INDUSTRY 4.0. THE END LEAN MANAGEMENT?

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Abstract

The fourth industrial revolution brings a new paradigm for business and manufacturing. This includes new concepts such as Internet of things (IoT), Industrial Internet of Things (IIoT) or Industry 4.0 (i4.0). Lean management is a current process improvement methodology. It also offers solutions for manufacture and other business. It focuses on the reduction of waste in order to increase value for customers within a philosophy of continuous improvement. This paper investigates the current involvement of Lean management in this new revolution. To do so, it explores the formal body of knowledge to determine relationships between the topic of i4.0 and Lean. It reviews the abstracts of publications on i4.0 and it measure the level of relationship of the topic of lean on them. The findings reveal that the abstracts of the papers on i4.0 have a low correlation with Lean. This indicates that still both topics develop knowledge separately. Then, it is important to start the inclusion of the benefits of Lean in the topic of i4.0.

Keywords: Industry 4.0 (i4.0), Lean Management, Internet of Things (IoT), Industrial Internet of Things (IIoT)

JEL Code: M11, L60, M15

Introduction

Each economic and industrial revolution brings new challenges and it determines new approaches inside the organisations (Perez, 2010). This fourth industrial revolution also contains several changes. Internet of things (IoT) (Islam, Kwak, Kabir, Hossain, & Kwak, 2015), smart factories (Rashid, Sayin, Oureshi, Shami, & Khan, 2011) and lately the concept of industry 4.0 (i4.0) (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014) bring to the scene new paradigm for business and manufacturing. Markets search for high customization. Manufacture and operations require different methods. This includes more flexibility, less human factor in routine activities, high interconnectivity among others.

Lean Management is a methodology to develop value while reducing waste (Hines, Holwe, & Rich, 2004). It basis are found in Toyota Production System (Womack, Jones, &

Roos, 1990). Although, this methodology develops its concepts in manufacture, today this methodology applies its tools out of this scope in areas such as Healthcare, HR departments, Higher education among others.

The i4.0 is taking stronger position as the new proposed paradigm to develop manufacture and business. The German government, other countries and important organisations believe on the benefits of i4.0 (Baur & Wee, 2015). Faster and precise processes, pallets efficiency and safety, error rates reduction, accurate data, among others constitute the list of improvements within this revolution that allow companies to get better results. Moreover, these improvements are also included in the promised benefits of current methodologies such as Lean management, Six Sigma or Quality Management Systems (QMS).

Therefore, this paper explores the relationship of i4.0 with these current and former methodologies, especially with lean management. Frison (2015) argues that i4.0 makes obsolete some lean techniques but i4.0 requests other lean tools to achieve its results. Today there are several conferences, submits, videos and blogs communicating the advantages of i4.0. Fortunately, in the last years also the formal body of knowledge comprises several publications about the topic. Then, this research performs a content analysis over this formal current body of knowledge in order to determine the relationship between the topics i4.0 and Lean management.

1 IoT, i4.0 and Lean

This revolution arrives with several new concepts. The first concept is Internet of Things (IoT). Internet allows connectivity among several different computer networks around the globe. Today, there are millions of people constantly connected via emails, social media or others (Haigh, Russell, & Dutton, 2015). Furthermore, there are millions of devices that constantly execute task to provide services. A lamp gives light for your night reading, a fridge keeps the food fresh for later consumption or a drip system in a hospital bed provides adequate dose of medication to a patient. Then, IoT is the integration of those devices as new networks into internet. This allows constantly exchange of data among the devices but also with humans (Islam, Kwak, Kabir, Hossain, & Kwak, 2015). There are two key concepts. First, it is the actual connection of those devices as networks to the internet. Then, it is about constantly exchanging data at “anytime, anywhere, anyone, anything, anytime, anyplace, any service, and any network” (Islam, Kwak, Kabir, Hossain, & Kwak, 2015).

This is a global phenomenon. It is consider a revolution. The global economy constantly faces new disruptive business such as Uber, Airbnb and others. Then, the processes and procedures to deliver any service should change given this revolution. The expectation of economic value per year is more than $ 11 trillion by 2025 with 70% of it from industrial applications (Manyika, et al., 2015). This is Industry Internet of Things (IIoT) the application of IoT in Industry.

The German government develops its own concept: Industry 4.0 (i4.0) (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). It comprises similar elements that IIoT but it has the approach of a revolution: The fourth industrial revolution. The craft manufacturing is the first stage to industrialization. Then, the electric powered tools facilitate those tasks. The introduction of computers in industry remarks the third industrial revolution. Computer Aid Design and Manufacture (CAD/CAM) and others technologies considerably increase the accuracy on quality and increases quantity. This new revolution encompasses the IoT together with Cyber-physical Systems, Wireless Systems, Machine Learning, Machine to Machine, Virtual Systems and other current technologies. The combination of all those technologies in the industry open the concept of Smart Factory: "Improving productivity in manufacturing through increasing flexibility, simplifying data acquisitions and analysis, and generating higher throughput while reducing manufacturing costs" (Temple, 2016).

Productivity, flexibility, performance, cost reduction are some of the improvements made possible by applying Lean Management. Specifically, Lean focuses on waste reduction to increase value for customers in a continuous improvement environment (Hines, Holwe, & Rich, 2004). The output of applying lean is better processes. For example: Efficiency, effectiveness, shorter lead and cycle times, lower inventories and others. These results arrive after the application of tools, methods or techniques such as Kanban, Just in Time, SMED, DFMA, Kaizen, among others. In summary, the offer from lean management is vast and applicable not just in manufacturing systems but also in services, which usually have data as a main source for their activities. Then, lean management is a methodology for process improvement.

2 Methodology

This research investigates the relationship between i4.0 and Lean management within the current formal body of knowledge. The research question is: Does lean management contribute with i4.0? In other perspective, it is i4.0 the end of Lean? The assumption is that

Lean still has something to contribute to an organisation despite their level of i4.0. Therefore, if a publication has higher relationship with i4.0 then its content has higher relationship with lean management. Text and content analyses are the methods to explore this hypothesis (Mayring, 2000).

The first step to develop this research is to consolidate a list of publications related with the topic of i4.0. The source to develop this research is publications at the Web of Science (WoS). This data base has specific benefits and weaknesses but belongs to the recommended data bases to find representative publications (Adriaanse & Rensleigh, 2013).

The exploration of the WoS data based is conducted on April 2016. The literature review reveals that the concept of i4.0 involves several keywords. Similar, there are several words related with this topic. Therefore, these words are used to search publications within the WoS data base. This data base offers several options to search for specific topics. Each search combines keywords and logic commands to determine a list of publications. This research uses four of these search combinations. The first combination is "Industr* 4.0". This command searches for all publications with topic on "Industry 4.0" and "Industries 4.0". The next combination searches for the topic "Internet of Things". The results from this search are refined by the word "Industrial". This combination retrieves the publications related with Industrial Internet of Things. The topics "Smart Factory" and "Smart manufacturing" comprises the third combination. It recovers papers related from both topics. The last combination is the topic "Cyber-physical systems" refined by the word "Industr*". This provides a list of the cyber-physical systems related with the words industry or industries.

It is possible that these combinations of searches capture publications outside the targeted topic. Therefore, it is necessary to review the title of each publication and determine its relevance to this research. Subsequently, each search combination provides publications that determine a specific list on i4.0.

The lists of selected publications include the usual citation information, such as title, authors and publication date. The lists contain just papers with abstract in English. This information consolidates the source for the text and content analysis. The first part of the analysis determines frequency of each word among all abstracts. Specifically, a web base tool for text analysis provides these frequencies (textalyser.net).

The text analyses rank the words of the abstracts in a list from the highest occurrence to the lowest. The most frequent words related with the topics determine the list of keywords from the abstracts. This exclude stop words. The review of this list classifies the keywords in two groups. The first group recognises keywords related with promise of Lean management.

For example: Value, Waste and Continuous Improvement (Hines, Holwe, & Rich, 2004). The second group focuses on the keywords related exclusively with i4.0. This includes words such as cyber-physical systems, networks and sensors (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). There are several keywords with similar word root. The word count is case-insensitive to ensure the inclusion of the keyword in any of its possible expressions.

There are two approaches to assign a value to the relationship of each abstract to either topic. First, the abstract that contain the specific keyword gets one point. The second approach assigns one point for each keyword found in the abstract.

The first approach allows the researches to determine the percentage of abstracts that include each keyword. It also facilitates calculating the percentage of keywords found in the abstract over the total number of keywords in the topic. The second approach calculates the percentage of keywords found in the abstract over the total number of words in the abstract.

Regardless of the approach, each abstract obtains two values: One value indicates the level of relationship of the abstract with the topic i4.0 and the second value illustrates the level of relationship with the topic Lean. The abstract with highest value represents the highest relation with the topic (i4.0 or Lean). The correlations among these values explore the relationships that this set of abstracts about i4.0 have with the topic of Lean.

3 Findings

The list of publications related with i4.0 contains 556 publications. There are 25 publications without abstract. The text analysis of the 531 abstracts founds 54079 words in abstracts. The analysis comprises 6723 different words. The Complexity factor (Lexical Density) is 12,40% and the Readability (Gunning-Fog Index) - (6-easy 20-hard) is 13,8.

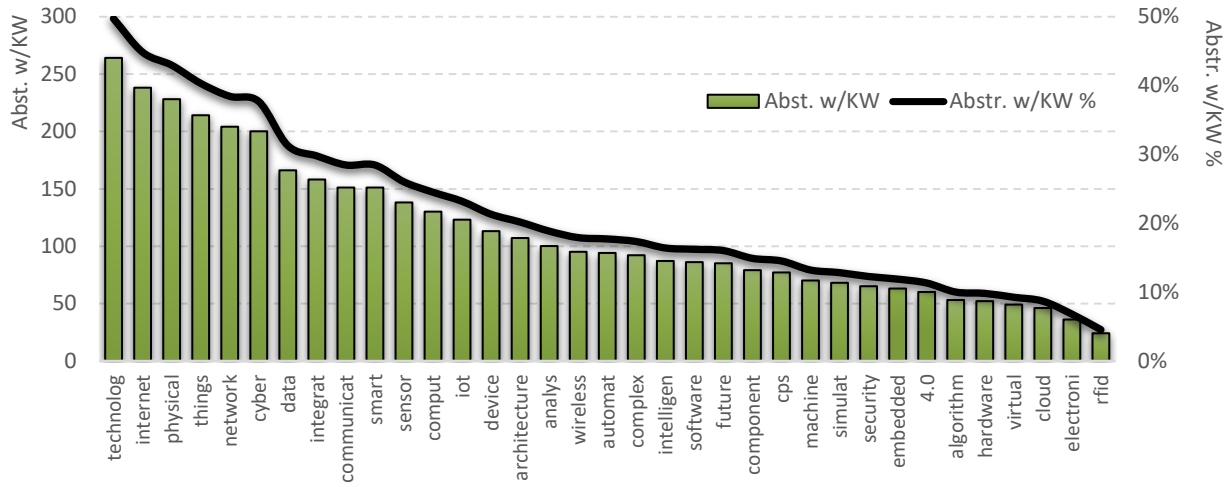
This web tools retrieve a report with the occurrence of each word. The most common word among all abstracts is “system” with 1324 occurrences and it appears at least one time in the 75% of the abstracts (word count is case-insensitive).

The list of words, without stop words, is the source of keywords. The majority of these words share similar root. Therefore, the keywords are the root of the words in relation with this research. There are a total of 73 keywords relevant for the research. The keywords exclusive to the topic i4.0 are 35. The keywords related with the promise of lean are 38.

These keywords appear at least one time in some abstracts. The exploration of the keywords on the topic Lean shows that the number of abstracts including the keyword “process” is 40% of the total number of abstracts. In the other side, just 1% of the abstracts

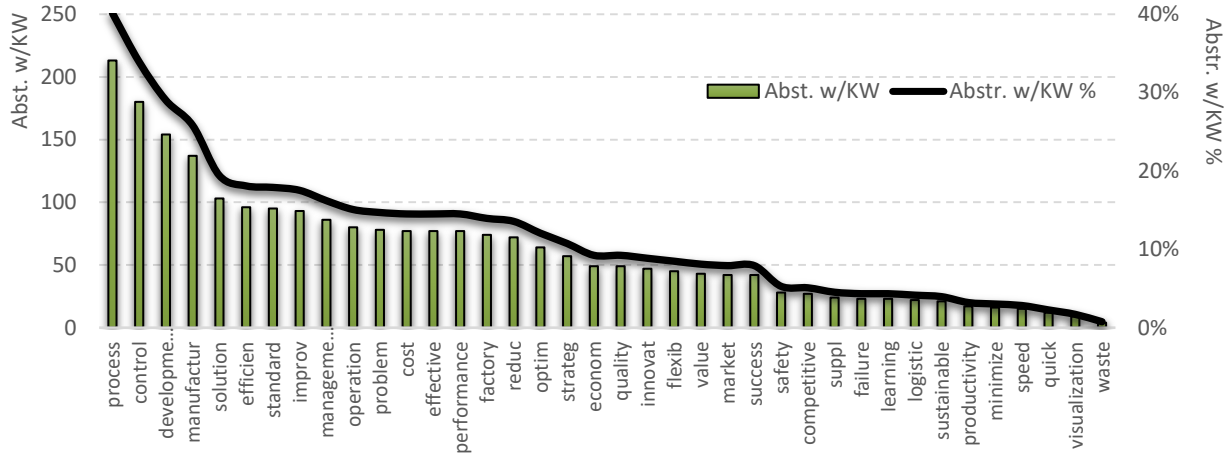
include the keyword “waste”. Similar, the analysis of the keywords on the topic i4.0 illustrates that the keyword “technolog*” appears in 50% of the abstracts while just the 5% of the abstracts include keyword “RFID”.

Fig. 1: Abstracts with the keyword - Topic i4.0



Source: Authors

Fig. 2: Abstracts with the keyword - Topic Lean



Source: Authors

The numerical value of the correlation coefficient is low and insufficient for the vast majority of keywords combinations among the topic of lean. The keywords “reduc” and “cost” has a correlation coefficient of 0.35. The correlation coefficient for the keywords “quality” and “manufactur” is 0.34. Tis coefficient for the words “market” and “improve” is 0.29. The keywords “waste” and “process” has a correlation coefficient for only 0.24. The

topic i4.0 presents higher and acceptable correlation coefficients. The keywords "internet" and "things" have a correlation coefficient of 0.80. It is follow by the combination "cyber" and "physical" with 0.67.The correlation coefficients of the keywords from both topics reveal the keyword "communicat*" and "market" with 0.43 and the keywords "4.0" and "productivity" with 0.33.

The regression analysis using the percentage calculated from the keywords in the abstract over the total of words in the topic reveals that the relationship between the variables is statistical significant (p = 0.000). There is 3.39% of the variation of Lean accounted for the regression model. The fitted model is linear. There is a negative correlation of 0.19 between both variables.

Moreover, the regression analysis using the percentage calculated from the keywords in the abstract over the keywords in the topic indicates same statistical significant (p = 0.001) and 2.54% of the variation of Lean accounted for the regression model. In this case, the fitted model is cubic. The following formula describes the model:

$$Y = 0{,}07198 + 0{,}6836\ X - 3{,}221\ X^2 + 4{,}758\ X^3 \qquad (1)$$

Moreover, the coefficient correlation for a linear regression of the data is 0.11. The percentage of variation accounted for this linear model is 1.08% and the relationship has statistical significance (p = 0.010).

Conclusion

There are three main words that describe Lean management: Value, Waste and Continuous Improvement. The findings show that these words have 26% of total occurrence among the abstracts. Additionally, the keywords "process" has the highest frequency among the words in the abstracts. This might be considered like a sign of Lean inclusion into i4.0.

Moreover, the low correlation coefficient between the different keywords doubts the acceptance of a relationship between the two topics. The only coefficient with significant relevance combines the keywords "internet" and "things". This confirms that the abstracts are related with the topic of i4.0 but it is not an evidence of Lean.

The regression analysis based on the calculation between keywords in the abstract over total words in the abstract reveals a negative correlation. The linear regression model based on the calculation between keywords in the abstract over keywords in the topic has a positive correlation coefficient but still low. Moreover, the fitted cubic regression model

introduces the possibility to confirm the hypothesis. The abstract with higher i4.0 content is best related with lean.

Nevertheless, the majority of findings show a lack of correlation among both sets of data. This indicates that the current body of knowledge on i4.0 has low or non-relation with the topic Lean. These findings radically reject the hypothesis of this research. It seems that a publication with high relationship with the topic i4.0 has lower relationship with the topic of Lean. Moreover, the low correlation coefficient also prevented from reaching this conclusion.

Further research is necessary to evaluate the inclusion of Lean in this new revolution. The review of the lean tools proposed by Frison (2015) determines a case studies research approach. Moreover, it is necessary to explore the possibilities of Lean beyond this approach. The inclusion of these cases in the formal body of knowledge corroborate that the i4.0 needs Lean to constantly develop solutions ahead of these discontinuous innovations.

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References

Adriaanse, L., & Rensleigh, C. (2013). Web of science, scopus and google scholar A content comprehensiveness comparison. *Electronic Library , 31* (6), pp. 727-744.

Baur, C., & Wee, D. (2015, 06). *Manufacturing's next act.* Retrieved 04 24, 2016, from McKinsey & Company: http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act

Frison, A. (2015). *Impact of Industry 4.0 on Lean Methods: and the Business of German and Chinese Manufacturer in China.* Frison Anton.

Haigh, T., Russell, A. L., & Dutton, W. H. (2015). Histories of the Internet: Introducing a Special Issue of Information & Culture. *INFORMATION & CULTURE , 50* (2), 143-159.

Hines, P., Holwe, M., & Rich, N. (2004). Learning to evolve: A review of contemporary lean thinking. *International Journal of Operations and Production Management , 24* (10), pp. 994 - 1011.

Islam, S. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K.-S. (2015). The Internet of Things for Health Care: A Comprehensive Survey. *IEEE ACCESS , 3*, 678-708.

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014, 08). Industry 4.0. *Business & Information Systems Engineering* (4), pp. 239 - 242.

Manyika, J., Chui, M., Bisson, P., Woetzel, J., Dobbs, R., Bughin, J., et al. (2015). *THE INTERNET OF THINGS: MAPPING THE VALUE BEYOND THE HYPE.* McKinsey & Company.

Mayring, P. (2000, 04). Qualitative Content Analysis. *Forum : Qualitative Social Research , 1* (2).

Perez, C. (2010, 01 01). Technological revolutions and techno-economic paradigms. *Cambridge journal of economics* (1), pp. 185 - 202.

Rashid, M. A., Sayin, E., Oureshi, H., Shami, M.-u.-D., & Khan, N. (2011). ERP-communication framework: Aerospace smart factory & smart R&D campus. *International Journal of Computer Science and Information Security* (7), pp. 116-123.

Temple, N. (Performer). (2016, 04 12). *The smart factory and the converging roles of IT, production and engineering.* Smart IoT London 2016, ExCel, London, UK.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The Machine That Changed the World: The Story of Lean Production.* New York: Rawson Associates.

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