Lean direction in literature: a bibliometric approach

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ABSTRACT
This research establishes a comprehensive chronological and geographical overview of the recent topics mostly debated about the use of Lean thinking in services, disclosing its main trends, gaps and weaknesses. An ample compilation of research from Web of Science and Scopus was examined, and bibliometric analyses were performed, namely publication counting, and abstract, co-citation and co-word analysis. Unfolding Lean implementation projects and evaluating its outcomes are the most frequent themes. Reducing waste and increasing efficiency are often mentioned as the benefits. There are clear gaps in research density between multiple service sectors and healthcare; lack of established models and extensive use of case study method are the weaknesses of the studies in this field. This paper allows Lean practitioners having a sketch of the landscape of this field and its trends. This is the first effort to synthesize those topics in service industry as a whole, using bibliometric methods.

1. Introduction

Over the years, Lean thinking (or Lean philosophy, or simply Lean) has come to be a trendy concept among manufacturing industry. The application of the improvement practices of Lean had written stories of prominent success in the manufacturing, production and construction industry (Oludapo et al., 2017). Meanwhile, the movement of cost reduction, quality improvement and flexibility increase in the service industry has been delayed (Suarez-Barraza et al., 2012). The service sector accounts for more than half of gross domestic product (GDP) and employment in most modern economies, but despite its important role, productivity levels in the service sector are much lower than those in the manufacturing sector (Leite & Vieira, 2015; Suarez-Barraza et al., 2012). Indeed, services with such a massive economic volume and crucial impact on daily life cannot be overlooked for optimization. Many scholars and practitioners have recognized this and see great potential in applying Lean thinking, an ideology that originated in the manufacturing industry, to the service sector, such as healthcare, finance, education and IT. In fact, Lean is already being applied in these sectors and has been growing faster recently (Bhamu & Sangwan, 2014; Dahlgaard et al., 2011; Gupta & Sharma, 2018; Jasti & Kodali, 2014; De Jong & Beelaerts van Blokland, 2016).
The increasing discussion of Lean in the service sector by academics and the application of Lean by companies have significantly increased the literature on the subject, which increases the need to organize this body of knowledge. This paper aims to conduct a systematic review of the implementation of Lean thinking in the service sector using bibliometric methods. It provides not only academic researchers but also industry insiders with easier access to the wealth of literature on Lean and enables them to be aware of the main issues in the field. The work also identifies the most commonly used Lean tools so that Lean practitioners can select the most appropriate techniques, derived from the extensive publications, for practical implementation. In addition, the study aims to identify the trends, gaps and patterns in the field by analyzing the current literature and make a corresponding thematic, chronological and geographical analysis of the literature, which will be of great use to the researchers in identifying future research directions.

With these research goals in mind, we conduct a bibliometric analysis of the literature. This methodology is effective for our purposes because it collects bibliographic information generated by researchers working in the field and uses this information to generate insights into the literature structure and thematic interests of the field (Zupic & Cater, 2015). Compared to traditional qualitative literature review, it uses a quantitative approach and aggregates data from numerous studies and scholars instead of manual selection. Therefore, bibliometric methods increase rigor and objectivity and neutralize researcher bias in reviewing scientific literature (Zupic & Cater, 2015).

This paper is the first attempt to conduct a bibliometric analysis on the topic of Lean implementation in the general service sector. Other bibliometric studies in the field of operations management (Merigó & Yang, 2017) or services (Mendes et al., 2017) and similar studies on Lean implementation are mainly of two types: i) bibliometric reviews in the context of a specific sub-sector in the service sector (mainly healthcare – for example, Aleu & Van Aken, 2017; Filser et al., 2017) and ii) other types of systematic literature reviews (rather than bibliometric methods) in the context of the whole service sector (e.g. Gupta et al., 2016; Leite & Vieira, 2015; Suarez-Barraza et al., 2012). A third category could be included (reviews of Lean implementation in sub-sectors of the service sector using non-bibliometric methods, e.g. Dahlgaaard & Dahlgaard-Park, 2006), but they have less in common with this study and are often reviewed by the studies from the two aforementioned categories. It is worth noting that there is no co-word analysis on Lean.

The paper is organized as follows: In Section 2, a literature review is conducted to introduce the concepts of Lean thinking and its implementation, characteristics and classification of services. The bibliometric methods are presented in Section 3, and then their results are stated and interpreted in Section 4, followed by the conclusion, main implications and limitations of the research.

2. Literature review

2.1. Lean thinking

Lean was originated in a succession of innovations in Toyota Motor Corporation in dealing with scarce resources and strong competition (Monden, 2011; Ohno, 1988; Shingo, 1988; Shingo & Dillon, 1989). These innovations included, e.g. the just-in-time production system and the Kanban method of pull production (Hines et al., 2004). The
term ‘Lean production/manufacturing’ is disseminated by Womack et al. (1990) when examining the performance differences between Toyota and other automobile manufacturers. In the 1990s, the adoption and emulation of Lean manufacturing reached a milestone by applying new designs developed based on Lean principles to the production system (Hines et al., 2004). The first complete Lean model was proposed in 1996 in the book Lean Thinking by Womack & Jones. These principles included identifying customer value, mapping the value stream, the flow production system, the ‘pull’ mechanisms to ensure the flow of materials and the pursuit of perfection through the continuous reduction of all forms of waste (Womack & Jones, 1996).

There is no single definition of Lean thinking, but it can be considered as a set of principles and tools in manufacturing to increase product or service quality, profit margins and market share by continuously improving processes and focusing on customer satisfaction and employee well-being (Hines & Rich, 1997; Kim et al., 2006; Liker, 2004; Shah & Ward, 2003). The principles of Lean were first proposed by Womack and Jones (1996). For decades, they have been the basis of the production systems of many Western companies that have successfully adapted Toyota Production System (TPS) (Hines et al., 2004). According to Womack and Jones (1996), the five principles are: 1. Value Identification; 2. Value Stream Mapping; 3. Creating Flow; 4. Pull System and 5. Perfection/Continuous Improvement.

Notice that in this article, the term ‘Lean’ has the usual meaning adopted in the context of production management and not the meaning used in the context of innovation management. In effect, the terms ‘Lean startup’ or ‘Lean entrepreneur’, although foreign in the context of production management, are used in the context of innovation management. (See Ojasalo and Ojasalo (2018) and Blank (2013) for witnessing the term ‘Lean’ being used in the innovation management context.)

Another classification of Lean thinking is the one that resulted in the House of Lean Production approach (Liker, 2004; Ohno, 1988). The House of Lean Production illustrates the key principles and how they work together as a complete system. Yet a further classification of Lean thinking: the Lean Principles according to the Toyota Way may be condensed in a set of 14 guiding principles to achieve the goals of Lean thinking. The fourteen TPS principles can be illustrated by a pyramid (Ohno, 1988) having the guiding philosophy in its basis (principle ‘Base management decisions on a long-term philosophy’) (Liker, 2004).

There are plenty of Lean tools/techniques. Liker (2004) and Ohno (1988) present some common ones: 5S (Sort, Set in order, Shine, Standardize and Sustain), Heijunka (leveling), Jidoka (automate stop automatically when detecting problem), Kaizen (continuous improvement), Standardization (document the work procedures that capture best practices) and Takt Time (align pace with customer demand). Some more tools can be referred, e.g. One-piece flow, Small-lot production, Pull system, Cellular production, Line balancing, Kanban, Visual control, VSM (Value Stream Mapping), 5 Whys, Cause-and-effect diagrams, Pareto analysis, PDCA (Plan-Do-Control-Act), Supply quality management, OEE (Overall Equipment Effectiveness), SMED (Single Minute Exchange of Die), Preventive maintenance, Flexible, Cross-functional teams and Self-directed work teams.

The implementation of Lean, from its birthplace, the automotive industry, throughout the manufacturing industry and into the service sector, has brought both qualitative and quantitative benefits that researchers recognize (Bhamu & Sangwan, 2014; Buehlmann &
Fricke, 2016; Gupta et al., 2016; Leite & Vieira, 2015; Mostafa et al., 2013). The most commonly referred benefits are reduced production lead time; improvement of setup, cycle and processing times; less defects and scrap; larger OEE; improved job satisfaction; better communication, etc. (Bhamu & Sangwan, 2014; Gupta et al., 2016; Mostafa et al., 2015). Implementing Lean is the most important part of Lean management. Although the benefits of Lean are well known, many organizations have failed to successfully put the philosophies into practice (Bhamu & Sangwan, 2014). Several issues related to difficulties in Lean implementation have been identified in the literature. Bhamu and Sangwan (2014) classified these problems into three categories: Pre-implementation problems (e.g. lack of Lean awareness programs for all employees), implementation problems (e.g. lack of effective customer–supplier relationships), and post-implementation problems (e.g. lack of employee review for recognition and awards). JadHAV et al. (2014) pointed out 24 barriers to effective Lean implementation, of which lack of resources for investment, lack of top management involvement and negative employee attitude or resistance are the most commonly cited barriers in the literature.

Aside from the problems in applying Lean in organizations, managers should also pay attention to how extensively Lean should be implemented and which Lean practices and tools we should choose because organizational features often influence whether a specific management practice will be effective or not; therefore, diverse organizations will and should implement different groups of practices (Galbraith, 1978).

2.2. Services and Lean in services

Nowadays, the service industry is indispensable to the global economy and closely linked to our daily lives. It contributes to more than half of GDP and employment in major economies (Leite & Vieira, 2015). As one of the pillars of modern economies, the service industry contains many sub-sectors: 1) Business: consulting, finance, banking, etc. 2) Commercial: retail, maintenance, repairs, etc. 3) Infrastructure: communications, transportation, etc. 4) Social and personal: restaurants, supermarkets, health, etc. and 5) Public Administration: education, government, etc.

Because services cover a particularly wide range of activities, the differences are extensive not only between service organizations within a group but also between service departments within a company. The diversity is so great that any global, all-encompassing approach to service management is inaccurate (Haywood-Farmer, 1988). There must be a classification scheme to segment these services according to their behaviors. Schmenner (1986) and MAister and Lovelock (1982) proposed a kind of two-by-two matrix to classify service activities based on how the service is produced. Although their names of axis designations are different, the concepts behind them are similar.

Although it was introduced in manufacturing, Lean management is also becoming popular in service organizations (Leyer et al., 2015). Thus, although the application of this philosophy is well established in the manufacturing sector, it is relatively new in service firms (Leite & Vieira, 2015). Nonetheless, the application of this philosophy can be seen in many services. Vijaya Sunder et al. (2018) report several examples in services: including banking and financial services, educational services, call center services and IT.
3. Materials and methods

This section is dedicated to the adopted methodology. It briefly introduces the bibliometric study background, the research design and chosen bibliometric methods, and the bibliometric data assembling process.

3.1. The bibliometric study

Although it is widely acknowledged that bibliometric methods have been used for at least a century, the development of bibliometrics in relation to a scientific field did not begin until the 1960s, which can be attributed to the Institute for Scientific Information (ISI), Science Citation Index (SCI) – a logical extension of the Eugene Garfield effort to support scientific literature searching (Garfield & Merton, 1979). Pritchard (1969) first proposed the word ‘bibliometrics’. Bibliometrics is an approach that quantitatively examines a large corpus of academic literature in order to assess the development of a particular research field, especially the intellectual structure of the literature in that field (Giannakis, 2012).

The choice for bibliometric methods instead of other review methods was determined by i) the fact that the amount of papers in the topic under study is enormous and consequently not manageable by other review methods; ii) the objective of neutralizing the subjective bias (Rothstein et al., 2006); and iii) the aim of making the results reproducible. As Wang et al. (2016) argue, bibliometric methods cannot eliminate completely subjectivity, but they greatly reduce the probability of human errors and the extent of subjective judgments.

Running bibliometric analysis has certain procedures. Zupic and Cater (2015) proposed the workflow into five steps, which will be followed in this study: 1) Research design; 2) Assembling bibliometric data; 3) Analysis; 4) Visualization and 5) Interpretation.

3.2. Research design

The research questions that will fulfil the main purpose of this study are as follows:

1. What are the most popular issues in implementing Lean thinking in key service sectors?
2. What are the trends, patterns, gaps and weaknesses in this area in a chronological (a) and geographical analysis (b)?
3. Which Lean tools are commonly used?

Table 1 reveals the bibliometric methods selected and a brief description. The various methods have different functions and will therefore answer distinct questions.

3.3. Assembling bibliometric data

The databases selected for this research were the Web of Science (WoS) and Scopus. Both databases are useful for building the bibliographic base. Scopus is the largest abstract and citation database for peer-reviewed literature (ELSEVIER, 2017). WoS is the oldest
In nutrition, science (ClarivateAnalytics, literature Teixeira, and their or Apart meanings, tions. -

Table 1. Bibliometric methods chosen and research questions answered.

| Bibliometric Method | Function | Research Questions can be answered |
|---------------------|----------|-----------------------------------|
| Publication counting and abstract analysis | Evaluate the basic information of the publications and compare the research performance of individual researchers, research institutions and nations | **RQ1** What are the most popular topics in implementing Lean thinking in major service sectors? **RQ2** What are the trends, gaps and weaknesses in this field? |
| Co-citation analysis | Represent a link between documents Identify the knowledge base of a topic/research field and its intellectual structure | **RQ2** What are the trends, gaps and weaknesses in this field? **RQ3** Which Lean tools are often used? |
| Co-word analysis | Find the network of themes and their relations that represent the conceptual space of a field. Track the evolution of a certain concept | |

Table 2. Keywords for searching.

| Main Keywords | Secondary Keywords | Tertiary Keywords |
|---------------|--------------------|-------------------|
| • Lean        | • Service          | • Implement       |
| • Lean thinking | • Service sector  | • Implementation  |
| • Lean philosophy | • Service industry | • Apply           |
| • Lean practice |                         | • Application     |
| • Lean tool    |                         | • Adopt           |
| • Lean technique |                      | • Adoption        |

citation source in the world and contains the most respected scientific journals (Pato & Teixeira, 2016). It gives access to a comprehensive collection of world-class research literature from a rigorously designated core of journals totaling over 33,000 titles (ClarivateAnalytics, 2017). These two major citation indexes and search platforms in the world ensure and simplify the collection of comprehensive and reliable publications.

To perform the search, the keywords should be defined. Since this topic consists of 3 factors, we defined 3 groups of keywords (see Table 2). The main subject is ‘Lean’, the scope is ‘Service’ and the action is ‘Implementing/Applying/Using Lean’. The keywords were explored using ‘Title, abstracts and keywords’ in WoS and Scopus. In WoS, the database of the search was set to ‘All databases’.

Next to the initial search in both databases, Scopus returned 3,036 results and Web of Science supplied 548 results. After removing duplications, there remain 2,259 publications. The results need careful screening because not all of them are related to the topic ‘Lean implementation in services’. For example, the word ‘lean’ can have different meanings, such as ‘slim’, which results in the inclusion of articles studying obesity and nutrition, and its appearance in the phrase ‘lean on’ also leads to some irrelevant papers. Apart from these, there are many articles that mention ‘service’ in the abstract but their main focus is in manufacturing industry. Figure 1 presents the whole screening process. In the end, 378 articles remained as the final database.

During the screening process, when reading all the articles’ titles, keywords, abstracts or full texts, the bibliographic information of the wanted articles was registered and also their geographic focus (country or region), target industry, department or certain activity and their main themes were identified.
Figure 1. Screening process.

The category of themes was developed and synthesized based on the research areas, research categories or research directions identified by previous literature reviews on Lean studies (Danese et al., 2017; Filser et al., 2017; Marodin & Saurin, 2013; Suarez-Barraza et al., 2012) and also was adjusted during the reading process. The final list of themes is shown below.

- Application of Lean in an activity/organization/industry
- Evaluation of outcomes of Lean implementation in an activity/organization/industry
- Development of a model/framework for Lean implementation
- Assessment of a model/framework for Lean implementation
- Discussion of Lean’s transfer to or implementation feasibility in services
- Drivers/Enablers for adoption of Lean
- Extent of Lean implementation in an organization/industry/country-region
- Key success factors (KSFs)/critical success factors (CSFs) of Lean implementation
• Other factors of Lean implementation
• Improvement of Lean implementation process
• Lean implementation issues/challenges; Lean tools/practices
• Relationship between Lean and overall performance
• Sustaining/improving Lean implementation outcomes.

3.4. Procedure of co-citation analysis

Co-citation analysis is to identify the intellectual structure of a research field by counting the frequency of two references being cited together and building a network for all the references based on this linkage (Zupic & Cater, 2015). The first thing to do is to obtain the knowledge base, in other words, all the cited references, of our selected 378 articles. The bibliographic data of the 378 articles was downloaded from either Scopus or WoS, and a data cleanup program was used to extract and clean their references. The cleanup work is necessary because the same publication may be in different formats, and there also exist a lot of mistakes in authors’ names, titles and journal names. The mistakes should be corrected, and different references that refer to the same publication should be unified into one unique format. The unifying work was accomplished first by the ‘clustering’ feature in the data cleanup program and then by going through a manual inspection in Microsoft Excel. Finally, 12,642 references were obtained.

The next step is to calculate, within the 12,642 references, the frequency of a pair of references being cited at the same time by an article among the 378 articles. The counting was performed in Microsoft Access, and a ‘network’ of co-occurrence of the references was obtained. It is worth mentioning that if a reference is highly co-cited with another reference, it means that the two references themselves are individually highly cited (Jarneving, 2005). The network was ranked from the highest times of co-occurrence to the lowest, and the pairs with less than 10 times of co-occurrence were excluded from the network. Finally, the network was introduced into VOSviewer, software for creating maps based on network data, for visualization.

3.5. Procedures of co-word analysis

The fundamental logic at the back of the co-word analysis is the same with that behind co-citation – the items needed for counting of times of co-occurrence is changed from references to words. The analyzing material for co-word analysis can be titles, keywords, abstracts or full texts. Solely using titles or keywords may be affected by ‘indexer effect’, which means the titles and keywords are too narrow to cover all relevant concepts of the text; however, using abstracts or full texts will suffer from noises brought by the large amount of irrelevant words (Zupic & Cater, 2015). We decided to use abstracts as the middle way to avoid indexer effect and also to mitigate the noises by using more concise texts.

The following step is to select a list of words. Microsoft Excel was employed to find the most frequently used words in the author keywords and abstracts of the 378 articles, and among them, we selected 83 words (see Appendix). This list of words can be considered as a ‘hotchpotch’ of mostly mentioned concepts in this research field, including topics, research methods, industries, Lean tools and all kinds of Lean terminologies. The words also need
unification, for example, ‘healthcare’, ‘health care’ and ‘health-care’ were all unified into ‘healthcare’; ‘value stream mapping’, ‘value stream map’ and ‘VSM’ were reconciled as ‘VSM’; ‘case stud’ was used for representing both ‘case study’ and ‘case studies’.

In order to analyze the evolution and trend of the research field, the 378 articles were divided into two time periods – 1998-2008 and 2009-2018 – for the purpose of a longitudinal comparison. Co-word analysis was conducted twice to these two groups of articles. Also, a co-occurrence threshold of no less than five times was applied. The number of items (words) in co-word analysis is much less than the number of items (references) in co-citation analysis, so the threshold was set lower to include more items. The final process was identical with that of co-citation: Microsoft Access was used to calculate the words’ frequency of co-occurrence in the abstracts, and the resulted networks were visualized in VOSviewer.

4. Results

4.1. Publication counting and abstract analysis

4.1.1. Chronological analysis of the articles

The ‘use of Lean in services’ is a very young research field, with the first related paper published in 1998 and the majority of literature concentrating in recent years. The exponential-like increase also suggests that the knowledge body is growing rapidly.

4.1.2. Geographic analysis of the articles

Among the 378 articles, 305 are empirical studies with specified countries/regions or theoretical studies having a certain geographic context. The rest of the articles do not have a geographic focus and are mainly theoretical papers or reviews.

We ranked the countries according to the times they are mentioned as the geographic context used in the publications. The USA is the highest cited country (114 articles), and together with the UK (60 articles), they have the dominant numbers of publications, showing that Lean is most extensively used in service sector in these two countries. Then, Canada with 16, Sweden and India with 12 articles.

The countries/regions were also integrated into their continents accordingly – North America and Europe together take up 82%, suggesting that these two continents are the pioneers of implementing Lean in services.

To have a further understanding on the trend of Lean in services chronologically and geographically, the countries were classified into developed countries and developing countries (based on International Monetary Fund, World Economic Outlook, October 2017), and, combining the publishing year, the chronological evolution of the number of publications by country type was obtained. The first publication studying ‘Lean in services’ in developed countries was published in 1998, and the number of studies rose rapidly after 2008. In comparison, the study focusing on developing countries only started in 2009, and both the publications per year and the growing speed are lower than those of the developed countries, meaning that the study in developing countries is yet in the early stages. Moreover, since most of the academic literature is empirical, one can deduce that Lean is more often implemented in services in developed countries than in developing countries.
Beginning from the end of last century, Lean was first discussed and transferred to services in developed world in North America and West Europe and after one decade spread to developing countries like India and Brazil.

4.1.3. Researched industries
Among the 378 articles, 23 of them do not have a specific industry focus – 12 articles explore Lean implementation in services in a general sense and 11 articles study the topic in a wider range, covering both manufacturing and service sector. For the rest of the 355 articles investigating Lean implementation in a specific service industry, we identified their industries and ranked them. The studies in Healthcare sector (247 articles) take the dominant percentage of 69.6%, followed by Public sector (31 articles) making up 8.7% and Finance with 4.5%. Other industries though have a large variety are no match for Healthcare in numbers. The extensive adopting of Lean thinking in Healthcare shows that this sector has an imperative requirement for quality improvement and cost saving and is adequate for Lean transfer.

4.1.4. Category of themes
Table 3 ranks the top 10 themes by their times of being discussed in the 378 articles. We can give a preliminary answer to our first research question. The most prominent topics in the 20 years research of Lean thinking in services are ‘Application of Lean in an organization’ (117 times) and ‘Evaluation of outcomes of Lean implementation in an organization’ (110 times). This shows that the study of Lean in services is mainly empirical studies, which record one or several Lean improvement projects and assess their outcomes, and sometimes they even do not have the following assessment. In contrast, ‘Development of a model/framework for Lean implementation’ (31 times) and ‘Lean tools/practices’ (22 times) are far less explored themes. This result echoes with conclusions of other systematic reviews mentioned that the current research of Lean in services is mainly occupied with case studies and lacks research rigor and mature model/frameworks (Aleu & Van Aken, 2017; Gupta et al., 2016; Leite & Vieira, 2015; Plytiuk et al., 2012).

‘Discussion of Lean’s transfer to or implementation feasibility in services’ (42 times) and ‘Lean implementation issues/challenges’ (49 times) topics show the researchers’ passion to explore the feasibility of Lean thinking in service sector both empirically and theoretically, and at the same time, they have encountered a lot of problems and identified many areas that need concerns.

| Themes                                           | Times discussed |
|--------------------------------------------------|-----------------|
| Application of Lean in an organization           | 117             |
| Evaluation of outcomes of Lean implementation in an organization | 110             |
| Application of Lean in an activity              | 75              |
| Lean implementation issues/challenges            | 49              |
| Evaluation of outcomes of Lean implementation in an activity | 47              |
| Discussion of Lean’s transfer to or implementation feasibility in services | 42              |
| Development of a model/framework for Lean implementation | 31              |
| KSFs/CSFs of Lean implementation                 | 27              |
| Extent of Lean implementation in an industry     | 25              |
| Lean tools/practices                             | 22              |
4.2. Co-citation analysis

After excluding the references that are co-cited less than 10 times, 71 most influential references remained for co-citation analysis. The network of these citations is visualized in Figure 2. Each bubble stands for one reference, and bigger bubble size means higher cited times. ‘Association strength’ is chosen as the method to normalize the strength of the links between units (Van Eck & Waltman, 2018). The lines connecting the bubbles represent the linkage between the documents, and shorter distance between bubbles indicates stronger connection they have. Five clusters can be identified from this network, as shown in Figure 2.

The biggest bubble alone with those smallest ones composes the first cluster. The big one is the famous book Lean Thinking written by Womack & Jones in 1996. This book first popularized the term ‘Lean thinking’ by its title and proposed the five Lean principles – ‘value’, ‘value stream’, ‘flow’, ‘pull’ and ‘perfection’. It is not surprising that this book is cited and co-cited the highest times, for it can be regarded as one of the foundations of Lean. Those small bubbles surrounding the big bubble are publications that are less influential and come from different topics. They are all connected to Womack and Jones (1996) but have no connections with each other or any other publications in this network. This may be because i) Womack and Jones (1996) is like a ‘textbook’ in this research area and is likely to be co-cited with publications from varied topics within this area, and ii) those small citations may actually have linkage with others, but the connections are not strong enough (co-cited less than 10 times) to be visualized in this network, that is why they are shown as scattered and lonely satellites around the star. Therefore, in defining this cluster, these small citations are insignificant and the cluster can be considered as solely represented by Womack and Jones (1996). We name it as ‘Lean Principles’.

Figure 2. Visualized co-citation network with clusters identified.
The second cluster can be divided into two sub-groups. The lower part closer to the center includes Lean roots that are even older than Womack and Jones (1996), for example, the very first ‘Lean’ coined in *The Machine That Changed the World*, written by Womack, Jones & Roos in 1990, and the precursor of Lean – The Toyota Production System, discussed by Ohno (1988), *The Toyota Production System* and Liker (2004) *The Toyota Way*. Also, within this group, there are some summarizing works about Lean, for instance, Hines et al. (2004) review the evolution of Lean thinking and Shah and Ward (2007) clarify concepts about ‘Lean production’ by a large-scale study. Apart from these, Rother and Shook’s book in 2003 *Learning to See* also belongs to this group. Published by Lean Enterprise Institute, an organization founded by James Womack, it is a ‘textbook’ teaching one of the core Lean tools – value stream mapping. Given the above, this sub-group was defined as ‘Lean History I – Lean Foundations’.

If we say the lower part of the second cluster depicts the early history of Lean, then the upper part reflects the history when researchers were discussing Lean’s transfer to services. From the influential citations, we can know that the exploration of Lean services in academic world began in as early as 1998, and the discussion was heated during the early years of this century. These publications can be considered as the theoretical foundation for the later studies investigating the feasibility of Lean in services in empirical manners. We gave the title ‘Lean History II – Lean Transfer to Services’ to this sub-group.

Tightly following the discussion of Lean transfer to services, studies in Cluster 3 and Cluster 4, which are all after 2005, mainly deal with Lean implementation in specified service sectors. References in Cluster 3 are all related to ‘Lean in Healthcare’, and this cluster is the biggest one. This is easily understandable since studies investigating Lean implementation in healthcare take a dominant percentage in the 378-article database. Like Cluster 3, Cluster 4 mainly focus on ‘Lean in Public Sector’, as public sector is the second most discussed sector following healthcare. It is notable that the three representative articles in this cluster all have Radnor as the first author (Radnor & Boaden, 2008; Radnor & Walley, 2008; Radnor et al., 2006), and Radnor also has two influential works in Cluster 3 (Radnor, 2011; Radnor et al., 2012), suggesting that she is an expert in Lean implementation in these two sectors.

The fifth cluster is the smallest one, but it gives interesting information. Three representative references in this cluster are about case study research method, explaining the use of case study method as a valid research tool. It demonstrates that case study method is a popular methodology adopted when investigating Lean implementation in services and again reinforced the argument that this research area is lack of standard framework because case study method limits the generalization of the outcomes (Plytiuk et al., 2012).

Regarding the locations of the clusters on the map, it is observable that Cluster 1 (mainly refers to Womack and Jones (1996)) and Cluster 2a are at the center of the map, suggesting they have the strongest associations with other clusters, based on the assumption that a topic closer to the center has higher centrality in the network (Romo-Fernández et al., 2013). Cluster 3, Cluster 4 and Cluster 5 are at the periphery reflecting their lower centralities. Cluster 5, in particular, stretches far away from the center and has the least links with others, illustrating that it is the most specialized cluster.
Table 4. Representative references of each cluster.

| Cluster | Representative References |
|---------|---------------------------|
| Cluster 1 – Lean Principles | Womack and Jones (1996) |
| Cluster 2a – Lean History I – Foundations | Womack et al. (1990); Ohno (1988); Liker (2004); Hines et al. (2004); Shah and Ward (2007), and Rother and Shook (2003) |
| Cluster 2b -Lean History II – Transfer to Services | Bowen & Youngdahl (1998); Piercy & Rich (2009); Swank (2003); Allway & Corbett (2002); Abdi, Shavarini & Hoseini (2006) |
| Cluster 3 – Lean in Healthcare | De Souza (2009); Spear (2005); Radnor et al. (2012); Young & McClean (2008); Mazzocato, Savage, Brommels, Aronsson & Thor (2010); Fillingham (2007); Ben-Tovim, Bassham, Bolch, Martin, Dougherty & Szwarcbord (2007); Joosten, Bongers & Janssen (2009); Kollberg, Dahlgaard & Brehmer (2007); Holden (2011) |
| Cluster 4 – Lean in Public Sector | Radnor and Boaden (2008); Radnor and Walley (2008); Radnor et al. (2006) |
| Cluster 5 – Case Study Research Method | Yin (2009); Eisenhardt (1989); Voss, Tsikritsis & Frohlich |

Table 4 lists the representative references of each cluster.

4.3. Co-word analysis

Figures 3 and 4 describe the visualized networks of the selected keywords for the two time periods, and the clusters are identified. As the same in co-citation analysis, the normalization method is ‘association strength’. The bubble size reflects the appearing frequency of the word, and the distance between bubbles infers the strength of their connection.

From the map of the period 1998–2008, we can know that healthcare was the first prominent service sector where Lean was applied, and to be specific, hospital and clinic are mainly the discussed organizations in this sector. The word ‘flow’ is closely connected to them because most articles were studying on creating a flow in hospital to improve service quality. The word ‘manufacturing’ has a high frequency in this cluster because researchers were saying ‘Lean is transferred from manufacturing industry to service sector’. Apart from these, ‘Lean principle(s)’, ‘tool(s)’, ‘waste’ and ‘efficiency’ are often mentioned concepts in

Figure 3. Visualized co-word network, 1998–2008.
this period. We can deduce that the contributions of Lean principles or Lean tools are often recognized as reducing waste and improving efficiency. Those minor words at the right side of ‘Lean’ are not significant in this map, but they still can inform us that ‘case study(ies)’ were used and ‘Six Sigma’ was already discussed before 2008.

We can identify two clusters in this period:

- Cluster A – ‘Adoption of Lean in healthcare in 1998–2008’, with representative words ‘healthcare’, ‘hospital’, ‘clinic’, ‘implementation’ and ‘flow’; and
- Cluster B – ‘Major themes of “Lean in services” in 1998–2008’, with representative words ‘service’, ‘principle’, ‘application’, ‘tool’, ‘waste’, ‘efficiency’ and ‘performance’.

After seeing the figure from 2009 to 2018 (Figure 4), we are able to observe an increase in the keywords both in regularity and in diversity, showing that the field has been expanding fast and the literature has considerably been enhanced. All the keywords that appeared in last period remain to be important in this period with higher frequency.

Before looking into details, it is needed to clarify two things:

(1) One can observe that the clusters have some overlaps with others, which is a normal situation, suggesting that there are connections between words that are from different clusters (Romo-Fernández et al., 2013). For example, ‘NHS’ (National Health Service) is painted in blue and belongs to Cluster 3, but clearly it has very close connection with ‘healthcare’, thus it can also be included in Cluster 1.
(2) ‘Lean’, ‘service’ and ‘implementation’ are words with extremely high centrality, which can be regarded as components in any cluster, thus they are not considered as representative words in any cluster.

Begin with the Cluster 1, the words ‘healthcare’, ‘hospital’ and ‘clinic’ are again three very influential words indicating that healthcare is still the leading service industry of implementing Lean and the number of related studies increased a lot. There emerged quite a bit sub-sectors or departments in healthcare, such as ‘NHS’, ‘emergency department’, ‘pharmacy’, ‘operating room’, ‘acute care’, ‘primary care’, ‘nursing’ and ‘radiology’, demonstrating that Lean implementation in healthcare grows not only in quantity but also in comprehensiveness. The word ‘flow’ is still closely related to this cluster, and now we know that creating ‘flow’ to reduce ‘waste’, increase ‘efficiency’ and improve ‘patient satisfaction’ is the common target of Lean implementation in healthcare. We define this cluster as ‘Adoption of Lean in healthcare in 2009–2018’.

‘Application’ and ‘tool’ are still remarkable, but around them there aroused many words that newly become significant, like ‘method’, ‘technique’, ‘model’, ‘framework’. This manifests that as the adoption of Lean increases, more and more Lean tools, techniques and methodologies are used in service industry, and frameworks and models are established based on successful cases. Indeed, in Cluster 2, some new bubbles are notable like ‘VSM’, ‘LSS’ (Lean Six Sigma), ‘DMAIC’ (Define, Measure, Analyze, Improve and Control), ‘5S’ and ‘Kaizen’. It is worth mentioning that these tools are not all in the same cluster because one paper normally uses only one or two tools, thus it is not often to see two tools appear jointly, as a result, they are scattered on the map and have no mutual connections. The name ‘Updating of Lean implementation’ is given to this cluster.

The mainstream research method of the literature is still ‘case study’, and the words ‘interview’ and ‘survey’ (Cluster 3) are common ways of data collection in that method. ‘Initiative’, which refers to one-time Lean improvement project, is often the research subject. The frequency of ‘qualitative’ is higher than that of ‘quantitative’. These jointly reinforce the argument that the research field is short of research rigor and generality (Aleu & Van Aken, 2017; Gupta et al., 2016; Leite & Vieira, 2015). Also, the linkage of ‘case study-performance-practice’ indicates that many articles are empirical case studies assessing the performance of an organization or a process after Lean practices. These studies are more like ‘verifying’ the effectiveness of Lean instead of ‘concluding’ it, as Plytiuk et al. (2012) states, the empirical case studies in this field, though have made considerable efforts, are merely describing certain practices, reporting their results of the initiatives, and have no intention to validate and establish theories.

Another two fresh words ‘challenge’ and ‘barrier’ within this cluster demonstrate that the process cannot always go smoothly. It is certain that along with the deepening of the application, researchers will find more and more challenges and barriers that need to be solved. To summarize, the third cluster can be called as ‘Current state of Lean research methodology’, consisting of ‘interview’, ‘survey’, ‘initiative’, ‘qualitative’, ‘quantitative’, ‘challenge’ and ‘barrier’.

Lastly, the smallest cluster (Cluster 4) ‘Adoption of Lean in public sector in 2009–2018’ represented by ‘public sector’ and ‘public service’ shows the transfer of Lean to public sector has begun in the new era. However, its tiny scale and marginal location manifest that the popularity of ‘Lean in public sector’ cannot yet be compared with that of healthcare.
5. Discussion and conclusion

As Lean thinking has been applied increasingly in service industry, the related literature is growing fast and accumulated substantial amount.

Through publication counting and abstract analysis, it was found that the research field began its explosion after 2009 and is still increasing rapidly. The studies happened mostly in developed countries, whereas studies in developing countries were lagging and only began from 2009. Articles focusing on healthcare sector are dominant in number, which is eight times the number of the second place, public sector. Most of the studies were of an empirical nature describing application of Lean in an organization or activity and evaluating the outcomes, while theoretical studies developing and assessing a model/ framework for Lean implementation are much fewer. The researchers also encountered a lot of challenges when transferring Lean into services.

Co-citation analysis identified the knowledge base of the 378 articles and classified them into five clusters, namely ‘1-Lean Principles’, ‘2a-Lean History I – Lean Foundations’, ‘2b-Lean History II – Lean transfer to Services’, ‘3-Lean in Healthcare’, ‘4-Lean in Public Sector’ and ‘5-Case Study Research Method’. From its knowledge base, we can also learn that the research field is very young, with the root of Lean being in 1990–1996, the discussion of Lean transfer to services happening in 1998–2006, and the application of Lean in services only scaling after 2005.

From the co-citation network map (Figure 2), some patterns emerge with clarity: (1) clusters ‘Lean in Healthcare’ and ‘Lean in Public Sector’ (clusters 3 and 4, respectively) are very close to cluster ‘Lean History I – Lean Foundations’, and there are many connections between each of the former and the later; (2) clusters ‘Lean in Healthcare’ and ‘Lean in Public Sector’ are also very close to each other; (3) cluster ‘Lean History II – Lean Transfer to Services’ is distant from clusters ‘Lean in Healthcare’ and ‘Lean in Public Sector’.

These patterns are very illuminating. From pattern (1), it can be inferred that the application of Lean to services is associated with a theoretical and more conceptual body of knowledge (cluster 2a). Rather surprisingly, the upper sub-cluster (cluster 2b), the one that deals with transferring Lean to services, is distant from clusters ‘Lean in Healthcare’ and ‘Lean in Public Sector’ (pattern (3)), revealing a very weak association. This oddity hints at a what may be a root cause of Lean not being widely applied across many more services (beyond healthcare and public services): the lack of fundamental studies on how to transfer Lean to services. In effect, Lean was primordially developed in and for manufacturing industry and not for services. Therefore, the approach to services must be adapted to fit the specificities of services. Future research should pursue this line of inquiry. This would promote both a wider application of Lean across services and an improved application of Lean in services where it is already being applied. Specifically, it is urgent to create a framework to guide Lean implementation in services.

Since clusters ‘Lean in Healthcare’ and ‘Lean in Public Sector’ are very close to each other (pattern (2)), they are strongly associated. This fact suggests that advances in the implementation of Lean in a service cross-fertilizes the implementation of Lean in other services. In fact, learning that a principle or a practice brought success to a service will inspire other services to use the same principle and practice. Moreover, the wisdom
learned from failures in some services will likely stimulate development in the other services. And, given this virtuous cycle of cross-fertilization, studies on implementing Lean in other services should be encouraged.

Applying the Lean principle, flow, to reduce waste and increase efficiency is the mainstream target of the literature. Lean tools that come into force are enriched, with VSM, LSS, DMAIC, 5S and Kaizen as the most prominent ones. Case study method is always the common research method, and interview and survey are popular data collection manners. It can also be interpreted that researchers will encounter more problems as the Lean reform in service industry goes to deeper ground.

The second co-word network map (Figure 4) also exhibits interesting features. The most striking is the complete absence of very many Lean practices in map. From this, it can be inferred that those missing Lean practices are not viewed as appropriate to be used in services. Therefore, research should advance new Lean practices consistent with services and try to reconvert some of the old ones to be usable in services.

It is also noteworthy that the ball corresponding to the word framework is distant from both the ball implementation and the cluster ‘Adoption of Lean in healthcare in 2009–2018’. This confirms the absence of a valid and effective framework to guide practitioners through Lean implementation. And again, it may explain why Lean application to services is still so narrow. Co-word analysis corroborates the call for urgently creating such a framework. According to Chang et al. (2015), combining different bibliometric methods can help to reveal more details about a research field, which include not only research topics, purposes, but also commonly used methodologies. Indeed, from the three analyses, we obtained a grand picture of Lean development in services full of details. Now we have a better understanding of its chronological development, the most common research themes and purposes, the most studied industries and regions, the most used Lean tools and the most adopted research methodologies. The obvious gap of this field is the insufficient studies in other service sectors except for healthcare and in other part of the world except for advanced economies in North America and Europe. The weakness is mainly related to the methodologies. Most of the empirical studies are case studies, whose limitation in generalization makes the articles into silos – though large in numbers but lack of mutual connection. The deficiency of mature model or framework inhibits the expansion of Lean implementation in services.

Table 5 summarizes the responses to our research questions (RQ1, RQ2 and RQ3).

### 5.1. Implications for research

Based on our findings, we can recommend several topics for further research:

- Build a framework to manage the implementation of Lean to services.
- Study the use of Lean to other services away from healthcare and public services.
- Study the so many Lean tools and practices that are lacking from the network maps.
- Investigate Lean in services in developing regions.
- Investigate Lean in services in geographies where it is still poorly studied (82% of the papers correspond to North America and Europe).
Table 5. Answer to Research Question 1, RQ2 and RQ3.

| RQ | Answer to Research Questions |
|----|-------------------------------|
| **RQ1: The most popular topics in Lean thinking in services** | - Most salient themes in the 20 years research of Lean in services:  
  Application of Lean in an organization  
  Evaluation of outcomes of Lean implementation  
  Application of Lean in an activity  
  Also popular themes, although not the first ones:  
  Discussion of Lean’s transfer to or implementation feasibility in services  
  Lean implementation issues/challenges. |

| **RQ2: The trends, patterns, gaps and weaknesses in this field** | TRENDS AND PATTERNS:  
- the Use of Lean in services is a very young research field (1st related paper published in 1998)  
- the knowledge body is growing rapidly, in an exponential-like behavior  
- about 80% of the studies have a certain geographic context  
- 20% are mainly theoretical papers or reviews (no geographic region)  
- the US is the most mentioned country along with the UK. Then, Canada, Sweden and India  
- North America and Europe together take up 82% = > these 2 continents are the pioneers of Lean in services  
- the studies in Healthcare sector take the dominant percentage (70%), followed by Public sector (9%)  
- the extensive adopting of Lean in Healthcare demonstrates that this sector has an urgent need for quality  
- the body of knowledge can be organized in 5 clusters: one central group (with 2 clusters) containing the seminal works (Principles) and the Foundations, and 3 other clusters at the periphery with Lean transfer to services works, Health care and Public sector researches and Case Study Research Method |

| **RQ3: Lean tools often used** | The analysis was divided in two periods:  
- 1998–2008: i) ‘Lean principle(s)’, ‘waste’ and ‘efficiency’ and ‘performance’ are often mentioned concepts in this period; ii) most articles were studying creating a flow in hospital to improve service quality; iii) until 2008, the lean tools were not highlighted in the studies, as any of the most used tools in services appeared in the co-word analysis.  
- 2009–2018:  
  ‘Application’ and ‘tool’ are still remarkable but around them there aroused many words that newly become significant, like ‘method’, ‘technique’, ‘model’, ‘framework’  
  the word ‘flow’ is still closely related to the central cluster and now we know that creating ‘flow’ to reduce ‘waste’, increase ‘efficiency’ and improve ‘patient satisfaction’.  
  some new bubbles are notable like ‘VSM’, ‘LSS’, ‘DMAIC’, ‘SS’ and ‘Kaizen’. Six sigma is the largest bubble  
  the frequency of ‘qualitative’ is higher than that of ‘quantitative’.  
  two fresh words ‘challenge’ and ‘barrier’ demonstrate that the process cannot always go smoothly. Along with the deepening of the application, researchers find more and more challenges and barriers that need to be solved |
• Research the obstacles and complexities that can put in danger the success in the implementation of Lean in services.
• Attempt to adapt the original Lean practices, that were developed in and for manufacturing industry, to be usable in services.
• Perform studies not only based in case studies that makes generalization unfeasible.

5.2. Implications for management
In terms of impact for managers this study offers the following:

• A draw of the panorama of the research field and enlightens them regarding the trends, patterns, gaps and weaknesses in applying Lean to services along three decades and in several world regions.
• The recognition of the existence of a considerable research on the application of Lean to services confirms the usefulness of it in practice.
• Practitioners in healthcare and public services can use Lean in a more informed and confident way as the amount of research is very high.
• Managers have a more knowledgeable application of Lean to services as the most studied Lean practices employed in services were recognized (VSM, LSS, DMAIC, 5S, Kaizen).
• The Lean principle flow was identified as prominently used in healthcare, which is very valuable for practitioners in healthcare, since it suggests that flow has had success in practice and the existence of a body of knowledge about how to apply such a principle.
• Our research found that the application of Lean to services faced several barriers and difficulties. This is crucial for managers, since it makes them conscious of the obstacles they may face.

5.3. Limitations
Although being the first bibliometric study investigating Lean implementation in whole service sector at full time range, the paper is not free of gaps and limitations. The researched articles are only collected from Scopus and WoS, so some influential articles from other databases may be missed out. The screening and categorizing process was done manually, thus may suffer from personal bias. Regarding the co-citation analysis, Franceschini et al. (2016) have reported errors in both the databases of Scopus and WoS, which will affect the accuracy of the cited references. As for the co-word analysis, the time period can be further divided into shorter segments to know subtler changes. Therefore, future researches can extend the data collection range outside Scopus and WoS.

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Appendix

List of words chosen based on author keywords and frequent words from abstracts.

| SS            | gap              | methodology       | quality improvement |
|---------------|------------------|-------------------|---------------------|
| acute         | health care      | model             | quantitative        |
| agile         | healthcare       | National Health Service | Queuing theory      |
| application   | higher education | NHS               | Radiology           |
| barrier       | Hospital         | non-value-added   | service             |
| Benchmark     | HRM              | Nursing           | Simulation          |
| Call Centre   | implementation   | Operating room    | Six Sigma           |
| Case study    | initiative       | Organizational change | supply chain        |
| challenge     | intervention     | Patient safety    | survey              |
| Change        | interview        | patient satisfaction | Takt time           |
| management    |                   |                   |                     |
| clinic        | IT support       | performance       |                     |
| Continuous    | Kaizen           | pharmacy          |                     |
| improvement   | Laboratory       | philosophy        |                     |
| critical success factor | | practice | Total Quality Management |
| CSF           | leadership       | primary care      | training            |
| DMAIC         | Leagility        | principle         |                     |
| efficiency    | lean             | process improvement |                     |
| emergency department | lean thinking | productivity | Triage              |
| Empirical     | logistics        |                   |                     |
| Financial     | LSS              | public sector     |                     |
| flow          | maintenance      | public service    |                     |
| framework     | manufacturing    | qualitative       |                     |

* Words marked with the same gray color have the same meaning but in different forms, so their numbers of appearance would be combined.
* ‘case study’ can index to both ‘case study’ and ‘case studies’.
* Actually the right expression is ‘value stream mapping’, but some people also use ‘value stream map’. Since searching ‘value stream map’ can also index to ‘value stream mapping’, ‘value stream map’ is chosen as the keyword.