Bibliometric analysis of quality function deployment with fuzzy systems

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ABSTRACT

Research on quality function deployment (QFD) with fuzzy systems has increased since the 2000s. The growing number of QFD applications with fuzzy systems indicates worldwide attention on this field of research. Then, two research questions arise: Are there some trends? And, are there some research gaps? This paper presents bibliometric analysis to answer those questions, performed on data from Scopus database, in a total output of 598 documents. Only articles and reviews were searched. China is the leading country in publication and international collaboration (207 published documents, more than a third of total). The main finding of analysis is the trend of QFD integration with fuzzy and multi-criteria decision-making (MCDM) methods. This could be observed with different applications as new product development, quality management, service quality, and supply chain management, to name a few.

Keywords: Bibliometrics, fuzzy systems, quality function deployment, Scopus.

INTRODUTION

Quality function deployment (QFD) is a method to translate, in an efficient way, needs of customers into development of new products or improvements in current ones (Kwong and Bai, 2002). However, a few proposals have been presented to enhance the performance of the original QFD method (Carnevalli and Miguel, 2008; Sivasamy et al, 2016).

Fuzzy systems have been successfully applied to deal with imperfect, vague, and imprecise information, often found in decision problems, including the QFD method (Rodriguez et al, 2016). In one of the first applications, a method of a robust design was developed for Kraslawski et al (1993). Fuzzy systems were applied in the "House of Quality": The main idea was to minimize the variability of product quality under fuzzy technological and economic constraints. Also, in early 1990's, fuzzy linear regressions equations were applied in QFD to estimate relationships among variables with limited and uncertain data (Moskowitz and Kim, 1993).

Fuzzy systems have also been applied to determine weights for customers' requirements (Akao, 2004; Kwong and Bai, 2003; Li et al, 2014). These applications include multi-criteria decision making (MCDM) methods, as the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Afterwards, developments in fuzzy systems, including intuitionistic fuzzy sets were integrated to MCDM for QFD (Jian et al, 2016; Onar et al, 2016; Osiro et al, 2018; Wang et al, 2017; Wu et al, 2017).

The growing number of QFD applications with fuzzy systems indicates worldwide attention on this field of research. Then, two questions arise: Are there some trends? And, are there some research gaps? This paper presents a bibliometric analysis which aims to answer those questions. Therefore, this is a literature review paper. Methodologically, it was performed a bibliometric study (Yataganbaba and Kurtbas, 2016; Zyoud and Fuchs-Hanusch, 2017). Section 2 presents a literature review on QFD and fuzzy systems. Section 3 presents methodological subjects. Section 4 points out bibliometric results. Section 5 presents contents analysis, and Section 6 the Conclusions.

LITERATURE REVIEW

Quality Function Deployment

QFD was developed by Dr. Yoji Akao and Dr. Shigeru Mizuno (Akao, 2004). Then, many researchers and professionals have proposed adaptations and improvements in the original QFD. Although QFD has been originally developed for product development planning, its applications have extended to

different processes such as costs analysis, managerial decision making, process planning, engineering, and teamwork, to name a few (Chan and Wu, 2002).

A complete QFD application consists of several relationship matrices. House of Quality (HOQ) is the first matrix, which translates customers' needs into technical characteristics of the product (Kahraman et al, 2006). Customers' requirements (CR) are obtained through surveys or direct questions to the customers. To develop a new product, CR must be translated into engineering characteristics (EC) (Chen et al, 2014).

HOQ has been used to determine the relationship between customers' needs, or CR, and quality characteristics or EC (Govers, 2001). Moreover, there are benchmark data (marketing and technical) which individually represent the competitive analysis upon customers and technology (Chen et al, 2014).

In the traditional QFD, the relationship between CR and EC is determined by a project team using linguistic expressions, such as: "very low", "low", "medium", "high" and "very high", with values that range from 1 to 5 being assigned to them (Chen et al, 2014). In addition, some QFD applications combine the method with MCDM techniques such as AHP or TOPSIS and fuzzy systems, to deal with the subjectivity and uncertainty of quality matrices analyses (Carnevalli and Miguel, 2008; Chan and Wu, 2002).

Fuzzy Systems

Fuzzy Sets Theory (FST) was introduced to deal with the uncertainty due to imprecision and vagueness (Tong and Bonissone, 1980). A fuzzy set X is characterized by a membership function μ, which assigns to each element x in the set a grade of membership ranging from zero to one (Zadeh, 1965). That is, each element in a fuzzy set is associated with a value indicating to what degree the element is a member of the set (Bevilacqua et al, 2006). A major contribution of FST is the capability of representing vague data (Buyukozkan et al, 2004).

Despite that, when handling vague and imprecise information whereby two or more sources of vagueness arise concurrently, the modeling tools of ordinary fuzzy sets have limitations. Hence, different generalizations and extensions of fuzzy sets have been introduced (Rodriguez et al, 2012).

Figure 1 presents an evolution of FST (Kahraman et al, 2016): from original type-1 fuzzy sets (Yataganbaba and Kurtbas, 2016), through type-n fuzzy sets (Zadeh, 1975) and interval-valued fuzzy sets (Zadeh, 1975; Grattan-Guiness, 1976), following by intuitionistic fuzzy sets (Atanassov, 1986), fuzzy multisets (Yager, 1986), nonstationary fuzzy sets (Garibaldi and Ozen, 2007) and, finally, hesitant fuzzy sets (Torra, 2010).

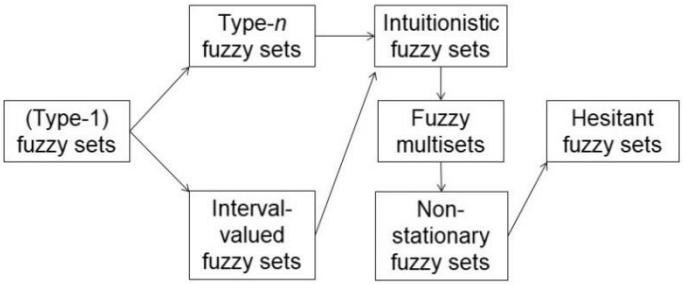

Figure 2 – Evolution of fuzzy sets theory (Kahraman and Onar, 2016).

Type-2 fuzzy sets and type-n fuzzy sets incorporate uncertainty about the membership function in their definition (Rodriguez et al, 2012). Membership function of type-2 fuzzy sets ranges over a type-1 fuzzy set. Generalizing, membership function of a type-n fuzzy set (n = 2, 3, 4...) ranges over a type-n-1 fuzzy set (Zadeh, 1975; Melin et al, 2013).

Nonstationary fuzzy sets introduce into the membership functions a connection that expresses a slight variation on them (Rodriguez et al, 2012).

Intuitionistic fuzzy sets extend fuzzy sets by an additional degree: the degree of uncertainty (Rodriguez et al, 2012). Intuitionistic fuzzy sets also incorporate a degree of hesitation, defined as 1 minus the sum of membership μ and non-membership ν degrees (Kahraman et al, 2018).

Fuzzy multisets based on multisets allow repeated elements in the set (Rodriguez et al, 2012). They are based on the concept of bags (Yager, 1986). A bag is a set with repeated elements.

Hesitant fuzzy set (HFS) is the most recently introduced extension of fuzzy sets. An HFS allows the modeling of uncertainty originated by the hesitation arisen in the assignment of membership degrees of the elements to a fuzzy set (Torra, 2010).

RESEARCH METODOLOGHY

Usually, bibliometric analyses are performed in one of four databases: Google Scholar, PubMed, Scopus, or Web of Science (Falagas et al, 2008). This paper presents a Scopus-based bibliometric analysis. Scopus was preferred because of the greater number of journals it contains (Zyoud and Fuchs-Hanusch, 2017). Scopus provides flexible review for several fields of science (Kulkarni et al, 2009). It allows the collected data to be analyzed without the need to separate the different sections (Yataganbaba and Kurtbas, 2016).

Scopus database was first searched for QFD with fuzzy systems in general. For this, the search bars of *abstract, keywords* and *title* on Scopus database were first filled with “fuzzy”, “house of quality”, “QFD”, and “quality function deployment”. Both Boolean operators “and” and “or” were searched. The query was it as follows: TITLE-ABS-KEY(QFD) OR TITLE-ABS-KEY (“quality function deployment”) OR TITLE-ABS-KEY (“house of quality”) AND TITLE-ABS-KEY (fuzzy) AND PUBYEAR < 2020. Only articles and reviews were searched.

Besides authorship, details such as citation, country, document type, impact factor (IF), institution, journal name and prevalent interest area were considered.

Citations were counted considering h-index. This indicator includes measures of quantity (amount of publications) and quality (citation rates) (Egghe., 2006). On Scopus, journals can be sorted with three indicators: Cite Score, SCImago Journal Rank (SJR) and Source Normalized Impact per Paper (SNIP). Cite Score measures average citations received per document published in the journal. SJR measures weighted citations received by the journal. Citation weighting depends on subject field and prestige of the citing journal. SNIP measures actual citations received in comparison to the citations expected for the journal’s subject field.

For each considered journal, IF was extracted from the Journal Citation Reports (Clarivate Analytics, 2018) and word frequencies were used in content analysis (Wang et al, 2017). Keywords have a great potential to reflect the focus of research. According to Tan et al (2014) the core words indicate the core literature within a specific field of research.

Co-occurrence analysis of keywords was performed with VOSviewer. This software builds maps of networks and uses “visualization of similarities” techniques of clustering, which are widely used in bibliometric analysis (Van Eck and Waltman, 2010).

After bibliometric analysis about QFD on the fuzzy environment, new searches were performed inserting, separately, those new expressions: “hesitant”, “intuitionistic”, “nonstationary”, “type-2” and “multiset”. The objective in the second search was to verify if there was any publication about QFD in other extensions of fuzzy environment

For the QFD method on Hesitant fuzzy environment, for example, the query was as follows: TITLE-ABS-KEY(QFD) OR TITLE-ABS-KEY ("quality function deployment") OR TITLE-ABS-KEY ("house of quality") AND TITLE-ABS-KEY (fuzzy) AND TITLE-ABS-KEY (Hesitant) AND PUBYEAR < 2020. Only articles and reviews were searched.

RESULTS

Ranks of Publications

The research performed, as described in Section 3, resulted in 598 documents: 588 articles and 11 reviews. That is, the overwhelming majority of publication is from articles, or else, original findings. Then, there is a lack on reviews in the QFD and fuzzy systems literature. Presenting a literature review, this paper contributes to the diversification of the literature of the researched field. The yearly average of publications is 22.

A gradual increase is observed, with a steep rise and breakthrough, in 2007. More than 79% of documents were published after 2007 (Figure 2). The years of 2009 and 2019 were outliers with more than 50 documents published. From 2010 to 2018, documents per year average 39. China is the leading country in published documents on QFD and fuzzy systems (Table 1). The 207 documents published by China are more than a third of the total. This result is even more impressive considering that Scopus counts China, Hong Kong and Taiwan, independently.

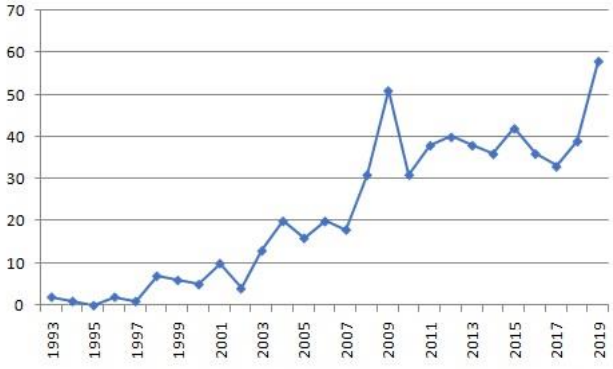

Figure 2 – Publication by year

Table 1 - Publications by country

Rank	Country	Documents	h-index	Citations
1	China (CHN)	207	26	3,104
2	Taiwan (TWN)	108	30	2,738
3	Turkey (TUR)	63	26	2,452
4	Iran (URN)	53	15	674
5	India (IND)	51	15	571
6	United States (USA)	34	17	1,442
7	Hong Kong (HK)	33	22	2,622
8	United Kingdom (UK)	22	14	1,038
9	Singapore (SGP)	19	14	933
10	Canada (CAN)	12	7	313

The average h-index for the top ten countries is 18 and the average of citations is greater than 2,500 citations per document. The 598 resulting documents received more than 15,000 citations. China keeps leading the rank considering the international collaboration (Table 2), besides of the moves in lower positions. Researches from Hong Kong and from the United States result from collaborations with more countries. However, China is the most collaborative country in the top ten.

Table 2 - Publications by international collaboration

Rank	Country	Documents	Collab. Countries	Top country
1	CHN	51	12	HK
2	HK	31	8	CHN
3	USA	24	10	TUR
4	UK	21	13	CHN
5	IRN	17	9	USA
6	TWN	16	6	CHN
7	TUR	15	7	USA
8	SGP	11	6	China
9	CAN	7	4	China
10	IND	2	2	Ethiopia

The institution with more documents published by first authors is *Galatasaray Universitesi*, from Turkey (Table 3), with 28 documents. The publication is worldwide spread in a hundred institutions. China has eleven institutions ranked in the top 20. This is a result of the active participation of China in this field of research. The most prolific author is Jiafu Tang, from Dongbei University of Finance and Economics, China. Dr. Tang published 26 documents (Table 4). Publishing 30 documents, Expert Systems with Applications (ESWA) is the leading journal (Table 5). ESWA is the second journal on Cite Score and IF (Table 6), leaded by Journal of Cleaner Production (JCP). On SJR, European Journal of Operational Research ranks first, followed by JCP, International Journal of Production Research, Journal of Intelligent Manufacturing and Computers and Industrial Engineering. ESWA leads on SNIP.

Engineering and Computer Science are the leading interest areas (Table 7). ESWA is the top journal in both areas. China is the top country in almost all areas, except Business, Management and Accounting, and Social Sciences. Three top authors, Kahraman, Ertay and Buyukozkan, co-authored the most cited document (Kahraman et al, 2006), which is cited 454 times (Table 8).

Table 3 - Publications by Institution

Rank	Institution	Country	Documents
1	Galatasaray Universitesi	TUR	28
	Northeastern University, China	CHN	28
3	Shanghai University	CHN	18
4	Hong Kong Polytechnic University	CHN	17
	City University of Hong Kong	CHN	17
6	National Institute of Technology, Tiruchirappalli	IND	16
	Southwest Jiaotong University	CHN	16
	National Cheng Kung University	TWN	16
9	National Chin-Yi University of Technology Taiwan	TWN	13
10	National Taiwan Ocean University	TWN	12
	The International Joint Research Laboratory of Integrated Automation	CHN	12
12	Zhejiang University	CHN	11
	Istanbul Teknik Universitesi	TUR	11
	Kun Shan University	TWN	11
15	Nanyang Technological University	SGP	10
	Shanghai Jiao Tong University	CHN	10
	Tsinghua University	CHN	10
18	Chang Jung Christian University	TWN	9
19	University of Shanghai for Science and Technology	CHN	8
	Beihang University	CHN	8

Table 4 - Publications by First Author

Rank	First Author	Country	Documents
1	J. Tang	CHN	26
2	Y. Chen	CHN	17
3	Y. L. Li	CHN	16
4	G. Buyukozkan	TUR	12
	R.Y.K. Fung	HK	12
	E.E. Karsak	TUR	12
7	C. K. Kwong	CHN	11
	Y. Pu	CHN	11
9	L. H. Chen	TWN	10
	W. C. Ko	TWN	10
	S. Vinodh	IND	10
12	J. F. Ding	TWN	8
	C. Kahraman	TUR	8
	G. S. Liang	TWN	8
15	X. Geng	CHN	7
	L. P. Khoo	SGP	7
	L. Z. Lin	TWN	7
18	X. Chu	CHN	5
	T. Ertay	TUR	5
	A. Liu	CHN	5

Table 5 - Publications by Journal

Rank	Journal	Documents
1	Expert Systems with Applications (ESWA)	30
2	International Journal of Production Research (IJPR)	29
3	Jisuanji Jicheng Zhizao Xitong (Computer Integrated Manufacturing Systems, CIMS)	27
4	Computers and Industrial Engineering (CAIE)	21
5	Total Quality Management and Business Excellence (TQMBE)	13
6	International Journal of Advanced Manufacturing Technology (IJAMT)	12
7	European Journal of Operational Research (EJOR)	11
	Journal of Intelligent Manufacturing (JIM)	11
9	Applied Soft Computing Journal (ASCJ)	10
	Journal of Cleaner Production (JCP)	10
11	Jixie Gongcheng Xuebao (Chinese Journal Of Mechanical Engineering, CJME)	9
	Quality and Quantity (QQ)	9
	Zhongguo Jixie Gongcheng (China Mechanical Engineering, CME)	9
14	Journal of Intelligent and Fuzzy Systems (JIFS)	8
15	Sustainability Switzerland (SS)	7
16	Computers in Industry (CII)	6
	International Journal of Logistics Systems and Management (IJLSM)	6
	International Journal of Productivity and Quality Management (IJPQM)	6
19	Applied Mathematical Modelling (AMM)	5
	Concurrent Engineering Research and Applications (CERA)	5

Table 6 - Citations by Journal

Rank	Journal	Cite Score	SJR (2018)	SNIP (2018)	IF
1	ESWA	6.36	1.190	2.696	5.71
2	IJPR	4.34	1.585	1.720	3.93
3	CIMS	0.84	0.299	0.591	-
4	CAIE	4.68	1.334	1.755	3.30
5	TQMBE	2.44	0.776	1.425	-
6	IJAMT	3.04	0.987	1.596	2.69
7	EJOR	4.98	2.205	2.455	3.03
8	JIM	4.20	1.389	1.921	2.32
9	ASCJ	6.27	1.216	2.369	2.21
10	JCP	7.32	1.620	2.308	2.35
11	CJME	1.10	0.435	0.927	1.00
12	QQ	1.40	0.421	0.886	-
13	CME	0.38	0.217	0.428	1.37
14	JIFS	1.96	0.412	0.818	-
15	SS	3.01	0.549	1.169	-
16	CII	6.05	1.242	2.395	-
17	IJLSM	1.31	0.330	0.758	-
18	IJPQM	1.33	0.345	0.736	-
19	AMM	3.36	0.873	1.495	-
20	CERA	1.79	0.549	1.225	-

Table 7 - Publications by Interest Area

Rank	Area	Documents	Journal	Country
1	Engineering	367 (61.37)	ESWA	CHN
2	Computer Science	267 (44.65)	ESWA	CHN
3	Business, Management and Accounting	141 (23.58)	IJPR	TWN
4	Decision Sciences	110 (18.39)	IJPR	CHN
5	Mathematics	109 (18.23)	EJOR	CHN
6	Social Sciences	37 (6.19)	QQ	TWN
7	Environmental Science	32 (5.35)	JCP	CHN
8	Energy	24 (4.01)	JCP	CHN
9	Multidisciplinary	14 (2.34)	Tongji Daxue Xuebao	CHN
10	Materials Science	12 (2.01)	JTE	CHN

Table 8 - Most Cited Documents

Rank	Document	Citations	Rank	Document	Citations
1	Kahraman et al (2006)	454	11	Bottani & Rizzi (2006)	158
2	Kwong & Bai (2002)	301	12	Fung et al. (1998)	156
3	Kwong & Bai (2003)	299	13	Vanegas & Labib (2001)	149
4	Chan & Wu (2005)	274	14	Bayou & de Korvin (2008)	146
5	Bevilacqua et al. (2006)	266	15	Chen & Weng (2006)	145
6	Kim et al. (2000)	220	16	Tang et al. (2002)	144
7	Chan et al. (1999)	217	17	Bouchereau & Rowlands (2000)	142
8	Khoo & Hot (1996)	198	18	Büyüközkan et al, (2004)	138
9	Temponi et al. (1999)	170	19	Chen et al. (2006)	135
10	Wang (1999)	169	20	Karsak (2004)	125

Contents Analysis

The analysis of the word frequency in published research has been a widely used tool to examine the content analysis of research (Wang et al 2017). The author keywords have a great potential to reflect the focus of research because the core words indicate the core literature within a specific field of research. It also helps identify the central topics and hot spots that will continue to be vital in the examined field of research, besides helping suggest new directions for science in the future (Tan et al, 2014; Zyoud and Fuchs-Hanusch, 2017).

Analysis of the co-occurrence of keywords of published research to examine the hot research areas was conducted by VOSviewer software. This software builds visualization maps relied on data of networks and uses the “visualization of similarities” mapping and techniques of clustering, which are

widely used in the analysis of bibliometric networks (Van Eck and Waltman, 2010; Zyoud and Fuchs-Hanusch, 2017).

In the resulting 598 documents there were a total of 1,432 keywords. There were 69 keywords that appeared at least in five different documents. Figure 3 presents a network map obtained with Software VOSviewer. Figure 4 displays the density visualization map-item density in association with published research that utilized QFD method on fuzzy environment. The central keywords are in the darkest areas (from red to blue)

For the same concept, different authors used different keywords. As a limitation of VOSviewer, in this case, keywords were counted apart. That is, "Quality function deployment", "QFD" and "Quality function deployment (QFD)" were counted as different keywords. Given this, eight keywords clusters were identified (Table 9).

The keyword analysis shows that there is a trend to apply hybrid methods, combining fuzzy systems, MCDM and QFD. The most used MCDM methods are AHP, ANP (Analytic network process), TOPSIS and GRA (Grey Relational Analysis). In addition, some authors use more than one MCDM method simultaneously. Advances in fuzzy systems application in MCDM are not independent of fuzzy systems application in QFD.

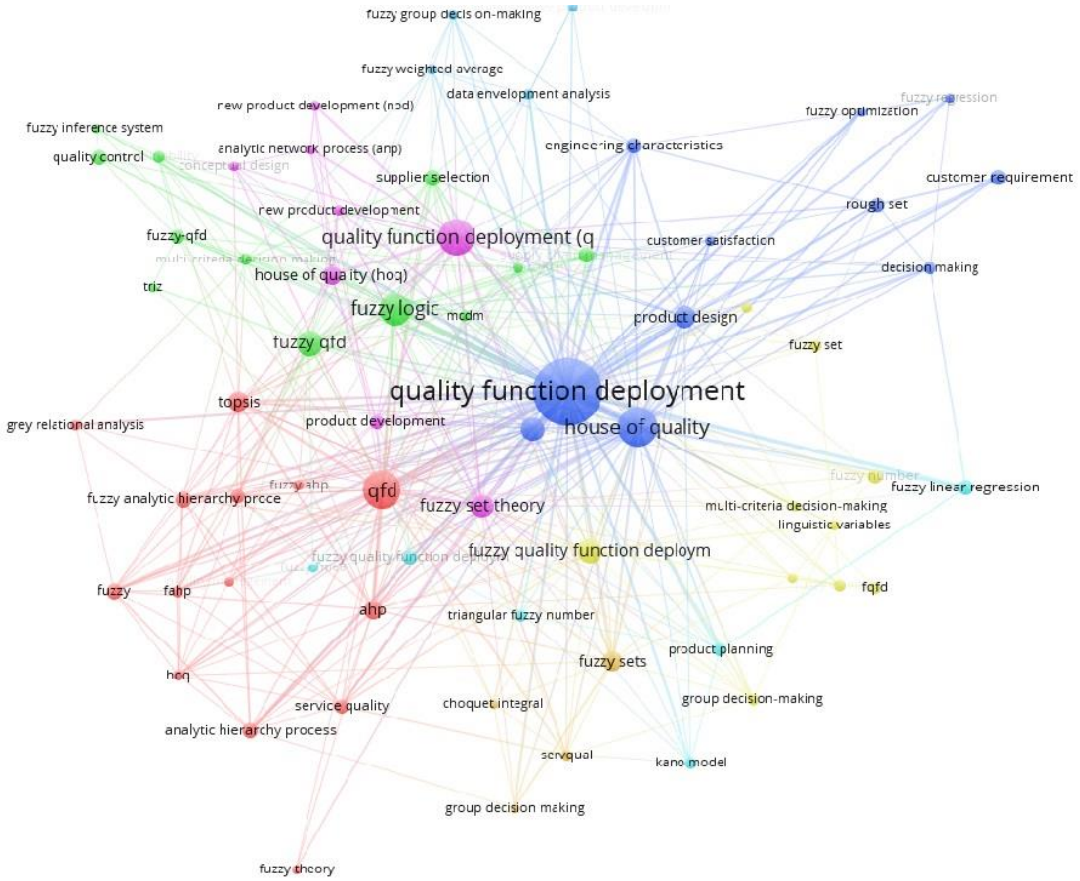

Figure 3 – Network of Keywords

Table 9 - Clusters of keywords

Clusters	Keywords
1	"AHP", "Analytic Hierarchy Process", "FAHP", "Fuzzy", "Fuzzy AHP", "Fuzzy Analytic Hierarchy process", "Fuzzy Theory", "Fuzzy TOPSIS", "GREY relational analysis", "HOQ", "QFD", "Quality management", "service quality", "TOPSIS"
2	"Analytical Hierarchy Process", "Fuzzy inference system", "fuzzy logic", "fuzzy QFD", "fuzzy-QFD", "MCDM", "multi-criteria decision making", "quality control", "supplier selection", "supply chain management", "sustainability", "triz"
3	"Customer requirement", "Customer requirements", "Customer satisfaction", "decision making", "engineering characteristic", "fuzzy optimization", "fuzzy regression", "house of quality", "product design", "quality function deployment", "rough set"
4	"Decision-making", "FQFD", "Fuzzy Goal programming", "fuzzy number", "fuzzy numbers", "fuzzy quality function deployment", "fuzzy set", "group decision-making", "linguistic variable", "multi-criteria decision-making"
5	"Analytic network process (ANP)", "conceptual design", "fuzzy set theory", "house of quality (HOQ)", "new product development", "new product development (npd)", "quality function deployment (QFD)"
6	"Fuzzy FMEA", "Fuzzy linear regression", "fuzzy quality function deployment (FQFD)", "Kano Model", "product planning", "triangular fuzzy number"
7	"Collaborative product development", "data envelopment analysis", "fuzzy group decision-making", "fuzzy weighted average".
8	"Choquet integral", "fuzzy sets", "group decision making", "SERVQUAL"

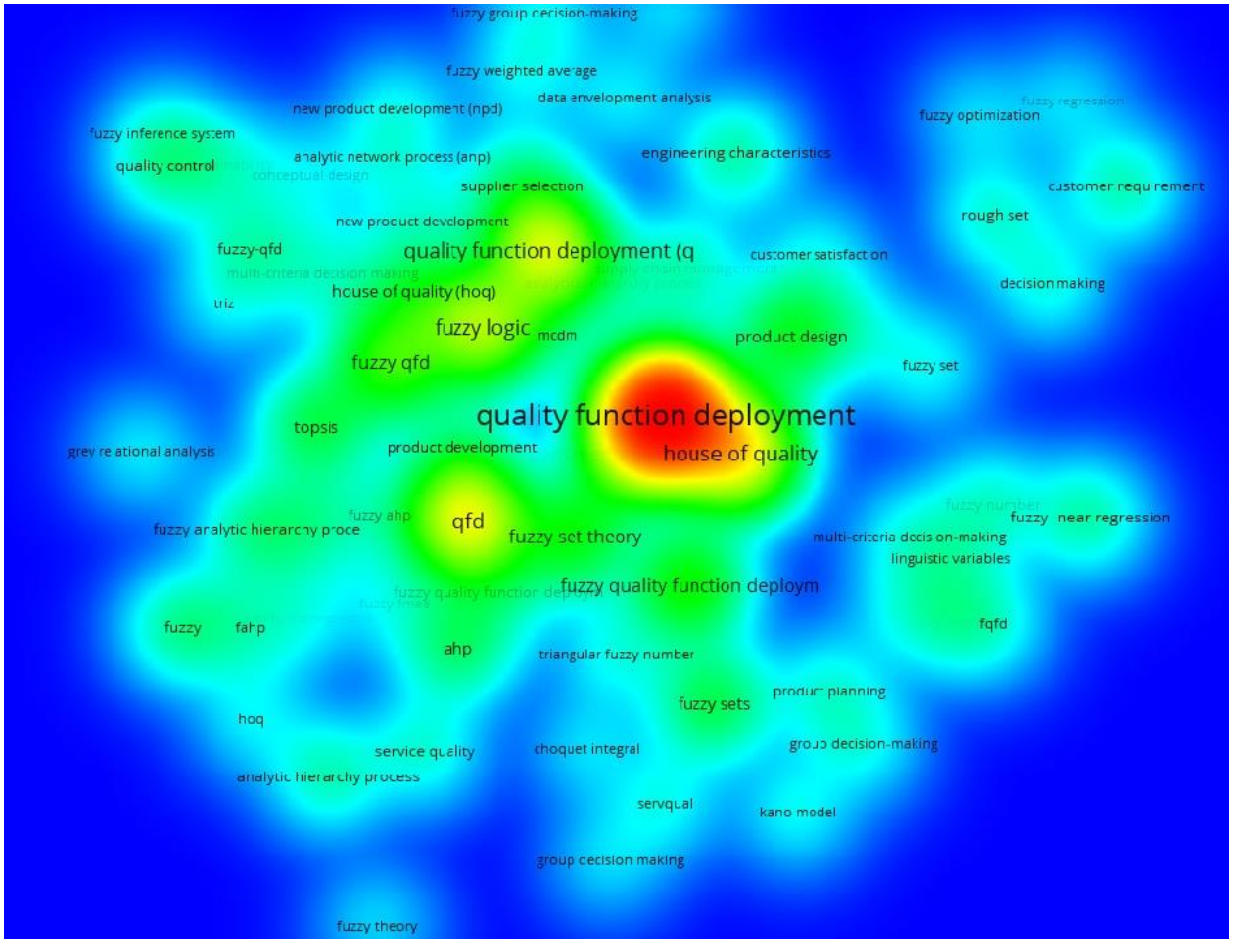

Figure 4 – Map-item density of keywords

Therefore, this is the hot topic of research on QFD and fuzzy systems: their integration with MCDM. Different applications were observed, including: "multi-criteria decision making", "Quality management", "service quality", "quality control", "supplier selection", "supply chain management", "sustainability", "Customer satisfaction", "product design", "conceptual design", "new product development", "product planning", and "Collaborative product development", to name a few. Moreover, "Choquet integral" was used in "group decision making" problems, such as determining a correlation among customer requirements (Yu et al, 2018).

Other topics of investigation include the Kano Model, FMEA and SERVQUAL, and “fuzzy goal programming”, “fuzzy linear regression”, “fuzzy optimization”, “fuzzy regression” and DEA (Data Envelopment Analysis) among others. The use of different types of fuzzy systems is a promising topic of research.

Map-item density also shows that there is a trend to use MCDM methods, such as AHP and TOPSIS, for example, with QFD method on fuzzy environment, forming new hybrid MCDM methods for solving decision problems.

Different generalizations and extensions of fuzzy sets have been introduced in MCDM methods, such as in AHP and TOPSIS, for example, that had already been used with QFD method. Therefore, it is assumed that new hybrid MCDM methods will be created using QFD in their composition on other extension of fuzzy environment.

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CONCLUSIONS

This paper presents a bibliometric analysis on fuzzy systems applied to QFD. The first quantitative result is the growing number of publications observed since 2008. The second result is the leading position of China, both in publication and international collaborations.

A qualitative result from the research is the widely spread publications in terms of authorship, interest area and journals. However, Computer Science and Engineering are the leading areas, with far more publications than other areas. Therefore, Expert Systems with Applications is the journal which published more documents on QFD with fuzzy systems. Two groups of researchers have outstanding publication productivity. A group led by Dr. Kahraman, in Turkey, and another led by Dr. Y. Chen, in China.

A strong relationship between MCDM and QFD with fuzzy systems could be identified as the highest studied topic. Innovations in fuzzy systems theory have also been applied to QFD, as the intuitionistic fuzzy systems and the hesitant fuzzy systems. However, no publication on type-2 fuzzy set, fuzzy multisets and nonstationary fuzzy sets were found despite having been successfully applied in multicriteria decision methods. A study on the advantage of applying these fuzzy extensions in the QFD method would be a research gap to be addressed by researchers.

REFERENCES

Akao, Y. (2004), “QFD: Quality function deployment. N”. York: Productivity.

Armacost R. L, Componation P. J, Mullens M. A and Swart. W. W. (1994) “An ahp framework for prioritizing custom requirement in qfd: An industrialized housing application.” IIE Trans., Vol. 26 , pp. 72–79.

Atanassov K. T. (1986). “Intuitionistic fuzzy sets”. Fuzzy Sets and Systems. Vol. 20, pp. 87–96.

Bevilacqua M, Ciarapica F. E. and Giacchetta G. (2006) “A fuzzy-qfd approach to supplier selection”. J. Purch. Supply Manag., Vol. 12 , pp. 14–27.

Bottani E and Rizzi A (2006). “Strategic management of logistics ser-vice: A fuzzy qfd approach” Int. J. Prod. Econ., Vol. 103 , pp. 585–599.

Bouchereau V and Rowlands H (2000). “Methods and techniques to help quality function deployment (qfd)”. Benchmarking. Vol. 7 , pp. 8–20.

Buyukozkan G, Ertay T, Kahraman C and Ruan D (2004). “Determining the importance weights for the design requirements in the house of quality using the fuzzy analytic network approach”. Int. J. Intell. Syst, Vol. 19 , pp. 443–461.

Carnevalli J. A and Miguel P. C. (2008) “Review, analysis and classification of the literature on qfd–types of research, difficulties and benefits”. Int. J. Prod. Econ, Vol. 114 , pp. 737–754.

Chan L. K., Kao H. P. Ng, A and Wu, M. L (1999). “Rating the importance of customer needs in quality function deployment by fuzzy and entropy methods”. Int. J. Prod. Res., Vol. 37 , pp. 2499–2518.

Chan L.-K and Wu M.-L (2002). “Quality function deployment: A literature review”. Eur. J. Oper. Res, Vol. 143 , pp. 463–497.

Chan L.-K. and Wu M.-L (2005), “A systematic approach to quality function deployment with a full illustrative example”. Omega–Int. J. Manage. S. Vol. 33 , pp. 119–139.

Chen C.-J, Yang S.-M. and Chang S.-C (2014). “A fuzzy integrating model ahp with qfd for assessing technical factors in aviation safety”. Int. J. Mach. Learn. Cyb.. Vol. 5 , pp. 761–774.

Chen L.-H and Weng M.-C (2006). “An evaluation approach to engi-neering design in qfd processes using fuzzy goal programming models”, Eur. J. Oper. Res, Vol. 172 , pp. 230–248.

Chen Y., Fung R. Y. and Tang J (2006). “Rating technical attributes in fuzzy qfd by integrating fuzzy weighted average method and fuzzy expected value operator”. Eur. J. Oper. Res., Vol. 174 , pp. 1553–1566.

Chen Y., J. Tang, R. Y. K. Fung & Z. Ren. Fuzzy regression-based mathematical programming model for quality function deployment. Int. J. Prod. Res. (2004). Vol. 42, pp. 1009-1027

Chuang P. T.. (2001). “Combining the analytic hierarchy process and quality function deployment for a location decision from a requirement perspective”. Int. J. Adv. Manuf. Tech., Vol. 18 , pp. 842–849.

Clarivate Analytics (2018). Journal citation reports. URL: https://clarivate.com/products/journal-citation-reports/ access: Nov. 2018.

Egghe L. (2006). “An improvement of the h-index: the g-index”. ISSI Newsletter. (2006). Vol. 2, pp. 8–9.

Falagas M. E., Pitsouni E. I., Malietzis G. A. and Pappas (G) (2008), “Comparison of pubmed, scopus, web of science, and google scholar: strengths and weaknesses”. FASEB J. Vol. 22 , pp. 338–342.

Fung R. Y. K, Popplewell K. and Xie J (1998). “An intelligent hybrid system for customer requirements analysis and product at-tribute targets determination”. Int. J. Prod. Res.., Vol. 36 , pp. 13–34.

Garibaldi J. M. and Ozen T. (2007) “Uncertain fuzzy reasoning: A case study in modelling expert decision making”. IEEE T. Fuzzy Syst., Vol. 15 , pp. 16–30.

Govers, C. P. M.(2001). “Qfd not just a tool but a way of quality management”. Int. J. Prod. Econ. (2001). Vol. 69 , pp. 151–159.

Grattan-Guiness I.(1976), “Fuzzy membership mapped onto intervals and many-valued quantities”. Zeitschr. f. math. Logik und Grundlagen d. Math., Vol. 22 , pp. 149–160.

Jian S, Xiu-Yan P., Ying X., Pei-Lei W. and Na-Ji M (2016). “A new method combining qfd with intuitionistic fuzzy sets for web services selection”. Int. J. Multim. and Ubiquit. Eng., Vol. 11 , pp. 107–118.

Kahraman C., Ertay T. and Buyukozkan G (2006) “A fuzzy optimiza-tion model for qfd planning process using analytic network approach”. Eur. J. Oper. Res., Vol. 171 , pp. 390–411

Kahraman C., Öztayşi B. and Onar S. Ç. (2016). “A comprehensive literature review of 50 years of fuzzy set theory”. Int. J. Comput. Intell. Syst., Vol. 9 , pp. 3–24.

Kahraman C., Oztaysi B., Onar S. C. & Dogan O. (2018) “Intuition-istic fuzzy originated interval type-2 fuzzy ahp: an applica-tion to damless hydroelectric power plants”. International Journal of the Analytic Hierarchy Process. Vol. 10 , pp. 266–292.

Karsak E.E..(2004). “Fuzzy multiple objective programming framework to prioritize design requirements in quality function deployment”. Comput. Ind. Eng., Vol. 47 , pp. 149–163.

Khoo L. P. and Hot N. C. (1996). “Framework of a fuzzy quality function deployment system. Int. J. Prod. Res. Vol. 34 , pp. 299–311.

Kim K.-J., Moskowitz H., Dhingra A and Evans G (2000). “Fuzzy multicriteria models for quality function deployment”. Eur. J. Oper. Res., Vol. 121 , pp. 504–518.

Kraslawski A, Koiranen T and Nystrom L (1993). “Concurrent engineering: Robust design in fuzzy environment”. Comput. Chem. Eng. Vol. 17 , S447–S452.

Kulkarni A. V, Aziz B, Shams I and Busse J. W. (2009). “Comparisons of citations in web of science, scopus and google scholar for articles published in general medical journals”. JAMA–J. Am. Med. Assoc., Vol. 302 , pp. 1092–1096.

Kwong C. K. and Bai H (2002).”A fuzzy ahp approach to the de-termination of importance weights of customer requirements in quality function deployment”. J. Intell. Manuf. Vol. 13 , pp. 367–377.

Kwong C. K. and Bai H (2003). “Determining the importance weights for the customer requirements in qfd using a fuzzy ahp with an extent analysis approach”. IIE Trans. Vol. 35, pp. 619–626.

Li M., Jin L. and Wang J (2014). “A new mcdm method combining qfd with topsis for knowledge management system selection from the users perspective in intuitionistic fuzzy environment”. Appl. Soft Comput. Vol. 21, 28–37.

Melin P., Astudillo L., Castillo O., Valdez F. and Garcia M (2013) “Optimal design of type-2 and type-1 fuzzy tracking controllers for autonomous mobile robots under perturbed torques using a new chemical optimization paradigm”. Expert Syst. Appl. Vol. 40, pp. 3185–3195.

Moskowitz H and Kim K (1983). “On assessing the h value in fuzzy linear regression”. Fuzzy Sets Syst. Vol. 58 , pp. 303–327.

Onar S. C., Buyukozkan G., Oztaysi B. and Kahraman C (2016). “A new hesitant fuzzy qfd approach: An application to computer workstation selection”. Appl. Soft Comput, Vol. 46 , pp. 1–16.

Osiro L., Lima Junior F. R. and Carpinetti L. C. R. (2018) “A group decision model based on quality function deployment and hesitant fuzzy for selecting supply chain sustainability metrics”. Journal of cleaner production. Vol. 183, pp. 964-978

Rodriguez R. M., Martinez L. and Herrera F. (2012), “Hesitant fuzzy linguistic term sets for decision making”, IEEE Transactions on Fuzzy Systems. Vol. 20(1). pp. 109 – 119.

Rodriguez R. M, Bedregal B., Bustince H., Dong Y. C., Farhadinia B., Kahraman C., Martnez L., Torra V., Xu Y. J., Xu Z. S. and Herrera F (2016) “A position and perspective analysis of hesitant

fuzzy sets on information fusion in decision making. to-wards high quality progress". Inf. Fusion. Vol. 29, pp. 1566–2535.

Sivasamy K., Arumugam C, Devadasan S. R., Murugesh R. & Thilak V. M. M (2016) "Advanced models of quality function deployment: A literature review". Quality & Quantity., Vol. 50, pp. 1399–1414.

Tan J, Fu H.-Z & Ho Y.-S (2014), "A bibliometric analysis of research on proteomics in science citation index expanded". Scien-tometrics. Vol. 98 , pp. 1473– 1490.

Tang J., Fung R. Y., Xu B. and Wang D. (2002) "A new approach to quality function deployment planning with financial consideration". Comput. Oper. Res., Vol. 29 , pp. 1447–1463.

Temponi C., Yen J and Tiao W. A (1999) "House of quality: A fuzzy logic-based requirements analysis". Eur. J. Oper. Res, Vol. 117 , pp. 340–354.

Tong R. M. and Bonissone P. P. (1980). "A linguistic approach to decision making with fuzzy sets". IEEE Transactions On Systems, Man and Cybernetics., Vol. 10 , pp. 716–723.

Torra V (2010)." Hesitant fuzzy sets". Int. J. Intell. Syst.. Vol. 25 , pp. 529–539.

Van Eck N. J. and Waltman L (2010). "Software survey: VOSviewer, a computer program for bibliometric mapping". Scientometrics. Vol. 84 , pp. 523–538.

Vanegas L.V. and Labib A. W (2001) "A fuzzy quality function deployment (fqfd) model for deriving optimum targets". Int. J. Prod. Res., Vol. 39 , pp. 99–120.

Wang J (1999) "Fuzzy outranking approach to prioritize design requirements in quality function deployment". Int. J. Prod. Res., Vol. 37 , pp. 899–916.

Wang L., Zhao L., Mao G., Zuo J. & Du H. (2017). "Way to accomplish low carbon development transformation: A bibliometric analysis during 1995- 2014". Renew Sust. Energ. Rev. Vol. 68 , pp. 57–69.

Wu S. M., Liu H.-C and Wang L.-E (2017), "Hesitant fuzzy integrated mcdm approach for quality function deployment:a case study in electric vehicle". Int. J. Prod. Res, Vol. 55 , pp. 4436–4449.

Wu S. M., You X. Y., Liu H. C and Wang L. E. (2017). "Improving quality function deployment analysis with the cloud multi-moora method". Int. Trans. Oper. Vol. 125, pp. 111–123.

Yager R. R. (1986). On the theory of bags. Int. J. Gen. Syst., Vol. 13 , pp. 23–37.

Wang L. Yu, L. and Bao Y (2018). "Technical attributes ratings in fuzzy QFD by integrating interval-valued intuitionistic fuzzy sets and Choquet integral". Soft Comput Vol. 22 pp. 2015–2024

Yataganbaba A and Kurtbas I (2016). “A scientific approach with bibliometric analysis related to brick and tile drying: A review”. Renew. Sust. Energ. Rev. Vol. 59 , pp. 206–224.

Zadeh L. A.. Fuzzy sets. Inform. Control. (1965). Vol. 8 , pp. 338–353.

Zadeh L. A.. The concept of a linguistic variable and its appli-cations to approximate reasoning–i. Inform. Sci.. (1975). Vol. 8 , pp. 199–249.

Zyoud S. H. and Fuchs-Hanusch D (2017). “A bibliometric-based survey on ahp and topsis techniques”. Expert Syst. Appl. Vol. 78 , pp. 158–181.