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LEAN APPLICATIONS: A SURVEY OF PUBLICATIONS WITH RESPECT TO SOUTH AFRICAN INDUSTRY

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ABSTRACT

South African industry faces immense global competition from developed countries such as Germany probably because of the adoption of lean manufacturing techniques by the latter. This study is a survey on publications concerning implementation and adoption of lean manufacturing in South Africa. To assess South Africa with regards to research publications on lean manufacturing, a benchmark exercise was conducted with Germany for the period 2014 to 2015. The study concludes by highlighting the gaps identified during this survey and recommendations.

OPSOMMING

Die Suid-Afrikaanse industrie staar hewige globale mededinging vanaf ontwikkelde lande soos Duitsland in die gesig, waarskynlik as gevolg van die aanneming van lenige vervaardigingstegnieke deur die laasgenoemde. Hierdie navorsing is 'n beskouing van die publikasies oor die implementering en aanneming van lenige vervaardiging in Suid-Afrika. Om Suid-Afrika te beoordeel aan die hand van navorsingsuitsette met lenige vervaardiging as die onderwerp, is 'n maatstaf oefening uitgevoer met soortgelyke publikasies in Duitsland in die periode van 2014 tot 2015. Die navorsing lig die gapings só geïdentifiseer uit en maak aanbevelings hieroor.

1 INTRODUCTION

The expansion of the South African Mining Industry in 1880s due the discovery of diamonds in Kimberly and gold in Johannesburg [11] created a demand for skills which led to the establishment of local academic and technical institutions. Year 1882 saw the conception of South African Association of Engineers and Architects [13] which was replaced by South Africa Association of Engineers in 1902 [49]. The establishment of the Union of South Africa in 1910 brought the refinement of the organisation to South African Institution of Engineers. The institution advocated for the enactment of South African Council for Professional Engineers, the act was passed in 1968 as Act 81of 1968 [13]. University of Pretoria was the first to offer graduate course in Industrial Engineering in 1961 and in 1975 the department of Industrial and Systems Engineering was established at the university [18]. Year 1986 brought South African Institute of Production Engineers; and Southern African Institute of Industrial Engineers was formally launched in 1981 [49]. The contribution of Industrial Engineers in modern industry is undisputed; and the success story of Toyota Motor Corporation [31] is a witness to the claim. Toyota philosophy of integrating complex manufacturing systems which consist of people, production equipment, time and money is a distinct referral point in terms of success within the Industrial Engineering discipline. Implementation of lean manufacturing system in United States of America (USA), Japan [20], India [16] and Germany is very popular; and a self-introspect survey is necessary to diagnose South Africa's weaknesses and outline areas of successes. This study is a survey on the publications concerning the application of Lean Manufacturing (successor of Toyota Production Systems) in South African Industry. The aim is to establish the level of implementation and adoption of lean manufacturing in South African industry based on published research. To establish the level of implementation of lean manufacturing in South African industry the following objectives were perused:

a) To determine the trends concerning the research work on lean manufacturing in South African industry
b) To identify the gap in terms of the application of the technique in South Africa

2 METHODOLOGY

A literature collection method employed for this survey is described in Section 2.1. Section 3 shows results of the conceptual and empirical aspects of the identified literature. A sub section in Section 3 is dedicated for benchmarking the publications for South African industry against Germany industry. This then revealed the disparities between the two countries and recommendations for South African industry is imbedded in conclusion section.

2.1 Systematic literature review methodology

Systematic literature review methodology is used to gather and analyse a vast amount of research studies and publications concerning a specific subject to answer predefined questions by integrating the empirical evidence from all relevant studies [57]. Multiple publications have been produced concerning the application of lean in manufacturing and service industries and this study seeks to gather and analyse publications focused on the application of lean manufacturing in South African Industry to understand trends in applications of lean manufacturing. This section describes in detail how the review was conducted and a summary of the methodology is shown in Table 1.

Table 1: Systematic Literature Review Methodology

Stage	Steps	Accomplished objective	How was it accomplished	Where it is presented
1) Planning the review	a) Review specification	a) Research questions development b) Selection of data sources c) Search terms definition	Determined the objectives of the study. The search term used was.	Section 1 and Section 2.1.1
2) Conducting the Review	a) Identification of the research	a) Identify publications on the application of lean manufacturing in South African industry	A total of 638 studies was yielded from the initial search	Section 2.1.2
	b) Study selection	a) Analysis of studies to ascertain the applications of lean methodology	Only 32 publications qualified for the survey after the removal of duplicates and non-relevant publications	Document progression is in Section 2.1.2 with full list in Appendix 1
3) Evaluation	a) Data extraction and analysis	a) Determine the trends in terms of research on the application of lean manufacturing in South African industry	To identify disparities with developed nations a benchmark exercise was conducted against publications for Germany Industry	Section 3

2.1.1 Data sources and data collection

To fully understand the demography of lean manufacturing in South African industry the author(s) conducted a systematic literature review on Scopus and Web of Science search engines. To avoid an ad hoc list of publications, the search filters was set on South Africa (Territory), 1970-2015

(Publication Year) and Article and Conference Paper (Document Type). Table 2 shows the search terms and the results yielded from the primary search using article title, abstract and keywords as the search fields.

Table 2: Initial Search Results

Search Terms	Search Field	Scopus	Web of science
Lean Manufacturing	Article tittle, Abstract, Keywords	24	17
Lean Applications	Article tittle, Abstract, Keywords	22	20
Lean	Article tittle, Abstract, Keywords	288	267

2.1.2 Data selection

The 638 publications reaped in the primary search were subjected to a rigorous examination to ascertain if the publication perfectly fit for the final review. The initial criteria measure was to check if the publication was in any way related to lean manufacturing. The vetting process was accomplished by checking the relevance of the tittle of the publication with respect to applications of lean manufacturing. In case of any uncertainty of relevance of the tittle, the abstract of the publications was investigated. In this preliminary vetting process 490 publications were eliminated from the sample list. The second evaluation procedure was to check if there were no duplicates across the publications list and 60 duplicates were removed from the list. Another 46 publications were eliminated from the list because they were irrelevant to the scope of the study. The last selection criteria were to check if the geographical focus of the study was South African industry and six publications were eliminated upon this criterion with an additional of four publications removed because they were inaccessible. A final data set of 32 publications was collected and the document progression during the publication selection process is shown in Figure 1.

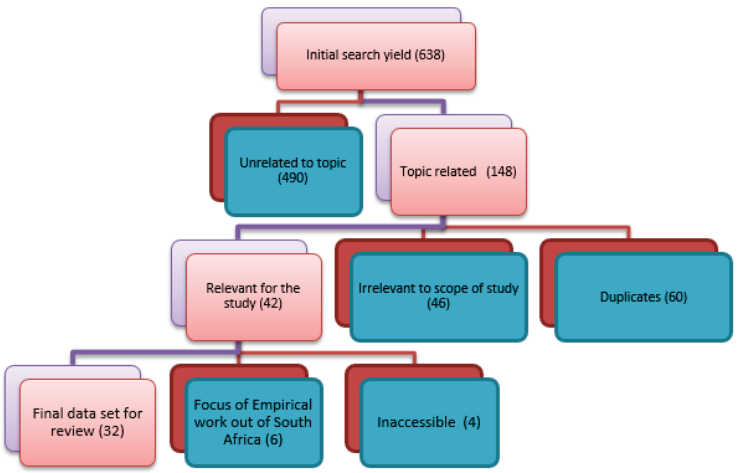

Figure 1: Document Progression

2.1.3 Data extraction and analysis

Intensive reading and assignment of specific codes and data categories to publications aspects was individually accomplished by the author. For each publication, conceptual aspects and empirical aspects were extracted and their respective sub components of interest are shown in Table 3. The year of publication, type of publication and publishing institution were captured to understand the context of the research work. Development of trends concerning the application of lean methodology was developed according to industrial domains, industrial sub-sectors and manufacturing layout strategies. Results of the analysis phase are clearly documented in Section 3.

Table 3: Data Extraction Categories

Conceptual Aspects	Empirical Aspects
• Document file name • Title of the document • Type of document (e.g. Journal or conference) • Year published • Published in (e.g. Journal name, conference name) • Authors • Geography of authors (country of affiliation) • Affiliations • Abstract • Lean tools applied (e.g. kanban, kaizen) • Framework for application of lean principles	• Focus of study • Industrial Domain (manufacturing or services) • Industrial sub sector (e.g. beverage, construction) • Manufacturing System (e.g. line, batch, continuous) • Conclusion

3 RESULTS AND DISCUSSION

This section shows the empirical and conceptual aspects of publications on applications of lean manufacturing in South African industry. It is crucial to highlight that the scope of the study was restricted to research work whose empirical boundary is within the confinements of the geographical boundary of the Republic of South Africa. A total of 32 papers for South African industry were published as shown in Figure 2 from 1989 to 2015.

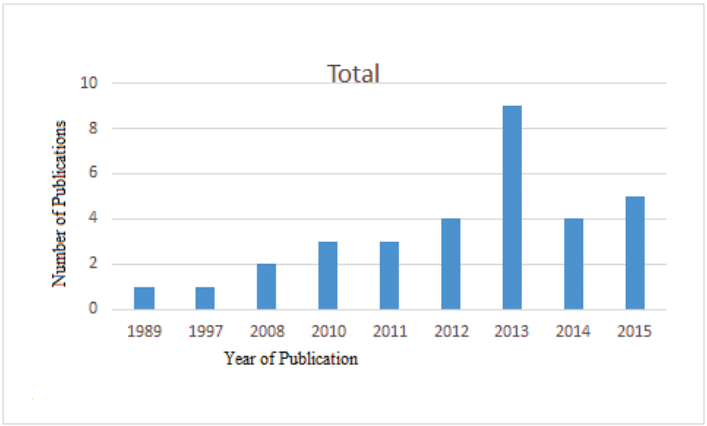

Figure 2: Lean Manufacturing Research Output Chronology for South Africa

The papers were published by different institutions as shown in Table 4, with a total of 12 journal articles and 20 conference papers (proceedings) to give a total of 32 publications.

The application of lean manufacturing was divided mainly into two industrial domains which are the production of goods (manufacturing) and services. Publications on manufacturing contributed 66% and 25% of the publications were from the service sector and 9% of the publications encompassed both sectors and was classified under generic category as shown in Figure 3. With reference to Figure 3, lean manufacturing is being slowly adopted into the service industry though the technique originates in manufacturing industry. Its application in the service sector is gradually increasing [26] due the immediate benefits of waste elimination.

Table 4: Publication Publishers

Studies published	Number of Studies
Journal Article	**12**
African Journal of Business Management	1
International Journal of Industrial Engineering	1
Journal of Manufacturing Technology Management	1
Learning Organization	1
South African Journal of Industrial Engineering	8
Conference Proceedings	**20**
2012 Proceedings of PICMET '12	1
2013 Proceedings of PICMET '13	1
2014 Proceedings of PICMET '14	2
2015 Proceedings of PICMET '15	1
IAMOT 2015 - 24th	2
Proceedings - 2010 IEEE 17th	1
Proceedings of IGLC16: 16th	1
Proceedings of CIE	3
SAIIE Conference proceedings (2009-2014)	8
Grand Total	**32**

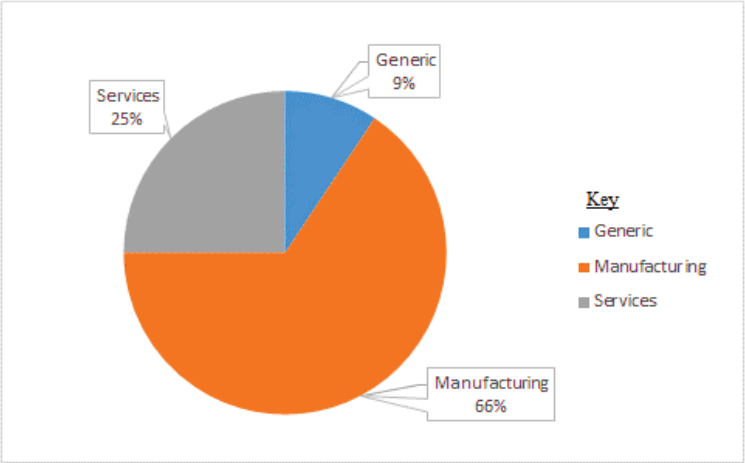

Figure 3: Industrial Domain (see online version for colour image)

The technique has caught much attention in automotive enterprise management [47] [38] [33] [8] [39] [54], food processing & beverages [41] and assembling of electronic components [52] as shown in Table 2. There has been much interest towards improving the public health care service delivery system [34] [29] and education system [22], [21], [5] throughput. Also in the rail [51], and road transport activities [23] lean tools have been implemented. Notably is the absence of key industrial activities [50] from Table 5 which include iron and steel production, foundry work, airline industry, hotel and catering services.

Absence of publications (in Table 5) on the application of lean in iron and steel production and limited publications on application of lean manufacturing in construction, mining and mineral processing may be due to the perception on the origins of lean manufacturing. Lean manufacturing originates from Toyota Production system which was initially aimed at improving assembly line production systems [2]. This explains the trends observed in Figure 4, where focus of published research has been directed mainly on batch manufacturing (31%) and line production (38%) which contributes 69% of total publications under the manufacturing domain. Ras & Visser [43] echo that the absence of lean manufacturing (continuous improvement methodologies) systems in mines is due

to the continuous operative nature of the system in which stops and start-ups are only limited to maintenance activities. There is a general voice from researchers advocating for application of lean techniques in any form of activity which include non-profit organisations' operations [4], information technology [26] and accounting services [7]. Despite Lean philosophy being an emblem of Industrial Engineering, the technique is yet to be fully adopted into the South African industry even though the discipline of Industrial Engineering had been existent in the country since 1961 [45].

Table 5: Industrial Sub sectors

Domain & Sub-sector	Manufacturing system	Number of publications
Generic		**3**
Generic		3
Manufacturing		**21**
Assembly (Electronic Components)	Batch	1
Automotive (Product Engineering & Design, Part manufacturing)	Line, Supply chain, product design	6
Beverage & Food Processing	Line	3
Biomedical (orthopaedic implant manufacturing)	Job Shop	1
Construction (Road & Earthworks)	Project	1
Fabrication	Job Shop	1
Forge Shop	Job Shop	1
Generic		4
Mining & Mineral Processing	Continuous	1
Textile (clothe manufacturing)	Batch	2
Services		**8**
Education		3
Generic		1
Health		2
Transport		2
Grand Total		**32**

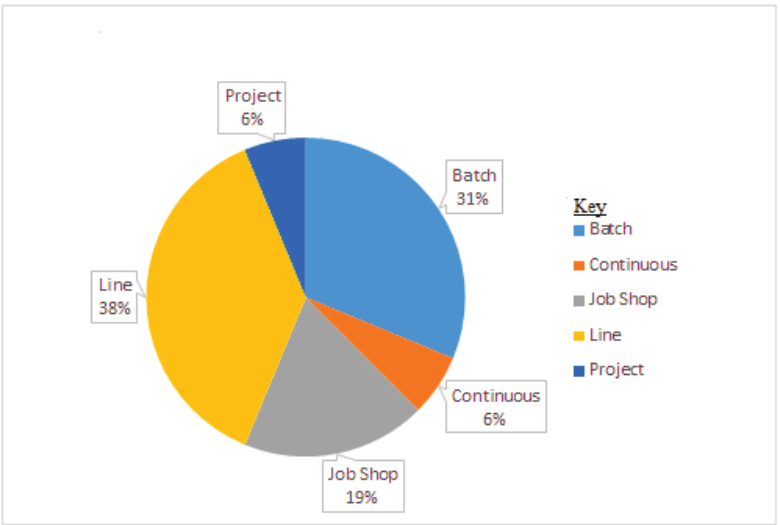

Figure 4: Publications with respect to layout strategies (see online version for colour image)

To determine the implementation and concept adoption of lean principles from the publications in South Africa, the study embarked on a benchmarking process against publications on lean manufacturing for Germany. Germany was selected due to strong bilateral relations between South

Africa and Germany, and research collaborations between the two countries. The authors used Scopus database web search engine to gather publications, and using “lean manufacturing” as the search term the initial search results reaped 224 publications. After a thorough screening process, 163 publications were found to be within the confinements of lean manufacturing. The publications’ quantity was too much for benchmarking process, the authors then streamlined the publications to a specific timeline of 2014 to 2015. A total number of 22 publications listed in Appendix Table 2 were used to rate publications from South African industry produced within the same time frame. The benchmarking process focused on the objective of the studies which gives the description of the actual research work [53]. The “objective” benchmarking results are documented in Table 6.

Table 6: Benchmarking objectives of Publications: South Africa and Germany (2014-2015)

South African Publications	Germany Publications
1)The ultimate aim of this exercise is to develop a theoretical lean culture causal framework [54] 2) The project objective is to improve the changeover performance of the 1600-ton forge [9] 3)This research project therefore aimed to develop a new continuous improvement model or technique that could be applied successfully to any minerals beneficiation plant [43] 4)To analyses the extent to which production of defective parts, overproduction, excessive inventory, unnecessary production steps, unnecessary movement of people, workers waiting for material and unnecessary handling of material affect the attainment of lean supply chain [6] 5)The objective of the study herein was to analyse and verify the impact that could be realised to the operational performance when these two concepts are implemented jointly [39] 6)The purpose of this paper is to explore the extent to which principles of lean product development are applied to product design and engineering at automotive companies in South Africa [38] 7)The objective of this paper is to highlight that 5S principles are fundamental to the workplace and to indicate that the monetary value of waste across the spectrum is insurmountable [42] 8)Lean Application in Student Finance Department within a Learning Institution Can Lead to High Academic Throughput [22] 9)Lean Implementation in the Gauteng Public Health Sector [29]	1) Investigates the effects of erratic demand on the performance of Pull Production Control Strategies [40] 2) To give an overview over existing combinations of Lean Production and automation technology, also called Lean Automation [27] 3)Development of different strategies for handling delivery peaks and evaluate them with respect to delivery cost, lead time and service level using real material consumption data from two large companies from automotive industry [25] 4) This paper presents a simulation based approach for monetary assessment of lean and green manufacturing systems considering non-monetary green limits [15] 5)This study aims to (1) Consolidate critical success factors (CSFs) for the implementation of Lean Management of IT organizations; and (2) Describe a theoretical foundation for these CSFs [26] 6) Evaluating the Effects of Energy Productivity Measures on Lean Production Key Performance Indicators [44] 7) Institutional and cultural barriers to transferring Lean production to China: Evidence from a German automotive components manufacturer [55] 8)To use shop floor management as a facilitator for competency development in production environments the problem resolution cycle known from lean production is picked up and thoroughly analysed regarding the integration of competency development [17] 9) This article presents an overview on sustainability issues with Lean paradigm perspective in Print Circuit Boards (PCB) assembly and resource consumption showing their structure and materials, legislation issues on material and production, and the alternative solutions for the recent green innovations and production of PCBs [10] 10) Selecting improvement measures for discrete production environments [12] 11) The purpose of this paper is to explore job design mechanisms that enhance team proactivity within a lean production system where autonomy is uttermost restricted [30] 12) The purpose is to clarify the role of the autonomy in compliance with the lean and agility goals [35] 13)Investigating existing analytical methods for measuring work to enable low cost automation [36] 14) The paper describes the state of the art for CIP-concepts as well as the Transformation-Waves in detail. It is validated that they are a very helpful brick for a sustainable vitalization and evolution of the Lean Production System [19] 15)This study focuses on the development of a framework that facilitates the systematic design of workshops focused specifically on the introduction of Lean principles and practices to program management and the professional workforce in a program environment [14] 16)To train lean management, resource efficiency as well as management and organization improvement skills [28] 17)This study investigates the general framework of the decisions in in-plant milk run systems, and also the other related decisions that affect or affected by milk run systems [1] 18)Integration of Case Hardening into the Manufacturing-Line: “One Piece Flow” [32] 19)This paper will present "digital Kanban"; a method to dynamically allocate the best possible match of excavators and transport vehicles at earthwork construction sites [24] 20) This paper presents two methods of dualising the time and energy consumption in the plastic injection moulding process [37] 21)This paper analyses the main aspects of the widely used "value stream design method" usually only applied within a single company, in the following called "local" [48] 22)This paper addresses the very current issue regarding the increase production flow efficiency by eliminating waste from the system, using Lean Manufacturing techniques [36]

Majority of publications from South Africa (2014-2015) aim to develop frameworks [54], models [43] and application of basic lean tools [9] [6] [41] [22] [29], whilst Germany publications (2014-2015) focus on tailor suiting lean principles to perfectly fit local industries [40] [25] [1] [32] . There is much more interest from German to embrace and combine lean manufacturing as an environmental conscious production system [15] [44] [10] which seeks to optimise the use of raw materials and minimise the amount of process wastes into the environment whilst other researchers in South Africa focus on applying lean principles in product design [38] and mineral processing [43], sectors in which lean manufacturing is perceived as alien. Another key missing element from the South African sample is research concerning effective training methods for management and staff on lean practices in organizations to increase their competency levels with regards to lean manufacturing as displayed by Germany publications [28] [17]. Data gathered from Germany indicates that out of the 22 publications sampled, more than 70% of the publications were aimed at improving the adoption and efficiency of that concept(s) whilst more than 55% of publications from South Africa focused on implementation of basic lean tools and framework development as shown by Figure 5. This indicates that implementation of lean manufacturing in South African industry is at the infancy stage and a wide gap exists between South Africa and Germany with respect to research on lean manufacturing and publications available in the public domain.

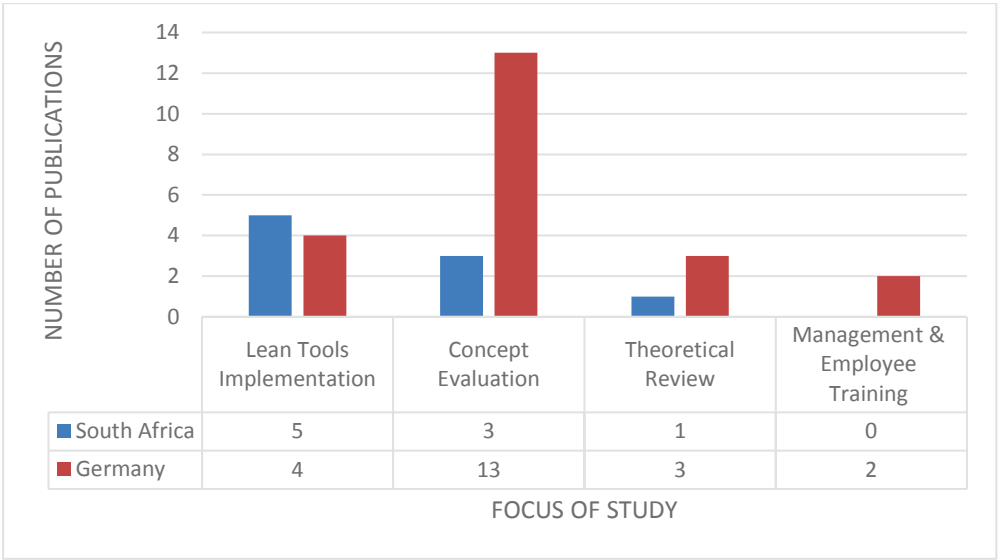

Figure 5: Benchmarking Analysis (2014-2015) Publications (see online version for colour image)

Results from this study ascertain also the sentiments by Liker [31] that most organisations (in South Africa) think they are lean by just implementing lean tools without considering the other aspects of the philosophy. Focusing on lean tools alone degenerates the objective of implementing lean philosophy which is anchored upon promoting cultural enablers [46] which focus on humility and respect for every employee. Organisations achieve this through ethical leadership that foster staff development by facilitating training and coaching. This will empower employees to be innovative on waste elimination tactics on the production line. Continuous improvement processes will then be achieved through implementation of lean ideas (tools), value stream mapping and support processes [31]. Employees or production staff will now have to strive for perfection whilst production is pulled by customer demand. Though perfection seems unattainable, striving for perfection will make the organisation dock on excellence. Organisations should be consistent when it comes to lean philosophy and lean enterprise thinking, policies should be deployed to maintain standard practices. It is through implementation of lean manufacturing as a culture that the organisation will reap meaningful financial benefits, improved product quality and a disciplined and skilled work force.

4 CONCLUSION

The survey conducted displays the trends on publications about lean manufacturing with respect to South African industry. The benchmarking process between South Africa and Germany publications on lean manufacturing displays a huge gap in terms of embracing and implementing the technique.

A wider gap exists specifically on publications that focus on expansion and evaluation of lean concepts as shown in Figure 5. Focus should be directed to exploration of effective learning and training channels for management and production staff to embrace lean philosophy as part of the production culture. Though Industrial Engineers have been present in South Africa for more than 50 years [49] [45], application of lean manufacturing is at infancy level. This is a waste of not fully exploiting Industrial Engineering skills and contributions (human capital waste) [3] [31] in the local manpower nexus. The implementation and adoption gap between Germany and South Africa can only be reduced or eliminated when academic institutions and research centres consider and allocate funds for further research in lean manufacturing. The transition in continuous improvement systems can be facilitated in five phases [54]. The first phase being application of basic lean tools in an unstructured manner of which this level has been attained as displayed by the results of the survey with 55% focusing on the application of basic lean tools. Transformation to the second level is obtained if every worker is made aware of the need to eliminate waste and a structured system for waste elimination is implemented. Level three is possible if strategic management imbed waste elimination as part of company's strategic objectives. Level four is attained when the organisation adopt a proactive approach to process waste elimination and the responsibility of waste elimination is given to line workers and production teams. Full capacity, level five is attained when the organisation adopt a learning behaviour approach. A learning organisation state is reached when the organisation implement proper learning systems in place for its workers and waste elimination is done systematically. It can be safely concluded that there is no systematic research in terms of application of lean manufacturing specifically on the following key economic activities in South Africa [50]: mining and mineral processing, iron and steel making, construction, hotel and catering services.

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