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Expanding Value Driven Design to meet Lean Product Service Development

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Abstract

The paper presents a discussion about gaps and opportunities for cross-pollination between Value Driven Design and Lean Product Service Development to promote the use of value-driven method and tools since the preliminary design stages. In particular the paper discusses how methods and tools developed in Value Driven Design have the potential to be applied in the preliminary design stage in the context of Lean Product Service Development. The paper concludes by defining a research area on Value Innovation method and tools for preliminary Lean Product Service Development.

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Keywords: Value Driven Design; Lean Product Service Development; Value Innovation; Preliminary Design

1. Introduction

A widespread servitization trend [1] has been observed among industrial companies acting in the global market. Product-Service Systems (PSS) [2], Industrial Product Service Systems [3], Total Offers [4] have gained popularity in the last decade as means to generate new revenue streams, to gain closer relationships with the customers [5] and to increase operational performances to a level not reachable by mere hardware improvement [6]. Increasing service aspects means for manufacturers to include new objectives into their product development projects, stretching and stressing the requirements for the 'hardware' [7]. The way the latter is designed strongly influences how the revenue streams are generated [8], how close the customer relationships can be established [9] and how services are planned and delivered to increase performances.

As with other complex development projects [10], efficiency and effectiveness during the early development phases are key factors to grant the success of the future PSS offer [11]. While a variety of methods and tools for an efficient and effective development have been developed in the context of "traditional" lean product development [12], the increased focus toward PSS solutions creates the need for approaches capable of encompassing lifecycle and service related aspects.

While available lean product development techniques are of undeniable interest to support the design of hardware within the PSS ecosystem, the mere translation of such principles into PSS design does not necessarily equate to an effective process, especially given the increased complexity of a combined product and service development. The term Lean Product Service Development (LPSD) is used in this paper to identify such area of investigation, that lies at the intersection between lean product development and lean service development.

Some examples of methods developed for effective and efficient PSS development are available in research [11][13].

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Those, despite never explicitly using the term “lean”, set the basis for the further development of methods and tools for LPSD. These works, in line with what emerges in “traditional” lean product development literature, highlight how the identification of value from the customer’s perspective shall be considered as pivotal in PSS design, and highlight the need of focusing research efforts in understanding and evaluating value in early stages of PSS development [13]. Such value can be created “either by contributing to design of a system that has certain desired properties or by allowing this to happen more effectively” [14, p 5].

The importance of understanding value in the early design stages is also recognized by the System Engineering literature. Here research has long observed that it is in the preliminary design stages that the decisions committing the major part of the product value are made [10]. Authors have highlighted that when the system grows in complexity, involving a high number of stakeholders and different value propositions – such in the case of PSS – the preliminary design stage does not typically involve a broad, systematic exploration of design alternatives [15]. This is because of the inability to systematically manage the complexity and ambiguity of the design space [15]. Several research efforts, mainly in the aerospace domain (e.g. [16][17]), have focused on design methodologies that use the concept of “value” as a means to manage such complexity. These efforts fall under the umbrella term of Value Driven Design (VDD) [18]. In spite VDD being today mainly limited to the aerospace domain, the core concepts of VDD shares similarities with those of LPSD. Firstly both approaches focus on “value” as a driving direction for the development. Secondly, both application contexts (i.e. aerospace design and PSS development) feature an increased level of complexity compared to traditional product development. Also, they both require the integration of different disciplines and the implementation of cross-disciplinary teams..

1.1. Aim of the paper

The above considerations have suggested the authors to explore similarities and differences between the VDD and LPSD research fields. The aim of the paper is to discuss gaps and opportunities for cross-pollination between the two domains, answering the following two questions:

- What are the overlapping aspect of the research in VDD and LPSD?
- What can LPSD learn from VDD research?

The answers to these questions ultimately has led the authors to discuss if a number of methods and tools developed under the VDD umbrella shall be limited to such definition or if they could be adopted in LPSD field, and eventually which would be the research directions to take and what definition shall be adopted.

The paper firstly describes the methodology at the basis of the work; then it presents a short literature review about the assessment of value in preliminary design of LPSD and VDD. Furthermore, it discusses opportunities for cross-pollination between the fields by highlighting differences and similarities between LPSD and VDD. Eventually, the paper highlights areas for future research within LPSD and VDD.

2. Methodology

The research emerges from both an academic and industrial-oriented approach. The analysis of previous work and case studies contributed to the development of a deep understanding of the research area. The existing literature concerning Lean Product Development, Value Driven Design and Service Engineering was studied in order to identify strengths, weaknesses and similarities of the approaches. Further analysis focused on a systematic review about how the concept of value is interpreted in preliminary design in the Engineering Design, Lean Product Development, Product Service Systems and System Engineering fields. The background knowledge concerning VDD methods and tools inspiring the discussion in this paper, is the result of case studies and action research [19] conducted within European and Swedish manufacturing companies in aerospace and construction sectors. The presentation of such case studies is outside the scope of the paper and references can be found in the text.

3. Literature review

3.1. “Value” in the preliminary design phase of Lean Product Service Development

The term “lean” was originally coined to define Toyota’s method of product development and its associated principles and practices [20]. Different interpretation of the “lean” principle share the recognition of the central role played by “customer value” and consider the identification of value streams a crucial factor toward improved efficiency and waste reduction [12]. Lean product development literature emphasizes concrete methods - that are “linear, steady and deterministic processes with accurate forecasting” [14, p10] - to balance immediate efficiency with lifecycle value and the possibility of requirements changes [14], However, the move towards “servitization” makes difficult to apply such a deterministic approach , mainly because complex systems development is largely dominated by uncertainty and ambiguity [14]. This points toward the need for defining LPSD to meet these emerging design challenges.

Even if not explicitly referring to the term LPSD, a number of authors in PSS design have investigated the aspects related to value generation and evaluation in the design of a PSS offer. Shimomura and Arai [11], described “Service Engineering” as a design methodology providing methods and tools to increase the effectiveness of PSS development. They recognized the need to focus on the value generated by the services identifying the satisfaction/dissatisfaction of a customer through some key “Receiver State Parameter”. They applied a set of tools to identify the most important contents and channels of the services, and QFD to calculate the importance of both service functions and entities. Using the same logic Kimita et al. [13] focused on enhancing the decision-making activity in preliminary design by providing an estimation of customer satisfaction in a conceptual stage. Differently from QFD, they introduced the use of non-linear function to better capture the relationship between quality and customers' satisfaction. In order to do so a "value function" (called Satisfaction-Attribute Function) is determined as a result of regression analysis on a set of questionnaire data.

A previous work by Gautam and Singh [21] has also used an optimization function to calculate customer perceived value in case of design changes, using "serviceability" as one parameter. However this approach is based on equations relying on a number of assumptions (e.g., no market turbulences, flat ground competition, necessity of decomposition of functions into physical part) that makes its practical use in a real scenario difficult.

Inspired by lean principles, researchers at Massachusetts Institute of Technology have also proposed the concept of "lean engineering" applied to aerospace product development [22]. Multi Attribute Tradespace Exploration and Integrated Concurrent Engineering [23] are examples of approaches for concept screening in the "lean engineering" context. The preliminary application of these approaches is nowadays only limited to aerospace product development projects.

3.2. A model-based approach for "value" quantification as promoted in VDD

Making design decisions is the result of a multi disciplinary task, where results and insights are traded against one another. To generate necessary information for decisions to be made, design teams commonly create models [24].

VDD aims to solve design trade-offs looking at how much customers "value" certain capabilities against others, hence proposes model-based enablers to identify the combination of attributes of a product that ultimately produces the best overall economic value in a lifecycle perspective. According to Collopy and Hollingsworth [18], VDD *"is not a new method, process, or tool for design. Rather, it is a framework against which methods, processes, and tools can be assessed."* They further believe that the best design for a system is the result of the optimization of the system value in the form of a financial objective function. Such reasoning implies the existence of a value function that can be used as a tool to trade-off different design alternatives in the light of the input data provided by the designers.

While traditional Systems Engineering focuses on a favorite point solution that fulfils a wide variety of requirements, VDD promotes the use of multidisciplinary optimization in the attempt to open up the entire solution space for consideration by the designers, systems engineers, program managers and customers [18]. The spirit of VDD is to avoid "local optimal" solutions that are based on the short-range exploration of the design space around a baseline solution; rather, it aims to explore a much larger amount of possible solutions, by means of quick what-if analyses that use a value function as a metrics to identify the best design in a given situation [18]. VDD is explained in literature as a cycle (Figure 1) [18]. Initially, the design team picks a point in the design space at which to attempt a design. At the Design Variables step, it creates an outline of the design, which is elaborated into a detailed representation in the Definition arc. In the Analysis arc, engineers produce a second description of the design instance, in the form of a vector of attributes. VDD proposes the use of *extensive attributes* – such as, weight, performance attributes, safety, cost and, in general, all those system attributes whose values are functions of the values at the component level [25].

While the design variables are defined to make sense to the design engineers, the attributes are defined to connect to the customer. The Evaluate arc is what differentiates VDD from traditional Systems Engineering. Here the attributes are assessed with an objective function or value model, which gives a scalar score to any set of attributes. If the current configuration has a better score than any previous attempt, it is the preferred configuration to date. At this point, the design teams can accept the configuration as their product, or try to produce an even better design by going around the cycle again. The Evaluate arc requires the development of a system value model, often conceived as a long-term profitability model.

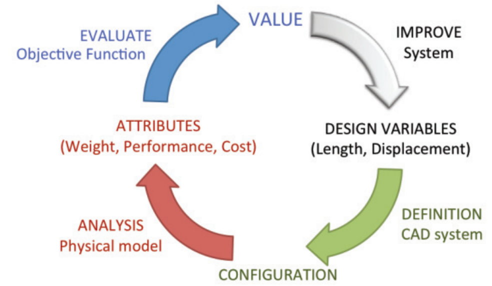

Fig. 1. The Value Driven Design Cycle (adapted from Collopy and Hollinsgworth [18])

Despite being a fairly new concept, VDD is increasingly discussed within the Systems Engineering community, and different examples of its application are proposed [16][17]. The major reason is that VDD can be exploited to highlight dimensions that add value from a system-level perspective, avoiding the trap of focusing only on the nearest customer and targeting 'local' optimal solutions [26].

4. Opportunities for cross pollination between VDD and LPSD

LSPD and VDD literature highlight a dichotomy, which the authors believe is complementary rather than mutually excluding.

LPSD focuses on delivering the highest value to the customer by increasing efficiency and reducing waste, with a strong focus the managerial aspects of the product and service development process.

VDD adopts a more engineering-oriented perspective, looking at the hardware attributes (mainly technical performances) as enablers for service provision. Hence, it proposes methods and tools that use value as metrics to select, as early as possible in the design process, the optimal configuration for a system and its sub-systems.

These perspectives should not be seen as contrasting, instead they represent an opportunity for cross-pollination between the managerial and the engineering design fields.

VDD research can mainly teach LPSD practitioners about the use of a model-based thinking when looking at value and impacts of design alternatives. VDD strongly focuses on the creation and use of models that are able to quantify what the system will be capable to deliver given a specific design configuration. This capability of developing and applying models to benchmark solution directions is something lean research may benefit from. Value models can be beneficial in their way to work as 'coordinative artifacts' [27] serving as basis for conversation and knowledge sharing within the cross-functional design team. For several disciplines, such as cost and material analysis, a range of models is already established, as well as roles in the engineering design teams. However when looking at value assessment in the context of LPSD models promoting the understanding of value and the determination of efficient mechanism for information flow have not reached the same level of maturity as in other domains. Based on such reflection, the ability to apply a model-based approach in LPSD is believed to be critical for successful cross-boundary discussion. Therefore the possibility to use value models as "boundary objects" [28] to facilitate cross-functional communication and to enable that the best, or at least the "most aware", decision is made, is regarded as a potential improvement for LPSD processes. In particular the opportunity to use such objects to better understand and reconcile conflicts in stakeholder needs (a topic discussed in lean literature by Siyam et al [14]) shall be regarded as a relevant improvement

A key difference is that VDD targets the value that a new solution can bring to the overall system of stakeholders involved. It does not map the value stream toward the customer, but it aims to analyze the value generated to the whole supply and customer network, including internal and external stakeholders. It claims that the best solution is the one that delivers the highest value to the system, and an increase in revenue will be the natural consequences of this. Such "system perspective" is increasingly important with more and more industrial offers moving toward PSS, and might address the limitation of lean techniques lacking of a whole system view, avoiding the risk of sub-optimization toward individual value attribute, a concern expressed by lean literature in complex product development [14].

To this purpose while Service Engineering uses Receiver State Parameters and Function Parameters to assess customers' satisfaction, VDD uses Value Dimensions and Value Drivers in a similar logic but with a wider perspective [31]. The major difference relies on the fact that Value Dimension and Value Drivers are derived from the needs of a wide set of stakeholders (i.e., company internal, supply chain, customers, customers of customers, institutions) and are assessed through semi-quantitative models [26] providing the final "design merit" as a needs-satisfaction measure given the trade-off (and prioritization) of contrasting needs.

4.1. Extending VDD to meet LPSD

In spite of some authors [29] claiming VDD to be cross-functional, existing case studies (e.g., [16][17]) are deeply engineering focused. The value of a "system" is calculated on the basis of the technical performances of the hardware, while service aspects and managerial implications are poorly, or not at all, considered in the value models. This is not surprising: VDD was introduced with the objective to select the best set of technical capabilities to accomplish a mission, or a project, given some cost constraints.

However, part of VDD literature is starting to recognize that the development of mathematical optimization functions [e.g., 18] is not the only way forward. Rather, it sees the opportunity to expand the notion of "value-driven" towards reinforcing early stages design iterations, and fostering communication and concurrent activities among customers, producers and suppliers [30].

The authors argue that some recent methods developed under the VDD "umbrella" term (e.g. [26][31][32]) shall not be considered as limited to the VDD domain. They should rather be rather as plastic approaches to promote value driven innovation in the preliminary design stage of a products/service system, and they should belong to a complementary context overlapping both with VDD and LPSD. This context is defined as "Value Innovation" by the authors, mainly as a bookmark on which to anchor the discussion about future research directions in the common VDD/LPSD domain (Figure 2).

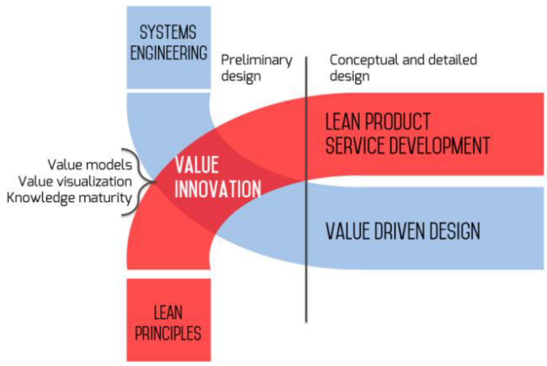

Fig. 2. Value Innovation: overlapping research areas between VDD and LPSD.

Value Innovation (VI) expands and differs from VDD by acknowledging that, when assumptions and forecasts prevail, the use of a subjective definition of value is more appropriate. VI emphasizes the role of the "value model" as that of a boundary-object, which is of an artifact able to raise awareness on what eventually value means for customer and stakeholders. The underlying assumption is that this awareness can be raised only if ambiguities and uncertainties can be clarified already during preliminary design. To do so, it is necessary to establish a dialogue among all actors in the cross-functional team, under the assumption that only if experiences and knowledge about what "is valued" are shared, it is possible to take more confident (and rational) design decisions.

The VDD literature [e.g., 30] has already pointed out that, early on in the design process, a more qualitative assessment of the "goodness" of a design should be preferred against a numerical (and monetary-based) encoding of preferences. Qualitative value models are believed to work more effectively as boundary objects than quantitative ones. Compared with the latter, they make possible to use a shared syntax to facilitate a process where individuals transform their knowledge [28] and learn about dependencies (and specify differences) across (e.g., functional, social) boundaries. Also, by being less discipline-specific, they do not demarcate any real territory: this emphasizes their mediating qualities and thus effectiveness. Furthermore, qualitative models are intended to capture a number of "intangible" aspects in the value analysis, which are difficult to monetize quantitatively (e.g., brand acknowledgement, knowledge reuse)[40].

How does a qualitative value model look like then? Decision-making matrixes, such as QFD, emerge as strong candidate approaches to perform a qualitative mapping between customer value perception and requirements for PSS. Still, the relationship between customer value and PSS is likely to be more complex than the pure product or service counterpart. The latter [33][34][35] has already shown that dependencies can be highly non-linear: this phenomenon is likely exacerbated looking at product-service combinations such as emerged both in Service Engineering and VDD literature [13][26]. Based on the work of Wooley et al. [36], VDD research has illustrated the application of non-linear functions to the development of semi-quantitative value models in an aerospace context [26]. Such approaches expand QFD by adding non-linear relationships, analogous to the Taguchi Loss Functions [37], which are believed to better approximate the customer response to changes in a product attribute [38]. In this spirit, semi-quantitative value models (e.g. [26][31][32]) have been recently proposed to increase decision makers' awareness of the value contribution of different design concepts. Moreover they encompass the value associated with the design that is generated, e.g. manufacturability, maintainability, serviceability, or other "ilities", not often emphasized by lean techniques [14].

VDD models have shown to be dependent from the availability of historical data, which are typically missing when performing a preliminary screening of new hardware-service combinations [26]. Using models in preliminary design implies the presence of not well-defined data suffering from a level of uncertainty in the evaluation. Claiming to evaluate the system value of a concept implies therefore to be able to address such uncertainty perhaps not by directly focusing on reducing it, but rather by assisting the decision makers to achieve a better understanding of what those uncertainties, ambiguities and assumptions actually involve [39]. Research in the dynamics of decision-making in product development has lead to the definition of the concept of Knowledge Maturity [39] as a way to model such uncertainties, ambiguities and assumptions used in early stage decision making. Such concept has been later adopted as an add-in for value models used in VDD [31].

Within a cross-functional team, the use of value as metrics for benchmarking design concepts is mainly a matter of conveying value-related information in a way that is clear, transparent and that stimulate associative processing and knowledge generation. The development of value visualization enablers is therefore another major topic in VI research. Recent contributions have proposed, for instance, the use of color-coded schemes in computed aided design environment to visualize the value contribution of PSS offers. [32].

5. Conclusion

The paper has discussed similarities, differences and opportunities for cross-pollination between the research fields of Lean Product Service Development and Value Driven Design, ultimately proposing a research area for the development of Value Innovation methods in the context of LPSD. Concerning the first research question the paper has highlighted that research works in VDD and LPSD, despite evolved in two different contexts, show similarities when it comes to the definition of the problem they are addressing and the product development contexts in which they are operating. Both VDD and LPSD aim at increasing decision makers' awareness about the "value" of different design alternatives (despite a not unique definition of value exist). Both the areas share the need to run such assessment in a preliminary design stage, when decisions committing the major part of the value have to be made. Both areas deal with high levels of complexity and cross-functional contexts, intrinsic in system engineering nature for VDD, and generated by the "servitization" challenges in LPSD case.

Concerning the second research question the paper has highlighted the potential role of an enhanced model-based thinking in LPSD, adopting method and tools to widen the value assessment to a larger base of stakeholders adopting VDD-derived methods to deal with contrasting needs. The use of value models as boundary objects for cross-functional discussion and decision-making is also seen as a promising application of VDD methods in LPSD.

The next step of the research will be the pilot application and test of VDD-derived methods in a real case study in PSS design in a context different from the aerospace product development, to verify the practical impact of VDD methods in LPSD, and collect data for the further development of value innovation methods.

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References

[1] Vandermerwe S, Rada J. Servitization of business: adding value by adding services. European Management Journal 1989, 6(4), 314-324.
[2] Goedkoop M, van Haler C, Riele H, Rommers P. Product Service-Systems, ecological and economic basics. Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ); 1999.
[3] Meier H, Roy R, Seliger G. Industrial Product-Service Systems—IPS2 CIRP Annals-Manufacturing Technology 2010, 59(2), 607-627.
[4] Alonso-Rasgado T, Thompson G, Elfström, BO. The design of functional (total care) products. Journal of Engineering Design 2004, 16(6), 515–540.
[5] Ravald A, Grönroos C. The value concept and relationship marketing. European Journal of Marketing 1996, 30(2), 19-30.
[6] Mathieu V. Service strategies within the manufacturing sector: benefits, costs and partnership. International Journal of Service Industry Management 2001, 12(5), 451-475.
[7] Sundin E, Lindahl M, Ijomah W. Product design for product/service systems: design experiences from Swedish industry. Journal of Manufacturing Technology Management 2009, 20(5), 723-753.
[8] Isaksson O, Larsson TC, Rönnbäck AÖ. Development of product-service systems: challenges and opportunities for the manufacturing firm. Journal of Engineering Design 2009, 20(4), 329-348.
[9] Lee J. Smart Products and Service Systems for E-Business Transformation. International Journal of Technology Management 2003, 26 (1), 45–52.
[11] Shimomura Y, Arai T. Service engineering–methods and tools for effective PSS development. In Introduction to Product/Service-System Design (pp. 113-135). Springer London; 2009.
[12] León HCM, Farris JA. Lean Product Development Research: Current State and Future Directions. Engineering Management Journal 2011, 23(1).
[10] INCOSE. Systems Engineering Handbook v. 3 edited by Cecilia Haskins; 2006.
[13] Kimita K, Shimomura Y, Arai T. Evaluation of customer satisfaction for PSS design. Journal of Manufacturing Technology Management 2009, 20(5), 654-673.
[14] Siyam GI, Wynn DC, Clarkson, PJ. Review of Value and Lean in Complex Product Development. Systems Engineering 2015.
[15] Ross AM, Hastings DE Warmkessel JM, Diller, NP. Multi-attribute tradespace exploration as front end for effective space system design. Journal of Spacecraft and Rockets 2004, 41(1), 20-28.
[16] Castagne S, Curran R, Collopy P. Implementation of value-driven optimisation for the design of aircraft fuselage panels. International Journal of Production Economics 2009, 117(2), 381-388.
[17] Cheung J, Scanlan J, Wiseall S. Value Driven Design—an Initial Study Applied to Novel Aerospace Components in Rolls-Royce plc. Collaborative Product and Service Life Cycle Management for a Sustainable World 2008, Springer London, 241-248.
[18] Collopy P, Hollingswort P Value Driven Design. Proceedings of 9th AIAA Aviation Technology, Integration, and Operations Conference 2009, Hilton Head, South Carolina.
[19] Avison DE, Lau F, Myers MD, Nielsen PA. Action research. Communication of ACM 1999, 42(1), pp. 94-97.
[20] Womack JP, Jones DT, Roos D. The Machine That Changed the World: The Story of Lean Production, HarperPerennial; 1991.
[21] Gautam N, Singh N. Lean product development: Maximizing the customer perceived value through design change (redesign). International Journal of production economics 2008, 114(1), 313-332.
[22] McManus H, Haggerty A, Murman E. Lean engineering: doing the right thing right. 1st International Conference on Innovation and Integration in Aerospace Sciences 2005.
[23] McManus HL, Warmkessel JM. Creating Advanced Architectures for Space Systems: Emergent Lessons from New Processes. Journal of Spacecraft and Rockets 2004, 41, 1, 69-74.
[24] Drucker PF. The Effective Decision. Harvard Business Review on Decision Making. Boston, MA, USA, Harvard Business School Press; 2001.
[25] Collopy P. Adverse Impact of Extensive Attribute Requirements on the Design of Complex Systems. AIAA 2007-7820, AIAA Aviation Technology, Integration, and Operations Conference 2007, Belfast, Northern Ireland.
[26] Eres H, Bertoni M, Scanlan J. Mapping customer needs to engineering characteristics: an aerospace perspective for conceptual design. Journal of Engineering Design 2014, 25 (1-3), 64- 87.
[27] Schmidt K, Wagner I. Coordinative artifacts in architectural practice. Fifth international conference on the Design of Cooperative System 2002. Amsterdam.
[28] Carlile PR. A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. Organization Science 2002, 13 (4), 442-455.
[29] Price M, Soban D, Mullan C, Butterfield J, Murphy A. A novel method to enable trade-offs across the whole product life of an aircraft using value driven design. Journal of Aerospace Operations 2012, 1(4), 359-375.
[30] Bertoni M, Eres H, Scanlan J. Co-creation in complex supply chains: the benefit of a Value Driven Design approach. In: Schaefer, D., (Ed). Product Development in the SocioSpere: Game changing paradigms for 21st century breakthrough product development and innovation. Springer; 2014.
[31] Bertoni M, Bertoni A, Isaksson O, Amnell H, Johansson C. Value-oriented concept selection in aero-engine sub-systems design: the EVOKE approach. In: Proc of the 23rd INCOSE International Symposium 2013, Philadelphia, PA
[32] Bertoni, A. Analyzing Product-Service Systems conceptual design: The effect of color-coded 3D representation. Design Studies 2013, 34(6), 763-793.
[33] Duck Young K, Xirouchakis P. Co2de: A decision support system for collaborative design. Journal of Engineering Design 2010, 21 (1), 31-48.
[34] Erginel N. Construction of a fuzzy QFD failure matrix using a fuzzy multiple-objective decision model. Journal of Engineering Design 2010, 21 (6), 677-692.
[35] Thurston DL. Real and Misconcieved Limitations to Decision Based Design with Utility Analysis. Journal of Mechanical Design 2001, 123, 176-182
[36] Wooley M, Scalan J, Eveson W. Optimising the Development of a Medical Device Using Formal Engineering Design Techniques and the CODA System. Proceedings of the 27th International Conference on Concurrent Enterprising 2001, 367-376.
[37] Wadsworth HM. Handbook of statistical methods for engineers and scientists (2nd ed.). New York: McGraw-Hill Professional; 1997.
[38] Anderson EW, Sullivan MW. The antecedents and consequences of customer satisfaction for firms. Marketing Science 1993, 12, 125-143.
[39] Johansson C, Hicks B, Larsson AC, Bertoni M. Knowledge maturity as a means to support decision making during product - service systems development projects in the aerospace sector. Project Management Journal 2011, 42(2), 32-50.
[40] Steiner F, Harmon R. The Impact of Intangible Value on the Design and Marketing of New Products and Services: An Exploratory Approach. Proceedings of PICMET 2009. Portland, Oregon USA.