QUALITY PAPER

Exploring research on quality and reliability management through text mining methodology

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Abstract

Purpose – The purpose of this paper is to explore and describe research presented in the *International Journal of Quality & Reliability Management (IJQRM)*, thereby creating an increased understanding of how the areas of research have evolved through the years. An additional purpose is to show how text mining methodology can be used as a tool for exploration and description of research publications.

Design/methodology/approach – The study applies text mining methodologies to explore and describe the digital library of *IJQRM* from 1984 up to 2014. To structure and condense the data, k-means clustering and probabilistic topic modeling with latent Dirichlet allocation is applied. The data set consists of research paper abstracts.

Findings – The results support the suggestion of the occurrence of trends, fads and fashion in research publications. Research on quality function deployment (QFD) and reliability management are noted to be on the downturn whereas research on Six Sigma with a focus on lean, innovation, performance and improvement on the rise. Furthermore, the study confirms *IJQRM* as a scientific journal with quality and reliability management as primary areas of coverage, accompanied by specific topics such as total quality management, service quality, process management, ISO, QFD and Six Sigma. The study also gives an insight into how text mining can be used as a way to efficiently explore and describe large quantities of research paper abstracts.

Research limitations/implications – The study focuses on abstracts of research papers, thus topics and categories that could be identified via other journal publications, such as book reviews; general reviews; secondary articles; editorials; guest editorials; awards for excellence (notifications); introductions or summaries from conferences; notes from the publisher; and articles without an abstract, are excluded.

Originality/value – There do not seem to be any prior text mining studies that apply cluster modeling and probabilistic topic modeling to research article abstracts in the *IJQRM*. This study therefore offers a unique perspective on the journal's content.

Keywords TQM, Quality management, Cluster modelling, Management fashion, Probabilistic topic modelling, Reliability management

Paper type Research paper

Introduction

Concerns about trends, fashions and fads in management research and practice is not a new phenomenon in the academic community (Abrahamson, 1996, 2009; Abrahamson and Eisenman, 2008; Abrahamson and Fairchild, 1999; Czarniawska, 2007, 2011a, 2014; Czarniawska and Panozzo, 2008; Parush, 2008; Starbuck, 2009; Trout, 2004). Researchers within the field of quality management (QM) and total quality management (TQM) are no exception to this general rule: the issue has fueled debate for many years with even Deming (1986) taking a stand urging scientists and practitioners to promote valid quality improvement measures instead of just flaunting slogans (Dahlgaard-Park, 1999, 2011; Dahlgaard-Park *et al.*, 2013; Rocco and Parry, 2011; Sila and Ebrahimipour, 2002; Sousa and Voss, 2002; Van Der Wiele *et al.*, 2000). As the ongoing digitalization of society offers access to an ever increasing amount of data as well as ever more powerful hardware and software, new methods of exploring and describing trends in digital material continuously arise (Glenisson *et al.*, 2005; Delen and Crossland, 2008; Dereli *et al.*, 2011; Rosen-Zvi *et al.*, 2010).

Against this backdrop, the *International Journal of Quality & Reliability Management (IJQRM)* offers an interesting object of study as it is one of few research publications dealing with QM and other aspects of business and manufacturing improvements that has a digital publication archive dating as far back as 1984. This unbroken sequence of publications with more than 240 issues available makes *IJQRM* interesting for research into how a publication and its research articles have evolved historically (Aggarwal and Zhai, 2012; Garfield *et al.*, 2003; Kent, 2014; Larose, 2005; Liu, 2011; Miner, 2012; Weiss *et al.*, 2012). A retrospective view on trends, fashions and fads are not useful for historical purposes alone, but can also help editors and publishers of today to gain a better understanding of the dynamics of the product, and make strategic decisions accordingly (Moro *et al.*, 2015; Finch, 1999; Heim and Field, 2007; Köksal *et al.*, 2011). Tapping into the historical progression of a research journal can also offer a helping hand to researchers in the midst of the publishing process by identifying the optimal journal for publication by providing information about what kind of research historically has been a cornerstone or stronghold of a certain publication (Becher and Trowler, 2001; Czarniawska, 2011b, 2014; Glenisson *et al.*, 2005; Rosen-Zvi *et al.*, 2010). Finally, analyses on research journals could serve as a way to identify upcoming trends, which might help in the decision making for future research as well as with the alignment or direction of research programs (Delen and Crossland, 2008; Dereli *et al.*, 2011). Hence, this study aims to, with the help of text mining methodology, explore and describe the digital library of *IJQRM* of the last 30 years, looking for possible trends, fashions and fads. The study does not aim to reveal or determine reasons for, or the dynamics behind, the emergence of, trends, fashions and fads in research, even if the topic is important and closely related to the issue of whether such trends really exist. The study does, however, address the possibilities and limitations of the tools and techniques used in this research.

Theoretical frame of reference

Academic contributions are valued differently within different academic disciplines. In general, the academic paper is seen as the highest ranking form of publication (Becher and Trowler, 2001). This means that by studying academic papers one can obtain an insight on which issues and topics have been addressed in *IJQRM* throughout the years – in other words which fashions and trends have prevailed. Czarniawska (2011a) challenges the perhaps common notion of fashion in research being something negative. According to Czarniawska (2011a), fashion is both a cultural phenomenon and a production system, and further suggests it is necessary to have a balanced approach between the two. Fashion, understood as the prevalent way of doing something, has a close connection to what Kuhn and others call paradigm (Czarniawska, 2011a). The problem seems to be that instead of studying fashion, or paradigms, so as to better understand them, researchers get stuck on moralizing about the issue (Czarniawska, 2011a). From this perspective it is easy to miss the potentially progressive momentum of fashion. In a way the very concept, or meaning of the word, “fashion” is paradoxical, both promoting innovation and reflecting “dime a dozen mass-production” (Czarniawska, 2011a). As summarized by Czarniawska (2011a): “On the one hand, its variety is limited by the iron cage of existing institutions, which fashion reproduces; on the other hand, fashion is engaged in a constant subversion of the existing institutional order, gnawing at its bars.” (Czarniawska, 2011a, p. 601)

Czarniawska and Panozzo (2008) shed further light on the issue with their modern interpretation of Gabriel Tarde who stated that fashion was to be contrasted with custom. Inventions and innovations, he argues, are improved imitations of a custom and claim superiority: first, on the base of value-added qualities; and second, on the basis of who coined and circulated them (Czarniawska and Panozzo, 2008). However, to determine which driving force is actually pushing a certain fashion becomes complicated as the two easily interlace

(Czarniawska and Panozzo, 2008). Sometimes the latter factor, the identity of the spokesperson, can blind us to the former factor, the real quality of a new fashion (Czarniawska and Panozzo, 2008). The third distinguishing feature of superiority for a new fashion is that it has many allies in other areas, being well anchored in existing research and so is not threatening to existing institutionalized structures (Czarniawska and Panozzo, 2008).

Another explanation for the occurrence of trends and fads in research could be scholars' attraction toward novelty, and consequently their limited interest and tolerance for the imitation and use of old theories and methods (Starbuck, 2009). Then again, it is also possible that we would observe less volatility in the academic community if earlier theories were actually giving valuable explanations; researchers would then possibly have more motivation to incorporate them instead of wasting time and energy constructing new ones (Starbuck, 2009).

Finally, Trout (2004) acknowledges the rise and fall of what he refers to as intellectual fashion. One of his main points is the divergence between epistemology and classical sciences. The latter, like theoretical physics, offer humans useful guidance about important matters; indeed classical sciences do not aim to be normative, as opposed to epistemology (Trout, 2004). He further states that if epistemology is to live up to its normative promise it must embrace what he calls ameliorative psychology, and start its journey toward epistemological excellence. Epistemological excellence can be defined as the efficient allocation of cognitive resources to robustly reliable reasoning strategies, applied to significant problems (Trout, 2004). A way of pursuing this road is to focus on hard theories, those that are easier to subject to reliable testing, as opposed to soft theories (Trout, 2004). Scientific computation of research publications offers a contrast to traditional literature reviews as a base for discussing trends, fashions and fads in research; and with epistemological excellence in mind could perhaps prove to be a way of looking into the question of trends, fashions and fads in research while at the same time honoring the call for reliable testing.

Text mining

A majority of business data are stored in unstructured form (i.e. text), some researchers citing numbers as high as 85-90 percent (Larose, 2005). With this background, a research paradigm labeled knowledge discovery in databases emerged, later evolving into data mining and in a similar manner into knowledge discovery in textual database. This in turn evolved into text data mining and the field finally settled on simply text mining (Larose, 2005). According to Miner (2012), text mining is one example of the larger academic practice that he labels text analytics which brings together and cuts across the disciplines of statistics, machine learning, management science, artificial intelligence, computer science and other disciplines.

Over the last few decades, data mining has been used frequently within business intelligence (BI), and text mining is expanding as a method to extract knowledge (Moro *et al.*, 2015; Chakrabarti, 2003; Kent, 2014). Purposeful text mining rests on the same assumption as data mining, that is, looking for valuable patterns, correlations and trends in large data sets with the help of statistical and mathematical techniques; a process too complex and resource demanding for manual processing (Aggarwal and Zhai, 2012; Liu, 2011; Weiss *et al.*, 2012). Hence, text mining is increasingly used in quality and business development with studies ranging from credit and insurance assessments and customer feedback loops to reviews of project, process and failure reports (Moro *et al.*, 2015; Choudhary *et al.*, 2009; Finch, 1999; Heim and Field, 2007; Kent, 2014; Khamis *et al.*, 2013; Köksal *et al.*, 2011; Lo, 2008).

Research on QM and TQM-related publications has been undertaken previously (Dahlgaard-Park *et al.*, 2013; Dereli *et al.*, 2011; Sila and Ebrahimpour, 2002). However, none of these studies have applied text mining methodology on research paper abstracts to identify trends and patterns and none have covered a time span of 30 years. The reasons for

using abstracts in the study instead of complete articles are mainly practical, as abstracts are easily collected and faster to process (Delen and Crossland, 2008). As abstracts are often seen as a distillation of the main findings in an academic article the unique points in the study should be reflected there, hence the approach of collecting and studying journal abstracts is common in text mining (Delen and Crossland, 2008). This is also facilitated by the fact that, as opposed to complete academic articles, journal abstracts are generally accessible for all visitors, and free of charge, making them cost-effective for large scale automatized collection. The *IJQRM* website operates according to these norms and it was therefore possible to collect abstracts from *IJQRM*'s digital archive in this manner.

Data source

The IJQRM

The *IJQRM* started in 1984 and has been in print annually since. In 1998, the *International Journal of Quality Science* merged into *IJQRM*. The subject area of *IJQRM* is Management Science and Operations and it is one of the few research publications in the area with an unbroken publication track record of more than 30 years, making it suitable for longitudinal studies and the identification of widespread trends and fashions in the research community. The journal describes itself and its topic coverage as follows:

The International Journal of Quality & Reliability Management (IJQRM) deals with all aspects of business and manufacturing improvements, from the training of senior managers, to innovations in processing and production to raise standards of product quality. It is this unique blend of managerial and technical material that makes IJQRM a valuable resource for senior managers striving for higher standards. Coverage includes:

- Equipment maintenance & availability.
- Gauging, calibration & measurement.
- Life cycle costing & sustainability.
- Reliability Management of Systems.
- Green Marketing.
- Product liability.
- Product testing techniques & systems.
- Quality function deployment (QFD).
- Reliability & quality education & training.
- Productivity improvements & regulatory standards for quality.
- Statistical process control.
- System modelling.
- Teamwork information your company needs to achieve and maintain competitive standards.

More information about the journal can be found at the journals website, <http://emeraldgroupublishing.com/products/journals/journals.htm?id=ijqrm>, where the data have been downloaded.

Methodology

Data mining process

Within the field of text and data mining there has developed a Cross Industry Standard Process for Data Mining (CRISP-DM) which consists of six phases: business understanding,

data understanding, data preparation, modeling, evaluation and deployment (Kurgan and Musilek, 2006). The phases are interconnected through feedback loops. This both implies that text and data mining is an iterative and dynamic process rather than a sequential process. This means that going backwards and re-doing stages on account of new results and insights further along the pathway is the conventional way of operating (Kurgan and Musilek, 2006). This study has been conducted according the CRISP-DM standard and an overview of the work process is described below:

- Business understanding includes definition of the study objectives, formulation of the problem and formation of the strategy to tackle the problem (Kurgan and Musilek, 2006). This study was driven by an interest to explore and describe QM research with the help of text mining methodology. The aim being to create an increased understanding of how the areas of research have evolved through the years.
- Understanding data refers to the collection and initial exploration and evaluation of the data, allowing for a possible change in scope and strategy (Kurgan and Musilek, 2006). After a comparative examination of QM journals, *IJQRM* turned out to be a suitable object of study as the journal's digital archive starts in 1984, which is among the earliest in its field, providing a basis for longitudinal studies. Also, the *IJQRM* database permitted automatized data collection, which was a prerequisite for this study. Data that were available from 1984 was: author(s), title, abstract and year of publication. Examples of other information that became standard later on in the publication's history are keywords, which were established in 1987, and type of publication (research paper, book review, editorial, etc.) which started to be systematically classified in 1992-1994.
- Preparing data includes cleaning the data of distorting information and values as well as narrowing down the elements and variables to be included and processed (Marbán *et al.*, 2009). Given the study objectives it was decided to use research paper abstracts and year of publication as the principal data source. The main issue became to isolate the research paper abstracts from other journal content such as book reviews, general reviews, secondary articles, editorials, guest editorials, awards for excellence (notifications), introductions or summaries from conferences and notes from the publisher. As noted above the systematic use of paper classification was not in place until the mid-1990s, thus the sorting of data before this date needed to be done manually. Manual handling showed that most publications in the 1980s were research papers – other content as exemplified above is a later novelty which may also explains why paper classification was a “non-issue” in the 1980s. Connected to the issue of paper type, it became necessary, through random sampling, to manually verify that the systematic classification of papers in the archive database was accurate, so confirming that research papers really were research papers, editorials were editorials, etc. The paper classification was found to be highly reliable. Finally, it was necessary to confirm that all classified research papers had a corresponding research paper abstract and year of publication.
- The modeling phase concerns the choice and calibration of methods to analyze the data (Marbán *et al.*, 2009). Cluster analysis with the k-means clustering algorithm was chosen as the principal method of data analysis; a detailed description of the section cluster analysis is provided below. In order to obtain an overall view of the dataset as well as a more delimited perspective on specific time periods, modeling was carried out both on the extensive data and on demarcated phases in time. Since the data set covers a time period of 31 years (1984-2014) time intervals of about six years were considered suitable as they gave some room for trends, fashions and fads to surge

and fall within each interval; moreover, it created five time series which could be compared. To fit 31 years into five time periods, the surplus year was added to the first time period (1984-1990) so that it contained seven years instead of six, on the basis that the number of research paper abstracts in the 1980s is considerably fewer than later on. The five time periods thus became: 1984-1990, 1991-1996, 1997-2002, 2003-2008 and 2009-2014.

- Evaluation of the modeling means that results are validated and compared with the objectives of the study (Marbán *et al.*, 2009). In addition to visual aids such as histograms, Pareto diagrams and pie-charts, this study used probabilistic topic modeling. The latent Dirichlet allocation (LDA) model, a distributed algorithm, was used to analyze and evaluate the results. It is described in more detail in the section “probabilistic topic modeling.”
- Deployment relates to the objectives of the study and ensures that the results are applied accordingly (Marbán *et al.*, 2009). The discussion and conclusions in this study are considered to correspond to the deployment phase of CRISP-DM.

Word vector generation

Regardless what type of text mining venture is attempted, it is necessary to transform the unstructured data (text) into structured data (numbers) through word vector creation (Larose, 2005; Miner, 2012). Hence, word vectors needed to be created for both cluster analysis as well as probabilistic topic modeling. Term frequency – inverse document frequency (tf-idf) is seen as an effective way of generating word vectors with systematic, unique and relevant weighting of words (Weiss *et al.*, 2012). Tf-idf was thus used for word vector creation in the cluster modeling phase. Apart from tf-idf no other weighting or pruning method was used, although so called stop words (and, so, yet, etc.) were removed as they slow down computation and do not add any relevant information for the cluster modeling or analysis. In probabilistic topic modeling every word is assigned a probability for every topic which renders the tf-idf formula incompatible, instead, word-frequency is the primary method for generating word vectors (Blei, 2012; Newman *et al.*, 2006). Word-frequency was therefore used for probabilistic topic modeling. As stop words had been removed prior to cluster modeling they naturally became excluded in the topic modeling phase, and as with cluster modeling no other weighting or pruning method was used.

Cluster analysis

Cluster analysis is a collection of multivariate techniques whose main goal is to group data based on its inherent characteristics (Hair *et al.*, 2014). The point is to classify an observation and assign affiliation to one specific cluster – i.e. the same observation cannot be assigned to several different clusters (Hair *et al.*, 2014). Cluster analysis should primarily be seen as an exploratory and descriptive technique since results are highly dependent on the specific variables used in the dataset and clusters will always be formed regardless of the existence of any actual structure in the data (Hair *et al.*, 2014). If it is intended to make inferences and generalizations from sample to population, then care must be taken as they are prone to error and need to be thoroughly justified (Hair *et al.*, 2014). According to Hair *et al.* (2014) cluster analysis is specifically suitable for, and often used in, research concerning taxonomy description, data simplification and relationship identification. Taxonomy description refers to an exploratory and empirically based classification of objects that results in a formation of a taxonomy (Hair *et al.*, 2014). Data simplification refers to group data and narrowing down variables and characteristics so that general patterns unfold rather than a myriad of unique observations (Hair *et al.*, 2014). Relationship identification concerns detection of

underlying structures and patterns in the overall data set that become apparent after clusters are formed, revealing links and associations that otherwise risk being obscured if individual classifications of data are made (Hair *et al.*, 2014). As the study's purpose falls both within taxonomy description and relationship identification, cluster analysis was chosen as the principal method of analysis.

Cluster analysis can be divided into two categories: hierarchical and nonhierarchical (Hair *et al.*, 2014). Generally hierarchical procedures are preferred when fast computations are favored and the sample size is moderate, below 1,000 (Hair *et al.*, 2014). Nonhierarchical procedures are preferred when the number of clusters is known or can be justified by a practical objective or theoretical basis and when outliers can cause concern, i.e. nonhierarchical methods are less sensitive to outliers (Hair *et al.*, 2014). As the aim was to find observable differences and similarities between time periods, and the overall dataset consisted of 1,475 observations, nonhierarchical measures were thought to be most appropriate, which initial testing and modeling confirmed. Even if several nonhierarchical clustering algorithms exist, k-means clustering algorithms dominate and are often used as a synonym for nonhierarchical clustering algorithms all together (Hair *et al.*, 2014). The issue of choosing the optimal k-means algorithm depends on the data at hand as well as which algorithms are available in the software package used (Arthur and Vassilvitskii, 2007; Jain, 2010; Stuti and Veenu, 2013). RapidMiner Studio© was used for cluster modeling; and experimentation revealed that using squared Euclidean distance as a divergence measure with Bregman divergences as a measure gave stable results.

Regardless of whether hierarchical or nonhierarchical clustering procedures are used, one of the critical issues at hand is choosing an appropriate stopping rule, i.e. to determine which number of clusters best represent the data structure (Hair *et al.*, 2014; Miner, 2012; Weiss *et al.*, 2012). There does not exist any standard objective selection process for choosing stopping rules; in addition, the specific theoretical and practical research situation needs to be taken into consideration as important conceptual issues may lie embedded in the data, e.g. manageability and communicability (Hair *et al.*, 2014). Thus, a combination of heterogeneity change, a measure of how the observations in each cluster differ from each other, and the avoidance of small, and single-member, clusters were applied in the study as it was judged to be a good way of balancing the practical aspects at hand with the purpose of the study. Modeling then started on the overall data set and testing was stopped at eight clusters as additional clusters resulted in the creation of a new extremely small cluster, less than 2 percent, and no overall changes in results, see Table I. For analytic and comparability purposes, in the following modeling sequences, the amount of clusters was kept to eight. Coincidentally, no other modeling session contained a cluster with less than 2 percent of the modeling data, which could be seen as further justification for the chosen amount of clusters. As can be seen in Table I, clusters 3 and 4 contained a majority of all

	4 clusters	5 clusters	6 clusters	7 clusters	8 clusters	Cluster 3 into 8 clusters	Cluster 4 into 8 clusters
Cluster 0	107 (7%)	132 (9%)	641 (43%)	355 (24%)	128 (8%)	47 (7%)	16 (5%)
Cluster 1	703 (48%)	652 (44%)	101 (7%)	47 (3%)	46 (3%)	46 (7%)	54 (16%)
Cluster 2	536 (36%)	130 (9%)	414 (28%)	131 (8%)	104 (7%)	79 (12%)	24 (7%)
Cluster 3	129 (9%)	459 (31%)	89 (6%)	663 (45%)	631 (43%)	143 (23%)	16 (5%)
Cluster 4		102 (7%)	129 (9%)	101 (7%)	334 (23%)	82 (13%)	64 (19%)
Cluster 5			101 (7%)	96 (7%)	98 (7%)	23 (4%)	32 (9%)
Cluster 6				82 (6%)	103 (7%)	119 (19%)	19 (6%)
Cluster 7					31 (2%)	92 (15%)	109 (33%)
Total	1,475	1,475	1,475	1,475	1,475	631	334

Table I.
Results from
clustering *IJQRM*
abstracts 1984-2014

data (66 percent) which is why they were further broken up into eight new clusters. Following this initial sort, modeling on the five time periods was executed, the results are shown in Table II.

In cluster analysis there exists no single method for validating, evaluating and labeling generated clusters (Hair *et al.*, 2014). This troubling fact is even more of a concern when it comes to evaluation of unstructured data (text) clustering as this is still a relatively novel area of research and classical processes for validating structured data (numbers) are not applicable (Aggarwal and Zhai, 2012). As the purpose of the study was exploratory, the aim being to look for underlying, hidden, structures in the data, no prior labels had been assigned. Consequently, there existed no labeling schedule to compare against. In other circumstances labeling beforehand is an approved and effective process of operating (Miner, 2012). However, in this study validation, evaluation and labeling of each cluster needed to be done following cluster modeling. One way to go about this is to use manual and qualitative processing, however, with large amounts of data automated procedures are often preferred (Weiss *et al.*, 2012). As the data set was deemed large and unsuitable for manual classification automated procedures were selected. One automated procedure on the rise for this purpose is probabilistic topic modeling (Mimno, 2012; Meeks and Weingart, 2012). As probabilistic topic modeling has shown great potential in the areas of historiography and bibliometric it was picked for the validation, evaluation and labeling of the created clusters.

Probabilistic topic modeling

Probabilistic topic modeling encompasses several associated methods that group words into topics on the basis of their most probable association (Blei *et al.*, 2003; Newman *et al.*, 2009). Although it is a relatively new method, topic models are generally considered to be a fast and effective way to identify and portray the most frequently occurring and probable themes and subjects in unstructured data sets (Xie and Xing, 2013). One well tested and conventional distributed algorithm for probabilistic topic modeling is the LDA (Welling *et al.*, 2008). As LDA is well accepted, well documented and available through the R topic modeling package, it was chosen for topic modeling in this study. R is a free software environment for statistical computing and graphics available for download at <https://cran.r-project.org/>

Simplified, topic models generate topic-characterized columns. Each column contains all the words in the data set, and words nearer the top of the column are more likely to be found together in the specific observation cluster, than words further down the same column (Blei *et al.*, 2003). Exemplifying with the help of results presented in Table AI, it means that topics, research paper abstracts, in cluster 0 have a high probability of covering various aspects of TQM, such as performance, implementation and manufacturing. Since each word in a data set has a probability to be associated with

Table II.
Results from
clustering *IJQRM*
abstracts into five
time periods from
1984 to 2014

	1984-1990	1991-1996	1997-2002	2003-2008	2009-2014
Cluster 0	15 (9%)	31 (10%)	40 (12%)	21 (6%)	18 (5%)
Cluster 1	30 (17%)	21 (7%)	82 (25%)	113 (34%)	49 (15%)
Cluster 2	12 (7%)	67 (22%)	7 (2%)	7 (2%)	22 (7%)
Cluster 3	30 (17%)	40 (13%)	52 (16%)	48 (15%)	108 (32%)
Cluster 4	12 (7%)	39 (13%)	50 (15%)	31 (9%)	43 (13%)
Cluster 5	15 (9%)	25 (8%)	19 (6%)	26 (8%)	37 (11%)
Cluster 6	26 (15%)	41 (13%)	32 (10%)	67 (20%)	22 (7%)
Cluster 7	34 (19%)	44 (14%)	46 (14%)	20 (6%)	33 (10%)
Total	174	308	328	333	332

another word in the same data set, the number of possible topics rapidly increases with the size of the data set (Blei *et al.*, 2003). Therefore, for practical and computational reasons, it is commonplace to delimit the number of topics into a manageable amount (Blei *et al.*, 2003). What constitutes a manageable amount of topics depends on the query at hand, however, the choice of topics is not a crucial computational decision since each topic uses all the words in the data set – words in one topic are not excluded from other topics in the same model. In the spirit of large scale trend spotting, it was therefore thought that a topic model containing five topics would be suitable as it allows for several different probable topics, yet five topics is a manageable amount for manual and qualitative analysis. Following the same line of thought, it was decided to use a topics first eight words in the analysis, i.e. the eight words which have the highest probability to be associated.

One issue that has attracted attention is the enhanced stability of topic models as they operate on random seeding for the creation of probability distributions (Hornik and Grün, 2011). In effect, this means that topic models with the same number of topics, and modeling the same data set, will always deliver slightly different results (Hornik and Grün, 2011). In R, there is a possibility of running the same model several times on the same data set after which the best fit is presented – a function called *nstart*. Simplified, the more runs a topic model does the more stable the results. However, with the side effect of prolonged computation time. To strengthen the reliability of the topic modeling results it was decided that each topic model should run on the same data set with two different *nstart* values. After experimentation, it was decided that *nstart* 1,000 respectively 2,000 was a satisfactory combination as additional runs did not seem to have any substantial impact on the outcomes.

When it comes to the analysis and evaluation of topic models no machine learning models have yet outperformed that of human judgment even if steady progress is being made in the field (AlSumait *et al.*, 2009; Dacres *et al.*, 2013; Chang *et al.*, 2009; Chemudugunta *et al.*, 2008a, b; Wallach *et al.*, 2009; Xie and Xing, 2013). Interpretation and evaluation was thus conducted by the author and is by nature subjective. The main advantage of this type of qualitative *modus operandi* is that it is fairly easy for someone with a general vocabulary to relatively quickly and efficiently interpret the context and implication of a generated topic. Czarniawska (2014) summarizes the issue by stating that many researchers have concluded that no software can interpret the collected field material and say “what it means” or “what it could mean”, which creates the possibility of several competing or complementing interpretations or views. This interpretation is the researcher’s prime responsibility.

Results and trends in the data

The results from the cluster modeling are shown in Table I. As mentioned in the methodological section, an eight cluster model was chosen as the final round of modeling. In this case the smallest cluster contained only 31 abstracts. Chopping up the data further by adding new clusters was hence deemed superfluous since clusters containing so few abstracts would make them unreliable for large scale trend identification, instead they would be zooming in on details. As clusters 3 and 4 together represented the majority of the data set (66 percent) they were further modeled into eight new clusters so that further analysis would be possible.

Figure 1, displays a visual representation of the final cluster modeling into eight clusters. From Table I and Figure 1, it is possible to conclude that a total of 1,475 abstracts, i.e. research articles, have been published between 1984 and 2014. Figure 1 shows that the edition has been fairly stable during the last 13 years, with a mean and median of 55 research articles annually and $\sigma = 1.6$. Further Figure 1 shows that the journal peaked in 1995 with 68 articles and has an all-time low in 1986 with only 16 research articles published that year. The two years are linked as the period 1986-1995 show a clear trend with increasing publications each year until the highpoint of 1995.

Figure 1.
IJQRM 1984-2014
in 8 clusters

The results obtained by topic modeling the eight clusters categorized in five topics, each with two different *nstart* values (1,000 and 2,000) can be viewed in Table AI. The eight clusters can, with the help of the generated topic models, be summarized in the following way:

- (1) Cluster 0 (8 percent) – TQM and QM; mainly implementation and performance;
- (2) Cluster 1 (3 percent) – QFD; design and development;
- (3) Cluster 2 (7 percent) – processes; design, capability, control and charts;
- (4) Cluster 3 (43 percent) – quality. A sub modeling into eight new clusters give:
 - Cluster 0 (7 percent) – study of quality companies, quality manufacturing, quality software, business excellence organizations;
 - Cluster 1 (7 percent) – QM practices;
 - Cluster 2 (12 percent) – quality costs, supply chains and benchmarking;
 - Cluster 3 (23 percent) – QM; training programs, performance, systems improvement;
 - Cluster 4 (13 percent) – quality design, quality methods, quality models and lean production;
 - Cluster 5 (4 percent) – self assessment, EFQM, management assessment and the Kano model;

- Cluster 6 (19 percent) – QM research; and
 - Cluster 7 (15 percent) – specific factors influencing quality; countries, management, environment.
- (5) Cluster 4 (23 percent) – reliability and failure. A sub modeling into eight new clusters give:
- Cluster 0 (5 percent) – fuzzy methods, fuzzy reliability systems, maintainability robust design;
 - Cluster 1 (16 percent) – reliability systems, production systems, processes and costs;
 - Cluster 2 (7 percent) – sampling and inspection;
 - Cluster 3 (5 percent) – software reliability;
 - Cluster 4 (19 percent) – maintenance;
 - Cluster 5 (9 percent) – failure and reliability; processes, systems and methodology;
 - Cluster 6 (6 percent) – warranty and repairs; and
 - Cluster 7 (33 percent) – reliability; models, data, methods and systems.
- (6) Cluster 5 (7 percent) – ISO; standards, performance, certification, benefits; implementation;
- (7) Cluster 6 (7 percent) – service quality; customer(s), SERVQUAL, relationships; dimensions; and
- (8) Cluster 7 (2 percent) – Six Sigma (and lean to a small extent); innovation, strategies, performance, learning and improvement.

The results obtained by cluster modeling the five time series can be viewed in Table II.

The results obtained from modeling the five time intervals can be viewed in Table AII. As for the overall cluster modeling in Figure 1, stack bar charts for each time period were generated as exemplified in Figure 2 and showed in Figures A1-A4.

1984-1990:

- Cluster 0 (9 percent) – quality circles; QM and managers in Japan, quality programs;
- Cluster 1 (17 percent) – quality; QM, quality assurance, quality auditing, quality control;
- Cluster 2 (7 percent) – sampling and inspection;
- Cluster 3 (17 percent) – costs; quality costs, design cost, energy cost;
- Cluster 4 (7 percent) – service quality and system analysis;
- Cluster 5 (9 percent) – liability, safety, computer system problems, quality problems and makership;
- Cluster 6 (15 percent) – manufacturing (quality) and process control; and
- Cluster 7 (19 percent) – reliability and failure.

1991-1996:

- Cluster 0 (10 percent) – quality; customer satisfaction, costs and QFD;
- Cluster 1 (7 percent) – repair costs and probability;

Figure 2.
IJQRM 1984-1990
structured into
8 clusters

- Cluster 2 (22 percent) – QM; costs, quality construction;
- Cluster 3 (13 percent) – quality and process control;
- Cluster 4 (13 percent) – quality models, QM awards, ISO certification;
- Cluster 5 (8 percent) – production, productivity and maintenance;
- Cluster 6 (13 percent) – TQM; implementation; and
- Cluster 7 (14 percent) – reliability, failure, service quality and manufacturing.

1997-2002:

- Cluster 0 (12 percent) – ISO; certification, benefits, performance;
- Cluster 1 (25 percent) – QM; practices, models, projects and manufacturing;
- Cluster 2 (2 percent) – processes, statistical engineering and data quality;
- Cluster 3 (16 percent) – control; design and processes;
- Cluster 4 (15 percent) – service quality; customers, SERVQUAL, benchmarking;
- Cluster 5 (6 percent) – failure, repair, stress, sampling;
- Cluster 6 (10 percent) – reliability and self-assessment; and
- Cluster 7 (14 percent) – TQM; implementation, framework, employees.

2003-2008:

- Cluster 0 (6 percent) – QFD;
- Cluster 1 (34 percent) – miscellaneous on cost, warranty, QM, etc.;
- Cluster 2 (2 percent) – Six Sigma; improvement, fad;
- Cluster 3 (15 percent) – TQM; performance and implementation;
- Cluster 4 (9 percent) – ISO; certification, implementation, practices;
- Cluster 5 (8 percent) – service quality; customer satisfaction, instruments, SERVQUAL;
- Cluster 6 (20 percent) – miscellaneous on maintenance, QM, quality models, process improvement, etc.; and
- Cluster 7 (6 percent) – failure and reliability.

2009-2014:

- Cluster 0 (5 percent) – control; charts, processes, design;
- Cluster 1 (15 percent) – service quality; customers, dimensions;
- Cluster 2 (7 percent) – Six Sigma and Lean; innovation, improvement, performance and learning;
- Cluster 3 (32 percent) – miscellaneous on quality, cost, performance, quality design, etc.;
- Cluster 4 (13 percent) – quality; QM, quality design, QMPS;
- Cluster 5 (11 percent) – TQM; performance, practices, self-assessment;
- Cluster 6 (7 percent) – reliability and failure; and
- Cluster 7 (10 percent) – ISO; implementation, performance and indicators.

The results show that *IJQRM* has had a stable edition profile during the last 20-year period after an initial ten-year period of growth. This development indicates that there existed a momentum for the type of research articles that the journal published during the 1980s and 1990s, which is why the issues and number of published papers steadily grew until reaching an equilibrium in the mid-1990s. Without taking indexing and ranking into account, this points toward *IJQRM* being a well-established and dependable scientific journal which sets the scene for profound and lasting academic debates over the covered research topics.

According to *IJQRM* itself the journal “deals with all aspects of business and manufacturing improvements, from the training of senior managers, to innovations in processing and production to raise standards of product quality”. The results support this statement: the journal is indeed versatile and offers a multitude of topics. Nonetheless, it is also clear that *IJQRM* is firmly grounded in quality and reliability management as the majority of abstracts in the overall cluster modeling, as well as the partitioned time series, fall into these two categories. Hence, researchers, practitioners and stakeholders with an interest in publishing and taking part of research findings regarding quality and reliability management have a dependable platform for distributing and sharing knowledge. Other identifiable topics that emerge in *IJQRM* through clustering are TQM, service quality, QFD, ISO certification and Six Sigma. These could be seen as topics receiving extraordinarily high coverage in *IJQRM* and it would be acceptable to highlight them when marketing the journal, as is done with QFD. Of the named topics, service quality is seen as the one least marketed and communicated, it could thus be worth emphasizing it in future

communication and information activities. The results clearly show continuous publication of service quality research articles and *IJQRM* is consequently justified in putting it forward as a key subject area. Accordingly, researchers focusing on service quality should not shed *IJQRM* but instead regard it as a well-grounded base for publication and knowledge retrieval.

Looking into the historical evolution of topics in *IJQRM* some variation between the chosen time periods can be noted. As the study explores for large scale trends, fashions, and fads small disparities within topics are not brought into focus, although it is feasible that the results could prove valuable for studies of more specific and rare topics. Starting in the 1980s there was a clear interest in quality circles as well as in Japanese manufacturing and management, after which it faded away. In contrast TQM appeared in 1991-1996 and has been a significant and reoccurring research topic right up until at least 2014. A similar journey can be identified for research on ISO, however, this initially broke through at a later time period, 1997-2002, after which it settled as reappearing topic. QFD has evolved somewhat differently, first showing up in 1991-1996 and then taking a leap into 2003-2008 where it constituted a cluster on its own, after which it fell into the background in 2009-2014. As a result, QFD could be classified as a topic in decline, or as a fading trend. In contrast, Six Sigma is shown as a topic on the rise, starting small in 2003-2008 and then coupled with lean growing in 2009-2014. Although only a possible indication of current trends, it may be worth noting that publications on reliability, failure and maintenance have decreased significantly during the last period of 2009-2014. In sum, researchers looking to publish in *IJQRM* could gain strategic benefits in the publication process by presenting research on Six Sigma and Lean and avoiding QFD, reliability, failure and maintenance.

An important result well worth reflecting on is the distribution of papers after cluster modeling; a tendency can be noticed for one or two large clusters to dominate while the other clusters represent a smaller and smaller portion of the total data set. The effect created is that of several distinct but small clusters and a few large ones which are hard to summarize and classify. A way of interpreting these results might be to argue that the abstracts become more and more coherent, i.e. they are harder to distinguish and classify for the clustering algorithm. This statement could be supported by the fact that a standard format for research paper abstracts in *IJQRM* was introduced in 2005, where all needed to contain: purpose, design/methodology/approach, findings, limitations, practical implications and originality/value. This change, surely with the intention of simplifying search and overview of abstracts, could well have led to a homogenization of abstracts which could prove to be a challenge for text mining with clustering algorithms. Clustering algorithms aim to identify similarities between objects, therefore it is natural that the outcome of a very homogenous material is a dominant cluster with a periphery of much smaller clusters, as even for homogenous data there is always some similarity between some objects in the data set, which then will be identified and grouped together. If this is true, other objects for identification and classification could prove better than abstracts, an obvious example being keywords. On the other hand, it would be unwise on the basis of these results to claim that the standardization of abstracts has a negative effect for text mining purposes as structure and coherence more often than not are positive in this regard. Conversely, yet still following this trail of thought, it is equally possible to argue that the research papers and their corresponding abstracts are actually more heterogeneous in later editions of *IJQRM*. Applying the same principle as above with a homogenous data set, it can be the case that even a much diversified data set will end up with few large clusters and several small but distinct clusters. However, in the latter case, the large clusters will be characterized by heterogeneity and not homogeneity.

Finally, it can be noted that there is no clear-cut sign of *IJQRM* changing direction in 1998 due to the incorporation of the *International Journal of Quality Science*. This does not mean that there was no change in direction; however, it does show that the influence was modest and that the journal did not change its fundamental orientation.

Discussion

Within the academic community there exists a debate regarding trends, fashion and fads in research (Abrahamson, 1996, 2009; Abrahamson and Eisenman, 2008; Abrahamson and Fairchild, 1999; Czarniawska, 2007, 2011a, 2014; Czarniawska and Panozzo, 2008; Parush, 2008; Starbuck, 2009; Trout, 2004). This study supports the claim that new topics and research areas are constantly introduced, indicating that there are indeed trends, fashion and fads in research. The study also shows that, in the case of *IJQRM* and the research it represents, there exists a stable nucleus covering quality and reliability management, which might be labeled the academic fields' core fashion or leading paradigm. However, the study cannot say anything about why or how new introductions or changes occur. The patterns could be explained by variables put forward by Czarniawska (2011a), Czarniawska and Panozzo (2008), Starbuck (2009) and Trout (2004), such as changes in the editorial board, new observations, experiences or interests in the academic community, alteration of financing and boredom. Additionally, considering the results it could be argued that established and fashionable terms such as quality or reliability management slowly become devalued due to inconsequential or frivolous usage. Subsequently, the terminologies become ill-defined, vague and all-encompassing rendering them unsuitable for research purposes. Conversely, researchers with a long-term commitment to quality and reliability management research might have an interest in actively reflecting upon their personal stand and influence on the fields epistemological development. If it is believed that the research area rests on a shaky theoretical base, it might be wise to prioritize terminological consistency and resist introduction and usage of new terminologies even if they increase the prospect of publication. Otherwise one renders the risk of contributing to the terminological inflation and further watering down the fields theoretical foundation. However, if one does not look upon the research field as weakly rooted in theory or publication is of high importance the results indicate that one should be cautious of fading stars, like QFD in this case, and instead prioritize topics on the rise, such as Six Sigma and lean in this study. For more detailed exploration of these kind of causes and effect-chains regarding trends in research, data mining studies like Dereli *et al.* (2011) are very complementary as they include supplementary information, e.g. name of writer, country of origin, university, etc. The combination of these two approaches could offer a way to identify the true driving forces behind trends that Czarniawska and Panozzo (2008) put forward as the main factors when new trends and fashions are launched.

This study supports the notion that QM as well as TQM gained an increasing amount of attention during the 1980s and 1990s as the number of publicized articles steadily grew, until the peak in 1995 after which the situation stabilized (Dahlgaard-Park, 1999, 2011; Dahlgaard-Park *et al.*, 2013; Rocco and Parry, 2011; Sila and Ebrahimpour, 2002; Sousa and Voss, 2002; Van Der Wiele *et al.*, 2000). Since the number of publications has stayed stable and has not decreased significantly this could be taken as proof of quality and reliability management as well as TQM, ISO and service quality being well-established fields of research that are here to stay, rather than transitory trends or fashions. Given the results from the overall cluster modeling (1984-2014) it might be tempting to label QM as the dominant paradigm or fashion, followed by reliability management, TQM, ISO and service quality. However, adding the chronological results, allows this order to be challenged. Essentially, by taking into account the possible effect of terminology devaluation, one could argue that quality and reliability management might have become too fuzzy and ambiguous, whereas TQM, ISO and service quality remain more distinct. If this is the case, TQM, ISO and service quality

might actually be the current paradigms, fashions or trends, each having more of a delimiting and unifying ability than both quality and reliability management.

It must be reemphasized that the study only encompasses one scientific journal, using an exploratory and descriptive methodology, which make the results highly dependent on the specific data set and modeling. Therefore, there may exist many possible explanations for the specific observations presented in this study. This means that keyword search studies like Dahlgaard-Park *et al.* (2013) serve as an complementary perspective to the kind of research presented in this paper since they include a broader scope of publications, albeit, not as innate. Combining the two approaches would, hence, be a way of exploring both the findings of this study regarding QM as well as exploring how keywords and abstracts correspond to each other, thereby validating the statement by Delen and Crossland (2008), Miner (2012) and Weiss *et al.* (2012) that abstracts are a more trustworthy summary of a research article than its associated keywords.

One big setback of trying to organize abstracts through cluster modeling is the risk of identifying trends and fashion in writing, rather than changes in actual research; an effect that could have influence at both a micro and a macro level. On the micro-level it could well be that researchers interested in a specific topic have a very similar way of describing their work and results when writing abstracts. This could then lead to an increased probability for the clustering algorithm to classify these abstracts as similar and to group them together into a cluster, instead of forming a cluster of another topic that is actually bigger but where the writers express themselves less consistently. At the macro level this line of thought would favor cluster modeling on abstracts later on in *IJQRM*'s publication history as they are standardized and, hence, would be easier to classify. As the results cannot be said to prove this point, it is interesting to reflect whether abstracts in the early days of *IJQRM* are actually better for cluster modeling as they are less uniform, displaying instead a diversity which makes them labor intensive for humans to look over and classify but easier for statistical and mathematical programs to work with.

Conclusions

This study supports the notion that there are trends in research, but as the results do not give any guidance as to the reasons behind these trends, complementary studies are needed. Topics identified by the study to be in decline are QFD and areas within the fields of reliability, failure and maintenance management. A topic on the rise is Six Sigma with a particular orientation toward lean, innovation, implementation and improvement.

The study supports quality and reliability management being the dominant fashion or trend in the covered academic field. However, the study also offers an alternative explanation discussing whether TQM, ISO and service quality might actually be the current paradigms and fashions in the field as they have remained more distinct, thus being less watered down than quality and reliability management.

The results verify the statement of *IJQRM* being a journal "dealing with all aspects of business and manufacturing improvements" with specific coverage of quality and reliability management as well as:

- TQM;
- Service quality;
- ISO;
- Process management;
- QFD; and
- Six Sigma.

Finally, the study propels further examination of cluster and topic modeling for both epistemological pursuits as well as for BI purposes, as these approaches offer a useful way of exploring and describing large quantities of unstructured data.

Future research

The collected data could be re-used but processed with different cluster-models as well as on the basis of other word vectors, e.g. term frequency. This would give an interesting view of how the document matrix affects the clustering and their content. Yet another angle would be to explore supervised learnings models, alternatively one could filter the data set for a specific topic, e.g. ISO, and subsequently model with this material, giving a detailed insight of a specific topic and its evolution over time.

Limitations

The study focuses on research article abstracts. Other journal content such as book reviews, general reviews, secondary articles, editorials, guest editorials, awards for excellence (notifications), introductions or summaries from conferences, notes from the publisher and articles without an abstract are not a part of the study which may exclude certain topics and trends.

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Further reading

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1984-2014 (nstart 1,000)					
Cluster 0 (8%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
TQM Research Based Study Case Findings Management Analysis Topic 1	TQM Quality Management Manufacturing Firms Total Business Performance Topic 1	TQM Performance Quality Implementation Study Research Impact Topic 2	TQM Performance Quality Implementation Study Research Impact Topic 3	TQM Quality Management Performance Research Customer Implementation ISO Topic 4	TQM Management Quality Performance Implementation Research Management Competency Case Topic 5
Cluster 1 (3%)	QFD Quality Design Process Product Function Process Customer Deployment Topic 1	QFD Product Cost Quality Function Process Target Customer Topic 2	QFD Quality Paper Approach Customer Order Process Supplier Topic 3	QFD Quality Deployment Paper Project Function Design Systems Topic 4	QFD Quality Customer Design Paper Deployment Function Product Topic 5
Cluster 2 (7%)	Process Control Quality Design Statistical Parameters Charts Data Topic 1	Control Sampling Design Process Chart Charts Economic Cost Topic 2	Chart Control Proposed Process EWMA Shewhart Mean Cusum Topic 3	Control Charts Quality Process Procedure Chart Production Improvement Topic 4	Control Process Quality Statistical Systems Chart Charts Improvement Topic 5
Cluster 3 (43%)	Paper Management Research Approach Purpose Methodology Quality Findings	Process Design Performance Approach Quality Study Methodology	Quality Management Manufacturing Study Product Control Approach Process	Quality Management Firms Companies Study Improvement Results	Quality Management Research Performance Practices Study Research Paper Companies
1984-2014 (nstart 2,000)					
Cluster 0 (8%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
TQM Study Quality Performance Research Management Findings Practices Topic 1	TQM Quality Management Implementation Performance ISO Results Factors Topic 2	TQM Quality Management Implementation Performance Service Total Topic 3	TQM Quality Management Manufacturing Firms Service Total Topic 3	TQM Quality Management Performance Implementation Research Study Purpose Topic 4	TQM Research Based Quality Paper Management Competency Case Topic 5
Cluster 1 (3%)	QFD Quality Strategic Customer Companies Findings Paper Relationship Development Topic 1	QFD Quality Product Design Order Method Process Customer Design Topic 2	QFD Quality Design Deployment Function Customer Process Paper Topic 3	QFD Quality Design Product Target Process Costing Function Topic 4	QFD Quality Customer Design Paper Deployment Function Product Topic 5
Cluster 2 (7%)	Process Control Sampling Charts Quality Design Procedure Paper Topic 1	Control Design Chart Process Cost Economic Charts Model Topic 2	Chart Control Proposed EWMA Process Cusum Charts Mean Topic 3	Control Process Charts Rules Shift Pattern Quality Topic 4	Control Process Quality Statistical Systems Chart Charts Improvement Topic 5
Cluster 3 (43%)	Quality Management Cost Costs Improvement System Project Manufacturing	Process Design Quality Study Performance Paper Results Product	Quality Management Performance Practices Research Findings Study	Quality Management Research Performance Purpose Methodology Design Findings	Quality Management Research Performance Practices Study Research Paper Companies

(continued)

Table AI.
Results from topic
modeling the overall
data set (*IJQRM*
1984-2014)

Table AI.

Cluster 4 (23%)	Topic 1	Failure FMEA Paper Fuzzy Cost Methodology Analysis Topic 1	Topic 2	Reliability System Maintenance Model Quality Systems Data Method Paper Topic 2	Topic 3	Design Method Approach Quality Product Paper Model Sampling Topic 3	Topic 4	System Availability Model Repair Time Paper Inspection Failure Topic 4	Topic 5	Reliability System Failure Software Approach Systems Data Topic 5	Cluster 4 (23%)	Topic 1	Failure Reliability Analysis Approach Maintenance System FMEA Paper Topic 1	Topic 2	Cost Model Quality Warranty Paper Costs Approach Topic 2	Topic 3	Reliability Data Software Model Failure Approach Method Systems Topic 3	Topic 4	System Reliability Availability Systems Failure Paper Time Model Topic 4	Topic 5	Approach Method Sampling Design Plans Distribution Stress Proposed Topic 5
	Topic 1	Quality ISO System Management Certification Firms Based Companies Topic 1	Topic 2	ISO Performance Companies Certification Certified Standard Paper Findings Topic 2	Topic 3	ISO Quality Certification Management Companies Benefits Organizations System Topic 3	Topic 4	ISO Quality Management Research Paper Implementation Approach QMS Topic 4	Topic 5	ISO Standards Management Quality Paper Implementation Systems Certification Topic 5		Topic 1	ISO Standards Management Quality Paper Implementation Systems Topic 1	Topic 2	ISO Quality Management Companies System Benefits Certification Firms Topic 2	Topic 3	ISO Quality Management System Paper Research Implementation Study Topic 3	Topic 4	ISO Certification Benefits Results Quality Research Organizations Paper Topic 4	Topic 5	ISO Performance Certification Certified Companies Study Paper Innovation Topic 5
	Topic 1	Service Quality Services Management Paper Research Study Model Topic 1	Topic 2	Service Quality Servqual Dimensions Model Customers Banks Services Topic 2	Topic 3	Service Quality Customer Reliability Internal Research Performance Study Topic 3	Topic 4	Quality Service Customers Customer Food Satisfaction Study Dimensions Topic 4	Topic 5	Quality Service Research Customer Performance Relationship Paper Purpose Topic 5		Topic 1	Quality Service Research Relationship Customer Performance Management Paper Topic 1	Topic 2	Service Quality Services Paper Perceptions Model Management Study Topic 2	Topic 3	Quality Service Customers Customer Servqual Dimensions Satisfaction Study Topic 3	Topic 4	Service Quality Reliability Model Internal Research Customer Study Dimensions Topic 4	Topic 5	Service Quality Model Customer Servqual Banks Analysis Banking Topic 5
	Topic 1	Sigma Paper Management Service Research Approach Methodology Findings	Topic 2	Sigma Performance Paper Data Levels Measures Approach Call	Topic 3	Sigma Organizational Innovation Learning Research Findings Management Study	Topic 4	Sigma Lean Improvement Paper Approach Quality Strategies Framework	Topic 5	Sigma Quality Service Management Knowledge Paper Purpose Research		Topic 1	Sigma Organizational Innovation Learning Quality Barriers Management	Topic 2	Sigma Paper Lean Improvement Practical Provides Implications Research	Topic 3	Sigma Management Approach Findings Purpose Strategies Methodology Paper	Topic 4	Sigma Paper Service Research Implementation Approach Purpose Management	Topic 5	Sigma Performance Approach Levels Measures Quality Call Improvement
	Cluster 7 (2%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7	Topic 8	Topic 9		Cluster 7 (2%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7	Topic 8	Topic 9

(continued)

Table AI.

1984-2014 Cluster 3 (nstart 1,000)					1984-2014 Cluster 3 (nstart 2,000)						
Cluster 0 (7%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Cluster 0 (7%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
	Quality Companies Management Process System Manufacturing Total Key Topic 1	Approach Research Process Paper Quality Value Mindful Design Topic 2	Quality Manufacturing Information Firms Management System Control Based Topic 3	Quality Software Development Paper Changes Management Approach Purpose Topic 4	Excellence Business Organizations Study Review Organization Research Managers Topic 5		Quality Companies Management Process System Manufacturing Total Key Topic 1	Approach Research Process Paper Quality Value Mindful Design Topic 2	Quality Manufacturing Information Firms Management System Control Based Topic 3	Quality Software Development Paper Changes Management Approach Purpose Topic 4	Excellence Business Organizations Study Review Organization Research Managers Topic 5
Cluster 1 (7%)	Quality Practices Management Companies Manufacturing Findings Culture China Topic 1	Quality Management Practices Study Companies Paper Warranty Research Topic 2	Practices Quality Employee Paper CSR Results Purpose CPFO Topic 3	Quality Management Practices Firms Performance Study Employees Organizational Topic 4	Quality Practices Performance Management Study Findings Research Data Topic 5		Quality Management Practices Performance Study Manufacturing Significant Based Topic 1	Quality Practices Management Performance Findings Study Employee Results Topic 2	Quality Firms Management Practices Performance Implementation Logistics Study Topic 3	Quality Practices Management Research CSR Managers Paper Perceptions Topic 4	Practices Quality Management Study Warranty Paper Organizational Research Topic 5
Cluster 2 (12%)	Quality Performance Research Companies Management Information Benchmarking Methodology Topic 1	Quality Costs COQ Value Improvement System Purpose Topic 2	Quality Supply Chain Study System Aspect Construction Analysis Topic 3	Quality Performance Management Construction Based Improvement Firms Award Topic 4	Quality Cost Costs COQ Model Paper Costing Data Conformance Topic 1		Quality Costs Cost Model Paper Costing Data Conformance Topic 1	Quality Cost Costs COQ Improvement Value System Rework Topic 2	Quality Management Based Construction Firms Paper Product Topic 3	Quality Supply Chain Performance Research Approach Management Aspect Improvement Topic 4	Benchmarking Performance Quality Construction Approach Management Improvement Topic 5
Cluster 3 (23%)	Quality Management Control Firms Improvement Systems Industry Program	Quality Management Study Housing Factors Enterprises Paper Research	Quality Management Systems Industry Program Manufacturing Performance Development	Quality Management Organizations Product Paper Study Performance Author	Quality Paper Approach Process Management Study Performance Research		Quality Organizations Training Program Manufacturing TQC Management Implementation	Quality Management Firms Study Performance Control Industry Managers	Quality Management Systems Improvement Control Customer Product	Quality Management Study Company Research Systems Paper Housing	Quality Paper Performance Industry Value Customer Approach Location
(continued)											

(continued)

Table AI.

Cluster 4 (13%)	Topic 1 Quality Application Methodology Production System Design Analysis Approach Using Topic 1	Topic 2 Quality Management Production System Research Systems Implementation Design Topic 2	Topic 3 Quality Systems Assurance Manufacturing Companies Article Production Managers Topic 3	Topic 4 Method Design Taguchi Approach Paper Study Response Proposed Topic 4	Topic 5 Performance Quality Production Health Paper Design Product LSS Topic 5	Cluster 4 (13%)	Topic 1 Production Lean Manufacturing Paper Performance Quality Research Implementation Topic 1	Topic 2 Quality Design Performance Product Methods Management Health Techniques Topic 2	Topic 3 Quality Model System Systems Management Control Scheme Auditing Topic 3	Topic 4 Quality Management Approach Systems Manufacturing Companies Successful Based Topic 4	Topic 5 Method Design Taguchi Response Study Proposed Problems Using Topic 5
Cluster 5 (4%)	Assessment Self Cpe Paper System Criteria Measurement Supplier Topic 1	Self Assessment Quality Improvement Performance Tool Criteria Paper Topic 2	Model Kano Approach Customer Management Knowledge Research Satisfaction Topic 3	Model EFQM Criteria Excellence Results Paper Analysis Education Topic 4	Assessment Self Follow Based Organization Paper Processes Topic 5	Cluster 5 (4%)	Model Kano Customer Approach Research Proposed Purpose Relationship Topic 1	Assessment Self Follow Paper Management Organization Processes Based Topic 2	Model Criteria EFQM Excellence Results Education Relationships Analysis Topic 3	Self Assessment Quality Model Organizations Paper Performance Improvement Topic 4	Management Assessment Measurement Knowledge System Based Criteria Factors Topic 5
Cluster 6 (19%)	Paper Project Decision Management Approach Methodology Portfolio Study Topic 1	Quality Research Information Process Paper Approach Value Implications Topic 2	Quality Process Management Improvement Study Based Paper Design Topic 3	Quality Project Management Improvement Product Performance Paper Development Topic 4	Process Paper Framework Analysis Approach Methodology Study Research Topic 5	Cluster 6 (19%)	Process Quality Results Design Capability Paper Research Product Topic 1	Quality Management Process Research Performance Paper Based Study Topic 2	Paper Project Approach Quality Methodology Findings Research Management Topic 3	Decision Paper Approach Research Methodology Analysis Making Study Topic 4	Quality Management Improvement Project Paper Product Development Research Topic 5
Cluster 7 (15%)	Quality Tpm Manufacturing Performance Management Factors Productivity Implementation Topic 1	Quality Paper Product Results Research Management Purpose Factors Topic 2	Quality Factors Management Environmental Paper Findings Purpose Companies Topic 3	Quality Countries Management Developing Research Sale Organizational Factors Topic 4	Process Mobile Study Factors Performance Design Analysis Optimum Topic 5	Cluster 7 (15%)	Quality Product Circles Management Study Environmental Sustainability Performance Topic 1	Factors Management Tpm Quality Implementation Paper Success Manufacturing Topic 2	Study Mobile Results Sale Design Performance Paper Level Topic 3	Quality Management Factors Paper Research Countries Purpose Findings Topic 4	Quality Results Productivity Factors Improvement Paper Research Performance Topic 5

(continued)

1984-2014 Cluster 4 (nstart 1,000)									
Cluster 0 (5%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Cluster 0 (5%)	Topic 1	Topic 2	Topic 3
Reliability Maintainability Design Management Organizational Performance Value Developed	Reliability Maintainability Design Management Organizational Performance Value Developed	Fuzzy Reliability System Approach Vague Interval Paper Using	Design Quality Robust Cost Model Proposed Life Optimization	Time Failure Simulation Logistic Analysis Availability Data	Fuzzy Method Non Numbers Customer Market Network Neural	Reliability Maintainability Design Management Organizational Performance Value Developed	Reliability Maintainability Design Management Organizational Performance Value Developed	Fuzzy Reliability System Approach Vague Interval Paper Using	Design Quality Robust Cost Model Proposed Life Optimization
Cluster 1 (16%)	Reliability System Method Time Cost Quality Product Design	Product System Systems Burn Model Failure Availability Method	System Reliability Design Algorithm Costs Paper Quality	Inspection Production Model Process Quality Costs Time System	Quality Cost Model Failure Prevention Process Approach	Reliability System Method Time Cost Quality Product Design	Reliability System Method Time Cost Quality Product Design	Product System Systems Burn Model Failure Availability Method	Design Quality Robust Cost Model Proposed Life Optimization
Cluster 2 (7%)	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans Inspection Tightened System Normal Switching Plan	Plans Sampling Acceptance Approach Design Optimization Based Levels	Sampling Distribution Plans Cost Lifetime Plan Number Products	Acceptance Distribution Plan Sampling Poisson Sample Number Size	Products Inspection Webull Series Shot Parameters Scheme Stage	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans Inspection Tightened System Normal Switching Plan	Acceptance Distribution Plan Sampling Poisson Sample Number Size
Cluster 3 (5%)	Software Reliability Model Optimal Testing Operational Quality Time	Software Reliability System Hardware Model Performance Restoration	Reliability Software Model Failure Models Proposed Time Homogeneous	Software Reliability Testing Growth Paper Models Results Sign	Software Reliability Design Based Component Systems Article Approach Paper	Software Reliability Model Optimal Testing Operational Quality Time	Software Reliability Model Optimal Testing Operational Quality Time	Software Reliability System Hardware Model Performance Restoration	Software Reliability Design Based Component Systems Article Approach Paper
1984-2014 Cluster 4 (nstart 2,000)									
Cluster 0 (5%)	Sample Time Analysis Data Simulation Failure Food Product	Fuzzy Method Non Numbers Customer Life Paper	Sample Time Analysis Data Simulation Failure Food Product	Sample Time Analysis Data Simulation Failure Food Product	Fuzzy Method Non Numbers Customer Life Paper	Cluster 0 (5%)	Sample Time Analysis Data Simulation Failure Food Product	Fuzzy Method Non Numbers Customer Life Paper	Sample Time Analysis Data Simulation Failure Food Product
Cluster 1 (16%)	System Systems Reliability Model Paper Obsolescence Analysis Purpose	Quality Cost Costs Model Approach Failure Prevention Inspection	System Systems Reliability Model Paper Obsolescence Analysis Purpose	System Systems Reliability Model Paper Obsolescence Analysis Purpose	Quality Cost Costs Model Approach Failure Prevention Inspection	Cluster 1 (16%)	System Systems Reliability Model Paper Obsolescence Analysis Purpose	Quality Cost Costs Model Approach Failure Prevention Inspection	System Systems Reliability Model Paper Obsolescence Analysis Purpose
Cluster 2 (7%)	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans System Inspection Tightened Method Normal Switching	Products Inspection Webull Series Shot Parameters Scheme Stage	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans System Inspection Tightened Method Normal Switching	Cluster 2 (7%)	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans System Inspection Tightened Method Normal Switching	Products Inspection Webull Series Shot Parameters Scheme Stage
Cluster 3 (5%)	Software Reliability Model Optimal Testing Operational Quality Time	Software Reliability System Hardware Model Performance Restoration	Software Reliability Design Based Component Systems Article Approach Paper	Software Reliability Testing Growth Paper Models Results Sign	Software Reliability Design Based Component Systems Article Approach Paper	Cluster 3 (5%)	Software Reliability Model Optimal Testing Operational Quality Time	Software Reliability System Hardware Model Performance Restoration	Software Reliability Design Based Component Systems Article Approach Paper
1984-2014 Cluster 4 (nstart 2,000)									
Cluster 0 (5%)	Sample Time Analysis Data Simulation Failure Food Product	Fuzzy Method Non Numbers Customer Life Paper	Sample Time Analysis Data Simulation Failure Food Product	Sample Time Analysis Data Simulation Failure Food Product	Fuzzy Method Non Numbers Customer Life Paper	Cluster 0 (5%)	Sample Time Analysis Data Simulation Failure Food Product	Fuzzy Method Non Numbers Customer Life Paper	Sample Time Analysis Data Simulation Failure Food Product
Cluster 1 (16%)	System Systems Reliability Model Paper Obsolescence Analysis Purpose	Quality Cost Costs Model Approach Failure Prevention Inspection	System Systems Reliability Model Paper Obsolescence Analysis Purpose	System Systems Reliability Model Paper Obsolescence Analysis Purpose	Quality Cost Costs Model Approach Failure Prevention Inspection	Cluster 1 (16%)	System Systems Reliability Model Paper Obsolescence Analysis Purpose	Quality Cost Costs Model Approach Failure Prevention Inspection	System Systems Reliability Model Paper Obsolescence Analysis Purpose
Cluster 2 (7%)	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans System Inspection Tightened Method Normal Switching	Products Inspection Webull Series Shot Parameters Scheme Stage	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans System Inspection Tightened Method Normal Switching	Cluster 2 (7%)	Products Inspection Webull Series Shot Parameters Scheme Stage	Sampling Plans System Inspection Tightened Method Normal Switching	Products Inspection Webull Series Shot Parameters Scheme Stage
Cluster 3 (5%)	Software Reliability Model Optimal Testing Operational Quality Time	Software Reliability System Hardware Model Performance Restoration	Software Reliability Design Based Component Systems Article Approach Paper	Software Reliability Testing Growth Paper Models Results Sign	Software Reliability Design Based Component Systems Article Approach Paper	Cluster 3 (5%)	Software Reliability Model Optimal Testing Operational Quality Time	Software Reliability System Hardware Model Performance Restoration	Software Reliability Design Based Component Systems Article Approach Paper

(continued)

Table AI.

Cluster 4 (19%)		Topic 1		Topic 2		Topic 3		Topic 4		Topic 5	
Maintenance Inspection Equipment Model Approach Paper Failure Strategy Topic 1	Maintenance Reliability Availability Importance Cost Component Systems Topic 2	System Reliability Availability Maintenance Cost Component Systems Topic 2	Availability Paper Performance Methodology Unit Tunnel Maintainability Systems Topic 3	Maintenance System Data Condition Failure Approach Fuzzy Using Topic 4	Maintenance Model Scheduling Paper System Approach Preventive Cost Topic 5	Maintenance Availability Performance Paper Unit Reliability Analysis Plant Topic 1	System Maintenance Availability Reliability Methodology Paper Cost Analysis Topic 2	Maintenance Approach System Data Model Using Failure Proposed Topic 3	Maintenance Model Inspection Equipment Optimal Rate Time System Topic 4	Maintenance Tunnel Cost Paper Method Design Topic 5	
Cluster 5 (9%)		Reliability Loss Approach Process Methodology Purpose Analysis FMEA Topic 1		Reliability System Analysis Failure Paper Design Failures Model Topic 2	FMEA Process Approach Lean Reliability Design Failure Control Topic 5	Process Lean Loss Approach Failure Methodology FMEA Function Topic 1	Reliability System Analysis Failure Paper Design Failures Value Topic 2	Failure Fuzzy Risk RPN Model FMEA Rules Proposed Topic 3	Failure Approach Methodology Analysis Modes Paper Purpose Reliability Topic 4	FMEA Failure Approach Methodology Process Design Analysis Paper Cost Topic 5	
Cluster 6 (6%)		Model Failure Warranty Allocation Rate Time Use Component Topic 1		Repair Policy Cost System Time Limit Algorithm Hand Topic 2	Warranty Analysis Data Claims Product Chain Design Practical Topic 4	Warranty Data Analysis Claims Product Age Costs Distribution Topic 1	Warranty Failure Product Costs Burn Cost Chain General Topic 2	Warranty Model Failure Implications Practical Allocation Approach Paper Expected Topic 3	Repair Warranty Cost Policy Repairs System Time Topic 4	Warranty Model Purpose Cost Implications Models Paper Policies Policy Topic 5	
Cluster 7 (33%)		Method Approach Proposed Reliability Paper Process Systems Data		System Failure Reliability Systems Model Availability Time Approach	System Reliability Paper Systems Approach Component Failure Data	Reliability Data System Human Error Paper Failure Analysis	Model Reliability Approach Systems Method System Paper Failure	Failure Reliability Data Approach System Model Systems Method	Test Distribution Stress Method Process Paper Design Reliability	System Reliability Failure Paper Components Component	

1984-1990 (nstart 1,000)					
Cluster 0 (9%)	Topic 1 Firms Quality Japanese Managers Traditional Criteria Management Manufacturing	Topic 2 Quality Improvement Account Article Company Firms Given	Topic 3 Quality Commitment Production Business Control Formation Organization Paper	Topic 4 Circles Quality Program Circle Implementation Characteristics Successful Analysis	Topic 5 Quality Study Circle Management Based Claims Limitations Literature
Cluster 1 (17%)	Topic 1 Auditing Performance Quality Companies Manufacturing Article Assurance Managers	Topic 2 Quality Program Control Havant TQC Cent Defectives Establish	Topic 3 Quality Competition Management Based Literature Assurance Strategy World	Topic 4 Quality Test Control Industry African Article Assurance Described	Topic 5 Quality Assurance Systems Article Based Control Technology Information
Cluster 2 (7%)	Topic 1 Vendor Test Buyer Department Maintenance Plan Results Control	Topic 2 Plans Sampling Errors Mil Quality STD Inspection Optimal	Topic 3 Sample Plan Size Tables Acceptance Lot Number Sampling	Topic 4 Intervals Sampling Economic Model Work Constant Design	Topic 5 Tightened Inspection Normal Switching Curves Emerge Generalized Shown
Cluster 3 (17%)	Topic 1 Quality Management Productivity Article Cost Economic Improvement Managers	Topic 2 Cost Energy Quality Line Manufacturing Reliability Design	Topic 3 Companies Data Analysis Described Dynamic Approach Compared Equipment	Topic 4 Program Methodology Process Score Tree Design Development Diagrams	Topic 5 Quality Cost Costs Improvement Control Data Management Using
(continued)					

Table AII.
Results from topic
modeling the divided
data set (*IJQRM* 1984-
1990, 1991-1996, 1997-
2002, 2003-2008 and
2009-2014)

Table AII.

Cluster 4 (7%)	Topic 1 Quality Product Service Indices Article Customer Market Competitive Topic 1	Topic 2 System Analysis Power Service Loss Sites Study Time Topic 2	Topic 3 Quality Argued Britain Developed Economy Limited Methods Relative Topic 3	Topic 4 Quality Statistical Changes Control Management Approach Aspects Topic 4	Topic 5 Quality Service Circles Development Health Police Article Assurance Topic 5	Cluster 4 (7%)	Topic 1 System Analysis Power Service Loss Sites Study Time Topic 1	Topic 2 Quality Service Article Police Program Assurance Costs Force Topic 2	Topic 3 Quality Product Circles Service Customer Development Health Achieving Topic 3	Topic 4 Statistical Changes Control Quality Britain Forward Increasing Lead Topic 4	Topic 5 Quality Indices Argued Britain Developed Economy Limited Topic 5
Cluster 5 (9%)	Product Design Liability Quality Article Directive EEC Examined Topic 1	Case Guides Safety Situation Worst Committee Drafting Expert Topic 2	Quality Countries Developing Levels Systems Time Article Based Topic 3	System Problems Programming Reliability Based Computer Development Efficient Topic 4	Makership Problems Quality Described Discussed Company Detail Topic 5	Cluster 5 (9%)	Case Guides Safety Situation Worst Committee Drafting Expert Topic 1	Product Countries Design Developing Liability Article Efficiency Industrial Topic 2	Quality Based Analysis Article Control Design Development Distribution Topic 3	Makership Quality Discussed Problems Described Liability Appraisal Company Topic 4	System Problems Programming Reliability Based Computer Development Efficient Topic 5
Cluster 6 (15%)	Manufacturing Quality System Systems Automated Control Production Flexible Topic 1	Manufacturing Quality Lack Quality Control Design Problems Techniques Topic 2	Process Quality Article Techniques Supplier Approach Control Production Topic 3	Quality Management Industry Companies Discussed Manufacturing Organizations Failures Topic 4	Process Control Cusum Statistical Type Average Charts Topic 5	Cluster 6 (15%)	Quality Manufacturing Industry Management Companies Awareness Managers Part Topic 1	Manufacturing Quality Production Article Lack Material Process Systems Topic 2	Quality Systems Control System Application Automated Design Failures Topic 3	Process Control Cusum Schemes Type Average Charts Cumulative Topic 4	Process Control Statistical Study Discussed Quality Supplier Techniques Topic 5
Cluster 7 (19%)	Failure Reliability Data Production Developed Devices Equipment Model	Quality Countries System Analysis Article Failure Inspection Ageing	Analysis Failure Quality System Reliability Soviet Data Article	Reliability Software Article Data Failure Search Estimation Model	Human Reliability System Error Data Article Assessment PSF	Cluster 7 (19%)	Quality Article Countries Reliability Soviet Product Optimization Research	Human Reliability Data System Error Failures Probabilities PSF	Failure System Equipment Production Cost Reliability	Failure Reliability Model Data System Analysis Rate Software	Reliability Article Failure Data Human System Analysis Profile

(continued)

Table AII.

(continued)

Table AII.

Cluster 4 (13%)	Topic 1 Quality Management Total Award Improvement Concepts Organizations Topic 1	Topic 2 Quality Model Costs Results Conformance Level Waste EQL Topic 2	Topic 3 Software Quality Process Model Improvement Product Optimization Reliability Topic 3	Topic 4 Quality Systems Companies Manufacturing Control Management System Certification Topic 4	Topic 5 Quality ISO TQM Management Organization Commitment Development Strategic Topic 5	Cluster 4 (13%)	Topic 1 Quality Model Reliability Process Improvement Failure Level Optimization Topic 1	Topic 2 ISO Quality Benefits Certification Auditors Commitment Process Standards Topic 2	Topic 3 Quality Costs Manufacturing Results Companies Conformance Model Waste Topic 3	Topic 4 Quality Management Total TQM Organizations Award Awards Organization Topic 4	Topic 5 Quality Development Software Systems Control Model Process Customer Topic 5
Cluster 5 (8%)	Maintenance Preventive Equipment Model Control Time Charts Condition Topic 1	Maintenance Training Reliability Human Model Systems Adequate Topic 2	Production Process Control Systems Inspection Model Artificial Circulatory Topic 3	Quality Productivity Performance Improvement Care Increase Service Achieve Topic 4	Quality Maintenance Production Circles Factors Improve Success Topic 5	Cluster 5 (8%)	Maintenance Preventive Equipment Control Costs Model Cost Rate Topic 1	Training Reliability Human Maintenance Model Skills System Systems Topic 2	Quality Production Circles Maintenance Applied Factors Improve Life Topic 3	Quality Productivity Performance Improvement Care Increase Service Achieve Topic 4	Production Process Control Systems Inspection Artificial Circulatory Heart Topic 5
Cluster 6 (13%)	Quality Management TQM Implementation Improvement Firms Process Operations Topic 1	TQM Employee Process Quality Participation Research TQC Implementation Topic 2	TQM Quality Hospitals Implementation Efforts Management Care Hospital Topic 3	TQM Quality Management Firms Made Research ISO Firm Topic 4	TQM ISO Organizations Quality Approach Implementation Management Based Topic 5	Cluster 6 (13%)	Quality Firms Implementation Management Made Programs TQM Improvement Topic 1	TQM Implementation Quality Hospitals Approach Efforts Firm Firms Topic 2	Quality TQM Management Results Implementation Systems Total Topic 3	TQM Process Organizations Factors Index ISO Quality Differences Topic 4	TQM Quality Employee Implementation Change Research Management Participation Topic 5
Cluster 7 (14%)	Failure Design Process FMEA Reliability Data Product Reports Topic 1	Quality Human Time Error System Manufacturing Airline Service Topic 2	Quality Product Process Costs Cost Processes Reliability Approach Topic 3	Quality Precision Group Laboratories Blocks Jit Customer Manufacturing Topic 4	Service Quality Services Management Perceptions Sector Dimensions Importance Topic 5	Cluster 7 (14%)	Quality Product Burn Optimal Cost Approach Costs Management Topic 1	Quality Precision JIT Manufacturing Equipment Laboratories Product Technology Topic 2	Quality Group Time Manufacturing System Methods Service Topic 3	Service Quality Services Perceptions Sector Dimensions Importance Series Topic 4	Reliability Failure Process Product Data Error Human FMEA Topic 5

(continued)

Table AII.

1997-2002 (nstart 1,000)									
Cluster 0 (12%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Cluster 0 (12%)	Topic 1	Topic 2	Topic 3
	Quality ISO System Costs Management Improvement Paper Registered Topic 1	ISO Certification TQM Quality Performance SMES Organizations Sized Topic 2	Certification Companies ISO Performance Benefits TQM Organizations Topic 3	Quality Companies Management Paper East Sector Collected Cost Topic 4	ISO Quality Hong Firms Management Certified Based Topic 5		Companies Quality ISO Management Based Model Paper Enis Topic 1	ISO Firms Certified TQM Management Companies Research Topic 2	Quality ISO Costs System Management Registered ABC Certification Topic 3
Cluster 1 (25%)	Quality Project Management Location Process Performance Construction Survey Topic 1	Quality Management Model Based Support Paper Change Approach Topic 2	Quality Management Manufacturing Product Based Performance Firms Time Topic 3	Quality Performance Firms Paper Company Approaches Suppliers Improvement Topic 4	Quality Management Practices Research Instrument Manufacturing Organizational Performance Topic 5		Quality Management Model Construction TQM Satisfaction Results Approach Topic 1	Quality Management Practices Performance Manufacturing Study Research Based Topic 2	Quality Location Approach Management Manufacturing Maintenance Design Product Topic 3
Cluster 2 (2%)	Process Capability Distribution Confidence Construct CPK CPM CPMK Topic 1	TQM Engineering Statistics Students Student Perspective Responses Analysis Topic 2	Process Geometric Gearbox Policy Deployment Model Approach Characteristics Topic 3	Approach Fault Tree Basic Ranking Analysis FTA Reliability Topic 4	Quality Data Information Demonstrate End Firms Survival Systems Topic 5		Process Capability Distribution Confidence Construct CPK CPM CPMK Topic 1	Process Geometric Gearbox Policy Deployment Model Approach Characteristics Topic 2	Quality Data Information Demonstrate End Firms Survival Systems Topic 4
Cluster 3 (16%)	Design Control Quality Process Cost Chart Statistical Parameters Topic 1	Approach Method Process Capability Indices Proposed Response Taguchi Topic 2	Control Process Chart Limits Tools Based Metric Procedure Topic 3	Quality Distribution Control Process Tools Product Companies Normal Topic 4	Control SPC Process Applications Chart Charts Non Techniques Topic 5		Control Design Process Charts Chart Quality Cost Statistical Topic 1	Control Process Distribution Limits Chart Performance Based Metric Topic 2	Quality SPC Distribution Non Applications Chart Reliability Product Normal Topic 4
1997-2002 (nstart 2,000)									
	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5		Topic 1	Topic 2	Topic 3
	Performance TQM ISO Certification Quality Business Results Topic 5	Certification Benefits ISO Companies Sized SMES Quality Organizations Topic 4	Quality ISO Costs System Management Registered ABC Certification Topic 3	Quality Performance Firms Based Product Paper Practice Reliability Topic 4	Quality Project Management Support Change Based Practices Process Reliability Topic 5		Quality Data Information Demonstrate End Firms Survival Systems Topic 4	Quality SPC Distribution Non Applications Chart Reliability Product Normal Topic 4	Quality Location Approach Management Manufacturing Maintenance Design Product Topic 3
	Process Capability Distribution Confidence Construct CPK CPM CPMK Topic 1	TQM Engineering Statistics Students Student Perspective Responses Analysis Topic 2	Process Geometric Gearbox Policy Deployment Model Approach Characteristics Topic 3	Approach Fault Tree Basic Ranking Analysis FTA Reliability Topic 4	Quality Data Information Demonstrate End Firms Survival Systems Topic 5		Process Capability Distribution Confidence Construct CPK CPM CPMK Topic 1	Process Geometric Gearbox Policy Deployment Model Approach Characteristics Topic 2	Quality Data Information Demonstrate End Firms Survival Systems Topic 4
	Design Control Quality Process Cost Chart Statistical Parameters Topic 1	Approach Method Process Capability Indices Proposed Response Taguchi Topic 2	Control Process Chart Limits Tools Based Metric Procedure Topic 3	Quality Distribution Control Process Tools Product Companies Normal Topic 4	Control SPC Process Applications Chart Charts Non Techniques Topic 5		Control Design Process Charts Chart Quality Cost Statistical Topic 1	Control Process Distribution Limits Chart Performance Based Metric Topic 2	Quality SPC Distribution Non Applications Chart Reliability Product Normal Topic 4

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Table AII.

Cluster 4 (15%)	Topic 1	Service Quality Customer Satisfaction Customers Management Performance Reliability Topic 1	Topic 2	Quality Management Information Based Improvement Supplier System Topic 2	Topic 3	Quality Service Performance Planning Study Measures Strategic Improvement Topic 3	Topic 4	Quality Service Model Servqual Attributes Analysis Topic 4	Topic 5	Quality Benchmarking Management Service Study Hotel Process Value Topic 5	Cluster 4 (15%)	Topic 1	Quality Planning Management Performance Improvement Benchmarking Information Strategic Topic 1	Topic 2	Quality Qld Management Design Paper Benchmarking Processes Service Topic 2	Topic 3	Quality Service Performance Competitive Hotel Analysis Management Satisfaction Topic 3	Topic 4	Quality Service Customer Study Customers Satisfaction Performance Requirements Topic 4	Topic 5	Quality Service Model Servqual Based Services Attributes Performance Topic 5
	Cluster 5 (6%)	Procedure Quality Sample Heuristic Analysis Data Fuzzy Mean Topic 1	Data Analysis Statistical Engine Failure Pld Procedure Based Topic 2	Unit Repair System Failure Policy Time Model Device Topic 3	Failure Model Time Equipment Optimal Paper Burn Effective Topic 4	Stress Model Step Using Method System Arrays Cumulative Topic 5	Stress Model Sample Step Cumulative Exposure Parameter System Failure Topic 4	Time Model Optimal Burn Proposed Effective Equipment Failure Topic 4	Time Model Optimal Burn Proposed Effective Equipment Failure Topic 4	Failure Analysis Data Procedure Based Cost Engine Factors Topic 5											
		Cluster 6 (10%)	Assessment Self Method Proposed Quality Model Paper Tool Topic 1	System Reliability Quality Systems Component Model Parallel Components Topic 2	Systems Quality System Audit Paper Performance Design Models Topic 3	Model Reliability System Risk Decision Failure FMEA Cost Topic 4	Software Reliability System Model Failure Time Models Inspection Topic 5	System Reliability Systems Component Inspection Failure Distribution Paper Topic 3	Quality Systems Model System Cost Maintenance Parallel Models Topic 2	Quality Systems Model System Cost Maintenance Parallel Models Topic 2	Model Reliability Design Method Proposed Study Use Developed Topic 5										
			Cluster 7 (14%)	TQM Implementation Management Quality Culture Environment Total Change	Quality TQM Management Training Implementation Companies Countries Level	TQM Study Factors Case Framework Analysis Companies Quality	TQM Decision Employees Management Team Employee Case Empowered	TQM Quality Manufacturing Management Firms Service Literature Companies	TQM Implementation Quality Management Firms Manufacturing Training Literature Organizations	TQM Quality Management Firms Manufacturing Training Literature Organizations	TQM Quality Management Firms Manufacturing Training Literature Organizations	TQM Quality Management Firms Manufacturing Training Literature Organizations									
																					(continued)

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Table AII.

2003-2008 (nstart 1,000)						2003-2008 (nstart 2,000)					
Cluster 0 (6%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Cluster 0 (6%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
	QFD Customer Method Project Quality Process Particular Prioritizing	QFD Strategic Deployment Paper Quality Development Software Strategy	QFD Design Product Requirements Consumer Methodology Quality Cost	QFD Application Design Quality Redesign System Methodological Social	QFD Project Success Companies Design People Applied Benefit		QFD Redesign Consumer Cost Product System Tools Application	QFD Customer Quality Crisp Matrix Model Success Deployment	QFD Strategic Deployment Method Customer Paper Project Particular	QFD Design Quality Methodology Project Customers Internal	QFD Companies Development Product Quality Implementation Process Applied
Cluster 1 (34%)	Topic 1 Quality Management Cost Research Value System Paper COQ	Topic 2 Warranty Reliability Model Availability System Failure Analysis Methodology	Topic 3 Paper Management Approach Quality Development Study Research Methodology	Topic 4 Paper Quality Purpose Methodology Findings Implications Project Approach	Topic 5 Quality Paper Design Approach Results Assessment Research Purpose	Cluster 2 (2%)	Topic 1 System Quality Paper Reliability Methodology Design Systems Value	Topic 2 Quality Management Paper Research Implications Methodology Assessment Findings	Topic 3 Warranty Study Paper Approach Findings Purpose Methodology Failure	Topic 4 Quality Paper Management Project Product Research Development Approach	Topic 5 Quality Cost Paper Research Costs Value Purpose Model
Cluster 2 (2%)	Topic 1 Sigma Paper Service SMES Organizations Results Study Findings	Topic 2 Improvement Process Quality Sigma Approach Assessment Shainin Vis	Topic 3 Quality Sigma Improvement Management Reliability Process Program Strategy	Topic 4 Sigma Management Fad Paper Authors Business Initiative Myths	Topic 5 Sigma Paper Accounts Method Literature Methodology Provides Reconstruction	Cluster 3 (15%)	Topic 1 Sigma Management Fad Paper Authors Business Initiative Myths	Topic 2 Sigma Paper Service SMES Organizations Results Study Findings	Topic 3 Sigma Paper Accounts Method Literature Methodology Provides Reconstruction	Topic 4 Quality Sigma Improvement Quality Management Reliability Process Assessment Shainin Vis	Topic 5 Improvement Process Quality Sigma Approach Assessment Shainin Vis
Cluster 3 (15%)	Topic 1 TQM Performance Research Findings Model Results Innovation Purpose	Topic 2 TQM Paper Research CSR Quality Purpose Findings Relationship	Topic 3 Performance TQM TPM Implementation Factors Research Quality Manufacturing	Topic 4 TQM Management Quality Total Performance Based Paper Study	Topic 5 Quality Management Practices Performance Organizational Firms China		Topic 1 Quality TPM Implementation Manufacturing Performance Management Maintenance TQM	Topic 2 Management Quality TQM Organizational Performance Practices Research Findings	Topic 3 TQM Paper CSR Research Excellence Findings Purpose Based	Topic 4 Performance TQM Quality Management Practices Research Innovation Impact	Topic 5 TQM Performance Relationship Factors Implementation Research Study Quality
(continued)											

(continued)

Table AII.

Cluster 4 (9%)	Topic 1 ISO Quality Paper Management Certification CSR Development Implications Topic 1	Topic 2 Firms Quality Management ISO Implementation Practices Strategic Efficiency Topic 2	Topic 3 ISO Quality Management TQM Companies Criteria System Study Topic 3	Topic 4 ISO Management Business Quality Paper Study Knowledge Manufacturing Topic 4	Topic 5 ISO Companies Benefits Findings Standard Certification Certified Survey Topic 5	Cluster 4 (9%)	Topic 1 ISO Management Quality Paper System Knowledge Processes Research Topic 1	Topic 2 ISO Benefits Certified Certification Companies Quality Management Paper Topic 2	Topic 3 Quality Firms ISO Management Business Practices Differences Manufacturing Criteria Topic 3	Topic 4 ISO TQM Implementation Paper Companies Quality Management Criteria Topic 4	Topic 5 ISO Certification Quality Companies Findings Approach Construction Development Topic 5
Cluster 5 (8%)	Service Quality Paper Research Patient Perceptions Attributes Literature Topic 1	Service Quality Research Customer Performance Management Employees Perceived Topic 2	Service Satisfaction Quality Quality Customer Performance Approach Paper Findings Topic 3	Service Quality Servqual Instrument Dimensions Scores Customers Model Topic 4	Service Quality Reliability Customer Research Customers Expectations Implications Topic 5	Cluster 5 (8%)	Service Quality Customer Research Performance Customers Perceived Employees Topic 1	Service Quality Perceptions Reliability Patient Attributes Tool Management Topic 2	Service Quality Satisfaction Practices Scores Model Results Services Implications Topic 3	Quality Service Instrument Servqual Dimensions Reliability Customers Implications Topic 4	Service Quality Customer Satisfaction Research Paper Performance Approach Topic 5
Cluster 6 (20%)	Quality Process Improvement Model Control Techniques Management Paper Costs Topic 1	Approach Paper Process Reliability Techniques Design Data Topic 2	Quality Methodology Chart Research Maintenance Proposed System Paper Topic 3	Maintenance Paper Model System Reliability Approach Scheduling Cost Topic 4	Test Reliability Approach Design Paper Distribution Life Time Topic 5	Cluster 6 (20%)	Quality Model Management Improvement Costs Paper Research Cost Topic 1	Chart Design Model Inspection Paper Manufacturing Approach Reliability Topic 2	Maintenance Paper System Reliability Methodology Approach Proposed Based Control Topic 3	Process Approach Quality Tools Paper Design Techniques Control Topic 4	Test Reliability Paper Model Design Time Optimal Life Topic 5
Cluster 7 (6%)	FMEA Failure Approach Paper Analysis Cost Design Effects	Fuzzy Rules Failure Rpn Risk Model Mode Proposed	Failure Reliability Analysis System Methodology Paper Product Modes	Method Quality Product Failure Data Reliability Proposed Model	Customer CCMS Market Product Comprehensive Tools Management QFD	Cluster 7 (6%)	Failure Reliability Analysis System Methodology Paper Maintenance Approach	Method Failure Product Data Reliability Model Proposed Quality	Fuzzy Failure Rules Risk RPN FMEA Analysis	FMEA Failure Approach CCMS Management Quality Customer Improvement	FMEA Quality Market Process Product Collaborative Environment Implementation

(continued)

Table AII.

2009-2014 (nstart 1,000)									
Cluster 0 (5%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Cluster 0 (5%)	Topic 1	Topic 2	Topic 3
	Control Chart Distribution Sample Fuzzy Demerit Process Based	Control Chart EWMA Approach Design Proposed Charts Mean Topic 2	Control Process Quality Stability Probability Production Chart Sample Topic 3	Control Design Charts Paper Sampling Procedure Parameters Process Topic 4	Chart Proposed Cusum Charts Design EWMA Parameters Process Topic 5		Control Chart Distribution Sample Fuzzy Demerit Process Based Topic 1	Control Chart EWMA Approach Design Proposed Charts Mean Topic 2	Control Process Quality Stability Probability Production Chart Sample Topic 3
	Quality Service Process Approach Research Model Customer Paper Topic 1	Quality Service Customers Dimensions Banks Services Banking Study Topic 2	Service Quality Internal Paper Encounter Findings Purpose Approach Topic 3	Quality Customer Relationship Service Research Findings Marketing Purpose Topic 4	Service Quality Purpose Research Excellence Award Performance Business Topic 5		Service Quality Research Reliability Internal Paper Encounter Findings Topic 1	Quality Process Approach Service Model Study Relationship Design Topic 2	Quality Service Customer Purpose China Approach Findings Food Topic 3
	Sigma Levels Data Side Level Colleges Quality Depno Topic 1	Sigma Management Findings Research Study Approach Knowledge Purpose Topic 2	Sigma Approach Performance Model Improvement Measures Call Implementation Topic 3	Sigma Lean Paper Improvement Purpose Research Service Practical Topic 4	Sigma Organizational Innovation Research Learning Paper Barriers Findings Topic 5		Sigma Lean Paper Improvement Purpose Research Approach Value Topic 1	Sigma Levels Data Side Level Colleges Quality Depno Topic 2	Sigma Research Service Approach Paper Framework Implementation Purpose Topic 3
	Quality Paper Design Approach Purpose Product Model Cost	Maintenance System Paper Data Approach Reliability Failure Analysis	Software Paper Research Approach Design Purpose System Methodology	Paper Approach Purpose Failure Methodology Design Value Findings	Design Paper Approach Method Purpose Methodology Study Distribution		Method Paper Design Approach Methodology Purpose Process Distribution	Approach Failure Model Paper Purpose Research Cost Maintenance	Paper System Availability Purpose Performance Approach Reliability Design
	Quality Paper Model Approach Improvement Management Topic 5	Design Quality Paper Process Approach Design Methodology Value Purpose	Design Quality Paper Process Approach Design Methodology Value Purpose	Paper Approach Learning Findings Study Topic 4	Design Quality Paper Model Approach Improvement Management Topic 5		Sigma Organizational Paper Model Performance Innovation Learning Research Findings Study Topic 4	Sigma Research Service Approach Paper Framework Implementation Purpose Topic 3	Design Quality Paper Study Purpose Design Reliability Software Value
	Cluster 3 (32%)	Cluster 3 (32%)	Cluster 3 (32%)	Cluster 3 (32%)	Cluster 3 (32%)		Cluster 3 (32%)	Cluster 3 (32%)	Cluster 3 (32%)

(continued)

Cluster 4 (13%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Cluster 4 (13%)	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
	Quality Design Paper	Quality Paper Approach	Strategies Paper PMFD Supply	Management Paper Study	Quality Management Practices Performance Findings Study Purpose		Management Quality Supply Chain Paper Approach Order Framework	Paper Quality Approach Design Lean Purpose Methodology Value	Paper Management Implementation QMPS Model Performance Research	Quality Management Findings Practices Study Research Purpose	Adoption PMFD Based Techniques Research Paper Purpose Management
	Aspect Topic 1	Strategy Topic 2	Framework Topic 3	Adoption Topic 4	Paper Topic 5		Framework Topic 1	Value Topic 2	Research Topic 3	Purpose Topic 4	Management Topic 5
Cluster 5 (11%)	TQM Performance Competency Based Training Quality Study Paper	Quality Management Performance TQM Practices Study Findings Purpose Topic 2	TQM Quality Based Design Paper Management Factors Topic 3	Business Internal TQM Management Paper Audit Excellence Self Topic 4	TQM Management Quality Research Model Study Role Findings Topic 5		TQM Quality Performance Management Study Practices Findings Research Topic 1	self Management Paper Assessment Approach Business Design Purpose Topic 2	TQM Based Competency Quality Training Paper Research Findings Topic 3	Management Quality TQM Practices Employee Performance Study Role Topic 4	TQM Quality Performance Research Product Management Study Implementation Topic 5
Cluster 6 (7%)	System Failure Reliability Component Repair Availability Redundancy Analysis Topic 1	Reliability System Components Software Design Systems Distribution Purpose Component Topic 2	Reliability System Approach Estimation Paper Distribution Purpose Methodology Topic 3	Failure Data Systems Repairable Analyze Model Time Approach Topic 4	Approach System Maintenance Time Failure Reliability Systems Cost Topic 5		Reliability Software Lean Systems Design Paper Approach Based Topic 1	Failure Systems Data Approach Repairable Model Time Reliability Topic 2	System Components Reliability Failure Series Time Paper Topic 3	Reliability System Estimation Approach Paper Purpose Design Distribution Topic 4	System Reliability Cost Maintenance Failure Paper Purpose Using Topic 5
Cluster 7 (10%)	Management Quality ISO Certified System Systems Companies Paper Performance	Performance Certified Companies Quality Innovation Results ISO Industry Paper	ISO Certification Standards Innovation Research Quality Paper Study	Impact Barriers ISO Methodology Research Analysis Main Organizations	ISO Management Implementation Paper Purpose Benefits LSS Standard		ISO Implementation Organizations Paper Research Benefits Management Purpose Topic 1	Quality Companies Certified ISO Certification Management Performance Study Topic 2	Certification ISO Results Research Management Quality Study Diffusion Topic 3	Performance ISO Indicators Paper Impact Methodology Analysis Research Topic 4	Management Quality ISO System Certification Systems Companies Innovation Topic 5

Figure A1.
IJQRM 1991-1996
structured
into 8 clusters

Figure A2.
IJQRM 1997-2002
structured into
8 clusters

Figure A3.
IJQRM 2003-2008
structured
into 8 clusters

Figure A4.
IJQRM 2009-2014
structured into 8
clusters

Appendix 6

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