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Quality Function Deployment and Analytic Hierarchy Process: A literature review of their joint application

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Abstract

The aim of this paper is to review the literature on the combined use of Quality Function Deployment (QFD) and Analytic Hierarchy Process (AHP) methodologies and to apply a comprehensive analysis over the resulting publications. The paper seeks to classify the articles with regard to their variations and extensions, and application areas. The articles are mostly applied in manufacturing, supply chain, higher education, strategy, service and sustainability. This review is characterized by a quantitative and qualitative approach of a non-probabilistic intentional sample composed of 100 academic papers – 98 articles and 2 reviews. For this purpose, the Scopus database was selected as a means to undertake a systematic investigation with a longitudinal cut from 1994 to 2015. The aim of this paper also contributes toward complementing Ho and Mehrjerdi revisions on deepening the QFD-AHP joint application. The limitation is related to the sample of works focus of this review, restricted to the Scopus database, thereby not characterizing the literature universe. A proposal for further investigations is to expand the search scope to other databases and to carry out a deeper analysis on each application area presented.

Keywords

quality function deployment, analytic hierarchy process, decision making, literature review

Introduction

The decision-making process is a constant and present activity in people's lives as well as in enterprises, industries, huge corporations, service providers and institutions. Well taken decisions lead companies to glory, or into bankruptcy, when poorly decided. Important decisions are difficult regarding their definition by containing technical issues, clients, demands, among other criteria that must be taken into consideration. Fortunately, numerous tools and methodologies assist with analysis of options and technical advices being necessary tools for companies to survive in market. In recent years, many companies are seeking Concurrent Engineering (CE) for competitiveness. This is a phase when companies are rethinking their way of working.

The Quality Function Deployment (QFD) is a planning and problem-solving methodology that is renowned for translating customer requirements into technical characteristics of a product (Akao and Mazur, 2003).

Generally, both importance ratings of stakeholder requirements and relationship weightings are determined by the arbitrariness of the decision makers. This may result in a certain degree of inconsistency, and therefore degrade the quality of decisions made. To overcome this drawback, AHP is used to evaluate them consistently (Ho, 2008; Ho et al., 2011; Scott et al., 2013).

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The AHP is a technique for organizing and analyzing complex problems, especially those regarding decision-making processes (Jenab et al., 2014) through pairwise comparisons that relies on the judgments of experts to develop priority scales (Saaty, 2008). Developed by Saaty (1980), it has been studied extensively for the last 20 years in several areas. It can be integrated in order to consider not only both qualitative and quantitative factors, but also some real-world resource limitations (Ho, 2008).

The integrated QFD and AHP is considered one of the most common combinations of both tools. Their joint application occurs in several studies and its most popular purpose is to assist decision-making.

Ho (2008) surveys the integrated AHPs through the literature and its applications with other techniques. Ho (2008) detects that QFD-AHP is one of the most commonly used integrated AHPs. Besides, it was observed that the integrated AHPs are most frequently applied in manufacturing and supply chain application area.

Mehrjerdi (2010) reviews the QFD methodology and its extensions. Furthermore, the review presents the QFD application areas, discusses the facts that make this method a success for new product development, and identifies the QFD fundamental management implications and the key benefits of its application.

In light of the Ho (2008) and Mehrjerdi (2010) studies, this article aims to carry out an in-depth analysis of QFD-AHP joint application in the literature. For this purpose, the authors seek to present QFD-AHP variations and possible extensions in 100 academic papers – 98 articles and 2 reviews – scope of this research – and to indicate the major application areas. An emphasis is given to the Concurrent Engineering (CE), shown in this review as the first methodology or tool used along with QFD-AHP.

A literature review is responsible for gathering and analyzing the most recent scientific works available that deal with a specific subject or that give theoretical and methodological basis for the development of research projects. As an additional contribution, the principles of the simultaneous engineering are also considered.

The structure of the paper is as follows: (a) section 2 offers a literature review of the QFD and AHP methodology; (b) the research method is presented in section 3; (c) section 4 discusses an overview of QFD-AHP on engineering and business literature – variations and extensions, and applications; and (d) conclusions are given in section 5.

Literature review

Quality Function Deployment

The Quality Function Deployment (QFD) technique was first developed in the late 1960s by Yoji Akao and Shigeru Mizuno (2003). Akao (1990) defines QFD as "a method for developing a design quality aimed at satisfying the consumers and then translating the consumer's demand into design targets and major quality assurance points to be used throughout the production stage". Most recently, Khan et al. (2016) have stated that QFD is an approach to both identify and prioritize customer requirements or requirements and to translate them into strategies for product development and process specifications in order to achieve customer satisfaction.

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a technique based on mathematical analysis and some psychology techniques to quantify and compare variables by the addition of views with geometrical averages to synthesize solutions (Saaty, 1990). It was developed by Saaty (1980) to assist in solving complex decision problems by capturing both subjective and objective evaluation measures. According to Raharjo et al. (2007), the AHP is considered as the most accurate way for humans to perfectly compare many criteria or alternatives two at a time.

Research method

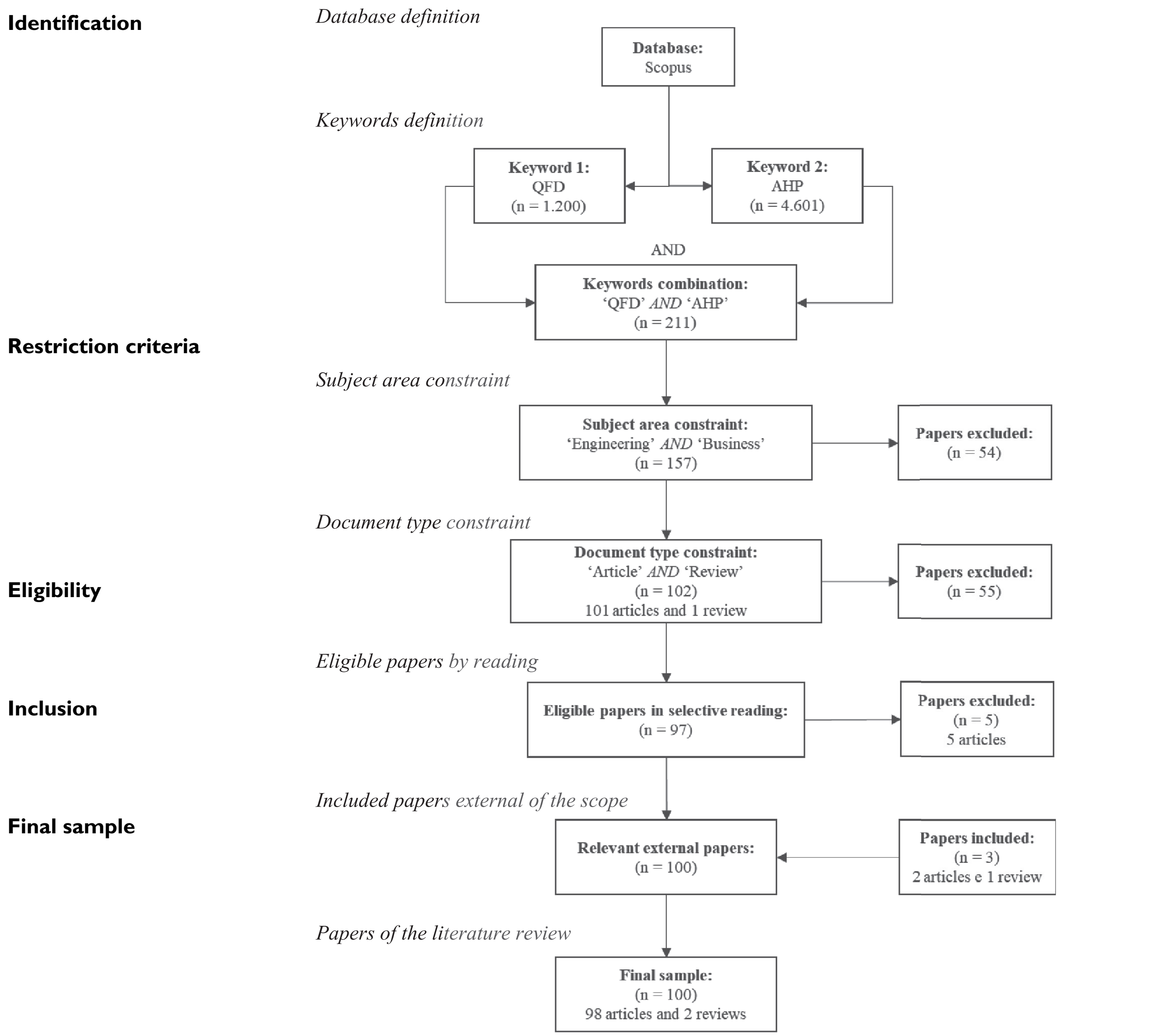
This study consists of a literature review of QFD-AHP applications. Therefore, the research structure follows four methodological steps: (a) sample definition; (b) studies classification; (c) connectivity between studies; and (d) applications analysis.

The investigation took shape after a concentrated effort to pursue the joint application of Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD) methods in articles and reviews of engineering and business areas in the Scopus database. The systematic investigation procedure covers a longitudinal cut from 1994 to 2015.

In order to refine the sample, the authors conducted selective reading, being able to exclude 5 articles that fit the research criteria, but, in their content, did not expose the combined use of QFD and AHP methods. Furthermore, it was possible to identify papers not included in the research results, but which proved to be extremely valuable and deserved to be incorporated, totaling 2 articles and 1 review of Ho (2008) about the AHP and its applications. Therefore, this review examines a final sample of 100 academic studies – 98 articles and 2 reviews (Table 1).

Following the methodological steps, the authors were able to organize a schematic table containing the final sample, 98 articles. The main informations collected in the schematic table were year of publication, journal of publication, country of application, application area,

Table 1. Flowchart of the papers identification and selection methodology for the QFD and AHP literature review.



specific segment, tools applied (variations and extensions), tools purpose, and results achieved.

This review will focus on the QFD-AHP variations and extensions (Section 4.1), and application areas (Section 4.2).

Overview of QFD-AHP on engineering and business literature

Ho (2008) states in his review that the combined QFD-AHP is one of the most commonly used integrated AHP's techniques for decision making. While the QFD analysis has the power to optimize the designers' solutions from the point of view of quality engineering, the AHP analysis helps to make the best decision in a multicriterion decision-making situation (Dziadak and Michalski, 2011).

The ultimate goal of using QFD and AHP is to help designers in developing new or existing products by incorporating customer requirements into engineering characteristics of the product. By doing so, the planners can then prioritize each product's attributes to set the levels needed to achieve such characteristics (Mayyas and Omar, 2012).

The main advantage of using QFD and AHP is their abilities to rank choices in the order of their effectiveness in meeting the functional objective (Mayyas et al., 2011), no matter the engineering stage, but, mainly, at the conceptual design stage (Mayyas and Omar, 2012). As can be seen, the project lifecycle using CE causes a peak of effort accumulation in the implementation phase when documentation and information transfer to manufacturing occurs. This peak is a consequence of the revisions in the project and the costs resulting from reformulations and reworking of equipment and tools.

They are an excellent combination because QFD does not have a fixed range and it is carried out through personal and subjective judgments, therefore leading to some degree of inconsistency. The variation is usually softened by use of AHP and its standard long-range scale (Mayyas et al., 2011) and the degree of consistency among the pairwise comparisons is measured by the final operation called consistency verification (Ho, 2008).

Succinctly, the QFD is a customer-focused method that usually begins by gathering their needs in order to transcribe them in product or service requirements. On the other hand, the AHP is based on simple mathematical formulations to prioritize competing options. It is possible to notice the complementarity of the tools at the QFD matrix, where the AHP is usually applied to ensure the customer requirements or engineering characteristics prioritization.

Nevertheless, a general criticism of systematic approaches toward decision-making and selection, as QFD and AHP, is that the result can be quite dependent on the criteria introduced in the process – customer requirements and technical requirements (Hazelrigg, 2003; Olewnik and Lewis, 2005). The company does not always have effective communication systems that allow an adequate exchange of information between the technical customer service and the product development sector. When this occurs, there is no learning process and the mistakes of a product end up repeating itself in future generations of products. To solve these problems, the implementation of the CE involves everyone in the organization which aims to improve the communication of all involved.

Despite the fact that the AHP has a few shortcomings such as the cost and time required to do the pairwise comparisons as the items get larger (Wang et al., 1998), its exceptional strength in quantifying intangible aspects, relative measurement, and consistency of decision makers outweighs other decision tools (Raharjo et al., 2007).

The following subsections aim to present QFD-AHP variations and extensions, application areas and correlation with Concurrent Engineering.

QFD-AHP variations and extensions

This section discusses and analyzes different variations and extensions of the QFD-AHP tool. Besides the traditional QFD-AHP integration, it is possible to notice the presence of QFD and AHP variations and extensions with other decision-making techniques, tools and approaches. Among the 98 articles, 48 (48.98%) applied only the traditional QFD-AHP combination. Meanwhile, 50 (51.02%) works lean on other variations and extensions.

The QFD variations identified are fuzzy QFD and Maintenance QFD (MQFD). The AHP variations are fuzzy AHP, Analytic Network Process (ANP), fuzzy ANP, Rough AHP (RAHP) and interval-based AHP (i-AHP).

The extensions are Concurrent Engineering (CE), Benchmarking, Neural Network (NN), Decision Making Trial and Evaluation Laboratory (DEMATEL), Linear Programming (LP), Interpretive Structural Modeling (ISM), Grey Relation Analysis (GRA), Extended Brown–Gibson (EBG) model, Data Envelopment Analysis (DEA), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Maximal Deviation Based Approach (MDBA), Minimal Deviation Based Method (MDBM), Balanced Scorecard (BSC), Statistical Process Control (SPC), Pugh selection matrix, Kano Model, Total Productive Maintenance (TPM), European Foundation for Quality Management (EFQM) and 360° approach.

The studies' approach, traditional or combined (variations and extensions), application area and purpose are summarized in Tables 2 and 3.

Applications of QFD-AHP

This section allocates the authors in accordance with the application area. Table 4 displays the wide applicability of the integrated QFD-AHP tool with a breadth of 8 application areas ordered by the number of articles: (a) manufacturing; (b) supply chain; (c) higher education; (d) strategy; (e) service; (f) sustainability; (g) marketing; and (h) energy. The manufacturing is the application area with greater relevance in the literature which includes 50 articles (47.17%).

In this review, sustainability is considered a secondary application area due to the fact that its articles are primarily applied in other areas.

As stated in the research method section, this review considers the analysis of 98 articles. However, 8 articles address sustainability. Therefore, for statistic purpose, they are accounted in duplicity, totaling 106.

In the subsequent section, an in-depth analysis will be carried out with the concurrent engineering role in the QFD-AHP integration.

Concurrent engineering and its integration with QFD-AHP tool

Concurrent Engineering, also known as simultaneous engineering, is a method of designing and developing products throughout several organizational functions in

Table 2. Cases of traditional QFD-AHP combination for decision-making.

Traditional approach	Authors	Application area	Purpose
QFD and AHP	Köksal and Eğitman (1998)	Higher education	Education requirement selection
	Lam and Zhao (1998)	Higher education	Teaching techniques selection
	Wang et al. (1998)	Manufacturing	Product design selection
	Xie et al. (1998)	Strategy	Customer needs sensitivity analysis
	Partovi (1999)	Manufacturing	Capital budgeting project selection
	Chuang (2001)	Supply chain	Facility location selection
	Madu et al. (2002)	Manufacturing	Sustainable product design selection
	Bhattacharya et al. (2005)	Manufacturing	Robot selection
	Dweiri and Kablan (2005)	Manufacturing	Product design selection
	Baramichai et al. (2006)	Supply chain	Business potential changes selection to improve agile supply chain capabilities
	Hanumaiah et al. (2006)	Manufacturing	Rapid tooling process selection
	Baramichai et al. (2007)	Supply chain	Business potential changes selection to improve agile supply chain capabilities
	Chen et al. (2007)	Manufacturing	Key objectives selection of KM system
	Hsiao et al. (2007)	Strategy	ERP success factors selection
	Hu and Zhang (2007)	Strategy	Hierarchical framework construction
	Raharjo et al. (2007)	Higher education	Quality characteristics selection to improve higher education quality
	Das and Mukherjee (2008)	Manufacturing	Product design selection
	Li et al. (2008)	Manufacturing	Product design selection
	Soota et al. (2008)	Manufacturing	Product design selection
	Chan et al. (2009)	Higher education	Subject selection for a training course
	Kim et al. (2009)	Manufacturing	Assessment criteria selection of MDO framework
	Soota et al. (2009)	Higher education	Curricular topics selection
	Wang et al. (2009)	Manufacturing	Product design selection
	Jing et al. (2010)	Manufacturing	Product design selection
	Li et al. (2010)	Manufacturing	Product design selection
	Tu et al. (2010)	Supply chain	Facility location selection
	Dziadak and Michalski (2011)	Manufacturing	Hardware selection
	Erkarslan and Yilmaz (2011)	Manufacturing	Product design selection
	Ho et al. (2011)	Supply Chain	Supplier selection
	Islam and Islam (2011)	Higher education	Factors selection for strengthening Muslim family institution
	Mayyas et al. (2011)	Manufacturing	Material selection
	Raharjo et al. (2011)	Higher education	Quality characteristics selection
	Rajesh et al. (2011)	Supply chain	Supplier selection
	Dai and Blackhurst (2012)	Supply chain	Supplier selection
	Mayyas and Omar (2012)	Manufacturing	Eco-material selection
	Paltayian et al. (2012)	Service	Bank selection
	Qattawi et al. (2012)	Manufacturing	Process selection
	Aguilar-Zambrano et al. (2013)	Manufacturing	Products evaluation in support of mobility
	Liu et al. (2013)	Higher education	Professional competencies selection
	Masoudi et al. (2013)	Service	Service features selection in a hotel landscaping design
	Scott et al. (2013)	Supply chain	Supplier selection
	Abdelhamid et al. (2014)	Manufacturing	Photovoltaic modules selection
	Hu and Xu (2014)	Manufacturing	Product design selection
	Chadawada et al. (2015)	Supply chain	Facility location selection
	Chowdhury and Quaddus (2015)	Supply chain	Portfolio of supply chain resilience strategies selection
	Scott et al. (2015)	Supply chain	Supplier selection
	Singh et al. (2015)	Manufacturing	Technology selection
	Khan et al. (2016)	Supply chain	Supplier selection

Table 3. Cases of QFD-AHP variations and extensions for decision-making.

Combined approach	Authors	Application area	Purpose
QFD, AHP and CE	Armacost et al. (1994)	Manufacturing	Product design selection
	Zakarian and Kusiak (1999)	Manufacturing	Multi-functional team selection
	Hsiao (2002)	Manufacturing	Product design selection
QFD, AHP and Benchmarking	Lu et al. (1994)	Marketing	Marketing policies selection
	Raharjo et al. (2010)	Strategy	Demanded quality selection
	Saricam et al. (2015)	Manufacturing	Working procedures selection
QFD, AHP, ANP and Benchmarking	Partovi (2001)	Service	Service management
QFD, AHP and ANP	Partovi (2006)	Supply chain	Facility location selection
	Partovi (2007)	Manufacturing	Process selection
	Andronikidis et al. (2009)	Service	Bank selection
QFD and fuzzy AHP	Kwong and Bai (2002)	Manufacturing	Product design selecion
	Kwong and Bai (2003)	Manufacturing	Product design selecion
	Weng et al. (2009)	Manufacturing	Product design selection
	Nepal et al. (2010)	Manufacturing	Product design selection
	Ho et al. (2012)	Supply chain	Supplier selection
	Liu and Zeng (2012)	Energy	Marine power plant design selection
	Bereketli and Genevois (2013)	Manufacturing	Sustainable product design selection
	Merino et al. (2015)	Manufacturing	Robot selection
	Wang (2015)	Supply chain	Supplier selection
	Huang and Hsu (2016)	Service	Service assessment
QFD, AHP and NN	Myint (2003)	Manufacturing	Product design selection
QFD, fuzzy AHP and fuzzy ANP	Büyüközkan et al. (2004)	Manufacturing	Product design selection
QFD, AHP and DEMATEL	Arai and Shimomura (2005)	Service	Service factors selection
Fuzzy QFD and ANP	Ertay et al. (2005)	Manufacturing	Product design selection
QFD, AHP and LP	Ko and Yung (2006)	Manufacturing	Product design selection
	Yung et al. (2006)	Manufacturing	Product design selection
QFD, AHP and ISM	Lin et al. (2006)	Manufacturing	Product design selection
Fuzzy QFD and AHP	Lu et al. (2006)	Manufacturing	Product design selection
	Raut et al. (2011)	Manufacturing	Car selection criteria
	Raut et al. (2016)	Manufacturing	Sustainable house selection
MQFD and AHP	Pramod et al. (2007)	Service	Critical factors selection on MQFD implementation
QFD, AHP and GRA	Yuan and Chen (2007)	Supply chain	Information system evaluation for supply chain management
	Chang (2012)	Manufacturing	Types of manufacturing flexibility prioritization
QFD, AHP and fuzzy AHP	Nagahanumaiah et al. (2008)	Manufacturing	Rapid tooling process selection
	Li et al. (2009)	Manufacturing	Product design selection
QFD, AHP and EBG	Parameshwaran and Srinivasan (2008)	Service	Service design selection
QFD, DEAHP and DEANP	Kamvysi et al. (2010)	Service	Bank selection
Fuzzy QFD, AHP and TOPSIS	Khademi-Zare et al. (2010)	Service	Strategic actions selection
	Kavosi and Mavi (2011)	Manufacturing	Product design selection
QFD and Rough AHP	Wang and Xiong (2010)	Strategy	Customer requirements prioritization
QFD, AHP and MDBA	Li et al. (2011)	Manufacturing	Product design selection
QFD, AHP, MDBM and BSC	Li et al. (2012)	Manufacturing	Product design selection
Fuzzy QFD and fuzzy AHP	Soroor et al. (2012)	Supply chain	Supplier selection
QFD, AHP and SPC	Moynihan and Sachdeva (2013)	Higher education	Teaching techniques selection
QFD, AHP and Pugh	Nixon et al. (2013)	Manufacturing	Solar thermal collector concept selection
QFD, AHP and Kano Model	Pi and Liu (2013)	Higher education	Students requirements selection for textbooks preparation
QFD, AHP and TPM	Sugumaran et al. (2013)	Strategy	TPM pillars prioritization
	Sugumaran et al. (2014)	Strategy	TPM pillars prioritization
QFD and *i*-AHP	Jenab et al. (2014)	Strategy	Variables selection to improve warranty management
QFD, AHP, EFQM, 360° approach and Benchmarking	Rabbanimehr and Shahin (2014)	Strategy	Manager performance evaluation

Table 4. Summary of QFD-AHP applications.

Application area	Number of articles	%	Authors
Manufacturing	50	47.17	Armacost et al. (1994); Wang et al. (1998); Partovi (1999); Zakarian and Kusiak (1999); Hsiao (2002); Kwong and Bai (2002); Madu et al. (2002)*; Kwong and Bai (2003); Myint (2003); Büyüközkan et al. (2004); Bhattacharya et al. (2005); Dweiri and Kablan (2005); Ertay et al. (2005); Hanumaiah et al. (2006); Ko and Yung (2006); Lin et al. (2006); Lu et al. (2006); Yung et al. (2006); Chen et al. (2007); Partovi (2007); Das and Mukherjee (2008); Li et al. (2008); Nagahanumaiah et al. (2008); Soota et al. (2008); Kim et al. (2009); Li et al. (2009); Wang et al. (2009); Weng et al. (2009); Jing et al. (2010); Li et al. (2010); Nepal et al. (2010); Dziadak and Michalski (2011); Erkarslan and Yilmaz (2011); Kavosi and Mavi (2011); Li et al. (2011); Mayyas et al. (2011); Raut et al. (2011); Chang (2012); Li et al. (2012); Mayyas and Omar (2012)*; Qattawi et al. (2012); Aguilar-Zambrano et al. (2013); Bereketli and Genevois (2013)*; Nixon et al. (2013)*; Abdelhamid et al. (2014)*; Hu and Xu (2014); Merino et al. (2015); Saricam et al. (2015); Singh et al. (2015); Raut et al. (2016)*
Supply Chain	17	16.04	Chuang (2001); Baramichai et al. (2006); Partovi (2006); Baramichai et al. (2007); Yuan and Chen (2007); Tu et al. (2010); Ho et al. (2011); Rajesh et al. (2011); Dai and Blackhurst (2012); Ho et al. (2012); Soroor et al. (2012); Scott et al. (2013)*; Chadawada et al. (2015); Chowdhury and Quaddus (2015); Scott et al. (2015); Wang (2015); Khan et al. (2016)
Higher education	10	9.43	Köksal and Eğitman (1998); Lam and Zhao (1998); Raharjo et al. (2007); Chan et al. (2009); Soota et al. (2009); Islam and Islam (2011); Raharjo et al. (2011); Liu et al. (2013); Moynihan and Sachdeva (2013); Pi and Liu (2013)
Strategy	10	9.43	Xie et al. (1998); Hsiao et al. (2007); Hu and Zhang (2007); Khademi-Zare et al. (2010); Raharjo et al. (2010); Wang and Xiong (2010); Sugumaran et al. (2013); Jenab et al. (2014); Rabbanimehr and Shahin (2014); Sugumaran et al. (2014)
Service	9	8.49	Partovi (2001); Arai and Shimomura (2005); Pramod et al. (2007); Parameshwaran and Srinivasan (2008); Andronikidis et al. (2009); Kamvysi et al. (2010); Paltayian et al. (2012); Masoudi et al. (2013); Huang and Hsu (2016)
Sustainability	8	7.55	Madu et al. (2002)*; Liu and Zeng (2012)*; Mayyas and Omar (2012)*; Bereketli and Genevois (2013)*; Nixon et al. (2013)*; Scott et al. (2013)*; Abdelhamid et al. (2014)*; Raut et al. (2016)*
Marketing	1	0.94	Lu et al. (1994)
Energy	1	0.94	Liu and Zeng (2012)*
Total	**106**		

*Articles with more than one application area.

concurrency and simultaneity (Prassad, 1999). Earlier, Leppitt (1993) defined Concurrent Engineering as a collection of methods, practices, tools, and approaches that aim at improving the total value chain in product development.

Concurrent Engineering is a broad philosophy that encompasses all of the supply chain. At the beginning of design, the objective was restricted to the simultaneous design of the product and its manufacturing processes. Over time, this philosophy began to involve all stages of the product life cycle, from its conception to its withdrawal from service, its final destination, after the end of its useful life. The main objective of Concurrent Engineering is to reduce the time from order to delivery, to a new product, with lower cost and higher quality. These processes are achieved through the parallel development of the different steps that make up product design with cross-functional teams.

Concurrent Engineering represents one of the earliest extensions of the QFD-AHP tool. CE stands out because of its versatility to be employed in several areas, as manufacturing and supply chain. For instance, integrating suppliers into the project speeds up, in general, their product development and integrating customers favors the fulfillment of their needs. CE can effectively contribute to the greater interaction between the various functional areas, especially R&D, engineering, production and marketing.

All 3 articles identified with a QFD-AHP-CE integration are included in the manufacturing application area: Armacost et al. (1994), Zakarian and Kusiak (1999) and Hsiao (2002).

Armacost et al. (1994) use a concurrent engineering approach, integrating the QFD and AHP techniques, in order to establish a framework for identifying and prioritizing the customer requirements to the development of one of the standard components normally associated with industrialized housing, namely a manufactured exterior structural wall pane. The concurrent engineering provides a mechanism for the holistic model that is based on the customer requirements using QFD.

Zakarian and Kusiak (1999) develop a conceptual framework for selection and prioritization of multi-functional teams based on AHP approach and QFD method. A mathematical programming model is developed to determine the optimal composition of a team. The methodology developed is tested by the selection of teams in concurrent engineering.

Hsiao (2002) addresses a concurrent customer-oriented design method integrating QFD, FMEA, DFA and AHP to develop a new product – a secure music-toy. The concurrent engineering concepts are used to create a high quality and low cost product that more fits the consumer needs.

In general, the CE has proved to promote a more holistic view, deploying competing values – not only quality – simultaneously and assigning concurrent work groups. Concerning product design selection, historically, the CE-QFD-AHP combination has shown its capacity to work with the whole product rather than its pieces, handling all life-cycle values. Concerning team selection, the CE-QFD-AHP combination has shown the importance of selecting experts from various disciplines that work in groups (teams) rather than individually in order to develop a quality product (Hsiao, 2002).

Conclusion

This review contributes to the literature with a detailed investigation of studies on the joint application of QFD and AHP. The present development analyzes studies, articles and reviews, published on the Scopus platform from 1994 to 2015 concerning engineering and business areas.

By means of using methodological metrics described in the research method and deepening the studies of Ho (2008) and Mehrjerdi (2010) about QFD-AHP, this review successfully collects and analyzes, by different angles, valuable information from the publications: variations and extensions, and application area. Therefore, it reaches the proposed goal by filling a gap left by time and generality of information found in the literature.

The integrated application of the tools is well divided between the traditional QFD-AHP concept (48.98%) and with the presence of variations and extensions (51.02%). In order to provide better organization of the results of the investigation, QFD and AHP variations are considered a separated cluster, with emphasis on fuzzy QFD, fuzzy AHP and ANP. The same principle is applied to cases in which other techniques are aggregated to the traditional QFD-AHP concept or its variations such as CE, Benchmarking, NN, DEMATEL, LP, ISM, GRA, EBG model, DEA, TOPSIS, MDBA, MDBM, BSC, SPC, Pugh selection matrix, Kano Model, TPM, EFQM and 360 degree approach.

Another important variation of QFD not considered in this review is the Concurrent Function Deployment (CFD) technique, because an integrated approach of CFD and AHP was not found in the literature. The CFD, first presented by Prasad (1998), is a variation of QFD that provides a method to deploy competing values simultaneously and assign concurrent work-groups to accomplish the jobs in an orderly non-serial fashion (Prasad, 2000). Therefore, just as QFD and AHP have proven to be a compatible match, the authors propose that a CFD-AHP integration should be considered as a possible future research. As result, the combination may be considered a useful asset in the concurrent engineering.

By cataloging all the applications considered, seven main areas – manufacturing, supply chain, higher education, strategy, service, marketing and energy – and one secondary area – sustainability – were identified. Manufacturing stood out as the most applied area.

A more detailed analysis was carried out with articles that applied the concurrent engineering jointly with the QFD-AHP tool.

A literature review consists of a meticulous and extensive critical analysis of current publications in a given area of knowledge in order to present a theoretical and methodological basis for the development of new researches. The authors feel that this review achieved this objective by presenting a detailed bibliographic and bibliometric analysis responsible the application area segmentation of the selected works, serving as a basis for new QFD-AHP researches. Besides, it was able to identify works that successfully managed to apply the concurrent engineering concepts associated with the QFD-AHP integration.

The main limitation is related to the works sample focus of this review with restriction to the Scopus database, not characterizing the universe of studies that jointly apply the QFD-AHP. However, the set of articles is considered appropriate by reflecting and inferring the totality thanks to the temporal scope, extensions and application areas.

This review may be further extended and enriched by inserting another database with the purpose of complementing the information and results obtained. This approach may ratify the knowledge extracted by the authors of this review and raise new foundations on

QFD-AHP. Moreover, a deeper analysis can be carried out on each application area in order to evaluate how the QFD-AHP combination behaves itself and how CE could be aggregate a different and more beneficial perspective.

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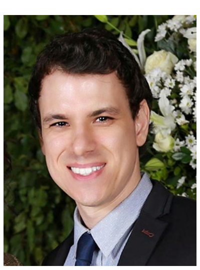

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