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New Product Development Method Trends and Future Research: A Systematic Literature Review

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Abstract: Research on new product development (NPD) has led to tools, methods, models, and frameworks that enable researchers to develop better products. However, a comprehensive review of the methods, models and frameworks related to NPD is lacking. This literature study aims to identify research trends, methods, and frameworks used in NPD between 2010 and 2019. A systematic literature review is conducted by developing a structured research protocol. An analysis of 50 selected papers shows that research on NPD can be categorized into 15 conceptual papers, six review papers, 28 case studies, and one survey paper. This paper provides an overview of each tool and presents future research opportunities. This paper concludes that future research can be directed toward combining several methods to design products that satisfy consumer desires with shorter design times, aspects of NPD collaboration, and aspects of changing consumer preferences.

Keywords: New product development, method, systematic literature review.

Introduction

At present, the products desired by consumers are increasingly diverse, both in terms of technology, product size, product quality, feature completeness, durability, and environmental aspects. Product design needs to pay attention to customer needs, consideration of the user's environmental aspects, and feelings. New Product Development is characterized as the way toward changing outstanding market opportunities into a beneficial product available to be purchased, for the most part comprising of an arrangement of steps wherein organizations can utilize them to accomplish commercialization objectives [1]. Normally, the New Product Development (NPD) process contains six phases: started arranging, idea generation, system-level structure, point by point setup, testing and refinement, and product improvement. Among all stages, the idea advancement stage is the most significant stage that does not just affect the downstream exercises of the whole process yet also essentially impacts the NPD's general accomplishment. In particular, the idea advancement process incorporates a few delegate exercises: (1) distinguishing customer needs, (2) conceptualization, (3) idea determination, (4) cost investigation, (5) model testing, and (6) benchmarking examination.

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Item improvement without remembering customers for the idea advancement process is bound to fizzle since huge gaps may exist between customer needs (CR) and managed functional designs. New item improvement is characterized as changing distinguished market openings into valuable items available to be purchased, for the most part comprising of an arrangement of steps wherein organizations can utilize them to accomplish comercialization objectives [1].

There are many methods, models, and frameworks that enable researchers to develop better products. Some researchers have reviewed NPD-related research with a specific focus on several sub-topics, namely TRIZ, cognitive concepts, life cycle assessment, eco-design, and sustainable product design, as shown in Table 1 but a comprehensive review of methods, models, and frameworks on NPD topics is still not found yet. This literature study aims to identify research trends, methods, and frameworks used in research between 2010 and 2019. The most recent literature review on the topic of New Product Development has a different focus. These focuses include Sustainable New Product Development [2], TRIZ method [3], eco-design methods and tools [4], Cognitive concept [5], and Life Cycle Assessment [6]. No literature review discusses critically the literature related to the whole methods/framework in New Product Development, and it will be discussed in this review paper.

Methods

Studies have been carried out using the systematic literature review (SLR) method, which refers to the guidelines suggested in [7]. The initial step in the SLR

Table 1. The used and unused criteria

Used criteria:	Criteria not used:
▪ Papers or paper analyses for the period 2010–2019 ▪ Research in the area of NPD ▪ Papers from a peer review ▪ Published in English ▪ Availability in chosen online databases	▪ Research beyond the NPD area ▪ Research that are more scientific, debate-oriented, reporting-based, and non-academic studies ▪ Not the outcome of a peer review process ▪ Unavailable in English ▪ Duplication

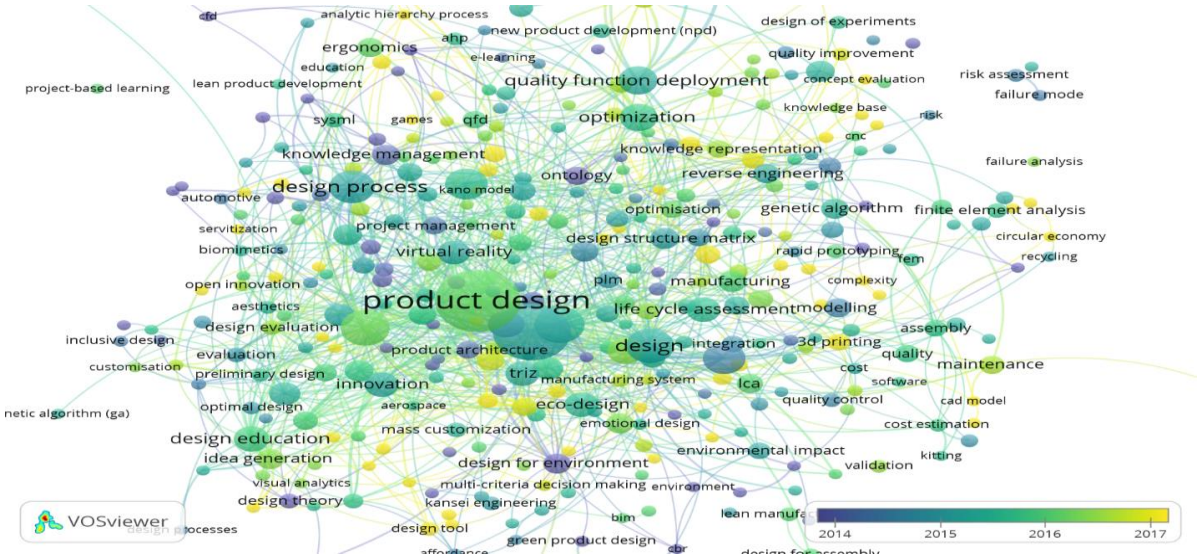

Figure 1. Relationship between keywords in new product development tool

is to develop a protocol to conduct a comprehensive review that can guide the SLR step. This protocol review aims to minimize bias in studies and be an important element of the SLR. This protocol provides a detailed plan for selecting literature and includes several stages: research identification, research questions, search procedures, selection criteria, quality assessment, data extraction, and data synthesis [7].

Research Question

Researchers have conducted research related to NPD for new framework/model/tool development and case studies. First, this study provides an overview of NPD research conducted during 2010–2019, highlighting the current status of the concept of NPD. Second, we report the results of theoretical/framework/model investigations, key factors, challenges, and knowledge gaps. To accomplish this objective, it is important to investigate the degree of research enthusiasm for this topic area. Thus, the following research questions (RQ) were posed:
RQ_1: What are the key areas of the NPD concept? Researchers need to grasp new product design better and distinguish the results from each article.

RQ_2: What are the theories/frameworks/models implemented within the definition of NPD? Scientists and professionals with research interests in creating new products can use this information to establish theories/frameworks/models.

RQ_3: What are some of the knowledge gaps in NPD research?
A better understanding of the knowledge gaps can help researchers gain new perspectives into areas that still need to be examined.

The used and unused criteria in this literature review are as shown in Table 1.

Paper Quality Screening (QS)

There are 5 (QS criteria) questions as follows:
QS1: Does the research topic discuss the New Product Development Tool?
QS2: Is the research context clear?
QS3: Does the research use a clear and correct methodology?
QS4: Was the data collection procedure well explained?
QS5: Is the approach to data analysis well explained?
To assess the quality level, 5 Likert scale are used: “Very high=5”, "High=4", "medium=3", “low=2”, and "very low=1".

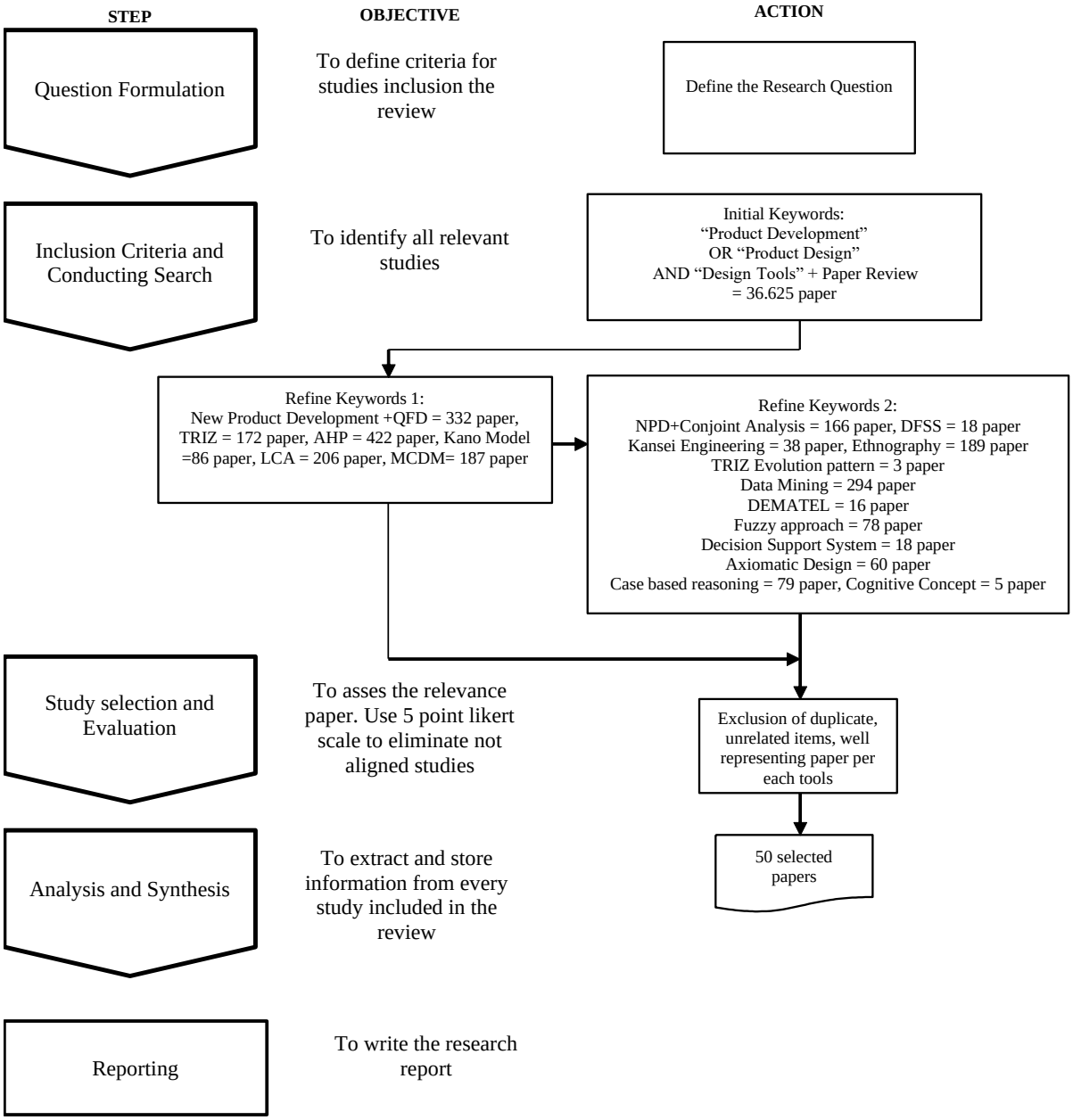

Figure 2. Systematic Literature Review

Keywords Definition

To limit the study, it is necessary to list the keywords as follows:

Data extraction and synthesis process

Initial Keywords

The initial keywords in this tudy are product design" OR "product development" AND "design tool"
By using this intial keywords, it can be visualize the result in Figure 1.

Refine Keywords (1):

The refine keywords are based on keywords got from first searching, as seen in Figure 1. Based on Figure 1 there is some interesting method/tool in the previous studies that are the "LCA", "multi-criteria decision-making in product design", "QFD", "LCA", "ecodesign, "Kansei engineering", "TRIZ", and "design tool". After conducted searching with refining keywords 1 then we get new keywords (refine keywords 2)

Refine Keywords (2):

After searching with refining keywords (1) then it gets the new NPD tools keywords such as design for six sigma (DFSS), conjoint analysis, data mining, DEMATEL, fuzzy approach, decision support system (DSS), Kano, axiomatic design, evolution pattern, case-based reasoning, and ethnography. The

systematic literature review process in this paper can be illustrated in Figure 2.

Database:
The following databases are selected to explore the research in New Product Development tools that we mentioned above. The databases are Sciencedirect, Emerald, Springer, and Wiley Online.

Results and Discussions

Based on used criteria and non-used criteria in Table 1 and considering paper quality using the Likert scale, 50 papers will be discussed. An analysis of the 50 selected papers shows that NPD research can be categorized into 15 conceptual papers, six paper reviews, 28 case studies, and one survey paper. Case studies conducted include automobile designs, multiple dwelling units, door-to-door delivery services, real-estate preference for eco-lighting, aircraft tail green products, mobile phone designs, automotive components, electronic switches, ultrabooks, and mechatronics. After selecting 50 good and valid articles, the next is to extract data from these articles. Figure 3 exhibits the number of papers in each category. Figure 4 presents the number of papers in each database.

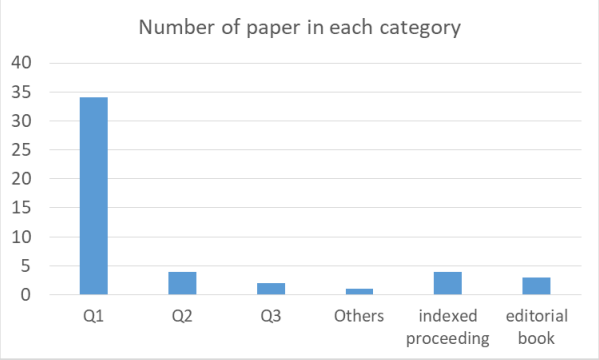

Figure 3. Number of papers in each category

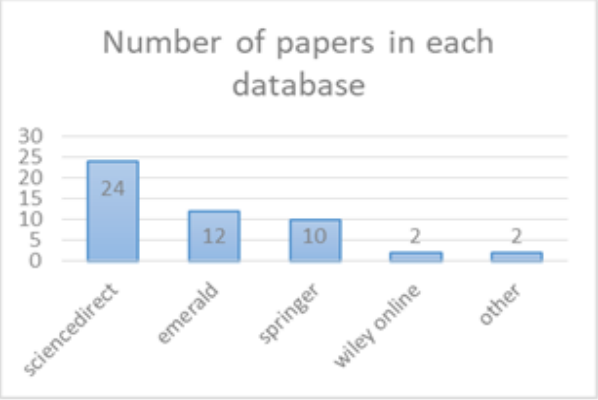

Figure 4. Number of papers in each database

Research Focus in New Product Development

Based on the focus of this research and the theory proposed by [2], the extracted papers can be categorized into the following three areas:

Sustainable Product Design

Sustainability can be defined as the capacity of an item or system to work continuously for long life with the least environmental effect. It involves three components: ecological, financial, and social considerations. The concept of sustainability has been applied to numerous fields, including engineering, manufacturing, and design. The item design process is one of the essential aspects of sustainable development. A sustainable design influences all the phases of an item's lifecycle, starting from the separation of raw materials to as far as possible in its life cycle [8].

Sustainable product development (SPD) is a principal issue in the manufacturing business, and designers are concerned with producing increasingly sustainable items. The main tasks in sustainability are (1) Deciding and organizing supportability that makes up the "sustainability plan;" (2) Producing sustainability proposals in the underlying structure by utilizing important devices and underlining the link between sustainability issues; (3) Assessing design execution against supportability motivation; (4) Creating systems for the following supportability. The SPD methodically considers the entire lifecycle of an item for practical, natural, and financial executions [2]. A few investigations that examined maintainable item configuration include [2, 6, 9, 10, 11, 12], and Gupta *et al.*, [13].

Eco-design

Eco-design or earth agreeable plan involves reducing the natural effect of items and administrations for the lifecycle duration while ensuring comparable or better administrations for end clients. The idea continues to fulfill customer prerequisites in an increasingly practical way [4]. Eco-design is characterized in ISO 14062 (ISO/TR 14062, 2002). For an eco-structure design with seven subjective ideas proposed in [5], research has been conducted on eco-structure, among others [4, 14, 15,16].

Common Product Design

This category is for product design that does not consider sustainable and eco-design factors. Some of the selected papers that fall into this category are [1, 3, 8, 17, 18, 19, 20].

Current Knowledge of the Tools Used in New Product Development (one method approach)

Among the 50 selected papers, the tools used in product design are identified in the following subsections:

Life Cycle Assessment

The LCA is an instrument designed to assess the effect of a product on the environment. Simplified product LCAs were introduced by applying a grouping approach to materials. As part of a simplified LCA approach, a simplified framework has been introduced for determining the environmental impacts associated with the material selection of a product. Based on the material analysis and physical, mechanical, and environmental properties, materials can be categorized on the basis of the material quality and efficiency in the environment. For each category, the material-based environmental impact drivers are described. Through mapping materials into the DM database, the material-related environmental effects in the different designs may be measured based on several classes of materials. The LCA tools have been used in [10, 21], whereas the simplified LCA has been used in [6].

Multi-criteria Decision-making in Product Design

Multi-criteria decision-making (MCDM) is a subdiscipline of operations research that specifically assesses various contradictory criteria in decision-making (both in everyday life, for example, industry, government, and pharmacology). The MCDM can be used as a tool in product design. The MCDM methods used in product design include:

a. AHP
The AHP is a decision-making method whereby a few options are generated to find the best decision. The AHP is used to select the right approach in product design. For complex problems, human reasoning and interpretation can be articulated linguistically and implicitly. Once a hierarchical structure is established, a comparison between elements of the same level is appropriate. The scale used in conventional AHP is 1–9, representing score between two criteria in example similar (score=1), moderately (score=3), strongly (score=5), very strongly (score=7), and extremely preferring (score=9) [10].

b. ANP
The ANP is a method for formulating decision-making similar to the AHP, considering the dependency between hierarchical elements. When a problem requires interaction and reliance on lower-level elements from higher-level elements in the hierarchy, they cannot be organized hierarchically. Therefore, the problem should be represented in the form of a network, not hierarchically. The ANP in product design can also be used to choose the best design (Younesi and Roughanian [12]).

Cognitive Concept

The cognitive concept is the concept of thinking, including processes related to perception, knowledge, problem solving, judgment, language, and memory. Cognitive concepts in product design are used to recognize consumer preferences for a product, for example, by choosing negative opinions, neutral, weak buying criteria, and strong buying criteria. Macdonald *et al.* [5] presented a paper review and proposed seven tools that can be used in cognitive concepts for choosing eco-design products. New products can also be produced from imagination. A new product design is a collection of features extracted from the existing reality. These features comprise knowledge of the forms, materials, techniques, and technologies used and are manipulated in mind: they can be resized, reshaped, or rearranged.

Design for Six Sigma

The DFSS is a constructive process requiring the inclusion of a client's voice in product design and process design. The DFSS is used to create quality designs through the application of strategic thought and techniques in the process of product creation. It includes systematic incorporation of the tools, procedures, processes, and team members over the entire product and process design phases. It comprises five stages: description, calculation, analysis, design, and verification of the data. Tools are used in each of these steps to ensure that the product and design processes are performed appropriately [22].

Conjoint Analysis (CA)

CA is one of the most common techniques for determining multi-attribute goods or services with different consumer expectations. When a component is decomposed into separate multi-attributes, it is possible to obtain the overall utility by combining the utility part value of the attribute with the related level. The CA is a process of making trade-offs between restricted alternatives, distinguished by different functional trait combinations. After conducting a CA, the two important results are the level of importance of the functional attributes and the utility part value of the attributes associated with certain ranks. Designers can use the CA to analyze segmented individual customers or groups [1].

Theory of Inventive Problem Solving (TRIZ)

The TRIZ is a logic and data-based approach to problem-solving that accelerates a team's ability to solve problems creatively. TRIZ is a powerful product development tool developed in the USSR, used in the early stages of design to help improve the design ideas and solve problems that arise in the product development process [10]. Many practitioners and researchers use TRIZ because of its ability to find evolutionary patterns in developing certain systems, thereby improving the performance of the products being developed. Based on the wide variety of issues frequently encountered in daily life, problems can be classified into two categories: routine and non-routine problems. A routine problem can be solved by standardization processes and various methods, such as mathematics, marketing, and design. A problem is categorized into a non-routine problem if the crucial steps are uncertain while solving the problem. TRIZ is a good method to solve non-routine problems. Several researchers have used TRIZ as single method such as [23, 24, 25, 26, 27].

TRIZ Evolution Pattern

As technology may progressively grow to become mature, there is a need to solve challenges, find new opportunities, prepare strategies, and forecast future directions. In particular, TRIZ researchers compare trends in developing such technologies. Eight evolution patterns have been proposed using TRIZ: (a) Stages in the evolution of technical systems, (b) Creation of greater values, (c) Formation of non-uniform framework elements, (d) Evolution toward greater dynamism and capacity to regulate, (e) Sophistication, and simplification, (f) Evolution by mixing elements that are unacceptable, (g) Shift to microlevel and increased use of fields.

Kansei Engineering

Consumers have a latent desire for new products. Kansei Engineering is a method used in product development that focuses on user "vibration" and translates this user vibration into real properties in a new design [28]. Kansei Engineering is a product development method for developing new design concepts inspired by human psychological processes [29]. Kansei Engineering can help explore consumers' impressions, feelings, requests, and emotions about a product. The obtained results can be used to determine the size, shape, features, style, and color of the desired product. Papers that reported the use of Kansei Engineering include [22, 30, 31, 32, 33, 34, 35, 36, 37].

Data Mining

Data mining is a process of searching for hidden and useful information by digging and analyzing data. This involves searching for data typically found in large amounts and then looking for previously unknown hidden patterns. Several organizations have recognized that information is key to supporting different operational decisions in this vast database. By extracting predictive information concealed from vast databases, organizations can also classify valuable consumers, forecast future actions, and allow businesses to make knowledge-based decisions. Data mining can help uncover secret information in this situation and turn data into actionable results. In developing products, data mining can be useful for formulating the "needs" and "wants" of consumers for a product, important features, integrating knowledge from consumers with product design, and strategies in product development [28].

DEMATEL (decision-making trial and evaluating laboratory)

The decision-making trial and evaluating laboratory (DEMATEL) are a non-conventional MCDM that accommodates the relationship between decision criteria DEMATEL in product design and finding the relationship between designs, including via measurement evaluation methods and strategic decision trials. Complex causal relationships can be visualized in terms of a matrix or chart. This is very useful in examining the causal and effect relationships between system components as a structural modeling approach. This modeling approach can improve the relative relationship between factors and is suitable for solving complex and interrelated problems. Several researchers and practitioners have used DEMATEL because of its strength and capabilities [6].

Fuzzy approach

Fuzzy logic has the value of uncertain information or ambiguity (fuzziness) between right or wrong and was first developed in 1960 by Dr. Lotfi Zadeh. Fuzzy logic was inspired by people who make decisions using ambiguous and inaccurate information. Fuzzy logic was developed based on human language (natural language). In fuzzy logic, this uncertainty is translated into a mathematical degree of membership. Fuzzy logic is generally applied to problems that contain elements of uncertainty, impreciseness, and noise. It can recognize, represent, manipulate, interpret, and utilize data and information that are unclear and uncertain. The fuzzy concept in product design has often been used in combination with other methods such as the AHP, ANP, and DEMATEL [1].

Decision Support System

The DSS is a system capable of delivering problem-solving capabilities and communication skills for semi-structured and unstructured problems. This method facilitates decision-making in semi-structured and unstructured environments where no one knows exactly how to make decisions. The DSS aims to provide guidance, predictions, and direct information to users for better decision-making. In product development, the DSS is used to select the final design. The final design selection requires consideration of market demand factors, design alternatives, and environmental situations and conditions that affect it. The DSS can aid in the selection of the final design [11].

Kano model

The Kano model is a method used for defining customer satisfaction, where this model attempts to categorize the characteristics of a product or service based on how well it can fulfill consumer needs. This model is one of the methods used to determine perceptions of the quality of a product from the perspective of the consumer and has been effectively used for product development. It is unproductive for a company only to meet basic needs and performance requirements. In a market with a high level of competition, companies need to adopt strategies and create product attributes that are specifically catered to please (over satisfying) customers [3].

Axiomatic Design

Axiomatic design (AD) methods establish a scientific theoretical basis that gives structure to the design process. AD offers perspectives that most conventional algorithmic design approaches cannot. It is a method used in product development with advantages over other methods because it can be used in all stages of product development, from concept design to detailed engineering design. This method is suitable for complex systems but can also be applied to simple products. AD combines conventional design theory with universal principles and applies priority standards to gain a broader perspective. AD allows designers to obtain a foundation to accommodate logical and rational thinking through a given process and tools. For example, AD can be used in the design of the orbital space plane, which houses complex systems. The logic developed by the designer is then supported by computerized calculations so that creative alternatives emerge from computers to obtain the best orbit [8].

Quality Function Deployment (QFD)

The QFD is a standardized approach used in design and product development processes. The QFD is used to assess customer needs and preferences as well as to systematically analyze a product or ability of a service to satisfy consumer needs and desires. Customer needs are intangible and can be converted into a functional attribute. Functional attributes are then converted into technical requirements, which later become the basis for determining product specifications. The manufacturing process is the basis for determining the requirements in production. The product development team communicates with the production team starting from determining technical requirements, benchmarking analysis, and determining product specifications assisted by the house of quality (HOQ) [12]. Some of the studies in which this method was used include [38, 39, 40, 41, 42].

Case-based reasoning

Case-based reasoning is a problem-solving method, the principle of which is to utilize past experiences that are similar to the problems faced today. Successful experiences in the past remain in the memory and can sometimes be used to solve similar problems today. Knowledge from the original case illustrates this issue and can help propose appropriate solutions. The CBR mimics human behavior when finding solutions to problems, e.g., when thinking about problems at hand, looking at similar problems, then uses the stored knowledge to solve the problems at hand, and stores the resulting solution in the brain to add to it. The brain can solve similar problems in the future by using similar problem-solving in the past. When using CBR on a computer, the human brain is replaced by databases stored in the computer. The CBR framework can be illustrated by cycles consisting of taking, reusing, revising, and retention [21].

Ethnography

Ethnography is the study of the life and culture of a community or ethnic group, for example, customs, habits, law, art, religion, and language. Ethnography discusses cultural phenomena in which researchers observe societies from the perspective of the research subject. The main purpose of ethnography is to provide complete and thorough insights into the views and actions of society and the people in it. For example, ethnography involves studying the traditional Subak irrigation method, which the indigenous people in Bali employ. By observing and describing this traditional method, we can obtain more information on Balinese culture. Ethnography has been used in children's psychiatric study narrative of perpetuating first nations genocide [43]. Ethnography

in product development is used to explore consumer desires by observing what they do, what their daily behaviors are, and their perceptions and daily activities. Through an in-depth observation, which may take up to several months, deep insights can be gained into the desires of a community for a product. Products produced from ethnographic studies will make them more suitable for desired tastes and reduce the risk of failure upon launch [5, 44, 45].

Current Knowledge on the Tools Used in New Product Development (Combined Methods Approach)

Based on existing reviews on our current knowledge of NPD, the most popular statistical and additional tools used in NPD are the QFD, Kansei Engineering, and TRIZ. The three tools are often combined with supporting tools such as the LCA, MCDM, cognitive concepts, DFSS, CA, data mining, DEMATEL, fuzzy approach, DSS, canoeing, AD, case-based reasoning, and ethnography. The main tools combined in the literature include the following:

Combining QFD with Other Methods

QFD has been combined with other methods including CA [1]), TRIZ and AHP [10, 11, 12], and [46]. The QFD method is relatively easy to combine with other methods because it is a tool that can be used at all stages of NPD. When determining customer needs when combining with TRIZ, a CA can be used to consider many variables. When the voice of consumers has uncertain value, the fuzzy logic is the preferred method that can be used, and when it leads to eco-design products, the LCA is a preferred one.

Combining Kansei Engineering with Other Methods

The Kansei Engineering method emphasizes the psychological feelings of users and is suitable when exploring consumer desires at the beginning of the NPD stage, though Kansei Engineering can be used throughout the NPD stages. The Kansei Engineering method has been combined with data mining [14], [32], Kano model [19], a fuzzy technique [31], and a knowledge-based system that leads to the DSS method [34].

Combining TRIZ with Other Methods

TRIZ, which was originally developed in Russia [21], has led to significant technological developments. The TRIZ has been combined with methods, among others, including DFSS [17, 22]), QFD and AHP [11]), QFD [47, 48]), DEMATEL [49], gray relational analysis [50], and Theory of Constraint [51].

Results and Discussions

The Current knowledge from the selected paper can be summarized in Table 2.

From the literature review result, most of the tools used in NPD are QFD, Kansei Engineering, and TRIZ. These three tools are often combined with supporting tools such as the LCA, MCDM, cognitive concepts, DFSS, CA, data mining, DEMATEL, fuzzy approach, DSS, canoeing, Axiomatic Design, Case-based reasoning, and ethnography.

Case studies and practical Implementation

From Table 2 we could separate design tools that have a case study and the one which was just conceptual or review. Based on the most used tools, TRIZ is the most used tool from the 50 selected papers with 17 papers. Papers that used TRIZ such as [3, 10, 11, 12, 17, 18, 21, 23, 24, 25, 26, 27, 47, 48, 49, 50, 51]. Only seven papers from the 17 papers have a case study that implemented the TRIZ method. We could summarize that TRIZ is relatively not user-friendly to be implemented in studies than the QFD tool. Although TRIZ can be combined with other methods such as QFD, AHP and LCA [10], DFSS [17], KE [18, 23], DEMATEL [49], GRA [50], TOC [51], the use of TRIZ is still in the conceptual model, so there is a gap to use the proposed tool that combined TRIZ with this other method.

The second most used tool is KE. KE was used by 14 papers that used KE in their studies. Papers that used KE such as [13, 14, 18, 23, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37]. Only four papers from the 14 papers have a case study that implemented the KE method. We could summarize that KE is relatively not user-friendly to be implemented in studies if compared with QFD. KE can be combined with other methods such as Data Mining [14, 28], TRIZ [18, 23], Fuzzy technique [31], and DSS [34], but these combined tools still in conceptual paper, and there is a gap to be implemented in a real case study. The distinctive paper in KE used paper. One study uses KE in emotional design that is an intangible product, not a tangible product such as a mechanical product and service product.

The third most used tool is QFD. From the 50 selected paper, there are 12 papers use the QFD. Papers that used QFD such as [1, 10, 11, 12, 15, 38, 40, 41, 42, 46, 47, 48]. There are eight papers from the 12 papers that have a case study that implemented the QFD method. We could summarize that QFD is a well-known method or tool that user-friendly can implement in case studies. QFD is also

Table 2. Summarized Research Focus, method and paper category from the selected paper

Authors	Research Focus			Method*		Case Study/review/ concept
	Sustainable Product Design	Eco Product design	Common Product Design	Single Method	Mixed Method	
Wang&Shih [1]	-	-	√	-	QFD, CA, DEMATEL	Ultrabook
Ahmad et al [2]	√	-	-	LCA	-	Review
Chechurin et al [3]	-	-	√	TRIZ	-	Review
Rossi et al [4]	-	√	-	-	-	Concept
MacDonald&She [5]	-	√	-	-	Ethnography, cognitive concept	Concept
Chang et al [6]	√	-	-	-	LCA, DEMATEL	Concept
Ashtiany&Alipour [8]	-	-	√	-	Axiomatic Design	Airplane tale
Kulatunga et al [9]	√	-	-	DSS		Concept
Vinodh & Rathod [10]	√	-	-	-	QFD, TRIZ, AHP, LCA	Concept
Vinodh et al [11]	√	-	-	-	TRIZ, QFD, AHP, DSS	Concept
Younesi & Roghanian [12]	√	-	-	-	QFD, TRIZ, ANP	Door to door delivery service
Gupta et al [13]	√	-	-	KE	-	Concept
Yeh & Chen [14]	-	√	-		KE, Data mining	Concept
Wu & Chung [15]	-	√	-	-	QFD, Fuzzy theory	Green mobile photo design
Bai et al [16]	-	√	-	Collaborative Design	-	Concept
Baril et al [17]	-	-	√	-	TRIZ, DFSS	Concept
Wang et al [18]	-	-	√	-	TRIZ, KE	Concept
Llinares & Page [19}	-	-	√	-	KE, Data Mining	Real estate preference
Gausemier & Moehringer [20]	-	-	√	VDI	-	Concept
Yang & Chen [21]	-	-	√	-	LCA, CBR	Concept
Wang et al [22]	-	-	√	-	TRIZ, DFSS, ANN	Sneakers
Jafari et al [23]	-	-	√	-	TRIZ, KE	Innovation Research Center
Ding et al [24]	-	-	√	TRIZ	-	Construction technology innovation
Mawale et al [25]	-	-	√	TRIZ	-	Medical infusion
Lee et al [26]	-	-	√	TRIZ	-	Aquatic product
Issa & Zentner [27]	-	-	√	TRIZ	-	Compliant robotic gripper
Vallet [28]	-	-	√	-	KE, Data Mining	Concept
Saeed & Nagashima [29]	-	-	√	KE	-	Concept
Zhou et al [30]	-	-	√	KE	-	Medical nursing bed
Smith & Smith [31]	-	-	√	-	KE, Fuzzy technique	Concept
Kittidecha & Yamada [32]	-	-	√	KE	-	Thai ceramics
Imai et al [33]	-	-	√	KE	-	Concept
Mele & Campana [34]	-	-	√	-	KE, DSS	Bottle design
Liu & Hsu [35]	-	-	√	KE	-	Mazu crown design
Lu et al [36]	-	-	√	KE	-	Semi conductor
Huang et al [37]	-	-	√	KE	-	Emotional design
Asadabadi [38]	-	-	√	QFD	-	Concept
Chen et al [39]	-	-	√	-	QFD, Fuzzy goal programming	Concept
Wu et al [40]	-	-	√	QFD	-	Rail catering service
Bolar et al [41]	-	-	√	-	QFD, Fuzzy cognitive map	Concept
Efe [42]	-	-	√	QFD	-	Dishwasher machine
LeFrancois [43]	-	-	√	Ethnography	-	Concept
Boellstorff [44]	-	-	√	Ethnography	-	Concept
Crabtree [45]	-	-	√	Ethnography	-	Concept
Wu & Chung [46]	-	√	-	-	QFD, Fuzzy theory	Green mobile design
Francia et al [47]	-	-	√		TRIZ, QFD	Open Molding manufacturing
Shahin et al [48]	-	-	√	-	TRIZ, QFD	Banking services
Chang et al [49]	-	-	√	-	TRIZ, DEMATEL	Concept
Lin et al [50]	-	-	√	-	TRIZ, GRA	Concept
Huang et al [51]	-	-	√	-	TRIZ, TOC	Concept

LCA/MCDM (AHP/ANP)/Cognitive Concept/D-FSS/CA/TRIZ/TRIZ Evolution Pattern/Kansei Engineering/ (KE)/Data Mining/DEMATEL/ Fuzzy Approach/ DSS/ Kano -Model/ Axiomatic Design/ QFD/ CBR/ Ethnography*

easily combined with another method such as Conjoint Analysis and DEMATEL [1], TRIZ, AHP and LCA [10], Fuzzy Theory [15], Fuzzy goal programming [39], Fuzzy cognitive map [41]. However, in [10, 11, 39, 41], the QFD is still in the conceptual model, so there is a gap to use the proposed tool such as combined QFD, TRIZ, AHP, and LCA [10], QFD, TRIZ, AHP, and DSS [11], QFD and fuzzy goal programming [39], QFD and Fuzzy goal programming [41] in a real case study. Ethnography such proposed by [43, 44, 45], can be used in product design, but in the 50 selected paper, no paper use ethnography in the real case studies, so it is interesting to use the ethnography in real product design case studies. Ethnography is a good tool to capture the customer needs from various daily activities in daily life. The weakness of ethnography is that it takes a long time to propose the customer's real need.

Collaborative Design was proposed by [16]. Collaborative Design proposed a responsiveness aspect to deliver the product to the customer in less time required. It can happen because the design task is divided into several product designers from several companies that willing to collaborate. It is also proposed a less new product design internal team. In the 49 selected papers outside [16], no paper considers collaborative design in designing the product using several tools and methods. So, it is an interesting topic to consider collaborative design using several methods that were previously discussed.

Analysis of the tool from the research focus

Sustainable Product Design

LCA is a good tool in sustainable product development [2, 6]. Sustainable product Design topic area is lacking discussion in responsiveness aspect [2]. Data Mining is a kind of NPD tool that we can use to support the responsiveness aspect for the LCA and the main NPD Tool such as QFD, Kansei Engineering, and TRIZ.

Ecodesign

Green mobile design is an interesting topic area in New Product Development [4, 5]. We can use LCA as the main tool to be supported by other tools like Kansei Engineering, QFD, TRIZ, etc. For the eco-design topic area, it needs to consider the cost-effectiveness aspect to support the eco-design product that can be sold at a reasonable price.

Common Product Design

Product Design in this category from the 50 selected paper in Table 2 we could summarize in the following categories such as Mechanical product (medical nursing bed [30], Thai ceramics [32], Bottle design [34], Mazu Crowned design [35], real estate preference [19], open molding manufacturing [47], dishwasher [42], airplane tale [8], sneakers [22], construction technology [24], medical infusion [25], semiconductor [36], aquatic robotic gripper [26], and Product Services (banking service [48], door to door delivery service [12], innovation research center [23], real estate preference [19], railway catering service[40]). We can use NPD tools such as Kansei Engineering, TRIZ, and Axiomatic Design for mechanical products. For product services, we can use NPD Tools such as QFD, TRIZ, and Kansei Engineering.

The tool should be simple user friendly, easy to be adapted, and make sure the final product has considered several aspects in product design [2]. So there also a gap between developing the new product design tool that can ensure the criteria above.

Knowledge Gaps

A review of the current knowledge on new product design tools/methods/frameworks has led to the following research gaps: **Gap 1:** Implementation in real case studies from the various combined tools proposed in previous studies. **Gap 2:** There has been no NPD collaboration that uses a combination of several methods. **Gap 3:** Implementation of real studies using ethnography, **Gap 4:** There is a need to develop a new tool that can accommodate user friendly, easy to be adopted, can make sure the final product is good, and has considered several aspects in product design.

Future Research Opportunities

Research Direction 1: A Study of Implementation of the various combined tool that was proposed in previous studies in real case studies in product design. **Research Direction 2:** A study in New Product Development that considers Collaborative Product Design and uses a combination of several methods. Collaborative Product Design is a new paradigm on NPD that product designers from several companies can discuss and divide jobs to get a better and faster product time to market. This paradigm can be supported by NPD Tools that we have discussed before. **Research Direction 3:** A study on the Implementation of real studies using ethnography, **Research Direction 4:** A study that develops a new tool that can accommodate user friendly, easy to be adopted, can make sure the final

product is good, and has considered several aspects in product design.

Conclusion

In this article, we presented a comprehensive literature review on several tools and methods used in NPD. The tools commonly used by designers were compiled and summarized, including the LCA, MCDM in product design (AHP and ANP), cognitive concepts, DFSS, CA, TRIZ, Kansei engineering, QFD, data mining, DEMATEL, fuzzy approach, DSS, Kano, AD, evolution pattern, case-based reasoning, and ethnography. Future research can be directed toward combining several methods to obtain products that can satisfy consumer desires with shorter design times, aspects of NPD collaboration, and aspects of changing consumer preference. This study can be used by scientists and professionals in the product design and development area.

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References

1. Wang, C. and Shih, C., Integrating Conjoint Analysis with Quality Function Deployment to Carry Out Customer-driven Concept Development for Ultrabooks, *Computer Standard Interfaces*, 36 (1), 2013, pp. 89–96.
2. Ahmad, S., Yew, K., Lang, M., and Peng,W., Sustainable Product Design and Development : A Review of tools, Applications and Research Prospects, *Resource Conservation Recycling*, 132, 2018, pp. 49–61.
3. Chechurin, L. and Y. Borgianni, Understanding TRIZ through the Review of Top Cited Publications, *Computers in Industry*, 82, 2016, pp. 119–134.
4. Rossi, M., Germani, M. and Zamagni, A., Review of Ecodesign Methods and Tools. Barriers and Strategies for an Effective Implementation in Industrial Companies, *Journal of Cleaner Production*, 129, 2016, pp. 361–373.
5. Macdonald, E.F. and She, J., Seven Cognitive Concepts for Successful Eco-design, *Journal of Cleaner Production,* 92, 2015, pp. 23–36.
6. Chang, D., C. K. M. Lee, C.K.M. and Chen, C., Review of Life Cycle Assessment towards Sustainable Product Revelopment, *Journal of Cleaner Production*, 83, 2014, pp. 48–60.
7. Kitchenham, B., Systematic Literature Reviews in Software Engineering-A Tertiary Study, *Information and Software Technology*, 52(8), pp. 792–805, 2010.
8. Ashtiany, M.S. and Alipour, A., Integration Axiomatic Design with Quality Function Deployment and Sustainable Design for the Satisfaction of an Airplane Tail Stakeholders, *Procedia CIRP*, 53,2016, pp. 142–150.
9. Kulatunga, A.K., Karunatilake, N., Weerasinghe, N. and Ihalawatta, R.K., Sustainable Manufacturing based Decision Support Model for Product Design and Development Process, *Procedia CIRP*, 26, 2015, pp. 87–92.
10. Vinodh, S. and Rathod, G., Integration of ECQFD and LCA for Sustainable Product Design, *Journal of Cleaner Production*, 18 (8), 2010, pp. 833–842.
11. Vinodh, S., Kamala, V. and Jayakrishna, K., Integration of ECQFD , TRIZ , and AHP for Innovative and Sustainable Product Development, *Applied Mathematical Modeling*, 38(11-12), 2014, pp. 2758–2770.
12. Younesi, M. and Roghanian, E., A Framework for Sustainable Product Design : A Hybrid Fuzzy Approach based on Quality Function Deployment for Environment, *Journal of Cleaner Production*, 108, 2015, pp. 385–394.
13. Gupta, S., Dangayach, G. S., and Singh, A. K., Key Determinants of Sustainable Product Design and Manufacturing, *Procedia CIRP*, 26, 2015, pp. 99–102.
14. Yeh, C. and Chen, M., Applying Kansei Engineering and Data Mining to Design Door-to-door Delivery Service, *Computer & Industrial Engineering*, 120, 2018, pp. 401–417.
15. Wu, Y. and Chung, C., Integration of Green Quality Function Deployment and Fuzzy Theory: A Case Study on Green Mobile Photo Design, *Journal of Cleaner Production*, 108, 2015, pp. 271-280.
16. Bai, Y. W., Chen, Z. N., Bin, H. Z. and Hu, J., Collaborative design in product development based on product layout model, 21, pp. 55–65, 2005.
17. Baril, C., Yacout, S., and Clément, B., Design for Six Sigma through Collaborative Multiobjective Optimization, *Computer & Industrial Engineering*, 60 (1), 2011, pp. 43–55.
18. Wang, F., Yeh, C., and Chu, T., Using the Design for Six Sigma Approach with TRIZ for New Product Development, *Computer & Industrial Engineering*, 98, 2016, pp. 522–530.
19. Llinares, C., and Page, A. F., Kano's Model in Kansei Engineering to Evaluate Subjective Real Estate Consumer Preferences, *International Journal on Industrial Ergonomics*, 41 (3), 2011, pp. 233–246.
20. Gausemeier, J. and Moehringer, S., VDI 2206- A New Guideline for the Design of Mechatronic

Systems, *IFAC Proceeding*, 35 (2), 2002, pp. 785–790.
21. Yang, C. J. and Chen, J. L., Forecasting the Design of Eco-products by Integrating TRIZ Evolution Patterns with CBR and Simple LCA Methods, *Expert System With Application*, 39 (3), 2012, pp. 2884–2892.
22. Wang, C., Yang, C., Wang, C., Chang, T., and Yang, K., Feature Recognition and Shape Design in Sneakers, *Computer & Industrial Engineering*, 102, 2016, pp. 408–422.
23. Jafari, M., Akhavan, P., Zarghami, H. R., and Asgari, N., Exploring the Effectiveness of Inventive Principles of TRIZ on Developing Researchers ' Innovative Capabilities: A Case Study in an Innovative Research Center, *Journal of Manufacturing. Technology Management*, 24 (5), 2013, pp. 747–767.
24. Ding, Z., Jiang, S., Ng, F., and Zhu, M., A New TRIZ-based Patent Knowledge Management System for Construction Technology Innovation, no. 71202101, 2017.
25. Mawale, M. B., Kuthe, A., and Mawale, A., Rapid Prototyping Assisted Fabrication of a Device for Medical Infusion Therapy using TRIZ, *Health Technology*, 9, 2019, pp. 167–173.
26. Lee, T. J., Hsu, M., and Dadura, A.M., TRIZ Application in Marketing Model to Solve Operational Problems for Taiwanese Aquatic Products with Food Traceability Systems, *Benchmarking: An Intertaional Journal*, 20 (5), 2013, pp. 625–646.
27. Issa, M. and Zentner, L., Application of the TRIZ Creativity Enhancement Approach to the Design of a Passively Adaptive Compliant Robotic Gripper, *Assembly Automation*, 33(3), 2013, pp. 231–239.
28. Vallet, F., Using Eco-design Tools: An Overview of Experts' Practices, *Design Studies*, 34, 2013, pp. 345–377.
29. Saeed, K. and T. Nagashima, T., *Biometrics and Kansei Engineering*. New York Dordrecht London: Springer, 2012.
30. Zhou, Z., Cheng, J., Wei, W., and Lee, L., Validation of Evaluation Model and Evaluation Indicators Comprised Kansei Engineering and Eye Movement with EEG: An Example of Medical Nursing Bed, *Microsystem Technology*, 1, 2018.
31. Smith, S. and Smith, G. C., A KE-LSA Approach for User-centered Design, *Journal Intelligent Manufacturing*, 24, 2013, pp. 919–933.
32. Kittidecha, C. and Yamada, K., Application of Kansei Engineering and Data Mining in the Thai Ceramic Manufacturing, *Journal of Industrial Engineering Intertaional*, 14(4), 2018, pp. 757–766.
33. Imai, M., Imai, Y., and Hattori, T., Collaborative Design and Its Evaluation through Kansei Engineering Approach, *Artificial Life Robotic*, 18, 2013, pp. 233–240.
34. Mele, M. and Campana, G., Prediction of Kansei Engineering Features for Bottle Design by a Knowledge Based System, *International Journal on Interactive Design Manufacturing*, 12(4), 2018, pp. 1201–1210.
35. Liu, S. and Hsu, H., Development of a New Cultural Design Process using Kansei Engineering and fuzzy Techniques A Case Study in Mazu Crown Design, *International Journal of Clothing*, 31(5), 2019, pp. 663–684.
36. Lu, T.P., Trappey, A. J. C., Chen, Y. K., and Chang, Y. D., Collaborative Design and Analysis of Supply Chain Network Management Key Processes Model, *Journal of Network and Computer Application*, 36(6), 2013, pp. 1503–1511.
37. Huang, Y., Chen, C. and Khoo, L.P., Kansei Clustering for Emotional Design using a Combined Design Structure Matrix, *International Journal on Industrial Ergonomics*, 42(5), 2012, pp. 416–427.
38. Asadabadi, M.R., A Customer Based Supplier Selection Process that Combines Quality Function Deployment, the Analytic Network Process and a Markov Chain, *European Journal of Operational Research*, 2017.
39. Chen, L., Ko, W., and Yeh, F., Approach based on Fuzzy Goal Programming and Quality Function Deployment for New Product Planning, *Euopean Journal of Operational Research*, 259(2), 2017, pp. 654–663.
40. Wu, X., Nie, L. and Xu, M., Robust fuzzy quality Function Deployment based on the Mean-end-chain Concept: Service Station Evaluation Problem for Rail Catering Services, *European Journal of Operational Research*, 263(3), 2017, pp. 974–995.
41. Bolar, A.A., Tesfamariam, S., and Sadiq, R., Framework for Prioritizing Infrastructure user Expectations using Quality Function Deployment (QFD), *International Journal of Sustainable Built Environment*, 6(1), 2017, pp. 16–29.
42. Efe, B., Fuzzy Cognitive Map Based Quality Function Deployment Approach for Dishwasher Machine Selection, *Applied Soft Computing Journal*, 83 (July), 2019, pp. 1-11.
43. Lefrançois, B., The Psychiatrization of Our Children, or, an Autoethnographic Narrative of Perpetuating First Nations Genocide through Benevolent Institutions, *Decolonizing Indigigeneity, Education & Society*, 2(1), 2013, pp. 108–123.
44. BoEllstorff, T., Nardi, B., Pearce, C.and Taylor, T., *Ethnography and Virtual Worlds a handbook of Method*. Oxford: Princeton University Press, 2012.

45. Crabtree, A., Rouncefield, M. and Tolmie, P., *Doing Design Ethnography*, Springer Berlin Heidelberg, 2012.
46. Wu, Y. and Chung, C., Integration of Green Quality Function Deployment and fuzzy Theory: A Case Study on Green Mobile Phone Design, *Journal of Cleaner Production*, 108, 2015, pp. 271–280.
47. Francia,D., Liverani, G.C.A. and Donnici, L. F.G., PrinterCAD : a QFD and TRIZ Integrated Design Solution for Large Size Open Moulding Manufacturing, *International Journal on Interactive Design and Manufacturing*, 12(1), 2018, pp. 81–94.
48. Shahin, A., Iraj, E.B. and Shahrestani, H.V., Developing House of Quality by Integrating Top Roof and Side Roof Matrices and Service TRIZ with a Case Study in Banking Services, *TQM Journal*, 28(4), 2016, pp. 597–612.
49. Chang, D., Liu, S. and Y. Chen, Applying DEMATEL to Assess TRIZ' s Inventive Principles for Resolving Contradictions in the Long-term Care Cloud System, *Industrial Management & Data Systems*, 117(6), 2017, pp. 1244–1262.
50. Lin, P., Lee, T.R., and Dadura, A.M., Using Grey Relational Analysis and TRIZ to Identify KSFs and Strategies for Choosing Importers and Exporters, *Journal of Manufacturing Technology Management,* 22(4), 2011, pp. 474–488.
51. Huang, Y., Liu, X., and Ai,H., Research on Application of Process Model for Product Concept Creative Design Based on TRIZ and TOC, *International Journal on Interactive Design and Manufacturing*, 11(4), 2017, pp. 957–966.