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Evolving Customer Expectations in Sustainable Product Design: A Systematic Literature Analysis

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***Abstract*—**Design is one of the most important stages in the process of product development. Product design has experienced significant changes over the years ranging from concentrating on cost and performance to combining economic, environmental and social considerations in customer requirements. Its evolution is in accordance with rapidly changing technology, economic situations, and climate change and environmental issues, as well as social context. Within product design, sustainability is a concept that balances economic, social and environmental aspects. This research aims to express changes in customer requirements over time from the viewpoint of sustainable design. It does so by systematically reviewing a broad scope of sustainable design literature. There is a need for a model to consider the changes that take place in customer requirements over time to build a successful relationship with customers which has been presented. Today's literature does very little to even mention it, let alone present any progress in it. Systematic literature reviews are conducted primarily to: summarize the existing literature around a subject, highlight commonalities to build consensus, illuminate differences, identify gaps that can be filled, provide a background to position future research, and build a framework that can help designers meet the challenges of sustainable design.

I. Introduction

I T is a well-known fact that design plays a leading role in product development. Product design is defined as a systematic and intelligent process for designers to generate, evaluate and specify designs of devices or processes, achieving users' needs and design objectives as well as satisfying a specified set of constraints [25]. A design format consists of shape, appearance, and structure of products. Function is considered as an important part of product design since the product will sell only if it operates as expected [25], [23].

Product design has witnessed dramatic and significant changes during the past decades. The objectives of the traditional design can be summarized as: durability, reliability, affordability, and aesthetic perspective of the product [25],
[20]. However, in the last decade, product design experienced fundamental changes in its concept from focusing on performance, function and durability to some other factors such as being environmentally friendly, considering global warming, reducing energy consumption, and conducting endof-product lifecycle management including reusing, recycling and remanufacturing [65], [6]. It should be noticed that while the traditional aspects of the design are important, both designers and consumers feel a sense of responsibility for natural environments and resources. These topics generate a new concept for product design, called sustainable design.

Sustainable design is a matter of the international concern. Numerous approaches have been developed over the last decades to deal with environmental catastrophes, such as cleaner production, cleaner technologies, waste minimization and recycling approaches, as well as eco-design and design for sustainability. However, now it is urged to a new strategy to motivate companies to meet customer needs and respond to the changing in customer requirements toward sustainable design [60].

Rapid population growth and the increase in quality of life have dramatically raised energy consumption and emissions globally [13]. Designers can contribute significantly to this issue by designing products that suit societal needs while minimizing the environmental problems. Decisions made at the first product and service design stage define the environmental and economic impacts on decisions in the future [38]. Therefore, it is important that designers adopt a design type focus on economic, environmental, and societal considerations together with cost and performance [64], [15]. However, designing sustainable products is by no means an easy task. Engineered products, such as living organisms, interact with the environment through energy and material flows at every stage of the life cycle from raw materials extraction and acquisition, manufacturing, transportation and distribution, use and maintenance, as well as reuse and recycle, and all the way through to disposal and waste management [22].

Protecting the environment has become more and more important and consumers are increasingly concerned about the impact of their behaviors on the planet; therefore, identifying consumer needs and behaviors has become an important issue [86].

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For the last decades, concerns about environmental problems have been increased [56], and consumers are realizing the consequences of their behaviors, environmentalism has become a major issue [5]. Now more than ever, consumers are aware of the seriousness of these environmental problems and are becoming more ecologically conscious, seeking to purchase green products and services, and preferring sustainable designs [48], [56], [70].

Despite their strong approximation, sustainable design literature defers from sustainability literature. Even if the second is encompassed by the first and is fundamental in this discussion, sustainable design goes beyond and includes the challenges to the conceptual challenges that deal with the following themes: focusing on performance, function, durability, being environmentally friendly, taking considerations for global warming, reducing energy consumption, conducting end-of-product life cycle management such as reusing and recycling. Another theme is remanufacturing, designing products and processes that satisfy societal needs, while simultaneously minimizing the associated environmental consequences. Making significant contributions at the initial design phase determines the environmental and economic impacts of future decisions and why studying changing customer requirements over the time is important? Product design should start and end with the consumer. There is a time-lag in this process between collecting the customer's opinion and the point when the product is ready to be launched into the market. This time-lag period may certainly change from one product to another. In this situation, does the product that is about to be launched now still meet the customer needs? Given that its design depended on the customer's opinion which was collected one year previously and due to the fast changes of today's market, the answer to this question is very likely to be no [67].

Studying the integration of sustainability in product design can be approached from various fields of literature and disciplines [89], [31], [26]. And many researchers studied sustainable development [79], [16]. Since sustainability is a concept to balance the economic, social and environmental assessments in product design, some researchers studied the environmental and economic assessments [72], while others define the major indicators of social sustainability like Wang and Kuo [87]. Vezzoli et al. [84] focused on the challenges facing Sustainable Product Service Systems (SPSS).

Previous literature reviews on sustainable design have brought interesting insights for theory and practice. They address several aspects of sustainable design, sustainable behavior [17], [10], sustainable manufacturing [77], [45], [54], sustainable supply chain [29], [18], [83] sustainable design principles [12] sustainable design indicators [9], educating sustainable design [69], [44], sustainable construction [9], and sustainable interior and architectures [36], [63], [41]. Some researchers paid much attention to effectiveness in sustainable design [76], [35]. And many researches about the integration of environmental requirements to sustainable design in practice has been achieved by several scholars [3], [85], [14]. These and other researcher [55], [8], [24] identified sustainable design.

Other researchers have focused their work on how to influence the consumers and shift their behavior to adopt environmental requirements and change their requirements toward sustainable design [78], [17], [51]. Boztepe [4] studied green consumers and the effect of green marketing on customers purchasing behaviors.

Customer requirements for sustainable design and the changing over the time formed the main subject of the study. Most of the papers were about customer requirements for product design in general [47], and many studies about changing customer requirements [46], [73], and very few were about changing customer requirements over the time [74], [7] but not about changing customer requirements for sustainable design, and some authors were more specific and proposed a model for expressing changes in customer requirements from the viewpoint of service design. The studies [49], [66], [71] focused on integrating sustainable requirements to the product and service design, and some authors like [91] focus at sustainable product design, while a limited number of researchers studied sustainable product and service design requirements like Griese [33].

Sustainable design tools have been proposed a lot during the last years. Bonvoisin et al. [3] developed an LCA-based framework for evaluating environmental impacts of ecodesign options of services that address eco-design of equipment, infrastructure and information. Gaha et al. [30] proposed a methodology to assist designers for selecting the most ecological product design by integrating feature technology and CAD design. Once its features are given, this methodology analyzes environmental impact of each CAD model. Romli et al. [71] developed an integrated eco-designmaking (IEDM) methodology by integrating life cycle assessment, eco-design process model and an enhanced ecodesign quality function deployment. This methodology analyzes the factors of environmental impact relating to manufacturing process, product usage and end of life strategy. Ghadimi et al. [32] proposed the Weighted Fuzzy Approach to assess the sustainability of a product. And integrated Morphological Analysis-AHP approach proposed by [40] helps the designers to select the best option having highest sustainability index among alternative options. Lin et al. [57] applied QFD method and used a fuzzy analytic network process to calculate global warming and environmental protection, and [28] proposed a model as a practical tool for decision-making which

features a single sustainability indicator linking economy and ecology (environmental impacts).

In the tools and approaches described in the previous paragraphs, sustainability requirements are often treated as customer requirements, this may reduce the importance of 'Sustainability Requirements' (SRs) over 'Customer Requirements' (CRs). These tools and approaches do not satisfy both CRs and SRs based on their importance. It is evident that many recent research works, instead of considering the three dimensions of sustainability, focus only on one or two dimensions [32], [11], and most researchers in this field ignore how the customer impacts design changing over the time for sustainable design in general.

To review customer requirements for sustainable design in general: a literature search was conducted, with the scope of the review limited to recent publications for the years 2011 up to 2016 using the full text and the titles, and the keywords "sustainability" and "sustainable design" and sustainable design requirements" in Google Scholar, and Science Direct, ACM Digital library, ACS Publication, IEEE Xplore, and ProQuest.

In summary, the literature on sustainable design in general, as well as specific changing in customer requirements, is very scarce in comparison to the thousands of studies in the field. Sustainable design and customer requirements were addressed in many articles, whereas the "changing in customer requirements for sustainable design" was missing.

II. Related Works

Related works were selected with a focus on sustainable design and customer requirements concept are roughly classified into three categories:

A. Sustainable design
B. Customer requirements for sustainable design
C. Changing customer requirements for sustainable design

In the sustainable design and customer requirements research literature, there are a few examples of reviews on 15 articles from journals and five thesis papers.

A. Sustainable Design

Küçüksayraç [52] conducted a systematic literature review on design for sustainability in companies in Turkey. He identified design for sustainability in general and then focused on its practice by companies in Turkey, and aimed to improve existing design for sustainability practices and spread best practices within the industry. The study investigated the best performing companies in the sustainability field in the country by addressing the scope of their practices, the drivers for these practices, the barriers they face during the process, the benefits they achieve and their further needs on sustainability. The findings expand on, and somewhat differ from, those from previous studies in Turkey, while also differing to a greater extent from previous studies in Europe. Like many other studies carried out in specific regions on the eco design practices of companies such as the Baltic States [1], Central America [21], and Northeast Brazil [19]. He focused in his literature review for the design for sustainability practices of companies on two surveys from the European context, one specifically from the Netherlands [80], [81] and one from the European Union [53]. Then he compered the results of his study to those from the two studies from the European context. The research questions investigate the design for sustainability practices of the best performing companies with the aim to expand and help improve his study reflects the participants' responses to the survey but does not evaluate the implementation process or output. And it does not provide information on how to change it or on how to promote design for sustainability within the industry. This study focused at the need for sustainability but didn't mentions the customer needs on sustainable design in general, or how to this needs keep changing

Bonvoisin et al. [3] provided an integrated framework for assessing environmental impacts and for supporting the design of environmentally-sound ICT-based optimization services and presented a comprehensive LCA-based framework to evaluate the environmental consequences of eco design optimization services. Based on an environmental model of optimization services, it defined a step-by- step method addressing three levels of potential improvement: Eco-design of equipment, infrastructure and information. The framework introduced was applied to a representative optimization service that leads to impact transfer. The framework helped to identify improvements that ultimately led to the design of a more environmentally-sound optimization service. Their framework addresses the environmental relevance of optimization services on a case by case basis, rather than trying to answer the question on a general level.

Gaha et al. [30] proposed a methodology based on feature technology and on the integrations realized on Computer Aided Design (CAD) systems. In "Numerical tools to integrate eco-design in the design process and develop products", they present a literature review of works treating integration between CAD and life cycle assessment (LCA) systems for "quantitative eco-design tool to realize environmental assessments". The idea is allowing designers assessing the environmental impact numerically in the CAD phase second, and they also introduced a state-of-the-art presenting feature based on modeling contribution in environmentally conscious production; also, they underline their role in Computer Aided Process Planning (CAPP). Thirdly, they described an approach based on features to assist eco-designers early in the design process. Then, they consider, a simple case study to validate it.

Zink [93] examined some question to show the need for a systems approach to design sustainable work systems and to show that sustainability is already a part of human factors thinking. The literature review contributed towards the formulation of a framework that provides discussion about the relevance of sustainability for human factors and ergonomics and discussion about sustainable work systems. Then he described a first frame work for the design of sustainable work systems from a human factors perspective after clarifying the history and defining the sustainability.

Kondoh et al. [50] conducted a literature review on business models and the externality in sustainable business design, as well as identifying relevant issues which the paper addressed through discussion on the review results. The authors classified the related works on the sustainability concept into two categories: the first one is eco-innovation/sustainable innovation, and the second is PSS and service related concepts. The objective of this study was investigating the key issues for supporting the design of sustainable business, focusing essentially on how businesses address external factors to meet multiple facets of sustainable value. To answer the research questions, the authors collected recent journal papers and technical reports, and selected 34 papers from 2005 to 2014. He conducted a survey on the study of business models, and in particular, sustainable business models. The survey in their study concentrated on modeling the influence of the external environment on the business characterized by "externality". Through the findings on the literature review discussion, they identified three key issues for constructing sustainable business model: taxonomy of externality, identification of a set of models (i.e., aspect model), and identification of interrelationship among them.

Lueg and Radlach [58] conducted a literature review on sustainable management control systems (SMCS), which involved a 'systematic' review based on an initial sample of 12,139 article. Due to the diverse terminology on SMCS, after using different search strings and the asterisk as a wild card within the title, abstract, and keyword searches for the period 1988 until 2013. The researchers then identify 83 empirical studies in the field of natural and social sciences published in 56 journals from the inauguration of SD. First, they identified diverse types of controls that organizations use to enforce SD. Second, they uncovered areas that have received limited attention and warrant future research. This includes the questionable transferability of findings from the environmental to the social dimension (and vice versa); an investigation of the context surrounding appropriate SMCS, such as industry or global region; their effect on SD/economic performance; as well as a better understanding of the interaction between different types of sustainability controls. Third, they discussed possible advancements in methodology, particularly challenging the overreliance on cross-sectional surveys and case studies. The study found that there are various types of SMCS in practice, and that far more studies were conducted on an environmental rather than a social or sustainability dimension. Yet, very few of these SMCS achieve a consistent link from SD to financial rewards and other kinds of compensation in contemporary organizations.

Wakkary et al. [85] presented literature related to the Sustainable Interaction Design field and discussed how sustainable interaction design (SID) can be known within a framework of social practices, by examining sustainability. First, they explored an overview of practice theory and explained the concepts that will frame the characterization of the studies, as well as they discussed the framework which they used for their analysis. Next, the authors explained the concept of design fictions and the impact of this idea, and then described how to shift from observations of practice into implications for interaction design and the dynamics of practices. This set the foundation for their argument to match practice theory with design fiction, in order to find new approaches to sustainable interaction design. They see that a practice-oriented approach is the one that supports their argument and assists designers to shift from modeling individual behavior to making sustainable behaviors part of interrelated practices and practice elements. They present two related studies for examination to prove their argument,

The first study of daily fix explores people's behavior and how they define their objectives break. The second study focused on green DIY (do-it-yourself) look at how green enthusiasts simplify their practices to make projects sustainable DIY. These studies showed two reformist daily practices and green enthusiasts in terms of materials and disciplines, and meanings, and they used a framework have been used before by shoves [75] to find the relationship between these elements. They believe that consideration of the dynamics of practice and their orders are the starting point for creating a new definition of sustainable design interaction (SID) roles. They also said that some designers design methods in ways of thinking about the challenges and clearly designed to interfere in the practice. Besides taking into account the SID in the focus of practice theories, they showed how design fictions are easily integrated into green practices in ways that convert those practices and make implications for the design transformations.

B. Customer Requirements for Sustainable Design

Biju et al. [2] conducted a systematic literature review on Customer and Sustainability requirements to focus on the ecodesign tools proposed during the last two decades. This paper proposed a new tool named 'Customer and Sustainability Requirements Evaluation Matrix' ('CSRE Matrix'), which assesses customer requirements and sustainability requirements separately to select the combination of the best options in the product development

stages using Fuzzy Analytic Hierarchy Process (FAHP) Matrix' to weigh the importance of customer requirements and sustainability requirements. The review focused on the eco-design tools used for developing products and to evaluate environ- mental impacts, and as well, examined the validity of the proposed tool by applying it in a company manufacturing umbrellas. The findings also suggested that in future researches that similar studies in process and other manufacturing industries need to be conducted to make 'CSRE Matrix' a much more accepted tool. To explain the usefulness of the CSRE Matrix, they conducted a case study in an umbrella manufacturing firm. They argued that the preferences of customers for environmental friendly products in the recent times reflect their changing desire towards a clean and green planet.

They mentioned in the introduction in their study that the customer requirements changing to sustainable design "The preferences of customers for environmental friendly products in the recent times reflect their changing desire towards a clean and green planet" with no explanation, as to why or how.

Buckow et al. [7] conducted a literature review on changing requirements and resulting needs for IT-infrastructure for longitudinal research in the neurosciences. They chose a mixed approach to reviewing literature and analyzing experiences of neuroscience research projects of the last 10 to 15 years from 2000 until 2014. The study identifies the challenges, requirements and solutions for IT-infrastructure for longitudinal research in neurosciences.

To identify IT-requirements into perspective, a literature research was performed addressing: (a) IT-infrastructure for neuroscience in general, and (b) literature focusing on the identified IT-requirements. The search was performed using the advanced search of PubMed as well as the one of the Web of Science to cover medical as well as informatics journals. According to the focus of this paper, the search interval was limited to the years 2000–2014 regarding the year of publication. Medical and IT-terms were used in combination to focus on papers describing the use of IT-infrastructure or specific IT-components in neuroscience research projects.

The literature on IT-infrastructure in general, as well as specific IT-challenges in neurosciences, is very scarce in comparison to the thousands of studies conducted in the field. The challenges and requirements were addressed in many articles, whereas proper solutions were missing.

Chitchyan et al. [14] conducted a literature review on Sustainability Design in Requirements Engineering: State of Practice. Their literature identifies several levels at which the adoption of "proven" useful practices can be hampered, and suggested that researchers, practitioners, teams, organizations, and professional practice regulators could all be responsible to a certain degree. They focused on the current state of sustainability in RE (Requirements Engineering) practice, and as well, investigated contemporary perceptions and attitudes on sustainability in RE practice and assessed whether they reflect the full scope of sustainability design. The study identified barriers to the engagement with sustainability design in RE practice and identified possible interventions. They characterized the current understanding of sustainability through a qualitative interview study with requirements engineers identify promising leverage points - effective places of change in the software profession - that would facilitate adoption of sustainability; however, the focus of their analysis was with RE in the software profession. They presented the qualitative study results discussing the requirements of engineering practitioners' understanding and behaviors towards sustainability, and they identified obstacles and reduction strategies concerning the daily work life application of sustainability design principles.

Wang and Tseng [88] addressed the major barriers for integrating subjective and qualitative customer's preferences into product design in general. For that, they presented a Naive Bayes-based approach to characterize the customer's technical functional requirements and subjective preferences, and map them to detailed attributes and design parameters. The customer's desired end product can be derived based on partial specifications. The paper also explained why it is hard to meet the customer needs and listed three reasons makes integrating the comprehensive customer requirements into design big challenge. The focus of their study was customer needs, and how to identify and determine customers preferences; however, the study failed to mention the ability of these factors to change with time.

C. Changing Customer Requirements

Raharjo et al. [67] conducted a systematic methodology to deal with the dynamics of customer needs in Quality Function Deployment and propose a novel systematic methodology to deal with the customer needs dynamics in QFD in general. They explained why it is important to consider the changes in customer needs. Their methodology places a heavy emphasis on the need to monitor and follow the change of customer's preferences over time. They concentrated on examining the uncertainty, and used 'fluctuation' in the customer needs over time. Most of the previous researches that studied uncertainty have not addressed the issue of how to consider future uncertainty and the changing of customer needs in QFD decision making analysis, and neglected to mention any of the sustainable requirements or the changing in customer needs for sustainable design. The same can be said for the study of Raharjo et al. [68] which briefly mentioned the use of interval estimate as a better measure for future customer needs in QFD, with no focus on sustainable requirements.

They try to answers two questions: 1) Why is it important to incorporate customer needs' when the design is dynamic? (2) What are the customer requirements? And which requirements does the customer prefer?

Compared to previous research, their paper contribution is three-fold. First, it proposed the use of a forecasting technique. Second, it explained how future uncertainty in the customer needs weights may be evaluated and transformed to the design requirements as prescribed in QFD model. Third, proposed the implementation of a quantitative approach that considered the decision-maker's attitude towards risk to optimize the analysis of QFD decision making. Then to show the practical applicability of the proposed methodology, they provided an example based on a real-world application of QFD. And from a methodological standpoint, the authors suggested that its worth to investigate for future work the dynamics of other HoQs elements apart from the VOC, and investigate on how to deal with the condition when there is inclusion of a new customer need (VOC) or exclusion of an old one as the passage of time.

Zeid [92] provided an integrated framework for CAD tools for sustainable design. The work discussed product cycle and sustainable design concepts and how they are implemented in commercial CAD systems, and provided a hands-on example on how to use the sustainability module of Solid-Works, a popular CAD system. The researcher provided an example to alleviate the reasons that challenge engineers and designers of all types of products. To do that, the author first overviews green design, and offers an example to show how to use the green design module of a CAD system, SolidWorks, to provide the designer with useful skills. The paper offered a framework that designers can map to their particular CAD system and investigate the use of its green design module. The author also mentioned that engineering design evolves over time and reflects societal needs and concerns over time, but did not define the sustainable requirements and how they impact on design if they change.

The aim of the paper of Schuh et al. [74] was the identification and handling of the leverages at an early stage to reduce the needed degree of changeability and to lower costs in production – and in consequence, to increase the competitiveness; for that, the Product Architecture Development Process (PADP) systematic design has been used. The authors mentioned that scientific literature about changeability in connection with the product design is rarely mentioned, and focused on the aspect of "product" and the changeability of the product design which can influence the production system within the company. In their opinion, the current situation of the manufacturing industry is characterized by permanent development (change) in economics, politics and society; thus, in order to react to those, companies have to be able to adapt the organization to the changes and regard the change in customer needs and market requirements as the major cause for change. And when they identified the changeability they mentioned that the changing environmental

conditions and technology lead the companies to adopt new production system to be able to respond proactively to future changes. Which as they see it's a big challenge companies have to face. However, the researchers did not study the changing toward sustainable design and didn't take into their consideration the changing of customer requirements when the environmental conditions change.

TABL
SUMMARY OF SELECTED LITERATURE ON CHANGING CUST

Reference	Objectives	
[67]	Propose systematic methodology to handle the customer needs dynamics in QFD (DQFD). The term 'dynamics' here is explained as the change of customer needs relative weights over time.	Pro
[88]	Addressing the major barrier for integrating subjective and qualitative customer's preferences into product design.	Us fu
[39]	Demonstrate how Kano Model and quality function deployment (QFD) were able to improve the design of school workshop's workstation via ergonomic design.	U
[74]	Identification and handling of the product sustainable design at an early stage to reduce the needed degree of changeability and to lower costs in production – and as consequence, to increase competitiveness.	
[85]	Contributing to the latter research on the applicability of practice theory to sustainable interaction design SID. To demonstrate how we can improve and develop interaction design outcomes by using practice theories as analytical tools.	An
[3]	Provides an LCA-based framework to assess environmental consequences and to design environmentally-sound optimization services.	i
[30]	Proposes a methodology based on feature technology and on the integrations realized on CAD of combining eco-design in the design process, as well as allowing the designer to assess the environmental impact numerically.	d re
[50]	Investigates key issues for supporting the design of sustainable business, especially focusing on how businesses deal with externality to meet multiple facets of sustainable value.	
[93]	Designing sustainable work systems.	Exa
[2]	Evaluates 'Customer Requirements' and 'Sustainability Requirements' separately during new product development using a CSRE Matrix.	T an th be CS Ma req
[52]	Improve existing design for sustainability practices and spread best practices within the industry.	In
[92]	Offers a framework that designers can map to their particular CAD system and investigate the use of its green design module.	Pr
[7]	Identifies challenges, requirements and solutions for IT-infrastructure for longitudinal research in neurosciences.	exp fro
[14]	Identifies obstacles and mitigation strategies regarding the application of sustainability design principles in daily work life.	en rec 1) 2)
[58]	Create an index of management control systems (MCS) that are used by organizations to implement sustainable development (SD).	C

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Hashim and Dawal [39] conducted a study on the method that can be followed by the companies to fulfill customer requirements and achieve the satisfaction measurements of new product development. Their goal was to show how it was typical of Kano and QFD is able to improve and develop the design of workstations and workshop school work through a comfortable and convenient design. They present their study in Kano model, methods and QFD for the development work and school workshop for student's station is designed to make it appropriate and commensurate with the needs of users.

To identify the problems of the current workstation, A Kano questionnaire was constructed by direct user contact through interview. They gave their opinions regarding the current workstation. All relevant comments and suggestions regarding ergonomic consideration were included in the questionnaire a survey was conducted with 255 students, then the data filtered and used in the House of Quality matrix. They found that both methods were able to prioritize the modification elements to be implemented into the new ergonomically designed workstation.

The study identified and prioritized the user and technical requirements to develop a modified workstation for a school workshop based on an ergonomic approach; however, they did not mention how to maintain customer satisfaction if their requirements have changed.

III. Other Related Works from Theses

In the sustainable design and customer requirements research literature, there are a few examples of reviews on 5 thesis's Published in ProQuest for 2011 to 2016

In his PhD dissertation, Farias [27] conducted literature review that included the following areas: (a) Sustainable architectural design; (b) Green Building Rating Systems (GBRS); (c) Importance of Building Performance Assessment; (d) Building Information Modeling (BIM); (e) BES and BIM; (f) Integrated Design Process (IDP); and, (g) Integrated Project Delivery (IPD); as well as selected case studies to show their benefits. The literature converges in terms of stressing the importance of a multidisciplinary design team using evidence to support design decisions, the importance of energy efficient buildings to tame the impact on the environment, and the impact that technologies to aid design have made into the design process (BIM, BES).

He examined the degree of adoption and impact of the three concepts of BIM, IPD, and BES on the design processes of advanced architectural firms when executing sustainable design. Three offices in the U.S.A., two offices in the U.K. and one in Malaysia were selected due to their commitment to sustainable design and influence in design. The literature review substantiates the importance of understanding the concepts of BIM, IPD/IDP and BES, and establishes that there is not yet a consensus or well understood set of practices to bring them together.

The analysis from the data supports several conclusions across a wide range of topics. The results show that it is possible to generalize the sustainable design processes. He created the design process for sustainability (DEPROSU) model from the literature review and then called interviews and seminars for collection of data. The author founded commonalities between the design processes and some selected firms, then presented those commonalities in the (DEPROSU) model, which can be used as standards for sustainable design, and then provided architectural designers with concrete types for developing and or validation of their design methods This research was limited to studying the perceptions of BIM, energy simulation and IPD in sustainable design methods within a small number of leading architectural design firms. It did not assess the effectiveness of the methods used by the firm or the quality of the resulting designs.

In his PhD dissertation, Hanes [37] addressed the need for multidisciplinary modeling in sustainability applications. Two methods for sustainable assessment, both of which combine mathematical and statistical modeling with LCA, were developed. To organize LCA, the author applied linear regression and model cross-validation techniques, he simplified the model to create streamlined life cycle inventories and estimates of the error in the streamlined inventories relative to a full inventory.

The paper presents process-to-planet (P2P) modeling for sustainable engineering applications, as well as the many applications of the P2P to engineering design. The findings suggest that the P2P framework results in environmentally preferable designs compared to traditional sustainable design methods. The author used the P2P modeling approach to integrate essential engineering models with macro-economic equilibrium models, to address engineering and economic policy design problems within the same framework, and then presented a case study to model the effects of an environmental tax policy on a P2P system and equilibrium models.

Morris [62] developed a new method and tool to help guide engineers to evaluate their electrical-mechanical designs towards satisfying the fundamental requirements of product sustainability, and use the specific results (i.e., measures) of the evaluation as feedback to improve the designs. The paper evaluated a theoretical model that analyzes the requirements of sustainability with product designs, and models the requirements of design for sustainability and determined the measures for the evaluation of the design for sustainability requirements, and then implemented the results into a tool that design engineers can use for design for sustainability. The author presented a multiplex method, with utility theory, and used detailed design life cycle data, and product architectural

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data to direct design decisions to meet product sustainability objectives like the reduction of less recyclable materials, inseparable joints, and improved product arrangement. The implementation of this research will help designers in optimizing life cycle objectives and range each design component's end-of-use strategy to both function and form, and modify specific design requirements that are directly affecting the product's end-of-use strategies to both function and form, as well as modify the requirements that are directly affecting the product's sustainability.

The researcher argued that the measurable requirements push designers to find waste that naturally exists from the design process. The tool yields an overall sustainability score and an end-of-use strategy for each part within the design. The study included many case studies in the Multi-Disciplinary Design Laboratory through Rensselaer's Senior Engineering Design project to help reduce the concept to practice and show that the proposed method is valid.

The objectives of this research were to:

1. Introduce product sustainability measures that affect endof-use strategies.
2. Capture design data and product configuration decisions (often made implicitly) that will affect sustainability.
3. Quantify the data through utility theory, allowing the user to rank and compare product architectures against sustainability measures.
4. Visualize this data by indicating end-of-use impact and architecture, with graphical outputs that fit in the embodiment stage of design.
5. Validate through comparative case studies to prove the results are internally (i.e. from given inputs, a sensible output is obtained) and externally consistent (i.e. the model output "agrees" with other sustainable assessment output).

Hosseinpour [42] integrated Axiomatic Design and QFD concepts with eco-design tools, such as Lifecycle Assessment (LCA), to establish the quantitative metrics for sustainable product design. A novel wheelchair is designed as a case study in this research.

The objective of the research was to develop a multi-criteria method for product design to map customer needs and sustainable requirements from qualitative criteria into quantitative metrics, and improve the ability of the product for ease of reusing, recycling and remanufacturing through the modularity.

The study also integrates traditional and recent sustainable methods to identify and map both sustainable criteria and customer considerations from qualitative into the quantitative metrics, to help designers to establish sustainable design metric at the early stage of design.

The researcher conducted a literature survey to define the concept of sustainability, which examines the current research and studies for sustainable design development. The framework and details of the research method, including the integration of traditional methodologies with the sustainable principles for product design and end-of-lifecycle management, are described, then discussed for sustainable product design. The axiomatic design and QFD methods were integrated with eco-design tools to develop a new multicriteria sustainable method. The main challenge in this paper was meeting the different requirements of design including cost, comfort, strength, environmental footprints, maintainability, and recyclability. In order to find a satisfactory solution, the priority and weight factors of sustainable design parameters were determined and then the customer needs and sustainable considerations were mapped into the functional requirements and design parameters based on the axiomatic rules to identify the minimum set of independent functional requirements.

A house of quality (HoQ) is formed to link the customer needs, sustainable considerations, and functional requirements. The design matrix is then established to find correlations between the functional requirements and design parameters, to determine the priorities of the sustainable design.

This research provides a quantitative multi-criteria method with adding the sustainable consideration to the integration of axiomatic design and QFD.

The aim of the work by Verhulst [82] was to gain profound insights on human factors and their influence on the implementation process of sustainable design in practice, by studying this implementation process from the perspective of change management.

First, the paper presents a theoretical framework on the implementation process of sustainable design from the perspective of two disciplines: sustainable design implementation and change management. The theoretical framework of the work, which is divided in three parts, is presented. These parts are: (1) Introduction on sustainable design literature; (2) Focusing on the change process from the perspective of change management; and (3) Identifies and compares overlapping subjects such as drivers, tools, methods, strategies and approaches, as well as success factors and obstacles and human factors in the fields of study. The literature review indicates a need to structure and cluster the wide range of influencing – human - factors. It also indicates the need for further exploration of the human factors from an empirical perspective. The paper included two case studies conducted by the researcher.

The research findings contribute to an understanding of the implementation process of sustainable design by studying how human factors influence different stages of this process from the perspective of change management.

Insights in the implementation process and the influencing factors can support scholars and practitioners with managing this process more effectively by enabling them to understand and plan the different process steps, while also foreseeing and incorporating human factors in each of the stages in this process. About future studies, the author suggests a focus on the translation from the descriptive study results into a prescriptive method, which might eventually lead firms to successfully change towards sustainable design.

IV. Research Method

This research consists of a systematic literature review (SLR) about changing customer requirements for sustainable design over time. This research followed the guidelines proposed by [43], [61], and was carried out in three stages: planning the review; conducting the review; and reporting and dissemination. Table II presents a summary of the main activities conducted in each stage.

A. Planning the Review

This review planned proposing research questions related to the research objectives.

With the increased use of the methods of fulfill the customer requirements of new products development, it is of the utmost importance to study integrating environmental customer requirements to the product and service design methods.

In this stage, an exploratory literature overview on the main related constructs was conducted. The Sustainability, Sustainable Design and Sustainable Design Requirements scope of the review was limited to recent publications for the years 2011 up to 2016 using the full text, the abstracts, the titles and keywords.

An important result of this stage is the preliminary version of the research question. Another result is the definition of criteria for the filters used for the papers which are a sample of articles on sustainable design. This definition is crucial for the research, since it determines the quality of the results. In the planning stage, categories to frame the papers for data analysis were also defined. Three types of categorizations were initially chosen, (sustainable design, customer requirements for sustainable design and changing customer requirements for sustainable design) on the research method. Only a few studies have focused on design for sustainability, and even few methodologies exist for the support of sustainable design from the customer satisfaction perspective.

Although there have been several contributions to the field of sustainable design, there are a lack of a coherent and consolidated views on the topic changes in customer requirements from the viewpoint of sustainable design over the time. Therefore, the main goal of this work is to develop an understanding of the methods used to measure the changes in customer requirement over time, and also to find out what is the objectives and the methods that the other researchers follows how they achieves that? To fulfil these objectives, the following research questions were formulated:

RQ1. What is the definition of sustainable design and the customer requirements for sustainable design according to published empirical studies?

RQ2. What are the methods used to measure the changes in customer requirements?

RQ3. What are the methods used to measure the changes in customer requirements for sustainable design over time?

B. Conducting the Review

In this stage, the findings of the search and extraction of information have been presented from relevant sources and databases, and represents the review itself, which initiated with the data collection. For this step, a sample of articles on sustainable design scoped databases from the year 2011 up to

2016. These databases were chosen given the comprehensiveness of papers including titles from Google Scholar, Science Direct, ACM Digital library, ACS Publication, IEEE Xplore, ProQuest, among others. The following filters were used: (1) in the title: sustainability or “sustainable design” or “eco-design” or “design for environments” or “green design”; (2) in the title or keyword or abstract: corporate* requirements * needs* indicators; (3) in the title: *changing * *over time; (4) in the title: measure* tools* integration* assessments* effectiveness * method* model* framework. The symbol (*) has the function to include any variation on the terms searched. The first reading of the papers was restricted to the title and abstract with the objective of excluding papers without adherence to the present research and without an available full paper. An extensive inspection of the study titles and abstracts was conducted on the final sample which consisted of 573 works. The result of this first round of classification revealed 63 candidate studies. The second round of readings, which included the full text, focused on the introduction, research method and conclusion section. At this step, the following data for each paper was extracted: research method, performance approach, aim and objectives of the research, contributions, main concepts/constructs, recommendation for future studies and general comments (if necessary), and studies were excluded based on the defined exclusion criteria. Out of the 63 studies pre-selected after the application of the inclusion criteria, 45 were excluded as they did not discuss any topic directly related to the scope of the current investigation. It is important to note that after a full paper review only 17 papers and five thesis were selected for the third round.

C. Reporting and Dissemination

This stage of the research, data analysis is done corresponded by literature review and data writing up surveys.

V. Research Results and Discussions

This section is dedicated in describing the data analyzed.

A. General Overview: Organizing the Literature and Main Topics

Descriptive statistics based on paper sample data were conducted, bringing an initial overview of the literature analyzed. Fig. 1 shows the main journals and articles published on sustainable design, and used to obtain the research sample articles. For example, according to the addresses of publishing the results of direct Science 20112016, the majority (3795) dealt with topics such as renewable and sustainable energy audits and included topics such as cleaner production (2819), and land use policy (660), and energy conversion and the Department of (648) and less the shape. 2 shows the addresses of publications related to sustainable design.

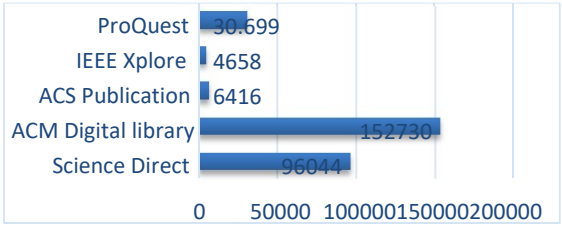

Fig. 1 Main Journals Publishing Sustainable Design Studies

Fig. 3 shows the yearly evolution of publications in the last six years of the Science Direct journal. This period has limited publications from 2011 until May 2016, And Fig. 4 shows the yearly evolution of the thesis published in the last six years After considering the universities (institutions) locations of each author for the thesis related to sustainable design studies of ProQuest from 1953 up to May 2016, the results shows that most of them are from Europe and United States of America and Canada (refer to Fig. 5). It is also possible to see that there are relatively few studies on sustainable design emerging from some Asian countries and from South America or the Middle East. The last six years the results of ProQuest for the thesis didn't change that much, the United States of America get the first place of the number of the thesis's in this six years, then Europe, and the Middle East get some changing and published more thesis, especially in Saudi Arabia and changed the place from the last place.

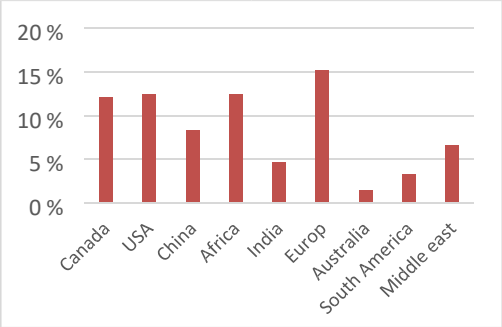

Fig. 5 The Locations of the Authors or the Universities for the Thesis

A. Overview of the Selected Studies

As previously mentioned, 17 studies were identified. Table III presents the distribution of the studies publication sources, and shows that of the 17 studies, about 76.5% (13 of them) were published in journals, and 23.5% (4 of them) presented at conferences.

for sustainable design, which is the main objective of the current study.

B. Discussion of the Results

An important aspect highlighted in the analysis for the universities (institutions) geographic locations of each author for the thesis related to sustainable design studies of ProQuest from 1953 up to May 2016. It was observed that 15.12% of all contributions were from European countries. This result is unsurprising, considering the fact that the concept of the sustainability started there in the 17th and 18th centuries [34]. Meanwhile, the second largest number of contributions come from the United States and African countries, while China contributed 8.3%, placing them fourth after Canada, and Austria contributed the least number of studies (1.4%).

Fig. 6 The Research Categories (by percentage)

Therefore the expected findings of the review was taken from (ProQuest) for the thesis, which has thesis's written in English, but many other countries the students in their universities they do not write their thesis in English, which made them not considered. Based on the findings, it could be concluded that many institutes in Asia and other countries are still in the process of adopting more thesis about sustainability.

According to the yearly evolution in the last six years of Science Direct journal the results shows that the articles about sustainable design increasing year by year, this shows how the awareness about the changing in the environments problems increasing and takes more attention every year. And it's the same with the thesis of ProQuest in the last six years, the thesis about sustainable design are increasing every year.

The results of this study found that most of the studies were exploratory in nature based on empirical investigations, newly proposed ideas and literature review papers. This finding reveals the fact that most of the efforts are focused on understanding and identifying sustainability and customer requirements.

About the research categories the results shows that most of the studies are about sustainable design in general then about customer requirements for sustainable design and the studies about changing customer requirements was just 13% which is very small average comber with the other works, but there are no articles about changing customer requirements for sustainable design, and the articles about changing customer requirements over the time was very few and not about changing customer requirements for sustainable design over the time. Most of the researchers in this field ignore how the design changing over the time for the sustainable design in general.

VII. Future Research

The addition of the current findings to the extant sustainable design literature suggests that additional work should focus on psychographics, to understand the customers purchasing behaviors, and how to influence the consumers and shift their behavior to adopt sustainable requirements and not just the environmental requirements. Since sustainability is a concept to balance the economic, social and environmental assessments in product design. And future research could further classify clients' backgrounds in order to find out
whether clients of different backgrounds show significant differences in responds to the sustainable design and what make them change their requirements.

As the environmental movement continues to mature, it is important that segmentation criteria be periodically investigated to validate their use in light of changes in customer requirements for sustainable design taking place, Researchers can contribute significantly to this issue, and additional attention should be devoted to identifying the sustainable requirements and the changing in sustainable requirements.

Also, additional attention should be devoted to identifying other practitioners and academic researchers

alike. This would facilitate the comparison of results across future studies, the authors should focus more on customer requirements for sustainable design and the changing over the time which formed the main subject of the study. And how the customer requirements changing over the time for the sustainable design

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