Lean in Healthcare: A Systematic Literature Review and Social Network Analysis

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Abstract
This article presents the results of a systematic review of 139 papers from the Lean Healthcare literature. Bibliometric citation/co-citation and Social Network analysis compound the strategies for investigating the articles sampled. The results reveal a still emergent field marked by poorly explored relationships and knowledge, indicating abounding possibilities for research.

Keywords: Lean, Healthcare, Literature Review.

Introduction
Fostered by international concerns around healthcare systems performance, over the past decade Lean thinking has been increasingly applied in hospitals for improving quality and reducing costs (Grove et al., 2010). Although its roots are in manufacturing, the initiatives demonstrate highly successful results in healthcare, as several authors have referred to it as one of the most widely used methodologies for process improvement in the healthcare industry over the past decade (De Souza, 2009). This popularity, in turn, has been attracting increased academic interest and a substantial amount of publications in journals and conferences, such that the theme has begun to appear as a recurring research topic, deserving some attention as a field of study. Assuming that all published material is not equal in quality and relevance to a particular topic, Pilkington and Meredith (2009) suggest that a relevant contribution for emergent research fields lies in literature reviews that are able to revealing the intellectual structure of the area by identifying the most influential and important publications in the area and their relationship to each other, providing subsidies for researchers to be able to channel efforts into what is really important. (Pilkington and Meredith, 2009).

In relation to Lean in healthcare research, no major reviews of the field have been presented. Among the articles identified in the related search, six papers that attempt to review part of the literature were found. Most of them, however, were focused on implementation issues or are restricted to a determined setting. As far as this research extends, studies devoted to provide an outline of the Lean in Healthcare literature in
its general scope are not yet present in the current literature, specially regarding to which actors and topics are in fact relevant for this field. Therefore, taking into account the background presented, this paper aims to present part of a major research devoted to map the development of scientific research in Lean Healthcare identifying the main practices and current research topics. By promoting the mapping of the field, the most important authors and publications of Lean in healthcare and the relationships among them will be determined, as well as general characteristics of research in the area.

Methodology

This research is a systematic literature review that employs a set of 139 scientific articles from the Lean Healthcare literature as a data source. Its nature can be framed as predominantly descriptive, since the main concern is posed in terms of describing and classifying a population or phenomenon (Selltiz, Wrightsman and Cook, 1987).

Data collection and delimitation

The research strategy involved searching for articles containing in its keywords or abstract the words “healthcare” or “hospital” accompanied of one of the key terms: “lean”, “Toyota”, “Value stream mapping”, “Kaizen”, “Poka-yoke” and “Kanban”. The databases selected for search were: Emerald, Wiley, Ovid sp, Scopus and Science direct. For including documents the following criteria were imposed: (a) articles had to be written in English. Documents written in another language and conference papers, editorials, letters, opinions or other similar publications were excluded; (b) no limits were imposed on publication date so that the results would show how research in this field had evolved from the time it first started to the present; and (c) after the abstracts had been evaluated, only those articles dealing with the use of the Lean philosophy in health care were included. As final criteria, was removed from the group articles whose source was not indexed in the Journal citation reports (JCR). This criteria was imposed in order to limit the analysis to publications with scientific rigor, aiming to circumvent the difficulties found by other authors against the representative presence of methodological and measurement limitations in the papers of the field (Vest and Gamm, 2009, Poksinska, 2010; Mazzocato et al., 2010).

Strategies of analysis

As the strategies of analysis two methods are employed: bibliometrics (including citation and co-citation) and social network analysis. According to Eom (2004), bibliometrics can be defined as the identification of patterns and trends in scientific communications by analyzing quantitatively and qualitatively an aggregate of information regarding authors and documents (conference proceedings, journal articles and books). The bibliometrics allow for the identification of trends in subjects such as core journals and patterns of library use (Ravichandra Rao, 1983). Specifically the analysis than based in co-citation data reveals relations among authors based in two types of connections: co-authorship and theme affinity, showing already existent relations among authors and possible opportunities. These connections however are determined considering as raw data the citations among authors. It is assumed that an author cite works that he considers relevant for the construction of his research, emerging then the assumption of affinity in research themes. Citations and co-citations in turn consist of different perspectives of analysis. In citation analysis researchers are interested in identifying the patterns of how
published articles are read and cited over time (Eom, 2004). As highlighted by Eon (2004), the citations analysis is concerned with simply counting the citations of a document or set of documents authored by an individual without considering intellectual linkage. On the other hand, the co-citation analysis is devoted to analyzing relations among pairs of documents cited by a third document (Small, 1973). To analyze than the pattern of citations and co-citations are employed the techniques of Social Network Analysis. The network perspective is based on the assumption that any system can be viewed and analyzed as a set of interrelated actors or nodes, which in turn, represent persons, firms, countries and so on. (Borgatti and Li, 2009).

Applications of SNA for analyzing the structure of a research field are already observed in several areas such as information sciences (Otte and Rousseau, 2002), Engineering (Ahuja, Magnanti and Orlin, 1993) and operations management (Pilkington and Meredith, 2009), reinforcing the applicability of this concept in the intended context. Regarding the purpose of the analysis, Pilkington and Liston-Heyes (1999) see this approach as instrumental in identifying groupings in a research field and comprehending the way in which these clusters relate to each other (Pilkington and Liston-Heyes, 1999). Once the network has been established, several algorithms can be employed for interpreting the results. This research will focus only on the application of the elementary ones basically described below:

- **Density**: Indicates the overall level of network connectivity. This measure compares the current level of connections in the network with the total possibilities, indicating at which level connections are already being exploited;
- **Centrality Degree (CD)**: It is defined as the number of connections that a node has in the network. It is understood that the greater the number of connections, the more privileged the position of the author, impacting on their ability to influence others.
- **Analysis of subgroups or clusters**: This technique relates to identification of sub-groups within the network based on established criteria. For the analysis presented in this paper, will be employed the k-cores algorithm, employed with the assistance with the Netdraw, part of the Ucinet package.

**Systematic literature review results**

**Main authors and themes**

The first aspect analyzed was the centrality degree index, resulting in a list of the most central authors in the citations network. Considering that the index is calculated based on the number of ties that an author has in the network, and that as elevated this index, more privileged is the position of the node (author) regarding to the other members of the network, these authors may be quoted as the most important in the network in terms of influence over the rest. The degree indexes of the 10 most central authors may be seen in the table 1.
Figure 1: Ten most central authors in the field according to the citations network.

<table>
<thead>
<tr>
<th>#</th>
<th>Author</th>
<th>Affiliation</th>
<th>Articles in the Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bassham, Jane E</td>
<td>Flinders Medical Centre, Bedford Park, Adelaide, Australia</td>
<td>3 75</td>
</tr>
<tr>
<td>2</td>
<td>Ben-Tovim, David I</td>
<td>Flinders Medical Centre, Bedford Park and Faculty of Health Sciences, University of South Australia, Adelaide, SA</td>
<td>3 75</td>
</tr>
<tr>
<td>3</td>
<td>Aronsson, Hakan</td>
<td>Linköping University, Department of Management and Engineering, Linköping, Sweden</td>
<td>3 71</td>
</tr>
<tr>
<td>4</td>
<td>Brommels, Mats</td>
<td>Karolinska Institutet, Medical Management Centre, Stockholm, Sweden</td>
<td>2 66</td>
</tr>
<tr>
<td>5</td>
<td>Holden, Richard J</td>
<td>Vanderbilt University School of Medicine, Department of Medicine and biomedical informatics, Nashville, USA</td>
<td>2 66</td>
</tr>
<tr>
<td>6</td>
<td>Mazzocato, Pamela</td>
<td>Karolinska Institutet, Medical Management Centre, Stockholm, Sweden</td>
<td>2 66</td>
</tr>
<tr>
<td>7</td>
<td>Thor, Johan</td>
<td>Karolinska Institutet, Medical Management Centre, Stockholm, Sweden</td>
<td>2 66</td>
</tr>
<tr>
<td>8</td>
<td>Spear, Steven J</td>
<td>Harvard Business School and Institute for Healthcare Improvement, Massachusetts, USA</td>
<td>2 64</td>
</tr>
<tr>
<td>9</td>
<td>Bill, John E</td>
<td>University of Michigan Health System, Ann Arbor, USA</td>
<td>3 59</td>
</tr>
<tr>
<td>10</td>
<td>Savage, Carl</td>
<td>Karolinska Institutet, Medical Management Centre, Stockholm, Sweden</td>
<td>1 58</td>
</tr>
</tbody>
</table>

Source: Elaborated by the author.

As might be observed, two authors that obtained similar centrality indexes lead the ranking: Jane Bassham and Ben-Tovim, both from the Flinders Medical Centre, Australia. Their preeminence is explained in terms of three articles from the period of 2006 to 2008 that report methods and improvements of a Lean initiative conducted in its hospital: “Redesigning Emergency department patient flows: Application of Lean Thinking to Healthcare” (12 citations) (Ben-Tovim et al., 2006); “Lean thinking across a hospital: redesigning care at the: Flinders Medical Centre” (9 citations) (Ben-Tovim et al., 2007); and “Redesigning care at the Flinders Medical Centre: clinical process redesign using "lean thinking"” (4 citations) (Ben-Tovim et al., 2008). On the following we highlight the presence of Spear, S.J., who contributes to the development of the lean system adapted to the Pittsburgh Regional Healthcare Initiative (PRHC) and the first implementation in the University of Pittsburgh Medical Center (UPMC). Spear is responsible for the most cited article of the sample "Fixing Healthcare from the inside, today" (Spear, 2005), which calls on healthcare companies to make improvements based on the success of PRHI. Might be highlighted also the presence of the group compound by Hakan Aronsson, Mats Brommels, Richard Holden, Pamela Mazzocato, Johan Thor and Carl Savage, that has its position mainly conquered by two papers collaboratively produced: “Lean thinking in healthcare: A realist review of the literature” (2010) (Mazzocato et al., 2010) and “How does lean work in emergency care? A case study of a lean-inspired intervention at the Astrid Lindgren Children’s hospital, Stockholm, Sweden” (Mazzocato et al., 2012). Nevertheless, when observing the characteristics of the citations of this group, may be observed that the preeminence of it is sustained based in the citations made, instead of received. Hence, it is an indicative that these articles have solid theoretical bases on Lean in Healthcare knowledge, instead of strong influence under the group.

On the following, a second analysis based in co-citations pattern, was performed aiming to recognize which are the research themes that are most strongly
present in the Lean Healthcare literature, as described in the methodology chapter. The graphic result of the analysis made by the k-cores algorithm is presented below.

Figure 2 - Knowledge groups in Lean Healthcare according to k-cores algorithm in the co-citations network.

Crossing the twenty-two resulting groups and the contend of the abstracts of the papers produced by the authors in each one, the analysis showed low theme affinity among the participants of the groups. Among the groups pointed by the k-cores algorithm, major affinities among the authors were found only in six (6) cases; the relation among the keywords of the six (6) groups with higher similarity are presented in the table below (table 1). A major number of members and consequently papers were found in two groups: the group represented by the light green in graph (55 members) and dark green (32 members).
Nevertheless, despite of fact that do not exist much cohesion referring to the theme into the groups, three themes were representatively presented in the network, being found in mixed groups: Applications of Lean in Emergency departments and Laboratories (mainly Pathology laboratories) and the use of Lean combined with Six Sigma. Taking into consideration that the field is still emergent in terms of research, a possible cause for this dissimilarity may be the absence of works in that specific theme, causing that the authors end up using what they consider as more related to its research.

**Level of knowledge exploration, cooperation and authors productivity**

An additional analysis performed was the indicator *density or Gamma index (D)* in the citations network. This measure evaluates the general level of connectivity in a network by comparing the amount of existing relations with the possible supported by the network (Hannemann and Riddle, 2005). Performing the calculation

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**Table 1 - Groups defined by k-cores that present theme similarities.**

<table>
<thead>
<tr>
<th>Color in the figure</th>
<th>ID of the group</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purple</td>
<td>NHS UK</td>
<td>NHS UK (3); Empirical research (2); Social dimensions (1); Application (1) Operating room suites (1); Lean and Six Sigma (2); implementation models (1); PDSA (1); Applicability (1); Socio-technical dimensions (1); Actor network theory (1); Simulation (1);</td>
</tr>
<tr>
<td>Dark gray</td>
<td>Lean in Pathology Laboratories (3).</td>
<td>Evaluate Lean results (1), surgical pathology laboratory (2), amended reports (1); Pathology laboratory (1);</td>
</tr>
<tr>
<td>Black</td>
<td>Reduction of variability and Six Sigma (6)</td>
<td>Cataract surgery (1); Lean Six Sigma (3); Trauma care (1); discharge procedure (1); Protocol for infection prevention (1); reduce variability (1); Medical visits in high volume surgery clinics (1), Operating rooms (1)</td>
</tr>
<tr>
<td>Red</td>
<td>Lean in Laboratories (7)</td>
<td>Laboratory (1); phlebotomy (1), blood draw (1); Lean six sigma (1); radiology (2); NHS (1); Pathology laboratory (2); autopsy (1); implementation methods (1);</td>
</tr>
<tr>
<td>Dark green</td>
<td>Lean in Pathology Laboratory and Emergency Department (18)</td>
<td>Implementation methods (1), Thyroid gland fine-needle aspiration (1); Pathology laboratory (7); Emergency department (2); Implementation Models (1); Nursing unity (1); Cardiac surgery (1); patient flow in a medical clinic (1); Teach lean in residency programs (1); Evaluate Lean results (1); amended reports (1); otolaryngology (1) operating room (1);</td>
</tr>
<tr>
<td>Light green</td>
<td>Lean, Lean Six Sigma and Emergency departments (31)</td>
<td>Implementation models (4); Emergency department (9); Lean Six Sigma (9); constraints theory (2); Literature review (3); evidence of effectiveness (1); Six Sigma (1), Studer's Hardwiring Excellence (1); Trauma care (1), discharge procedure (1); lean capabilities (1); Trauma resuscitation unity (1); Pediatric unit (2) Operating rooms (1); chronic obstructive pulmonary disease (1); socio technical dynamics (1), simulation modeling (1); Supply chain (1); operating rooms (1); infusion pumps (1)</td>
</tr>
</tbody>
</table>

Source: Elaborated by the author.
by the assistance of Netdraw is obtained an index of density of 2.44%, standard deviance of 0.1581. The graph with the citations network is presented in the figure below.

**Figure 3 - Lean in Healthcare knowledge structure based in citations.**

Following the literature, we can interpret than that currently the level of exploration of the knowledge in the field is pretty limited.

Considering also the pattern pointed by Hanneman and Hiddle (2005), the network is far from being considerate dense, once that to achieve this attribute is required that the network reaches a minimum density of fifth 50%.

The last analysis then are based in simple bibliometric data: the level of cooperation in the researches construction and productivity.

Regarding to the first aspect, an elevate number of authorships per article is observed: from the total of 139 papers, 435 authors can be extract as the responsible for the publications; indicating that the researches in this area tend to be constructed in collaboration. As may be observed in the chart, 48% of the papers of the sample have between 3 and 5 authors and 17% have more than six authors, reaching a maximum of 12 authorships in one only paper. Comparing these results with the area of finance in Brazil, based in a study of 815 articles, the data present an inverse pattern where 82.5% of the articles has among one and two authors and the remaining 17.5% are distributed among three to six authors per article (Leal, Oliveira and Soluri, 2003).

**Figure 4 - Distribution of authors quantity per paper published.**
Analyzing the individual productivity of these authors, a total amount of 89.20% of the authors published just one article along the period of the fifteen years (1998-2012) analyzed. On the other hand, only 10.80% of the authors of the field have published more than one article, achieving a maximum of 8 articles per author.

In order to compare the pattern found with other areas, the number of publications per author was analyzed according to the parameters established by the Lotka’s Low, which is widely used to evaluate the productivity of research fields in general areas (Eom, 2009). It determines that the number of authors that publishes n papers is equal to \(1/n^2\) authors that publish only one article. Thus, the number of authors publishing two articles is equal to 1/4 of the authors that published one article, the number of authors who publish 3 articles is equal to 1/9 of that published one article, and so on (Leal, Oliveira and Soluri, 2003). Chung and Cox (1990) than demonstrate that is possible to consider the number of authors with only one article as constant in 60.80%. Based then in this value is possible to calculate the proportion of authors that are supposed to publish a determinate amount of articles in accordance with the international pattern of Lotka’s Low.

Hence, in order to compare, the table below presents the number of authors according to the quantity of articles published in the sample and the parameters established by Lotka.

<table>
<thead>
<tr>
<th>Articles/Author</th>
<th>Nr of authors</th>
<th>% of the total</th>
<th>Lotka’s Low parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>388</td>
<td>89,20</td>
<td>60,80</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>8,05</td>
<td>15,20</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>1,84</td>
<td>6,76</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0,46</td>
<td>3,80</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0,23</td>
<td>2,43</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0,00</td>
<td>1,69</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0,00</td>
<td>1,24</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0,23</td>
<td>0,95</td>
</tr>
</tbody>
</table>

Source: Elaborated by the author.

As presented in the table, the amount of authors that publishes only one article is 28.4% higher than the parameter established by Lotka, which indicates that the research in this area is comprised by a much larger portion of discontinued research than the expected in research fields. In consequence, the proportion of researchers that perform more than one study in the theme becomes greatly reduced.

**Conclusion**

This paper was devoted to mapping the characteristics of scientific research in Lean Healthcare identifying the main contributors and general characteristics of the research field obtained by Social Network and bibliometric analysis.

The results showed that the research in the field tends to be produced collaboratively. Nevertheless, despite the positive high level of collaboration, the results show that in Lean in Healthcare the percentage of authors that publish only one (1) paper in this area during their careers is 28.4% higher than the (60.8%) determined as pattern by Lotka's Law, which indicates that research in this area is compromised by a much larger portion of discontinued research than is expected in
research fields. Hence, the data indicate that in general do not exist continuity of the research efforts in the area and that the proportion of researchers who devote greater efforts to develop researches in the area is greatly reduced. Based in these data in turn is possible to infer that this discontinuity of the research efforts might be one of the cases to the limited use of research methods and substantial amount of theoretical/conceptual studies of weak contributions reported by the literature of the area. Considering that a substantial amount of the papers studied are reports of applications of lean in a determinate setting, this data may also indicate that the implementation of Lean was not sustained or not expanded to other areas of the institution, once the absence of a second paper may be caused by the absence of results good enough to motivate a new publication tentative, suggesting also that in practice the Lean may be occurring as a passing fad in hospitals instead of a methodology that achieve its objectives through continuous and incremental process improvement.

As second point, taking into consideration the density and cluster analysis, the results indicate a field still underexplored in terms of research and not yet well structured in terms of themes and author relations. Despite the already substantial number of articles published, the general characteristics of the field demonstrate concerns excessively focused on practice, which can be observed by the articles’ content and limited exploration of the research methods also observed. Therefore, these limitations indicate that research in Lean in Healthcare is a fertile field for the development of research on several topics, presenting several opportunities for authors interested in the area.

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