	▽	●	▽	2	3	1	1
10%	7	Compliance	●	○	○	○	○	○	●	●	▽	●	2	1	1	1
		Importance Rating Sum (Importance x Relationship)	661.19	455	485	506	610	357	557	691	243	679				
		Relative Weight	13%	9%	9%	10%	12%	7%	11%	13%	5%	13%				
		Our Product	4	3	3	3	2	4	4	3	3	3				
		Competitor 1 (Cooper, 2019)	2	1	2	1	1	1	3	2	1	2				
		Competitor 2 (Kang et al., 2018)	2	2	1	2	4	1	2	3	2	1				
		Competitor 3 (Setti et al., 2021)	3	1	2	3	3	2	3	3	2	3				
		Technical Competitive Assessment														

Figure 12.
HOQ IDeS method assessment

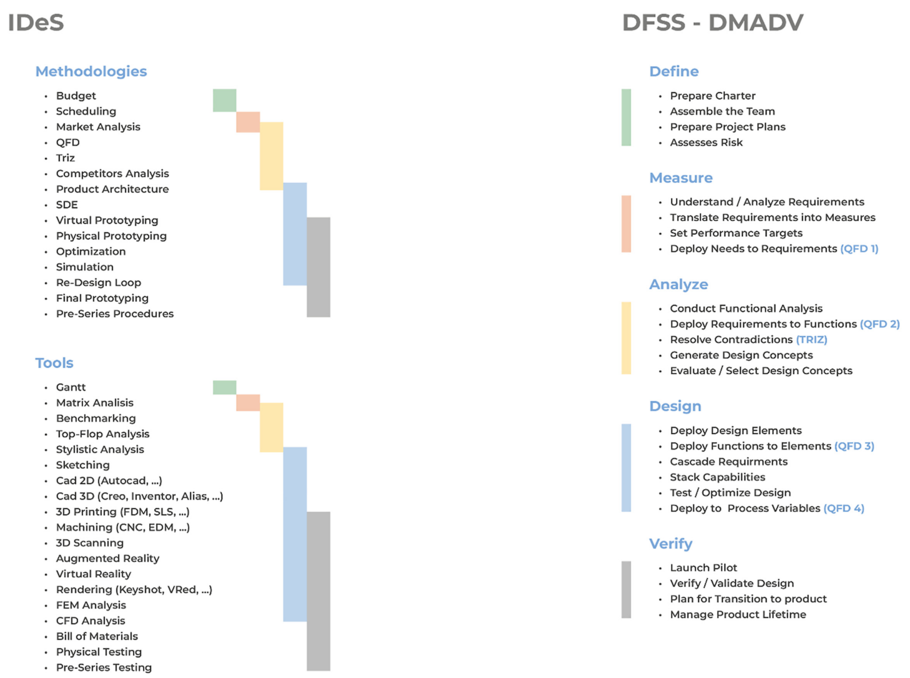

Figure 13. DFSS and IDES tool comparison and overlap

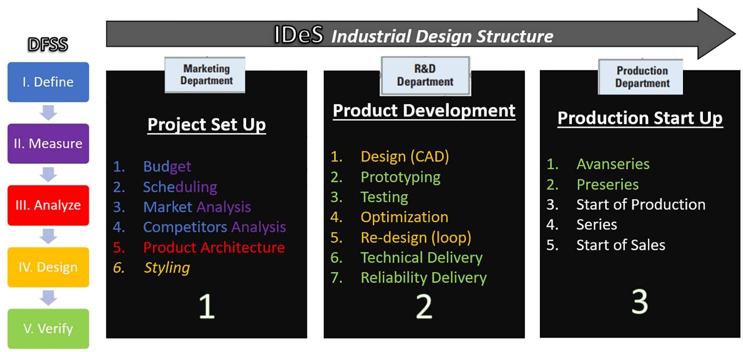

Figure 14. Integration of DFSS into IDeS

updated data throughout the entire organization. This could affect the final product development time, as well as configuration and overall quality levels, during the avanseries units (process design) throughout the first manufactured and reliability growth-driven studies carried out with the preseries units in which the final production processes are validated before the start of production (SOP).

(3) IDeS as a methodology for organization structuring with quick adaptation in today's industrial challenges

Historically, companies lacked to understand the compromise of including manufacturing engineering and production from the start in product development practices that often results in a product arrival to market that lacks a defined manufacturing process, delivering poor process efficiency and poor process quality that leads to low profitability (Miles and

Roberts, 2019). Even though wide research has been made about improving the existing product development methodology of DFSS, authors agree that implementing DFSS to the reality of each sector made hard to present a general process model as achieved by the six sigma approach (Patel and Desai, 2018). The results of Miles and Roberts (2019) shown that 42% of surveyed consultants found difficulties at implementing DFSS and 38% found QFD and lean processes difficult to implement as well. Therefore a number of models based on DFSS have been proposed by Shokri and Li (2020), Ericsson *et al.* (2015), Patel (2017), Berryman (2002) and Soderborg (2004) among many others, findings that demonstrate how important is to have a tailored model true to every single reality. Nevertheless, a comprehensive, reliable method that considers the actual benefits of unified, cross functional interactions across the whole organization to speed up development times could be useful to conduit of organizations to implement DFSS in their organizations more efficiently.

Moreover, the approach proposed with IDeS would aid companies to systematically interact with all organization levels, therefore reaching all stakeholders' involvement into each project that is needed to reach industrial efficiency leaded by customization. Findings by Daft *et al.* (2010) correlated the concept of design into five of the author's seven main pursuals established by organizations (Figure 15), concluding that specific inputs and decisions from the top management and project leaders are key to be communicated and implemented into the design and styling department, whose outputs would spread systematically throughout the rest of the organization, affecting importantly the timing for decision-making in other departments. This would determine a different strategy for adapting the cultural behavior and environment across the entire organization.

Moreover, a different schematization would be required to arrange leadership within the organization based on the stages led by the product design phases that is to fully interact participants from all involved departments from early product feasibility and conceptualization analysis until production start-up. This change could suggest that a different scheme is required in a modern matrix-schemed organization in which the head of product design (style and engineering) would help the top management to better perceive upcoming challenges and efficiently take decisions as well as finding opportunities and threats, as seen in Figure 16. This approach establishes the value to appropriately design and engineer each individual component, adding up to an overall product success. The technical and style design departments could oversight digital information sharing based on latest technologies of Industry 4.0 as augmented reality (AR) (Xiong *et al.*, 2021), cyber physical systems (CPS), as well as other technological tooling and methods that also aid the pro-ecological design and assessment of sustainable product development practices (Paprocki, 2019) to convey product development information across all project stakeholders, helping to ease implementation costs by saving important resources, time and proving value savings over time (Miles and Roberts, 2019).

Afterwhile, IDeS would englobe all individual-skilled engineers from all departments into a single area called product engineering (PE), in which its knowledge would be spread systematically through the development stages.

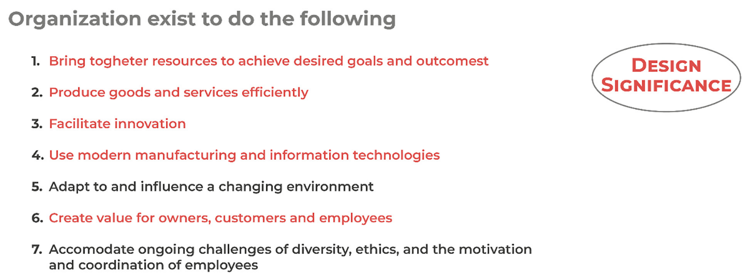

Figure 15.
Importance of design to reach the goals of an organization

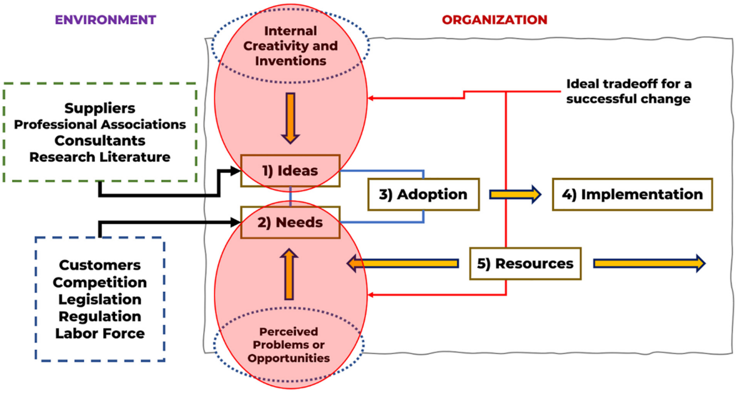

Figure 16.
Ideal trade-off for initial product decisions

4. Findings and research challenges

Numerous applications of IDeS have already been presented in the literature. Remarkably, the industry application range varies from the context of automotive car design and mobility solutions to biomedical and health care. This shows that an application of the described methodology is not constrained to a particular context but is suitable to most industrial areas whose product has to be sold to the final customer.

Different product prototypes and case studies were presented from different industry sectors like automotive (Frizziero *et al.*, 2022), marine (Frizziero *et al.*, 2021) until medical (Frizziero *et al.*, 2019).

4.1 Case study

Further, a case study applied to the development of a new product according to the IDeS methodology, is shown in Figure 17 and helps to understanding it. The request was to develop a new city car model. The first thing IDeS requires is the determination of a project budget and the time scheduling constraints of activities, typically governed by a Gantt chart showing the start and end day of each activity. This is followed by the market and customer

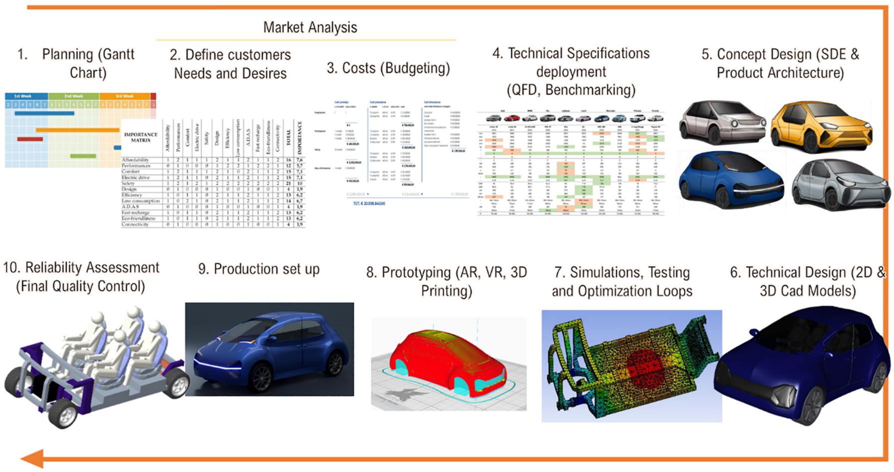

Figure 17.
Case study of IDeS application – city car

needs and desires ought to define the target market and customer segment to which the product will be targeted (young people, adults, the elderly, men, women, commuters, city dwellers only . . .). Therefore, an analysis of competitors cannot be missing, i.e. companies operating in the same market segment. Benchmarking makes it possible to understand which product features rival companies to put greater investments, thus outlining which ones need to be focused on to win over competitors and bring innovation. The next phase concerns the application of stylistic design engineering, a methodology for valuation of the stylistic trends that can be associated with the product (retro, advance, natural, stone, futuristic and so on) so as to choose for the best one, in line with the design specifications (volumes, geometries, maximum allowed overall dimensions and so on).

Instead, the product development macro phase includes the CAD design of the vehicle and, poststructural verifications performed with virtual finite element simulation tests, an initial physical prototyping of the product or some of its parts take place. This is followed by rapid prototyping and experimental testing phases for structural validation of each vehicle component. At that point, the product bill of materials (BOM) will be fully defined, and the organization of the manufacturing process and the first series prototypes of the vehicle can proceed.

Consequently, the IDeS method has proven to being able to track down the entire development stages of an industrial project, since the birth of the idea, from a “white sheet” project definition and then adding up budget and scheduling targets toward a market definition and positioning, continuing with product and process engineering until the SOP milestone. In this way, IDeS embraces a wide organizational management and traceability that otherwise is impossible with general management tools like QFD and DFSS, as seen in Figure 18.

Conventionally, customer requirement management entails an iterative process aimed to gather the needs, constraints and conditions from the end users, interpretation practices until reaching tangible product specifications (Hehn and Uebernickel, 2018). Afterward, the customer satisfaction is issued again to redesign the product in the upgrading phases (Zhang *et al.*, 2019). Nowadays, agile contexts in organizations collect data from users continuously after the launch of the product and use this to portray technical improvements (Sjödin *et al.*, 2020). However, digitalized services nowadays allows to systematically incorporate the request for satisfaction of customer needs to validate the existing performance (Poth and Riel, 2020; Montagna and Cantamessa, 2019). Hence, testing and validation phases will no longer follow the conception of the product but coexist in a continuous circle. Although today it is not possible to find this continuous circle of execution, satisfaction and validation in every sector, this is the direction that can be hypothesized (Cantamessa *et al.*, 2020). Moreover, today’s conditions require to spread customers’ demands on all areas, aided by proper infrastructure and tooling to deliver the information, including physical and/or virtual models in which all parts of the organization can relate to (Figure 19) including process simulations ought to achieve a flexible manufacturing performance (Zghair *et al.*, 2018) and virtual reality (VR) applications that could manage project-related outlines in all areas across most development

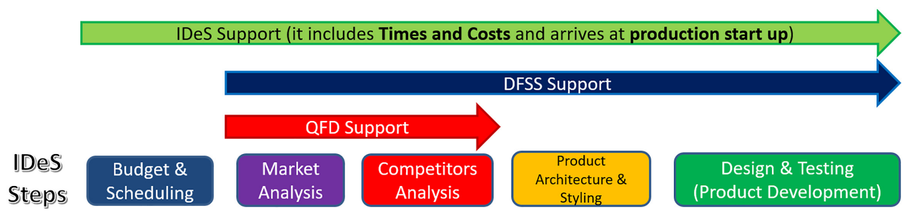

Figure 18.
IDeS methodology embraces QFD and DFSS as it trades off product development with budget and scheduling

stages from environment evaluation (Vitali *et al.*, 2021), through preliminary customer-driven product assessment (Vanacore *et al.*, 2021), until virtual manufacturing (Peruzzini *et al.*, 2021).

5. Discussion

Figure 20 summarizes the fact that IDeS methodology for product design and development could integrate other well-known approaches intended for quality assessment like DFSS, and tools for specifications collection like QFD. With this, IDeS proved to have a wider approach to execute projects concentrated mainly on VOC inputs, awareness of which must be expanded across the entire organization in this way helping companies to improve the organization plan ought to react sooner to the continuous market and technology changes.

Moreover, the concept of IDeS summarized on Figure 21 has the potential to drive companies to rearrange their managerial organization to be compliant to the market reality at the present day. Unifying the platforms used to identify client requirements to share product information across the enterprise would increase the efficiency of management instruments to reach productivity and save important time and resources (Kjaer *et al.*, 2019).

Nevertheless, further research based on IDeS method application is required in order to evaluate the inclusion of specific management tools that would help to ease information collection and sharing driven by Industry 4.0 technology. Figure 22 summarizes the application of this method into the organization.

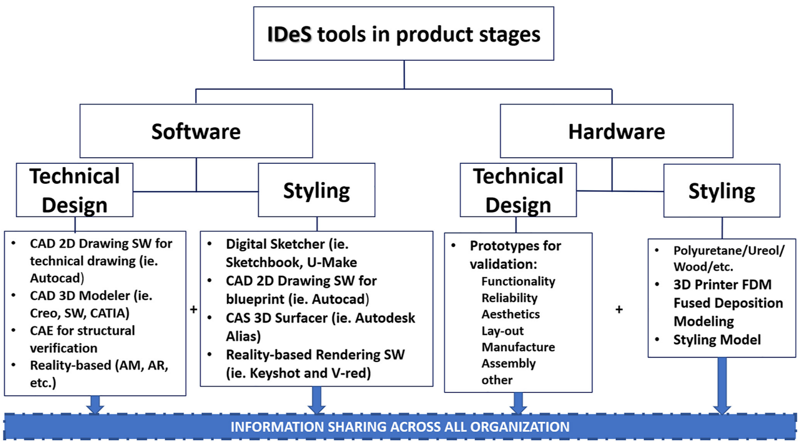

Figure 19. Tooling used in IDeS that include styling and engineering design areas

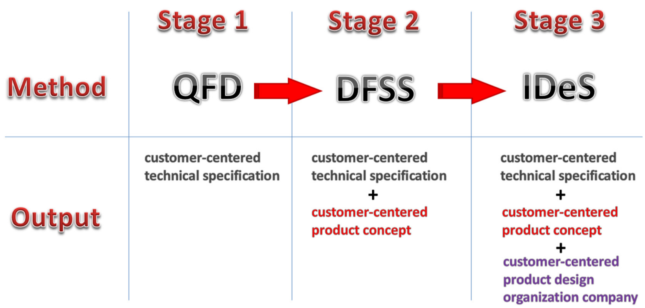

Figure 20. IDeS implementation of QFD and DFSS

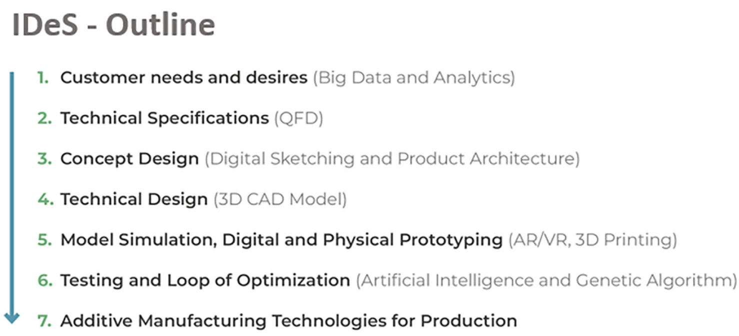

Figure 21.
Outline of the IdeS method

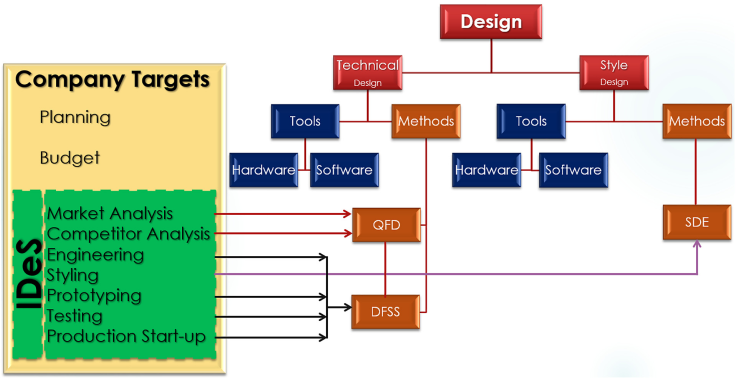

Figure 22.
Summary: IDeS methods to apply into the organization

6. Conclusion

The conception of IDeS as an integrated method for product development management has been established to be able to fully combine other known tools found in six sigma like QFD, customer data analysis, SIPOC, as well as the project charter, scope and timeline. IDeS was correlated with the DMADV approach of DFSS that guarantees a proven system aimed to reduce overall product time to market whilst achieving to account for current market requirements owned by a fast change in customer behavior.

Moreover, this concept enables organizations to practically implement proper Industry 4.0 technological tooling systematically across all product development areas. The information created could be known immediately across all parties involved, obtaining lower time and resources to perform changes. This updated approach based on the systematic use of technology for product development management enables organizations to widen their product efficiency and minimizing the risks. This last statement allowed to create a strong link between the design structure complexity (styling plus engineering) across the company organization. This engagement must be exploited to guarantee a product that answers immediately to the customer and the industry and a quick reaction to market demand fluctuation and would be a key guideline for companies ought to succeed.

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