

Braga

ELEC 2018

14-15 November

Lean Educator's Role in Lean Development
Proceedings of the 5th European
Lean Educators Conference



TITLE

Proceedings of the Fifth European Lean Educator Conference (ELEC2018)
"Lean Educator's Role in Lean Development"

EDITORS

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Anabela Carvalho Alves
Nelson Costa
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Hotel Vila Galé, Braga, Portugal, 13-16 November 2018

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ISBN 978-989-20-9274-4

To cite:

Dinis-Carvalho, J., Alves, A. C., Costa, N., Lima, R. M. and Sousa, R. M. (2018). Lean Educator's Role in Lean Development. Proceedings of the Fifth European Lean Educator Conference (ELEC2018), 14-15 November, Braga, Portugal.

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Programme

		Conference Day 1 14-nov	Conference Day 2 15-nov
From	To		
08:00	09:00	Check In	
09:00	09:15		Daniela Kudernatsch (Kudernatsch Consulting & Solutions) (Hoshin Kanri – an approach for integrated strategy execution)
09:15	09:30	Welcome and programme overview	
09:30	09:45	Pascal Pollet (Sirris) (New Perspectives on Lean Education)	Jorge Ferreira (IKEA Industry) (The water in the fish tank)
09:45	10:00	Euclides Coimbra (Kaizen Institute) (The Evolution of Kaizen Lean to a Full Management System)	Carlos Ribas (Bosch) (Consistency and stability of continuous improvement)
10:00	10:15		
10:15	10:30		
10:30	10:45	Break	Break
10:45	11:00		
11:00	11:15	Jannes Slomp (HAN University of Applied Sciences) (Appreciating the Value of Goal-oriented Sequential Dependencies)	Parallel Sessions, round 3
11:15	11:30	Isao Yoshino (Toyota) (Hoshin Kanri & Kan-Pro & A3)	
11:30	11:45		
11:45	12:00		
12:00	12:15	Round table discussion	
12:15	12:30		
12:30	12:45		
12:45	13:00	Lunch	Lunch
13:00	13:15		
13:15	13:30		
13:30	13:45		Monica Rossi (Politecnico di Milano) "The Lean Educator's Mashup"
13:45	14:00	Parallel Sessions, round 1	John Bicheno (University of Buckingham) "Platforms, Pirates, Parkinson, Potent Technologies"
14:00	14:15		
14:15	14:30		
14:30	14:45		
14:45	15:00	Break	Break
15:00	15:15		
15:15	15:30		John Y. Shook (Lean Enterprise Institute) "The Past, Future and Current States of Lean Thinking"
15:30	15:45	Parallel Sessions, round 2	
15:45	16:00		
16:00	16:15		
16:15	16:30		Closing
16:30	16:45		
16:45	17:00		
17:00	17:15	John Y. Shook & Isao Yoshino (Moderator: Joakim Hillberg) "Developing Lean Thinkers – Lessons from Toyota"	
17:15	17:30		
17:30	17:45		
17:45	18:00		
19:00	20:00	Networking Dinner	
20:00	21:00		
21:00	22:00		



Paper Sessions

Parallel Session 1				
14/nov		90min		
Topic University – Industry Collaboration				
Room Viana do Castelo Session chair: Anabela Alves				
Paper	Title	Speaker	Tempo	
22	University and Spin-off Cooperation Fosters the Technology Transfer to Industrial Companies	Paulo Peças		
41	The new Brazilian legal framework of science & technology, and its role as an inductor of the introduction of lean processes in micro and small enterprises	Sicy Melo		
79	A3-thinking in student projects and its impact on developing continuous improvement in industrial practice	Gerlinde Oversluize	18+4	
31	Lean School: an example of industry-university collaboration	Jose Antonio Pascual Rua		
Topic Sustainable Lean Manufacturing: factors of success and problem solving strategies				
Room D.Afonso Henriques Session chair: Helena Navas				
Paper	Title	Speaker	Tempo	
66	Lean leadership: systematic literature review	Susana Duarte		
32	Why developing supervisors' TWI skills is fundamental for your Lean Journey?	Agata Pawlukoic		
50	The Problem with 'Tools and Techniques'; Why Becoming a 'Learning Organisation' is Vital to a Successful Lean Transformation.	Graham Canning	18+4	
77	Triz as a support methodology for new product development	Helena Navas		
Topic Lean Training				
Room Braga Session chair: Rui Sousa				
Paper	Title	Speaker	Tempo	
54	Teaching and Implementing Lean Construction in the Construction Industry.	Janni Tjell and Kajsa Simu		
36	Implementation of Lean Development in industry	Sebastian Allegretti		
7	How Geographic and Cultural Factors Influence Lean Training & Implementation	Maria Pia Caraccia and Jo	18+4	
35	Effectiveness of a Lean Simulation Training: Challenges and Insights into Different Didactical Concepts	Martin Adam		
Topic Approaches to Lean				
Room Guimarães Session chair: Rui Lima				
Paper	Title	Speaker	Tempo	
2	Big Lean Deployment : A comparison of 3 different approaches across 3 multinational organisations	Neil Trivedi		
	Lean Global Network: A global network of sharing, collaboration and development	Sérgio Caldeirinha	25+5	
12	Strength-based lean: a different way	David Shaked		
Parallel Session 2				
14/nov		75min		
Topic Value Flow and Process Mapping				
Room Braga Session chair: Rui Sousa				
Paper	Title	Speaker	Tempo	
23	Industrial Case Study based on Master Thesis as a way to develop New Lean applications – The case of Material Flow Cost Accounting combined with Lean-b	Helena Cecilio		
27	Improving the physical arrangement of Production line through value stream mapping: a contribution of the company's effective lean culture	Joaquim Craveiro	20+5	
46	A Game for Process Mapping in Office and Knowledge Work	Rui Sousa		
Topic Lean Games				
Room D.Afonso Henriques Session chair: Carina Pimentel				
Paper	Title	Speaker	Tempo	
59	Experience based recommendations for the development of serious games	Ignace Martens		
78	Lego Serious Play as a Business Innovation enabler	Mandy Tawalbeh	20+5	
16	Capital Flow Design – Management Accounting's Role in a Lean Enterprise	Mathias Michalicki		
Topic Lean Training				
Room Viana do Castelo Session chair: Rui Lima				
Paper	Title	Speaker	Tempo	
3	A proposal for developing competencies through lean culture for maintenance teams.	Marcelo Oliveira		
28	Train the Trainer – what does it really mean?	Frida Egerlid	20+5	
68	Different approaches to teach LEAN	José António de Sousa Ba		
Topic Lean at Universities				
Room Guimarães Session chair: Anabela Alves				
Paper	Title	Speaker	Tempo	
20	Lean Education: what academy know and what importance they give to it?	Anabela Alves		
53	The future of Continuous Improvement	Ton van Kollenburg	20+5	
21	Lean Divestment: the Lean Into Our Future (LIOF) Programme at Roche Clarecastle	Mark Fillingham		



Parallel Session 3

15/nov

90min

Topic	Detecting and Elimination Muda		
Room	Guimarães Session chair: Anabela Alves		
Paper	Title	Speaker	Tempo
4	Application of lean education for the elimination of waste in a company of the stamped products sector	Gustavo Guimarães	18+4
6	Towards Reducing Queues: Muri, Mura, Muda	John Bicheno	
55	A New Approach to Developing Lean Understanding in Higher Education	Ralph Kriechbaum	
49	Monitoring and controlling real-time production using waste identification diagram	Rogério Santos Menezes	

Topic	Industry 4.0		
Room	Viana do Castelo Session chair: Carina Pimentel		
Paper	Title	Speaker	Tempo
11	Industry 4.0 as a way to enhance Lean Manufacturing and Six Sigma	Farid Mendonça Júnior	18+4
24	Industry 4.0-based improvement of the Lean game by using the innovative decision support system	Nikola Gjeldum	
69	Industry 4.0: Knowledge and capabilities needed for workers, middle-managers and top managers	Carina Pimentel	
81	Learning Lean in High-Variety/Low-Volume: Lessons Learned from the EuroLean project and the learning model in the Lean4.0 project	Menno Herkes	

Topic	Lean Applications		
Room	Braga Session chair: Rui Lima		
Paper	Title	Speaker	Tempo
14	Lean practices to improve the learning process and production document control: a case study.	Marcelo Pereira	18+4
80	Operations Management and Lean Production – an overview based on publications in journals	Rui Lima	
37	Application of Kaizen philosophy to increase productivity: a case study in an electronics industry	Décio Reis	
73	Improving healthcare quality in a oncology public day hospital	Julio Garcia Sabate	

Topic	Lean Games		
Room	D.Afonso Henriques Session chair: Rui Sousa		
Paper	Title	Speaker	Tempo
63	An Educational Game for Mixed Model Assembly Line Design Using Lean Concepts	Can Yukselen	18+4
67	The contribution of simulation games in learning Lean Education in students of production engineering	André Aquere	
26	Use of gamification as a tool for developing competences - a proposal of application for analysis and prevention of failures	Simone Sarges	
38	Would you like some Wine? Introducing Variants to the Beer Game	Christoph Roser	

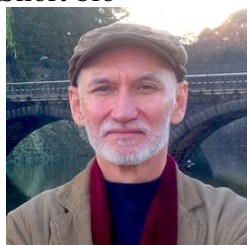
Invited Speakers

PAEE'2014 attracted renowned keynote speakers, who are experts at Lean Education and working closely with industry. We are honoured to have the following inspiring keynote speakers: **John Y. Shook** (Lean Enterprise Institute, USA), **John Bicheno** (University of Buckingham, UK), **Isao Yoshino** (Toyota, Japan), **Jorge Ferreira** (IKEA Industry, Portugal), **Carlos Ribas** (Bosch, Portugal), **Euclides Coimbra** (Kaizen Institute, Portugal), **Jannes Slomp** (HAN University of Applied Sciences, The Netherlands), **Daniela Kudernatsch** (Kudernatsch Consulting & Solutions, Germany), **Pascal Pollet** (Sirris, Belgium) and **Monica Rossi** (Polytechnic Milan, Italy). We hope their talks inspire you to do better.

John Y. Shook (Lean Enterprise Institute, USA)

Theme: Learning Lean Thinking: Past, Current and Future

Short bio



Senior Advisor and Executive Chairman, Lean Enterprise Institute
jshook@lean.org

John Shook learned about lean management while working for Toyota for nearly 11 years in Japan and the U.S., helping it transfer production, engineering, and management systems from Japan to NUMMI and subsequently to other operations around the world. While at Toyota's headquarters, he became the company's first American kacho (manager) in Japan. In the U.S., Shook joined Toyota's North American engineering, research and development center in Ann Arbor, MI, as general manager of administration and planning. His last position with Toyota was as senior American manager with the Toyota Supplier Support Center in Lexington, KY, assisting North American companies implement the Toyota Production System. As co-author of Learning to See John helped introduce the world to value-stream mapping. John also co-authored Kaizen Express, a bi-lingual manual of the essential concepts and tools of the Toyota Production System. In his latest book Managing to Learn, he describes the A3 management process at the heart of lean management and leadership. Shook is an industrial anthropologist with a bachelor's degree from the University of Tennessee, a master's degree from the University of Hawaii, and is a graduate of the Japan-America Institute of Management Science. He is the former director of the University of Michigan, Japan Technological Management Program, and faculty of the university's Department of Industrial and Operations Engineering. He is the author of "Toyota's Secret: The A3 Report"; Sloan Management Review, July 2010 and "How to Change a Culture: Lessons from NUMMI"; Sloan Management Review, January 2010, which won Sloan's Richard Beckhard Memorial Prize for outstanding article in the field of organizational development. Shook is a sought-after conference keynoter who has been interviewed on lean management by National Public Radio, Bloomberg News, The Wall Street Journal, Entrepreneur, and numerous trade publications.

John Bicheno (University of Buckingham, UK)

Theme: Platforms, Pirates, Parkinson, Potent Technologies

Short bio

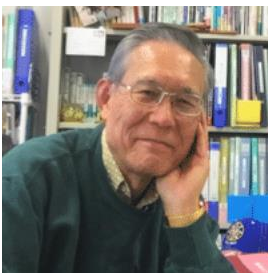


John Bicheno is Professor of Lean Enterprise at the University of Buckingham, Buckingham UK. Previously he was with the Lean Enterprise Research Centre, Cardiff, where for 12 years he was course director of the M.Sc. program in Lean Operations. He has written 11 books on lean, one of which, The Lean Toolbox, has sold over 110,000 copies.

Isao Yoshino (Toyota, Japan)

Theme: Hoshin Kanri & Kan-Pro & A3

Short bio



Isao Yoshino is a 40-year Toyota leader and spent a total of 14 years in the United States working on various projects; manufacturing, locally in Florida, water-ski boats equipped with Lexus engines, market research on stationary fuel cell equipment, etc. In 1979 and 1980, he became in charge of “Manager-Development Program”, which was a two-year company-wide program (called “Kan-Pro” in Japanese) for all the back-office managers at Toyota HQs in Japan. All managers created their own Hoshin Kanri documents using an A3 and went through a presentation two times a year (in June & December) with the officers attending for Q & A sessions. Through those two years, he witnessed all the managers reconfirm their roles & responsibilities and also relearn the importance of Hoshin Kanri. Yoshino believes the “Kan-Pro” campaign is one of the key practices that made Toyota what it is now. In 1983, Yoshino became a training manager to the shop-floor group & team leaders from NUMMI (a joint venture established in 1983 between GM and Toyota). He hired John Shook, now CEO of Lean Enterprise Institute, to prepare and run the training. Shook and Yoshino helped NUMMI to change their culture from “confrontation” to “cooperation”.

Jorge Ferreira (IKEA Industry, Portugal)

Theme: The water in the fish tank

Short bio



Jorge Ferreira is currently Unit Operations Manager at IKEA Industry Units in Portugal and China. He has more than twenty-five years' experience in international industry companies, namely in the automotive sector. Jorge has worked in areas as diverse as Human Resources management, Industrial Engineering, project management and Production Units management. In 2007 he took up the challenge of establishing IKEA's industrial group in Portugal. His daily mission is to lead people and teams in a journey that prioritizes the needs of people together with the needs of the business, through continuous improvement of performance & delivery and at the same time stimulating learning & development in such diverse backgrounds as Portuguese, Russian and Chinese contexts.

Carlos Ribas (Bosch, Portugal)

Theme: Consistency and stability of continuous improvement

Short bio



Carlos Ribas is the Bosch representative in Portugal, accumulating this function to the Plant Management of Bosch Car Multimedia in Braga. He holds a degree in electronic engineering and acquired his global executive leadership and management skills in Portugal and abroad, at Hoechst (1984-1988), Yazaki (1988-2002) and Bosch (since 2003). His strategic priorities are innovation and development of high-technology products and the sustainable increase of the activities of Bosch in Portugal.

Euclides Coimbra (Kaizen Institute, Portugal)

Theme: The Evolution of Kaizen Lean to a Full Management System

Short bio



Euclides Coimbra is a worldwide Thought Leader in Continuous Improvement. He has an extensive experience in cultural change and Kaizen Lean transformation processes. With international experience in several sectors, he has been mainly focused on the coordination and development of new areas as well as the management of large global projects. Author of the books "Kaizen in Logistics and Supply Chains" and "Kaizen: A Strategy for Improvement, Growth and Profitability".

Jannes Slomp (HAN University of Applied Sciences, The Netherlands)
Theme: Appreciating the Value of Goal-oriented Sequential Dependencies

Short bio



Jannes Slomp is Full Professor World Class Performance at the HAN University of Applied Sciences. He wrote and co-authored 44 papers in academic journals, more than 40 papers for scientific conferences, and 11 chapters in scientific books. In addition, he wrote several papers in professional journals. His interests concern lean and quick response manufacturing, automated technologies and lean product development. His research group of the HAN Lean-QRM Center consists of more than 24 scientific workers.

Daniela Kudernatsch (Kudernatsch Consulting & Solutions, Germany)
Theme: Hoshin Kanri – an approach for integrated strategy execution

Short bio



Daniela Kudernatsch founded KUDERNATSCH Consulting & Soution in 2001. Since 2008 she has been Vice President of Liker Lean Advisors, Europe. Her areas of expertise include Hoshin Kanri (Policy Deployment), Lean Management (Lean Expert), Lean Six Sigma (Master Black Belt), Lean Leadership (certified Lean Leadership Coach and KATA Coach) and Change Management. With experience from over 60 companies she accompanied companies of various sizes and industries (industry, telecommunication, automotive, logistics, insurance and finance), while also supporting the implementation of these as part of change management programs. Among those companies are Siemens, Xerox, Toshiba, ThyssenKrupp, Swisscom, Toyota Germany, Volkswagen, Mannesmann Salzgitter, AXA Versicherung, SwissRE, ADAC , DZ BANK, Sparkasse, Postbank, Credit Suisse.



Pascal Pollet (Sirris, Belgium)

Theme: New Perspectives on Lean Education

Short bio



Pascal Pollet obtained a Master's in Electrical Engineering at Ghent University. After graduating, he worked as a researcher in optical systems and imaging algorithms at KU Leuven. After a few years he made the switch to the industry, where he worked in the engineering and production departments. Pascal Pollet currently works at Sirris, the knowledge center of the Belgian technology industry, as a researcher and consultant. He is thoroughly experienced in lean manufacturing and in Quick Response Manufacturing (QRM). He also supports enterprises in drawing up their technology strategy, in fine-tuning their business models and researches the possibilities of lean product development. He currently serves as the chairman of the QRM Institute.

Monica Rossi (Polytechnic Milan, Italy)

Theme: The Lean Educator's Mashup

Short bio



Prof. Monica Rossi

monica.rossi@polimi.it

Affiliation: Politecnico di Milano Department of Management, Economics and Industrial Engineering

Since 2010, Monica has been engaged in research on lean product and process development. She has held visiting researcher positions at both Massachusetts Institute of Technology (MIT), USA and Tokyo Metropolitan University, Japan. Monica is currently assistant professor at Politecnico di Milano, Italy where she holds Product Lifecycle Management lecture and faculty member at MIP where she manages a project on Design Driven Innovation.



Workshops

An important feature of the ELEC is the extensive workshop programme. Serious games, exercises, *gemba*-based action-learning, projects approaches are fundamental for students to learn practical and deep meta-skills for lean and critical thinking. This learning tools are usually aimed at the increase of student involvement in learning, therefore, a conference like ELEC aims the same so promotes active involvement of its participants. Nine different workshops were scheduled but due to reduced registrations, three were cancelled. The six workshops presented were the ones described below.

Workshop 2 - Personal Hoshin (Isao Yoshino)

The target to attain in this workshop was to understand the key elements of Hoshin Kanri concept and establish each participant's own "personal Hoshin document" (so that they can apply it at their own worksite). The session was organized in the first half a talk about "Hoshin Kanri at Toyota" & my own "Hoshin document". In the latter half, each participant will create his/her own Hoshin document. Then they will be divided into a pair and discuss each other's Hoshin.

Workshop 3 - The Lean Games (John Bicheno and Pia Anhedo)

Games have been an integral part of Lean Education and Training ever since Hewlett Packard made their 'Stockless Production' video in 1982. Over two decades John Bicheno has been developing and refining games for all aspects of Lean and Operations Management. In 2014, John published the 2nd edition of his book *The Lean Games and Simulations Book*, which contains over 30 short games and variants covering a wide range of areas. The session includes the games: 1. Systems: the Squares Game; 2. Understanding installed capacity, pull, and flow – several dice games; 3. Understanding flow – post-it game with batching and flow; 4. Standard work – throwing airplanes; 5. Behaviour change – write your name; 6. Go to gemba; 7. Multitasking; 8. 5S numbers; 9. Kata puzzle and 10 Line balance with the 'bucket brigade' (if there is time).

Workshop 4 - Muda, Mura and Muri (John Bicheno)

The aim of the workshop is for participants to gain an in-depth understanding of the elements influencing FLOW, their interaction, why they are sometimes not appreciated, and how they form the basis for a Lean schedule. Muda, Mura and Muri workshop, the participants will have the opportunity to explore, in depth, the elements of Kingman's equation – that has been called 'The Equation of Lean' - arrival variation, process variation, demand types, load, capacity, and process time.

Workshop 5 - Lean in high-variety/low-volume organizations (Jannes Slomp and Pascal Pollet)

Quick Response Manufacturing (QRM) can be seen as a manufacturing strategy and tools for getting flow in high-variety/low-volume organizations. It is the 'lean' philosophy for companies that have to cope with a variety of customers and routings of products through the factory. Rajan Suri developed QRM and wrote the landmark book, *Quick Response Manufacturing*, in 1998. Since the publication of this book, many companies have proven the value of QRM with impressive results. In the course

of years, many researchers and educators at various (applied) universities and many QRM practitioners further developed QRM tools and methods. In this workshop, the organizers discuss the key principles and elements of QRM. Also, they explain and do exercises with some key QRM tools for the analysis of high-variety/low-volume order flows. Next, they focus on the application of QRM in companies and go deeper in the concepts of Quick Response Offices Cells (QROC) and POLCA manufacturing.

Workshop 7 - Competencies driven by Lean Education (Anabela C. Alves)

Lean Education (LE) derives from a methodology that emerged in the industry and nowadays was spread to all industries and services, including the education services, not only as a way to improve these services but, more important, as a pedagogical platform to innovate the learners curricula and better prepare them to professional world. In 2015, Anabela co-authored the book “Lean Engineering Education: Driving Content and Competency Mastery”, sponsored by Board of Education of ASME and published by ASME Press and in 2017 “Lean Education: An Overview of Current Issues” published by Springer. Both books intended to show the pertinence of professionals, engineers or others, learn Lean Thinking principles and the need to educate all people on those. The participants will have the opportunity to discuss the current professionals’ needs and competencies in teams. Each team discuss some topics such as weaknesses of current problem solving strategies (Content vs competencies, Holistic vs compartmentalized, passive vs active learning methodologies, link to industry,...), Lean Engineering concept, principles, tools and system-thinking, ethics and sustainability competencies. Then some scenarios will be provided to participants to discuss professional competencies needed for industry. It is intended to introduce the taxonomy 3H.

Workshop 9 - Training Within Industry (TWI) - fundamental skills for supervisors (Agata Pawlukojs and Franklin Fernández)

Lean has improved the competitiveness of many companies and the value they deliver to customers. Despite these achievements, many companies are stuck after their initial Lean efforts. The results are not sustained. There are many reasons for this but one of them is the lack of skills of front line supervisors. Managers and supervisors are not able to create conditions for performance in changing environment. The aim of the workshop is for participants to gain a good understanding of the Training Within Industry Program for supervisors' skill development and why TWI skills are fundamental for the success in Lean. In the "Training Within Industry (TWI) - fundamental skills for supervisors" Workshop, where you will have the opportunity to explore the 3 elements of TWI Program. You will learn about the 4 Steps of Job Relations, Job Instruction and Job Methods and how using the 3 TWI skills can help your teams, supervisors and team leaders, in achieving a better performance. You will participate in a life on job training demonstration using the JI 4 Step method and you will learn how to analyze jobs for training. You will also learn how TWI methods provide the practical application of the "Respect for People".

General Information and Services

Conference Venue

All conference sessions will be held at the Vila Galé Collection Braga.

Address:

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Email: braga@vilagale.com

Website: <http://www.vilagale.com/en/hotels/porto-and-north/vila-gale-collection-braga>

Conference Registration

Registration will be open at 17:00-19h00 on November 13th and 14th from 8h00 in the Conference Venue.

Internet

Wireless internet access is available in the Conference venue. Computers and multimedia projectors will be available during presentation sessions.

Secretariat

Abreu Events

For general information about the congress, including registration, please contact us at:

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ROUND 1 - WEDNESDAY 14TH NOVEMBER

1.1. University – Industry Collaboration

University and Spin-off Cooperation Fosters the Technology Transfer to Industrial Companies

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Abstract

The Lean origins come from academic realm, from Frederik Taylor, to Womack, Jones and Roos. The continuous search for better ways of production managing and control fostered a permanent development of methods and its enhancement by the academic community. One of the main reasons for this is the fantastic combination of accumulated and structured knowledge existent in university faculties and researchers, with the energetic, fearless and open-minded characteristics of highly skilled master and doctoral students.

In this paper the authors show that this combination can be strengthened by the creation of spin-offs based in the university community. In fact, the knowledge derived from scientific work can be quickly and truthfully transformed into products or services to the society by the agility of processes and resources management of a spin-off company. The case of a spin-off company offering its expertise to companies in the areas of Lean manufacturing & services and 'continuous improvement'- based on problem-solving, is presented and discussed. Four successful projects ran by the spin-off on manufacturing companies, in close collaboration with the university, are described in terms of objectives, elements involved, duration and results.

All the projects were developed by three elements of the spin-off company and one Mechanical Engineering Master Student (developing his/her Master thesis). One of the projects consisted in the lead time reduction from plastic part design to the injection of the plastic part, including the mould manufacturing, by the application of Lean design throughout several processes of design and manufacturing, and meetings in order to integrate both processes. The second project consisted in a production system diagnosis. The spin-off elements and the Master student developed a customized and replicable Lean Assessment model and its improvement solutions. The third case was the adaptation of several Lean tools, like VSM, SMED and others to the industry 4.0 environment. The fourth project consisted in an efficiency-based diagnosis to assess the



operator's procedures, machines capability and planning reliability. The work was accomplished by the application of time and methods studies, spaghetti diagrams, etc. and the efficiency was increased using 5s, SMED, TPM and other tools.

Keywords: University-Industry collaboration; Lean manufacturing; Spin-off; Technology transfer

The new Brazilian legal framework of science & technology, and its role as an inductor of the introduction of lean processes in micro and small enterprises

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Abstract

The purpose of this article is to analyze the applicability of Law No. 13,243 of January 11, 2016, known as the Legal Framework of Science and Technology. The recognition of science and technology as a risk activity, focusing on results rather than procedures, means that researchers are more effectively engaged in activities involving innovation. The article was constructed with bibliographical support seeking to contribute to a different view of the control organs regarding the research. The new Brazilian legislation brings with it the expectation that research and market have a process of approximation, reducing the distance between the knowledge produced in universities and their transformation into wealth. The possibilities arising from the new legislation tend to have effects in solving problems of quality, productivity, cost reduction, with the possibility of incorporating benefits to production and competitiveness, with the introduction of technology, methods and processes aligned with Lean production. It concludes that the Legal Framework for Science and Technology, with its specific purpose of reducing bureaucracy in the country's research and innovation activities in general, is an important instrument in the integration of the academic and scientific community at all levels, and companies, representing a new path to lean education.

Keywords: innovation, knowledge management, Legal framework of science and technology, lean culture.

Introduction

The new Brazilian landmark of science, technology, and innovation represents a turning point for universities and for the development of the Brazilian economy in the renewal of its market capacity because it provides for stimuli to scientific development, research, scientific and technological training and innovation. The old legislation hindered the paid work of researchers from public institutions in projects related to the productive sector, and the new legislation allows private initiative, research institutes, academy members and public educational institutions to work together to market scientific production of which in many cases was lost in laboratories. This approach tends to make it possible for knowledge restricted to the academic environment and larger organizations to be effectively incorporated into small and medium-sized enterprises, which tend to have greater difficulties in incorporating knowledge into their operations. The text also analyses the Decree No. 9,283, dated February 7, 2018, which regulated the Legal Framework, since it brought the forms of concessions of benefits and incentives to R&D and Innovation activities, the legal formatting appropriate for the achievement of these instruments, and established the tools that allow Public Entities to grant legal privileges for research, development, and innovation in the technological field.

Brazil is now ranked 69th in the Global Innovation Index, based on a study by the University of Cornell at the World Intellectual Property Organization (WIPO). Among the 18 countries in Latin America, Brazil ranks 7th. The biggest problem identified is the downward trend, since the country ranks 47th in 2011.

In the implementation of the new law, the collaboration between universities and research institutes was prevented by the current regulations restricting the participation of researchers from public universities in remunerated activities of innovation or applied research. Professors from public universities, with exclusive work contracts, were prevented from promoting paid research in collaboration with companies. In addition, the control mechanisms did not offer legal certainty to the companies requesting the research, away from universities and research institutes. The Innovation Survey (PINTEC), which is a research carried out every three years, by the Brazilian Institute of Geography and Statistics (IBGE), an institution of the Brazilian Institute of Geography and Statistics (IBGE), was used to give a brief overview of the scenario of innovation activities undertaken by Brazilian companies. The Brazilian government, which covers the sectors of industry, services and electricity and gas. PINTEC follows the Oslo Manual recommendation, in which product and process innovation are defined as the implementation of products (goods or services), new or substantially improved processes. The documentary research carried out in the previous legislation, the results presented in PINTEC and the comparison with the new possibilities introduced in the new Legal Framework, made it possible to outline a prospective scenario for the new moment presented for relations between the Academy, Governments, and Companies.

The need for organizations to promote systematic value creation for customers and thus position their products to the standards required by global market competition drives organizations on a constant search for innovation. This requirement positions Lean as the management philosophy that, for consistent results, is capable of promoting significant changes in the way companies handle their processes. Growing interest in Lean has provided the development and sharing of new techniques and experiences that enhance results and enable a growing learning curve. The Lean set of knowledge essentially aims to eliminate waste and solve problems, which implies that processes and products are constantly undergoing evaluations and changes, which are the basis of the innovation processes necessary to maintain the competitiveness of organizations and adapt to market needs. This applies to all types of organizations, whether private or public. It is precisely this need to eliminate barriers to innovation where the new Brazilian Science, Technology and Innovation legislation will play a fundamental role when fully implemented. Since there is no way to dissociate the Lean from Innovation, it is in this view that the article is based

Literature Review

Brazilian scenario

The legislation in force before the new Legal Framework was a deterrent to Brazil's innovation actions. In order to be able to visualize the possibilities brought in by this new moment, an analysis of the results of the PINTEC 2014 survey is necessary.

The study shows that there was a growth in 2012 of 1.90% of GDP in relation to the previous year and, respectively, of 3.00% and 0.50% in the years 2013 and 2014. The survey indicates that in Industry, 14.5% of companies promoted product and process innovation and 18.2% only process.

In the Services sector, 15.9% made innovations in product and process 11.8%; only in process. The innovation in processes in the Brazilian industry was 32.7% and in the services sector 27.7%.

An analysis of Table 1 shows that the smallest companies have the lowest rate of innovation in processes and this is due to the budget constraints of smaller companies to invest in materials, equipment, hire skilled labor, and have access to Science and Technology Institutions (STIs) and the lines of development of government agencies, such as BNDES and FINEP.

These would be the major beneficiaries of the new legislation because they can benefit from the approach to universities and institutes and research, and can access techniques and methodologies capable of introducing significant improvements in their products and processes, at a cost compatible with their capacity, or even without no cost of implementation, possible in partnerships where they are objects of academic research. This is a revolution.

For companies that implemented some innovation in the period from 2012 to 2014, research shows that the introduction of technological innovations in the market is important for 30.8% of companies in the industrial sector and 46.4% of service companies. The acquisition of external R&D and Innovation is considered important only for 5.4% of the industries and 5.3 for the service companies. Internal R&D and Innovation development are important for 15.2% of industries and for 39.2% of service companies. Training of human resources is considered important by 61.5% of the industries while the services sector has a percentage of 67.5%. In their manifestations of importance, Brazilian companies do not consider research institutes and technology centers as sources of information for innovation. The industry index stood at 18.5% and the service sector at 25.5%. Similarly, universities are considered sources of information for innovation by 16.4% of the national industry and by 25.7% of the service sector, which indicates the distance between academia and the market.

Table 1 - Innovation in Processes by company size (IBGE,2014).

Busy Person Tracks	Innovation in processes (in%)	
	Industry	Services
De 10 a 49	30,00	25,80
De 50 a 99	40,10	35,70
De 100 a 249	44,80	35,40
De 250 a 499	49,40	44,30
Mais de 500	59,80	43,60
Total	32,70	27,70

Considering the sectors of industry, electricity and gas and services, the investment in innovative activities and internal R&D and Innovation of Brazilian companies was 3.31% of the companies' net revenue. The service sector was the one that most invested in innovation and R&D and Innovation, totaling 9.94%, followed by the manufacturing industry with 2.84%, the extractive industry with 1.85% and the electricity and gas sector with 0, 74%. Sectors that depend fundamentally on intellectual capital, such as software development, have investments of more than 10%. Architectural and engineering services, which have not yet incorporated Building Information Modeling (BIM) into their processes, have investments of less than 2.5% in innovation. It is not the purpose of this study to evaluate these numbers, but the percentages presented show that R&D and Innovation activities are outside the immediate objectives of a large number of Brazilian companies.

It is of great concern to the industrial sector that, instead of aiming to meet world quality standards, especially those related to the implementation of systems aimed at Industry 4.0, demonstrates the preference for the acquisition of innovation incorporated in machinery and equipment, with 40, 2% of the expenses for this item and, despite considering important human resources training, in 2014 only 1.0% of the expenses had this destination. The internal expenses with research and development were 31.5% and the external expenses were 8.0%.

Considering that part of these expenditures involves the purchase of knowledge, this is a clear option for the innovation incorporated into equipment, which allows manufacturing with better quality and more quantity without, however, having the development of innovation from R&D and Innovation as a goal. This can be a dangerous strategy for the medium and long term, especially when one observes the low percentage of revenue invested in innovation.

Even more worrisome for Brazil is the low number of post-graduate human resources in research and development activities in industrial and service companies. The last survey (Innovation Research: 2014 / IBGE, 2016) identified 146,000 professionals working in internal research and development activities in full or part-time companies and presents another worrying factor that is the trend of displacement of professionals from the integral period for a partial period in the activity.

When analyzing the qualification of these professionals, it is verified that only 7.9% in industry and 15.3% in the service sector have a the post-graduate level education. The largest contingent of researchers has an the an undergraduate degree, with 60.5% in industry and 63.2% in the service sector. Certainly, this affects the quality of the final results of the investigation processes.

Keeping a professional with a Ph.D. in his or her workforce is not feasible for smaller companies and considered expensive by medium and even larger companies. The solution to this problem is the partnerships between companies, universities, and research centers that did not happen due to the obstacles of previous legislation.

The results above show a low level of investment in innovation, coupled with the low qualification of the human resources involved, as a result of improvements in products and processes introduced. The approach of the companies with the Academy is fundamental for an organized and continuous updating of the business processes with the best practices and technologies being implemented. The promotion of this interaction tends to introduce state-of-the-art practices into production.

The new Brazilian legal framework

First of all, it is necessary to say that there has always been a segregation between the Public and Private Authorities in Brazil. Federal Decree n°. 9.283, published on February 7, 2018, regulated the provisions of Federal Law n°. 13.243, of 2016, known as the Legal Framework for Science, Technology, and Innovation, and promoted significant changes regarding this separation.

A framework was inserted in the Brazilian Federal Constitution through Constitutional Amendment n° 85, which changed and added provisions in the Constitution to update the treatment of Science, Technology and Innovation activities.

The new set of legal rules has as its main mission to encourage the creation, implantation, and consolidation of environments that promote innovation. The purpose is to promote technological development, remove bureaucratic barriers that hamper the activity of innovative researchers and entrepreneurs, increase competitiveness and interact among the characters involved in this R&D and Innovation ecosystem, including Public Agencies, Development Agencies, Technology Parks, Institutions Scientific and Technological Research, Private Companies, among others.

The aim is to stimulate and support strategic alliances, development of cooperation projects between companies and STIs for the generation of innovative products, processes and services, transfer and diffusion of technology, contemplate networks and international projects of technological research, technological entrepreneurship and creation of innovation, incubators, and technology parks, training and qualification of qualified human resources.

Universities and public STIs may share intellectual capital, laboratories, equipment, instruments, materials and other facilities with companies and individuals for research, development and innovation activities, provided that such permission does not directly interfere with their activity or conflict with it. In addition, it may directly assign to companies the use of real estate for the installation of environments that promote innovation.

The legislation prior to the Legal Framework explicitly prohibited that such actions were implemented, characterizing this type of collaboration as misuse of public resources, subjecting managers to penalties such as reimbursement of values to public coffers and large fines.

This unfavorable environment of cooperation has brought significant damage to all concerned and to the quality of human resource training at all levels. By preventing the academy from having a closer approximation to the productive environment, the ability of students and researchers to actually implement the objects resulting from academic research was restricted, restricting the learning process based on practical experience resulting from interventions in productive processes, which is a fundamental step for the training of human resources qualified to work in the productive sector.

The new law extended the mechanisms of economic subsidy to micro, small and medium enterprises, implementing, among other measures, the technological bonus, destined to the payment of contracting technological services. It authorizes the law even though the economic subsidy can be used by companies both

for the financing of research activities and for capital expenditures. Before, the economic subsidy could not be used for the acquisition of capital goods.

It is important to emphasize that this possibility brought by the norm comes in many ways to contribute to the interaction between the public and the private since few companies have enough capital and expertise to set up their own laboratories. The universities have the infrastructure already installed, and the use of this by the companies is obviously a huge advantage for both parties.

There is no point in innovation if you do not leave the university benches for production environments. In order for this migration from academia to industry, it is necessary that the technology transfer process developed in STI take place.

The new law also allows the Scientific and Technological Institutions (STIs) to sign agreements with companies for the development of joint research, and STI may assign to the private partner all intellectual property rights through financial or non-financial compensation, provided that economically measurable, and technology transfer should be formalized through a technology transfer agreement.

According to the Innovation Law, all ICTs must have a Nucleus of Technological Innovation (NIT) that will be responsible for the management of the innovation policies that should be able to negotiate and manage these contracts, which need for a technical and legal body to supervise the execution of these contracts, in order to verify if they are in accordance with the contractual clauses. It is important to note that this change in the standard is very attractive for the formalization of a public/private partnership since the ownership of the results of research is no more property of the public institution, who before was forced to open a public competition to license the technology. This system was completely discouraging to private companies since there was no way to be sure that the company that financed the research would license the result.

Likewise, the public government allowed to directly foment technological innovation in companies and STIs through various mechanisms, including the direct contracting of research projects involving technological risk, for the solution of a specific technical problem or obtaining of product, service or an innovative process, without the obligation of the acquisition process.

The use of intellectual capital is seen with the possibility of public service researchers in an exclusive dedication to engage in paid research, development and innovation activity in STI or company, provided that assured to the continuity of their teaching and research activities.

Public institutions may be minority quotas in the social capital of technology-based companies and investment funds to innovation, either direct or indirect, through investment funds constituted with own or third-party resources, among other actions. The federal government may also become a partner of startups.

Universities, besides the well-known vocations for teaching, research, and extension, can collaborate for the emergence of companies with the participation of their teachers and students. Usually, academic startups are more successful in transferring knowledge than other companies. This is because they have the technical advice of academics that integrate the corporate structure, knowing the technical aspects of the inventions.

However, it is important to emphasize that the Brazilian Securities and Exchange Commission still needs to regulate this type of investment, which is fundamental for the sector, since it is a measure adopted by the main universities and research centers of the world.

The technological order is also one of the innovations brought with the new Legal Framework. Through it, organs and entities of the public administration may contract directly public or private STI, private nonprofit entities or companies, alone or in consortium, directed to research activities and recognized technological qualification in the sector, with a view to carrying out R&D and Innovation activities involving technological risk, for solving a specific technical problem or obtaining an innovative product, service or process.

The supply of the product or the innovative process resulting from the research, development and innovation activities ordered may be contracted by no-bid acquisition, including with the developer of the order, subject to the provisions of specific regulations.

This possibility brought by the norm allows the public sector to break the bureaucratic barriers, until then in force, that established complex rules for the contracting of technological services, which required the

elaboration of previous detailed projects and the observation of deadlines for the processing of acquisition and proposals and resources to the results that sometimes took years and did not always reach a satisfactory result.

This extreme bureaucracy has made the Brazilian State an unfavorable environment to adopt technologies that allow the optimization of resources and their availability in the right place at the right time, Lean philosophies that need to be incorporated into the provision of public health services, education, connectivity, among other important actions in a country with more than 220 million inhabitants and a continental size.

In parallel with this new contracting format, it is important to highlight that the use of the incorporation of knowledge and technologies of social impact will only have the expected effects if the human resources of the Brazilian public sector is duly qualified. This need will promote a strong acceleration in inclusive Lean programs in the public sector in areas where they are usually not included in the academic curriculum of the courses, such as in the social sciences and health, generating new opportunities for new players and new career opportunities.

Another relevant point brought with the Legal Framework is that the accounting procedures of resources passed on under the Law should follow simplified and standardized forms and, in order to ensure governance and transparency of information, be carried out annually, preferably through electronic sending of information, according to the regulation.

Conclusion

We can conclude that the new set of legal rules will significantly influence the production of science through articulation with technology and innovation, which will imply the increase of additional resources coming from the private sector. In the same way, it will affect the quantity, quality, and flexibility of scientific production.

In order for this to happen, it is essential to promote joint R&D and Innovation activities between the public and private sectors of the Brazilian economy, through relationships that articulate knowledge and resources in a clear and safe way for both.

This ensures greater predictability and, consequently, attractiveness to investments in the area of Technology and Innovation.

Acknowledgments

The authors wish to thank the project partner Amazonas State Foundation for Research Support (FAPEAM - Fundação de Apoio à Pesquisa do Estado do Amazonas) for facilitating this work.

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A3-thinking in student projects and its impact on developing continuous improvement in industrial practice

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Abstract

In this paper, we study the value of using the A3-method in student projects which are performed in industry. We performed a survey among 98 students about their experience with the use of the A3-method. Students appreciated the problem solving structure of the A3-method and how it supported communication with people of the company in which they performed their projects. Weaknesses of the A3-method, mentioned by the students, related to a certain extent, to a lack of experience. It is not easy to present all relevant information on one, readable, Other weaknesses of the A3-method, mentioned by several students, related to the industrial context of the project. The lack of clear vision in the company and the missing of an improvement structure complicates the development of a good A3-project. In the paper, we also performed two longitudinal case studies at companies where already a number of students performed their A3-projects. We focused on the impact of the applications of the A3-method by students on the development of Continuous Improvement in the companies. We found that both companies embraced the concept of the A3-method and extended its' use to all improvement projects in the company. Furthermore, both companies developed Hoshin Kanri to align the various improvement projects. The need to do so was triggered by several issues that came up by using the A3-method in the companies. Next, both companies also invested in training of their employees in order to gain a culture of learning. In general, we can conclude that the A3-method is a strong tool which supports the lean journey of companies and students. It also creates fruitful synergy between the teaching and learning activities at applied universities and the development of continuous improvement in companies.

Keywords: A3-method, continuous improvement, teaching and learning, Hoshin Kanri

Lean School: an example of industry-university collaboration

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Abstract

The aim of this paper is to contribute to the lean education topic through the presentation of the “Lean School”. The “Lean School” is a learning factory laboratory developed in conjunction with an industry partner (Renault-Nissan Consulting) to improve the capabilities of students of the Faculty of Engineering of the University of Valladolid, the employees of its factories and other workers of companies in the region of Castile and León. It can be used for educating academic students as well as to train industrial participants thereby improving knowledge transfer between universities and industry.

The “Lean School” does not focus on teaching manual skills. We use a simulated manufacturing environment to teach lean manufacturing tools and concepts using learning-by-doing didactic concepts to help us train engineers with high employability and adapted to the needs of the companies in the environment.

In the “Lean School” different configurations can be used depending on the learning objective: quality, stock management, flow management, balancing, sequencing, 5S, kitting, etc. But in general, the learning practice is very similar: we start from an initial configuration where we show the students/workers the starting situation focused on detecting the problem to be studied taking into account the tools/concepts that have been previously explained in the theory classes.

The modular configuration of the laboratory production area allows for a quick transition from one configuration to another depending on the evolution in the learning process of the students/workers (different depending on their training and/or abilities). So we can transform a traditional factory into a lean factory in a three-stage to six-stage process, going from a disorganized and low standardized push flow where we are only able to manufacture one version of a product to an optimized pull flow with a wide variety of manufactured versions.

At each stage, with a certain configuration, a production of between 15 and 30 pieces is made. Once completed, the students/workers (teacher guided) are responsible for redistributing the workstations, rebalancing the activities (in each workstation), proposing corrective actions and designing elements to help in manufacturing, to improve quality and delivery times.

In this paper we will use the experience acquired over the last years, in the Production Flows Improvement training programme, to present the “Lean School” fundamental principles, as well as to provide some insights about the lessons learned.

Keywords: Lean Manufacturing, Learning factory, Learning-by-doing, Laboratory

Adaptation of the lean thinking and culture of the high-scale automotive industry to teams composed by people with generation "Z" characteristics

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Abstract

The International Organization for Standardization (ISO) and Project Management Body of Knowledge (PMBOK) standardizes project management and production of the current automobile industries. This model considers usual behavioral characteristics of previous generations for directing resources, establishing deadlines, and accomplishing goals for team members. Nowadays, the advent of the "Z" generation in universities and introduction into the labor market has brought difficulties in adapting its characteristics to the industrial market and lean production, causing conflicts in the work environment, loss of motivation, and reduction in efficiency. Industrial activities, according to lean culture, ought to be executed with sufficient dialogue. Although technological, working in industrial activities is not as fun as working in gaming development companies or Internet technology, causing talent evasion and shortage of labor in the mass production automotive industry. This article will highlight some of the main difficulties of adaptation of the "Z" generation into the automobile production industry on a large scale and present proposals on how to eliminate these difficulties in order to maintain high team performance, taking full advantage of the positive characteristics.

Keywords: generation 'Z', automotive industry, lean adaptation, lean culture.

Introduction

Currently the lean production system is a fundamental part of the organizational culture of the automobile industries, and greatly contributes to achievement of positive results. However, this culture and its way of thinking is facing challenges and is suffering increasing resistance of acceptance by the new generation of workers, which are now in the labor market. These young people have some very peculiar characteristics that differ from previous generations.

Some characteristics are common to young people of all generations, such as impulsiveness, lack of discipline, and reduced responsibility with results. Besides, this new generation of youngsters, called generation Z, have some very specific characteristics, according to Brito (2013), including that they are individualistic, immediate, antisocial, eccentric, disrespectful to elders, and have difficulty in performing in team settings. He suggests that these young people will have serious difficulties in the labor market; this observation has been confirmed in the teams that were part of this work.

These young people increasingly require resources to carry out their activities without clearly demonstrating the real need, such as more powerful computers, access to unnecessary systems,

different schedules, flexibility of rules, etc. only to the satisfaction of their facilities. These supposed needs that are often created in social networks, leading managers to cope increasingly with adaptive conflicts and making the problem quite relevant in organizations.

Literature Review

The constant search for new markets and increased sales has always provided the marketing area with the vanguard of the study of the generations, since the habits of each generation are demonstrably variable and directly impact consumption. According to Smith (2012), studies have come out and are indeed anticipating unique behaviors of the so-called Generation Z.

Some of these behaviors have aroused great concern in industries because they are already directly affecting their results and may even affect the perpetuity of business. Due to these impacts, a more in-depth study of the generations in industry is necessary to assist managers in decision-making and elaboration of management strategies to revert potential negative impacts.

According to Brito (2013), the last generation of workers can be divided into Boomer, Baby Boomer, X, Y, and Z. According to him, these classifications were defined every 25 years with reference to World War II, but now we have a new generation every 10 years.

Thus, we define the Boomer generation as born between 1921 and 1945 with a duration of 25 years, the Baby Boomer generation as born after World War II between 1946 to 1965 lasting 20 years, generation X as born between 1966 and 1980 with a duration of 15 years, generation Y as born between 1981 and 1995 with duration also of 15 years, and generation Z as those born between 1996 and 2005 with duration of 10 years.

The Boomer generation contributed greatly to the success of corporate systems of the past that were based on respect for authority and hierarchy. As they lived in an environment of world wars, they are inclined to seek peace and prosperity with objectivity and hard work. Due to their age, most of them are retired and directly influence the generations x and y through consultancies and exchange of experiences.

According to the Encyclopedia Britannica (2018), the Baby Boomers were named after the explosion of babies born in the United States after the Second World War. It was a period of prosperity, and many couples who had their marriage postponed due to war, began to form their families at the same time. It is estimated that there was birth of 75 million Americans between 1950 and 1960.

Most managers at the highest hierarchical level in corporations are part of this generation. They are very experienced and accustomed professionals who achieve their goals with great determination and work. On the other hand, they conflict directly with generations Y and Z, since they grew in the companies by several decades of much work and advanced through a system of meritocracy. They are primarily responsible for corporate culture and prefer more systematic planning schools that support little room for change and opinions. Indeed they believe that younger generations have very little to contribute.

Generation X has as its main characteristic the beginning of large-scale computer use. Seniors of this generation also hold senior management positions in some companies and have created informal work environments with reduced hierarchical levels. They have a more stability-oriented profile and are resistant to innovation and major changes, seek to balance work with quality of life, i.e., develop their career with dedication to family and personal activities.

Next, generation Y has a peculiar characteristic according to Taylor (2018), the existence of a micro generation formed by people belonging to the end of generation X and beginning of generation Y, known as xennials, basically born between 1977 and 1983. This micro generation had an analogical childhood but lived a digital youth. In their childhood, there was no Internet and no cell phone. They saw this technology arise and become quickly adapted. Nowadays, they have some habits of consumption known as "vintage", which is the purchase of products sold in the 80's, such as vinyl records, walkman, videocassette, etc. They have the determination of generation X and the optimism of generation Y.

The youngest of this generation, known as millenials, already present the precursory difficulties of generation Z in their work activities, by having a fast expectation of growth without results. Some, even though they are



over 30, are still out of the market. The so-called NEET (not in education, employment or training) or more recently NLFET (neither in the labor force nor in education or training), are supported by their parents.

Those who do not fit these characteristics have a number of positive points, as they have grown up in an innovation-driven environment. Therefore, they naturally have the ability to accept change, perform multiple tasks simultaneously, and are optimistic in achieving their goals.

Generation Z, also known as the digital generation, according to Pinho et al. (2015), was the first generation to live a totally digital childhood and youth. They are aware of problems that may arise from overexposure in social networks. Most of these young people, according to Lanier (2017), prefer private social networks like Snapchat. According to this author, these young people grew up in an environment of global recession and wars, having access to all kinds of information quite easily. They need stability at work, quite different from the millennials, who managed to develop focus and objectivity as positive characteristics.

They are fully adapted to the globalized world and expect diversity in their workplaces. According to Fine (2015), they grew up seeing a black president in the United States and popularization of gay marriage in several countries. They have initiative and believe that they can do something about their everyday affairs.

As negative aspects, according to Vieira (2017), they have the culture of "I know", because as they grew up in intuitive environments they believe that they have mastery over certain technologies before even using them.

From the career point of view, they want a rapid rise and are frustrated by the ascension history of older individuals. Many are leaving the industrial branch and seeking the entrepreneurship of the startups movement as a way to quickly achieve financial success, glimpsing only the aspects young millionaires who are shown in the media and on social networks.

Methodology

The methodology adopted was the systematic review of the literature on characteristics of the generations, their behavior in industry, and ways of teaching the Lean system for new generations. After this review, an automation team of the Manaus two-wheeled automobile industry was evaluated. It was composed of young people, in order to identify their greatest difficulties in adapting in the large - scale automotive industry to the Lean culture.

The two-way tool was used, in which interviewer and interviewee exchange impressions about certain situations. The interviewer collects information, directs the employee to evolve his / her skills to achieve established results, asks questions to clarify situations in which he / she perceives ambiguous or inconsistent answers, seeking to identify behaviors. Finally, it is possible to manage which activities adapts for each employee, acknowledge their efforts, and encourage them to dedicate themselves and become enthusiastic in achieving their goals, focusing on the development of their competencies.

It is expected that the interviewee will listen carefully and ask questions to have a better clarity of what is being said, be receptive to accept and propose valid points as indicators of their behavior and development, reflect on what was said to be able to establish their goals, and commitment with the process for the correct functioning of the methodology.

After the interviews, a plan was developed to adapt the Lean culture to the characteristics of this team, according to the literature, seeking measurable optimization of the results to confirm effectiveness of the actions.

Team Diagnosis and Implantation of Improvements

Through the tool known as two-way, an individual interview was conducted with the team's 24 employees. In this interview the characteristics of each individual were evaluated based on the expected theoretical reference for generation Z. We verified that 90% of them belong to this generation.

Practical evidence of most of the characteristics was provided during interviews and their expectations for a review of how departmental goals were elaborated.

Focusing in the characteristics of generation Z, it was verified that for the elaboration of goals and determination of the working conditions, it is necessary to give them margin to the collaboration and attendance to some expectations, carefully explaining the causes of the partial attendance or the reason for not meeting other needs.

During the preparation of the review of goals and working conditions, the main demands of the team were: a lighter and more playful work environment aimed at stimulating creativity; possibility of relaxation intervals with different activities, such as the game of pool, which has been practiced for years by older employees from other departments with low adherence by the younger ones; respect for schedules; provision of advanced resources with more advanced design stations; and greater diversity in the work environment.

After consensus from the team, it was decided that the first stage of the review should happen at no cost to the company in order to demonstrate methodology effectiveness. Such a strategy would thus ensure that top management would support upcoming cost revisions.

The first actions that were taken included: acquisition of practice tennis table that was paid by employees; allowing employees to practice sports in interval breaks; allowing employees to use video games paid by the employees in interval breaks; eliminating the possibility of holiday cancellation; and increase the use of departmental achievement awards, a practice that is common of some managers, to commemorate the department at the end of the month.

To meet these planning review needs, a managerial meeting was held and the possible gains that these actions could provide. This was based on indicators chosen by the B.S.C. methodology, reviewed. The indicators that were presented were: absenteeism, overtime, project events on time, and amount of corporate training conducted, all with monthly evaluation.

Results and Conclusion

In order to verify the results, indicators monitored by departmental management were also used. Thus, it was possible to compare them with older performance data. The indicators are: absenteeism, overtime, project events, and corporate training. After the initial actions were carried out without cost to the department, the following results were presented, graphically illustrated.

The absenteeism indicator shows how motivated the staff is to not miss work. Other symptoms that are not always evident include a good, pleasant, and safe work environment. Rigid and inflexible managers can also make a big impact on this index in teams composed of younger people.

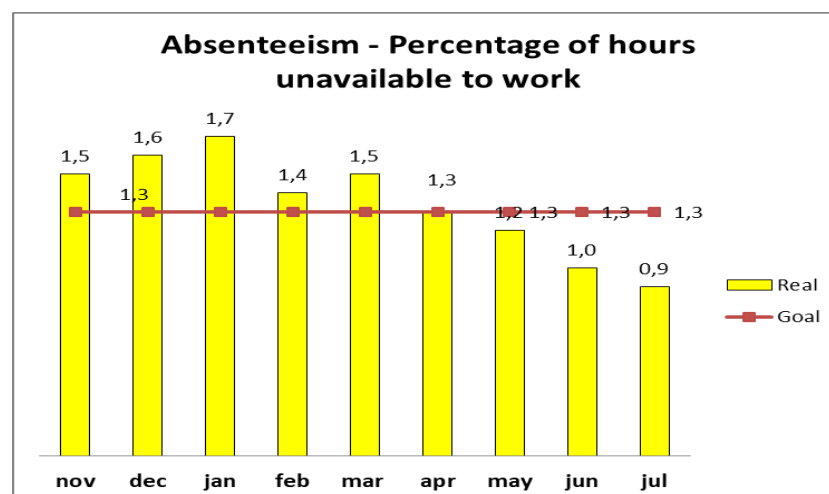


Figure 1 - Reduction in absenteeism index.

The overtime indicator shows how much work was necessary beyond the previously defined schedule, increasing costs throughout the project chain. Project errors and rework can greatly impact on this important indicator. Younger teams may, depending on the commitment to results, perform the same task over and over again without considering these costs. Efforts are needed by managers to explain to young people all the amounts involved in the occurrence of overtime and where injury affects themselves.

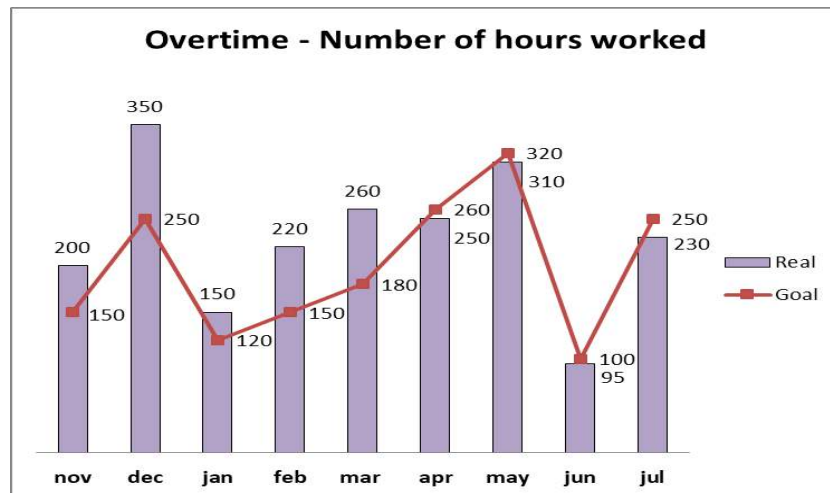


Figure 2 - Reaching overtime goals (quantity reduction).

The project event indicator shows how much the team is focused on their goals, and is committed to delivering results. Each project has the following events to approve: concept, 3D design (three-dimensional drawing), electrical design, assembly, tryout, and the first production batch. As there are several projects occurring simultaneously each month there are approvals of different project steps. Approval of each step is pre-programmed in the project schedule and generates this indicator.

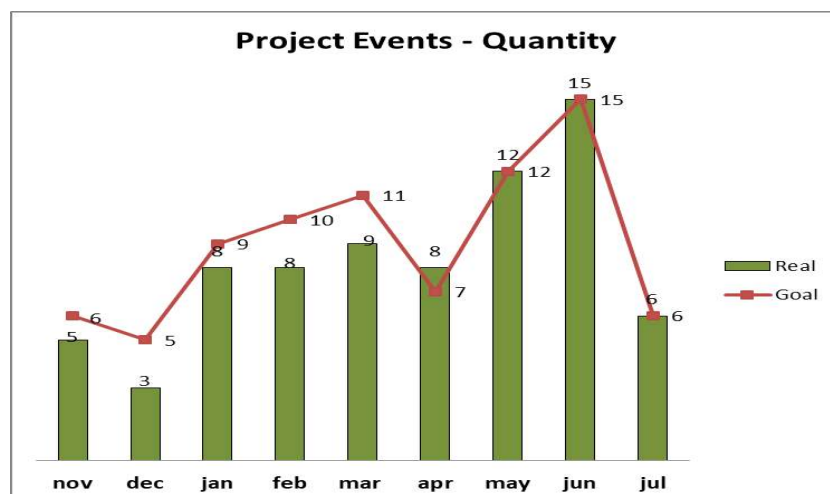


Figure 3 - Achieving Project Event Goals: Approvals and Releases.

The indicator of conducting corporate training shows the determination to stay in the company in a stable manner. This must be considered, since some trainings and methodologies are very specific, and it would not be beneficial to the company to change jobs. These trainings make employees more agile in internal systems and adept at organizational Lean culture.

The more training one completes, the greater is the employee's ability to understand the ideas of older managers and to reconcile them with the Lean culture. The creation of an environment favorable to collaborative discussion stimulates the young people to encourage others, and this is shown in the chart below.

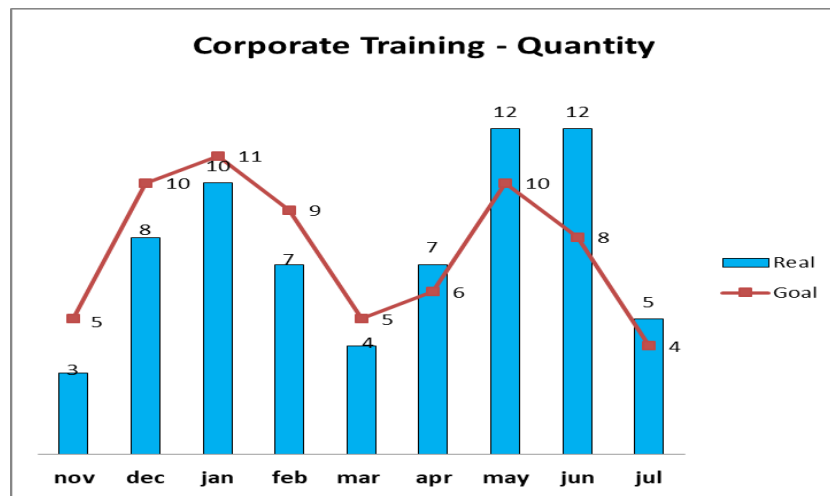


Figure 4 - Overcoming the goals of conducting corporate training.

Optimization was verified in all analyzed indicators after the first month of implementation. During the four months that we have analyzed so far, there has been evidence of effectiveness of the results. There is an indication that analysis of the generations can be used to perform management actions to improve team performance, especially those that are composed by younger people.

Indirect gains were verified in improvement of harmony in the work environment, which is also one of the goals of the company philosophy: respect for the individual. There was an increase in opinions offered by the youngest in meetings of project analysis and improved communication between teams.

Future work ought to focus on justification for approval and acquisition of more modern project stations, retraining of software development projects, hiring of new employees with different profiles to increase department diversity, and physical investment for the modernization of the office environment.

It was also verified that it is possible to change some characteristics of the company without impact on its fundamental values. However, it is necessary to convince managers from previous generations of the effectiveness of these actions, which conventionally have been viewed as a waste of resources and promotion of an exaggerated informality in the work environment.

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QRQC Methodology and Form A3 in solving quality problems in a multinational company of the Industrial Pole of Manaus

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Abstract

The article presents the results of a quality improvement project implemented in a company installed in the Industrial Pole of Manaus - PIM. The average daily production of the unit is 10.7 million parts per day. Prior to the implementation of the project, the plant had an average product nonconformity index of 1.22% and the level accepted by the company was less than or equal to 1%. Data processing indicated a high sample dispersion, and a Cp value of 0.15. The Quick Response to Quality Control (QRQC) was used to support the actions developed along with Ishikawa Diagram, Data Analysis, A3 form and PDCA system. Minitab statistical software was used to calculate the process capability. The data collection was recorded in a spreadsheet in Excel and the quality problems identified based on the reports of monthly indicators generated by the factory management. At the end of the project, new data were collected and the Cp index was raised to 2.20. The amount of tailings was reduced by almost 8 million pieces in the first year, contributing to cost reduction with rework and scrap generation. The reduction of the nonconforming plant percentage was reduced to 0.87%.

Keywords: A3 form, Process mapping, QRQC methodology, Quality improvement.

1. Introduction

The company studied is a large multinational, world leader in its segment and has been in Brazil for more than 60 years. It has a strict quality policy and is very demanding as to the good functionality of its products. In every manufacturing organization are problems related to production processes, whether related to raw material, method of work, labor, among others.

Whenever a nonconforming product is detected, an investigation is initiated to find the root cause of the failure and this flow may take longer than ideal. In this work, the reduction of the index of nonconforming material will be worked.

To maintain the quality of manufactured products, the company needs to make investments that can be questioned. According to Crosby (1999), quality does not cost money, but it is an investment with assured return. In fact, what costs and causes great losses to companies is "not quality", that is, the lack of an acceptable level of quality. Not quality is the fact that a certain product has not been manufactured within its specifications.

Given that in the current economic scenario, it is essential that the index of materials produced that are reworked for quality problems tend to be kept to a minimum, large companies are looking for innovative methods of reducing these indicators, and it is also ideal that the time for analysis and resolution of problems be reduced as much as possible.

The QRQC methodology consists in solving quality problems in a maximum time of 24 hours and has been increasingly used and well accepted in the automotive industries, which called the attention of the organization studied to invest in a project that uses the methodology allied to basic tools of quality.

According to Coltro (2012), the QRQC methodology is intelligent for this type of situation and is due to its innovative character, since the organization manages to work with several quality tools in only one method, making the process simpler, easier to access and understanding among all hierarchical levels.

In the evaluated company the problems related to quality had a very long resolution time, it often took months before the situation was remedied, and with studies carried out a project was elaborated using the QRQC methodology, together with an A3 form in PDCA format.

In this form, the problem is described in detail, specifying all the details involved and their actual agents. The A3 also serves to record the solutions already completed for eventual inquiries in case of recurrence of occurrences or even to help the other areas of the factory in similar situations.

The quality tools are essential in the development of this work and are present in the day to day of the sector in which it was developed. These tools were fundamental for the realization of the mentioned project and will continue being essential for the continuity of the same during the next years.

2. Literature Review

2.1. QRQC Methodology

The QRQC method is a quality management system that aims to satisfy the customer through immediate actions, many quality problems have solutions that can take months to correct, QRQC system has emerged through the need of industries for rapid responses. Rocha *et al.* (2017) sustains that The QRQC (Quick Response to Quality Control) is considered as a management methodology in view, since it includes the main quality tools for the analysis and identification of problems arising in the production process, being used mainly in the automotive industries

According to Brito *et al.* (2017), QRQC is not only a quality control tool and method for problem solving but also an innovative concept in the field of global quality management. Balteanu *et al.* (2015), the QRQC's mission is to focus mainly on quality-related issues, but also solve many other problems, more broadly, technological problems, safety issues or reliability issues.

For Mitreva *et al.* (2016), the application of the Quick Response Quality Control (QRQC) methodology aims to solve problems of quality control of products quickly. This method was introduced in Europe and France in the automobile industry in the early 2000s. It is primarily used to deal with problems that occur on a day-to-day basis in a systematic way in order to improve factory floor indicators such as: customer complaints and internal scrap indexes, OEE, accident rate, goal splitting between others (Wojtaszak and Bialy, 2016).

The QRQC approach is more than a problem-solving tool. It is rather a culture or mentality that is applied to all aspects of recurring business. It emphasizes the top-down approach and uses the bottom-up approach (with regard to communication pathways).

The basis of QRQC is the rapid response to a quality or manufacturing problem, whether it is an external customer, internal customer or a supplier, and among its characteristics, it is important to promote cultural change, that is, it is not only a tool for improvement of quality, but also a culture for continuous quality improvement. Seleme and Stadler (2008) define the methodology as being a logical sequence employed to achieve the desired goal, while the tool is a resource used in the method.

2.2. Ishikawa Diagram

Ishikawa Diagram or Cause and Effect Diagram is a common tool used for cause and effect analysis where the possible causes for a given problem or event are identified.

Essentially, the cause-and-effect diagram breaks the "whole" into "parts" and is particularly useful by breaking the relationship between a problem (effect) and all possible factors that are related to it. According to Raazick

et al. (2016) Cause and Effect Diagram "is a tool that helps identify, classify and display possible causes of a specific problem or quality." The basic structure of the diagram is seen in Figure 1.

Basic steps to construct the diagram need to be followed, such as: making sure there is consensus in the group about the "need" and the characteristics of the "make statement" before starting the process of building the diagram. If appropriate, you can "insert" branches that do not contain much information in other sectors.

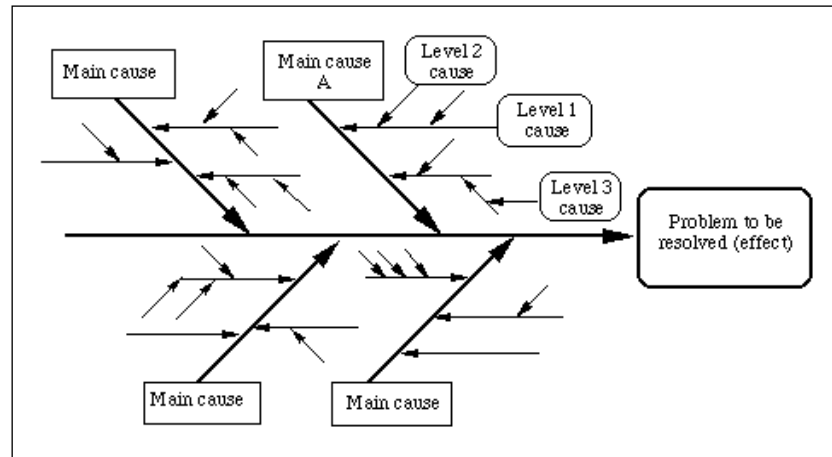


Figure 1 - Ishikawa Diagram.

2.3. PDCA

According to Leonel (2008), Walter A. Shewhart was the first to discuss the concept of PDCA in 1939 when he introduced the notion that the constant evaluation of management practices is critical to the evolution of an enterprise.

In the 1950s, W. Edwards Deming promoted PDCA as a continuous process improvement. He also referred to the PDCA cycle as the PDSA cycle ("S" for study). The PDCA cycle was a method designed to control actions and ensure that they were followed according to how they were established so that the results were satisfactory.

According to Moen and Norman (2010), PDCA has its roots in the method and philosophy of science that has evolved for more than 400 years. It is believed that the improvement model is an important evolution of the PDCA cycle.

2.4. Minitab

Minitab is a statistical analysis software. It can be used to learn concepts in the practice of statistics, as well as statistical research.

The statistical analysis software applications have the advantage of precision, reliable and generally. It becomes faster than the statistics of computation and graphics of hand drawing. Minitab is relatively easy to use when you know some basics. It is a statistical software with intuitive capabilities, and allows obtaining descriptive statistics, simulations and distributions, elementary statistical inference (Cymrot *et al.*, 2006; Feinberg and Siekpe, 2003).

2.5. Capability Calculation

A process even with controlled and predictable variability can produce defective items. Consequently, it is not enough to put the process on control and say that the process is able to meet customer specifications.

According to Santos (2009), the process capability ratio, also known as process capability, because it is a calculation based on the limits, does not take into account the location of the nominal value, since it only measures the difference of the specifications in relation to the dispersion of the process.

Study of the ability of a process is to compare the product's own variability with the requirements or specifications for the product. Capability is the analysis if the process is meeting specification limits, crucial factor for good productivity. To calculate the capacity one must know how to calculate some indices, the main ones are Cp and Cpk.

The Cp is the potential capacity index of the process. It considers that it is in the center of the specified nominal value. Cpk is the performance index used when the process is not centered on the specified nominal value, and takes into account the process average distance in relation to the specified limits. Capacity indices are dimensionless measures that quantify the capacity of a stable process. The main indices are shown in Figure 2, where LSE is the upper limit specified, LIE is the specified lower limit, μ is the average of the process and σ is the standard deviation of the process.

$$\begin{aligned}
 (i) \ C_p &= \frac{LSE - LIE}{6\sigma} \\
 (ii) \ C_{pk} &= \min \left\{ \frac{LSE - \mu}{3\sigma}, \frac{\mu - LIE}{3\sigma} \right\}
 \end{aligned}$$

Figure 2 - Capability calculation equation

3. Methodology

For the accomplishment of this research, the history of problems related to the quality was analyzed, and then viable solutions were studied to improve the process of resolution of the situations. As for the project, schedule was divided into the following steps:

- a) Research: the data survey was recorded by a spreadsheet in Excel and the problem was found based on the reports of monthly indicators that are generated by the management of the factory, so it was noticed that the indices of nonconforming material were above the established target. The team researched effective and fast problem solving ways and the one that best fit the situation due to its benefits and, which will be the basis of the QRQC methodology work.
- b) Infrastructure: for this work to be feasible and its application possible it was necessary to equip the quality team with a practical structure that can be taken to any factory environment. They were made with external suppliers, mobile whiteboards 2m high by 2m wide, which can be taken to any area of production and make the work more dynamic, also printed forms A3 size.
- c) Training: with the project based theoretically and ready to be put into practice, representatives from each area were trained to be able to participate in the company's problem-solving team. An employee of each area was recruited to be of the team, such as maintenance, quality, production, etc. The project participants are chosen according to their involvement in the process, all employees who are in the day-to-day process of the process being studied to participate in the brainstorming, without necessarily being a leadership position, provided that they have practical experience in the process, time people, there are people of basic academic level education as a high school and also engineers to provide the technical knowledge.
- d) Implantation: with the project participants properly trained, cases began to be studied, each case has a team and particular analysis.

For an item to be evaluated as QRQC in the company was adopted the method of recurrence of an item, if a problem is repeated during the month, a QRQC is opened and the same is worked on the factory floor with the quality team along with production and manufacturing.

The evidence used to verify that the item requires a QRQC or is not the nonconforming material control sheet.

4. Results Evaluation

The problem of this work was to reduce the indices of products not conforming manufactured, which at the beginning of this study were on average 1.22% in the year 2015, so the objective was to reduce this percentage to the level accepted by the company that is smaller or equal to 1%.

In the year following this study, with the implementation of the QRQC project this index was reduced to 0.87% as can be analyzed in the table 1 below.

Table 1 - PNC Annual Indicator 2015 x 2016.

Total Year 2015					Total Year 2016		
Sector	Goal	Production	PNC	%	Production	PNC	%
SETOR 1	1,00	1.828.677.618	18.010.791	0,98	2.013.943.530	11.765.900	0,58
SETOR 2	1,00	421.195.267	499.025	0,12	419.984.342	783.900	0,19
SETOR 3	1,00	420.940.698	314.500	0,07	427.694.092	133.200	0,03
SETOR 4	1,00	436.308.625	5.722.000	1,31	442.512.700	6.831.750	1,54
SETOR 5	1,00	216.803.061	5.527.564	2,55	185.634.777	3.011.516	1,62
SETOR 6	1,00	6.303.928	-	0,00	7.988.150	39.000	0,49
SETOR 7	1,00	10.771.813	97.520	0,91	9.437.889	188.496	2,00
SETOR 8	1,00	139.352.414	-	0,00	6.516.752	14.400	0,22
PNC Geral	1,00	2.481.789.304	30.171.400	1,22	2.642.091.007	22.863.112	0,87

The method used to register the cases of QRQC was the form A3 with the format PDCA, in which the problem found is described in detail, the root cause of each item is analyzed and an action plan to solve it is then elaborated.

This form A3 will be explained in table 2 below.

Table 2 - Steps of the A3 form used in the project.

ITEM	DESCRIPTION
1. OPPORTUNITY	Name the problem to be resolved shortly.
2. DECOMPOSITION OF THE PROBLEM	Describe the problem in the smallest detail by using the 5W2H method for the team to be aware of the situation faced. If possible, add compliant and non-conforming product photos.
3. DEFINE A GOAL (THE CHALLENGE)	Establish a goal to be achieved, always with measurable units. Example: Quantity of machine waste to be reduced.
4. ANALYZE THE ROOT CAUSE	Use the Ishikawa diagram or five whys, or another quality tool that is appropriate for the situation, to discover the root cause of the problem.
5 & 6. DEVELOP AND IMPLEMENT PREVENTIVE ACTIONS	In this topic is drawn up in the team action plan to be followed, each action added has a responsible and a completion date. In this item are added measures of

	immediate containment of the problem, corrective and preventive actions.
7. EVALUATE THE RESULTS	Evaluate the results after the completion of the action plan to approve or disapprove the QRQC.
8. NORMALIZE	With the completed and approved form, regulate completed actions through training, procedure, or whatever method is appropriate.

In order to prove the data collected during the two years of study, the tool for calculation the capacity was used through statistical software Minitab, which generated two graphs for analysis and verification of the data.

In the first graph, we have the demonstration of the process capability before the project is implemented, where we can see high dispersion of samples and the value of $C_p = 0.15$, which we use to know the sigma level of the process, in the case was 0.45 sigma.

After the implementation of the project, samples of the analyzed indicator were collected again, and the results were satisfactory. The sigma level of the process studied was raised to 6, in the year 2016 for the indicator of nonconforming product, the graphs generated can be analyzed below in the graphs represented by figure 3 and figure 4.

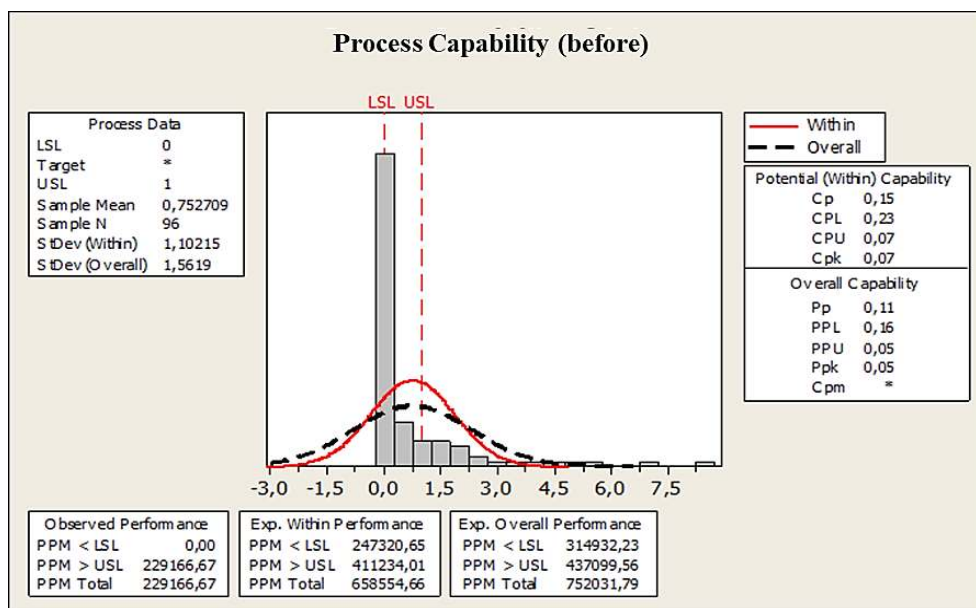


Figure 3 - Capability chart of the process before the project.

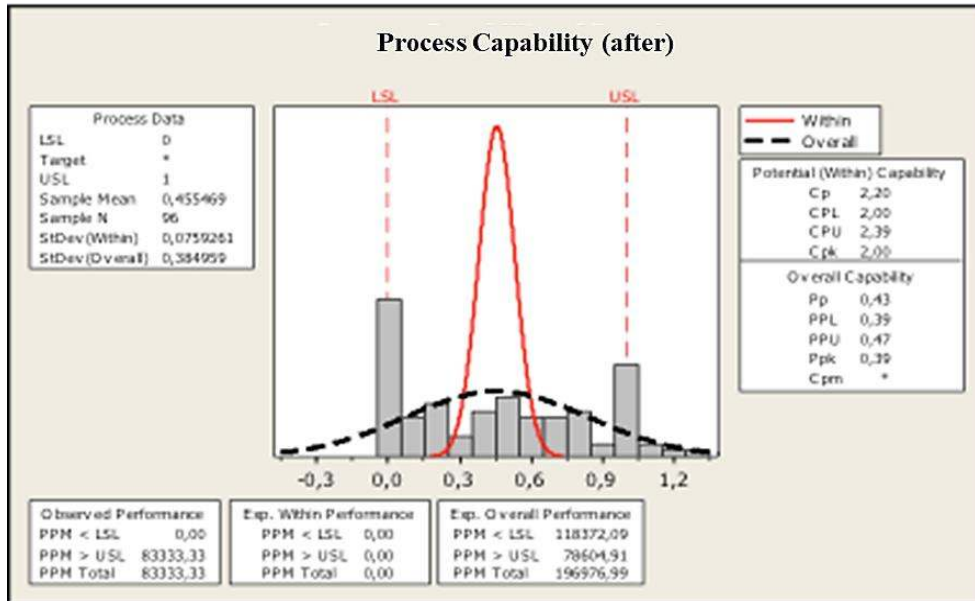


Figure 4 - Capability chart of the process after the project.

The company studied has a high number of parts produced, reaching an average of 10.7 million parts per day, adding up all the productive areas of the company.

After the implementation of this project, it was possible to reduce the number of tailings in almost 8 million pieces, contributing to reduce costs with rework and scrap.

Another item that was improved was the amount paid to employees of the annual profit sharing, in which the nonconforming index is one of the influential indicators in the amount to be received by employees.

5. Conclusions

In the current global economic scenario, companies operating in the industrial sector must always be innovating their production processes to maintain customer satisfaction. However, it is known that there are implications in the production lines that cause the indices of nonconforming material to exceed the established goals, which was the case studied in this work.

With this challenge, a project was designed to reduce the percentage of nonconforming material produced in the company under study to the minimum value established by the organization's high level, which was 1% of the total production volume.

These indexes are controlled by the company's management that prepares a monthly report of verification and verification if the areas are meeting the requirements controlled by indicators.

In order to reach the objective, the QRQC problem solving methodology was used to improve the productivity of the plant, and this tool was used in conjunction with quality as Ishikawa's diagram of capacity calculations. The older employees of the organization had some resistance with this new methodology because they did not know the system, after the implantation they were trained, and currently they can help in the analyzes at the operational level.

The human-resource was a challenge to be faced because on the factory floor, it is common to find people who do not have the concern on the quality part of the product. It was verified through the data collected in the managerial reports that after the implementation of the project, the designated goal was successfully achieved in two years of study.

All employees of the organization became aware of the new method of problem solving and were involved in the cases of their respective areas, an interesting factor that enabled the exchange of information of the practical workforce that has the experience in the process, with the engineers who could align the technical knowledge.

The indicator used in this research was the monthly nonconformity index, which was reduced from 1.22% in 2015 to 0.87% in 2016. However, the company also has monthly control of the amount spent on scrap during the months of the year, and this can be studied in a future project so that it can be reduced as well.

This research also allowed us to explore new quality control techniques that proved their effectiveness. In addition, it was possible to share this knowledge with other company employees, emphasizing the importance of creating and maintaining a culture based on lean premises.

It was important to deal with employees who were trained in different cultures, where there was no major concern with the quality check of the material produced. With this, the self-control of the processes can also be reinforced, not only being dependent on the quality inspectors to check parameters and material, making the operators more autonomous and the process more dynamic.

Acknowledgments

The authors wish to thank the project partner Amazonas State Foundation for Research Support (FAPEAM - Fundação de Apoio à Pesquisa do Estado do Amazonas) for facilitating this work.

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1.2 Sustainable Lean Manufacturing: factors of success

Lean leadership: systematic literature review

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Abstract

Many studies over time have been recorded as fundamental research for lean management system transformation and understanding. It is widely accepted that the role of leadership is of great importance for a lean manufacturing sustained implementation. However, studies that truly investigate its role to a sustained lean implementation are still limited. With the purpose of contributing to a better understanding of the lean leadership topic and its relationship with sustained lean implementations, in this paper a preliminary analysis is provided through a systematic literature review (SLR). The methodology adopted to conduct the SLR included the following steps: (1) planning and formulating the problem; (2) searching the literature; (3) data gathering and source evaluation; (4) data analysis, synthesis and interpretation; and (5) results presentation. A search in numerous publishers' electronic databases was performed to find relevant publications. In this paper, a presentation and discussion of a synthesis of the literature is firstly included. Secondly, the lean leadership alternative approaches and the influence of the organizational structure/levels of management on lean leadership are also scrutinized.

Keywords: Lean Leadership; Lean Leaders; Lean Managers; Sustainable Lean Manufacturing; Systematic Literature Review

Introduction

It is widely accepted that the role of leadership is of great importance for a lean manufacturing sustained implementation. Furthermore, for lean implementation to be successful there should be a long-term commitment from the leadership (Liker, 2004). According to Dombrowski & Mielke (2014), a “lean implementation to succeed requires not only a system change but an effective leadership, necessary to catalyse and sustain that change”. Moreover, leadership plays a central role in establishing conditions to succeed (Mann, 2009). It is the most important piece in a lean manufacturing implementation (Dombrowski *et al.*, 2017). Therefore it could be the missing link between lean initiatives and a sustainable manufacturing implementation (Dombrowski & Mielkel, 2014). To implement lean manufacturing, people apply a set of lean tools to improve and standardize processes (Alefari *et al.*, 2017; Mann, 2009). However, “implementing tools represents at most 20 percent of the effort in Lean transformations. The other 80 percent of the effort is expended on changing

leaders' practices and behaviours, and ultimately their mindset" (Mann, 2009). According to Dombrowski *et al.* (2017), lean leaders' bridge between the technical system (methods and tools) and social system (people). It is of extremely importance that lean leaders at the three levels (senior level, function level and department level) of the organization play their role. Moreover, Mann (2009) consider that their involvement and contributions include: (1) managing arrangements that crosses internal boundaries, (2) supporting a long-term vision of the organization's producing processes, (3) sharing the responsibility with everyone for meeting the commitments and (4) a regular and direct involvement. In their study, Alefari *et al.* (2017) highlight the importance of lean leader's commitment. For them, the main lean implementation barriers related to leaders is the poor commitment from the top because of poor knowledge or belief on the approach and because of the change inertia or the commitment lasted too shortly.

Some models dealing with the lean leadership/lean culture topic can be found in the literature. In their study Dombrowski & Mielke (2013) propose a lean leadership model defining five different principles of lean leadership, namely: (1) improvement culture, (2) self-development, (3) qualification, (4) gemba, and (5) hoshin kanri. The authors developed a survey around the conceptual model and concluded that some lean leadership characteristics have been misunderstood and others are not used as thoroughly as they should. Moreover, Hines (2010) develops a model entitled "Lean Sustainability Iceberg Model" focused on the development of a lean culture, which differentiates between factors above and below a waterline. The enabling factors that are below the waterline are strategy and alignment, leadership, and behaviour and engagement while the factors that are above the waterline and which are visible are technology, tools and technologies, and process management. The same author argues that the sustainable lean thinkers need to learn to see and act below the waterline as well as above it. Another contributing model for lean implementation, incorporating the leadership element, is the Lean "Leadership People Process Outcome" model that was proposed by Dibia *et al.* (2014). Their model considers the following four elements: leadership, people, process and outcome. Furthermore, Liker & Trachilis (2014) put forward the "Lean Leadership Development Model", deeply focused on the development of people, that considers the following four steps: commit to self-development, coach and develop others, support daily kaizen, and create a vision and align goals. At the center of the model are a set of core values to be accomplished: challenge, kaizen mind, go and see, teamwork and respect.

Although several authors (see e.g. Moeuf *et al.*, 2016; Dombrowski *et al.*, 2017; Holtskog *et al.*, 2016) highlight the importance of the leadership in a lean implementation, it remains unclear the research development around the topic of lean leaders' characteristics on the sustainable implementation of lean manufacturing. Several authors (Goodridge *et al.*, 2015; van Dun *et al.*, 2017) claim that the research on this subject remains incomplete. In addition, Poksinska *et al.* (2013) state that there are only some studies that have described and empirically investigated the subject of lean leadership even though lean implementation has been the subject of a significant amount of scholarly research (Dibia *et al.*, 2014). Also, from our literature analysis it can be concluded that there is room for further research developments regarding the behaviours and competencies of desired leaders and managers across different levels (from top management to front-line leaders) of the lean organizations. An interesting contribution to this subject, exploring the results achieved in two alternative studies developed by Cardiff University and University of Twente, can be found in Found *et al.* (2009).

Within this context and in order to assist additional research, this paper presents a systematic literature review (SLR) on the current state of research on the topic of lean leadership to sustain the lean manufacturing implementation system. A SLR is a meticulous and well-defined review process that responds to a specific research question (Thomé *et al.*, 2016). Our research is grounded on two main questions: (1) What are the lean leadership alternative approaches/characteristics (e.g. traits, skills, behaviours, values and practices) to sustain lean manufacturing implementation? and (2) How organizational structure/levels of management influence the lean leadership? The present study intends to evaluate if the thematic of lean leadership that make up a lean management system on industrial companies has been a relevant research topic. The selection of the literature was based on the research questions. Furthermore, this study presents a qualitative analysis of the research. The study shows that this thematic is still an emergent research topic and needs more development research. The reminder of the paper is organized as follows: section 2 covers the research methodology; section 3 presents the sample characteristics and outlines the findings and discussion regarding the research streams, and the conclusions are presented in section 4.

Research Methodology

A systematic literature review is a method which ensures consistency by applying transparent steps. The methodology to conduct the systematic literature review comprised the following steps: (1) planning and formulating the problem; (2) searching the literature; (3) data gathering and source evaluation; (4) data analysis, synthesis and interpretation; and (5) results presentation (Thomé *et al.*, 2016).

The first step was to plan and formulate the research problem. The definition of the scope, setting the boundaries of analysis, and the research questions were defined to guide the research. This was addressed based on the existing literature.

Two important aspects to outline in a SLR are the selection of relevant databases and the criteria terms. Various publisher's electronic databases, namely Science Direct (Elsevier), Scopus and Web of Science were used to find the relevant articles. Different databases were used to obtain a deep understanding of the lean leadership concept and characteristics. For each database, the results were downloaded in single batches and on the same day. Several articles were extracted from different disciplinary areas such as business, management, engineering and science. A number of articles were excluded since they were out of the scope, as articles in the healthcare subject, in order to obtain only the ones that are in the thematic of the lean management system on industrial manufacturing contexts.

The rule for the search engine was based on the variables identified in the research scope. Several keywords-based searches were applied to find the relevant literature. To collect articles published the keywords selected were the following ones: "lean leadership", "lean leader(s)", "lean culture", and "lean manager(s)". Literature search was performed without restricting the search to a specific period, and so considered the time period as "all years".

The research team developed the overall process, from keywords definition, to article collection and protocol definition to register data. A protocol to record all imported articles was defined. An Excel Microsoft spreadsheet was used as supporting tool for analysis, and registering the important data related to each article. The information recorded are: (1) database, (2) research keyword, (3) journal of publication, (4) title, (5) authors' name, (6) link of publication, (7) year of publication, (8) volume, number and pages, (9) author keywords, (10) abstract and (11) article type.

A point of saturation was identified when the same articles were appearing repeatedly (Garza-Reyes, 2015). In addition, the team research carried out the examination and selection of the articles based on criteria for inclusion and exclusion. The study only considered English articles and those that were connected with the lean terms defined. The lean terms adopted in the research were the following: lean leadership, lean leaders, lean managers, lean culture, lean manufacturing, sustainable lean and industrial companies. All articles were manually analysed through the reading of the titles and abstracts to guarantee that only the articles that fit in the research scope were considered (Caldera *et al.*, 2017). The articles that clearly did not address the scope of the research were removed. Also, only articles peer reviewed from journals and articles from conferences were selected to ensure the quality of the sources selected. All book chapters and white papers were eliminated. In addition, duplicate articles were eliminated. The findings resulted from the analysis and synthesis of the data are discussed in the following section, as descriptive findings.

Findings and Discussion

An original sample of 188 articles was reduced to 162 by removing duplicates. From the total of 162 articles, 41 articles were selected for the research study considering the title analysis, abstract and keywords of the papers. This reliability analysis was performed in two phases. In a first phase two different researchers analysed autonomously and independently the database. Afterwards, in a second phase, the researchers met in person to define the final list of papers, considering the first phase results and the researchers' point of views when the results analysis didn't converge in the first phase. Furthermore, during the second phase, when there was a disagreement between the researchers' point of view the divergences in opinions were discussed, supported by a new analysis, until a consensus was achieved. The results obtained were 25 (61%) journal articles and 16 (39%) conference articles (Figure 1). These were all the articles that referred to leadership characteristics as well as related topics, such as the influence of the organizational structure/management levels on lean leadership. Figure 1 confirms that journal articles are the preferred way for researchers to disseminate and publish their work in this thematic.

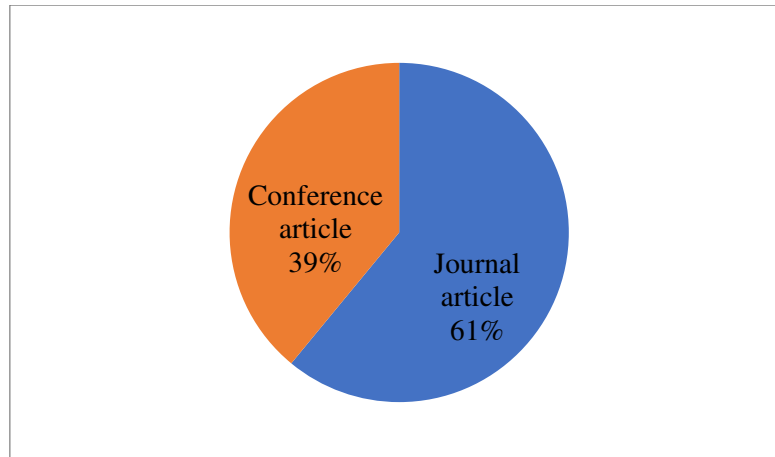


Figure 1 – Percentage of articles published

The articles were found through the search engine on each database. Through the keyword search different articles were found. Figure 2 shows the distribution of articles by keyword search distributed by conference articles and journal articles. The keyword search “lean leadership” was the one that returned more articles, followed by “lean culture”. This is in accordance with Poksinska *et al.* (2013) that claims that: [lean] leadership is the key factor in creating and changing organisational culture. Also these authors consider the same roles for leaders and managers.

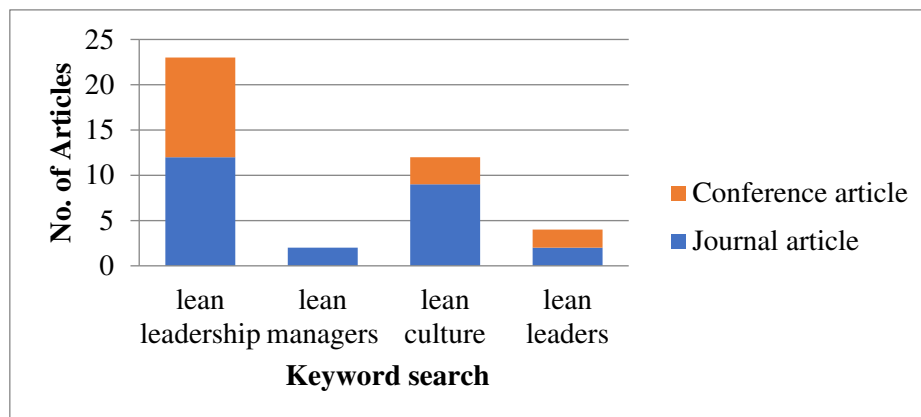


Figure 2 – Number of articles by Keyword search

Although the terms lean and lean manufacturing were used for the first time in 1988 (Alefari *et al.*, 2017; Poksinska *et al.*, 2013), the results from the study show that only articles written from 2010 to 2018 are found. Figure 3 presents a chronological summary of publications. From the figure it is possible to notice an increasing growth trend in the investigation on this subject over time. As the research study has been developed in July 2018, the year 2018 is not complete and a trend to an increase in the number of publications until the final of the year can be anticipated. Over the years, the subject has been gaining interest within the researchers, particularly in the recent past years. Most of the articles (over 70%) were published after 2013, highlighting the relatively novelty of this field of research. This is in accordance to Hogg (2011) that highlights the spread of lean over every system type, anywhere and in every sector, integrated with all other processes and initiatives, including the company's vision, operations strategy, and each day's driving standards.

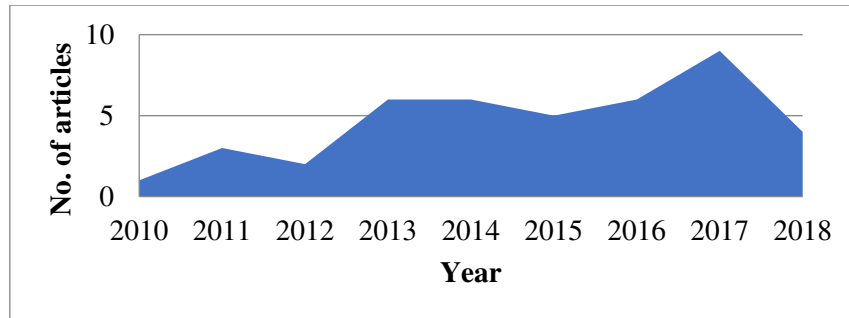


Figure 3 – Temporal distribution of the articles

Regarding the number of articles per publication (Figure 4), a high dispersion is quite evident. The journal “Procedia CIRP” is the journal with more conference articles published, representing about 12% of the total, followed by the “Journal of Manufacturing Technology Management” that represents 7% of the total. Moreover, the publications “Total Quality Management and Business Excellence”, “IFAC-PapersOnLine” and “Development and Learning in Organizations: An International Journal”, represent 5% of the total each. In the remaining publications only one paper was published in each one of them. As a final conclusion, about 34% of the articles were published only in 5 publications out of 32 alternative journals/publications. This range of journals and conferences diversity may be explained due to the fact that this subject is a general and a central thematic. Indeed, lean manufacturing is widely applied to all industry sectors (Testani & Ramakrishnan, 2011; Poksinska *et al.*, 2013).

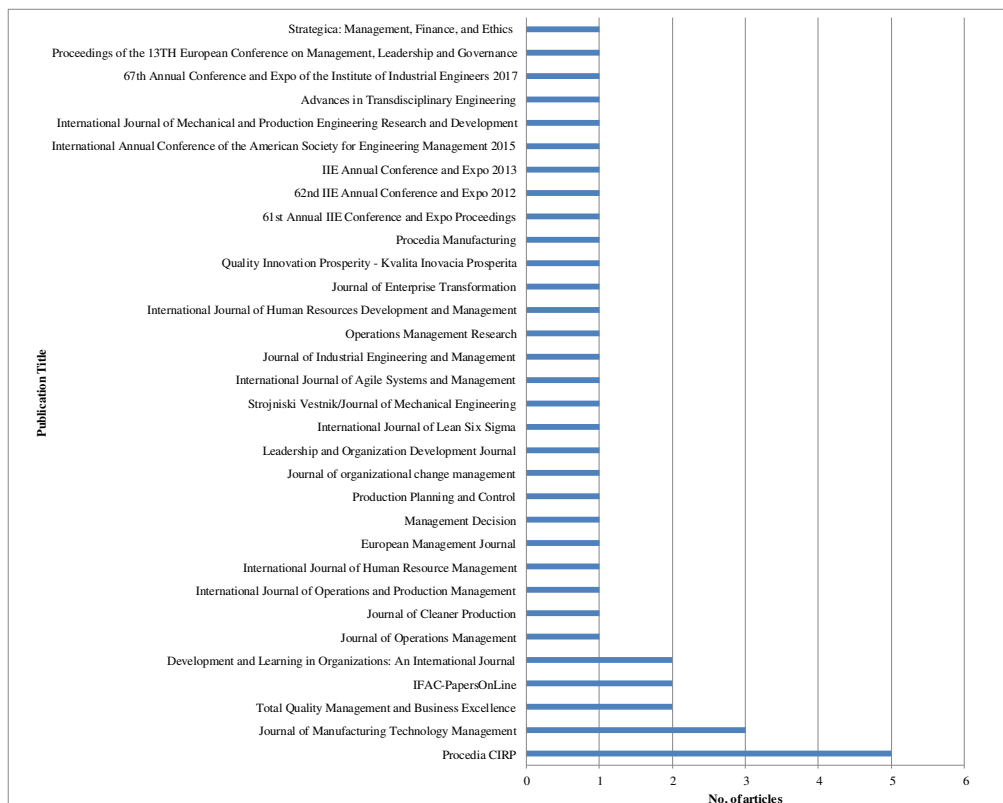


Figure 4 – Number of articles per publication

The analysis of the scientific areas of the articles published on peer reviewed journals, excluding conference articles, is presented in Figure 5. The sample size was 25 papers. This analysis was performed considering the main scientific areas of the journals described in the journals’ websites. Furthermore, papers were organized in the following 5 areas: (1) Operations Management (OM), Logistics, Supply Chain Management (SCM) & Quality; (2) Human Resources (HR), Learning & Organization Studies (OS); (3) Management; (4) Mechanical

Engineering and (5) Cleaner Production (CP), Environmental & Sustainability. Two main scientific areas emerge from our analysis that showed that 80% of the papers were published in OM, Logistics, SCM & Quality and in HR, Learning and OS areas.

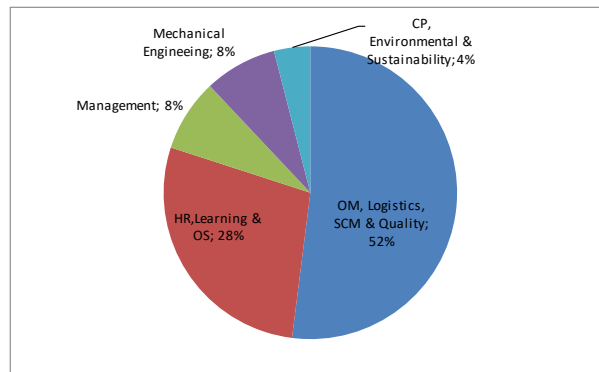


Figure 5 – Percentage of articles per scientific area from the journals sample.

The sample characteristics analysis also showed that in terms of the research approach applied 28 articles had an empirical focus, while 13 papers were mainly conceptual. None literature review paper was found. All the articles included in the sample were analysed and categorized based on the research questions. By the preliminary analysis obtained from the systematic review of the literature, different streams are considered but in some cases overlapped. A preliminary categorization was defined, considering the abstract analysis of the articles. Figure 6 shows the dominant streams of lean leadership to sustain lean manufacturing implementation. The category “General” includes papers that do not fit any of the two research questions presented in the Introduction section. It is possible to see that the influence of organizational structure/levels of management on lean leadership is the topic that needs more research. Furthermore, the analysis also shows that despite the moderate level of research about lean leadership, the majority of the research about the topic is concerned with the lean leadership characteristics, such as the study of the leaders’ traits, skills, behaviours, values and practices, and their importance for a sustainable lean implementation and for the acquisition of a lean culture.

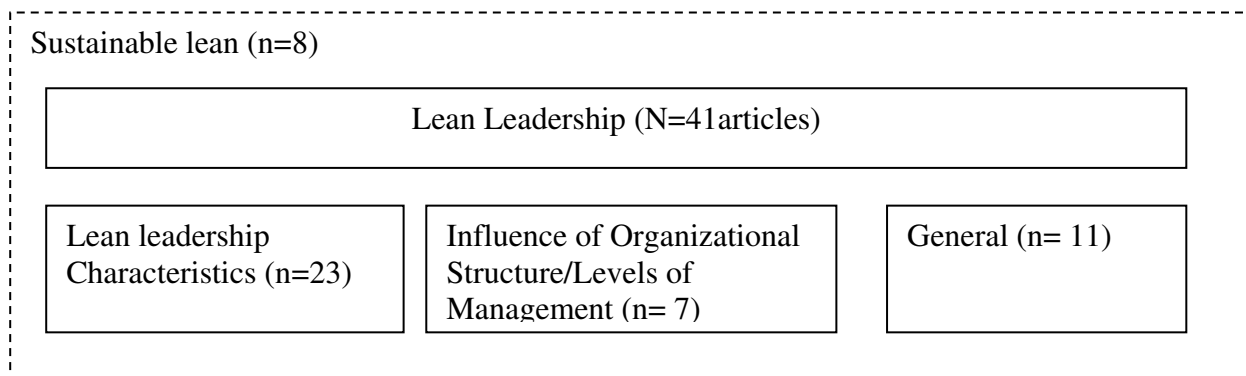


Figure 6 – Preliminary categorization of the sample

Concluding Remarks

The lean manufacturing topic has received a broad attention from academics and practitioners all over the world. However, the majority of the literature is mostly concerned with the technical aspects of a lean implementation even though there is a general agreement about the importance of the people engagement and of lean leadership to the lean sustainability over time. Despite that fact, the soft component of lean is a much less researched theme. Only in the most recent years this topic seems to have attracted the researchers’ interest. Nonetheless, although several literature reviews can be found about lean, there has been no prior literature

review specifically dedicated to the lean leadership concept, making it an interesting topic for research. Therefore, in this study a systematic literature review was carried out and the preliminary results achieved presented. From the findings it is possible to state that most of the articles were published after 2013, highlighting this thematic as an emergent research topic. Furthermore, a trend toward the increase in the publication of articles on this subject is expected to continue in the future. The topic is mostly found in publications from the Operations Management, Logistics, Supply Chain Management and Quality areas, as well as in Human Resources, Learning and Organization Studies areas, although a high dispersion can be found regarding the publication titles. Also, a prevalence of empirical papers over conceptual ones is found and the favourite mean to disseminate lean leadership research is through peer review journals.

This research considered two research questions: (1) What are the lean leadership alternative approaches/characteristics to sustain lean manufacturing implementation? and (2) How organizational structure/levels of management influence the lean leadership? From our preliminary analysis 23 papers of our sample could be associated to research question (1) and 7 to the second research question, showing that there exist prevalence to the study of the set of ideal leadership approaches and characteristics that make up a lean management system on industrial companies instead of the study of the relation between organizational structures/levels of management and the lean leadership role.

Despite the important contribution of this paper, there are limitations of the study that should be noted. The study was performed through the analysis of the titles, abstracts and keywords of the papers sample. Further research on the sample is needed, namely the articles carefully reading, in order to fully answer the above presented research questions and also to identify other possible gaps in the literature and find new paths for research relative to lean leadership. Also, regarding the Research Methodology a deeper source evaluation should be performed in the future, namely through the analysis of further articles referenced in the current sample to be included in the final sample.

Acknowledgements

Authors would like to acknowledge to UNIDEMI - Research and Development Unit for Mechanical and Industrial Engineering (UID/EMS/00667/2013) for its support. Carina Pimentel would like to acknowledge to the research unit on Governance, Competitiveness and Public Policy (project POCI-01-0145-FEDER-008540), funded by FEDER funds through COMPETE2020 - POCI (Programa Operacional Competitividade e Internacionalização) – and by national funds through FCT (Fundação para a Ciência e a Tecnologia), for its support.

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Why developing supervisors' TWI skills is fundamental for your Lean Journey?

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Abstract

Lean improved the competitiveness of many companies and the value they deliver to customers. Despite these achievements, many companies are stuck after their initial Lean efforts. There are many reasons for this, one of them is lack of skills of front line leaders. Managers and supervisors are not able to create conditions for performance in changing environment.

Operators are afraid of change, they don't clearly understand its purpose and goals. They do not trust their leaders. They do not follow the standards. Lean implementers are familiar with these problems. What could we do to overcome these obstacles? We need to ask ourselves if the leaders have knowledge and skills needed for implementing Lean. Many of them have good knowledge of Lean principles and tools. However having knowledge is not enough, leaders need to develop skills that will help them in creating the right conditions for their team members performance.

What are the fundamental skills needed by front line leaders when implementing Lean?

Training Within Industry Program lists them as: skill in Leading, in Instructing and in Improving Methods. There is a skill development program for each skill: Job Relations, Job Instruction and Job Methods. When supervisors develop the 3 TWI skills, they are able to solve the obstacles that raise at the shop floor.

Respect for People is one of Lean principles. How can supervisors demonstrate Respect for People? Job Relations helps supervisors to understand what are the specific actions they can take daily to create a trustful environment that will enable their teams performance.

"Without standards, there cannot be improvement" but operators do not follow the standards. What can supervisors do to help team members to follow the standards? Job Instruction teaches supervisors how to instruct workers so that the standards reflect in their performance.

"How can I improve the work?" Job Methods helps supervisors to focus on the processes in their area, analyze jobs, generate ideas and implement them together with their team members.

TWI program develops new behavioral routines of the leaders, so that they can create the right conditions for their team members performance every day.

Keywords: Training Within Industry; TWI Program; supervisors' skill development; Job Relations; Job Instruction; Job Methods

The Problem with ‘Tools and Techniques’; Why Becoming a ‘Learning Organisation’ is Vital to a Successful Lean Transformation.

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Assignment Submission
Lean Competency System – Level 3b
Cardiff University
February 2018

Executive Summary

This paper explores underlying reasons why, after many decades of attempted Lean improvement programmes, so few organisations have managed to reach the levels of success exhibited by Toyota.

A review of recent literature suggests that critical elements of the Toyota Production System have been overlooked; the less tangible elements that engage and support the workforce in structured improvement activity (or ‘Kata’). This activity is core to Toyota’s efforts in becoming a ‘Learning Organisation’, and this paper details research from outside the ‘Lean’ environment showing how organisations can enable or inhibit their ability to excel at this.

The paper also explores how ‘western’ leaders differ in their approach to problem-solving than those in ‘eastern’ regions. This may be a significant factor in why ‘linear thinking’ is prevalent in the application of ‘Lean’, resulting in a greater focus on the ‘tools’ than on the human elements of the approach.

A survey has been done of leaders and Continuous Improvement professionals from 22 organisations to support the above research. Findings from this survey suggest that very few organisations currently use the ‘Kata’ approach. Also, there is often very little appetite to support either a ‘learning from mistakes’ or a ‘trial-and-error’ approach to problem-solving, both of which form part of the ‘Scientific Method’ at the core of the ‘Kata’ improvement process.

The report concludes that there needs to be a much stronger focus given to the promotion of the ‘Kata’ approach through Lean training and coaching. And that promotion of the ‘tools and techniques’, developed by Toyota, as potential ‘solutions’ to other organisation’s issues needs to stop. More effort should be spent developing appropriate solutions which move the organisation towards its ‘Vision’, and these could be very different from recognised Lean tools. This also addresses the need to look at the whole ‘system’ that makes up an organisation, and challenges some of the ‘linear thinking’ paradigms that have developed due to the way that Lean has often been implemented.

Introduction

In 2006, H. Thomas Johnson, Shingo Prize and American Society for Quality Deming Medal winner, and Professor of Business Administration at Portland State University asked an important question:

“If businesses everywhere have given enormous attention to Lean management programmes for over a decade, how is it that none succeeds as Toyota has at continuously improving lead time, cost, productivity, quality and – perhaps most importantly – financial performance year after year?” (Johnson, 2006).

Similar observations have been made in other sectors where Lean is being applied. A study by Burgess (2012) on Lean deployment in the Healthcare sector, concluded that there was:

“...no firm evidence that Lean implementation improves performance at an organisational level” (Burgess, 2012, pg.288).

In its 2007 Census of Manufacturers, Industry Week found that only 2 percent of companies surveyed - that had a Lean programme - achieved the anticipated results. In fact, less than a quarter (24%) of all companies reported achieving significant results (Pay, 2008)

With such an under-whelming success rate, it is important to understand more about the fundamental reasons for such poor results from Lean’s adoption? This paper investigates the hypothesis that there are two inter-linked reasons for this, which although not exclusively to blame for the perceived under-performance in some organisations, go some way to explaining why it has proved so difficult for firms to emulate Toyota’s success.

Lean as a suite of ‘tools & techniques’?

The first factor explored in this paper is that, too often, Lean is perceived as a replication of tools and techniques as developed from the Toyota Production System (TPS); whereas it should be considered to be a system of



structured ‘learning’. This would suggest that tools developed through 50 years of the TPS are only actually optimal solutions for the very specific problems in automotive manufacture. This paper explores the theory that organisations - whilst mindful of how Toyota develops solutions using a structure methodology (known as ‘Toyota Kata’) – should, in practice, develop rapid improvement cycles of their own, generating their own solutions, and moving towards their own ‘Vision’.

Is ‘linear thinking’ inhibiting the success of Lean?

The second part of the hypothesis is that organisations (especially those in the West), and their leadership in particular, see problems in a ‘linear’ way. And therefore, apply Lean tools with this filter in place. This paper provides evidence to suggest that this often leads to poor implementation, short-term gains that are soon lost, and a failure to apply Lean to the real strategic and systemic issues affecting business performance.

This study starts with an academic and business literature review into why Lean programmes are perceived to have failed, and then explores how other authors perceive Lean’s effectiveness as an approach for ‘Systems Thinking’. It then details research that the author has conducted with a number of organisations actively engaged in Continuous Improvement activity, to understand how structure, behavioural and cultural conditions encourage or inhibit both ‘Systems Thinking’ and the development of a ‘Learning Organisation’.

Literature Review

When investigating reasons why companies (those participating in the 2007 Industry Week survey mentioned in the introduction) failed to achieve their anticipated levels of benefit, Pay (2008) suggested the following factor:

‘Senior Management is unwilling to accept that cultural change is often required for Lean to be a success’.

Pay (2008) explains that the empowering of teams and the positioning of decision-making at the lowest possible level is a requisite part of a successful Lean programme, and that many management teams are simply unwilling to ‘let go of the reins’ and allow this culture to grow.

Seddon (2003, pg.139) takes this a step further and lays down a gauntlet for organisational leaders:

“Are you prepared to change your own role? Could you conceptualise your work as ‘working on the system’?”

His view is that systemic factors such as structure, policy, procedures, measurement (in particular) and IT etc. are the things that really need to change (Seddon, 2008, pg.120). He argues that ‘management’s’ role needs to change from managing people – to managing the system – understanding and improving how well the work flows, end-to-end, to fulfil the customer’s demands.

This review seeks to explore this assertion and take it further. That it is necessary, for a truly transformational Lean programme to be able to succeed, for management to actively foster the principles of a ‘Learning Organisation’ as described by Peter Senge in his seminal book ‘The Fifth Discipline – The Art and Practice of the Learning Organisation’ (Senge, 2006). This being where an organisation promotes a culture where the whole system is improved through deep understanding of processes, building a shared vision, development of mental models, personal mastery (and development) and team learning (Senge, 2006, pg.12).

Senge (2006, pg.11), as well as being critical of the practise of benchmarking ‘best practices’, notes that simple replication of other’s (namely, Toyota) techniques and approaches is not sufficient. He cites a senior Toyota manager who having conducted hundreds of tours for visiting executives commented that they “see all the parts and have copied the parts. What they do not see is the way all of the parts work together”. Senge also asserts that ‘no great organisations have ever been built through trying to emulate another’. That would appear to present a profound challenge to the Lean community, and the traditional linear approach to a Lean deployment programme.

Senge (2006, pg 24 -25) addresses several of the ‘cultural’ and competing elements, which he calls ‘learning disabilities’, that prevent management teams from working collectively on the complex issues that might be affecting their organisation. He suggests that people are ‘hard-wired’ from an early age to never admit they don’t know the answer, and that corporations actively reinforce this lesson by rewarding people who most stridently advocate their own views, rather than taking time to inquire into complex problems. Could it be that a Lean programme that is limited to the scope of current understanding, and which doesn’t begin to address the large scale and complex threats to an organisation, is already doomed to failure? As Senge (2006, pg.24) puts it, ‘the analysis of the most important problems in a company, the complex issues that cross functional lines, becomes a perilous and non-existent exercise’.

So why is ‘linear thinking’ so prevalent in the way that problems are tackled, rather than ‘systems thinking’ - where solutions that look holistically at the total system are developed? Senge (2008, pg.250) explains that:



“because we see the world in simple, obvious terms, we come to believe in simple, obvious solutions. This leads to the frenzied search for simple ‘fixes’”.

Checkland (1991, pg.154) notes that problems are often recognisable in two forms:

“*structured* problems which can be explicitly stated in a language which implies that a theory concerning their solution is available and *unstructured* problems which are manifest in a feeling of unease, but which cannot be explicitly stated without this appearing to over-simplify the situation”.

He explains that structured problems are usually approached by what he terms ‘hard’ systems thinking, as they conform to an approach where use of a well-defined ‘problem-solving’ methodology can be used (Checkland, 1991, pg.155).

Checkland (1991) suggests the existence of ‘human activity systems’, which do not readily conform to structured and predictable definitions of a system. He observes that:

“the contents of such systems are so multivarious, and the influences to which they are subject so numerous that the passage of time always modifies the perception of the problem”.

Senge suggests a new term to describe the many situations where cause and effect are subtle, and where effects over time of interventions are not obvious. He calls this ‘dynamic complexity’ (Senge, 2008, pg.71). An example he uses should be very familiar to anyone who has experience of problem-solving in an organisation; where an action has one set of consequences locally and a very different set of consequences in another part of the system. Senge (2008, pg.72) concurs with the view of Seddon (2003) quoted earlier that:

“The real leverage in most management situations lies in understanding dynamic complexity, not detailed complexity.”

So how does Lean, and its implementation across many different industries in the past 40 years, compare to the vision of ‘Systems Thinking’ espoused by Senge and Checkland?

Pound, Bell and Spearman (2014, pg.8) take a strong view that Lean practitioners have become almost obsessed with replicating the Toyota Production System (TPS):

“Very often, Lean practitioners consider the TPS, with its focus on achieving one-piece flow as the *end*, rather than as a *means* to the ultimate end, which is long-term profitability.”

Pound et al (2014, p15) go further and say that a reason why many firms don’t make a success of Lean is that Lean actually ‘promotes’ improvement by imitation.

In an article critiquing the many poorly executed Lean programmes in North American manufacturer’s (McCullough, 2011), the Managing Director of Alix Partners, Steve Maurer observes:

“Most continuous improvement initiatives focus too much on implementing a particular ‘checklist’ of program tools and processes.”

The same feature describes the evolution of a Lean approach at Canadian window firm ‘All Weather Windows’. Jason Fleming, the CI Manager of ‘All Weather Windows’ describes how it took six years of attempting to implement Lean tools before they realised that:

“It (the company) had to come up with its own definition of Lean”.

He goes on to say:

“It’s been a lot of trial and error. We’ve taken pieces here and there and put together what works for All Weather Windows”.

His final statement echoes the criticism of Pound, Bell & Spearman (2014) when Fleming recommends that organisations:

“Adapt lean thinking to the kind of work you do, don’t just copy Toyota. And finally, don’t make it about targets”. (McCullough, 2011)

Johnson (2006) believes that the failure of Lean initiatives is an ‘unintended consequence’ of the mechanistic way that managers take actions to improve financial performance. He suggests that there is a belief that financial results are a linear product of independent contributions from different parts of the business. He believes that this thinking and behaviour stems from out-dated business philosophies, based on 19th century mechanics and 18th century physics – the paradigms of whole-equals-sum-of-parts and win-lose competitive principles, for example. He proposes that the reason so many Lean initiatives fail to deliver long-term financial results is because of the failure of business practice to adapt to the more systemic, cooperative, win-win principles of 21st century cosmology and life science.

Perhaps more importantly for the successful deployment of Lean, Johnson (2006) proposes the view that managers believe that linear cause-effect connections at the abstract quantitative level apply everywhere in the world. Hence, they proceed to manipulate and control people and things according to linear principles. It is

this pervasive view that means that Lean initiatives struggle in non-Toyota environments. Leaders simply do not change their mechanistic thinking to a more systemic one; the approach that Toyota has been using for decades.

Outside of the manufacturing sector, the interpretation of Lean as a ‘model’, with a framework of tools and approaches that can be lifted ‘wholesale’ into the service industry sector, has attracted criticism and doubts as to its effectiveness. Arfmann & Barbe (2014) seek to discredit the notion of Lean Service Transformation completely; on the basis that there is little evidence of an emerging ‘model’ for Lean in service industries; that results are either misinterpreted or not valid, and that the application of Lean principles (such as the definition of non-value added activity, and the use of ‘pull systems’) have not been properly developed or do not apply in service organisations. Interestingly, in quoting an earlier study by Burgess (2012), and the perceived failure of Lean in the service sector, they argue that Lean can’t be credited for some of the improvements reported, because:

“Attention on particular problems, and the willing(ness) of management to understand the underlying reasons led to actions that helped to improve the business”.

And furthermore that:

“It is not the knowledge about lean methods, tools or transformation processes that help organisations to improve their performance. It is knowledge about daily business reality that counts and enables managers to take action to really improve their performance” (Arfmann & Barbe, 2014, pg.20).

It is fascinating to read that these report authors saw the above activity as not being part of ‘Lean’, whereas the dogmatic application of inappropriate or badly suited tools was.

Another factor in the prevalence of ‘linear thinking’ could be that there is a desire from business leaders when trying to ‘engage’ their workforce - or ‘influence’ their superiors to the benefits of Lean - to oversimplify its approach? Pound et al (2014, pg.69) suggest so, stating that they have found executives and managers are predisposed to favour simple solutions over complex ones. As a counter-point, they quote Albert Einstein, who once said, “A theory should be as simple as possible, but no simpler”.

So, does this mechanistic and linear predisposition impact the way in which Lean is applied to organisations (especially those in the West)? Could this be a reason for the poor levels of success for many of the Lean implementations quoted? Perhaps even the measure by which ‘success’ is rated is flawed, as it is potentially also grounded in the same linear thinking?

In their book, *Toyota Culture: The Heart and Soul of the Toyota Way*, Liker and Hoseus (2008) draw comparisons to the different ways that ‘eastern’ and ‘western’ cultures think about problems. They suggest that westerners tend to believe in ‘controllability’ more than easterners, and that that westerners are more likely to see logical rules to understand events than easterners. This, they suggest, goes some way to explaining why a ‘western’ implementation of Lean is akin to the application of a tool kit; one that helps control the work environment to achieve specific measurable objectives. They compare this objectification of the workplace, and the associated seeing of simple cause-and-effect relationships, with the reality of a complex dynamic environment; and the approach that Toyota take in making improvements in such situations (Liker & Hoseus, 2008, pg.24). They argue that Toyota’s approach is foremost about getting the team in an area to see the ‘waste’, and to use clear and rigorous thinking and teamwork to solve problems. They also suggest that Lean leaders at Toyota:

“Realise that most ideas for improvement are simply good guesses and need to be verified through experimentation”.

This leads to a desire that there be many experiments being run, by many people working in the process, with associated monitoring and learning in place (Liker & Hoseus, 2008, pg.24).

Denning (2011) provides further insight into this approach:

“The experts don’t tell the plants what to do.....instead, what you see is the result of many small steps, some of which were discarded, and others embraced.... the result of many cycles of Plan-Do-Check-Act”.

He goes on to suggest that, “Continuous Improvement is a way to achieve things that you don’t necessarily know how you are going to achieve” (Denning, 2011)

If leaders do grasp the need to inculcate a sense of learning through experimentation in their organisations, what factors might prevent this approach being more widespread? In his best-selling book *Black Box Thinking: Marginal Gains and the Secrets of High Performance*, Syed (2015, pg.13) proposes that it is the human response to failure that inhibits the freedom to learn through experimentation. He argues that a ‘deep

instinct to find scapegoats' and to apportion blame, inhibits our ability to learn from mistakes. This in turn leads to a 'fear of failure' whereby:

"we don't want to think of ourselves as incompetent or inept. We don't want our credibility to be undermined in the eyes of our colleagues".

Syed (2015, pg.53) draws on the experience of the Virginia-Mason Health System to illustrate the impact of addressing this human behaviour. Syed, in an interview with Gary Kaplan, the Chief Executive of Virginia-Mason, noted that when Kaplan had witnessed the use of the 'andon' system at Toyota, during a study tour to Japan, he adapted this system to the healthcare environment, through the introduction of Patient Safety Alerts. It is interesting to note that Kaplan makes the following caveat:

"If a culture is open and honest about mistakes, the entire system can learn from them. That is the way you gain improvements".

According to Syed (2015, pg.55-57), the success of the Virginia-Mason Health System is not a one-off, it has become a 'method'. In other words, a properly instituted learning culture which has transformed the performance of hospitals around the world. In another example from manufacturing design, Syed (2015, pg.135) describes how biologists made 449 experiments on the design of a nozzle in a part of their process, each one based on learnings, or failures even, from the previous experiment. Each experiment was tested rapidly, resulting in a single outstanding nozzle design.

Syed (2015, pg.58) asserts that there are two components vital for a learning culture to flourish. A system, by which learning opportunities can be identified and captured; and a culture (or mindset), that encourages learning through failure and experimentation towards improvement, even if there are many cycles of this before the ultimate goal is achieved. Syed (2015, pg.276) describes this approach in individuals and companies as a 'Growth Mindset', where a culture was perceived as being more honest, collaborative and the attitude to errors was far more robust. Typical statements that represented this type of organisation were:

"This company genuinely supports risk-taking and will support me even if I fail".

"When people make mistakes, this company sees the learning that results as 'value added'".

The importance of leadership, in creating and encouraging a culture where people feel able to both admit mistakes and to be given the opportunity to learn from them without fear of reprisal or blame, should not be understated. Just 'telling' people that its acceptable to admit mistakes will not change a culture overnight. Syed (2015, pg.64) quotes Gary Kaplan again:

"You can have the best procedures (for reporting mistakes) in the world, but they won't work unless you change attitudes towards errors".

In his book 'Good to Great: Why Some Companies Make the Leap...and Others Don't', Jim Collins presents clear evidence that leaders, from 11 major US corporations that had consistently out-performed their rivals over a 25-year period, generated a climate where truth is heard, and brutal facts confronted (Collins, 2001, pg.74). Interestingly, one of the recommended practices Collins details is to "Conduct autopsies, without blame", thereby allowing for the 'truth' to emerge, and for the organisation to learn from the mistakes made (Collins, 2001, pg.77). There would appear to be a clear link between the mind-set and behaviour of leaders in an organisation, and the prevailing culture whereby 'learning from mistakes' is embraced.

So how does Toyota provide a 'vehicle' or structure, that allows for rapid 'organisational learning' through trial-and-error, where teams are permitted to experiment (and indeed learn from mistakes)? Spear and Bowen (1999) captured Toyota's use of the 'Scientific Method' as a key component of improvement effort within their businesses. They codified the critical elements of Toyota's success into four 'Rules', the fourth of which highlights that the TPS creates a 'community of scientists'. Rule 4 states:

"Any improvement must be made in accordance with the 'Scientific Method', under the guidance of a teacher, at the lowest possible level of the organisation" (Spear & Bowen, 1999).

Mike Rother's seminal work, "Toyota Kata" seeks to explain this approach in more detail (Rother, 2010). The term 'Kata' – as defined by Rother himself, and borrowed from martial arts terminology – is a series of steps for both an improvement and coaching cycle, that guide individuals through a rapid series of single-step experiments towards a 'Target Condition'. This 'Target Condition' is a predefined series of attributes that move a team or organisation towards an ultimate 'Vision', but which can be expressed as the way something should ideally operate at a specified time in the future. Rother believes that this standardised pattern of behaviour at Toyota, repeated over-and-over at all levels of the organisation, is the key to Toyota's continuing success (Rother, 2010, pg.15).

Furthermore, and in direct challenge to a lot of Lean deployment assumptions, Rother asserts that all of the tools associated with the Toyota Production System (and by obvious inference, Lean), have actually been developed by Toyota as ‘Target Conditions’ towards a longer-term ‘Vision’. Rother gives a detailed example of how the tool of ‘kanban’ is used at Toyota as a ‘Target Condition’ towards single-piece flow (Rother, 2010, pg.99). He argues that the implementation of a kanban card system without the associated ‘learning’ from the team members as to why this is a step towards a longer-term goal misses a vital point:

“It is the striving for target conditions via the routine of the improvement kata that characterises what we have been calling ‘Lean Manufacturing’” (Rother, 2010, pg.101).

So where does the Toyota Kata approach fit in terms of a ‘Systems Approach’ to problem-solving? Checkland (1991, pg.241) describes his own 7-step methodology for system problem-solving as:

“a learning system which aims to increase knowledge in and understanding of a real-world situation regarded.....as a problem.”

Rother also recognises the dynamic complexity of real-life situations and posits the idea that ‘Kata’ - with its contingent approach to incremental improvement - allows for dynamic and unpredictable conditions (Rother, 2010, pg.16). The rapid cycles of Plan-Do-Check-Act (PDCA) - through ‘Scientific Method’ experimentation - that underpin the ‘Kata’ routine allow for constant course adjustments. As the student learns more about the nature of the problem or reflects that the situation is different than first thought, the next step can be planned or ‘Target Condition’ redefined (Rother, 2010, pg.136). Checkland’s work appears to reinforce the idea that effective problem-solving in a ‘Learning Organisation’ is actually a journey towards an ultimate ‘vision’, understanding more about the situation as one progresses., rather than the delivery of a ‘quick fix’. He suggests: “The notion of a ‘solution’, is inappropriate in a methodology which orchestrates the process of learning which, as a process, is never-ending” (Checkland, 1991, pg.279).

It is Rother’s view that these iterations form the basis for Toyota’s continued success in tackling systemic and complex problems. Rather than devise large-scale vehicles for solving complex problems, the ‘Kata’ approach moves gradually towards a vision, removing numerous obstacles along the way, this is far removed from a ‘linear thinking’ approach. In a statement that profoundly challenges the beliefs of many Toyota Production System (TPS) advocates - and an entire Lean tools & techniques consultancy and training industry - Rother concludes:

“Toyota does not really have any obvious solutions to offer us, but rather a means for us to sense situations and develop appropriate, smart responses” (Rother, 2010, pg. 161)

Although, in practice, the impact of the above statement is somewhat diluted by the fact that much of Rother’s Toyota Kata book gives a closely detailed description of the ‘how’ and ‘why’ of TPS tools. It would appear that even advocates of the ‘Kata’ approach are still closely wedded to many of the Lean tool and techniques.

The next part of this assignment is to investigate how well understood the principles of ‘Toyota Kata’ are in organisations, how well ‘Systems Thinking’ is adopted, and whether organisational leadership is promoting a culture of a ‘Learning Organisation’.

Results and Findings

In order to understand more fully the level to which organisations have started to employ both ‘Systems Thinking’ and using Lean as an enabler to become a ‘Learning Organisation’, a research questionnaire was developed by the author to get the views of senior managers and change leaders across a range of organisations. 22 respondents replied. Full details of the responses are provided in Appendix A of this report.

The first questions on the survey, asked participants to confirm which, if any, improvement approaches (or ‘brands’), their CI programme was aligned to. Lean was the most dominant ‘brand’ for CI programmes from the survey (with 28% of respondents). However, 36% of respondents said that their improvement activities weren’t aligned to either Lean, Six Sigma, TPS. Half of these respondents preferred the term ‘Operational Excellence’. Although somewhat vague in its definition, this term appears to be based around fundamental Lean principles of Flow and Continuous Improvement and may well have developed as an alternative to the Lean ‘brand’ in sectors where this term might be perceived as too ‘manufacturing’ oriented (Institute for Operational Excellence, 2016).

The second question asked respondents for supporting comments regarding the ‘branding’ of their improvement programmes. Respondents used a variety of terms to suggest that they were actually adapting or tailoring elements of Lean (and other improvement methodologies) to meet their organisation’s particular circumstances:

“A bespoke approach based on Operational Excellence”
“Encompasses elements of Lean and TPS”

This could be interpreted as a positive step towards some organisations developing their own unique improvement solutions, but further research might be required, as there is also a danger that this might be ‘cherry-picking’ or ‘watering down’ certain ‘Lean’ tools.

Question three sought to understand how respondents’ organisations involved people in their improvement efforts. Tellingly, no respondents answered that ‘Everybody is involved, at all levels. It’s part of our DNA’, suggesting that there is still a considerable way to go for most firms in making improvement part of their daily activity. 23% of respondents did agree that ‘Most people were involved (in improvement activity), at some point’, which shows there are organisations moving toward the ‘high bar’ of total involvement. The largest category of responses (36%) was that improvement activity is led by ‘a team of internal experts, with ad hoc support from other team members’. This at least suggests that organisations have internalised some of the skills required to lead improvement activity, but it’s likely that these team members are still using Lean or Six Sigma techniques as opposed to the development of solutions that are adapted to the specific requirements of their business. 27% of respondents said that their organisation relied on ‘external experts, with ad hoc support from internal team members’. Without significant focus on ‘knowledge transfer’ from the external experts, it’s unlikely that there would be much evidence of organisational learning in firms in this category. 14% of respondents said that their organisation had ‘no structured approach to problem-solving or improvement’ at all. In the supporting comments provided in question four, there appeared to be a theme emerging of reliance on external expertise support:

‘Most major improvement projects are consultant led, with mix of contractors & internal support.’

‘It’s led by a mix of internal and external experts (80% external).’

‘Most major projects involve some external specialists - marketing, telephony, Operations Excellence.’

Question five in the survey sought to rate the effectiveness of organisation’s ability to solve complex problems. When asked to score their organisation’s ability at this competency respondents average score was 4.3 out of 10. The median score (with 6 respondents scoring at this level) was 3 out of 10. Supporting comments included:

‘We have trained our people in problem solving techniques, but we haven’t yet built the structure to support it.’

‘We have built some good structures and approaches but still dependent on a few key personnel.’

‘The central team are skilled in PS but the rest of the business not so.’

‘Good at pilots not so good at full implementation.’

‘A lot of linear thinking in the organisation.’

These comments suggest that often problem-solving skills are not widely adopted outside a group of dedicated staff, and that even then, their efforts might well start to stall when the approach is tried across organisational boundaries. This is somewhat short of the ideals of total workforce involvement in improvement and kaizen activity as practised at Toyota.

Question six attempts to assess the respondents view on whether their organisation learns well from mistakes. The average score for responses was 3.8 out of 10, with a median score of 3 (5 respondents scoring at this level). Questions later in the survey explore reasons why this low level of confidence might be the case.



When asked, in question seven, what tools or methodologies organisation's use to help structure their problem-solving efforts, over 76% recognised the Plan-Do-Check-Act cycle (PDCA). This was by far the most popular tool, with the Six Sigma continuum of Define-Measure-Analyse-Improve-Control (DMAIC) being the second most recognised (33% of respondents). A3 based problem-solving was used by 24% of respondents. Only 2 respondents (9.5% of the survey respondents) said specifically that they used the Kata approach.

Supporting commentary to the previous responses is given in question eight. There is a evidence that there has been some local adaptation of these tools (or at least changes to the terminology to better suit the organisation):

'Based around PDCA but given different names internally.'

'We have developed our own 'Way' based utilising a DMAIC approach.'

Question nine explores how well an organisation's culture 'allows' its team members to run controlled 'trial-and-error' experiments, a key part of the 'Scientific Method' which underpins Rother's (2010) Improvement Kata. In our survey respondents scored this at an average of 3.6 out of 10. Two scores, 2 out of 10 and 5 out of 10 were both given by 5 respondents each. The comments provided in support of this question provide a fascinating insight into the range of adoption of this approach. Those showing an organisational capability for this, commented:

'New leaders encourage this.'

'CEO believes in this stuff.'

'We have spent time on developing our best practice, next step is to move more of the organisation to this model.'

'We've had projects where we've been able to run 'trial & error' experiments but these have been localised projects. On a recent wider project across the company, we wanted to take this approach but have hit some barriers.'

Other respondents reported a number of potential operational and cultural barriers in the adoption of this approach:

'Potential negative impact on customer and client SLAs. Time and capability to design.'

'Sensitive environment (healthcare), so highly risk averse.'

'Not really - we don't have enough time generally to allow the thinking time needed.'

Although it is encouraging to see that some organisations are being supportive of this approach, there clearly remains significant cultural barriers to its widespread use.

Question 10 in the survey, attempts to understand what these barriers to adopting a 'learning by mistakes' approach might be. The results are illuminating. Many respondents thought that their organisation was too 'risk averse' to take this approach. Comments included:

'We invest a lot of time, effort and money in a "safety first" culture, taking risks is not something we would readily support - mixed messages.'

'Risk aversion (Banking environment).'

'Healthcare culture is not aligned to test and learn.'

‘Risk adverse (sic) / clinical environment.’

What is quite fascinating is that some of these respondents are clearly working in a healthcare environment, the exact area that Syed (2015, pgs.52–58) uses as a case study for an organisation (Virginia-Mason Health System) that has transformed patient safety, through its approach to reporting and fixing medical errors and using Lean practices.

Further respondent comments referred to the challenge that there wasn’t sufficient time allowed for such an experimentation-based approach:

‘Time, credibility, the need for a quick fix. No one wants to be seen as doing anything suboptimal.’

‘Time starved people - understand the concept but often too busy fire-fighting to stand back.’

‘Too many fires to fight not allowing time to draw breath.’

It might be possible to argue that organisations that ‘don’t’ invest time in structured problem-solving (irrespective of the method used), will very often become stuck in such a culture of fire-fighting. This situation may also be influenced by a number of other factors, including leadership styles, culture, and performance measurement. Other respondents commented on these factors, as reasons why a ‘learning’ organisation hasn’t been adopted in their locations:

‘The CEOs attitude to failure.’

‘Blame culture. Concentrate on who rather than why.’

‘People don't see it "as their jobs" and there is no performance management system to recognise their efforts.’

‘Annual performance incentives do not encourage controlled risk-taking.’

The final three questions (11 – 13) asked respondents to gauge how much improvement effort was spent at different levels of the business. This was to illustrate whether Lean thinking (or other improvement methodologies) was being deployed both tactically (at a local level) and strategically (across whole Value Streams or Organisations). The results showed a wide range of responses, with many comments saying that valuable improvement time was ‘wasted’ or was focused outside of the organisation itself:

‘No co-ordinated approach to improvements.’

‘Having meetings that don’t achieve anything.’

‘Fire-fighting.’

‘With our supplier base.’

Of those whose improvement efforts were focused on internal challenges, an average of 40% of the time made available was spent on local improvement initiatives, 29% on Value Stream or System-wide improvements, and 24% across 2 or more departments. It would appear that most organisations in this survey still focus their improvement activity resources predominantly on local or departmental problems.

Conclusions and Recommendations

The survey results show that there is still a predilection towards a ‘tools-based’ application of improvement methods, usually led by either internal or external consultants. Lean would seem to be the improvement system of choice, but there is a tendency for it to be applied locally rather than in a transformational way across whole organisations.

There appears to be little appetite amongst leaders from the surveyed organisations to encourage a ‘learning from mistakes’ approach. Paradoxically, organisations with the highest potential for these mistakes to be the costliest (in both financial and human terms) appear to be the most reluctant to encourage ‘organisational learning’ from such errors.

Perhaps unsurprisingly, given the results mentioned above, there’s very little evidence of the use of the ‘Scientific Method’ or the ‘Toyota Kata’ approach. What is more, there seems to be major leadership, cultural and behavioural barriers to such an approach being effectively nurtured. The fact that this approach to improvement has been documented as being a critical enabler for successful implementation of Lean (or a version of the TPS) for 19 years (since the 1999 HBR article by Spear & Bowen), it’s extremely disappointing that the ‘Kata’ approach is still seen as being a ‘marginal’ activity, rather than core to the very success of organisational improvement.

Liker and Hoseus (2008, pg 39) describe Toyota’s culture as being like the intertwined helixes of a DNA molecule, with one strand being the Product Value Stream and the other being the People Value Stream (see Figure 1 below). Clearly promoting a culture where one creates a ‘community of scientists’ requires as much, if not more, focus and leadership support than deployment of proven tools and methodologies.

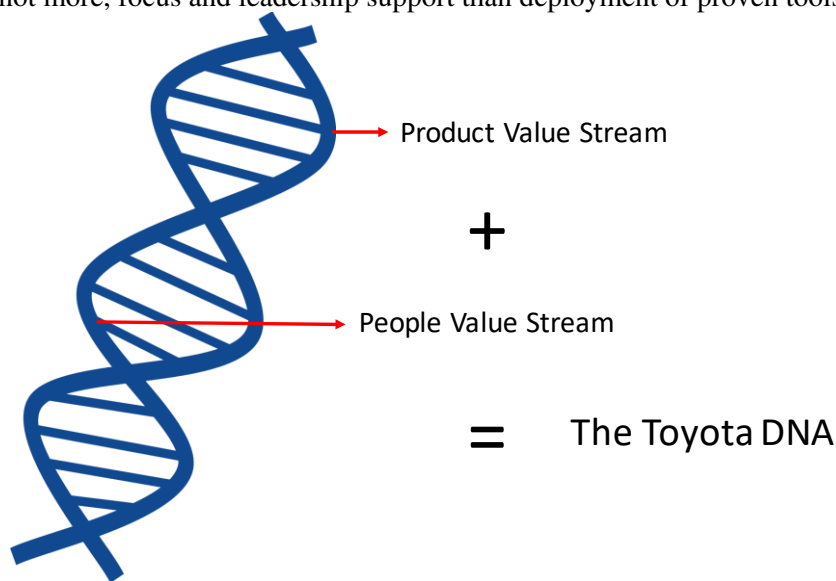


Fig.1: The intertwined Product and People Value Streams

(adapted from ‘Toyota Culture: The Heart and Soul of the Toyota Way’. Liker & Hoseus (2008))

For example, a key part of the shift towards a ‘Learning Organisation’ is the commitment to training and coaching people in improvement using the ‘Scientific Method’. Spear and Bowen (1999) articulate this as follows:

“For people to consistently make effective changes, they must know how to change and who is responsible for making changes.”

It would seem quite possible that many leaders simply do not have the ‘risk appetite’ to commit to developing the second strand of the DNA helix. In a recent blog, Bob Emiliani (2016) concluded that the failing of Lean to live up to its potential could be attributed to two assumptions that leading Lean thinkers have made about leaders. These assumptions being:

Vastly overestimating the extent to which conservative business leaders might be interested in a progressive system of management, the extent of their curiosity, and the extent of their interest in improving their leadership behaviours and competencies.

Overestimating the extent to which people in top leadership positions care about people. If Lean is, as some say, “all about people,” then it is clear that most leaders don’t care about people, particularly when the distance between them and the shop or office floor, both physically or in rank, is great.

During the literature research for this paper, it has become evident that the association between Lean / TPS and ‘Linear’ rather than ‘Systems’ thinking has evolved, not because of the way in which it is successfully deployed at Toyota, but where it has become synonymous with a tools-led, carbon copy approach to Lean or



TPS implementation. It may be that there is a link to leadership attitudes to Lean, as described by Emiliani, in that a ‘watered down’, tools-based approach to Lean, led by consultants, with a local focus, might yield short-term improvement, but that this would not require the investment and coaching of the organisations workforce (who may instead actually become ‘victims’ of this ‘slash-and-burn’ approach).

The key recommendation of this report is that - for organisations to truly excel in improvement activity and become a ‘Learning Organisation’ - they must be prepared to ‘bin the tools’. Although a whole consulting and training industry has grown up around tools and methodologies developed at Toyota, these have become an ‘end’ in themselves, and are not seen by most as the ‘means’ by which Toyota works towards its Vision. It should be accepted that the TPS is the ‘best-known’ answer at present for the circumstances that Toyota is in. This should mean that solutions (through many iterations of an improvement cycle, using the Scientific Method) will develop for other organisations that are different than the familiar artefacts of the TPS (and will probably be better suited to that organisation’s particular environment). If Lean tools are used, they should be clearly seen as a bridge-head towards a clearly articulated Vision, specific to the organisation. A ‘stepping stone’ towards the development of more optimal solutions tailored to the needs of the business.

A further recommendation is that the principle of the ‘Learning Organisation’ needs to be promoted as a founding principle of Lean, rather than a ‘nice to have’ or something that will develop organically over time, or as an organisation ‘matures’. There is very little evidence from this report’s survey to suggest that this is happening. Authors referenced in this report such as Syed and Senge, show compelling evidence that this approach works, even when de-coupled from a typical ‘Lean journey’. It might be that, in order to overcome leadership’s reluctance to fully embrace both the Product and Human elements of a successful Lean improvement programme, more use should be made of ‘thought leadership’ in the area of ‘Learning Organisations’. Leaders who might be ‘switched off’ by the perception that Lean is a tool-kit to be mechanistically applied could be re-engaged by this wider argument for whole organisational learning.

In terms of developing capability and knowledge in the skills required to generate a ‘community of scientists’, the ‘Kata’ method needs to be taught and used more widely. Although there is some activity in this area, non-Toyota ‘Lean’ coaches are unlikely to have a depth of experience in ‘Kata’. Ironically, ex-Toyota coaches – who may well be very capable in coaching and training the ‘Kata’ approach – often find it difficult not to try and ‘impose’ a classic TPS tool to a situation. For an organisation to truly learn, they must suppress this natural reaction, and allow the team to develop (through their own cycles of improvement) their own solutions.

Clearly for this greater focus on the ‘human’ element of improvement to flourish, the role of leaders needs to change too. Maybe also, the perception of what makes a ‘good’ leader in government, the media and the public too. It is a challenge recognised by Syed (2015, pg.283), who concludes that society has to reframe the definition of ‘failure’ to enable people and organisations to learn from mistakes.

For all of this to lead to more successful improvement efforts, Leaders need to become ‘Systems Thinkers’ as described by Checkland (1991) and Seddon (2008) earlier in this paper. This doesn’t necessarily mean that they need to tackle complex problems in a ‘different’ way than described by the ‘Kata’ approach, but they recognise that they can apply this thinking to iterate towards a Vision, whilst creating conditions where the ‘Scientific Method’ use is widespread and constant in their organisations.

Finally, measurement of performance need to promote rather than discourage organisational learning. Senge (2006, pg 364) quotes H. Thomas Johnson, the author of ‘Relevance Lost: The Rise and Fall of Management Accounting’ as making a profoundly important observation about the success of Toyota as a ‘Learning Organisation’. He observed that the key to Toyota’s ongoing success was not the driving of results through target setting, but actually connecting measurement and targets to an in-depth process knowledge, especially at the front-line. Senge (2006) concludes that Toyota’s approach was akin to embodying patterns of nature into its culture, which in turn means that their team members became superior learners.

H. Thomas Johnson himself sums up the challenge:

“The dilemma facing all companies that intend to become Lean is that they can follow a truly systemic path to Lean, or they can continue to use management accounting ‘levers of control. They can’t do both.” (Johnson, 2006)

The author has benefitted greatly from writing this paper. The review of current thinking on ‘Learning Organisations’ and the psychology that often prevents the admission of error or permits ‘learning from mistakes’ has been a revelation. The survey that accompanies this paper provided a great level of insight into both how improvement programmes are being deployed in organisations, and just how far removed this is from the intertwined helix DNA model of the TPS. Through this research, I have deepened my knowledge of the

‘Toyota Kata’ approach to improvement. This will benefit me greatly in my career as a Continuous Improvement practitioner. If Lean is ‘seen’ as part of a lateral thought process in my client’s organisation, then it has probably not been implemented beyond the ‘tools and techniques’ level. Toyota’s forefathers recognised fully the complexity of systems, so rarely appear to attempt ‘big bang’ change. Instead, they used a ‘Kata’ approach at all levels and then iterated (rapidly in most cases) towards their Vision, developing a deeper level of understanding along the way. This model is the new challenge for organisations wishing to become ‘Learning Organisations’.

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Appendices

Appendix A – Level 3 Assig

Triz as a support methodology for new product development

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Abstract

Growing demands and rapid changes in markets compel organizations to think more about innovation and continuous improvement. Nowadays, any growth strategy, and even its own survival in the markets, is increasingly being applied by new approaches and management methodologies. The study developed in the scope of this paper focused on the approach and interpretation of the use of the TRIZ methodology, in search of new ways of solving problems, identifying their support tools. Another concept explored and related to TRIZ is the New Product Development (NPD). The present paper aims to approach the concept of TRIZ regarding NPD and the way they are related by following innovative doctrines appealing to creativity. Within this paper and through the analysis of the different fields investigated, a diagrammatic model was proposed contemplating concepts and relations between them. In order to analyze the feasibility of the implementation of this same diagrammatic model in an industrial environment, a case study was presented in a company that uses TRIZ, and through a conclusive analysis, it is verified that the proposed model can be used as support in solving problems of an innovative and creative nature inherent to the implementation of new management processes and their improvement.

Keywords: TRIZ, NPD, Lean, Innovation, Problem-solving.

1. Introduction

The Inventive Problem Solving Theory, better known by its Russian acronym, adapted to the Latin alphabet, TRIZ - *Teoriya Resheniya Izobretelskikh Zadatch* - is a methodology specialized in the resolution of problems of an innovative and inventive nature, based on the study of them and the planning and implementation of solutions, based on the study of the patterns of circumstances in which problems occur.

It is a methodology widely used in the areas of engineering and management, having great importance in improving the effectiveness in the development of new products and improvement of existing products by the organizations. Contrary to what one might think, the TRIZ methodology is not based on the intuitive and spontaneous creativity of the individuals but demonstrates that the skills of being innovative and creative can be learned (Lopes, 2015).

The knowledge and application of this methodology becomes beneficial for a wide range of NPD market segments and continuous product improvement being a natural amplifier of innovative and effective decisions. TRIZ alternates critical thinking of the population in order to promote enrichment in decision-making and in dealing with the problems inherent in innovation (Savransky, 2000).

The market has increasingly shown its competitive, dynamic, changing nature, making it necessary for organizations to be efficient, effective, productive and flexible. Therefore, with high responsiveness in the least possible time, thus making a difference, companies that present more and better results, generators of

innovation. Therefore, it should be noted that through systematic product innovation there will be greater success in the acceptance of new or improved products by the market, and in gaining new segments. Being the TRIZ methodology, in a perfect connection with the success of the companies, increasingly, it can be seen that the simple application of good traditional engineering practices may not result in remarkable results, often having to make decisions about problems that occur naturally in an innovative organization and TRIZ being an asset to this type of occurrences, causing companies not to lose competitive advantage (Matos, 2017).

TRIZ, as it can be applied at both the product and service levels, can be applied in a variety of areas, such as risk management, product design / design, problem solving, business management, strategic planning, analysis of causes, research and development, technological forecasting, educational planning and, finally, public relations and publicity, among others (Kurosawa, 2014).

In short, TRIZ consists of the recognition that a system evolves towards the increase of ideality, through the resolution of contradictions, minimizing the introduction of new resources. It can be said that for the creative solution of problems, the TRIZ methodology provides a dialectical form of thinking.

Also, Zhang and Shang (2010) state that TRIZ is considered a kind of innovative theory, which works mainly by solving contradictions. This methodology, based on the evolution of technical systems, basically consists of several types of methods, calculations to solve technical problems, innovative exploration, etc. As the overall understanding of system resolution.

According to Soares (2008), the TRIZ methodology consists essentially of: 39 engineering parameters; 40 inventive principles; resolution matrix of contradictions 39x39; 76 standard solutions; the Inventive Problem Solving Algorithm (ARIZ); an engineering and effect knowledge base, and a series of methodological systems for understanding the problem and implementing its solution. This author also points out that TRIZ is based on the idea that all technical problems have already been solved in some way in the past, and that the principles inherent in their solutions are stored in databases resulting from the analysis of thousands of patents, which began to be required in the former USSR in the second half of the twentieth century.

2. The importance of TRIZ methodology in NPD

The success of organizations is increasingly related to the concept of innovation, which is increasingly seen as a moment of inspiration or a discontinuous and unpredictable occurrence, coming to be seen as a planned and managed activity. Companies are increasingly feeling the need for a continuous and systematic kind of innovation. This is crucial for increasing the efficiency of organizations, improving their competitiveness and profitability. In this context, the Lean philosophy presupposes a systematic search for continuous improvement of processes, by reducing waste and increasing efficiency. Lean can be applied in virtually all areas and functional activities of companies, making them more efficient and competitive, and therefore more apt to integrate NPD processes, namely those that use TRIZ methodology tools, as one of their means of support (Dias, 2015). On the practical level, TRIZ can be seen as a set of analytical tools that aid in the detection of contradictions in systems, in formulating and problem solving through the elimination or mitigation of found contradictions (Navas, Abreu and Dias 2016).

2.1. The TRIZ methodology and the concept of Innovation

Innovation can occur accidentally and/or through a "stroke of genius" or through the manifestation of some inspired element. However, after the development of the TRIZ methodological tool, it became possible to systematize the innovation itself (Dias, 2015).

As an alternative to accidental innovation, systematic innovation also occurred according to certain standards. This finding is in line with studies of the phenomena of complexity, where predictions are far less common, much less exact results: instead, patterns are detected in innovative problem solving. And such patterns were detected by Altshuller (1999), of the information obtained through the myriad of patents analyzed, applying them as a way of advancing the systems through their various evolutionary stages (Dias, 2015).

In general TRIZ is applied in the following way, according to Yang and Chen (2011): an inventive problem is reformulated into a generic TRIZ problem, and then the methodology tools are introduced to analyze and propose a general solution, which transforms it into a particular solution adapted to the concrete inventive

problem that gave rise to this process. Thus, a generic solution is interpreted to solve a specific inventive problem, as illustrated in Figure 1.

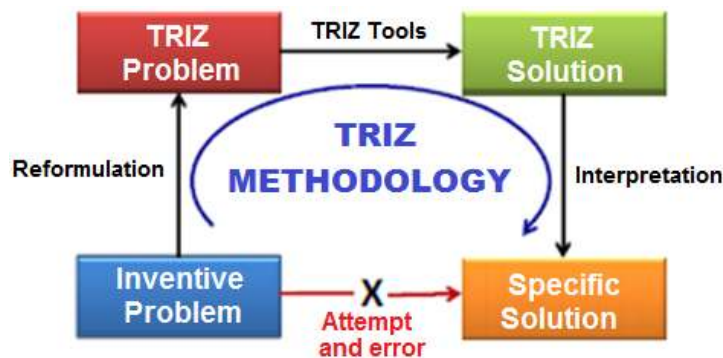


Figure 1 - TRIZ process in problem solving. Source: Adapted from Matos (2017).

In 1946, Genrich Altshuller developed an approach to the theme of innovation levels and their measurement, since not all innovations are identical. An innovation can be a simple change to an existing product or, at the opposite extreme, the development of a technological system totally different from the ones that existed until then. Altshuller systematized the solutions described in patent registers, dividing them into five levels (Altshuller, 2001):

- Level 1: Routine solutions using methods well known in their area of expertise. This category constitutes about 30% of the totality. This level is not considered innovative.
- Level 2: Small corrections in existing systems using methods known in the industry. About 45% of the totality.
- Level 3: Important improvements that solve contradictions in systems typical of a given branch of industry. About 20% of the totality. This is where creative design solutions come in.
- Level 4: Solutions based on the application of new scientific principles. About 4% of the total. At this level the problems are mostly solved by replacing the original technology with new technology.
- Level 5: Innovative solutions based on scientific discoveries that have never been explored before. Less than 1% of the totality.

TRIZ assist in the elaboration of solutions of levels 2, 3, 4 and 5 where TRIZ tools can be a useful support, according to the level of innovation (Ramos, 2015). The five levels of innovation are shown in Figure 2.

Level 1	Level 2	Level 3	Level 4	Level 5
Existing Products	Small Improvements - Matrix of Contradictions	Great Improvements - Contradictions - S-Field	New concept - Contradictions - S-Field - ARIZ	New Discoveries

Figure 2 - TRIZ tools incorporated in the 5 levels of innovation. Source: Adapted from Matos (2017).

The authors of the theory sought to exclude level 1 of the concept of innovation, so they have not developed

tools for this case, and that this is due to the fact that it does not make sense to apply TRIZ to products that already exist and will not be changed. The use of the TRIZ methodology in the fifth level of innovation for "new discoveries", is a more current and futuristic approach that points TRIZ as an important tool used in NPD, nowadays and in the future (Matos, 2017).

Levels 2 and 3 are classified as being "innovative" and level 4 of an "inventive" character. This does not mean that each level is better than the previous level, but rather different. But it can be considered a good level that allows solving the limitations of the system itself, bringing it closer to the ideal system. However, the higher the level of innovation, the more detailed is the analysis and the research, and the more expensive the NPD process or the implementation of improvements (Matos, 2017).

According to Navas, Abreu and Dias (2016), TRIZ aims to assist the development of projects and the solutions generate, especially in environments characterized by profound changes or based on the application of radical scientific discoveries, where the use of traditional engineering and management practices cannot produce remarkable results. The practice of traditional engineering attempts to solve such problems finding acceptable compromises, while TRIZ aims to eliminate such a commitment. TRIZ seeks to overcome these conflicts through the application of creative solutions.

The TRIZ methodology is based on the following grounds (Navas, Abreu and Dias, 2016):

- Ideality;
- Contradiction;
- Resources;
- Systematic Approach;
- Functionality.

The TRIZ methodology can be seen and used at various levels. At the highest level, TRIZ can be seen as a science, as a philosophy or a way of being in life - a creative way and a permanent quest for continuous improvement (Navas, Abreu and Dias, 2016).

2.2. The TRIZ methodology integrated in LEAN Philosophy

The Lean philosophy has been adopted by a number of industrial sectors, increasingly moving away from the approach focused solely on reducing office waste and reducing costs, to a new approach that seeks to increase consumer value by introducing new products or features and the elimination of superfluous activities (Machado and Tavares, 2008).

Lean production is focused on the flow of value that gives rise to products, aiming at maximizing value and eliminating waste, optimizing the entire process and not only of its constituent parts. The idea is to make the value circulate continuously throughout the organization, reaching the consumer as soon as possible (Matos, 2017). Figure 3 shows the principles of the Lean philosophy

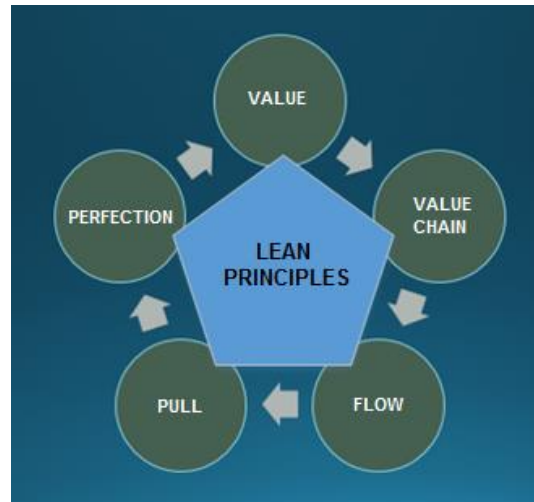


Figure 3 - Principles of Lean Thinking. Source: Adapted from Matos (2017).

The Lean philosophy is based on five fundamental principles (Womack and Jones, 1996):

1. *Value* - Specification of the value of a particular product that the customer really wants, that is, the characteristics and functionalities of the products that satisfy the customers' needs and expectations must be identified - quality, quantity, time requirements and service.
2. *Value Chain or Stream* - Identification and analysis of the flow of value for each product. It is translated by the sequence of activities and processes involved in the sequence of processes involving the product, which must be analyzed and defined. Consequently, activities that do not add value to the product should be identified.
3. *Flow* - Establishment of a continuous flow of value. Once the value chain and its wastes are identified, the organization must create a continuous flow, which is characterized by the ability to produce only what is needed for the moment.
4. *Pull* - Let the customer "pnavasull" the product through the implementation of the Pull system. This production system tries to let the customer lead the processes, that is, it allows production only when the order is made by the customer. So this is the only way to produce just what is needed and when needed, because only what the customer really wants is produced.
5. *Perfection* - Seek for perfection. After applying and upholding the above principles, the organization must constantly seek innovation and continuous improvement, and consequently perfection in the processes of waste disposal and value creation. In this way only activities that add value must be present in the processes.

Given the above principles, the main goal of the Lean management paradigm is to increase value creation by reducing waste, which means, creating more value with less resources. A Lean organization understands what constitutes value for the customer, and from that definition, focuses on the key processes to increase it. The ultimate goal will be to create a perfect process of creating value for the customer, continuously seeking improvement (Domingues, 2013).

Lean thinking should encompass all employees in the organization, sometimes requiring significant changes in attitudes and behaviors. Lean leaves deep marks both in organizations as well as in people who work and

collaborate in them. A Lean thinking environment requires a "learn to see" approach, with the goal of finding obstacles (wastes) that need to be removed. At the beginning of Lean implementation, a large majority of improvements can be achieved with relatively simple solutions. With the advancement of the Lean implementation process, the growing need for truly innovative solutions is emerging, and radical changes are sometimes necessary (Machado and Tavares, 2008).

The TRIZ methodology has a set of different analytical techniques and instruments, which can be used together or separately, in the generation of solutions for detected problems or in the analysis of failures. Several Lean techniques and concepts can be used in conjunction with TRIZ instruments. As a potential solution generator, TRIZ will be able to assist in the creation and development of Lean Management environments. The combination of Lean's analytical tools with TRIZ's innovative capability can bring significant benefits to organizations (Machado and Tavares, 2008).

TRIZ does not compete with other methodologies nor does it intend to replace them, but can be used to highlight its weaknesses, and can synergistically complement other methodologies, namely Lean.

In analyzing the topic, Radeka (2007) identifies a parallelism between TRIZ and Lean. The first step in solving a problem with TRIZ is to analyze the problem, trying to find ways to frame it, in order to create an ideal solution. Through TRIZ it is sought that the problem has an ideal end result, that is, a solution that avoids unnecessary waste and damages. As an example, in the automotive industry, the ideal end result is the customer-ready automobile, without it having to think about the quality, labor, raw material or supply chain involved. This is a result that falls within the scope of Lean practice, namely the fifth principle of Lean thinking – perfection (Radeka, 2007).

Lean is popular within many organizations, and is perhaps the main innovation tool for most. Many top management elements have resorted to Lean, and many engineers have been looking for specific training in this area. But there is the notion that TRIZ can complement the weaknesses of the Lean. While the Lean is efficient in finding problems that need solving, TRIZ is quite effective in overcoming the contradictions (Radeka, 2007).

3. Successful Case of application of the TRIZ Methodology

This case regards a configuration of a low-pressure chemical vapor deposition (LPCVD). In a work published by Robles *et al.* (2009) it is shown an example of improvement success according to the use of the TRIZ methodology, and the tool used was the matrix of contradictions. According to Figure 2 it can be seen that this improvement corresponds to a level 2, being highlighted as a "small improvement" in the classification of the inventive levels.

An example of the use of the contradiction matrix relates to chemical reaction deposition during the fabrication of electronic components. Chemical vapor deposition (CVD) consists of contacting substrates with one or more reactive gases. The gas chemically reacts to deposit a solid film on substrates. One way of producing microelectronic components is to use a low pressure chemical vapor deposition reactor (LPCVD) with a vertical configuration (Figure 4A).

In analyzing the development of the reactor, the authors verified that several disadvantages have arisen related to the performance and configuration of the reactor. A contradiction is identified to improve the quality of the deposition of a silicate film on small fins; the space between the fins should be large to permit complete circulation of the gases between the fins and efficient deposition of silicates.

As a result, the number of fins within the reactor is very low affecting productivity. The problem is stated as "increasing productivity in the reactor without radically changing its shape". The two parameters for the generic problem are as follows: "Productivity" to be improved, but it degrades the "Form" of the system. The use of the contradiction matrix provides four inventive principles in the following hierarchical order: 14 (sphericity), 10 (previous action), 34 (rejection and regeneration pieces) and 40 (composite materials). Next, was selected Principle 14 "sphericity" which is decomposed into 3 sub-principles:

- Replace linear parts or flat surfaces with curves and cubic shapes by spherical shapes;
- Use rollers, spheres, spiral domes;

- Replace linear motion with a rotating motion (use the centrifugal force).

One interpretation of this principle is to change the shape of the useful work area; should be spherical. This solution is shown in Figure 4B. The new reactor has a capacity of 90 fins, while the initial one has a capacity of only 25; consequently, productivity is radically improved.

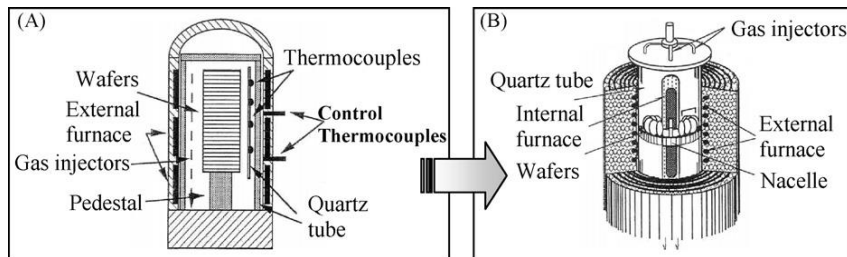


Figure 4 - Reactor capacity of 25 fins (A); Ballast with capacity for 90 fins (B). Source: Robles *et al.* (2009).

4. Case Study

The objective of this study was to evaluate the applicability of the TRIZ methodology in Industrial environment in Portugal. To this end, a Portuguese SME (small medium enterprise) of renown in the metalworking sector was selected. Its mission is to manufacture products and commercialize services in the field of metal mechanics and HVAC systems (heating, ventilation and air conditioning), which aim at total customer satisfaction and which are distinguished by their high level of quality, which is one of the main values adopted by the company, together with the valorization of its human resources, loyalty to its partners (suppliers, customers, employees, etc.) and collaboration for an improvement of the environment.

About company's most significant management strategy, it can be concluded that it is its relationship with its suppliers and customers, which distinguishes it more from its competitors: in this context, the company can be characterized as an organization which, through customer requests, always works in order to obtain the best results of processes for the production of an established product, always trying to avenge in the market, since the involvement of suppliers and customers in the planning and production processes, make the final products meet the pre-defined requirements as much as possible and can avenge in the market.

With the customization of the products manufactured, the company works according to the specific requests of its customers, and with a very competitive quality/price ratio. Thus, customers do not seek other companies over this one, nor does it produces new products without being at the request of its customers. Involvement of suppliers helps a lot in meeting product requirements.

In terms of company management at the process level, the company has the conditions and needs to choose the use of the TRIZ methodology to improve or solve a problem, so it was founded that the main sectors affected in the company with TRIZ implementation were reflected in: warehouse management; quality management and production management, which contribute to many improvements, and the TRIZ tool used in problem-solving processes is the Matrix of Contradictions.

These improvements have a huge impact, because being applied in the process surroundings, consequently there are associated improvements. The fact that there are improvements in the warehouse management allows to obtain improvements in the organization of the stock and reduce production times that will have advantages in productivity and reduction of costs, taking advantage of the value of the TRIZ methodology in a Lean way of working.

5. Conclusions

Organizations need to have analytical tools appropriate to the implementation of systematic innovation and increased creativity. In this field TRIZ is applied in the NPD, as an innovation tool that allows finding innovative and creative solutions to problems in an efficient and effective way.

The general procedure of the TRIZ methodology begins with the identification of specific problems. These are then transformed into generic problems, in which generic solutions are subsequently selected for each problem. And finally, these solutions are tailored to specific problems, identified initially, resulting in innovative and creative solutions. Through the tools of support of the TRIZ methodology, it is possible to outline tasks, make a structural analysis, identify and formalize the contradictions and, finally, find solutions. Thus, through this methodology, it is possible to benefit the various functional areas of industrial companies.

About the TRIZ methodology, the advantage that seemed to be the most striking was its great simplicity of application, resulting in creative and innovative solutions. Since its application area is much more comprehensive than what concerns mechanical systems, it is possible to apply the TRIZ methodology in a wide range of branches of activity and functional areas, within organizations, starting from their generic standard solutions.

Through the case study carried out for this paper, it was concluded that the company studied currently applies the TRIZ methodology in warehouse management, and with that has obtained good results in solving innovative and creative problems inherent to stock management processes by using the Matrix of Contradictions.

6. Acknowledgements

The authors of this article wish to thank the Organizing Committee of the ELEC 2018 International Conference, for the opportunity to participate in it and the inspired motivation to carry out this paper. It is also intended to express gratitude to all the members of the scientific community who, in the past, have written R&D works that served as references for the literature review done in this research work in particular. Lastly, a thank-you is sent to the company that collaborated to carry out the presented case study, even though it preferred to remain anonymous, contributed to increase the knowledge about the subject in question.

The author from UNIDEMI-FCT NOVA would like to thank the Faculty of Science and Technology of the New University of Lisbon (UNL) and the Portuguese Foundation for Science and Technology (FCT) through the Strategic Project no. UID/EMS/00667/2013. Their support helps make our research work possible.

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1.3 Lean Training

Teaching and Implementing Lean Construction in the Construction Industry

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Abstract

Lean Construction is a deviation from Lean Production in terms of being project based and focused on the building industry. Lean Construction was introduced in 1992 by Lauri Koskela, who identified the importance of taking the three parameters: Transformation, Flow and Value (TFV) into account in the construction industry. Even though the development of the theoretical framework for Lean construction as well as practical implementation has been going on for almost three decades, the concept is still only implemented in a fraction of the construction companies in the world. One of the benefits of applying Lean construction, is that it provides tools and methods for project teams to be adjustable and capable of identifying and mitigating late and unpredictable changes which are very common in the construction industry and at the same time hold the focus on producing value for the client.

The aim of this contribution, is to share the experience gained from having worked with teaching and implementing Lean Construction principles in one of the biggest Scandinavian construction companies. The company neither is nor have been a declared Lean company. This embraces that initially; the teaching and implementation was not directly supported from the executive management. The interest of working with Lean principles comes from the bottom up. Throughout the last two decades many initiatives have been initiated, mostly with focus on implementing tools and processes in the production phase. Since 2011 an initiative was taken to address how Lean construction principles could be applied in the design phase. Since then, practical training has been given to design managers in applying lean tools, support has been given to the management level just above the design managers (middle management level) coaching has been given to top (regional) management and information has been directed at the executive management level. This approach has been fruitful in terms of having developed an internal Lean design concept which has become a strategic development area for the company. We obviously still have many challenges, in terms of developing a more throughout understanding of the methodology. With this presentation we will share our experiences from this journey in terms of having worked with developing building industry specific concepts as well as teaching and implementing Lean throughout the organization for the past 7 years. Moreover, we will give an outlook on teaching and implementation strategies including which current challenges that we are facing.

Keywords: Building industry specific concepts; Construction design; Lean training



Implementation of Lean Development in Industry

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Abstract

While a large number of companies use lean management techniques in production to cut down on waste and add value, these techniques could also be of great value in product development and other cost centres. The search for barriers to implementing lean management in product development reveals that there are few quantified studies that take an empirical approach to analysis of the association between implementing lean methods and the role of the lean method educator. This paper introduces ideas on things the lean educator can do to create and carry out training for potential lean management technique users who wish to apply lean management to their own working environment. The paper seeks to identify the important factors that will provide an understanding of lean management's basic principles and enable the application of lean management principles to product development in an efficient, effective way. Different ways of training will be shown with a stress on the trainer's handling of external influences and ways to implement the techniques up in enterprises.

Keywords: lean development, implementation barriers, lean educator, adoption of lean

Introduction

Lean management is in widespread use in helping businesses to compete in an increasingly global market (Abreu-Ledón, Luján-García, Garrido-Vega, & Escobar-Pérez, 2018). It would be wrong to regard it as merely a management phrase. It is a mindset that must form part of the strategy in every division and penetrate all departments. Every commercial activity should have as its driver a focus on the maximum possible quality of customer service delivered in the shortest possible time (Womack & Jones, 2003). Implementing lean management throughout the strategy of the entire company and achieving operational perfection demands that particular attention be paid to the workforce and the suppliers (Shah & Ward, 2003). Giving them respect allows improvement of the business process and identification and elimination of waste throughout the value chain. Waste may be defined as anything that offers the customer no benefit. All that is needed to detect waste in a direct production department is to collect up all semi-finished products that no one wants and to identify transport routes that are not needed (Welo & Ringen, 2016; Womack & Jones, 2003), but these visual indicators of waste are not present in indirect business units like product development (Schulze & Störmer, 2012). When developing a new product, an iterative process is needed and therefore adds value. Configuring new products and processes is itself a process rooted in the development department and has an influence on every step in the value stream. Be that as it may, lean thinking is as yet unusual in development (Hoppmann, Rebentisch, Dombrowski, & Zahn, 2011; Kennedy, 2008). It is, however, possible to apply to development the lean manufacturing management principles defined by Liker and Morgan (Liker & Morgan, 2006). New product development is influenced by certain processes and tools and a strategy that is not only transparent but also accepted by all. If development time is to be reduced and flexibility in responding to customer needs is to be achieved, the problem must be clearly defined in advance and attention should be on the whole production and product life cycle (Kiefer, Allegretti, & Breckle, 2017). Because company regulations and documentation

may be seen as constraints on creativity, they should be examined with care to make sure that they add value (Visser & Dankbaar, 2002). If the organisation is to learn and improve, communication must be seen as a fundamental tool (Liker & Morgan, 2006). These are ways of thinking that may be regarded as innovations in development (Baregheh, Rowley, & Sambrook, 2009; Crossan & Apaydin, 2010; Damanpour, 1991) and a number of factors can accelerate the adoption of innovations. Rogers (Rogers, 2003) defines the criteria for innovation as: that it can be observed; that it can be tested; that it is complex; that it is compatible with what exists; and that it offers advantage. The trainer's role in implementation is important because training can win acceptance for the new skills and foster a holistic view of lean thinking (Analoui, 1994).

This paper examines which of an educator's skills and beliefs are significant in improving the results of training in development and achieving a greater degree of adoption. We identified from the existing literature a lack of empirical analysis examining differences in the rate of adoption of lean management between the production and the development areas, and so this paper will seek to quantify the success of training in lean development by looking at the adoption factors and attitudes in the organisation to innovation. We draft theoretical hypotheses about how the educator's skills may correlate with adoption characteristics. To set this in motion, we collected the contact details of lean educators in order to invite them to complete a standardised questionnaire. The aim was to achieve a European perspective and so we invited educators from Austria, Finland, Germany, Ireland, Italy, the Netherlands, Norway, Switzerland, and the UK.

Theoretical Background and Hypotheses

Organizational Innovation and Adopting Characteristics

Bringing about a full implementation of lean principles demands different processes, different workflows, and different thinking not just organisationally but among individuals. Lean management is innovatory in every area throughout the organisation, (Daft, 1978; Dombrowski, Mielke, & Engel, 2012; Rauch, Dallasega, & Matt, 2016) but a number of factors decide whether or not a process innovation will be adopted. Rogers's Diffusion Theory (Rogers, 1983) took an early focus on product innovations adoption and later studies established that the diffusion theory can also be transferred to the adoption of services, as well as organisational and process innovations (Damanpour, 1991). The successful adoption of product and process innovations demands an understanding of problem-solving and the properties of the product (Spath, Renz, & Seidenstricker, 2009). Innovations are adopted on the basis of the diffusion process and the perceived properties of adoption. The diffusion process may be considered a sort of innovation timeline, with a steady increase over time in the number of adopters. When half of the maximum possible adopters have adopted the innovation, the rate of exception peaks and from then on spreading the innovation becomes harder and the number of adopters begins to fall. This research, however, is concerned with the adoption factors and not with the diffusion theory. The adoption factors are those characteristics that must exist in an innovation in order for it to be accepted and (Rogers, 1983) divides them into five types: relative advantage; observability; testability; compatibility; and complexity. The rate at which an innovation that is accepted increases in line with the people's and the organisation's openness towards the first four of those factors. How complex the innovation is perceived to be may delay the rate of acceptance (Flight, D'Souza, & Allaway, 2011; Ostlund, 1974). Relative advantage is subjective and must be decided by each adopter. For each person, adoption will be likely when the new behaviour is seen to be better for that person than the previous behaviour. Observability describes the extent to which visible models can explain the innovation, which will find more ready acceptance when the product's usefulness can be seen in advance. Observability has a great deal in common with trialability because, if an innovation can be tested, the change will be that much easier to deal with (Rogers, 2002). Last among the positive link attributes is compatibility, which exists when the new idea matches what the adopter already knows. To be adopted, an innovation must match the organisation's experiences and expectations. As the innovation's complexity increases, there is a reduction in its acceptance and so it is important that the degree of complexity is easily seen by adopters (Rogers, 2003).



Educators Role

An educator can help an organisation to achieve its goals. There is a need for someone with the knowledge and skills to improve key resources and create a view on the part of the employees that is value-oriented (Nikandrou, Brinia, & Bereri, 2009). After analysing 300 papers, Blume et al. divided the trainer's tasks into two categories. The first is to generalise content for all trainees, and the second is to check how the training has been communicated after a set time period (Blume, Ford, Baldwin, & Huang, 2009). The effectiveness of training can be measured by the responses of trainees during training, by actions learned, by changes in behaviour during exercises, and by results (Ghosh, Satyawadi, Prasad Joshi, Ranjan, & Singh, 2012). All of the organisation's requirements and those of trainees should form part of the trainer's preparation. Analoui (Analoui, 1994) suggests ways to ensure that trainers and organisations are efficiently developed. It is important that trainers understand both the socio-technical content and why the training is needed. Adoption of innovations is facilitated when the company fosters a culture that supports innovation. When problems arise between trainers and trainees, they may be caused by personal factors or they may be due to a lack of technical understanding. To achieve a solution, the trainer must understand the root of the problem and deal both with personal factors and with technical misunderstanding. It is very important that the trainer evaluates the content and uses the training process to replicate the goals (Analoui, 1994).

Hypotheses Overview

Sim and Rogers (Sim & Rogers, 2008) demonstrated that employees did not understand the potential of lean management initiatives and point to a need to improve training if the management is to achieve greater penetration in enterprises. What for the most part influences successful training is a combination of the trainer's teaching skills and getting the design of training exercises right (Martin, 2009). To gain an understanding of what makes good training, we carried out a meta-analysis and reviewed a large number of articles. Analoui (Analoui, 1994) examined the roles an educator may play and the competencies they require. Ghosh et al. (Ghosh et al., 2012) studied trainer attributes to identify where educators needed to improve. An overview by Arthur Jr. et al. covered the criteria by which training is evaluated (Arthur, Bennet, Edens, & Bell, 2003) how training needs are implemented, the skills needed by the trainer and how the attributes are matched. No study could be found in the existing literature that matched an educator with the characteristics of the adoption rate set out by Rogers (Rogers, 2002). For that reason, we will examine the relationship between relative advantage, compatibility, complexity, trialability and observability in order to answer the questions: is there a correlation between these factors, and do educators consider them differently when preparing their training? It was on these criteria that we formulated the hypotheses which include every attribute of the characteristics of the adoption four times in order to examine every possible connection there may be between them. Rohrer (Rohrer, 2000) examines what connection exists between complex production problems and their solution using simple visualisation, a context applicable also to the problem of barriers to adoption. When the topic is transferred to training, the actual connection allows presentation of our first hypothesis H1:

H1: An Educator who works to establish clear training also makes the training more observable.

For participants to be offered lasting personal advantage, the design of the training must be simple. According to Burden and Proctor, (Burden & Proctor, 2000) success comes from evaluating training before it is given, while it is being given, and after it has been given. This enables trainers to explain and adapt to complex circumstances. Our assumption that this need is met in lean development training is expressed in H2:

H2: An Educator who works to establish clear training also gives trainees a relative advantage.

An effective way of presenting complex facts simply is to prototyping. Using the model, theory can be tested in advance. Coopriider and Henderson (Coopriider & Henderson, 1990) also demonstrate the importance of prototyping. The connection achievable by a prototype is better understood and similar testing possibilities make it possible to apply it in other situations. The connection to the training environment is investigated in hypotheses H3 and H4:

H3: An Educator who works to establish clear training also provides opportunities to test the content of the training.

H4: An Educator who works to establish clear training is also more likely to provide training compatible with the background and experience of the participants.

The satisfaction of participants in training was examined by Harris et al. (Harris, Chung, Hutchins, & Chiaburu, 2014) to establish whether they were able to evaluate the content against an agreed consensus and then to apply it in their own field. The relationship between compatibility and observability is examined in hypothesis H5:

H5: An Educator who works to establish compatible training for the participants also makes the training more observable.

Karayanni (Karayanni, 2003) studied the behaviour of web shoppers. The research framework referred to the relationship between the adoption characteristics of compatibility and relative advantage. These two attributes strongly affect the rate at which participants in this study adopt innovations and it is therefore necessary to understand the relationship between them.

H6: An Educator who is more likely to provide participants with training compatible to their needs offers participants a relative advantage.

Lane and Mitchell (Lane & Mitchell, 2013) investigated a multilevel train-the-trainer model in which the level of knowledge the trainers have is compatible with that of participants and this allows us to formulate Hypotheses H7:

H7: An Educator who is more likely to provide compatible training for the participants also offers the opportunity to test the training content.

According to Hayes et al. (Hayes, Eljiz, Dadich, Fitzgerald, & Sloan, 2015), trialability and observability combined constitute the main factor for adoption by employees of a process innovation. They constructed an animated computer simulation of the introduction of lean system thinking to healthcare services. We formulated Hypotheses H8 to transfer this positive effect on the role of the trainer in the adoption of innovation:

H8: An Educator who offers the opportunity to test the training content also makes the training more observable.

Contrary to the conclusions of Rogers, Moore and Benbasat, and Damanpour and Schneider (Damanpour & Schneider, 2006; Moore & Benbasat, 1991; Rogers, 2003), Hsbollah and Idris (Hsbollah & Idris, 2009) say that the only factors of importance in adoption are trialability and relative advantage. They researched all five factors but found that significant results were delivered only by those two. If they are right, then trialability and relative advantage are also interesting factors in our study:

H9: An Educator who offers the opportunity to test the training content also offers participants a relative advantage.

According to Ghosh et al. (Ghosh et al., 2012), participants can become more motivated when they observe that they can transfer and use the content. We therefore investigate the relationship between relative advantage and observability:

H10: An Educator who offers the participants a relative advantage also makes the training more observable.

Methodology

To evaluate the hypotheses, we defined a standardised online questionnaire. For each adoption factor, we reviewed five items, each with a relevant score. Items relating to observability were given codes OB1 to OB5; those relating to trialability were given codes TR1 to TR5; those relating to complexity were given the codes CX1 to CX5; those relating to compatibility but given the codes CB1 to CB5; and those relating to relative advantage were given the codes RA1 to RA5. In formulating the questions, we drew mainly on examples from Agarwal, Flight, Montandon, and Moore (Agarwal & Prasad, 1997, Flight, D'Souza, & Allaway, 2011, Montandon, 2006, Moore & Benbasat, 1991). The questions were presented with a five-point Likert scale (Likert, 1932) from very low to very high. To get results that related only to Lean Development, we use this as a criterion to filter potential participants by this criterion, accepting results only from Lean Development educators who answered every question in our survey. A total of 1,262 potential participants were invited to participate in our survey; a review of the results showed that 117 participants were relevant to our research. 48% of the participants work as employees in a company, 33% are self-employed in their own company and the remaining 19% work as freelancers or in other forms of organization. When issuing invitations, in order

we focused primarily on participants with more work experience to achieve a more significant result. We could find no clear definition of work experience by years, so selected the period from zero to less than three years as less work experience, with 3 to 10 years as multi-year work experience and more than ten years as high experience. 36% of our participants were in the high experience category, 46% had several years' professional experience and 18% had less work experience as educators.

To validate our questionnaire, we used bivariate analysis methods. We began by subjecting articles to a reliability analysis. To improve the quality of the research, the article was evaluated with a Cronbach's Alpha Test. Any article with a lower impact than the 0.70 threshold has been removed for the following study (Taber, 2017). The total value of Cronbach's alpha was 0.795. The objects OB1, OB2, TR2, TR3, CX1, CX2, CX3, CX5, CB2, CB5 and RA1 were removed after the test. To test the differences in variation in our model, we ran a T-value test at a significance level of 5%. Only values ≥ 1.96 would indicate the null hypothesis to be wrong (Hair, Ringle, & Sarstedt, 2011). The relevant observability points were OB3 (t-value = 4.512), OB4 (t-value = 3.074) and OB5 (t-value = 3.096). For the test option attribute, it was TR1 (t-value = 7.463), TR4 (t-value = 5.288), and TR5 (t-value = 5.909). Complexity left only one relevant item, CX4 (t-value = 2.828), while characteristics remaining for compatibility were CB1 (t-value = 6.675), CB3 (t-value = 5.342) and CB4 (t-value = 3.577). For the most recently studied characteristics of relative advantage, only one object was removed, leaving RA2 (t-value = 3.275), RA3 (t-value = 4.501), RA4 (t-value = 2.900) and RA5 (t-value = 2.848) as relevant to our study.

Next, we tested for correlation between elements with Pearson's Ratio (Cressie & Read, 1989). Linear correlation between parameters is high at values of -1 or +1, while cell values of 0 indicate that no linear correlation exists between those parameters. The Pearson correlation can be seen in Table 1.

Table 1 – Pearson's Ratio

	OB3	OB4	OB5	TR1	TR4	TR5	CX4	CB1	CB3	CB4	RA2	RA3	RA4	RA5
OB3	1													
OB4	.044	1												
OB5	.060	.031	1											
TR1	.424	.152	.0110	1										
TR4	.256	.078	.296	.316	1									
TR5	.244	.108	.202	.349	.291	1								
CX4	.241	.128	.272	.010	.268	.202	1							
CB1	.233	.253	.086	.400	.116	.250	-.070	1						
CB3	.368	.297	.051	.320	.292	.359	.188	.332	1					
CB4	.348	-.030	.311	.228	.341	.109	.222	.186	.093	1				
RA2	.184	.063	-.027	.325	.170	.218	.001	.223	.225	-.002	1			
RA3	.094	.031	.252	.272	.256	.292	.113	.204	.186	.135	.395	1		
RA4	.087	.262	.129	.247	.110	.244	.191	.190	.164	.009	.309	.270	1	
RA5	.092	.310	.153	.285	.068	.291	.129	.192	.188	.017	.231	.214	.381	1

The variables we used were classified into disjoint groups and subdivided by cross-tabulation into every possible combination of expressions. The data were evaluated with the Cramer-V value and the significance level. Cramer-V uses chi-square statistics to measure coherence and can take values between zero and one. The higher the value, the more likely it is the correlation exists between the variables. The limit is 0.2, with lower values indicating that it is unlikely that the two variables are related. The significance level defines the

probability of assuming a false result; for values lower than 5%, there is no significant probability of the statement being wrong and it is therefore relevant for significant results (Krantz, 1999).

Results and Discussion

Hypothesis H3 is significant (Cramer-V = 0,21; Level of significance 2,8%). Hypothesis H5 is completely significant, because the level of significance is at a value of 0% (Cramer-V = 0,29; Level of significance 0%). Hypothesis H7 gave Cramer-V -0,41 and Level of significance 0%; Hypothesis H8 gave Cramer-V = 0,34; Level of significance 0%; Hypothesis H9 gave Cramer-V = 0,29; Level of significance 0,2% and Hypothesis H10 gave Cramer-V = 0,20; Level of significance 3,4%, meaning that all four of these hypotheses are significant. The highest correlation between the variables is for H7. It can be deduced that educators should offer the opportunity to try the training content, if the trainees understand it. Every hypothesis concerning variable TR is significant, and it can be deduced that lean development educators always offer the opportunity to test the training content. Three of the four OB variables are confirmed. The educators usually train in a way observable by participants. Variables RA and CB are each included twice in significant hypotheses, and the variable CX once only, indicating a lack in those three variables making it necessary for lean development trainers to change their training for these variables to increase the rate of adoption. The opportunity to observe lean management in other departments should always be provided. These conclusions show a good overall adoption rate for lean management but trainers need to improve on other factors including simplifying training content or they must offer a relative advantage to trainees in the trainees' own work if implementation of lean development is to be achieved. It is not enough for trainers to know these facts; they must offer actions to improve detrimental characteristics and to reinforce the others. Here are some suggestions for resolution of these issues.

- Communication barriers can be overcome if the trainer adapts his or her linguistic quality to that of the trainees. Trainers should use as few foreign words as possible and include words that participants are familiar with.
- People are more likely to adopt lean thinking if they are discovering a problem themselves. The problem could be a real problem in the development area of the enterprise or a theoretical one created by a simulation game. A good way to enable participants to find problems is to ask what at work dissatisfies them, because matching dissatisfaction to problems that lean management can solve will offer personal benefits.
- Communication is the most important aspect of training and it is necessary for trainers to understand what needs and expectations trainees have and to meet those requirements. There should be continuous feedback from trainers and trainees and in the opposite direction.

The biggest challenge is transferring lessons learned into action. Ways in which the transfer can be supported will be an interesting area for future research, which could also deal with such areas as the innovation culture existing in the customer's organisation. It would also be useful to examine whether the results of this study can be transferred to other cost centres.

Conclusion

This paper examines the relationships between attributes contributing to the adoption of lean development in industry. Of the ten validated hypotheses, six are significant. Lean development training is not currently offering trainees a relative advantage but is doing a good job incompatibility of training. Trainers should consider the characteristics for adoption further in order to increase the rate of adoption.

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How Geographic and Cultural Factors Influence Lean Training & Implementation

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Abstract

Globalisation has led to the creation of many pan-national companies that deliver their products and services on every continent. When these organisations develop a corporate continuous improvement (CI) approach, it has to be deployed regionally in an effort to ensure that a common methodology is used to help drive improvements in service delivery and quality. Having a common CI approach also enables inter-regional staff interaction and collaboration.

Evidence suggests there are several challenges in such deployments due to geographic and cultural factors that mitigate against the advantages of a singular global approach and the challenge is to find in the right balance between uniformity and allowing some variation to cater for local conditions that does not become too much of a compromise.

The presentation will examine the impact that geographic and cultural factors have on the development and delivery of lean training in organisations and on the implementation approach adopted.

Drawing on the experiences of global logistics company Panalpina and data from experienced practitioners, it will discuss how factors such as language, technology, social norms, diversity, natural environment, learning styles and location can impact a CI programme's effectiveness, support and level of engagement. It will highlight barriers to the development of effective workplace learning, suggest good practices that ensure that learning is applied effectively in the workplace and indicate avenues for further research.

Keywords: Culture; geography; training



Effectiveness of a Lean Simulation Training: Challenges, Measures and Recommendations

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Abstract

Teaching adults in Lean Management faces certain challenges. A well-known concept to deal with them is activity-based learning as it is provided by Learning Factories. This paper explores the main challenges and its influence as well as learning methods in the context of a Lean Learning Lab. The effectiveness of the training is evaluated by the overall impression, by how easy it is to understand the theory and whether the participants dared to transfer the content into their working environment. The study was conducted in the Lean Lab of the University of Applied Sciences in Kufstein during the years 2016 – 2018 with a sample of 234 participants from different local companies. The study showed that participants had difficulties with understanding the benefits of lean management and the theory and the terminology of Lean Management. This was significantly influenced by the hierarchy of job and their level of education. Of major help during the training was the change between theory and practice. Important was also the “do-it yourself” approach. Here, too, the job position determined the choice of support significantly. When it comes to the effectiveness of the training with regard to understandability and transfer, not all of the Lean tools were evaluated similarly. Transfer to real life was significantly influenced by how understandable the Lean tools were and how easy it was to implement them in the Lean Lab. This study gives statistically proven insights into how to organize a Lean Basic training for adults in order to gain the required effectiveness.

Keywords: lean management, lean production, learning factory, training, didactical concepts



1.4 Approaches to Lean

Big Lean Deployment : A comparison of 3 different approaches across 3 multinational organisations

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Abstract

This project aimed to compare:

The different approaches taken by the 3 organisations, in terms of the relative strengths and weakness of top down and bottom up approach, as seen in the organisations. In addition, the different types of organisational structure and use of external resources were compared and evaluated.

Over the period of deployment all 3 organisations experienced significant business change. The impact of these changes on the programmes was evaluated.

The overall impact of the differing programme approaches by evaluating their relative merits and also their relevance to each organisation.

The scope of the evaluation was limited to the 3 organisations. The data and information were limited to the experience of the author working as part of the operational excellence teams of the organisations. Additionally, data was gathered from interviews from key individuals from the Lean teams to provide real life feedback on the challenges and merits of the different approaches.

The results of the investigation proved revealing. All 3 approaches can claim success in terms of capability building, longevity of the programme and business results. All 3 organisations experienced major change and business environment change through the life of their Lean programmes. Within the life spans of their programmes they all experienced significant changes, successes and failures. All 3 organisations used external resources to a varying degree. This varied from being a “top up” for internal resource or specific situational reasons – e.g. top execs, to full blown creation and support for the programme provided externally.

The different methods to deployment have been created through adaptation of the approach to the perceived organisational culture and style. Each deployment has been designed to fit the way of working as well as the culture of the organisation. For example, where top level support was more important, more effort was spent training and coaching these individuals. Where the work environment was more programme based, the projects tended to be more specific rather than site wide or function wide deployment.

Keywords: Lean; Deployment; Global; Comparison; Lessons; Boot camp; Team leader; Leadership; Sustainability

Lean Global Network: A global network of sharing, collaboration and development

Sérgio Caldeirinha

Abstract

LGN was formally chartered as a Massachusetts not-for-profit legal entity in September 2007 with 14 member institutes. Today, LGN is a consortium of not-for-profit organizations dedicated to advancing lean thinking and practice throughout the world to make things better and is comprised of 28 institutes or partners and dozens of co-learning partners across the globe, Portugal included.

Through co-learning action research partnerships with universities and leading companies and organizations across all sectors, and an online community of over 300.000 persons, LGN members gather the best in lean thinking and share it with the lean community and beyond in three fundamental ways: Share knowledge on lean thinking and practice to develop skills within the community; Collaborate on joint projects and events; and Develop new educational materials such as publications and training.

LGN consist of Education, Action Research through Co-Learning Partnerships and Projects. LGN run experiential on-site learning activities. Over the past 20 years, LGN institutes have: Hosted 25,000 attendees at 100 conferences or “summits”; Published 34 book titles, some Shingo Award Winning, that have sold approximately 100.000 copies; Created content for websites that receive over 1 million visitors per day (www.lean.org); Summits reaching several hundred to over 1,000 attendees; and Published more than 600 articles in Planet Lean website (<http://planet-lean.com>).

Lean Academy Portugal proposes to share the outcome of decades of research and learning, within LGN and their co-learning partners by showing one of it’s major breakthroughs: The Lean Transformations Framework (figure 1)

Observing efforts in the community over many years we have learned that successful transformation calls for a situational approach that is based on innovating key dimensions of any organization through addressing a series of questions.

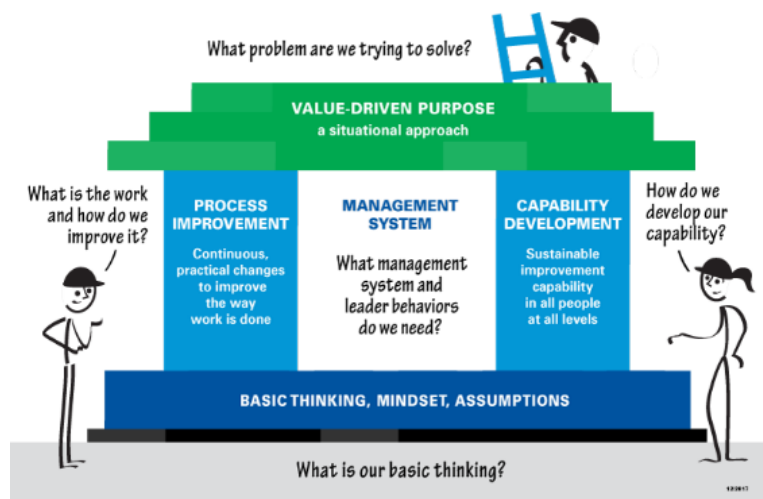


Figure 1- The Lean Transformation Framework

These questions are fractal—meaning that the same questions apply whether working at the macro enterprise level or the level of individual responsibility as you dive progressively deeper into each dimension. But, while the transformation model that has emerged through years of experience is situational, the nature of the



questions represent a clear point of view: if an organization fails to address each question, and with a sense of how each relates to the others, the transformation will struggle to sustain its momentum.

Questions of the Lean Transformation Framework

- 1. What is the purpose of the change: what problem are we trying to solve?*
- 2. How are we improving the actual work?*
- 3. How are we building capability?*
- 4. What leadership behaviors and management systems are required to support this new way of working?*
- 5. What basic thinking, or assumptions comprise the existing culture, and are driving this transformation?*

We believe that there are certain approaches to answering each of the 5 questions that will yield greater success in a lean journey.



Strength-based lean: a different way

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Abstract

Most applications of Lean Thinking assume that there is a 'perfect state' for each organizational process, and that the current state deviates from the 'perfect state' due to inefficiencies and waste.

This way of thinking means that, in order to improve processes, we have to focus on the identification of gaps between the current state and the desired/perfect state (this is called 'deficit focus'). Then we find root causes for these gaps and fix them in the hope of making a sustainable improvement. At best, this approach takes you back to a state of status quo ('good') where expectations are met but rarely exceeded.

The strength-based approach to process improvement has a different focus. Instead of focusing on what is defective and inefficient, it helps management and staff identify what is already working efficiently and generates value in existing processes and systems (this is called 'strength focus'.) They then define ways to grow and expand those parts and implement good practices elsewhere.

This focus on the search for and growth of existing efficiency enables new ideas to emerge and supports implementation of process improvements by raising confidence, energy and engagement levels. The strength-based approach to Lean is more natural to work with and more sustainable in the long term. The deficit focus of traditional Lean tends to weaken the system - even when it is successful - because it instills doubt and despair by giving unbalanced attention to waste and by amplifying inefficiencies.

In every organization, there is a wealth of knowledge and practical experience about efficient and value-adding ways to work. This approach has better chances of success as it relies on existing good practices and internal knowledge rather than introducing 'solutions from elsewhere'.

Teaching improvement teams and all members of the organization how to find what is value-generating for customers drives them to consciously and unconsciously seek ways to deliver even more value - isn't that what we're all about?

Strength-based Lean combines the rigour of Lean with the innovation and energy of Appreciative Inquiry and other strength-based approaches to organizational change, creating a more successful, inclusive and sustainable result.

In this Presentation, I will provide an overview of the various strengths-based approaches to organizational change, highlight the links between them and the classic practice of Lean, share a story of applying the approach, its value-add and a few ideas for possible first steps.

Keywords: Strength-based Lean; value-creation; A different approach to Lean; Appreciative Inquiry

ROUND 2 - WEDNESDAY 14TH NOVEMBER

2.1 Value Flow and Process Mapping

Improving the physical arrangement of the production line via value stream mapping: a contribution of the company's effective lean culture

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Abstract

The wide use of the Lean Manufacturing (LM) philosophy, through the use of the tools available, by the most diverse organizations, allowed them to reach objectives in the most efficient and effective way. In fact, it supported the study to identify alternatives for improvements in the production process, such as the analysis of the physical arrangement, object of this work. The contribution of this study was to apply the Value Stream Mapping (VSM) tool to improve the productivity of the production line of an assembly industry, comparing the results of the pushed production strategy (before) with those achieved through pull production (after) aiming to achieve potential benefits, such as reducing production lead-time, eliminating waste and simplifying the flow. A current state map is designed to document the physical arrangement on the shop floor. Next, a future state map is developed to design a multiproduct production process flow, allowing two simultaneous products. In addition, the results allowed identifying possible improvements, such as quality control capable of detecting a problem closer to origin, traceability, ways to increase of productivity and reduce process lead-time, visual control in the process, multifunction workers and the participation of all involved in the process, promoting the culture of continuous improvement in the organization.

Keywords: lean manufacturing, physical arrangement, process mapping, value flow, value stream mapping.

Introduction

The functions of planning and controlling processes are paramount factors, to the management within the factory for efficiency and competitiveness. In addition, one of the effective management approaches is the Lean Manufacturing (LM) system that has been evolving its concepts in many companies. The scientific approach of this philosophy was first published in the works of Womack, Jones & Roos (1992), Shingo (1981), Womack & Jones (1996) and Hines, Holweg & Rich (2004) that motivated many manufacturing companies to plan new strategies of manufacturing management.

Lean system characteristics focus on simplifying material flow, reducing inventory, leveling production, increasing turnover frequency and production based on customer demand (Womack et al., 2004). In this way, most industries introduce into their production system techniques and lean manufacturing philosophy methods to improve productivity, eliminate waste, improve quality as well as lower the cost by eliminating non-value added activities (Womack et al., 2004; Srinivasaraghavan & Allada, 2006). In order to map the current operational state of a manufacturing process and identify sources of waste, the Value Stream Mapping (VSM) developed by Rother & Shook (2003), a lean tool that helps to improve the flow of materials and information of a product or service that makes its way through the value chain.

The purpose of this article is to apply the VSM by initially evaluating a current state map identifying the opportunity to implement various lean philosophy techniques. A second step is to design a future state map based on the improvement implemented, establishing a new process flow control. In addition, demonstrate the productivity gain over the constraints of the line cycle time.

Materials and Method

The work to be carried out consists of analyzing the current state of the production process of a company in the electronics segment located in the industrial center of Manaus - AM, Brazil, in order to apply lean principles and optimize the process. An evaluation of the assembly process was conducted to describe the initial situation of the layout through direct observation. Information on actual manufacturing activities based on the thermal relay product with four temperature specifications to suit the market, all with the same standard operating procedure. The production line is constituted with seven workers, two machines and an oven equipment.

The cycle time or the measured processing time is according to manufacturing data collected from the production, over a period of three months. For a successful implementation, each concept taught had employee perceptions, commitment, work method and communication, for lean transition, knowing that motivation for cultural change is necessary to improve employee perception (Losonci et al., 2011).

The Mapping Process

The main elements considered in the process evaluation for the implementation of lean improvement are value stream mapping (VSM), which defines the flow of value as an activity of all, including value-added activity and activity not aggregated to the value, necessary for converting the raw material into finished product by mapping the process and information flows essential for each product (Rother and Shook, 1999; Filho and Fernandes, 2004).

Several authors have applied value-flow mapping in other areas, such as Taylor (2005) Lasa, Laburu and Vila (2008), Seth and Goel (2008), Coronado M. and Lyons (2007) and Hines, Francis and Found). In this sense, the value stream mapping seems to be the most appropriate tool for the evaluation of the manufacturing line based on the thermal relay product.

Product Process Flow

With the use of value mapping, it was possible to identify and propose changes to improve the process of assembly of the product, in the initial state layout Figure 1. Observed the time of change, transport time, queuing, handling and time data of the machine, (QC) (Abdulmalek and Rajgopal, 2007), were tabulated during the first month of the monitoring period.

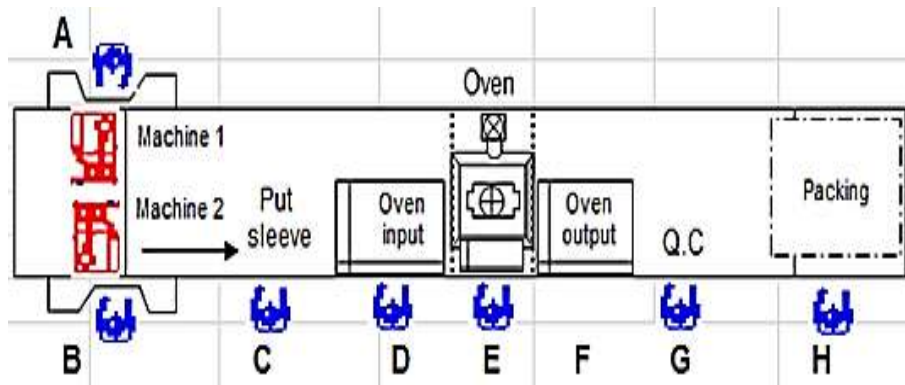


Figure 1 - Initial state layout thermal relay assembly.

The assembly flow starts workstation A and B with the customer order, supplying material to subsequent workstations, connecting the beginning and end of the product path to the H (packing) station.

The frequency of supply of material and information is compromised by the specifications of the different products in the current state, single flow route, real reduced daily capacity with two shifts 7.3 hours, already discounted lunch time, labor (seated) with 90% efficiency, customer 7,200 per day, batch sizes not defined, quality control does not guarantee packaging more than one product simultaneously.

Work station D (oven input) prepares lots of 15 pieces before oven. The workstation E (oven) is also responsible for working station F (oven output). The cycle time (C.T) in seconds and standard time (S.T) calculated according to Table 1.

Table 1 - Manufacturing data of the thermal relay assembly line in the period.

Task	Operator	C.T (sec.)	Tolerance	S.T (sec.)	Production/h
crimping	A, B	5.61	90%	6.17	583
put sleeve	C	3.27	90%	3.60	1,000
oven input	D	3.28	90%	3.61	997
oven	E	0.49	90%	0.54	6,666
oven output	F	0.45	90%	0.50	7,200
Q.C	G	3.09	90%	3.40	1,058
packing	H	0.30	90%	0.33	10,909

Work measure – Takt time

Takt time refers to the frequency of a part or component that must be produced to meet customer demand. Takt time depends on the demand for monthly output, if the demand increases the Takt time decreases, if the demand decreases the Takt time increases which means that the output interval increases or decreases.

In manufacturing, it refers to the frequency of a part or component must be produced to meet customers' demand (Sundar et al., 2014). Rahani and al-Ashraf (2012), have suggested that the importance of measuring Takt time due to costs and inefficiency of factors in production before demand, which includes storage and retrieval of finished products, premature purchase of raw materials, premature expenditures with wages, the cost of missed opportunities to produce other goods, identify idleness of the labor. In this study, the formula

applied to the Takt time calculation is the time available (per shift) divided by the demand (per shift), as we will see below.

$$26,280 \text{ seconds (time available)} \div 3,600 \text{ pieces (demand)} = 7.3 \text{ seconds/units.} \quad (1)$$

Drawing the future state map target for a lean flow through the production line and the elimination of the root causes of the wastes identified. Once the key characteristics of the future state are identified and in progress are reviewed with the top management to obtain better condition of the future state.

Looking at the current state map figure 1 several things appeared: (a) intermediate inventories between workstation, (b) production lead-time between workstations and constraint bottleneck, (c) idleness of the labor, due to low level of commitment (seated workstation), (d) process flow does not guarantee more than one product simultaneously. Therefore, to create an ideal future state map, adopting lean manufacturing tools to reduce different types of waste in the current manufacturing system. Method to establish VSM is presented though the following:

- Receiving / supplying Just in time;
- One piece flow / batch size reduction;
- Work according to takt time / synchronized production;
- Production pulled / just in time - Kanban;
- Kaizen;
- Work in teams;
- Commitment of employees and senior management;
- Multi-skilled worker / role rotation.

Work measure – Takt time

Value Stream is defined as "the set of all the specific actions needed to take a specific product through the three critical management tasks of any business: problem solving, information management, and physical transformation." Value-flow mapping allows a view of the entire value stream of a product, shifting the focus from under-optimization of individual processes and instead aiming to improve the whole (Rother and Shook, 2003).

According to Dengiz and Akbay (2000), cellular manufacturing defines the grouping of facilities to produce the product with minimum processing time, waiting time and transport, smoothing process flow. Additional floating line flow is enhanced by the concept of U-line and line balancing concept, kanban is the material flow control mechanism that provides the right amount of parts at the right time (Graves et al., 1995; Sundar et al., 2014).

The stages of this Kanban implementation are stage of production and stage of withdrawal. Unit flow just-in-time production system to adopt direct programming without interruption, reflow or scrap, relaxing takt time and reducing the risk of machine failures and operator errors (Hines et al., 2004; Li and Rong, 2009). Production leveling increases production volume as well as production mix and production efficiency by reducing waste, irregularity and overloading of people or equipment (Liker, 2004).

A set of kaizen activities initiated and implemented in an effort to optimize the productivity of the new U-line assembly, Figure 2. The assembly process is monitored and during the monitoring phase, continuous evaluations of any product discrepancies or imperfections are being addressed immediately. Necessary countermeasures are made to ensure the effectiveness of the new VSM of the future state and the productivity stability of the line is achieved.

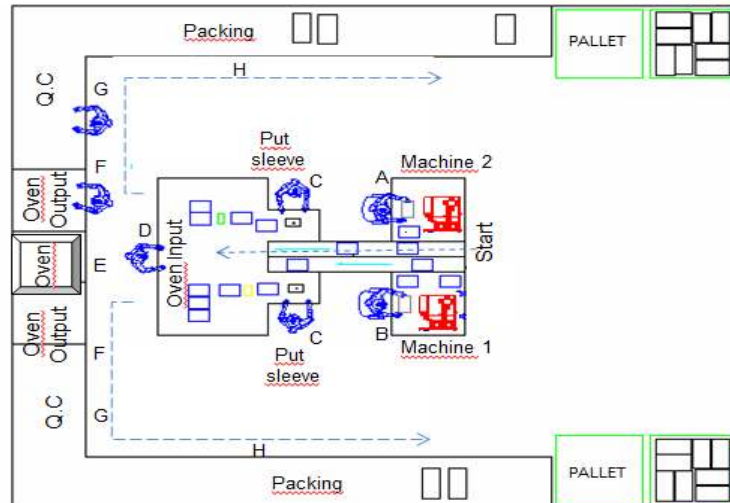


Figure 2 - Future state layout U thermal relay assembly.

Results

This analysis was performed comparing the performance of the thermal relay assembly line before and after the implementation of kaizen in terms of quantity of production per man and quantity of orders with more than one product per shift. It establishes a new process flow control, gaining productivity relative to line cycle time constraints and employee perceptions.

Improvement in the process Flow

The result of the future state map of figure 2 presented improvements in the product assembly process, with the U-line assembly implementation, lean methods and tools, and production resources dedicated to the manufacturing of a product family. Thus, intermediate inventories were reduced between the workstations with respect to bottleneck restriction A and B, through the transfer kanban, representing the one piece flow with predefined processing lot with 100 pieces per box.

The proposed new physical arrangement establishes the criterion that only workstation A and B can and should be performed with seated operators. In the other stations, the activities are carried out standing, facilitating the rotation of function, a requirement that will provide greater participation of the workforce. It also allowed reducing the variability of the task time with respect to the restriction bottleneck, mainly due to the human instability in relation to the work rate and motivation, as well as the sensitivity of detected process failures closer to the origin. This will allow an even more frequent supply of material and information, taking into account the specifications of the different products. It means quantity of orders with more than one product per shift thermal relay.

Note that C, D, E, F, G, H workstations are performed by the five labors, using multi-enabled worker concept, alternating with rotation of functions, simultaneously meeting the two directions of the assembly flows, according to customer demand 7,200 products thermal relay per day with different specifications. Ensuring the traceability of the lots coming from workstation A and B with colored card in box identifying machine 1 and machine 2 respectively. The visual control flow kanban with lots 100 pieces per box, identified with a "green" color block for the next work station or "yellow color" queue waiting, FIFO control (first in, first out) and manufacturing shift.

The workstation E (oven) simultaneously attending the two directions of the assembly flows, with specifications of the different products, has an important responsibility to process one batch of product at a time, transferring to the next work station F (oven output), according to colored card in box identifying respectively the flow of each product. Quality control (QC) established better control over batches of processed products, following different flows, ensuring adequate identification in the packaging for product traceability.

Employee perceptions for effective lean culture

Employee perceptions help identify the factors that influence employee perceptions for successful lean transitions. With a future state map, the new work environment allowed to analyze the cultural change among the workers in the daily life. Teamwork and concepts taught help to determine which factors make workers feel that lean transformation has been successful, promoting awareness of critical intrinsic factors (commitment, belief) and external factors (lean working method, communication) that affect the success of lean implementation from the workers' point of view. It has been proven that successful transformation is in the hands of levels of employee commitment, beliefs, communication and working methods. Here it was verified in the autonomy of the employees in the execution of activities alternating between workstations, with rotation of functions.

The activities performed by employees defined standard work refers to the most secure and effective method to perform a job in the shortest repeatable time, because of the use of resources such as people, machinery and materials. Standardization of work results in a set of standard operating procedures, which contains the worker's work process, such as process steps, job sequences, cycle time, work in process, process control. Performing a specific job within the established time is possible to control and improve the project work, with respect agility in the execution of the activity at work, promoting reorganization of work in relation to fluctuation of Takt time. In addition, with increasing demand, we can add workers incrementally. If demand declines, we can incrementally remove workers from the assembly line. The understanding of this concept in the perception of the employees promoted a group dynamics capable of combining joint efforts at possible times that formed queues in certain workstations, promoting the immediate balance of the process, proving that, for successful lean transitions, the perception of employees can be achieved through training and awareness-raising, defining roadmaps, metrics and measurement.

Bottleneck or constraints can not stop

The Pull system allows production based on customer demand, the successful traction system depends on the product flow in small batches, stimulating processes to reduce time (to stop overproduction) and refueling by signaling a kanban signal and leveling of the mix and quantity of products over time. The flow of a part refers to the concept of moving a batch of parts at a time between operations within a cell. Selections of the work model, assignment of operation to the U-line, and the production sequence are important factors to consider when designing the value stream. The bottleneck identification or workstation restriction A and B defines the downstream process, is identified by determining the maximum cycle time in the line ($S.T = 6.17$ seconds). Production capacity is decided by this bottleneck cycle time. Line capacity is the division of the total available time (per shift) and bottleneck cycle time ($26,280 \text{ seconds} / 6.17 \text{ seconds} = 4,259$ units). If bottleneck cycle time Takt time, customer demand is not met.

The previous state map served production demand, with production mix restriction, i.e., the process flow does not guarantee more than one product simultaneously, with this the customer expectation is not met; it does not create value for the customer. With the delivery of projected production future state map, expected future product mix demand, takt time is identified for the manufacturing system. With known takt time, the bottleneck process is identified from value stream mapping (VSM), the gap between capacity and demand is calculated and, based on this gap, the lean implementation plan is meet customer requirements, frequency of delivery with product mix over time.

Note that with the balancing of the U-line in equilibrium the capacity mix of production 8,518 units in two shifts, provided using multi-skilled worker concept, alternating with rotation of workstations functions A and B every two hours. Reducing the variability of task time due to human factors, weariness, and monotony.

Based on customer demand, the number of workers and machines within the workstation are increased or decreased to overcome the line imbalance. The positive result in the production improved the condition of the preventive maintenance planning machine 1 and machine 2. In addition, it aims to establish Continuous Improvement Initiatives aimed at reducing failures, a management-driven element that strives for cultural change in the workplace. When process stability is established, continuous improvement tools are necessary to determine the root cause of inefficiencies and to apply effective countermeasures to reduce these inefficiencies.

Discussion

The results obtained through Lean Manufacturing principles showed the importance of the value stream mapping tool (VSM), comparing between formerly pushed production and the later with pulled production implementation. The key elements available in the Value Stream documented in the Future State Map Figure 2 have established a sequence of improvements in the thermal relay production process.

Rother and Shook (2003) points out that the vision of the entire value stream is important, shifting the focus from sub-optimization of individual processes, and instead aiming at improving the whole. Establishing a flow of multi-product production process, with the implementation of U-line assembly. According to Dengiz and Akbay (2000), Cellular Manufacturing defines the grouping of facilities to produce the product with minimum processing time, waiting time and transport, smoothing process flow.

According to Sundar *et al.* (2014) lean principles defines the value of the product / service as perceived by the customer, classifying the added value activity and eliminating non-added value activity. With future status map, the successful implementation allowed two simultaneous products representing value to the customer, possible with four different products per shift. In addition to ensuring quality control capable of detecting problem closer to origin, traceability, visual control in the process.

According to Losonci *et al.*, (2011), the motivation for cultural change is necessary to improve the perception of the employee. Important result achieved with future state map with implementation of work in teams; commitment of employees and top management; multi-skilled worker / role rotation.

The understanding of this concept in the perception of the employees promoted a group dynamics capable of combining joint efforts at possible times queues were formed in certain workstations, promoting the immediate balance of the process. In addition, all the participation of all involved in the process in a continuous improvement activities.

In a comparison between the initial and proposed physical arrangement, it can be seen that the new arrangement allows greater flexibility to the line, facilitating the execution of several activities associated to the productive process, such as better material flow in the line, optimization of activities and functions performed workers. In addition, it allows for the redefinition of jobs as well as the reduction of cycle time and inventory.

Conclusion

The application of value stream mapping (VSM), a lean philosophy tool, aimed at creating perceived value by the client, allowed the mapping of the path needed to convert the raw material into finished product through the mapping of process flows. It also allowed identifying wastes within the thermal relay production process and implementing improvements with future state map for the elimination or mitigation of waste.

Confirming that value stream mapping can contribute to the reduction of intermediate inventories between workstations, with the U-line assembly implementation, improving the use of production resources dedicated to the fabrication of a product family. In addition, using multi-skilled worker concept and rotation of functions, the new working environment allowed analyzing the cultural change of the workers in the daily life.

Thus, it is concluded that scientific works with this purpose are important to introduce new maps of the future with VSM tools, to disseminate an effective lean culture in the organizations through training, as they demonstrate the need to apply appropriate tools for the improvement in its activities, as well as to promote the motivation of the employees, for carrying out activities of greater added value.

Acknowledgments

The authors wish to thank the project partner Amazonas State Foundation for Research Support (FAPEAM - Fundação de Apoio à Pesquisa do Estado do Amazonas) for supporting this work.

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Industrial Case Study based on Master Thesis as a way to develop New Lean applications – The case of Material Flow Cost Accounting combined with Lean-based performance indicators

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Abstract

The last course of the Integrated Mechanical Engineering Master Programme at Instituto Superior Técnico (Universidade de Lisboa) is the development of a Master thesis for a period of a semester. In the Production Management group of the Mechanical Department, the Master theses under industrial environment are stimulated as a consequence of the strong network of this group in the industrial Portuguese Sector. Each student has to develop a work that is pertinent to the company, with applicable results and, at the same time, respect all the requirements of a Master thesis: be scientifically framed; applies existent knowledge or methodology; define or model the problem with some abstract level; define a formal strategy (hypothesis) to solve/understand the problem and apply it to a case (real or simulated) to assess the proposed strategy. To accomplish these two aims at the same time, the resulting Master thesis often proposes the customization or even adaptation of the original method to the specific industrial reality. This is usually the case when the topic of the Master thesis is in the realm of Production Management and Lean Manufacturing. These theses begin usually with a Lean-based diagnosis to identify the main incidence of Muda and its quantification. After the identification of the root causes, the students propose the use of several tools simultaneously and in several cases the adaptation and integration of Lean tools and/or integration of Lean tools with conventional methods of production management. Examples of that are the integration of SMED with VSM, the application of VSM to multiple products, the extension of VSM to multi-streams, the application on Visual Management to the product production mapping, the application of Lean-based indicators after a Material Flow Cost Accounting (MFCA) assessment, among others.

In this paper, these type of Mater thesis are described and the referred examples are briefly explained. The integration of MFCA with Lean is presented in more detail. The MFCA combines physical flows and monetary units and presents the results as product cost and waste cost, focusing on the material and energy losses. Beginning with MFCA, the approach identifies the causes of high-cost values in specifics process/phases of the production system. With this quantitative diagnosis, the thesis proposes a matrix-solution based on Lean management tools. This approach allows a clear and quick identification of critical cost and energy-related problems, allowing an early problem-solving phase.

Keywords: Lean Manufacturing; Master thesis in an industrial environment; Material flow cost accounting; Lean problem-solving

A Game for Process Mapping in Office and Knowledge Work

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Abstract

Regardless of the company type, the processes of office and knowledge work play a determinant role in terms of the company's overall performance and, naturally, they must be object of continuous improvement. It is true that improving such processes is not an easy task, but the justification that is usually pointed for that is the workers' rooted habits / resistance to change. However, most likely, workers are not given opportunities (nor tools) to stop and think about the processes they execute so they can improve them. Nevertheless, in order to be effective and efficient (i.e. to be really useful in practice), these tools (and associated methodologies) must be simple (i.e. easy to learn and apply).

This paper describes a project that provides workers (or students) the opportunity (gamified training session) to learn how to map and improve office and knowledge work processes, that includes a simple graphical tool with a reduced set of symbols. In the training session the participants will map and improve a specific process (based on an industrial scenario). The session is conducted as a serious game and involves competition, which are elements usually recognized by their potential to increase motivation and engagement, as well as knowledge retention. In fact, the main purpose is not the mapping and improvement of the specific process presented by the game, but the learning of a graphical tool to map processes that participants can apply to their own scenarios, identifying thus improvement opportunities.

In terms of methodology, the work encompasses the (i) realization of a training session with 18 professionals of Industrial Engineering divided in 3 teams, (ii) application of a questionnaire to all participants about their perception / opinion about the session (7 questions using a five-point Likert Scale and 2 open questions), and, (iii) analysis / discussion of the gathered results.

Regarding the structure, the paper begins with a brief review about the concept of office and knowledge work itself, process mapping and gamification, followed by the presentation of the simple graphical tool. Then, the training session is described, followed by the analysis / discussion of the gathered results. The paper ends with the main findings and some directions for future work.

In summary, one may say that the participants considered the training session as useful and that they feel able to conduct in their companies a session on mapping and improvement of processes of office and knowledge work.

Keywords: Office and knowledge work; process mapping; continuous improvement; serious games; training

Acknowledgments: This work was partially supported by projects COMPETE-POCI-01-0145-FEDER-007043 and FCT-UID-CEC-00319-2013, from Portugal.



2.2 Lean Games

Experience based recommendations for the development of serious games

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Abstract

Since 2010, several serious games have been developed and used at the Lean Learning Academy of the University of Leuven in Belgium (a lean design game, a lean production game, a lean office game, a quick response manufacturing game and a lean healthcare game). These games are non-computer-based simulations of real but simplified processes from different work environments. This article stipulates the issues and the pitfalls encountered during the development and coaching of serious games and based on personal experiences. The aim of this article is to let you reflect about whether or not serious gaming is the right teaching method to learn about a topic and to guide you through the different successive steps of the development of a serious game. Finally, the article describes how a serious game can show companies how to transform into a learning organization and how the effectiveness of serious gaming can be measured..

Keywords: lean, serious game, coaching, evaluation, Kirkpatrick

1. KU Leuven Lean Learning Academy

The KU Leuven Lean Learning Academy (www.leanlearningacademy.be) is the training and expertise centre in the field of production management of the University of Leuven at the Technology Campus in Ghent (Belgium). It delivers all kind of trainings in the field of production management both to master students Engineering Technology as well as to managers and employees involved with process improvements. Over the past decennium, with the help of these master students, several serious games and tools in the area of production management have been developed and tested.

2. Physical multiplayer simulation games

Several definitions of a serious game can be found in literature but they all point to a learning method using game principles for the purposes of learning, (soft) skill acquisition and training. Several classifications of serious games can be made: edutainment games, advergAMES and simulation games (www.game-learn.com, 2018), physical games and computer based games, single player games and multiplayer games (Wan, 2016). This article focuses on physical multiplayer simulation games.

One of the important general lean behaviours is to go to gemba, go and see, talk with people and measure data. This justifies our choice for physical multiplayer simulation games. This kind of serious gaming allows

- to deepen knowledge by the application of lean tools in the game context,

- to train behaviour (e.g. go to gemba, learn to see, walk between lines, continuously look for improvement opportunities, don't push in a pull system, stop the line, share information,...),
- to learn how to e.g. introduce a kanban system, map an office process, make a value stream map, use a teamboard for continuous improvement, use a POLCA system,...
- to offer a safe learning environment in which people can make mistakes without harm (e.g. improve the process of medication delivery in a hospital, experiment with lot sizes on kanban cards, take design decisions, completely reorganise the work flow,...),
- to show the unexpected impact of improvement actions, suggested and implemented by participants themselves. A simulation game that would illustrate obvious concepts only, is boring and a waste of time for all people involved!

Physical multiplayer simulation games stimulate interactive learning, promote critical thinking and reflection and relate theory to reality. They are fun to play and participants like the competitive aspect (Wan, 2016).

3. What are the benefits of our physical multiplayer simulation games?

- Our customers from the workforce report that employees that participated in a lean game show much less resistance against change afterwards. This can be explained: during the game they experienced that those improvement actions were beneficial both for the organization as well as for their personal situation at work (e.g. neat workplace, no more waiting, no more searching (visual aspects), easy to deliver good quality (poka yoke), involvement in team meetings,...).
- Simulation games augment understanding of concepts and methods since they are embedded in the context of the game. This is the best way to implement the constructivist approach (Catalano, Luccini & Mortara, 2018). After playing, participants spontaneously say things like e.g. "Now I understand what's the full meaning of a Customer Order Decoupling Point (CODP)" or "Thanks to the game I have seen how a pull system works".
- Participants learn, in a safe environment, how a lean implementation may go (how to start, what to measure, how to communicate, how to work together,...). When they make mistakes, there is no harm. They just learned something important.
- Physical multiplayer games improve team spirit and group dynamics (teamboard, to-the-point stand-up team meetings, teamwork, communication during the game, discussions after each game session,...).

4. What are the drawbacks of our physical multiplayer simulation games?

- Some preparatory work has to be done: replenish consumer goods, make copies, repair tools, prepare game set-up, provide catering for participants, reserve room, prepare coaching,...
- A minimum number of participants (8 to 12) is necessary in order to play the game. All players should be available during the same period of time and such a game may take several hours to play.
- A big class room (roughly 8m x 8m) is needed with easily movable tables and chairs.
- All our games are coached by one instructor. In case you prefer to coach participants with more instructors, make sure the other instructors are also available.

So, if you can overcome the preparatory work, the other drawbacks just need some planning and communication.

5. Game development

After more than 10 years of serious game development, an approach has been developed for an efficient way to design such a game step-by-step and to validate it in cooperation with experts from the workforce.

5.1. Define objectives

- Define the target group(s) of participants: e.g. engineering technology students, managers and employees in charge of process improvement projects.
- Consider their expected foreknowledge: e.g. What do they already know about lean? What's their professional expertise?
- What is for the ordering party a typical intended result of a lean game training (i.e. Training Needs Analysis)? If knowledge is the only objective, a game is not the most efficient working method!
- What should participants be able to do after this training?
- Define the learning objectives: lean tools/concepts/skills/behaviours. Use the taxonomy of Bloom (Worwic Community College, 2018) to describe them. For example: At the end of the game, participants should be able



- | | |
|---|---------------------------|
| o to define a Customer Order Decoupling Point (CODP),... | (level 1: knowledge), |
| o to identify buffers,... | (level 2: comprehension), |
| o to set up a pull system,... | (level 3: application), |
| o to inspect a process for wastes,... | (level 4: analysis), |
| o to make a plan to start a lean culture in the company,... | (level 5: synthesis), |
| o to award the best improvement ideas,... | (level 6: evaluation). |

5.2. Read about the subject, interview, go and see

- Visit companies, talk to experts, ask for a short internship, interview experienced people, e.g. go and see and talk to doctors and nurses about common processes in a hospital to prepare for the development of a lean healthcare game.
- Take note of both best-in class implementations as well as bad examples. You can use the bad examples as the game set-up in a first game session and you can use the best-in-class examples to determine the KPI target values in the game.
- Read books and articles about the subject, e.g. read about 'Set Based Concurrent Engineering' if you want to develop a lean design game. When you talk to experts, they can tell you what you should read about.
- Ask the experts what they use as performance criteria to measure the performance of their processes, e.g. for a lean design a low committed cost is very important, among some other criteria. Ask them also what methods/tools they use to improve processes, e.g. standardisation of product parts/modules/options is used to minimise committed cost. The output of this action is a complete list of KPI's and improvement actions/tools/methods.

5.3. Describe current processes and identify differences and wastes

- How are comparable processes organised in different companies, e.g. the process of making an invoice or the process of placing an order? How many people are involved? What equipment is needed? Is it convenient to simulate such a process in a game?
- What are differences in performance between those comparable processes: delivery time, costs, quality, errors, rejected parts, rework, throughput time, inventory levels, flexibility,...?
- What would be the causes of those differences?
- The output of this step is a list of processes with for each process repeatedly observed wastes.

5.4. Describe the ideal state of processes

- The ideal state of a process corresponds with best practices in the workfield or with new opportunities.
- Digitalisation should not be in the game, it can be added as soon as processes are optimised and of course, then, it will result in further improvements. The message is that it has no sense to automate processes as long as they are full of waste.
- The ideal state should not be restricted by e.g. a rigid labour legislation, the current layout, machines and tools present, competences available in the company, current communication habits,... The game should show participants that a better solution is possible when they manage to think out-of-the-box, freed from current habits and internal rules, and when they have a view on the whole process instead of only on their own job.

5.5. Define KPI's and design a teamboard

- A teamboard is an important tool to create a lean culture. It mentions all KPI's important for the team together with the target values for each KPI. It visualises goals, target values, detected problems and improvement ideas from team members. It shows team progression over time or - in other words – it gives employees feedback on the results of the sacrifices they have made. In this sense it motivates team members to persevere in the search for improvement. This daily focus and involvement is the basis for a lifelong learning culture and a learning organisation. This is an important message the lean game can bring to participants. At the same time they learn how a teamboard looks like and how it should be used. During or after each game session, KPI's are measured and compared with their target value. Each time a target is not

met, the team has a problem. Participants formulate the problem and one of them writes it down on the teamboard.

- If you have time, you can add a session about policy deployment (hoshin kanri) to explain how a teamboard fits in a bigger picture.
- A teamboard has a column for every game session. How many sessions should be organised? It depends on which improvement ideas can be found after playing the first session and which improvement ideas can only be found after playing a second session? Or can all improvement actions be derived from the current state? In reality, we want to measure the impact of every separate improvement action in order to be sure that they all have a positive contribution to the KPI's. Therefore, in the workfield, improvement actions are implemented one by one. In a game however, the time available for training is limited. Then, a set of improvement actions is implemented simultaneously. Don't forget to explain this to participants!
- Pay attention as instructor: participants should not define a problem as an absent solution, e.g. the problem is that we need more specific tools. A problem is an unwanted situation. Each time a KPI value is worse than its target value, this should be formulated as a problem.
- Let participants complete the teamboard after each game session. Don't do it yourself! In their company, they will also have to do it. If the instructor fills in the teamboard, it fosters the impression that this is not their task and that in their company, a team leader or manager will take care of the teamboard.

5.6. Define and elaborate the process that will be simulated during the game

- Design the basic game for around 8 participants. Create additional tasks just in case there are extra participants: let them map the process, draw the information flow, classify the orders,... Another option is that you extend the game with additional modules. E.g. our lean healthcare game consist of a basic game (8 participants) and can be extended with 2 extra modules (room clean up for a next patient (to illustrate SMED) and oncological day treatment (to illustrate one-piece-flow)).
- Be sure that processes are enough realistic (but not too complex), look familiar and are fun to play.
- Normally, the first session of the game includes common wastes, all visible or at least measurable (bad KPI values). The inefficiencies included in the processes may lead to a slight frustration, but here it is important that you can argue that this is the way such processes are executed in certain organisations. Make the length of this first game session long enough to make all problems visible but short enough for the participants to stay concentrated and engaged.
- The last session of the game should have streamlined processes, easy to carry out, a visibly balanced flow and significantly improved KPI values.
- Think about flexibility and adaptability: make the game adaptable to a varying number of participants, to a shorter available time, also playable in an external location, with standard consumables you can buy anywhere (e.g. white A4 paper sheets, paperclips,...).
- Make or buy extra equipment in case of equipment failure.
- Don't make your game too complex, a lean game should be lean also!
- All participants should have an overview of the ongoing processes (to see wastes, to see how a pull system works, to see how POLCA works,...). Therefore, avoid to choose a too big product for the simulation, to use equipment higher than 1m, to put workstations too far from each other and to isolate participants in the set-up of the game.

5.7. Make instruction sheets

To minimise the cognitive load for participants, it is essential that instructions are clear.

- Use the SIPOC system (Supplier-Input-Process-Output-Customer) as the general structure of an instruction sheet.
 - o Supplier: Where does your input come from: from a department, from the customer,...?
 - o Input: What is your input: an order form, a drawing, a patient file, an email,...?
 - o Process: What are you expected to do: draw, calculate, cut, assemble, complete a form,...? What safety measures do you have to take: wear safety goggles, safety vest, ear caps,...? How many time do you have to finish your job: takt time, standard time, customer lead time,...?
 - o Output: What should the result of your process look like? What do you have to deliver? What are quality criteria of your product: tolerances, features,...?

- o Customer: Where do you have to bring your deliverables or who will come to pick them up?
- Identify each kind of document with a logical code in the footer of the document: e.g. <university>-<game>-<language>-<session number>-<kind of document>-<version number>
- Mention materials needed on a workstation at the top of its instruction sheet.
- Print data sheets on coloured paper and laminate them to make them reusable.
- Print forms that participants have to complete on white paper. Each time the game is going to be played, blank forms will have to be copied. To save paper, use a smaller paper standard (e.g. A5, A6,...).
- Add pictures that clearly illustrate instructions.

5.8. Create a software to visualise game progress and process parameters

Any kind of real-time feedback and of self-evaluation is an important factor that supports engagement (Catalano, Luccini & Mortara, 2018). To provide real-time feedback (about e.g. order launches and order lead times, events, KPI values, customer claims,...), a monitoring software should be developed.

- Visualise actual performance in real time: e.g. an Excel document with a running clock (Visual Basic for Applications), a graphical representation of order lead times, a visualisation of events and an overview of measured KPI values and their target value.
- Measure all important safety and quality criteria by a specific KPI,
- Let the software calculate as much KPI's as possible (to save time after a game session),
- Add visual and audible signals to put attention on new events: e.g. activate a computer beep each time a new order is launched, or each time a customer claim is received.
- Let the software present a graphical overview of KPI values to use during the discussion after a game session.
- Let the software present the evolution of KPI values over all game sessions. This summary shows to all participants the sometimes unexpected big impact of improvement actions.

5.9. Make a (PowerPoint) presentation as an introduction to the game

The game can be introduced using a presentation. The presentation should cover following topics:

- o Why do we play a game? What's the aim of the game? How long will it take?
- o What are the processes, the different roles, the documents used?
- o What do you expect from the participants? What are the rules of the game (e.g. to exclude the learning curve effect (routine), participants have to choose a different role in every game session)? What are participants not allowed to do (e.g. change the set-up during a session, use their smartphone,...)?
- o Explain the teamboard, the monitoring software, the use of equipment (e.g. polystyrene cutting tools),...
- o Any questions?

5.10. Make a separate presentation with exercises, current and improved situation

After each game session, participants put KPI values on the teamboard, formulate problems and generate improvement ideas. To coach this process and to be able to create a deeper learning experience for the participants, a supporting (PowerPoint) presentation may be a big help. The presentation shows for every improvement action, the current state of the process, explains the tools used, and shows their step-by-step implementation. Finally, the presentation also contains the improved set-up of the game. Avoid too much text on the slides. Use drawings, pictures, diagrams and other visuals to support your explanation.

5.11. Write an instructor manual

An instructor manual should be a big help for the instructor to prepare and coach the game play. It's important that the instructor can rely on the completeness of the manual. Then, it will reduce stress and give confidence. A typical content of the manual:

- A material list mentioning everything you need to play the game. Such a list is important when you have to take the game with you to play it at another location (e.g. in-company). The list includes not only all game materials but also spare batteries (charged), teamboard materials (headers, magnets, magnetic smileys, whiteboard markers, post-its, coloured stickers, flip-over, markers), extension cord,...

- A checklist mentioning all documents that have to be printed each time a game will be played,
- A script with preparatory activities: e.g. reserve room, computer, beamer and catering, check tools (e.g. battery charge, cutting tools,...), print copies, remind participants about the exact location and timing of the game,...
- Set-up of game session 1: e.g. position of the tables, computer, beamer, projection screen,...
- Introduction to the game, supported by a (PowerPoint) presentation,
- Instructions to coach participants during game session 1,
- Instructions for the discussion after game session 1: questions the instructor should ask, a list of possible improvement actions, supporting documents, presentation with exercises,...
- Idem for the other game session(s).
- Concluding questions and remarks, e.g. what have you learned during this game?

5.12. Organize a try-out with the target group

- First, play the game step-by-step on your own. Check the availability of all documents, the condition of game equipment, the software, the necessary space,...
- Then, if you have the opportunity, play the game with your students. Use their feedback to adapt the game.
- Finally, invite experienced people from the workfield. Be sure the game is smoothly playable at that moment. Don't waste their time (e.g. missing documents, unclear documents, failing software,...). Take note of their feedback and ask for proposals. For the workfield, it's important that the game is authentic and relevant and that the learning outcomes are worth the time invested by the participants.

5.13. Determine and improve the effectiveness of your serious game

Effective means: the game reaches his goals.

- for the trainer: it was worth the effort,
- for the participants: it was worth spending half a day, they learned about relevant topics,
- for the employer of the participants: the game resulted in enhanced performance on the job.

After people followed lessons, they are expected to use the acquired knowledge to perform their job more efficiently. But during these lessons they were not trained in implementing this knowledge on the job! In this cases, a physical multiplayer simulation game, played after these lessons, can provide a safe learning environment to coach implementation efforts. After playing the simulation game, it is a smaller step for participants to implement on the job what they have learned. They now have a deeper understanding of concepts and they have learned the skills and attitudes to improve processes. For training evaluation, the New World Kirkpatrick Model (www.kirkpatrickpartners.com, 2018) can be used. For game evaluation it may look like table 1 below. For each aspect of the evaluation model, a recommendation to improve the game is added.

Table 1 – New World Kirkpatrick Model for serious game evaluation

Kirkpatrick Level	Sub-aspect	Q = Question = What we want to evaluate R = Recommendation to improve the game
Level 1: REACTION	Customer satisfaction	Q: Are participants satisfied with the game? R: Try to make the game enjoyable (e.g. use funny names, allow participants to talk during the game, create surprising but realistic incidents,...).
	Engagement	Q: To what degree were participants actively involved in the game? R: Take care that all participants have a meaningful role in the game, that they have an overview of all ongoing processes and that during the game they are not isolated from the group. Try also to reduce participant's cognitive load (e.g. by explaining the game at the start, by providing clear instruction sheets, by launching a test order before the real start of the game session, by being available as a coach, by removing any useless redundancy and complexity from the game,...).
	Relevance	Q: Will participants have the opportunity to use or apply on their job what they have learned during the lessons/game?



		R: Try to know in advance who your participants are, in what (improvement) processes they will be involved and, if possible, what they will have to do in the near future.
Level 2: LEARNING	Knowledge Skills Attitudes	Q: To what degree did participants acquire the intended knowledge/skills/attitudes? R: Be sure that the content of the game is rich and covers the most common issues of the topic of the game (e.g. lean design, lean office, lean production,...). Explain the learning points of the game as a final summary. Q: Do participants believe that it is worth to implement on the job what they have learned during the lessons/game? R: Yes, if during the game they can experience the beneficial impact of improvement actions not only on the KPI's but also on the perceived work load, on the ease to deliver good quality, the number of disturbing customer calls,...
	Confidence	Q: Are participants confident that they will be able to implement it? R: Avoid to create a demo simulation. Give participants the freedom to act or not to act during the game. Take enough time for the discussion between game sessions: this is an important learning moment for the participants. Let them reflect on what happened during the game session. Make sure that during the game they learned how to implement useful lean concepts.
	Commitment	Q: Do participants intend to implement it on their job? R: Include in the game mainly those issues which are relevant for most of the companies.
Level 3: BEHAVIOUR	Use	Q: To what degree do participants use or apply on their job what they have learned during the game? R: Contact participants and their superiors afterwards to ask about it.
	Required drivers	Q: Does the employer provide the right processes and systems that reinforce, encourage and reward performance of critical behaviour on the job? Are all obstacles removed that prevent such critical behaviour? R: In order to maximize the impact of the lean game training, contact the employer of the participants in advance and convince him/her to provide support for the participants after the lean game training (coaching, help desk, follow-up, rewards,...).
Level 4: RESULTS	Established outcomes	Q: To what degree do targeted outcomes occur as a result of the game and the subsequent reinforcement actions from the employer? R: Ask the employer some months after the lean game training.
	Leading indicators	Q: What short-term observations and measurements show that critical behaviours are on track to create a positive impact on desired results? R: Convince management that it is crucial that they take the lead immediately after the lean game training!

The Kirkpatrick model is based on research conclusions that “as much as 90% of training resources are spent on the design, development, and delivery of training events that yield 15% on-the-job application (Brinkerhoff, 2006). Reinforcement that occurs after the training event produces the highest level of learning effectiveness, followed by activities that occur before the learning event. Currently, learning professionals are putting most of their resources into the part of the training process that produces the lowest level of business results. They are spending relatively little time on the pre-training and follow-up activities that translate into the positive behaviour change and subsequent results that organizations seek (www.kirkpatrickpartners.com, 2018)”.

You can also augment effectiveness of your training using the evidence-based recommendations and best practices for maximizing training effectiveness mentioned in the article ‘The Science of Training and Development in Organizations: What Matters in Practice’ (Salas, Tannenbaum, Kraiger and Smith-Jentsch, 2012). The article contains tables with steps to take before, during and after training, a description of

accompanying actions and the resulting outcomes. All outcomes are aspects of ‘enhanced performance on the job’, the ultimate goal of training.

Brinkerhoff’s Success Case Method (Brinkerhoff, 2005) is based on the comprehension that training can only increase employee capability. Afterwards, employees should be coached to use this augmented capability to improve processes. Brinkerhoff’s Success Case Method can then be used to measure and improve the impact of training. The method is based on the idea that we can learn best from those participants who have been most successful in applying in their job what they have learned during training, but also from those participants who have been the least successful. Some weeks/months after training, a small number of participants from both groups are interviewed to identify and document factors in the organizational environment that facilitate or hinder implementation and adoption.

So, training is only successful if it finally results in better performance in the jobs of all participants.

5.14. Promote your game

The development of a serious game takes time. Once it is finished – of course it will be subject to a process of continuous improvement – it should generate an educational return. In order to be able to play the game frequently with people from the target group, you should promote your game:

- Explain the game on your website and on social media,
- Make and distribute flyers,
- Contact and inform program leaders, teachers/professors, decision makers, HR managers,...
- Collect feedback and references of groups that played the game and use them in your communication.

6. Conclusion:

This article focused on developing, playing and assessing physical multiplayer simulation games. These games can be used as a safe training environment to close the gap between what people have learned in a course and its implementation on the job. Although this kind of lean training program needs more preparatory work and the use of a coach, with such games, a training provider can contribute to all levels of the Kirkpatrick model (for the evaluation of training effectiveness). The message of this model is that training effectiveness can be augmented dramatically

- if a Training Needs Analysis (TNA) is performed before the training,
- if management provides support for the participants after the lean game training.

Although this article has been enriched with examples from the experience we have built up during more than 10 years of developing and coaching serious games, we continue our journey and we hope our experience will grow further. We also hope we can share it with many people and that we can also learn from the experiences of other instructors and developers.

Acknowledgement

I would like to thank Johan Batsleer, senior consultant and lean expert from Amelior. He instructed me in coaching serious games. He also contributed to the quality of course materials in our Lean Learning Academy. In the past 10 years, he was always prepared to join the try-outs we organized with the workfield. Some recommendations in this article were formulated first by him.

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Lego® Serious Play® as a Business Innovation enabler

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Abstract

Improvements in innovation and quality processes can be achieved through the use of novel approaches such as LSP, which enables abstract thinking and advocates an open-mind for unconventional solutions. Within the scope of business processes and structures, the LSP methodology enables collaborative reflection on both single and complex procedures (regardless of rank) in the form of a 'thinking space' based on a flat hierarchy. The employment of total engagement using games and virtual worlds are used to change the working world and businesses activities. The collaborative nature of the work necessary for creating a Lego model establishes a shared comprehension of a certain problem or issue.

Hence, LSP is found to be a suitable methodology for identifying improvements by delineating the actual situation and procedures in the business structure. These initial steps involve the development of learning and comprehension of the current system through consideration of varying stakeholders' perspectives and understanding of the challenges associated with the existing conditions and structures. LSP acts as a learning enabler by creating clarity and support mechanisms for innovation developments and improvement.

In this paper, the authors present how the LSP method can enable Business Innovation based on case studies from the authors' own experience in industry. Therefore, the participants compose two different target groups – either a mixed group consisting of employees from different SME respectively multipliers or a group of employees from one enterprise. The group composition and the participants' background influence the LSP workshop related to structure, procedure and results. Conditions, challenges and factors for successful LSP workshops are evaluated.

Keywords: LSP, Business Innovation, Serious Games

Motivation and objectives

The increasing importance of innovations (Franke et al., 2016) results either from the increasing market requirements (Reguia, 2014) or from the necessity to improve products and processes taking new technologies and digital approaches into account (Radziwon et al., 2014; Lasi et al., 2014). Innovations are only successful if the products and services offered meet the needs of end consumers by offering added value (Cavaye, 1995). Business Innovation is therefore an essential competitive factor for the design of innovative products, services and processes (Reguia, 2014). In this innovation process, itself it is crucial to integrate knowledge from different stakeholders. With their knowledge and experience, employees in particular contribute to ideas for improvements in the work process having a high degree of effectiveness, quality and practicability, which in turn positively influences the efficiency of the innovation and improvement process. In addition, participation strengthens trust, loyalty and commitment, so that the jointly developed solutions receive a higher degree of support during the implementation process. (Riedel et al., 2017) Nevertheless, it is essential that the group fits together to create a productive and effective team spirit promoting creativity, exchange of ideas and a dynamic

working atmosphere itself (Mathieu et al., 2014).

Since the deployment of “Serious Play” in the context of Business Innovation, it is recognized that Lego® Serious Play® (LSP) can assist in creating ‘action research’ capacity and contribute to academic understanding and practical value (Kristiansen & Rasmussen, 2014). Gamification concepts can also encourage total engagement using games and virtual worlds and can positively influence the way people work and how businesses compete (Roth, Schneckenberg, & Tsai, 2015). This results in creating a different approach to the development of people and how they also create abstract thinking for real conditions and contexts through the use of metaphors. Multilayered problems and complex processes or structures become tangible in the form of a model and result in the development of a common understanding of the issues as they are visualized by reducing complexity through the use of metaphors and the creation of a 3D model. (Schulz et al., 2015)

The successful innovation process and methodological procedure of LSP depend on the workshop topic, the participants regarding their professional background, experiences, skills and the overall workshop group composition. (Tawalbeh et al., 2017; Emanuel et al., 2018) Hence, the conditions, challenges and factors to be successful as well as methodological adaptations for these two target groups are juxtaposed in this article leading to valuable insights into the mechanisms of that special type of serious games.

This article starts with an overview referring to Business Innovation, serious play in general and the method Lego® Serious Play®. The application of the LSP method in different contents by varying participation groups is in the focus of the following case studies. Hence, two main case studies show the challenges, benefits and factors to be successful by working with participants of a different professional background.

Business Innovation

Business innovation is the creation of a new value which the costumer or the enterprise earns from new products, processes or services (Sawhney et al., 2006). Hence, business innovations are crucial for enterprises to satisfy clients’ needs by protecting and extending their competitive situation (Gakkai, 1988). Whereby, innovations are the drivers of the whole national economics (Bauer, 2013).

Each kind of innovation is based on new ideas resulting from many different stakeholders – e.g. end users, customers – or results from new procedures, structures and technologies. Business innovations are divided into two groups; product innovations and process innovations – creating different impacts on the company in general. The competitive strategy of the enterprise is especially influenced by each kind of innovation. Furthermore process innovations can form the economic efficiency of the value chain of the company. The key aspect is the improvement of business and production processes (Gakkai, 1988), which can vary in terms of their temporal effect and the extent of such an effect. Subsequently, differentiation can result in radical and incremental innovations. Consequentially, "radical" innovations can lead to far-reaching changes, whilst "incremental" innovations continuously drive the change process forward. (Schumpeter, 1942)

Hence, it is necessary to study challenges across the enterprise with open innovation approaches considering internal as well as external ideas in the development of innovative processes (Gassmann, 2008). One prominent approach is ‘serious play’ which is described in the following section.

Approach of Serious Play in Business Context

The term “play” can be defined as throwing aside the rules of "normal life" for a certain time to follow new rules or try out new possibilities. Playing is a voluntary activity with active (often physical) commitment. The term "serious" attempts to distinguish playful activities in a work situation or in the life context of an adult from those activities carried out by children in which play is used for its own sake. (Rieber et al., 1998)

Hence, the term ‘serious play’ can be used to describe activities in which fun-oriented, intrinsic motivated actions are used to achieve serious and extrinsic motivated goals from the work context (Statler et al., 2011). This apparently paradoxical approach is based on the positive aspects of playing (Statler et al., 2009). Cognitive abilities grow (Vygotsky, 1978) while the productivity in the work context increases (Starbuck & Webster, 1991). Furthermore, organizational scientists prove that through playful interventions we can promote learning and critical reflection (Schulz, 2006). Last but not least, experience, new methods and concepts can be conveyed in game situations (Tröger et al., 2011). In addition to these individual effects, it is attributed to serious play that it serves to promote a shared understanding in groups (Oliver & Roos, 2007).

Serious Play should be particularly suitable for situations that require creative, out-of-the-box or holistic thinking and a high degree of personal commitment. Playing games is also seen as an interactive way of telling stories effectively, which is fundamental for cognition and learning. Formal game research has led to the establishment at least three game levels: (1) participation (fun and games); (2) problem solving (development of physical and mental perceiving tools); (3) catalytic action (that allow an individual to intuitively tap into opportunities, to become spontaneous). Play research has strong anthropological roots and is divided into four thematic areas: play as progress, play as fantasy, play as self and play as power (Rieber et al., 1998). The Serious Play's approach uses the above combined mechanisms by raising players' awareness of problems and ideas and fostering of their creativity whilst enabling teamwork etc. The content or context of the play is "serious" in that it deals with questions relating to real life or working life. In practice, there are various approaches to 'Serious Play', e.g. theatre games, physical modeling, and also the use of Lego for building metaphors and stories, namely the Lego® Serious Play® approach. (Kelly & Riedel, 2014)

The method Lego® Serious Play®

Lego® Serious Play® (LSP) was originally developed to facilitate the strategy development function of the Lego Company. LSP is a facilitated workshop in which participants respond to tasks by creating symbolic and metaphorical models from Lego bricks and then present those models through storytelling to other participants in order to achieve a common understanding of each other as well as the topic. The LSP method is based on following basic values: 'The answer is in the system'; 'Everyone has to express his/her reflection'; 'There is no ONE right answer.'

In this way, the method enables a more unbiased, free-thinking and playful interaction between the participants, which leads to a common understanding, creative ideas, etc. (Kristiansen et al., 2009; Hansen et al., 2009).

The LSP concept is based on several key theories: (1) the importance of play as a learning method by exploring and telling stories; (2) constructionism; (3) the hand-mind connection as a new way for creative and expressive thinking; and (4) the role of the different types of imagination.

The first step for a successful implementation of LSP is to ask participants – after some simple tasks for skills building – to create a model of a particular problem with Lego. So everybody gets in touch with modeling and metaphorical thinking. In the subsequent spontaneous construction process, the participants give the models meaning by "tapping into their brains". When the construction phase is complete, each person explains their perception (or story) to the other participants. The other participants can ask for clarification of details, but they must respect the model and also the importance attached to it. During the reflective part of the workshop, insights are created for the individual and the team as a whole. (Frick et al., 2013; Kristiansen et al., 2009; Hansen et al., 2009).

Using individual models, the participants are then be challenged to build a common model, produce relations between the individual models and create a landscape that also models external "agents". This newly collaboratively constructed model can then be the basis for testing, for the analysis of certain scenarios and finally for the extraction of guiding principles. (Kristiansen et al., 2009)

Since LSP is a more generic principle, it can be applied to a variety of problems, e.g. strategy, product or organizational development, change management processes, mergers and acquisitions (Hadida, 2013; Jentsch et al., 2011; Frick et al., 2013; Hansen et al., 2009). Considering the mechanisms and theories inherent in the LSP method, it is proven that it is also suitable for positive impacts on contexts of reengineering of any kind of processes (Dempsey et al., 2014), participative engineering (Kelly & Riedel, 2014), team development (Jentsch et al., 2011) and knowledge sharing related to digitalization (Tawalbeh et al., 2016).

Case Studies on group composition as an influencing factor on LSP

Ontology of design activities so that proponents of models or theories of design and practitioners have a shared understanding of what each specific design activity entails (Sim and Duffy 2003). Although methods for generating research questions are not mutually exclusive, nevertheless they support a more reflective scholarly attitude due to mixed method approaches to create more complex research designs (Sandberg and Alvesson 2011). 'How to' guides and resources focusing on key themes, create a structured approach to research activity (Cousin 2009) whilst also supporting guidance and the flexibility to adapt, refine, expand or trim. In addition

to questionnaire surveys (Emanuel et al., 2018) participant observation as a qualitative research method (DeWalt, & DeWalt, 2011) is used to explore how LSP enables abstract thinking and an open-mind for unconventional solutions. . A case study approach is used in this study, as it will provide an appreciation of these issues in its natural real-life context (Crowe, Cresswell et al. 2011). The study will derive knowledge from theory with the empirical context of conducting this study based on LSP instructor's observation which will also derive knowledge from the experience of LSP facilitation and implementation.

The wide range of fields associated with LSP show that it is applicable for varying objectives in business, training, educational, family, and mentor contexts (Peabody, 2015). Just as the field of application varies, so too does the target group. As a result, the groups of participants are made up of people from different backgrounds, qualifications and experience influencing the dynamics of the group and therefore also the process and the results of the serious game. (Mathieu et al., 2014) Therefore, it is decisive to understand those influencing factors. Perspectively, those factors should be taken into account when designing and running the workshop.

A selection of case studies with different groups of participants will be presented. A case study is a “detailed examination of a single example of a class of phenomena” (Abercrombie et al., 1984 p. 34). It is useful to create hypotheses which can later be systematically tested on a broader empirical basis (Flyvbjerg, 2006).

This is the first case study based on a mixed group of participants. Therefore two use cases are described in a combined way. Following, there is one example with multipliers (case study 1a) and another one with entrepreneurs from different SME (case study 1b). Additionally, a complete different concept is shown in form of a case study with employees of a single company (case study 2).

By having those deep insights in the case studies, the examination of challenges, benefits and success factors of the LSP approach in conjunction with its characteristics will be possible.

Case Study 1: Lego® Serious Play® with a mixed group of participants

Content-related Objective

Lego® Serious Play® workshops were used to raise awareness of the digitalization and their potentials for SME and multipliers. Multipliers like the Chambers of Industry and Commerce, Chamber of Crafts and business development agencies who work with SME (Case Study 1a) respectively entrepreneurs from different SME (Case Study 1b) were asked to interchange their own knowledge about potentials and challenges of digitalization for SME and then develop a common understanding of this area with a playful approach.

Case Study 1a: Lego® Serious Play® for multipliers

In general, getting to know the method LSP is more in the focus than the deviation of concrete following implementation steps for Industry 4.0.

Case Study 1b: Lego® Serious Play® for entrepreneurs from different SME

Getting to know and using the LSP method as deriving the following steps for the further development of the company in the sense of Industry 4.0 and digitization are in focus.

Methodological requirements

The workshop takes place in a **neutral environment**, whereby a room with **sufficient space and large tables** is a prerequisite. However, there should also be room to move, for example, to change seats at the table and provide for a new/different perspective. The participants take part in an **external workshop**, which removes them from their everyday working environment and therefore reduces the influencing factors. Nevertheless, it is necessary to **directly ban technologies** such as smartphones, tablets and laptops from the workshop environment.

The **5 to 8 participants** of the workshop must get the possibility to prepare for the workshop by **getting an overview** related to Industry 4.0 topics. This preparation is a prerequisite for a successful workshop where everybody is able to bring own ideas into the innovation and creation process.

Methodical approach and the resulting challenges



At the beginning there was a sensitization for the method Lego® Serious Play® and its use. This was needed in order to exercise metaphorical building, because none of the bricks would represent the thoughts of the builder in a way, such that every other participant would have the same interpretation of the model in his mind. That was why exercising story telling followed. Afterwards, the participants dealt with their previous idea of Industry 4.0 in a small individual model. Since the workshop participants were from different SME as well as business areas and each had different technical backgrounds and experiences, the individual ideas of Industry 4.0 differed greatly. Telling stories about the individual models thus opened up new perspectives of Industry 4.0 to the participants without additional activities by the moderator.

Nevertheless, there was a great challenge in developing a common model. The different backgrounds of the participants thus brought with them a different understanding of business processes, structures and organizations. However, in order to build a common model for a common understanding, an appropriate starting point had to exist. For this reason, a fictitious company was introduced. In the following step each participant was assigned a corresponding role in the company. This assignment was based on the professional background and the origin of the participant so that the entrepreneurs could identify better with the respective role and could also incorporate their own experiences. In contrast, the roles of the multipliers were distributed randomly. The identification of the participants involved with the fictitious company tended to take longer with multipliers than those in workshops with entrepreneurs because multipliers often come from state institutions. As these people do not work in a manufacturing company, they may therefore not be familiar with the individual processes and structures, which can be influenced by Industry 4.0 in general.

In the interests of the fictitious company, everyone developed first their own vision for the year 2022 as a digital pioneer among SME. The objective was to dissolve themselves from an actual state and start thinking in a target state. In this context, the question was raised as to how the pioneering role was achieved and which digitization technologies, services and structures were to be used in the corresponding corporate departments whilst considering the involvement of employees. This was provided for a sequence of step by step questions. Mainly, multipliers approached this challenge with an open mind and used visionary thinking to lead them to novel and unbiased results, whereby they had to judge, if the company could really implement these ideas by the year 2022. In comparison, the imagination of the entrepreneurs was more realistic, as the concrete target situation was thoroughly thought through.

After storytelling and completion of the common, the Lego model was developed with stakeholders and external factors scenarios were examined. This led to a deeper understanding about how to actually change imaginations and develop links between the individual models. However, if the focus was entirely on getting to know the methodology a tendency to distance oneself from reality resulted. This weakened the meaning of emergences, which led to the argument that the fictitious company was "naturally" prepared for the developments.

Just by using LSP, the participants got a vision for the fictitious company and derived general action strategies as a result. However, an unanswered question remained, especially asked by entrepreneurs: Where do we start to implement Industry 4.0 components? That was why there were integrated some more moderating elements and approaches of agile project management. By returning to the actual state of the company the participants were led to choose a pilot and the technologies and structures with regard to Industry 4.0 resulting in possibly highest effects. Therefore, the degree of prior knowledge or preparation for the workshop was crucial, as a lack of knowledge made it more difficult to mention concrete ideas for implementation and linger on a more abstract level like "We have to implement linkages between our products and services". In general the definition of concrete measures was rather difficult for the multipliers. On the other hand, entrepreneurs gave a lot of input, which made it difficult or even impossible to keep to the time frame.

One of the most important findings of such a Lego® Serious Play® workshop is that participants are often astonished at how quickly they can come to joint results with stranger participants (Emanuel et al., 2018).

Case Study 2: Lego® Serious Play® for employees of a single company

Content-related Objective

The Lego® Serious Play® method is used in the company to examine existing processes and identify optimization potentials with regard to lean management.

Methodological requirements

Especially for a LSP workshop in an enterprise, **preexisting relationships** are crucial to convince the enterprise to consider taking employees out of their regular work activities. To get the employees' capacities is easier, if trust and credibility preexists. Such a preexisting relationship can convince the management to take a risk in running an LSP workshop. Senior management commitment is also a key success factor because it leads to an ease of implementation and resource management for the workshop.

A LSP workshop should take **place offsite**. Having zero distractions is vital for the innovation process and the reason why each **technology is not permitted**. The participants must be provided with an opportunity to concentrate on the task without any distractions via mobile technology.

Prior discussions (at least 2) around the topic are vital to generate the topic including reasonable tasks to accomplish in the provided time. Hence, the shape of the theme of the workshop is defined. **Planning** the theme, **schedule** (including estimated timing) and **location facilities** are critical as well as risk assessing the plan in terms of fewer or more participants than planned. Especially for the location facilities, as there are some specific layout requirements. For example, a U shaped layout facilitates participants' access to models and movement around the workshop with flexible and comfortable furniture with recommended tables of approximately 4x3 ft.

Nevertheless, the **expectations of the participants** have to be gathered at the start of the workshop to determine whether the workshop did not meet, met or exceeded these expectations. In this context, the setting of the rules of the workshop is necessary by a clear description to ensure that all participants engage and that respect is maintained.

Managing participants who do not wish to participate involves innovative strategies. Reluctance to engage with the workshop needs patience and understanding. This can be understood in the pre-planning phase and overcome during the workshop delivery if additional background is provided by the enterprise.

Methodical approach and the resulting challenges

Participants from the same unit in an organization were introduced to the LSP method to develop a shared improvement strategy for their service unit. Participants first became familiar with the Lego bricks through two icebreaker exercises and they then focused on building individual models to identify improvement processes related to their individual role in an organization. This facilitated a sharing of knowledge about participant's perceptions of their role in an organization, together with identifying enablers and challenges associated with their role. Although the participants were from the same Unit, their rank and length of service in the organization varied from junior to senior and did not correlate with number of years' service which also resulted in a variance in ideas around improvement. The mix of experience with new perspectives together with a variety of levels across roles led to an interesting diverse range of opinions and discussions around improvement. This storytelling effect of LSP facilitated this diversity of conversation through a forum which created equality across participants regardless of grade or length of service. The majority of the participants were positive about their involvement in the development of the strategy but a reluctance to engage was a factor for one participant who did not see the value in playing with Lego for 6 hours. When negativity is a factor, it can impact on the workshop. However, an experienced facilitator can mostly manage these participants through coaxing techniques and continuously involving and praising said participants. In this case, the reluctant participant was transformed by the end of the workshop and effectively contributed to the development of the strategy for the Unit.

Following the individual model build and storytelling, the group were tasked with developing a shared physical model in order to assist the Unit in realizing a shared vision for an improvement strategy. This part of the workshop was very challenging for participants, as a consensus had to be reached before the model was built. Much discussion and debate took place between participants before alignment was reached and compromise was agreed between roles in considering how improvements could be achieved. During the discussions, all questions were asked directly to the model and this helped relieve potential tension. Participants suggested how to merge work tasks in order to achieve efficiencies and also consideration was given to swap tasks between roles. This resulted in participants being open to such implementation once the workshop was completed.

Once an agreed model was built, the participants then got another opportunity to risk assess the potential

failings of the agreed model. Reality hit at this point of the workshop as participants realize that the strategy they have collectively agreed was in front of them in the form of a Lego model. Alterations took place to match resource constraints. The next stage was to agree the steps to be taken in order to realize the strategy.

Related to the main objective of the workshop, the group composition has to be chosen. There are multiple options for composition which are acceptable but which require consideration in the pre-planning phase: (1) cross disciplinary from various levels, (2) cross disciplinary from similar level or (3) discipline focused. Thereby, a small group of 4 to 8 participants is ideal because everyone has an opportunity to speak without everyone in the group getting bored of participants speaking around the same theme. Senior Level Leadership support in both participating in the workshop and listening carefully to other participants is important because decision making to effect change is easier managed and more successfully implemented when leadership are involved.

During the workshop the group bonds in a way that is unique as each will have a similar amount of time to articulate their vision for the current state and the future state models. Everyone shares their vision. It is critical that respect builds among the participants as they begin to understand each other's roles, viewpoints and challenges. Therefore, maintaining the game rule that the questions are directed to the model results in removing the personalities and potential for conflict. The focus is on the issue/opportunity identified.

Enjoyment of the process, regardless of the outcome, is vital. Participants move from a narrow focus to a more holistic systems approach to problem solving. The result may surprise participants if they enjoy the process and let their minds become free. Open minds will enhance creativity and innovation and as a consequence, the workshop results in enhanced outcomes i.e. achieving the pre-set theme and additional outcomes.

Conclusion

Lego® Serious Play® is a powerful tool enabling a creative business innovation process through abstract thinking. However, its success depends on the methodological adaption related to the group composition and the workshop topic. The study derived knowledge from theory with the empirical context of conducting this study based on LSP instructor's observation and the experience of LSP facilitation and implementation. From the two different perspectives of the case studies, we learn that in an in-house LSP workshop, management support in both preparation and implementation as well as the prevailing team atmosphere (existing conflicts, communication barriers) has a decisive influence on the overall result. However, if the workshop is conducted with a mixed group of foreign participants, the focus is on building a common understanding of what can be achieved, for example, through a fictitious company. Additionally, building up knowledge and getting to know other workshop participants with different backgrounds and experiences represent interpersonal challenges that have to be solved at the beginning of the workshop in order to achieve a successful process.

In both case studies, storytelling elements were of utmost importance as ideas, imaginations and thoughts could be translated easily between participants. In this way, the individual participant contributes to the overall system, whereby different perspectives are taken into account.

Each workshop is different and each brings its own unique challenges. The group dynamic is determined by the problem that is to be solved. In the case of technical problem solving, it is a straightforward process with the only variance being the participants and their approach to solving the problem. In softer people and team issues, the approach is deeper and requires more carefully management.

Nevertheless, this research is characterized by limitations because only three case studies are compared regarding their success factors. The comparison is not based on a predetermined classification scheme related to the group composition or on a subjective judgment of success and its significant factors. Hence, there are a lot of opportunities for further studies in understanding how LSP can be more successful with varying participants.

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Capital Flow Design – Management Accounting's Role in a Lean Enterprise

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Abstract

Lean Production Systems are the accepted benchmark for an efficient and effective production. Despite the rising prevalence of Lean in manufacturing and service companies, traditional management accounting systems are widely used unmodified in companies. This often creates distinct conflicts for the management during a Lean transformation. Traditional management accounting is a model based on assumptions that are not valid any more in today's Lean companies. As an approach to solving this problem the paper shows the ten guiding design principles of an Accounting for Lean system. The principles were developed by an intensive literature research as well as a three-year case study in a manufacturing company. The consideration of these principles in the design of the company's internal management accounting system creates financial information, that actively support the Lean strategy. The resulting management accounting system for Lean companies is called Capital Flow Design.

Keywords: Accounting for Lean, Lean Accounting, cash flow, management accounting.

Traditional management accounting as barrier for Lean

"Standard-cost accounting systems are incompatible with Lean. They are antithetical to Lean practice because they encourage and reward precisely the behaviours that you want to eliminate. In fact, I think of standard-cost accounting as "the anti-Lean". (Byrne, 2013)

Despite distinct developments in production systems towards Lean, traditional management accounting systems are widely used unmodified in companies (Rao & Bargerstock, 2011). The basic structure and principles of traditional accounting were developed to support tayloristic mass production systems in sellers' markets about 100 years ago (Darlington, 2012).

Most companies do not adapt or question their management accounting systems during the Lean transformation, which results in conflicts between accounting and Lean. In literature, there exist many examples of top management stopping Lean turnarounds, because their organization's accounting system is unable to show any or even negative financial results (e.g. DeLuzio, 2006; Sobczyk & Koch, 2008). Especially in early Lean implementation phases, blind faith in the Lean success is rarely enough for CEOs and CFOs.

For a sustainable and resounding success it is not enough to implement Lean exclusively in production and logistics. A company is a living system (Johnson, 2006), that interacts permanently with all direct and indirect functions. Figure 1 shows the necessary elements of a successful Lean transformation environment and the mutual relationship of the single aspects (c.f. Gerberich, Teuber, & Schäfer, 2006; Grasso, 2006; Grasso, Tyson, Skousen, & Fullerton, 2015)

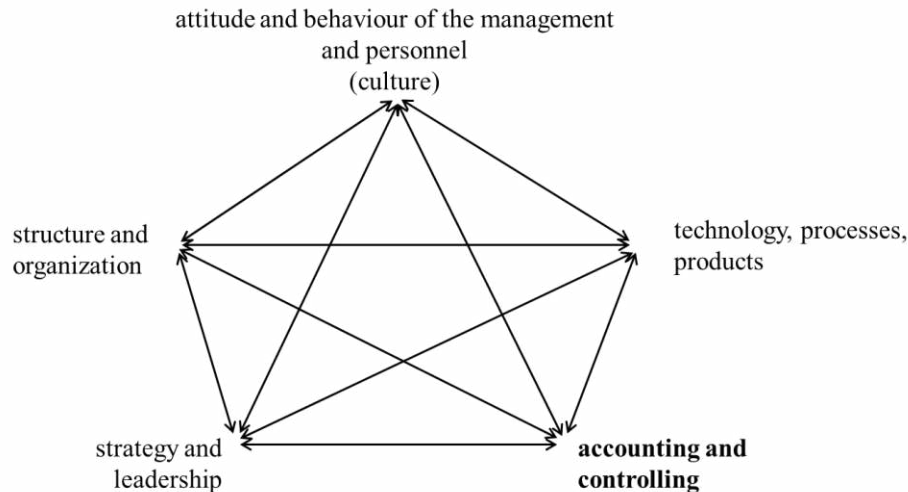


Figure 1 – Elements and their relationship for a successful Lean transformation

Every element of a successful Lean environment in figure 1 influences all other elements and is influenced by all others. The research and business practice show current developments in the following elements:

- Culture, in terms of kaizen or Toyota Kata (Rother, 2013)
- Structure and organization, like management principles and value stream orientation (Rother, Shook & Wiegand, 2004; Schneider, 2016)
- Strategy and leadership, like Hoshin Kanri (Kudernatsch, 2013)
- Customer focused design of products and processes with methods like target costing (Cunningham 2003).

In contrast to these elements, accounting and controlling are a quite unexplored field in the Lean movement (Chiarini, 2012; Huntzinger, 2007). Due to the high importance of the accounting system for internal communication, budgeting and controlling aspects it needs to be changed for supporting the Lean strategy (Ahlstroem & Karlsson, 1996). Therefore, the core research question of the paper is “What are the guiding design principles of management accounting system for Lean?”.

To answer this question section 2 will give a short summary of the assumptions of traditional accounting and its deficits in a Lean company. Section 3 shows the results of an empirical analysis of requirements on management accounting system for Lean. This is the foundation for the development of ten guiding design principles of the Capital Flow Design System in section 4. Section 5 gives a short summary.

Assumptions of traditional management accounting systems

Management accounting systems are a model of the company’s financial reality. The validity of a model is always dependent on its underlying premises and assumptions. These assumptions must be considered during the interpretation of its results and information. The correctness of financial statements about the profitability of a production system is therefore dependent on the assumptions of the applied accounting system (c.f. Ansari, Bell, Klammer, & Lawrence, 1997).

To understand the roots of the conflicts between traditional management accounting and the Lean philosophy (c.f. Michalicki, 2016; Smith, 2000) you need to identify the assumptions of traditional accounting systems and analyse, if these assumptions are still valid in a Lean environment. The following groups of assumptions of traditional accounting systems have been detected:

- Assumptions about the production system and factory type

- Assumptions about the cost structure and main influencing factors of costs
- Assumptions about the production and market environment.

Assumptions about the production system and factory type

Traditional cost accounting systems reflect the time of emerging mass production systems (Darlington, Found, & Francis, 2016). The core of most modern management accounting systems was developed in the 1920s (Cunningham, Fiume, & Adams, 2003) without any significant improvements or adjustments (Solomon & Fullerton, 2007). Therefore, traditional accounting supports the production system and factory type of the early period of industrialization including their premises about achieving highest profitability. Most companies were anonymous single-step mass producers with a low level of automation (Brauckmann, 2015), which is the opposite of highly integrated and partly automated Lean enterprises.

Traditional accounting systems have been developed for tayloristic mass production systems with a high division of labour and big batches for generating economies of scale (Cunningham et al., 2003). The assumption is, that concentrating similar resources like machines or employees improves the efficiency. In contrast, this functional organization and local optimization is seen as the central driver of waste in Lean Thinking (Kennedy & Brewer, 2006).

Assumptions about the cost structure and main influencing factors of costs

Traditional accounting systems assume the cost structure of a mass producer of the early 20th century, which differs fundamentally from modern industrial companies. The typical cost structure till the 1950s was characterised by high direct labour costs and low overhead costs of typically below 10 % of the total costs. The continuously rising effort for planning, controlling and managing tasks causes a much higher portion of overhead in modern companies. Direct labour costs are constantly decreasing due to automation, rationalization and outsourcing. Figure 2 summarizes the development of cost structures in the last decades (c.f. Solomon & Fullerton, 2007).

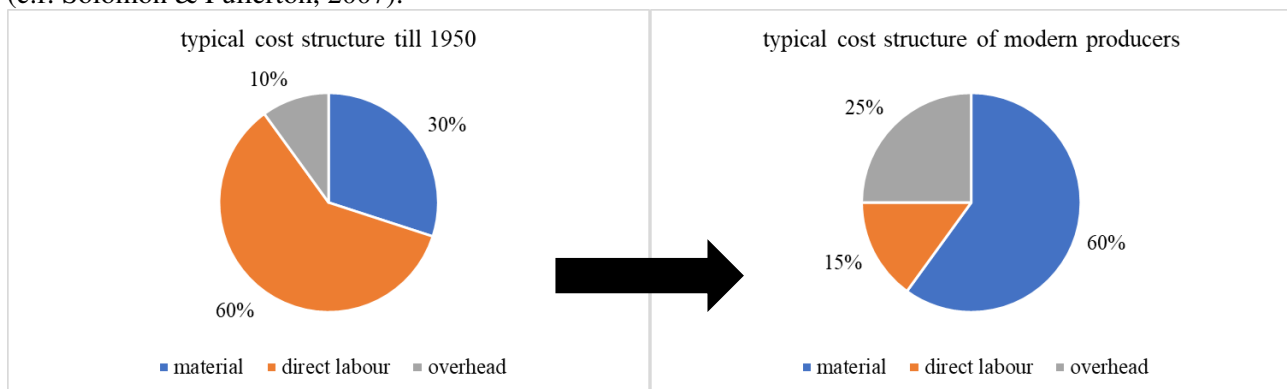


Figure 2 – changes of cost structures

The changing cost structures limit the usability of traditional management accounting systems considerably. Traditional costing systems were not developed for handling high overhead cost as well as high fixed costs that are dominant in modern production systems (Coenenberg, Fischer, & Günther, 2016)

The main influencing factor of costs in traditional accounting systems is the capacity utilization of resources. But modern production systems are characterised by a fixed cost portion of 70 – 90 % of total costs without material or other external costs. Therefore, the utilization of resources does not have a great impact on total costs (without material). The calculative reduction of unit costs through high capacity utilization does usually not affect the spending, the total costs or even improve the cash flow (Darlington et al., 2016).

Assumptions about the production and market environment

The economies of scale describe the fact, that unit costs decrease with rising production volume. This Tayloristic view bases on the assumption of a sellers' market, where the sales volume is constantly increasing and the whole production volume can be sold with constant prices. These assumptions are not valid for modern buyers' markets, where product life cycles get shorter, customers define the value and the market is highly competitive. The singular focus on economies of scale in a buyer's market can cause overproduction, the worst of all kind of wastes in Lean Thinking (Ohno, 2013). So, the economies of scale are true in general but only valid for companies in a sellers' market.

The view of unsaturated demand manifests in the traditional calculation of cost of goods sold. The fixed costs of a period are traditionally spread over the whole production volume of the period. So unit costs and total costs of goods sold get less the more it is produced. By adding a portion of fixed costs to the overproduced volume, rising inventories of work in progress or finished goods get motivated (c.f. Silvi, Bartolini, & Visani, 2012). In Lean Thinking overproduction has no value at all from the customers point of view.

All these assumptions lead to the fact, that traditional accounting systems work actively against a Lean Production System. Despite some singular developments on the field of Accounting for Lean (e.g. value stream costing (Maskell, Baggaley, & Grasso, 2012)) a systematic approach for the identification of requirements on a holistic management accounting system for Lean companies is missing.

Empirical analysis of requirements on management accounting systems for Lean

To identify requirements on an accounting system for Lean companies, interviews with experienced Lean practitioners were performed. Guided qualitative interviews with experts are a recommended way of empirical information collection in complex situations (Buber & Klein, 2007). For the traceability of the research process the following framework conditions of the interviews are defined:

- **Research object:** The focus is on determining requirements of profit and loss responsible managers in Lean Production systems on a management accounting system.
- **Target group:** The target group consists of company-internal customers of management accounting information. An expert in case of the study is a manager with profit and loss responsibility in a Lean Production system. The expert needs to have a profound knowledge and practical experience in Lean Production. The target group consist of managers from the middle and upper management level, ranging from industrial foremen up to CEOs. Two Lean consultants are included. The size and respective industries of the expert's companies varied widely.
- **Random sample:** The random sample is N=23 interviews. Qualitative interviews cause high effort for preparation and execution. The sample size of 23 ensures an economically justifiable effort-benefit relation and is accepted for hermeneutic interpretation of the statements (Helfferich, 2009). The 23 interviewees are out of twelve different companies.

A detailed description of the interview methodology and the analysis procedure can be found in (Michalicki & Schneider, 2017). The following list shows the top three extracted requirements from the expert interviews (with reference to the number of deductions on statements of the experts):

- Value stream as a holistic profit center and calculation object
- Value-added and non-value-added cost categories
- Direct costing on the value stream level to avoid cost allocation

Value stream as a holistic profit center and calculation object

Many experts stated, that their traditional accounting approach focuses on local/single objects like product costs or cost centers. But the calculated effects of isolated cost objects are sometimes not relevant in a more holistic value stream view. The widely-used hourly rate calculation shows cost changes only, if the direct

minutes (of persons or machines) change. This fact undermines today's growing importance of overhead costs. The standard accounting tools are not able to cost the changes by the Lean transformation on indirect functions like logistics or production planning. A more holistic and process-oriented cost view for planning and controlling purposes is needed. The highly differentiated cost center structures in most companies need to be replaced by a more simple and holistic value stream view. Lean Production systems focus on improving value streams. Therefore, value streams should become the calculation objects in Lean companies.

Value-added and non-value-added cost categories

Lean focuses the reduction of waste (non-value-adding work in the customer's view). Traditional accounting does not consider this view of resource consumption. It is neither able to quantify the amount of non-value-adding work nor to locate the greatest monetary potential for Lean improvement projects. This creates two main problems:

Lean managers get challenged in determining the results and benefits of Lean. While soft facts like reduced lead times or less transportation effort can be quantified easily, the costs, especially unit-costs, stay mostly constant. Some experts stated that some traditionally calculated unit-costs even increased after some kaizen events. Justifying a Lean improvement project in front of upper management gets difficult when (calculated) costs rise.

Most experts were concerned about the profitability of their Lean efforts. Although their aim is to realize the greatest financial impact of Lean projects, the lacking knowledge about the monetary amount and location of non-value-adding activities creates problems. For this reason, Lean managers are not able to maximize the financial benefit of their limited resources (capital and money) for kaizen (optimization) projects. Planning and controlling the costs of value-added activities and waste can be a solution by the opinion of the experts.

Direct costing on the value stream level to avoid cost allocation

In the opinion of many experts, the traditional cost allocation process is just a mathematical solution for handling overhead, but it creates a lack of transparency. Overhead allocation hides waste and motivates local improvement. Traditional cost accounting was not invented for the allocation of increased overhead costs.

During the interviews, there was no clear consensus in the solution of the overhead problem. Some expressed a more detailed allocation process (like done by activity based costing) as a solution. This mind set of "improving the system by detailing every aspect and improving every detail" can be traced back to the Tayloristic management view and be declared as unsuitable for the complexity of modern production (Schneider, 2016). The other mentioned solution was to avoid allocations as much as possible. This implicates a more suitable direct costing method.

Further findings of this empirical research is described in (Michalicki & Schneider, 2017). These requirements are the basis for the development of the guiding principles of an Accounting for Lean system.

Guiding principles of Capital Flow Design

The transfer of knowledge in the form of principles is deeply rooted in the Lean philosophy (Schneider, 2016). On this occasion, a principle can be defined as a tenet, that gives direction (in contrast to a strict rule). Considering the results of the empirical research as well as a literature research and personal experience as Lean consultants ten principles of an Accounting for Lean system are identified. Table 1 lists the principles and connects them with the explained requirements and the five Lean Thinking principles according to Womack and Jones (Womack & Jones, 2013).

Table 1 – Guiding principles of Capital Flow Design

Empirical requirement or Lean Thinking principle	Guiding principle of the management accounting system for Lean	Short description



Value stream as a profit center / Identification of the value stream	Value stream orientation	A hierarchy of reference objects (e.g. company → value stream → process) ensures that all costs can be assigned, while the value stream level is a must. Periodical financial statements and one-time profitability analysis should focus on value streams.
Value-added and non-value-added cost categories / Flow of the value	Total cost focus (spending)	Unit costs /product costs lose their relevance in buyers' markets and often motivate overproduction through economies of scale thinking. It is more important to plan and control the total costs / spending of the value streams and the total company.
Specification of value from the end customer standpoint	Value adding orientation	The cash flow must be differed in value adding and non-value adding parts. This ensures the end customer orientation in the accounting system and aligns the language of production and accounting.
Value-added and non-value-added cost categories	Shop floor orientation	Actual costing must consider shop floor data about capacity usage (e.g. stoppings, defects, waiting).
-	Behavioural orientation	Behavioural orientation towards Lean thinking must be embedded in periodical and one-time calculations.
Flow of the value	Cash flow orientation	Predominating usage of spending instead of costs; production and information flow improvement is accompanied with cash flow changes.
Direct costing on the value stream level	Direct costing principle	Allocation of overhead costs hides waste and reduces the controllability of costs.
-	Cost relevance principle	Every decision needs individual monetary information. A basic monetary record of costs and capacity usage is the fundament for individual decision accounting in the Capital Flow Design system.
-	Contribution principle	Complex production systems create the need for several financial perceptions by contribution accounting
Specification of value from the end customer standpoint.	Capacity usage orientation	Cost of value added and non-value-added resource consumption can only be determined by analysing the capacity usage of all resources.

The full realisation of the principles in table 1 creates a management accounting system for Lean that we call "Capital Flow Design". Figure 3 shows the framework of the Capital Flow Design System.

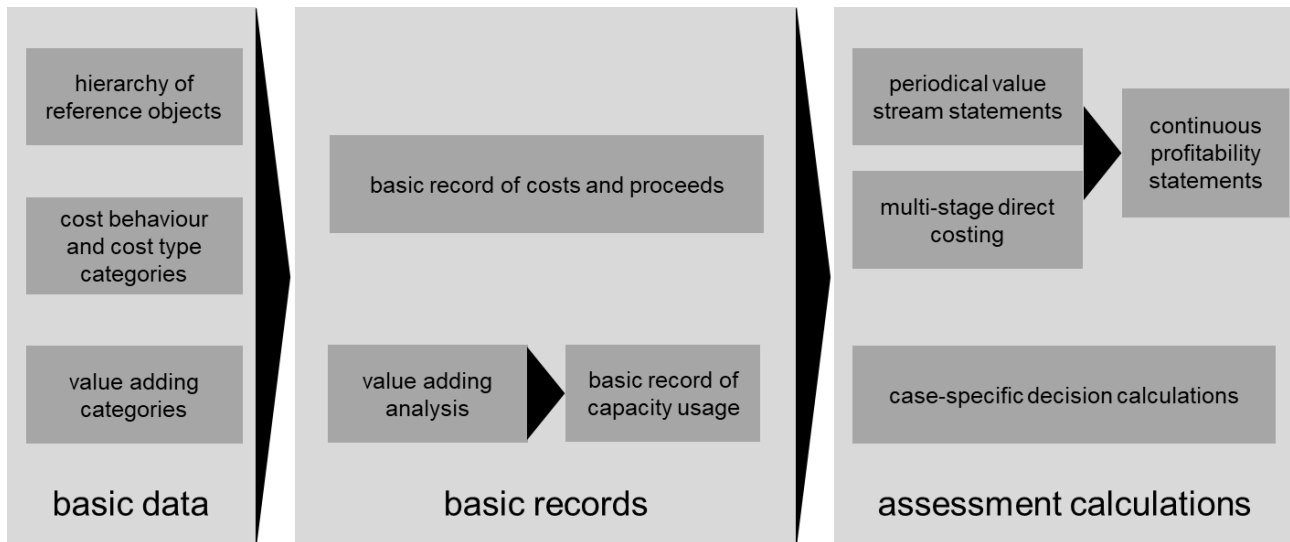


Figure 3 – Framework of Capital Flow Design

The Capital Flow Design System consists of three basic elements:

- the basic data
- two basic records and
- the assessment calculations.

Basic Data

The hierarchy of reference objects forms the basis for the realization of the direct costing principle. Their purpose is to avoid relevant cost allocations by providing hierarchically ordered and multi-level reference objects. All costs in the company are clearly assigned to a reference object, without any allocation. Typical levels are company, value stream, process, workplace.

In addition to the reference objects, the cost types significantly characterize the following basic records. A cost type is used to describe and cover the costs (spending) for a type of production factor used (personnel, material, etc.). As far as the cost types are concerned, it is important to define as clear as possible the cost behaviour categories. The central cost behaviour categories are performance costs (total variable costs) and fixed costs. The purpose of this categorization is to classify the recorded cost elements regarding the main determining factors in order to be able to assess short- and long-term decisions with relevant costs.

The last element of the basic data is the value adding categories. These serve to integrate the value understanding of the customer regarding the internal use of resources in cost accounting. Controlling and production thus create a uniform language. The following basic records of the capacities as well as all assessment calculations use the defined value-added categories.

Basic records

After defining the basic data, the period-related basic calculations can be carried out. The basic record of costs (spending) and proceeds is mentioned first. This represents a period-related and allocation-free acquisition of all costs and proceeds for the respective reference object. The reference object hierarchy, the cost types, and the cost-behaviour categories are used as input. The purpose of the basic record of costs lies above all in the provision of all information modules for the subsequent period-related income statements as well as the case-specific decision calculations. It is usually carried out in a table format with the reference objects in the columns and the cost types in the rows.

The basic record of the capacity usage is founded on the results of the value-added analysis. It is used for the period-related quantification of the total resource input in original determination variables and their pro rata attribution to the value-added categories. In addition to the value-adding analysis, capacity data (e.g. the number of available worker hours), shop floor data from different systems (e.g. actual downtimes) and standard times are used as input. In contrast to the basic record of costs and proceeds, the basic records of the capacity

usage thus represent the non-monetary view of the production system and calculates with original quantities of the production factor input.

Assessment calculations

If both basic records have been carried out, the data base exists for different assessment calculations. In the assessment calculations, a distinction is made between regular period-related income statements (standard calculation) and problem-specific decision calculations (special calculation). Both are typically performed in a multi-stage direct costing way.

The main purposes of the standard calculations are the ongoing planning, performance control as well as the behavioural control. For these income statements, a link between the basic records of cost and proceeds and the basic records of capacity usage is created.

Various decision calculations or case-specific evaluations are possible with both basic records. This includes the planning and control of investments or rationalization measures. The basic record of the capacity is primarily used to consider the origin of costs from the analysis of resource procurement and its use, while the basic record of costs provides decision-relevant cost data. Investment calculation and cost accounting are integrated here.

The Capital Flow Design system is a system of cost accounting and cost analysis for a variety of evaluation and decision purposes that meets the requirements of Lean production systems.

Summary and perspectives

Traditional management accounting systems are a typical barrier to a sustainable Lean transformation. Despite some singular developments on the field of Accounting for Lean a holistic approach is still missing. The Capital Flow Design system was developed as a management accounting system, that actively supports the Lean strategy. It is built upon ten guiding principles that emerged from empirical research with Lean practitioners. The Capital Flow Design system was successfully tested in a pilot value stream of a German electronics manufacturing company. The first practical use initiated a considerable paradigm shift towards Lean in the company. Further research will examine the overall transition of the traditional cost accounting system to the new system.

To further disseminate the system, it is important to point out the dangers of traditional accounting already in the (university) education and to show Capital Flow Design as an alternative for Lean companies. Therefore, Capital Flow Design is used to expand traditional Lean simulation games by an accounting module. It is necessary to show managers and accountants in Lean companies the conflicts between traditional accounting and the Lean philosophy as well as the alternative “Capital Flow Design”. The basic concept of an Accounting for Lean simulation game is described in (Michalicki, 2016b).

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2.3 Lean Training

A proposal for developing competencies through lean culture for maintenance teams

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Abstract

The purpose of the paper is to analyze the implementation of training sessions for maintenance personnel of the industrial hub of Manaus in Brazil and to propose a competency mapping process with the concept of lean culture. The data analyzed were obtained through a questionnaire sent to the companies of the industrial hub and the information received was explored to identify the behavior of the human resources management in the companies. The results of the study showed that the investment for competence development of maintenance teams is low and is related to characteristics such as business segment and use of Total Productive Maintenance (TPM). Furthermore, another finding is that local and international companies have different approaches to training their teams, especially in training of equipment, production process and mode of operation. This work emphasizes that the action plan of training programs for the maintenance team should be aligned with the strategies of the organization to show positive results and an effective way to get this is to connect the training sessions with each pillar of lean culture.

Keywords: lean culture, lean maintenance, maintenance management, training plan.

Introduction

In recent times, the maintenance area is gaining greater prominence in what concerns its influence on productivity and the strategic basis of an industry. According to standard EN13306 (2018), maintenance is the joining of all technical, administrative and managerial actions during the life cycle of an item to preserve and restore it so that it remains in the state in which it perform the function for which it was designed. According to this standard, all activities that manage maintenance objectives, strategies and responsibilities are part of what is called maintenance management.

Maintenance management encompasses both specific maintenance working with the assets themselves and approaches to ensure the appropriate work programs, technologies, and procedures that are in place to obtain reliable maintenance. In other words, a reliable maintenance is related to the number of activities, such as inventory, purchasing, Computerized Maintenance Management System (CMMS), operational involvement, Total Productive Maintenance (TPM), technical and interpersonal training, statistical financial optimization and reliability maintenance (Kefalidou, Golightly, & Sharples, 2018). Therefore, according to the authors, without adequate maintenance, the services act with high risk of failure and can generate indirect effects for

user satisfaction and direct to the work of the maintenance team. With the evolution of production management strategies, some cultures and methodologies have emerged that help in the process of improving the results of a company and that can be implemented in the maintenance sector, one of them is lean culture. In this work some of the principles of this culture will be correlated with the training base of the people who work directly with the sector placed in focus. According to Stone (2012), human resource development can be defined as a process for developing and releasing human expertise through organizational development, training and staff development for the purpose of better performance and consists of an area with little research when establishing a literature perspective on lean strategies.

The objective of this work is to evaluate the qualification system (training) of the teams that work in the area of maintenance of companies based in the studied industrial center and, from that, to propose a process of competence development for teams through lean culture. Based on the results obtained, some hypotheses were tested to see if the training of the maintenance team was connected with some characteristics such as use of Computerized Maintenance Management System (CMMS), adoption of Total Productive Maintenance (TPM) and origin of the company, among others.

Therefore, this study seeks to answer the following research question:

- How lean culture can influence skills development for maintenance teams?

This article is organized as follows. The second section is a literature review of lean principles and their influence on maintenance. The third section demonstrates aspects of data collection and analysis and hypothesis testing. The fourth section demonstrates the process of the competency development proposal. Finally, the fifth section concludes on all the aspects mentioned throughout the paper.

Literature Review

Lean Culture

Since the 1950s, Toyota's lean production or production system has had its principles evolved and implemented by Toyota company. The lean production system had two pillars, initially Just In Time (JIT) and Autonomation (intelligent automation) as shown in figure 1 (Aziz & Hafez, 2013).

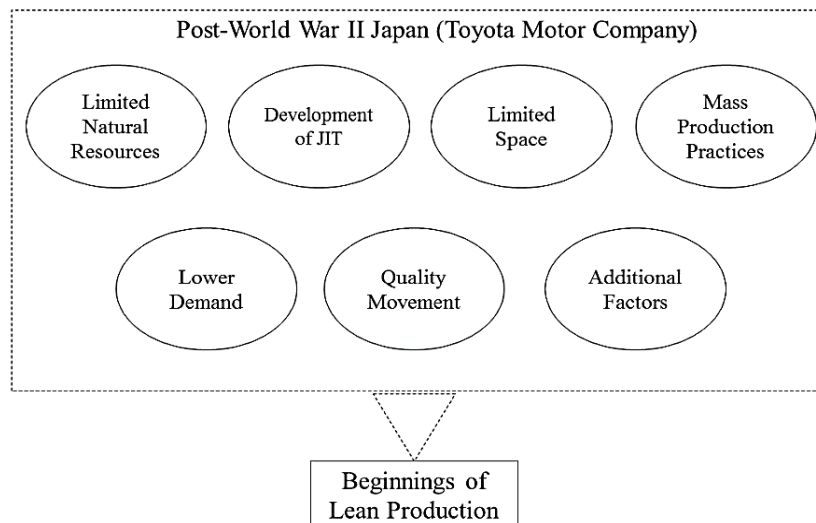


Figure 4 - The beginning of lean manufacturing (Aziz & Hafez, 2013)

The term "Lean Production" was created by Krafcik in 1986 and became known with the authors Womack, Jones and Roos in the book "The machine that changes the world" in 1990. Few researchers claim that Lean Production is not just tools and techniques with the philosophical and management support, but a specific type of organizational culture that can be described through specific characteristics (Peczely & Obermayer, 2017).

According to Caldera *et al.* (2017), the lean way of thinking is a business approach that offers better value to clients by removing activities that do not demonstrate added value. The authors further note that in addition to



what we call lean culture, the lean movement itself has several derivations that do not extend only to production but also to lean construction and lean thinking for example. According to them, in the last two decades, lean manufacturing processes have evolved with the implementation of mechanisms for material flow, visualizing waste reduction and value flow mapping tools, correlating with synergistic results in operational and environmental performance.

According to Van der Merwel *et al.* (2014), the leaders of organizations that have difficulty implementing the lean approach are those who can not understand it as a management philosophy. Many authors argue that organizational culture is one of the most difficult organizational aspects to change, that lean culture is vital to the success of any lean implementation plan, and that future research is needed to create and maintain culture. The authors further note that it is believed that it is virtually impossible for organizations that use traditional manufacturing methodologies to compete successfully with lean organizations and also argue that although factories have introduced lean techniques relatively easily, they still find it difficult to achieve the organizational culture and mindset that provides lean core. Finally, research on the low rates of lean implementations of success confirms that failure to use the techniques was not a contributing factor, but did not change the organizational culture, however, it was the primary cause of failure to implement lean (van der Merwel *et al.*, 2014).

Lean Maintenance

Lean maintenance is conceptualized as a proactive maintenance operation that employs planned and scheduled maintenance activities through Total Productive Maintenance (TPM) practices using maintenance strategies developed through the application of reliability centered maintenance (RCM) and practiced by teams highly trained (Mostafa, Dumrak, & Soltan, 2015). In addition, it generates a desirable result, which can reduce unexpected and downtime by optimizing maintenance support activities and maintenance overload (Mostafa *et al.*, 2015). According to the authors, in order to effectively achieve an improvement with lean maintenance, it is necessary to use the main lean tools. The use of comprehensive lean tools develops maintenance activities within an organization including 5S, TPM, general equipment effectiveness (OEE), Kaizen, Poka-Yoke, process activity mapping, Kanban, computer-system-managed (CMMS), Enterprise Asset Management system (EAM) and Takt Time. As a first step in integrating lean culture into the maintenance process, Mostafa *et al.* (2015) proposed a roadmap for lean maintenance, as shown in figure 2.

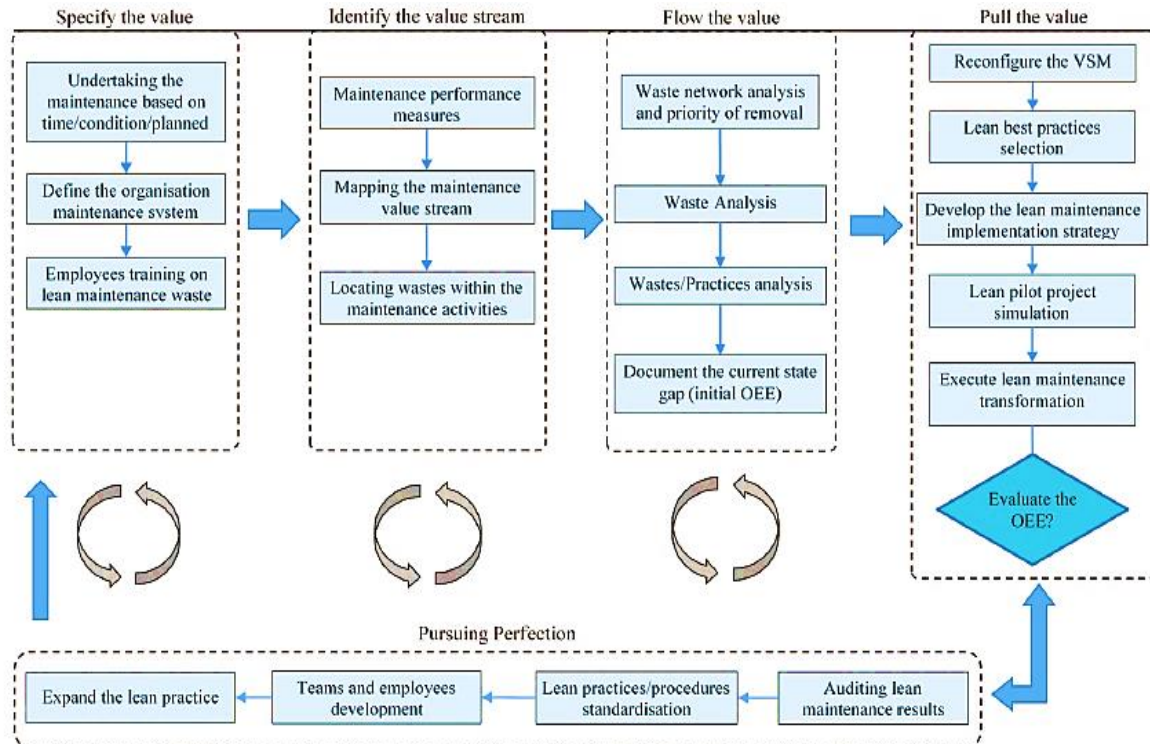


Figure 5 - Lean maintenance roadmap (Mostafa et al., 2015)

Ayadi *et al.* (2014) states that new maintenance strategies that serve the industry have their importance in maintaining the process and impact on the performance of production facilities, so we have developed optimization methods that allow maintenance managers to construct or modify maintenance strategies and the requirements imposed by production. To this end, the maintenance of industrial systems becomes a strategic function in the management of the company, as already reported in this work.

Maintenance Teams Competencies

According to the work developed by the Management, N. I. A. M (National Immovable Asset Maintenance Management) of the Department of Public Works in South Africa (2017), the word *competence* can be described as a combination of skills, knowledge, and related attributes to produce a job or task following a defined pattern. It is also noticeable the increase of the application of competences to obtain results relevant to the business strategies and the vision of the organization. Employees learn and develop many competencies throughout their careers and by developing the skills of employees, the organization will empower them and direct them to a personal development of self-evaluation and continuous improvement. On the maintenance side, Oliveira (2012) reports that maintenance costs are linked to the practices adopted, and in an organization where maintenance is done reactively, costs are higher. And in a paradoxical way, it is argued that not always the minimum cost is the best value, factors such as strategic vision and planning must be considered adequate for the functions related to the training of the team and operational resources.

Finally, in the work developed by Oliveira *et al.* (2014), it was concluded that the average in relation to equipment training is high. In contrast, training in the production process and mode of operation, methodologies, techniques and maintenance tools has a lower frequency. Moreover, it shows that the investment in competencies does not appear as a priority to the organizations, directly affecting the operations that they execute.

Data collection and analysis

This article presents the results of a research applied by Oliveira *et al.* (2014), in the scope of investigating maintenance management practices. The sample size used was 72 out of 430 companies inside the industrial pole, resulting in a response rate of 16.74%. In this context, we intend to explore the results obtained related

to knowledge management in the maintenance area of organizations. In the qualification of the maintenance teams, the survey pointed out that 58.33% of the companies recognize having a formal training plan for the maintenance team. However, it is not guaranteed that it will be held due to many reasons, such as budget constraints, unavailability of the team, among others. The adoption of practices that allow the development of skills of maintenance teams assumes the premise that the results of this area will be improved.

In order to evaluate the effectiveness of the training performed by the companies in the maintenance teams, the research sought to investigate, firstly, the existence of a formal competence development plans to evaluate some relevant points that are associated to the application of methodologies to support maintenance management. Moreover, it intends to evaluate the use of performance indicators, application of fault analysis techniques with the purpose of improving the activities established in the maintenance plans and development of personal skills.

Table 1 consolidates the results of a five-level Likert scale in relation to the frequency of performing some types of training that the company can offer to its maintenance teams. Although organizations claim they have a formal training plan for maintenance teams, only 60% do, in fact, do, but do not give their implementation guarantees effectively. In addition, it presents the averages obtained for each type of formation where, in general, an index below 4 is identified.

Table 1 – Training sessions for the maintenance teams

Activity	Average
Maintenance technicians receive training in the production process and method of operation	3,54
Maintenance technicians receive training on equipment	3,46
Technicians receive training in methodologies, techniques and tools to help maintenance management	2,87

According to the responses of the respective companies' maintenance areas, the survey identifies that 56.94% of these offered training / training sessions for 40% or less of maintenance personnel, while only 15.28% of companies offered training to about 81-100% of their team, setting a low investment in the development of competence of the company's maintenance teams.

Relationship between training plan for maintenance team and adoption of TPM

The Total Productive Maintenance (TPM) methodology is widely recognized for combining technical actions with those aimed at training the maintenance and production teams. In this sense, the hypothesis that ***'adoption of TPM is related to the existence of a training plan for the development of competencies of the maintenance team'*** was formulated, in order to identify dependency relation between the existence of training plans and the adoption of this methodology. According to the data obtained, the results show $\chi^2(1) = 8,316$ and $p\text{-value} = 0,007$, and it is concluded that the adoption of TPM *is related to the adoption of a training plan for the development of competencies of the maintenance team*.

Mean of training frequency responses performed by the maintenance area and adoption of TPM

In order to identify the mean of responses to the different training modalities and adoption of TPM, as well as their dependence relation, some premises were elaborated: ***'training in productive process and mode of operation'***, the means of not adopting MPT and of TPM are 3.03 and 3.74, respectively with p-value of 0.013; ***'training in equipment'***: the means of not adopting PMS and adopting PMS are 3.24 and 3.74, respectively followed by p-value of 0.070; ***'training in maintenance management methodologies, techniques and tools'***: the means of not adopting TPM and adopting PMS are 2.18 and 3.33, respectively, with a p-value of 0.000. With respect to the frequency of *'training in production process and mode of operation'*, as well as in relation to *'training in maintenance management methodologies, techniques and tools'*, the average responses of the training frequency in these activities by the companies that adopt and do not adopt the TPM are different and we can assume that the adoption of the TPM is a factor that drives the formation of training for the maintenance

teams. On the other hand, with respect to the frequency of '*training in equipment*' the average of the responses of the training frequency in these activities by the companies are the same and the adoption of the TPM is not a relevant factor for this type of training to be performed with the teams of maintenance..

Origin of companies and skills development plan for maintenance teams

The Chi-square test was applied to evaluate the companies' response through the adoption of a training plan for the maintenance team, in order to identify the relationship between the '*competence development strategy*' and the origin of the company. The results are $\chi^2(1) = 8.625$ and $p\text{-value} = 0.044$, and it is concluded that the adoption of the training plan for the maintenance teams depends on the origin of the company. Regarding the results of the survey, 58.33% of the companies confirm that there is a training plan that allows the professional development of maintenance technicians, while 41.67% affirm that there is no formal plan. Evaluating companies that have a formal development plan, 71.43% are of international origin and 28.57% are of national origin.

Segment of the company and the adoption of a competence development plan for the maintenance teams

Based on the assumption that the segment to which the companies belong influences the adoption of a competence development plan for the maintenance teams, the companies in the personal care (100.00%), automotive (83.33%) and (60.00%) stand out. In the broader context, there is no distinction between companies when we refer to the training strategy of the teams, although companies in the plastic injection (50.00%), electro-electronic (48.15%) and metal / metal-mechanical (41, 67%) have a lower index.

Difficulties faced in the training of maintenance teams

Based on the assumption that the difficulties faced by the maintenance area are common among companies, the research results show that: '*the lack of training of the technical team*' is indicated by 34.72% of the companies; the '*low competence of the technical team*' is pointed out by 23.61% of the companies; the '*low motivation of the technical team*' is pointed out by 13.89% of the companies and the '*low level of education of the technical team*' is pointed out by 11.11% of the companies. Regarding the industrial segment to which the companies belong, the result of the research identifies that the companies of the electronics sector stand out, when compared with the other sectors, with respect to the difficulties encountered by the maintenance area within the scope of competence management.

Level of schooling of the maintenance team

Based on the assumption that the level of schooling of company maintenance teams is adequate or meets the needs of the maintenance area, we can see that, according to the results obtained in the survey, 64.79% of companies affirm that up to 20% of the maintenance team members have higher education, setting at a low rate schooling of team members.

Average responses and training frequency in the area

The Mann-Whitney independence test was applied to evaluate the mean responses of national and international companies using a Likert scale used to evaluate the training frequency performed by the company's maintenance areas. Regarding the premise that '*Maintenance technicians receive training in the production process and mode of operation*' the average obtained was 3.06 (national) and 3.76 (international). Regarding the premise '*Maintenance technicians receive training in equipment*', the average obtained was 3.23 (national) and 3.78 (international). Finally, for the premise '*The technicians receive training in methodologies, techniques and tools to help maintenance management*', the means obtained were 2.63 (national) and 3.05 (international), respectively. As a result we have, in the general context, companies of international origin dedicate more training to their teams when compared to companies of national origin.

Training provided to members of maintenance teams

Based on the assumption regarding the training given to the members of the maintenance teams of the company, it is verified that the companies of international origin impel this practice with more intensity. In the

general context, companies of international origin train their respective teams in greater numbers when compared with companies of national origin. Based on the assumption that the segment to which the companies belong boosts the training offered to the maintenance teams, we can perceive that, according to the results obtained in the survey, 29.17% of the companies affirm that members of the maintenance teams received some type last year.

Proposed competency development process

The competency development process proposed in this work consists of a mapping aimed at identifying the competence level of the team and their technical, personal and operational skills.

Through the use of a scale (1 to 4), members are classified according to the level of knowledge and understanding related to the operation and maintenance of equipment, process knowledge and teamwork skills. An example of the model of this analysis is illustrated in figure 3.

VERSATILITY CHART (MANAGER)						
☐ NORMAL OPERATIONS		☐ CRITICAL OPERATIONS		☐ SIGNIFICANT OPERATIONS		→
[1]	DO NOT HAVE ANY SKILL	1	2	3	4	5
[2]	LOW SKILL AND NEED SUPPORT TO ATTEND	P	P	P	P	P
[3]	GOOD KNOWLEDGE AND SKILL, PREPARED TO ACT BY ITSELF	e	e	e	e	e
[4]	EXCELLENT KNOWLEDGEMENT, INSTRUCTOR	r	r	r	r	r
[NR]	NA	s	s	s	s	s
		o	o	o	o	o
		n	n	n	n	n
		A	B	C	D	E
EQUIPMENT/PROCESS		EVALUATE BY				
X		3	3	3	3	3
Y		3	3	2	2	3
Z		3	3	2	2	3
J		2	3	2	2	3
K		2	3	2	2	3
L		1	4	1	1	2

Figure 6 - Versatility Chart proposed

Based on this, it is possible to list the gaps of knowledge and skills of the team, as shown in figure 4, identifying which deficits and which person stands out in each skill. At the end of this analysis and individual assessment, the manager has the necessary information to develop and justify a corporate training plan, since it identifies the really necessary and adequate trainings for the team, besides giving support in the development of a departmental and personalized training plan.

In addition, the investment is planned and avoids waste with training that does not add value to the team.

Instructions:
Evaluate each person in your group. Use "Person 1, Person 2, etc to enter "current" skill levels.
Enter items in Yellow fields only. Use the 1 to 5 scale for current skill level to indicate each person's current level.
Each person will have an average score below name. Rolled up average of your group will be in average of all persons.

	Average of all persons			Person 1		Person 2	
	Average	Average	Gap	Average	Gap	Average	Gap
	3,17	2,43	-0,74	1,50	-1,67	3,06	-0,11
Final Assembly/Packing Engineering Skills	Target	Current	Gap	Current	Gap	Current	Gap
General	1 to 5	1 to 5		1 to 5		1 to 5	
Understands & can perform process of switching between products	3	2,44	-0,5555556	1	-2	3	0
Perform pFMEA for functional area	2	2,00	0	1	-1	3	1
Understand & follow control plan	3	2,44	-0,5555556	1	-2	3	0
Depaneling							
Calibrate machine	3	2,33	-0,6666667	1	-2	3	0
Operate machine	3	2,78	-0,2222222	2	-1	4	1
Install Product specific tools	4	2,67	-1,3333333	1	-3	4	0
Develop SW and/or operating parameters	2	2,00	0	1	-1	4	2
Screwdriving							
Calibrate machine(s)	3	2,67	-0,3333333	2	-1	3	0
Operate machines	3	2,67	-0,3333333	2	-1	3	0
Run CpK study	2	1,33	-0,6666667	1	-1	2	0
Install Product specific tools	4	2,56	-1,4444444	1	-3	3	-1

Figure 7 - Relation of gaps knowledge

Antosz (2018) develops a work that has an approach focused on the level of knowledge of the employee of the maintenance area. However, to proceed with this evaluation will require a lot of time and more complex analyzes about the gaps of competences.

Conclusion

We can realize that when all factors related to lean methodology are used correctly it can provide great improvements. This work presented the influence of this methodological aspect when used in the scope of maintenance, mainly in what concerns the formation of human resources and development of competences. It is observed a relationship of dependence of the training plan of the maintenance team in the following analyzed aspects: the adoption of TPM, this one that is related to the types of formation of training in productive process and mode of operation and training in methodologies, techniques and tools to aid maintenance management'; the origin of the company, noting that international companies are more concerned about the qualification of the maintenance team; segment of the company, even if it is not widely significant.

One of the main facts observed were the main difficulties faced by the companies, the lack of training of the technical team; the low competence of the technical team; the low motivation of the technical team and the low level of education of the technical team. These are features that can be circumvented using lean culture tools as strategy. The proposal specified in this study essentially addresses the fact of planning competency development for and maintenance team assertively, according to the need for training and lack of intellectual capital for increased organizational productivity. This eliminates the possibility of wasteful training and training on topics that address issues that are not aligned with the need and goals of the organization.

Adopting lean tools alone does not guarantee the full success of a training, competency and training plan for the maintenance team if it is not linked to the organization's strategic planning. In addition, although lean tools prove their effectiveness, it is necessary to foster and maintain, within the organizational culture, what are called lean results culture.

Finally, in order to incorporate the lean culture in the maintenance area of an organization, it was sought to make a detailed survey of the greatest difficulties and dependencies that the development of competences of the teams of this area face and, thus, to contribute with a new form of mapping the human resources training planning with the premises that lean culture determines, that is, the elimination of waste, process optimization and continuous improvement.

The recognition of the necessary competencies, as well as the gaps that the team members have, are aid mechanisms for the mapping of training needs, planning and execution of the development of skills developed in the organizational scope.

In this way, it is highlighted that this culture, when implemented and worked in the correct way, is necessary for the way in which it can bring innumerable impacts within the organization, ranging from aspects in the scope of teamwork to financial factors, generating reduction costs and improvement in the performance of the respective maintenance teams and the organization.

Acknowledgments

The authors wish to thank the project partner Amazonas State Foundation for Research Support (FAPEAM - Fundação de Apoio à Pesquisa do Estado do Amazonas) for facilitating this work.

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Train the Trainer – what does it really mean?

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Abstract

An essential part of Lean is training. Many organizations find it simple to outsource the whole training to external trainers who are experts. It is a quick, easy and reliable way but skills often do not remain within the organization and off-the shelf training is often not adapted to the organizational setting.

Another way is to use the concept of “Train the Trainer”. Their internal competence is developed by training internal trainers that then do the training. Unfortunately, there are pitfalls also here and even though internal competence is developed, quality can be harder to secure and thus it does not always support lean implementations in the way we want.

One interesting organization that has practiced and developed their way of “Train the Trainer” is BillerudKorsnäs, a global paper and packaging provider. Instead of simply outsourcing the lean training to external experts they have trained and developed their own trainers. How did they think? What did they do? On-the-job training of trainers, carefully observed by experts and individually coached is one of the main success factors.

Frida Egerlid, head of Business Process & Operational Excellence will share her thoughts and experiences with you. She will go through not only how the training was built, but also the struggling on an individual level, what is required to succeed, how the individuals developed and last but not least the results.

Pia Anhede, who is the other presenter has been working as a management consultant with lean transformation in over 25 years and in over 15 counties. Pia will set the scene by describing the structure of the trainings and the role of coaching. Pia was the external trainer/coach during the process.

Keywords: Train the trainers; learning while doing; struggling while learning and training; line personnel as facilitators

Different approaches to teach LEAN

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Abstract

Training students of engineering, production managers, supervisors and workers in the concepts, tools and skills set of LEAN is a diverse and demanding task.

The different challenges presented to the trainers, the prerequisite to assess the current level of knowledge of the majority of the students and the need to use different approaches given the multiple target learners, alongside with the pedagogical tools used to achieve the objectives of the formation and the desired learning outcomes will be described.

A resumed survey of the existing principal approaches to teach LEAN will be presented. A preliminary discrimination on what are the common methods to all “targets” and what are the specific approaches that must be “tailored” to singular types of learners will be listed.

The level of “know-how” and “know-why” for the major concepts and tools of LEAN to be applied to each major “target” of learners will be debated, depending of the “tool box” and work experience of the trainees. Success examples will be presented as “case studies”, alongside with failures on training programs that fell short of expectations.

Particular coverage will be given to the empirical evidences of the results of LEAN implementations by final year graduation projects of Engineering students in industrial and services companies that may be a real world “proving ground” for the dissemination of the approach to improve the efficacy of the operations in the “hosting” companies.

New opportunities for transmitting knowledge to learners using simulators and content freely available on the internet are discussed.

Keywords: LEAN; TPS; Teaching; Learning; Training



2.4 Lean at Universities

The future of continuous improvement

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Abstract

How fast is the world changing in the current times of digitalization, automation, aging of society, sustainability and internalization? How will this affect continuous improvement? How should we prepare students for this?

Some of these changes do not occur as fast as others. Especially the aging of society can become a serious problem if labor productivity does not improve faster. Continuous improvement, like Lean Six Sigma, can support speeding up the improvements in labor productivity. Research shows there is a need for bachelor students to learn about continuous improvement. More than ever do they have to learn about leadership and culture, because these elements are said to be increasingly important in today's continuous improvement. It is crucial they don't only learn about the improvement tools, but also about realizing improvement, which means being able to do a thorough analysis in combination with the implementation of the solutions found. Aside from this, it is important to pay attention to standardization, because this remains difficult for companies. Instead, they fall back in their previous patterns, and fail to realize improvements in labor productivity. Furthermore, students must learn to become better at analyzing data, for instance, by using process mining or other tools to analyze big data.

Keywords:

Labor productivity, continuous improvement, DMAIC, process mining

Introduction

Productivity growth in the developed countries decelerated in recent years (CPB, 2017), while demographic developments, like aging of society, require a more efficient use of the available workforce (Wierenga, 2012). After explaining this contradiction, the following questions will be answered in this paper. Can continuous improvement on a micro level help increase labor productivity on a macro level? What are the major themes of continuous improvement in the future and how can they support increasing labor productivity? What new subjects do people in the future, like current students, have to learn and will it be possible to apply those subjects? These questions are answered using several methods: literature study, logical reasoning, questionnaires and a case study.

Preliminaries

To be able to understand this paper, the following definitions and terms are being used.

Labor productivity: the amount of added value per working hour. The added value is the sum of all goods and services produced minus the worth of all the spent products and services (CBS, 2018).

Continuous improvement aims to produce and deliver products to customers, according to their requirements and with less defects, less human effort, less space, less equipment, less materials and less time required (Lean Enterprise Instituut, 2009). Therefore, non-value-adding activities and variation are eliminated from business processes. There are many variants of continuous improvement such as Lean Six Sigma.

Kaizen: deviating from common use of the word kaizen in literature (Imai & Geertvliet, 2001), kaizen is defined as improving in a structured way, using methods like DMAIC, which is short for Define, Measure, Analyze, Improve and Control. It is an improvement cycle to solve problems in a scientifically-based way, starting with an analysis of the problem and its probable causes, followed by the implementation, evaluation and standardization of improvements.

Process mining: *“a fast growing discipline that is focused on the analysis of events logged during the execution of a business process. Events contain information on what is done, by whom, for whom, where, when, etc.”* (Tax, Lu, Sidorova, & Aalst, 2018).

Standardization: the process of coming to mutual and uniform agreements about the input, transformation or output of a process in order to realize a stable outcome of the process (Hoof & Kollenburg, 2018).

A changing world

The demands of stakeholders are becoming more and more complex and the environment of organizations is changing faster and faster, resulting in a situation where the only constant factor is change (Cozijnsen & Vrakking, 2003). This change comes in various forms, like digitalization, internationalization, 24/7 society, sustainability, technologies like additive manufacturing, aging of society, and scarcity of personnel (Kollenburg, 2014). Organizations also have to deal with increasing demands regarding quality, corporate responsibility and ethics. So, are organizations capable to adapt at the required pace?

Gordon (2016, p. 2) states: *“Our best measure of the pace of innovation and technical progress is total factor productivity (hereafter TFP), a measure of how quickly output is growing relative to the growth of labor and capital inputs”*. Figure 1 shows the development of the three components for annual growth: education, capital deepening and TFP. *“Because the contributions of education and capital deepening were roughly the same in each of the three intervals, all the faster growth of labor productivity in the middle period is the result of more rapid innovation and technological change”* (Gordon, 2016, p. 16).

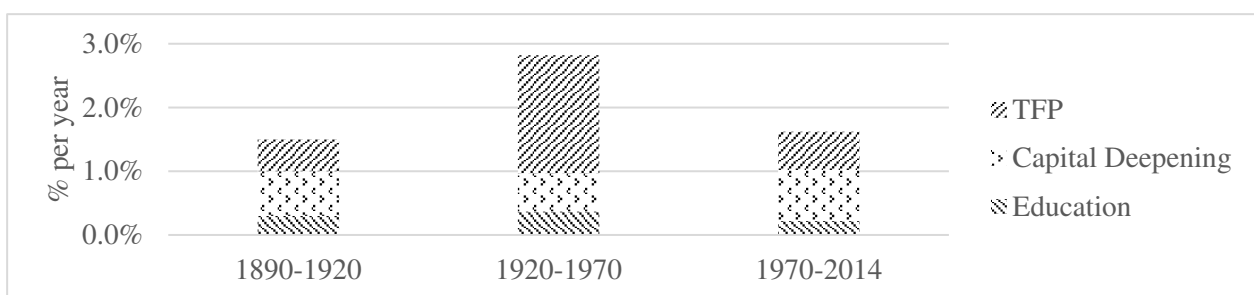


Figure 1 – Average annual growth rates of output per Hour and its components, selected intervals, 1890 – 2014 (Gordon, 2016)

The concern about the rate of change in the world also came forward in a study among 42 small & medium enterprises (SME's) in the south of the Netherlands (Kollenburg & Schreuder - Roijmans, 2018). On one side, companies reported expecting changes in many themes over the next five years, e.g. digitalization, marketing instruments, customer demands and required competences. On the other side, they said their current four most relevant customer demands will stay the same within the next five years: good service, high reliability, high quality and high flexibility.

It seems uncertain whether times are changing rapidly, and the underlying question is whether labor productivity is increasing rapidly enough. Regarding demographic developments, like aging of society, a more efficient use of the available workforce is required (Wierenga, 2012), which means labor productivity must increase. Assuming an average annual economic growth of 2%, an annual increase of labor productivity by 4% until 2035 is required, because of the aging of society, to maintain the same level of welfare in the Netherlands until 2035 (Sol, 2017). Looking at labor productivity in the Netherlands, however, a growth of 1,3 percent per year can be observed between 1996 and 2015 (Blom, 2017), which is similar to the numbers of Gordon (2016). This limitation of growth is stronger, considering the most important growth in the period 1970 – 2014 took place between 1994 and 2004, due to ‘ICT producing’ and ‘ICT using manufacturing’ (CPB, 2017). Growth of labor productivity in the Netherlands in the last five years is about 1% on average (CPB, 2017). This is far below the required 4% to deal with the aging of society.

Increasing productivity with continuous improvement

Several causes of labor productivity slowdown are being mentioned: a lack of breakthrough technology, low customer demand, no longer valid measurements of labor productivity, increased rules regarding e.g. safety and environment, a lack of capital investment, less education, capital misallocation and older people being slower in labor productivity improvement. Research, however, doesn’t show a satisfactory explanation for this. (Blom, 2017) (CPB, 2017). The proposed countermeasure is innovation and especially digitalization and automation, also referred to as Smart applications (Lagarde, 2018) (Aegon, 2016) (ABN Amro, 2018) (ADP, 2018) (Sol, 2017). The results and proposed countermeasure are based on macroeconomic surveys, but as Drummond (2011) concluded after several years of research of Canada's failing productivity growth: *"The productivity research effort must shift. It must go more micro than macro."* One (micro-) way of trying to increase productivity is with the use of continuous improvement. Research shows the social relevance of continuous improvement is a.o. improving the efficiencies of organizations, thus creating more output against less cost (Kleeff, 2012) (Brouwer, 2014) (Dijk, 2015).

Because continuous improvement is aiming for elimination of non-value-adding activities, waste or losses (Locher, 2011) (King, 2009) (Shirose, 2007), it can be reasoned that producing a product correctly on the first attempt, so without e.g. rework and waiting, is more productive than not making it right the first time.

Labor productivity on macro level is calculated by dividing all the goods and services sold minus the exported ones by the total working time. Simply put, the same way of thinking is used on micro level, where the total added value of a company is divided by the spent working time to determine labor productivity. Therefore, it is logical to say improvements in labor productivity at micro level will lead to improvements on macro level.

Future themes of continuous improvement

Although continuous improvement started centuries ago when Venice started building galley ships in a continuous process (Leaninfo, 2018), especially Japanese companies like Toyota benefitted after World War 2 from the rise of continuous improvement, when they achieved much better results in productivity in Japan compared to the Western world (Womack, Jones, & Roos, 1990). This made Western companies like Scania, SaraLee, St Antonius Hospital, ABN AMRO, Heineken and Philips start using continuous improvement and achieve major results like increased productivity, quality and turnover and also higher skill levels of employees and less absenteeism (Brah & Chong, 2004) (Emiliani, 2007); (Doraa, Kumarb, Goubergen, Molnara, & Gellynck, 2013) (Ede, 2018). Continuous improvement is also finding its way in other areas like healthcare, services, construction and SME’s (Wierenga, 2012) (Kleeff, 2012) (Brouwer, 2014) (Dijk, 2015).

But on what themes should continuous improvement help companies in the future and how can these themes help increase labor productivity? In a questionnaire distributed by Avans University of Applied Science eighty continuous improvement experts were asked in 2016: “According to you, which existing themes on continuous improvement will still be relevant in five years?” and “According to you, which new themes on continuous improvement, are important in five years?”. The answers were categorized, so ‘kaizen’ also contains ‘DMAIC’ and ‘improvement projects’, and the themes that were mentioned mostly, were selected. The responses that were mentioned most often, are summarized in table 1.

Table 1 – Relevant themes on continuous improvement in five years (source: own research, 2016)

Question	n	Top 3 responses
According to you, which existing themes on continuous improvement will still be relevant in five years?	50	1. Kaizen (15x) 2. Leadership and culture (13x) 3. Standardization (6x)
According to you, which new themes on continuous improvement, are important in five years?	47	1. Digitalization and data analysis (11x) 2. Leadership and culture (8x) 3. Standardization (5x)

Table 1 shows there are four important themes in five years: ‘kaizen’, ‘standardization’ and ‘leadership and culture’ stay relevant while ‘digitalization and data analysis’ becomes an important theme on continuous improvement.

The importance of kaizen

The importance of the first theme is logical, because ‘kaizen’ is the very core of continuous improvement. This was confirmed in a survey among 48 Lean Six Sigma experts (Kollenburg, 2018), where the percentage of improvement projects or kaizen was questioned, in which all of the improvement steps, like Define, Measure, Analyze, Improve and Control, were taken. The results are shown in figure 2. Assuming the 63%-group had on average $1/6^{\text{th}}$ (median between 0 and $1/3^{\text{rd}}$) of the projects with a complete improvement cycle, while the 21%-group used a complete cycle on average in 50% of the cases, the group of 11% in $2/3^{\text{rd}}$ and the 5%-group in 100% of the projects, calculation shows that on average in $1/3^{\text{rd}}$ of the projects the cycle was fully used. The other $2/3^{\text{rd}}$ of the projects missed relevant steps, which likely resulted in improvements that were not implemented or not being sustained. This means no effective improvements were made in the long run. Therefore, kaizen is a theme that requires a better execution if it has to contribute to increasing labor productivity.

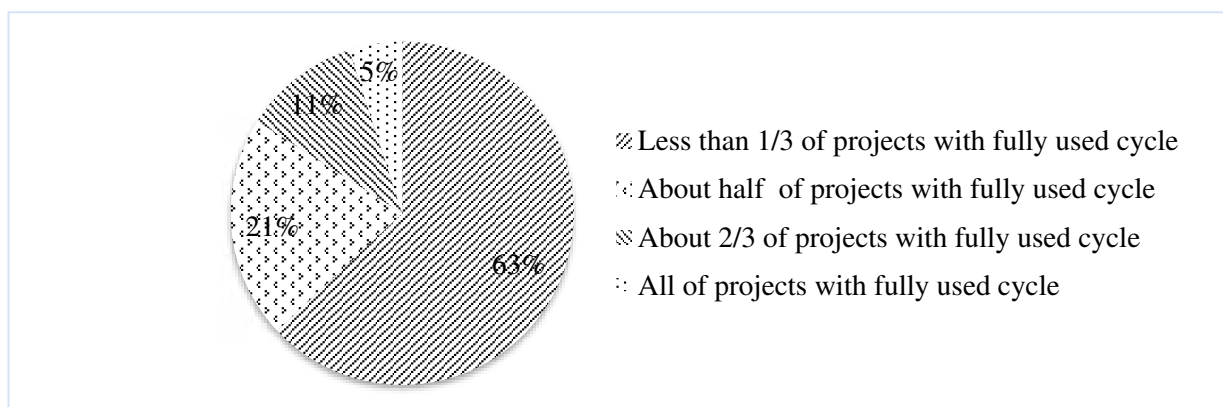


Figure 2 – The percentage of improvement projects with a complete DMAIC (Kollenburg, 2018).

The importance of standardization

The second theme, standardization, is directly linked to kaizen, because improvement without standardization leads to non-sustainable results. This is consistent with the findings of Dombrowski and Mielke (2014) who argued “*that many lean implementations fall short of expectations in the long term. Enterprises achieve significant results in the first years of lean by implementing kanban, 5S, SMED, FIFO and many more but improvements stagnate sooner or later.*” (Dombrowski & Mielke, 2014, p. 565).

The importance of leadership and culture

Dombrowsky and Mielke (2014) found a different type of continuous improvement process in the few enterprises with a successful and sustainable lean implementation. This continuous improvement process is

linked to a different leadership approach, which supports the relevance of ‘leadership and culture’ as a theme.

The importance of digitalization and data analysis

‘Digitalization and data analysis’ becomes a relevant theme in continuous improvement, in the first place, because of the increase of digitalization and the importance of data in everyday life. Secondly, data analysis is used more often, e.g. the growth of the use of software to improve processes (Gartner, 2018).

Creating the right competencies

Universities can support companies with their continuous improvement efforts by teaching student’s continuous improvement skills. Looking at the themes of the future, they could be educated and trained in:

- Completing the full improvement cycle, including implementation (and the required social and leadership skills) and standardization;
- Application of data analysis, with regard to continuous improvement.

These are discussed below.

Fully going through the improvement cycle

At Avans University of Applied Science the current way of going through the improvement cycle by bachelor students was studied, using 25 theses of students, to see what would have to be improved in the current situation to go through the improvement cycle fully. Four of the most important items students have to learn when using the DMAIC-cycle are (Kollenburg, 2018):

1. Complete the full DMAIC-cycle;
2. Make an unambiguous definition of the problem, without ‘jumping to solutions’;
3. Base the improvement investigation on real facts of the problem or the process which is under study;
4. Use logical thinking in the analysis, making sure there is a logical relationship between problem, cause and solution.

A brief review of these results with five universities of applied science showed that these outcomes are recognizable. Especially the first result, not yet completing the full cycle, was recognized and is also in line with the results of the survey carried out among experts about the complete use of the improvement cycle.

Subsequent research (Hoof & Kollenburg, 2018) studied the reasons why students of the minor Continuous Improvement at Avans don’t implement their improvements during their internships. Though the response group was small (n=19, the total population is estimated at thirty companies) it seems the main reasons are a lack of commitment and difficulty of behavioral change. Because ‘leadership and culture’ is one of the main themes in continuous improvement, this matter needs more attention.

Given the standardization trend in the continuous improvement future and the results of the research about the use of DMAIC by bachelor students (Kollenburg, 2018), standardization was emphasized more strongly in the minor program. The lessons on standardization were improved by extra education in the necessary knowledge and skills. This appears to have a positive effect on the complete fulfillment of the improvement cycle in the projects the students performed. While in 2016 only one project (out of twelve) included aspects of standardization, this increased to eight projects in 2018. Steps to learn to complete the full improvement cycles are possible, although adjustments in the program of the minor have to be made.

Application of data analysis

For students to become more proficient at continuous improvement, they need to develop good data analysis skills. Considering the advent of big data, students should be trained in process mining. Below an example of this.

To understand how process mining works, consider a process consisting of five activities A, B, C, D & E and three items that went through this process as is shown in table 2. It shows some cases go through different activities, or through the same activities, but in a different order (Filaire, 2017). For instance, case 1 is passing all five activities in the order A, B, C, D, E while case 2 starts after case 1 with activity A and moves

from there to C, B, D and E. In this process this results in sixteen events. With process discovery, which is the main part of process mining, process models are being extracted in an agnostic way from these events, and transformed into a process model.

Table 2 – Example of three items going through a process with five activities (based on: Filaire, 2017)

Case	1	2	1	1	3	2	3	2	1	2	2	3	3	1	3	3
Activity	A	A	B	C	A	C	B	B	D	D	E	C	D	E	D	E
Time ->																

The required key attributes for process mining analysis are: activities (process steps), item ID (the unique identifier of any item going through the process, like a patient or a work order) and timestamp (in case of performance evaluation to know when each item arrived or left any activity) (Filaire, 2017). Process mining can be used on any information system, using transactional systems such as ERP, CRM and SCM, because these systems will offer information on events in some form (Aalst & Weijters, 2004).

To create a process model, several problems have to be overcome, like hidden tasks (which exist, but are not recorded), duplicate tasks, non-free choices (where decisions about the process flow are already made outside the process), process loops (when the same task is executed multiple times), registration of the duration of the task, noise (incorrect information) and incompleteness of the data (Aalst & Weijters, 2004). To be able to use the results of process mining, these should be visualized and give insight in the process. Nowadays there are more than ten software packages, like Celonis and Disco, which are capable of overcoming most of these problems (Gartner, 2018). The correctness of data remains a critical factor though.

Education in process mining started in a joint case study of Avans and NHL Stenden Universities of Applied Science. After setting up the program, the teachers involved were trained in the steps of executing process mining. They learnt how to inspect the data from an ERP-system, that was selected for this purpose, then they had to import the data into the Disco process mining software and finally they were taught how to analyze the process with the software, looking at the process, the statistics and the cases.

Subsequently, a group of sixteen Industrial Engineering bachelor students was trained in the same way. After the training, the students analyzed the production data of a machining company in groups of two students. For each event, eight attributes were given: production order, article number, amount planned, amount produced, start date, finish date, machine group and activity. The students had to find the bottleneck in the process, starting with adjusting the raw data of the process in Excel, e.g. uniforming the coding of the dates and removing out-of-scope events. Subsequently, they imported the data in Disco process mining software and started analyzing the process, the statistics and the cases. This resulted in finding a lot of different products and a lot of different processes, because the students were found to be looking at the data from different perspectives. Therefore, some of the students chose to focus on the product that was produced the most and were able to determine the bottleneck, although they couldn't find the reason for this bottleneck, because they missed additional information and weren't able to validate their outcomes in real life.

The evaluation of the course, using an unstructured interview, showed that process mining was well-connected to the experiences of the bachelor students involved. Students responded positive to using real data and solving a real problem. The level of competence of the students varied strongly, however. Some students turned out to be beginners in Excel, while others showed a lot of experience. The consequence was that the quality of the outcomes was very different per group. Not only with regard to Excel, but also in the depth of the analyses. Most students accepted the given data too quickly, not being critical enough about their exact meaning. Because making sure the analysis is based on the right data is a critical aspect of process mining, this is a point that has to be improved.

Because the course was based on a case with real data but without contact with the company where the data were collected, it was impossible for the students to validate the outcomes. This way of working may lead to the situation where process mining is nothing but learning how to 'push some buttons'. This is undesirable, because process mining is a discipline that requires a specific set of skills people need to learn and process mining is just a starting point for the discussion with the domain experts (Filaire, 2017).

Conclusions and discussion

Conclusions

Five conclusions can be drawn based on the research detailed in this paper. Firstly, we have to deal with a number of changes in society; Especially digitalization drives these changes. Aging of society requires extra labor productivity to be realized, but the increase of labor productivity is slowing down. Secondly, organizations are increasing their productivity with use of continuous improvement, which in turn can lead to an increase in labor productivity at the macro level. Thirdly, ‘kaizen’, ‘realizing sustainable results’ and ‘leadership and culture’ stay relevant themes in continuous improvement, while ‘digitalization and data analysis’ increase in importance. These themes are relevant to improve labor productivity with continuous improvement. Furthermore, it is possible to learn to use the complete improvement cycle fully, though improvements have to be made. Finally process mining can be used by bachelor students for analyzing a process, but it’s important they learn to use it with a critical view within a realistic setting, which includes contact within the organization where the process runs.

Discussion

Because of the small sample sizes in the mentioned studies and, therefore, a lack of statistical evaluation the conclusions in this paper need to be supported by further research.

To use the improvement cycle fully, in order to make it relevant for creating sustainable improvement in labor productivity, research is required to find out which steps in the improvement cycle aren’t done properly by companies and students and for what reasons. A second subject for further research is the use of process mining in an improvement cycle like the DMAIC cycle. Process mining can be helpful in achieving fast, high quality and sustainable improvements. Table 3 gives an overview of the possible applications of process mining in a DMAIC cycle. These suggestions need a closer look to judge their contribution and practical usability.

Table 3 – Overview of the possible use of process mining in a DMAIC cycle.

Step in DMAIC cycle	Use of process mining
Define	The choice of the improvement project can be done based on real data from processes within an organization.
Measure	Measuring current process performance, depending on the quality of the data, this can be done faster than current approaches with a high quality level.
Analyze	Fact-based and fast analysis of processes resulting in areas for improvement.
Improve	Based on real process data and in combination with the proposed improvements, the future situation can be simulated, thus clarifying the real impacts of the improvement on the process.
Control	Installing process mining in the daily operations management gives the opportunity to sustain the improvements.

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Lean Divestment: the Lean Into Our Future (LIOF) Programme at Roche Clarecastle

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Abstract

In May 2015 Roche announced that they would be divesting the site in Clarecastle. From May 2015 through to April 2016, the site was actively for sale with a potential buyer entering a due diligence process in late 2015. Unfortunately, this process proved unsuccessful, resulting in the site downsizing its' headcount by 50% (125 people) between May to Dec 2016. At the end of 2016, the site leadership team were posed with the question: how do we engage all employees remaining on site for the following three years until closure at the end of 2019? This led to the creation of our site vision "to ensure the flawless supply of our product (CellCept) while building our people for their future lives outside of Roche". This was the genesis of the Lean into Our Future (LIOF) programme.

Roche Clarecastle started its' lean journey in 2009. Between 2009 to 2013 their lean program was heavily focused on the deployment of lean tools (kaizen, production level loading, business process management, goal deployment and A3 problem solving). From 2013, the focus of the lean program shifted to more systemic change such as TQM, TPM and material flow (examples of key initiatives during this period include: discrepancy reduction; 5S; operator asset care; and, lead-time reduction). The incremental implementation of lean tools throughout the period from 2009 to 2016 created a strong foundation of internal lean knowledge and capability. This was the landscape and foundation for our LIOF programme.

Recognising that the previous lean implementation had been focused solely on tools, systems and performance improvement, the LIOF programme made a promise to employees to be 'better for the business and better for you' and placed leadership behaviour at its core. In this paper we explore the magic that happens when leaders 'turn the mirror on themselves' and when the interest of the learner rather than organisation lies at the centre of a lean transformation effort. That magic consists of a remarkable level of engagement, step changed financial performance and a depth of continuous improvement experience aligned perfectly to future employability.

Keywords: Lean; Learning; Leadership, Behaviour; Divestment.

Lean Education: what academy know and what importance they give to it?

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Abstract

Lean Thinking (LT) has been applied in different contexts, from production to education. Whereas its application in the production sector is well-recognized, mainly due to the economic benefits it brings, its application in the education sector is still confused and/or unaware by most people, particularly, educators. Perhaps because LT in education can be applied in different contexts: 1) in the administrative processes of schools and universities; 2) in the classroom and 3) in the pedagogical projects curricula. In all of them, with the same purpose: improving the process and/or the learning methodology by using LT principles and tools. LT has been recognized more and more as a philosophy and a way of life, however, most people heard or think about Lean as a production methodology/model. Few people are aware of strong turn that Lean could allow when naturally embed in our way of thinking. When considered seriously, this philosophy leads us to a whole new world of thinking. In this new world, it will be necessary to think always with the heart, heads and hands (3H) through the processes, independently of which we are talking about. More than technical knowledge, the fourth industrial revolution demands thinkers that have a whole system-thinking, a sustainable conscious and an ethical behavior. The authors of this paper believe that Lean Thinking provides these competencies to the new professionals, independently of their professional activity. So, several workshops have been promoted to disseminate this paradigm. Some workshops in different contexts were settled and operationalized, involving more than 30 participants. This paper reports and discusses the results of assessment of such workshops collected through a questionnaire. The workshop participants profile will also be presented to show the heterogeneity of academy interested in the topic, stressing the increasing interest in this topic.

Keywords: Lean Education; Academy; Workshops

Acknowledgments: This work was partially supported by projects COMPETE-POCI-01-0145-FEDER-007043 and FCT-UID-CEC-00319-2013, from Portugal.

Lean Divestment: the Lean Into Our Future (LIOF) Programme at Roche Clarecastle

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Abstract

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Keywords: Lean; Learning; Leadership, Behaviour; Divestment.

ROUND 3 - THURSDAY 15TH NOVEMBER

3.1 Detecting and Elimination Muda

Application of lean education for the elimination of waste in a company of the stamped products sector

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Abstract

The present work was carried out in a company of the sector of Metal Imprints that provides parts for automakers of the Two Wheels Sector that needed to improve the productivity of the process of stamping and welding in the year of 2017. It intends to present the process of development of the professionals of a company of printed products, from the application of tools associated with the philosophy of lean manufacturing, aiming to carry out activities that reduce the waste in the productive process. For this, the methodology used was a case study, in addition to bibliographical research on the themes of lean manufacturing and lean education. The main results achieved were the absorption of the knowledge obtained that enabled the generation of activities that contributed to the reduction of wastes within the analyzed processes. In the end, we can conclude that for companies to remain competitive in the market, they must invest more and more in human capital. In this sense, lean education is a very viable alternative for reaching the goals and objectives of organizations.

Keywords: lean culture, lean education, lean manufacturing.

6. Introduction

The two-wheel fleet represents a significant fraction of the means of transportation in Brazil. 26,159,702 motorcycles are circulating in the country in 2017, which reflects a 26.94% share of the general fleet of motor vehicles, according to the Brazilian Association of Manufacturers of Motorcycles, Mopeds, Scooters, Bicycles, and Similar (ABRACICLO) in the year 2018.

The leading motorcycle manufacturers in the country, as well as a part of their suppliers, are located in the city of Manaus, Amazonas. Where they began to integrate with the Industrial Pole of Manaus (PIM) since the 1970s and is currently one of the essential industrial poles in Brazil, having billed a total of US \$ 25.6 billion in 2017, according to data from the Manaus Free Zone Superintendence (SUFRAMA) in 2018. The two-wheeler sector is one of the most significant for the IMP, producing 884,433 units, with revenues of 3.4 billion dollars (SUFRAMA, 2018).

Despite the significant numbers, the two-wheeler sector has been experiencing a downturn in recent years, as shown in Figure 1. Motorcycle production fell by 51.91% between 2010 and 2017, with the main reasons for this fact occurred were political and economic conditions that occurred in Brazil.

The two-wheeler market is dependent on financial credit and, in this period, there was a sharp decrease in credit for motorcycle purchases, which ultimately affected retail sales.

Faced with this scenario of shrinkage in production, motorcycle manufacturers have had to adapt their production processes to this new reality, reducing costs in order to maintain their profit margins. In this context, the application of tools following the philosophy of lean manufacturing has proved to be an interesting alternative for companies to remain competitive in the market.

However, it was noticed that most suppliers of parts for motorcycle factories did not follow the same methodology.

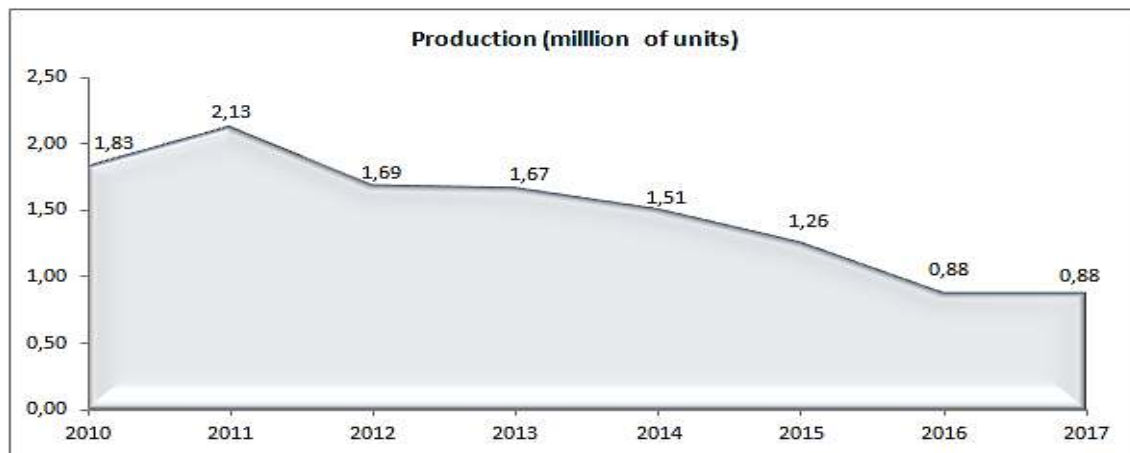


Figure 8 - Production level of motorcycles during 2010-2017 (Yearbook of the Brazilian Industry of Two Wheels, 2018)

Thus, the present work was developed in a company that supplies stamped products to the motorcycle factory of PIM, having chosen the sectors of stamping and soldering of this company to carry out the research and the problem found was the high index of waste in the process in the year 2017. The objective of the work is to educate the company's professionals according to the philosophy of lean manufacturing in order to reduce the waste of the process. The specific objectives are: a) to carry out training with the company's technical staff; b) map the company's processes; c) define activities that generate value d) implement improvements that reduce waste.

This work is vital for the company because it aims at reducing waste, which, consequently, will minimize costs and increase the efficiency of production processes, and motivate employees to develop professionally. For academia, this work is essential because it will generate knowledge that can be used by other researchers, as well as provide the development of future research. For society, the opportunity to buy cheap products that generate less impact on the environment. This article is organized as follows. The second section is a literature review of lean principles and their influence on the organization. The third section addresses the methodology adopted. The fourth section shows the results and discussions. Finally, the fifth section concludes with all the aspects mentioned throughout the paper.

7. Literature Review

7.1. Lean Manufacturing

The term Lean Manufacturing became popular after the publication of the book *The Machine That Changed the World* of James P. Womack, but its roots came from the principles of the Toyota Production System (TPS) of Taiichi Ohno. Womack (1998) argues that lean thinking is a way of

specifying a value, performing in the best sequence activities that generate value, uninterrupted and increasingly efficient.

Ohno (1997) classifies activities in value-added work (processing that modifies the form or character of the product), work without added value (activities that do not generate value but need to be performed in the current condition of a production process) and waste (repetitive and unnecessary movement), the latter being the focus of improvement work. It also classifies the wastes into overproduction, waiting, transportation, processing itself, stock, movement and manufacturing of defective products.

Several tools have been created following the principles of Lean Manufacturing, but one, in particular, will be the most used in this article, the process flow map. According to Rother & Shook (2003) the value flow mapping is a tool that helps to see and understand the flow of material and information as the product follows the flow of value. This philosophy has been experiencing continuous evolutions since its development until the present day, following a natural evolution, in order to seek the continuous improvement of the system through the discipline and dissemination of the good practices of management (Jones & Womack, 2002; Pinto, 2009; Clark *et al.*, 2013; Shamah, 2013; Mann, 2014; Bortolotti *et al.*, 2015; Kavčič & Gošnik, 2016; De Vin *et al.*, 2017).

7.2. *Lean Education*

As stated in the previous section, the origin of lean manufacturing is related to the elimination of waste within the productive processes of the factories, but over the years its application has been extended to several other branches of activities, among them education. Vukadinovic *et al.* (2017) noted that much has been researched on the subject and concluded that the development of Lean companies is conditioned by the availability of increasingly qualified and educated human resources. In this sense, it is observed that not only the qualification acquired during the academic life but also the education within the companies is necessary.

According to Alves *et al.* (2014), people within a company are simultaneously assuming the role of coaching or training, teaching and learning from each other. The successful implementation of lean strategies requires the involvement of teams and a profound cultural change, as a conditional step to achieve the success that lean methodology advocates (Clark *et al.*, 2013; Karim & Arif-Uz-Zaman, 2013; Vilkas *et al.*, 2015; Wagner *et al.*, 2017).

8. Methodology

The research carried out is identified as a case study. The team was composed of two people, responsible for carrying out the theoretical training of Lean Manufacturing with the technical staff of the supplier, in addition to carrying out the analyses and proposing the improvements as planned in the schedule.

The information was collected through the monitoring done in the production process, as well as data provided by the company itself. The research was carried out in the Stamping and Welding sectors.

A bibliographic review was carried out to identify articles, books and manuals that dealt with the stamping and welding process, as well as references to the tools of Lean Manufacturing and Lean Education, necessary for the research to be carried out.

9. Case study

The research was conducted in a company that supplies stamped products to motorcycle manufacturers, to preserve their name, in the present work it was called Supplier. It is a private company, is located in the Industrial Pole of Manaus and has its headquarters in the city of São Paulo.

The main products manufactured in the Manaus plant are stamped and welded items in general, which form other main components of the motorcycle, such as the chassis.

9.1. Training

The work was divided into two stages: the theoretical part and practice. It was first started with the training phase, in total there was 10h of theoretical training, divided in two days. On the first day, the key employees of the company were gathered, among them the director, manager, managers, engineers, planner and buyer, aiming to present the Lean philosophy, show the relevance of its application to the company, the importance of each one of the members present for the adequate progress of the work, besides explaining how research would be done in practice.

This first day of training intended to show that even without participating directly in the production process, Lean thinking needs to be present in everyone within the company in order for the goals to be achieved. The second day of training counted on only the two engineers of the company; the objective was to present the tools that would be used in the course of the work. The concepts were shown through a presentation prepared by the researchers that contained concepts of value stream mapping, value-adding activities, line balancing, the seven wastes, as well as cases of application of these concepts. After the technical presentation phase, the on-site observations were initiated in the process.

9.2. Identification of Opportunities for Improvement

The research was carried out in the production process of the plant during the period of two weeks, to carry out the analysis was chosen the stirrup, part whose function is to support the feet of the driver (Figure 2), which has higher added value and higher production volume, in addition to going through all the processes.

The piece consists of seven items, one being purchased and the other being processed in npve different tonnage tools between 80T and 200T. Then all are welded in a single weld line, and the final product is shipped to be painted at a paint factory, returning to the company and then shipped to the motorcycle factory.

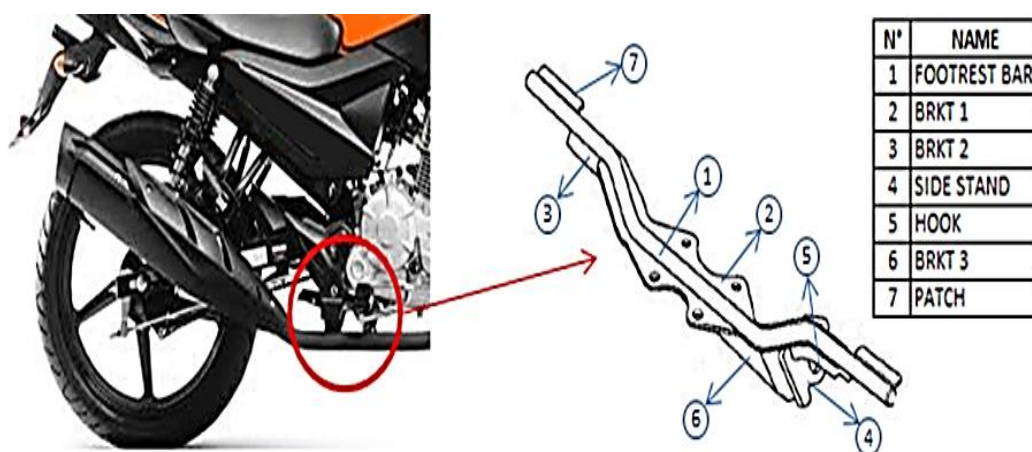


Figure 2 - Motorcycle Parts

First, the company's Planning and Production Control and Materials department was investigated, responsible for receiving orders from the motorcycle factory and carrying out the programming of the machines, as well as the acquisition of raw materials. It was found that a demand forecast was received for six months of production, by which the raw material planning was done for each month

the actual ordering products. Based on this planning was done the planning of the machines of the factory. There are suppliers of raw materials from Manaus and São Paulo, and the stock was for three months of production, while the stock of finished products served three days of manufacture of the customer. The evaluation of the stamping area was done in all the tools that manufacture the parts of the stirrup in order to find losses. Due to similar processes, similar losses were found. In order to investigate the cause of these losses, the processes were all filmed and then analyzed.

The primary losses were excessive movement and lack of standardization in the stamping activity (Figure 3). Also, it was observed that there were tools that could be conjugated. The study identified a cycle time of 10 seconds and an OEE (Overall Equipment Effectiveness) rate of 65%, where the loss of velocity was the rate that contributed most to the low index.

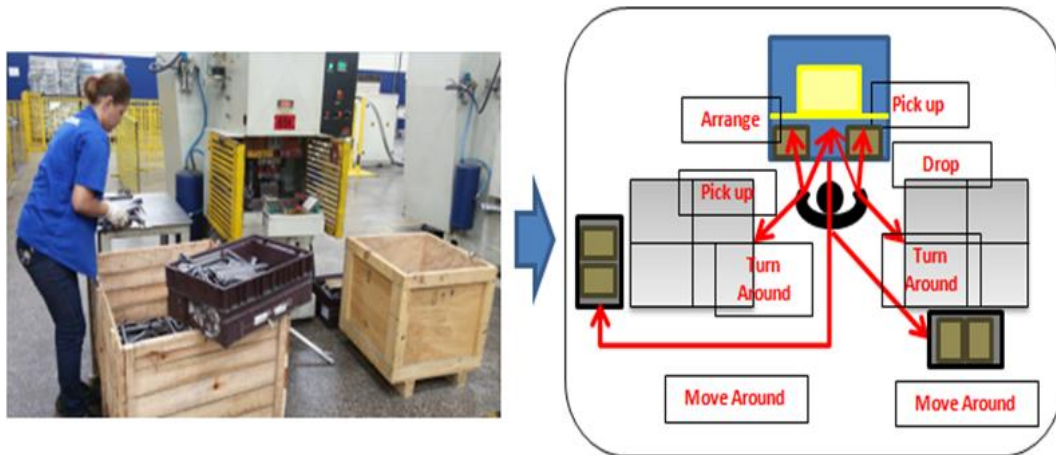


Figure 3 - Identification of losses from the production line

The welding line is composed of nine employees, five welders and four auxiliaries, according to Figure 4. The same procedure of video analysis was adopted for this phase, in order to find the losses in the process.

The most relevant losses were the imbalance of the line that generated waiting time inside the process and the presence of activities that did not add value, as is the case the withdrawal of welding spatters, since these spatter does not interfere in the quality of the product, since this part is not an apparent component of the bike.

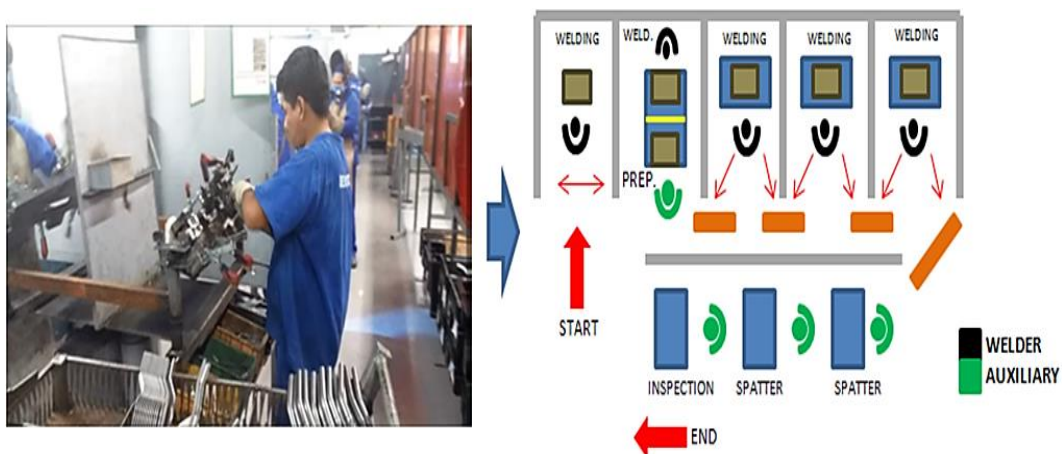


Figure 9 - Welding line process

The cycle time found was 65 seconds. The OEE had a rate of 68%. Figure 5 below shows the balancing found for the weld line.

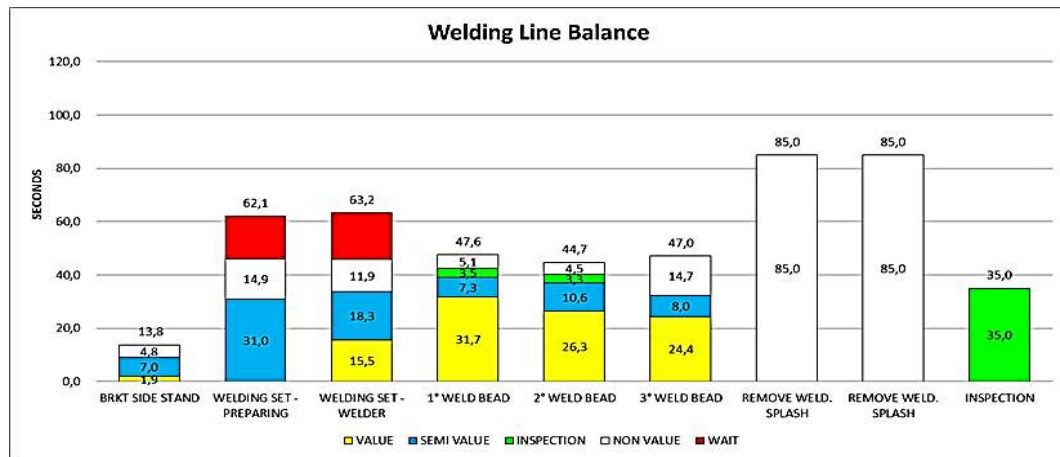


Figure 5 - Welding line balance

After analyzing all the processes of the plant, the *Value Stream Mapping* was elaborated for the item analyzed, as shown in Figure 6.

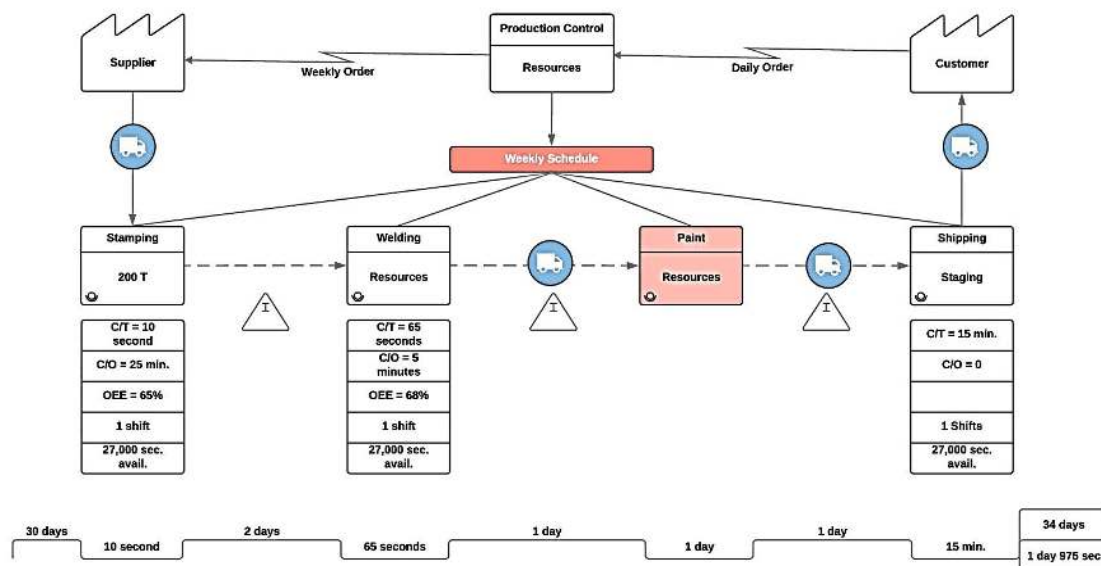


Figure 6 - VSM for the process line

9.3. Proposals for Improvement

After the period of identification of the wastes in the factory processes, the stage of a survey of the improvement ideas began. For the company's warehouse, it was verified with the material planning sector that there was no need to maintain the quantity of stock at current levels because most of the items manufactured use the local raw material.

It was then proposed that for local raw materials the stock would be 15 or 30 days depending on the volume of production of the manufactured items and for the raw materials coming from São Paulo, the stock would be 45 or 60 days, also depending on the volume of production.

For the stamping area, it was indicated the standardization of movements for the operation in the presses, in addition to the raw material approximation for the operator, in order to reduce the loss of time with movements that do not add value to the product, as shown in Figure 7.

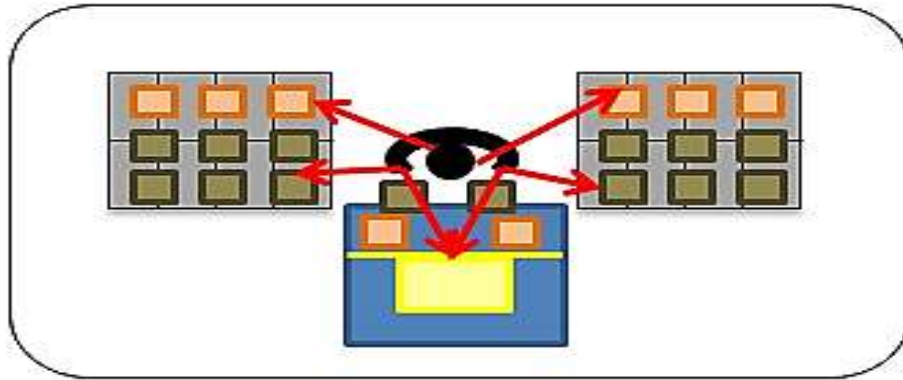


Figure 7 - Stamping area process

In the welding sector, it was proposed to balance the welding processes and eliminate two welding stations. It was also recommended to withdraw the solder splash process, since this activity, besides not adding value to the product, its elimination did not alter the quality of the final product, the new layout of the proposed line and its respective cycle times were as demonstrated in Figure 8.

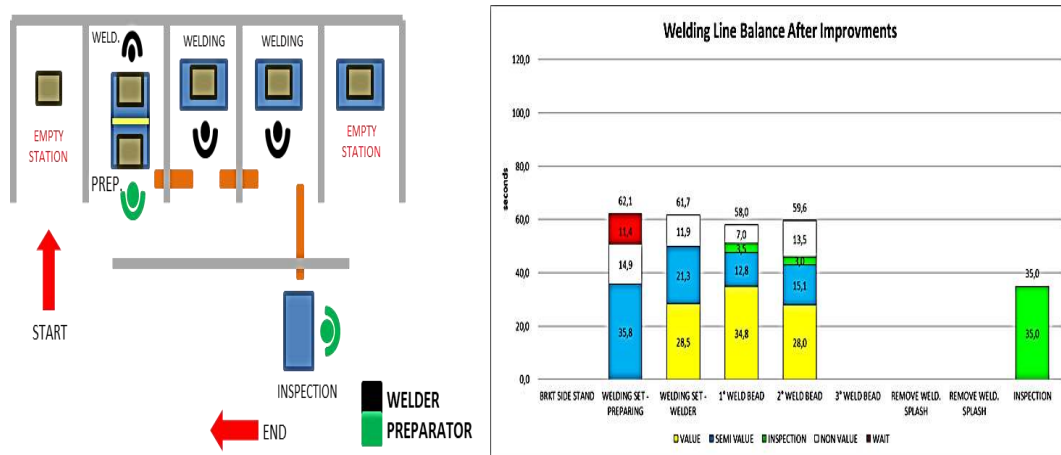


Figure 8 - Welding area process

9.4. Implementation of Improvements and Discussion of Results

The improvements were applied in the process according to the proposals presented. For the warehouse, it was possible to reduce the space of stock, besides improving the control of raw material.

In the stamping, the approximations and standardization of the processes generated a reduction in cycle time of 2 seconds and an increase in OEE to 74%. In the welding sector with the new balancing and the withdrawal of positions that did not add value, it was possible to maintain the same cycle time using only five operators and with an OEE rate of 75%.

The results obtained were entirely satisfactory, since the employees of the company assimilated well the concepts of Lean Manufacturing, from the operators who were willing to test the proposals presented to the director who supported at all times the progress of the activities. The current status is shown in Figure 9.

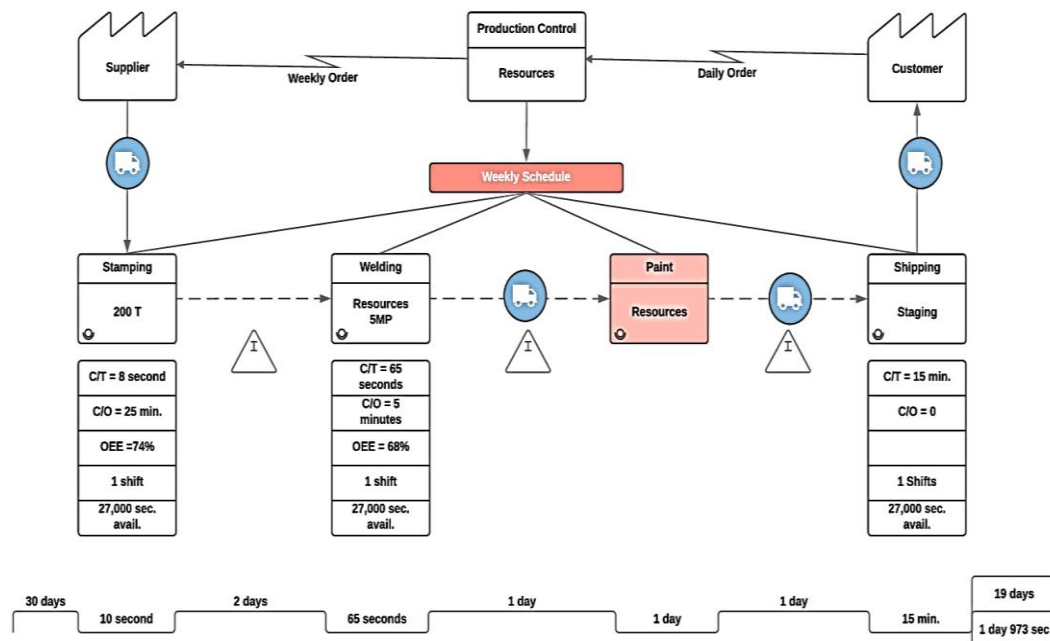


Figure 9 - VSM for the process line after improvements

10. Conclusion

The primary objective of the work was to foster education processes through the use of lean manufacturing methodologies and techniques aimed at waste reduction and process optimization.

Taking advantage of the case study presented in this article, it is verified that the implementation of the Lean Manufacturing philosophy proved to be an essential instrument for the company to improve its production processes and reduce waste.

Despite the good results obtained through training, as a point of improvement, it is suggested that, when possible, the theoretical training can be done in two days in order to better assimilate the theory by the students.

The mapping of processes and the definition of activities that add value served to visualize better the productive system, which facilitated the proposition of the improvements that should be made. Finally, the implementation of the proposed improvements proved to be active, and the goal of reducing waste in the process was achieved.

What is expected for the future work is that the technical staff that has been trained can multiply the knowledge acquired for the other employees of the factory, and that the same activity can be carried out to reduce the losses in the processes of other manufactured items, thus promoting , the cycle of continuous improvement advocated by this philosophy of lean management.

Adopting lean tools alone does not guarantee the full success of a training, competency and training plan for the production team if it is not linked to the organization's strategic planning.

Also, although lean tools prove their effectiveness, it is necessary to foster and maintain, within the organizational culture, what is called lean results culture.

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Towards Reducing Queues: Muri, Mura, Muda

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Abstract

Taiichi Ohno of Toyota is reported to have said, 'All we are trying to do is to reduce the time from order to cash.' Kingman's equation offers a unifying concept around the hard (quantitative) elements that contribute towards this reduction in lead time through the Toyota concepts of Muda, Muri, and Mura. The equation, based on queuing theory, incorporates four elements: arrival variation, process variation, utilisation, and process time. Utilization has two elements, arrival rate and process rate. This means that there are five interacting elements to the queue or cycle time of a process. Variation can be aligned with Mura, utilisation with Muri, and each element contains waste or Muda. This review paper explores the elements of Kingman's equation and their interactions, the relative effectiveness of Six Sigma, TPM, and various Lean tools. In particular, the paper explores some overlooked aspects of demand and variation, that lead to Lean initiatives not meeting expectations. The ultimate aim of the paper is to contribute towards a unified understanding of Muri, Mura, and Muda: their interactions, priorities, and appropriate use.

Keywords: Queues, variation, capacity, lead time, process improvement, service improvement.

1. Introduction

Lead time is central to Lean operations as Taiichi Ohno's (1998) famous quote indicates: 'All we are trying to do is to reduce the time from order to cash.' Lead time comprises a series of queues, actual process times, and move times. The queues may be of customers, orders, inventory, and information. In the Toyota system, three aspects have been given attention: muda, muri, mura. Of these 'muda' or waste has received much attention, (Womack and Jones, 2003) but the others have been far less prominent. This point has been made strongly recently by Hopp (2018). The mathematics, statistics and psychology of queuing has of course been extensively studied, and is found in numerous standard Operations Management texts and papers. (See, for example, Kingman 1962, 1966; see Pound *et al* 2014 for a modern interpretation)

This paper will use Kingman's approximation of the expected waiting time for a general G/G/1 queue. Kingman's equation contains terms for variation ('mura') and utilization (aligned with 'muri'). Queues, of course, are a major source of waste (or 'muda'). The equation is given as:

$$E(W_q) \approx \left(\frac{\rho}{1-\rho} \right) \left(\frac{c_a^2 + c_s^2}{2} \right) \tau \quad (1)$$

Here:

$E(W_q)$ is an approximation of the expected average queue time.

ρ is the utilization, expressed as a decimal within [0..1] This is the fraction of time that a workstation is not idle for lack of work or customers. More simply, it is Load / Capacity (or arrival rate / production rate). 'Muri' or overload is aligned with high utilization.

c_a^2 and c_p^2 are the coefficients of variation in arrival and processing given by σ_a / t_a and σ_p / t_p . σ is the standard deviation and t is the mean (or average) processing time – or mean inter-arrival time in the case of t_a . They are thus relative measures. These are types of ‘Mura’.

τ is the ‘average processing time to do one task. It does not include the time the station is starved for lack of work or blocked by busy downstream stations.

According to the Kingman equation, there are three variables (arrival variation, process variation, and utilization), plus a process time element, that contribute to the overall cycle time through the process. Since utilization is the ratio of two factors there are thus five factors that influence queue time. Each of these factors almost invariably contains avoidable or waste (muda) elements. As we shall see, some of these elements are externally (or customer) caused, others are internally (or process) caused. Klassen *et al* (2007) also made use of the Kingman equation and focused on the trade-off between capacity, variation, and inventory. They concluded, *inter alia*, that attention must shift towards the largest sources of variability and that approaches to attenuate the need for trade-offs could be divided into internal and external factors.

Figure 1 shows the average queue length in relation to capacity utilization for various coefficients of variation. A coefficient of variation of 0.6 would be low, as found in highly repetitive (typically manufacturing) operations, and a coefficient of 1.4 would be found in a repetitive service such as some call centres. (Pound *et al* 2014). Note that the impact of variability is not linear, but grows exponentially as utilization changes.

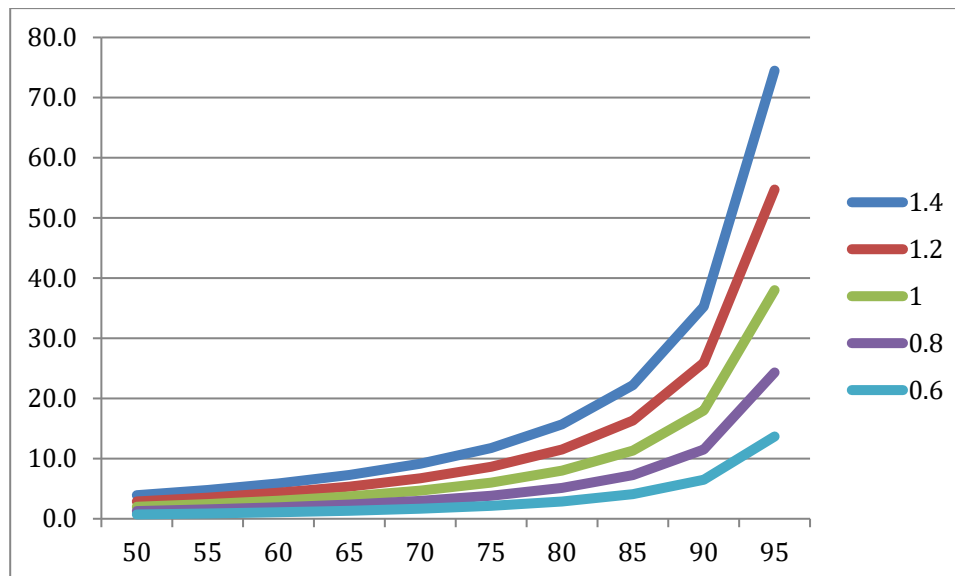


Figure 1. Representative Average queue time factor (vertical axis) vs utilization (horizontal axis) for various coefficients of variation, between 0.6 and 1.4

2. Variation

In the sections that follow some characteristics of the types of variation will be discussed with the aim of reducing their magnitude. The focus will be on elements that have often been ignored in literature but have been found in numerous studies by the author, his colleagues, and his Masters students. A summary is given in Table 1.

2.1. Mura: Process Variation

Reducing process variation has often attracted extensive attention through initiatives such as Six Sigma, standard work, 5S, and TPM (Total Productive Maintenance). These ‘standard’ Lean initiatives will not be discussed in detail, but rather some causes of variation will be given.

Kingman formula element	Element types	Where generated	Specific types and opportunities
Variation	Process variation	Externally generated	Capability, Effort, Request, Subjective preference
		Internally generated	Stoppages within and between batches
			Part proliferation
	Arrival variation	Externally generated	Classification: (Normal, erratic, lumpy, intervention.)
			Pareto demands and pooling
			Supply Chain amplification
		Internally generated	Push systems and transport
			Consequential demands
			Value Stream amplification
			Information flows
			Intervention, Deliberate, and Inadvertent

Table 1 - Variation generators

2.1.1. Externally Generated Process Variation

In service, Francis Frei (2008) has described five types of ‘customer-introduced variability’. The first of these relates to arrival variation, but the last four are relevant to process variation. The five are: Arrival variability (the time between arrivals), Request variability (variation of customer requests), Capability variability (variation of customer skills within the interaction between customer and service provider), Effort variability (how much preparation or effort has the customer made – for example before airport security), and ‘Subjective preference variability’ (customers having different expectations as to what is or should be provided). Segmentation and education are responses to several of these categories, as used call centres, hospital triage and airport security.

2.1.2. Internally Generated Process Variation

Part and Product Proliferation and Commonality: Excess part proliferation typically results from design activities that are uncoordinated with manufacturing requirements. Excess product proliferation, or variety, typically results from marketing activity which prioritises sales over operations. Of course, there are trade-offs to be made between marketing opportunities and opportunities of reduced variety that work through to reduced inventories and queues. The effects of product variety and proliferation may be mitigated by mixed model production and ‘heijunka’. Such solutions, however, require advanced scheduling skills. Part proliferation can be reduced by concepts such as value engineering and group technology. These latter methodologies are attractive because they generally do not compromise marketing requirements.

Stoppages within and between batches: Unplanned stoppages within and between batches add to variability. Unplanned stoppages occur randomly, whereas planned stoppages for maintenance do not necessarily add to variation. Due to variability, stoppages often result in increased inventories in manufacturing and in customer queues. Stoppages, of course, also detract from capacity and are discussed in the later section on Utilization. Total Productive Maintenance is a standard Lean approach aimed, inter alia, at reducing stoppages, but the effect on variation is seldom discussed.

2.2. Mura: Arrival (Demand) Variation

2.2.1. Externally Generated Arrival Variation

Variation Classification. A useful classification of arrival variation (based on Syntetos *et al.* 2005) is as follows:

Normal. (In service, many arrival patterns follow the Poisson distribution.)

Lumpy (Some periods with zero demand, interspersed with irregular non zero demand. For example, customers arrive at a bank at morning tea time and at lunch time.)

Erratic (High variability small demand transactions with occasional very large transactions. For example, heavy demands on 'pay day'.)

Management intervention (Arising out of deliberate management actions to adjust inventory levels, for example in a warehouse or shop.)

With the first category, it is simply good practice to plot demand on a control chart and separate common cause from special cause variation. With the final three categories above, the arrival patterns should never be simply accepted and should always be questioned. (Why is it lumpy? How did it arise? What are the causes? Can it be smoothed?).

Pareto Demands and Pooling. In both products and services, virtually all demand occurs according to a Pareto-like phenomenon, with a small proportion of products or services accounting for a large proportion of total demand. (Slack *et al.*, 2016) This would occur, for instance, in both manufacturing and in a call centre.

A useful analysis is the 'Glenday Sieve' (Glenday and Sather, 2014) that has been widely found in practice. Typically, 6% of cumulative stock keeping units (SKU's) (or customer call types) account for 50% of cumulative volume, and 50% of cumulative SKU's account for 95% of cumulative volume. The significance of such analysis is that, within the top category, demand variation is dampened by virtue of volume and number of sources. This is the pooling effect. Thus, arrival variability in the top demand types can effectively be reduced by separating out frequently occurring demand types from low demand types, and managing them separately. High demand products enable more stable, repetitive schedules whilst low volume types are fitted around the high volume produces. (This is also known as 'Runners, Repeaters, Strangers' scheduling. See Bicheno and Holweg, 2015). In call centres, an effective approach is to divert high volume, routine call types to regular staff whilst sending low volume but high variation calls to specialists. (Seddon, 2003)

Arrival variation and Supply Chain Amplification: The 'Bullwhip effect' is well known, and strategies to reduce the effect are not repeated here. (Naylor *et al.*, 1999)

1.2.2 Internally Generated Arrival Variation

This is an important category for managers because here, of course, variation is caused internally within the organization rather than externally by customers.

Push Systems and Transport: When a batch of work is pushed rather than pulled onto the next operation irrespective of the utilization or load at that next operation, the queue is often increased. Push-based transport or material handling systems, occur widely in hospitals, offices, or manufacturing and result in increased variation at downstream workstations. (See, for example, Schonberger 1982, Pound *et al.*, 2014.)

Consequential demands: Rework, failure demand, and superfluous demands result in additional demand and as such are discussed under Utilization. They occur due to inadequate internal actions. However, the additional demand that is caused also affects variation. Worse, these additional demands tend to occur just when resources are busiest, thereby increasing queues at the worst time.

Value Stream Amplification: Within an organisation, as a product or service flows along a value stream, scheduling or batching decisions can affect variation usually negatively but sometimes positively.

Batching decisions. Products may be batched for process or setup reasons. Batching may save setup time, but an often-ignored consequence is an increase in variation.



MRP consolidation results when an MRP system consolidates orders into time buckets. This is often done automatically using rules such as ‘period order quantity’ or ‘economic order quantity’. The often-overlooked result is that small steady orders – ideal for a Lean, stable schedule – are converted into larger lumpy orders. Schedule stability is a desirable aim for Lean schedules with Toyota, for example, striving to maintain a steady schedule for months on end. The classic ‘level’ and ‘chase’ scheduling strategies are discussed in many Operations textbooks, the trade-off being between holding more inventory using a level schedule against the cost of rate changes (setup, manning, overtime,) using a chase strategy. (See, for example, Slack *et al*, 2016). Variation, however, is seldom mentioned.

Propagation. This occurs where variability of a process may affect the variability of another downstream process. The most severe propagation occurs when low variation demand hits a high variation, high utilization work centre. (Hopp, 2008). As Reinertsen (2009, page 67) notes, ‘Managing the process upstream of the bottleneck is a valuable tool for improving flow at the bottleneck.’

By contrast, value stream variation may also be reduced by using postponement. In service the example of Benetton’s ‘Jerseys in Grey’ whereby colours are added locally, is well known.

Information flows: Information can be used, particularly in service, to reduce arrival variation. Customers can be influenced to arrive early or late in order to avoid queues with information about the current or expected queue situation. (Examples are found at Disney World, airport security, and with call centre queues.)

Other Types: Deliberate, Intervention, and Inadvertent

Deliberate (Outside of Operations): Variation caused by deliberate action results from management intervention outside of the operations department but internal to the organisation. An example is pricing that is widely used in both manufacture and service to influence both demand and variation, but uncoordinated pricing can increase variation. Ideally, such variation is addressed at Sales and Operations Planning meetings.

Intervention. Intervention variation results where management makes adjustments to inventory levels or to layout. For instance, management may adjust safety stock levels to meet changed service rate requirements or seasonality. It follows that timing and magnitude is critical when management interventions are made. On the positive side, layout changes can reduce variation when a cell is created from formerly separate processes when operations are balanced. (Schonberger, 1982).

Inadvertent. Inadvertent variability may result from errors such as over-ordering, from ignorance about computer system defaults, or from uncoordinated decisions between marketing and operations. It may occur where, for example, a manager introduces a new employee, a new machine, or a new procedure. Unfortunately there are many examples where the causes of arrival variation have been completely ignored even within organizations that have been ‘doing Lean’ for many years. Inadvertent actions, of course, lead to longer queues. A question that should always be asked as ‘how much demand variation is self caused?’ Examples are numerous but include:

Quantity discounts, encouraging customers to make larger earlier orders, rather than discounts for regular orders. This type should not be confused with coordinated marketing promotions aimed at capturing market share.

End of month ‘hockey stick’ orders. This occurs when several orders are placed together, typically at month end, rather than uniformly. A major cause of this lumpiness is simply internal reporting arrangements rather than true customer requirements.

Simple uncoordinated sales, where major sales are simply taken as they occur without questioning timing or quantity. The author has experienced instances where customers would prefer more frequent regular demand but were never asked.

End of financial year adjustment policies to inventories that aim to make financial statements look good, but that play havoc with production variation

‘Large machines’. The often-unintended consequence of employing a single large machine, usually for ‘economy of scale’, rather than several smaller machines is increased variation and longer queues in front of the large machine. (See, for example, Schonberger, 1982).

Consequential. Consequential variation results from rework and failure demand, discussed below. These affect both load and variation. As noted above, such consequential variation often happens at the worst possible time – when utilization is highest!

3. Muri: Utilization: Arrival Rate

In Kingman’s equation, utilization (here taken as muri), particularly at high levels, has a major impact on queues. This was summarised in Figure 1. In Table 2 the elements of utilization together with opportunities for the reduction in utilization, are summarised.

Arrival rate (or demand) can be externally generated by a client or customer, or internally generated within the organisation. Demand can be necessary, consequential, or unnecessary. Arrival types are often not homogeneous but have different values and priorities. Arrivals should first be analysed for priority (as in hospital triage) or value (as in service or manufacturing). In a service environment some arrivals are urgent and should go to the head of the queue. In manufacturing, contribution per bottleneck minute (Bicheno and Holweg, 2016) is a recommended prioritising analysis. Such prioritising may lead to arrivals being temporarily or permanently rejected. (“Please try again later.”)

Kingman formula element	Element types	Where generated	Broad categories	Specific types and opportunities
Utilization (Arrival rate / Production rate) (Muri at high levels of utilization)	Excess Arrival (or Demand) rates	Externally generated	Unnecessary	Superfluous demand
			Consequential	Failure Demand
		Internally generated	Unnecessary	Overproduction and Redundant demand
			Consequential	Rework
	Production rate detractors	Internally	Equipment losses	Availability, Speed
			Time Losses	Dispensable time

Table 2 - Utilization

3.1 Externally Generated Arrivals

3.1.1 Externally Generated Consequential Arrivals.

Seddon (1983), concerned primarily with service operations, made a useful distinction between ‘value demand’ and ‘failure demand’. Value demand is actual, first time, demand generated by a customer and is also known as ‘fresh demand’. (Ding et al, 2015). Failure demand is caused by ‘not doing something or not doing something right first time’. (Seddon, 1983). Failure demand comes from dissatisfied external customers; rework comes from internal sources about which a customer will often not be aware. Misdiagnosis would be an example in health care. Seddon has identified large quantities of failure demand in call centres. Reducing failure demand in a highly utilized resource will lead to a dramatic reduction in cycle time, as indicated in Figure 1. Failure demand in manufactured products may require work carried out under warranty or with support from a call centre.

3.1.2 Externally Generated Unnecessary Arrivals

Superfluous arrivals, or demands, are externally generated by unnecessary work that results in internal workload. An example would be unnecessary demand generated through the ‘bullwhip’ effect.

In service, superfluous demand may occur due to misinformation, misdirection, ignorance, or social need. Thus a person may go to A&E when she should go to a chemist, or may go to a bank teller out of loneliness. Reinertsen (2009) referring to design or software development, has pointed out that in periods of high demand, some lower priority ‘requirements’ (i.e. features) should be dropped. **Frequent callers** represent a special type of superfluous demand. This, of course, is a form of Pareto demand discussed earlier. In the UK health service, frequent callers are responsible for perhaps 10% of total calls, some from hypochondriacs, others from people with genuine multiple problems. As a result some hospital trusts have established special frequent caller channels.

3.2 Internally Generated Arrivals

3.2.1 Internally Generated Consequential Arrivals

Rework is internally generated demand resulting from defects or errors that require work to be re-done until considered satisfactory to be sent out externally. A customer may not be aware of such rework, but of course is often affected by the delay that is caused. We may note that rework or failure demand may lead to yet further rework or failure demand, and as a result the true extent of such demand may not be easy to detect. The writer has come across several cases where the lead-time as calculated using a value stream map (sum of inventory times and process times) is misleading because of work recycling.

3.2.2 Internally Generated Unnecessary Arrivals

Overproduction is internally generated demand or arrivals that result in products or services that are not subsequently used, at least in the short term. Overproduction is one of the classic ‘7 Wastes’ of Lean, often described as production that is ‘too much, too early, or just-in-case’. (Womack and Jones, 2003).

Misallocated demand occurs where an alternative, usually less loaded, resource could be used but is not used. A service example is where a highly utilized doctor nevertheless does some work that could be carried out by a nurse or administrator.

Redundant demand occurs when excess service is given. A free service may be provided in order to mollify a complaint. A doctor may prescribe complex investigations out of uncertainty or out of fear of legal action. In Lean terms, this is one of the classic wastes called ‘over processing’.

4. Muri: Utilization: Production Rate (or Capacity) Detractors

4.1 Equipment Losses result from machine breakdowns. This could include Internet interruptions. Availability losses are best calculated through $(MTTR / (MTBF + MTTR))$, where MTBF is mean time between failures and MTTR is mean time to repair or restore uptime. Availability is given by $MTTR / (MTBF + MTTR)$. Each of these factors can often be improved upon, for example by ‘6 Big Losses’ analysis, planned maintenance, criticality analysis, refurbishment, and JI (Job Instruction), to mention a few. (McCarthy and Rich, 2004)

4.2 Dispensable Time Losses occur within both manufacturing and service and the effect is to reduce capacity, or the effective production rate. Most employees have experience of having to attend wasteful meetings, completing surveys of no apparent benefit, producing reports and measures that are unlikely to be read, or attending general training much of which is irrelevant. Smartphone messages and e-mails have become major distractors. It is essentially bureaucracy or ‘clutter’ (The *Economist*, 2014). Such demand may also involve what Northcote Parkinson (1958) proposed in his amusing book ‘Parkinson’s Law’. André Spicer (2018) and Graeber, (2018) refer to such work as ‘bullshit’.

5. Utilization, Variation and Process Time Together

The preceding sections discussed the contributing causes of the four variables affecting queues in manufacturing and service. We now return to Kingman's equation to help understand the effect of reducing each of these variables. Refer to Figure 2, and begin with a typical queue curve shown as the leftmost curve in the figure. Notice that variation reduction at low levels of utilization has little impact.

Possible approaches to reducing queues are illustrated. Assume we are at point A. We may be able to reduce variation, whilst remaining at the same level of utilization, relocating to point B. Or we may be able to reduce utilization, whilst remaining at the same level of variation, relocating to point C. Or we may be able to reduce variation and utilization, relocating to point D.

The best strategy would depend on the relative costs and speed of either reducing variation or utilization. By understanding the range of causes of variation and the drivers behind utilization – arrival rate and production rate – it will be apparent that some changes can be made quickly and at very low cost. Examples would be simply to ask customers to spread their orders more evenly or to change the batching rule in an MRP system. Experience with both Six Sigma and standard work (on variation reduction) and with TPM (on improving uptime) is that both have diminishing returns. This would suggest that taking the 'low hanging fruit' in both areas would be more cost effective than continuing to pursue one whilst ignoring the other.

The ideal position (or 'sweet spot') would be to operate at the bottom right hand corner, with high utilization and no queue. Thus unlikely possibility can only be achieved with both zero arrival variation and zero process variation. However, by eliminating *self induced* variation (of both types) the ideal may be approached. This should be the first goal of 'Mura' reduction. Likewise excess load (muri), particularly *self induced*, could move operations towards the sweet spot.

In Lean manufacturing, flow is approached by reducing batch sizes with changeover reduction. As a result the use of complex calculations is reduced. Likewise, queue (and lead time) reduction should be approached by acting on those variables that are the root causes - mura (unnecessary variation), muri (excess utilization), and finally through muda (waste).

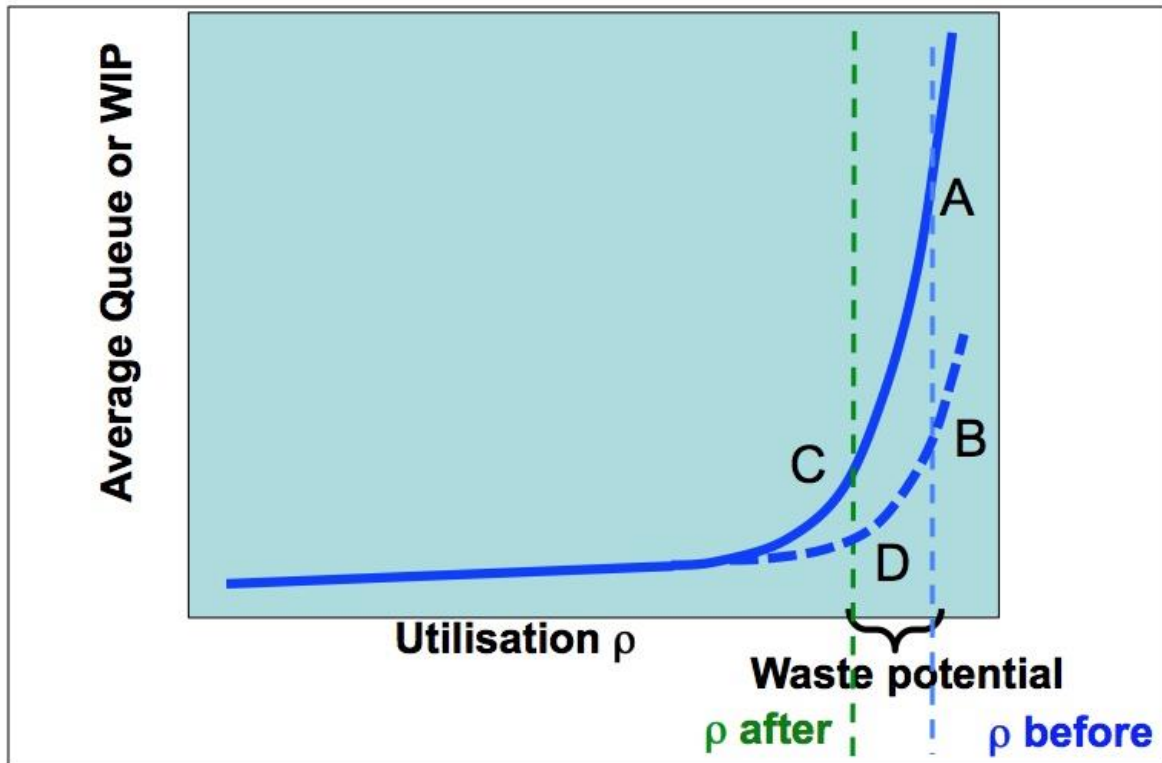


Figure 2. Queue Reduction Approaches

6. Conclusion

Queues are fundamental considerations in both manufacturing and service operations. Kingman's equation identifies four variables affecting average queue length. Both utilization (comprising load and capacity) and variation (comprising arrival and process types) are seen to have both externally generated and internally generated drivers. Some of these drivers are well known, but others are sometimes missed or ignored (in both practice and in classic Operations Management texts) despite the fact that some have large impact whilst others require only low cost interventions. The paper also reinforces the TPS focus of muri, mura, muda, in that order, and cautions against some Lean Six Sigma practices that may be misplaced.

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A New Approach to Developing Lean Understanding in Higher Education

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Abstract

In 1996 the authors of “Lean Thinking” James P. Womack and Daniel T. Jones described five principles on how to approach the changes necessary in an organizational context in order to achieve the level of operations they had described in their first book “The Machine That Changed the World” published in 1991. The focus was to share with the readers how the companies had achieved the level of what was called “Lean” thereafter. The research described in this conference paper is an innovative approach that sheds light on a new approach to verify the effectiveness of a new way of learning to develop added value processes with reduced and eliminated forms of Muda. This new form of teaching developing lean processes differs from the sequence of principles described in the book called “Lean Thinking”. The research was conducted to better understand the challenges educators face in their approach developing an understanding of what the American authors called “Lean” among their students in a university context. In the past teaching had followed the sequence of “Lean Thinking” principles taken from the same named book in the specific order: Value, Value Stream, Flow, Pull and Perfection. Leading students through these five principles had demanded specific sessions of input between the different principles. Without clear guidance from the educator it was impossible for students to understand the necessary steps from one principle to the next. Starting with a traditional batch-and-queue approach of value creation for customers, it had been very demanding for educators to help the students understand the necessary steps to be taken in order to move to a what Womack and Jones called a “flow” approach to value creation.

In the new approach developed in order to open the opportunity to change the role of the educator, the sequence of the five principles has been altered to create an environment in which the students can better develop lean thinking on their own. It requires less additional input from the educator between experiencing the different principles. Thus the educator may give the learners an opportunity to develop an understanding out of their own thinking rather than based on specific input given through principles described in a book written by American authors. The learners get the chance to experience the outcome of their own thinking capabilities. They now may develop a level of pride on the outcome of their own thinking that has been made possible through the new approach to developing an understanding of what the American Authors called “Lean”.

Keywords

Lean; Lean Higher Education; Educator’s Role; Lean Thinking; Lean Principles

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3.2 Industry 4.0

Industry 4.0 as a way to enhance Lean Manufacturing and Six Sigma

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Abstract

The Lean Manufacturing principles are a systematic approach to identify and eliminate waste through continuous improvement. The principle applies tools and methods to systematically eliminate elements that do not add value to the process. On the other hand, the Six Sigma methodology should be used when the variables are unknown, in order to obtain a reduction in variability of the processes to reduce the occurrence of problems or defects. The combined use of these two methods is known as Lean Six Sigma. With the advance of Information and Communication Technologies (ITC), in the context of Industry 4.0, machines will be making ever the more data available, using Machine Learning to map the individual and group behavior. With this behavior exposed and mapped, it will unleash the Lean Six Sigma methodology, as there will be less unknown variables. This article intends to make a counterpoint between the current visions of Lean Six Sigma with the digital components of the Industry 4.0. The methodology will consist of researching secondary data through revision of literature, scientific articles and books specialized in the field of Lean Manufacturing, Six Sigma and Industry 4.0. It is an exploratory research, based on reference and qualitative research.

Keywords: lean manufacturing; six sigma; industry 4.0

11. Introduction

The term "Industry 4.0" has been raising questions about the applicability of the Lean Manufacturing and Six Sigma methodologies to solve problems in industries in face of the technological advances of this theme. Some believe that the application of artificial intelligence in machines can lead to the obsolescence of such methodologies. On the other hand, others believe that the use of these technologies will enhance these methodologies, furthering them to points never achieved before. This study aims to provide a counterpoint between the current view of Lean Six Sigma and the digital environment of Industry 4.0, showing how the factories' digitalization can improve their performance by mapping the individual and group behavior of machines, production lines and even whole factories. Section 1 will review Lean Manufacturing, Six Sigma, and Industry 4.0. Section 2 will explain some technologies that enable the emergence of Industry 4.0. In Section 3, the interactions

between Industry 4.0 and Lean Six Sigma are highlighted, and then a conclusion about the use of digital technologies as a way to enhance the use of these methodologies is presented in section 4.

11.1. Lean Manufacturing

The term Lean Manufacturing derives from the adjective “lean”, as in “containing little or no fat” (Merriam-Webster, 2006), and therefore, implies that any unnecessary excess is eliminated. This philosophy had its beginning related to the evolution of industrialization, and the consequences of the events in the industrial processes after the 1950s (Andersson, Eriksson, & Torstensson, 2006). American scholars, who analyzed the changes and their impacts on the manufacturing process, mainly from observations at Ford, were not successful at convincing American industries to implement their ideas of Statistical Process Control (SPC) and quality. However, through post-war US aid to Japan, professor and statistician Deming resonated in Japanese society - especially among engineers - by taking SPC concepts developed by the Hungarian-American Shewhart, and their applicability in the quality of industrial products. Together with Deming, the engineer Juran, who had published a book on quality control, started a new revolution in Japan, where large Japanese industries that had visited American and their state-of-the-art factories such as Ford, brought concepts of productivity, but adapted them to introduce new concepts. Taichii Ohno and Shigeo Shingo introduced these new techniques at Toyota, where they became known as the Toyota Production System (TPS). Just in Time (JIT) was one of the first concepts. Recognizing that input and intermediary inventory played a significant role in efficiency and costs, Toyota realized that workers could contribute much more than just repetitive work, and more tools were introduced, such as the quality circles.

The Japanese Ishikawa joined the Americans Deming and Juran to contribute to the progress achieved, resulting in work cells with rapid product change capabilities and the capacity to manufacture diverse products, unlike the system adopted in Western industries, which lacked flexibility. Setup times were reduced and lots of smaller quantities with the advantages of continuous flow allowed the Japanese industries to have an efficient production, with the capacity to offer more variety, without giving up quality or efficiency (Barsalou, 2013). And all this change was only possible thanks to the culture on the factory floor, which allowed greater participation and involvement of the workers in the analysis and decision making, unlike the productive processes adopted by the western industries. The human element was important and valued, undergoing a learning and empowerment transformation, contrary to the culture of the worker in the western industries.

This transformation happened in Japan between the 1950s and 1960s and eventually spread from Toyota to be adopted by other Japanese industries related to manufacturing, without initially being noticed in the rest of the world. It was Lean, as it focused on the constant reduction of waste, such as overproduction, excess of inventory, handling, waiting, transport, over-processing, and rework, later known as the seven Wastes (Womack, Roos, & Jones, 1990). After 1975, the results of Japanese industry became evident in the rest of the world, and the world began to study the Japanese industries. The concepts of Lean Manufacturing started to be copied by Western industries, worried in achieving the productivity and quality of their Japanese counterparts (Barsalou, 2013).

Lean concepts are still developing, and have moved on from the early days of manufacturing. They are now applied in services and knowledge work, and according to Krospu-Vehkaperä and Isoherranen (2018), who state that “lean thinking is a cultural change that focuses on utilizing people as efficiently as possible”, and its main concept, that of “providing value to the customer while reducing or removing activities that do not add value”, rely heavily on respect of people. The evolution of Lean from manufacturing to encompass services is also clearly indicated by Gupta, Sharma and Sunder M. (2016), who found that prior to 1998, they found no reference to Lean in

services. Only after 2004, did they report an uninterrupted flow of publications relating lean to Services.

They also clearly define lean as a philosophy rather than a methodology, that has a “multi dimensional approach encompassing wide variety of management practices based on philosophy of eliminating waste through continuous improvement”, and reliant on people. The current developments of Lean, which are often related to, but not limited to Services and knowledge work, are a departure from the notion that value is created when internal wastes are eliminated, to expand the definition of the value proposition to the customer. The currently expanded view is that value to the customer is also increased, when additional features or services are offered, and, which do not generate additional costs (Hines, Holwe, & Rich, 2004).

11.2. Six Sigma

The Six Sigma methodology, derived from statistics, where the Greek symbol sigma represents the standard deviation of a population, and ranges from 0 to 6, where the highest value represents the lowest deviation. Typically, the term Six Sigma represents a statistical methodology used to measure and analyses processes, focusing on reducing process variability. Statistically, six sigma, which is the maximum measurement on the scale commonly used, represents only 3.4 defects per million opportunities in processes (Michael Brassard, Finn, Ginn, & Ritter, 2002).

The Six Sigma methodology started in the 1980s, when American industries realized that they were losing competitiveness to Japanese manufacturers, not only because of price competitiveness, but also because of the quality of American products. That was the moment they started to visit Japan to learn how to improve their processes. The quality of the products needed to improve to compete with Japan. Especially the microprocessor manufacturers such as Motorola, suffered the consequences, because the chips, as well as tiny, were numerous, and could not be individually tested before being installed into electronic appliances and computers due to the complexity and costs of such tests. However, the end products were defective due to chip defects.

Tennant (2001) explains that Six Sigma was developed at Motorola, in America, after benchmarking visits to Japan, where SPC techniques were used in conjunction with other Total Quality Management (TQM) tools to develop a methodology for continuous improvement, which sought to drastically reduce the incidence of "defects" in products. Internally, it came to being known as Six Sigma, because the goal was to reach levels with the minimum acceptable defects in the processes.

The development of the methodology had a big impact on the few large American industries that had adopted this methodology, to the point that General Electric defined Six Sigma as one of its business strategies in 1995. Combining various tools and techniques to improve processes within an organization and based exclusively on statistical data for process analysis and control, was a way to bring the Japanese vision of continuous improvement to the American industries, in order to improve product quality and customer satisfaction as a relevant indicator.

Much more than just the disciplined application of a sequence of tools within the methodology, Six Sigma needed a strong cultural change in organizations, as each process came to be seen as a customer of the previous process, or as a supplier of a subsequent process, and needed to achieve low defect rates, to obtain customer satisfaction.

The successful companies in incorporating these changes reaped the benefits, since one of the paradigms changed, was that it was not enough to have satisfied customers, but to achieve those goals with profitability. There was a need to deliver value to the customer, through quality, but also to the shareholder, with profitability. As a result, companies began to reverse quality issues and sell more, as well as offer better returns to their investors. The robust 5-step process, following the sequence

Define, Measure, Analyze, Improve and Control (DMAIC), if properly applied, ensures results in almost all processes, and requires training of all levels of workers using this methodology.

The companies with the best results tend to be those with the highest trained contingent, as the philosophy and culture of Six Sigma are integrated in all actions, due to the culture of the use of statistics and facts to pragmatically evaluate the processes and achieve constant improvements. The Industry 4.0 is the union of several technologies that allow seamless integration between physical space and virtual space. The virtual space will use information collected directly from the physical space, through sensors. This data will be used to model the actual behavior of the machines and from there they will return to the machines as a response in actuators or in their control parameters. This section deal with technologies that will enable the integration of physical and virtual worlds, here treated as Physical Systems (PS) and Virtual Systems (VS).

11.3. Lean Six Sigma

Lean Six Sigma is the combination of Lean Manufacturing and Six Sigma methodologies (George, 2002). Again, the American company General Electric (GE) is attributed the vision of having combined Lean with Six Sigma. Recognizing that Six Sigma reduced process defects but did not focus on waste, GE leveraged its use of Six Sigma by combining it with Lean's tools and vision in using the methodology. The results achieved were expressive, since the visions complement each other, potentiating the efforts of continuous improvement, reducing defects and waste simultaneously.

The success of Lean Six Sigma implementation, rather than individual methodologies, requires a comprehensive training of employees, including leadership, to achieve the required level of culture that ensures continuous process improvement through day-to-day application of concepts by all workers, with the discipline and diligence taught by the Japanese in Lean Manufacturing, and the pragmatism of using SPC and facts, not inferences, from the Six Sigma methodology.

11.4. Industry 4.0

Capitalism goes through its newest transformation or industrial revolution, better known as Industry 4.0, which originated in Germany in 2010, when the German Government launched a proposal to change the status quo to a new level of innovative production known as intelligent industry.

This model promises to change the productive status quo by modifying the way goods are produced and services offered around the world with real implications in value chains worldwide. The new model uses new tools such as intelligent manufacturing, Internet of Things (IoT), cyber-physical system (CPS), Big Data & Analytics, sensors, among others. These are new concepts that will modify the reality of the factory floor, the man-machine relationship, production and consumption, value chains, physical and digital space, productivity, communication between machines, with a greater degree of automation and integration, flexibility of manufacturing, among others.

According to (Reiner, 2014), Industry 4.0 is "a strategic approach to the integration of advanced control systems with internet technology, which enables communication among people, products and complex systems". According to the Kagermann, Wahlster, & Helbig (2013) sponsored by the German Government, this new revolution will bring greater flexibility and robustness, as well as high-quality standards in engineering, planning, manufacturing, operation and logistics processes. Among the technologies that will bring a great impact on the production system, it is worth highlighting: the Internet of Things, Cyber Physical System, Big Data and the sensors.

The manufacture enabled for the IoT refers to an advanced principle in which typical production resources are converted to the manufacture of intelligent objects capable of detecting, interconnecting

and interacting with one another to automatically and adaptive manufacturing logic (Zhong, Xu, Klotz, & Newman, 2017).

On the other hand, the CPS corresponds to the union of the physical and digital environment, and can be defined as the integration of physical processes with computing, where physical processes are controlled and monitored by computers and embedded networks (Hermann, Pentek, & Otto, 2015).

12. Technology Enablers in Industry 4.0

The Industry 4.0 is the union of several technologies that allow seamless integration between physical space and virtual space. The virtual space will use information collected directly from the physical space, through sensors.

This data will be used to model the actual behavior of the machines and from there they will return to the machines as a response in actuators or in their control parameters. This section deals with technologies that will enable the integration of physical and virtual worlds, here treated as Physical Systems (PS) and Virtual Systems (VS).

12.1. Cyber-Physical Systems (CPS)

The CPS refers to a new generation of systems that enables the integration of computational and physical capacities with human ones (Chen, 2017). According to Tao & Zhang, (2017), the convergence of physical and virtual space in industries can be divided into four phases. In the first phase, only the physical space exists, and all depends on a physical action. In the second phase, virtual space begins to exist and to be improved.

In the third phase the interaction between the physical and virtual spaces begins, and in the fourth phase, there is a total integration, in such a way that an action in one space results in an event in the other. This total integration is called the Digital Twin System (DTS). The DTS consists of four elements: Physical System (PS), Virtual System (VS), Shop-floor Digital Twin System (SDTS) and Shop-floor Service System (SSS) (Tao & Zhang, 2017).

The data are taken from the PS and sent to VS, where a comparison is made with the virtual models. SDTS manages PS data and comparisons generated in VS and feeds back into SSS where it interfaces with industry management systems such as Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES). In the same way, the SDTS can, from the comparison of the results, return to the PS with the action request. That is, in DTS data travels in all directions generating actions that are reflected in both the PS and VS.

12.2. Internet of Things (IoT)

One of the technologies that enables the existence of a DTS is IoT. As an application in an industrial environment finds different conditions, depending on the type of industry, a specific term was created for IoT applied to Industries: Industrial Internet of Things (IIoT). IIoT refers to the integration and connectivity between machines, devices, humans and resources through a network of sensors and software for industrial and operations purposes (Chen, 2017).

What differentiates IIoT from machine to machine (M2M) is that in IIoT this communication is intelligent and autonomous, enabling systems to feel, decide and act. IIoT and CPS technologies have enabled unprecedented industry integration, with CPS as the backbone for IIoT implementation.

As a result, manufacturing control systems have become capable of processing a large amount of data, information, and knowledge in real time, taking these systems from an intensive information model to an intensive knowledge model.

12.3. Sensors

Sensors are essential devices for the existence of IoT, as they allow the digitization of the physical aspects inherent to each system. These have evolved from basic sensors to intelligent sensors, causing a revolution in how these physical aspects are collected, analyzed and distributed to intelligent systems (Lebsack, 2017).

One of the main drivers for the development of smaller and cheaper sensors has been the smartphone industry. On the other hand, the access to cheap sensors allowed the development of intelligent systems capable of being integrated in any application (Derrick, 2017). These intelligent sensors are formed by three blocks: 1 - the sensor device, which measures a physical parameter of the real world, 2 - a computational block that analyses the measurements made, and 3 - a communication block that exports the information to a larger and smarter system.

12.4. Big Data Analytics (BDA), Artificial Intelligence (AI) and Machine Learning (ML)

The big data in a smart plant mainly includes real-time data from sensors, machine registration, and manufacturing process data, which has a large volume, comes from multiple sources and has value (Santos et al., 2017).

Big Data Analytics can be understood as the process of extracting knowledge and information from a large amount of data, discovering hidden clusters and their correlations so that systematic patterns can be recognized and a better decision is made (Chen, 2017). While the BDA extracts knowledge from data exported by the PS, the AI, through ML, processes the knowledge to decide, in an appropriate manner, what action must be taken by the system (Ahuett-Garza & Kurfess, 2018).

13. Industry 4.0 and Lean Six Sigma

Although Industry 4.0 is an initiative that aims to give machines autonomy and intelligence, it is not mutually exclusive with Lean Six Sigma. On the contrary, the use of Information and Communication Technologies (ICT) will allow all entities of the value chain to be identified and communicate autonomously to create a better interaction with employees and business partners (Sanders, Elangeswaran, & Wulfsberg, 2016).

According to Kolberg & Zühlke, (2015) Industry 4.0 seeks the optimization of the value chain through the implementation of autonomous and dynamic production. This autonomous production will use CPS and IIoT as core technologies, which will allow a major advance in manufacturing productivity by expanding the capabilities of products, machines, and people.

In addition, the large amount of data collected by Big Data facilitates and drives the work of Lean Six Sigma in the search for complementary optimizations, through the availability of information, which was previously difficult to obtain. The maximum use of this synergy will fundamentally depend on people's skills, aiming to adapt the culture to a new vision through the integration of Industry 4.0 with man, and its capacity for holistic analysis and application of Lean Six Sigma in this new environment.

13.1. Smart Operator

Operators use Lean Manufacturing tools such as Andon to visualize status and improve time reaction to maintenance and quality issues in production lines. In Industry 4.0, machines equipped with appropriate sensors monitor failures, productivity and functionality by comparing PS results with VS

results in DTS. The system then alerts the operator via virtual reality (VR), by sending a notification that can be received on a smart watch or tablet, or via augmented reality (AR) using a smart glass.

The operator can act from the alerts decreasing the time between the occurrence and the notification. In this way, the operator is free to focus efforts on the activities that generate value added to the product, resulting in an increase in productivity. Factory learning is also using VR for learning with the Virtual Reality Learning Environment (VRLE).

The VRLE satisfies different operator needs, such as knowledge, understanding, simulation, application, and creativity (Rodriguez, Quint, Gorecky, Romero, & Siller, 2015), which reduce the defect rate by training in a controlled environment or even redesign process steps using Lean Six Sigma techniques prior to physical implementation.

13.2. Smart Product

Lean philosophy takes care of the material positioning at the process station to improve productivity and reduce assembling errors. The products in the Industry 4.0 era carry configurations and manufacturing information that is communicated to the autonomous manufacturing units.

Therefore, these products can be assembled in lot sizes as small as one, as they will inform the manufacturing unit what the manufacturing sequence is and what materials should be used. An intelligent product is also able to collect information during and after its production and during its life cycle, to be used to improve the product (Kolberg & Zühlke, 2015) which, for instance, can be done using Six Sigma methodology.

13.3. Smart Machine

Lean philosophy uses Kanban to control the right code and quantity to be delivered to a production line. The new generation of machines are already able to communicate directly with the stock to inform the materials used (electronic Kanban), request replacement of items (Just in Time - JIT), inform the lost amount of materials by failures and the quantity that will be returning to the stock, eliminating the need to count material on returning to stock. Lean philosophy uses Single Minute Exchange of Die (SMED) to reduce setup time, while intelligent machines in the Industry 4.0 era can self-configure themselves according to the product information making the production lines more flexible, dynamic and optimized.

Furthermore, machine-learning algorithms, enhanced with inputs from analysis made with Six Sigma methodology, compare individual performances over time, with the performances of the machines in groups, contributing to the optimization of production, improving the quality and availability of the machines.

14. Conclusion

Lean Six Sigma powered by Industry 4.0 digital technologies such as Cyber-Physical Systems (CPS), the Internet of Things (IoT), Sensors, Big Data Analytics (BDA), Artificial Intelligence (AI) and Machine Learning (ML) will improve your application and increase visibility for human resources in problem solving, fault identification and overall efficiency improvement.

Lean Six Sigma has an opportunity to enhance its performance, since CPS enables the communication and transmission of data from all entities of the value chain. This data, analyzed by Big Data Analytics and processed by the algorithms of machine learning, will allow the knowledge of previously unknown aspects, when compared to the conventional methods of data analysis. Still, autonomous machines eliminate waste by reducing setup, decreasing failures, communicating with systems and operators by eliminating steps.



The training of the people who work in Industry 4.0 will be fundamental to succeed in the necessary cultural adaptation in this new environment, where man will work in a digital environment, with access to data in quantities and qualities about the industrial process never seen before in history.

The present study is not conclusive on the subject. So further research is called for to verify the needs of adaptation of human resources, with emphasis on training, to this new interaction between Lean Six Sigma and Industry 4.0. Furthermore, the new interactions between the new technologies of Industry 4.0 and Lean Six Sigma can also be better exploited.

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Industry 4.0-based improvement of the Lean game by using the innovative decision support system

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Abstract

The Lean Learning Factory is used for the education of industry employees and students in the environment similar to the real factory shop floor. The education process has to be adapted to the increasing variability and changeability due to demands for personalized products in practice. By applying a concept of integrative procedure for management of production and service improvement process on the didactic lean game, it is decided which concept will be developed that will assist trainers during a simulation run. The simulation manual data gathering process and the simulation run results presentation require a large effort of the educator. This disadvantage is even more emphasized if slightly different or personalized products is to be assembled in one moment during the simulation run. The main aim of this research is the application of the developed decision support system within a defined procedure for the selection of the optimal improvement variant. It is based on the multi-criteria decision-making with the help of the HUMANT algorithm and Web application user-friendly interface for defining decision-makers preferences. The system is presented and tested. The decision has been presented. It is decided to use an application of Industry 4.0 concept related equipment, RFID readers and tags for real-time data gathering and automated analyzing and preparation of the gathered data for presentation.

Keywords: decision support system, improvement process, lean games, data gathering system, Industry 4.0-based equipment development, Learning Factory

Introduction

A production of personalized products according to the demands of the customer is encouraged by globalized market, ICT technologies and supply chains that are effectively organized which results in low transportation and delivery costs. On the other side, production of personalized products and configured products in low volume / high production mix, put additional effort to production planning and control department to organize

production shopfloor in an efficient way. The knowledge from academic institution about new and emerging organizational methods and technologies could be transferred to industry by the utilization of a Learning Factory concept. The Learning Factory (Tisch et al., 2013) is one of the two most common approaches to Lean education, another approach is through workshops and seminars on specialized Lean academies (Carvalho et al., 2013; Alves et al., 2017). The Learning Factory concept presents simulation of a real factory environment through specialized equipment. The mission is to integrate needed knowledge into the engineering curriculum by using didactic games and production of real products which presents simplified real processes from industry. The usage of didactic games for Lean education has been well accepted and popular in the academic community (Da Silva et al., 2013; De Vin et al. 2018). The learning environment is established in one laboratory at the University of Split, Faculty of electrical engineering, mechanical engineering and naval architecture (FESB). It is named Lean Learning Factory (LLF) and it represents a simulation of the real factory through specialized equipment, specially designed to demonstrate and to teach Lean tools and methods. A laboratory is the learning environment not just for students but for engineers from manufacturing and service enterprises. The improvement process of one didactic lean game within LLF is presented in this paper. By developed integrative procedure for management of production and service improvement process, it is decided which concept will be developed that will assist trainers during the simulation run.

Background

The Croatian economy is still burdened by previous economic system inherited anomalies and some transitional problems. The most evident one is low productivity additionally burdened by a great number of employees and obsolete technology. A lack of products and services demanded by developed and globalized markets resulted, besides other problems, with enormous foreign debt. Public companies privatization, which is a prerequisite for sound market basis establishment and prospective growth, has not been successfully implemented. Most public companies completely disappeared in the privatization process, and those that managed to survive, have undergone numerous recovery programs or have gone into liquidation. In these conditions, small and medium-sized enterprises development has not been supported by big industrial systems. Therefore economic development has been mostly turned to the service sector, especially tourism. Cooperation between economy and science is still rather weak, and the accompanying infrastructure required to support technological development and innovations was developing rather sluggishly. Taking all this into consideration, in the lack of a unique and commonly agreed economic strategy, individual implementation of Lean management in companies, including companies in European funded project, could be a turnaround to a successful economic development for a number of companies.

Among different national and European funded projects that were, or still are in execution phases, a research group from FESB, leads the project funded by Unity through Knowledge Fund in 1C My First Collaboration Grant call, named "Development of integrative procedure for management of production and service improvement process". Project acronym "DEPROCIM" is chosen. Besides FESB as a leader partner, University of Mostar, Faculty of mechanical engineering, computing and electrical engineering from Mostar, Bosnia and Herzegovina, is co-leading academic institution. The research proposed in this project is focusing on cooperation with partners from industry in order to define and apply the procedure for management of production and service improvement process. This project aims at the application of results within the industrial sector, which is, with the share of approx. 20% of GDP, very important to Croatia.

The results of the project proposal, i.e. developed procedure, will be implemented and tested in form of pilot project in four companies. The first company, which is from Bosnia and Herzegovina is FEAL Ltd. It is also co-founder of the project, with the total of 20% matching funds in the total project budget. Additional three Croatian SME enterprises were included as project partners for from Croatian. The first one is Končar - Power Transformers Ltd. in Zagreb with 607 employees. The second one is Dalstroj, Plc, SME medium-sized enterprise, which is a manufacturing company with 83 employees. The third one is Service Center Trogir (SCT) Ltd., SME medium-sized enterprise, which is yacht marina and repair/maintenance service for all types of vessels, with 120 employees. As LLF was already established prior to the start of DEPROCIM project, it is decided that the developed procedure will be tested and validated on one Lean didactic game in LLF. Therefore, DEPROCIM project will be used to improve the didactic part of LLF.

The establishment of the didactic part of LLF has been encouraged by project European Initiative on Learning Factories and project Network of Innovation Learning Factories (NIL) financed by Deutscher Akademischer Austauschdienst German Academic Exchange Service (DAAD), in which FESB took part (Tisch et al., 2016). The LLF laboratory (Fig. 1) is equipped with didactic and real products production and assembly lines for demonstration and learning of Lean tools and methods.

Equipping process in LLF is continuous and it started in 2011. During project named Master studies programme and continuing education network in Product Lifecycle Management with Sustainable Production 144959-TEMPUS-2008-IT-JPCR server and eight personal computers are financed, including 80 licenses for PLM software Siemens (NX, Technomatix and Teamcenter) (Gecevska et al., 2010). This gave opportunities to engage students for problem-oriented projects with the possibility of manufacturing, assembly and implementation of designed equipment. Together with the 3D printer, small machine tools and 3D scanner currently installed in the laboratory, this computer equipment offers us a support for Lean product development education.



Figure 1 – LLF with computer equipment, didactic equipment and production lines for real products

In next chapters, LLF utilization will be presented, followed by the introduction to DEPROCIM project and application of developed procedure on the Lean didactic game case study.

Lean Learning Factory utilization

The Learning Factory is first presented as the outcome of The Manufacturing Engineering Education Partnership (MEEP), which was formed in January of 1995 (Kagerman et. al, 2014). It was realized as the result of a grant from the ARPA Technology Reinvestment Program in Manufacturing Engineering Education. A total of 43 faculties participated either in program management, course design, Learning Factory development, or industrial advisory board coordination. The specific objectives were the implementation of (Kagerman et. al, 2014):

- A practice-based engineering curriculum - which balances analytical and theoretical knowledge with manufacturing, design, business realities, and professional skills;
- Learning Factories at each partner institution - integrally coupled to the curriculum, for hands-on experience in design, manufacturing, and product realization;
- Strong collaboration with industry - through advisory boards and industry-sponsored capstone design projects;
- Dissemination - to other academic institutions, government and industry.

The Learning Factory's mission is to integrate design, manufacturing and business realities into the engineering curriculum. This is accomplished by providing a balance between engineering science and engineering practice (International Atomic Energy Agency, 2006; Potocki et al., 1995).

The LLF goals are already partially aligned with objectives listed by Kagerman et. al. For hands-on experience, both didactic games and real products development and production are used. Educational modules are embedded in undergraduate and graduate curriculums. The modules are also used during workshops and seminars for industry employees. Besides theoretical knowledge that is transferred through presentations and whiteboard, many Lean methods and tools implementations supported by hands-on experience using different

equipment in LLF are embedded in education process. Beer board game (Forrester, 1961) is used in education for supply chain management tools, demonstrating to the participants how the bullwhip effect can easily occur in supply chains. As a part of product development activities, together with the industrial partner, the electronic version is developed, which is currently in the testing phase. It is more flexible in supply chain configuration and is enormously easier for the educator to lead simulation runs (Gjeldum et al., 2017). The development process of the electronic version was also used for learning purposes as problem-oriented projects to be solved by students. Another game is developed using a bunch of toy trucks and toy formula cars which can be easily assembled. Besides line balancing process education, the assembly process can be schematically expressed, analyzed and improved by using this game. Besides those, some other simple games, spreadsheets and paper boards are used.

With the effort to make the hands-on learning process more familiar to industry employers, assembly stations and conveyor lines for gearbox assembly have been developed. Complete gearboxes, originally from FIAT 128 and its succeeding models, are used to show learners effect of numerous tools and methods for improvement and resolving assembly, warehousing and inbound logistics problems. Company “BeeWaTec” from Germany, donated and equipped supermarkets for assembly stations. Real assembly stations and tools for complex product assembly, together with real products for assembly, gives the opportunity to learners for further development of balanced assembly lines, assembly documentation and procedures, conveyor system or other transport system, clamping tools, measurement procedures and quality assurance tests. The complexity of the assembly process of the whole gearbox is too high and time-consuming. Therefore, continuous improvement of the assembly line, simplification of gearbox parts for easier assembly and elimination of many steps which have to be done are performed.

In order to promote domestic legacy and fit the diversity of products, LLF developed a version of Karet, which is, generally, a toy used for descending down the slope. As Split city terrain configuration is hilly, Karet was used for generations for play and for transportation of load down the slopes in some cases.

For both real products used, gearboxes and Karet, students took part in design, simulations, selection of concepts or equipment and realization of production and assembly line. Students were included in the design of karet. Intensive students involvement is done through graduate thesis and individual projects related to courses. Therefore, it could be concluded that the continuous development and improvement of LLF can be considered as a Learning Factory realized objective.

The most used hands-on simulation in LFF is didactic game “Lego flowcar®”. It involves methods related to efficient warehousing and logistics systems and balanced workload on assembly stations for different game scenarios. Methods for information flow optimization are also included.

Currently, original Lego flowcar® is modified in means of initial process workloads, warehousing system, number of participants and many other aspects. The number of iterations is set to two or three, depending on an available time frame for the simulation runs. In order to have equality of participant skills for different iterations, the worm-up period is provided, where participants can practice to assembly cars from Lego bricks without time frame defined. In the most cases the final goal is to produce 10 toy cars per team as fast as possible (Fig. 2.). Competition is also formed, between three or two teams, depending on the number of participants.



Figure 2 – Toy cars assembled as a results of the three teams competition simulation run

The initial layout configuration is shown in Fig 3.

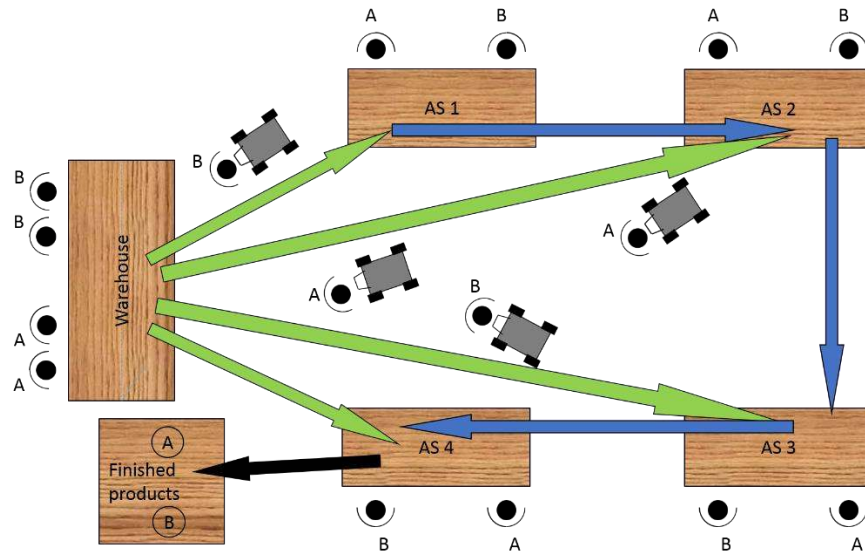


Figure 3 – Layout of initial assembly line with two teams

Symbols with letters A and B (Fig. 3) represents participants in two teams, A and B. Rectangles presents tables, and arrows present material flow. There are three types of material flow, from warehouse to every assembly station (AS) for bricks (green arrows), from assembly station to succeeding assembly station for subassemblies (blue arrows) and from assembly station AS4 to the warehouse of the finished product (black arrow).

The simulation run can last up to 20 minutes, and one trainer cannot monitor all processes, repeat the already explained rules in first moments of the simulation to participants, and monitor finished products for lack of quality. Therefore, one or two additional technicians are often included to gain as much data they can in a given period of time. Nevertheless, increased number of simulation trainers results with different observations and conclusions, which has to be discussed at the end of the simulation, and prepared to be presented to participants. It often takes the necessary time to draw graphs and to write necessary data on the whiteboard, to be discussed with participants in details.

At the end of the discussion, generally few participants are not satisfied with concluded remarks, and they lose interest in next simulation iteration. It is common between participants to negate observations that are compromising their perception of their own abilities. They are trying to switch guilt to some other participants in their team, as they are not considering the whole process and their role in it on objective manner. It is found that simulations with more than one trainer increase the satisfaction of participants and finishes with a short and constructive discussion on how to improve the current assembly process. The main reason is that more data is written on the whiteboard that convince all participants in process duration times, waiting times, delivery times, problems with logistics and warehousing etc. The disadvantage of this practice is an engagement of several trainers instead of one.

As Lean game strategy and simulation runs through iterations show very good results, which are convincing about advantages of Lean methods implementation, the sequence of this didactic game does not need to be improved. Final configuration and reallocation of employees often resulted with more than 85% reduction in batch production time. But, the trainer activities, e.g. data gathering process and presentation preparation time need to be improved. The additional effort of trainer occurs when variability or changeability is introduced in the assembly process. Generally, the Lego cars are all the same shape, size and colors in the simulation. But, when the request to slightly different Lego car to be assembled occurs, the participants react on the different way and in different moments during the simulation run. Realization of the requested variant should be monitored in detail for gathering of the precise process and waiting times to be presented. Naturally, participants instantly preplan all processes to finish the special requested Lego car as soon as possible, which is not a case in the real environment. In the case of preplanning, data gathered are not correct and do not reflect the real production process. Therefore, to avoid this, besides higher variability, changeability is also planned, with trailers of different shapes besides cars. This will improve the lean game in terms of product personalization, but it will additionally burden trainer.

Therefore, some new strategy or assistance system should be developed and engaged. It should provide data gathering of individual process times, waiting times and lead times. In the end, the system should have analysis possibilities, with the fast transformation of the gathered data and presentation in form of graphs. The selection of the optimal system that can be realized with satisfying outcomes presents a problem which cannot be solved easily. Therefore, in this paper, the developed procedure within DEPROCIM project and its Multi-Criteria Decision Making (MCDM) algorithm will be applied to the given problem.

DEPROCIM project procedure application

Continual improvement of production and service processes consists of small incremental and breakthrough improvement steps that require large investments. Lean management concept is understood as the realization of Lean principles through the efficient application of methods and tools in order to detect and eliminate waste in production and service processes. Although implementation of Lean management methods and tools does not require significant investments, a negligible number of Croatian companies implemented it. Previous studies indicate a need for further research to assist Croatian companies in Lean management implementation toward finding their way of improvement for efficient production or service systems. The research proposed in this project is focused on the implementation of procedure in partners' organizations. But the developed procedure and MCDM algorithm should be validated in the laboratory environment. Therefore, the didactic game presented is used for the case study in laboratory environment.

The developed integrative procedure for management of the continual improvement process consists of four main procedure steps. The first step is gathering the process data for mapping purposes. As the data gathering and the presentation process performed by trainers should be mapped and improved, process data are gathered by observations of trainer activities during the simulation runs. Observations showed lack of trainer time to record all necessary data generated during the simulation run. Addition period of about 15 minutes is necessary for the preparation of the quality presentation. Therefore, trainers often resort to whiteboard presentation with a minimum amount of data, which reduces the quality of presentation and prolong successive discussion with participants. If the presentation is done on a whiteboard, the quality of the drawn graphs and readability of the data is low. On the other side, limitations in the whiteboard size reduce flexibility in showing the different data. In Fig. 4. it can be seen how whiteboard could look like after long discussion on results.

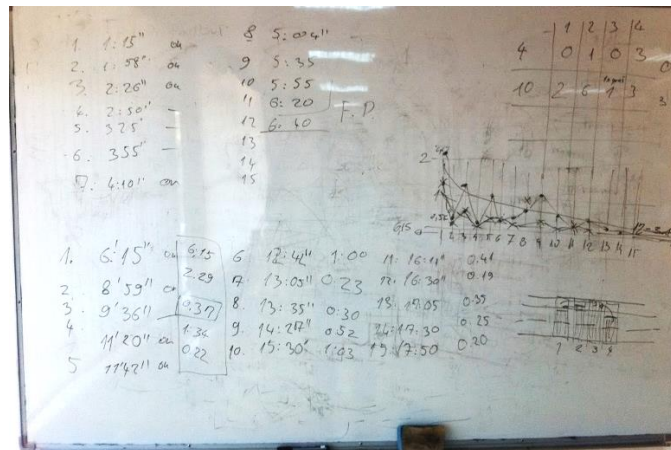


Figure 4 – Whiteboard after data gathering and discussion

In the second procedure step, mapping of processes and detecting needs for improvement take place. This is one parallel process to the simulation run that is followed by another single process, which results with data and graphs presentation. Therefore, mapping of the process is not required in this case.

In the third step, the implementation of different possible improvements is simulated in order to evaluate the impact of organizational and technology changes. Analyzing the available solutions on market, elaboration of concepts, calculating the total costs, spreadsheet simulations and constraints considerations present an exceptional effort. Those steps are not presented in this paper. The expected performance and other data of different systems which could be developed and realized are shown in Table 1. This table represents the input

data for the fourth step, which will utilize an innovative multi-criteria decision making a support system for prioritization of proposed improvement processes.

So, in the fourth step, the prioritization of the proposed improvement variants, or alternatives, and selection of the variant with the highest priority, or among the highest priorities, will be made by using the HUMANT algorithm. The HUMANT algorithm supports decision-making in the problems with multiple objectives or multiple criteria (Mladineo et al., 2015). In this research, it has been applied onto evaluation and ranking (prioritization) of the proposed improvement variants by taking into account six different criteria.

The improvement variants' evaluation table (Table 1) represents an input data for the HUMANT algorithm. However, these data are objective data on the improvement variants, and the missing data are the preferences of the subjective decision-maker. By defining the decision-maker's preferences, a subjectivism enters the analysis. This subjectivism is crucial because decision-maker (production manager or technology director) can assign his/her subjective weight to each criterion, depending on the strategy and possibilities of the company. For instance, if the company is willing to invest a lot into production improvement solutions, then criterion "price" gets low weight because the company will spend as much as needed to improve their production. On the other hand, sometimes a low-cost improvement is needed, and in that case, the criterion price will get a high weight. So, this subjectivism is something really important in this step of the production process improvement. In order to facilitate the definition of the criteria weights, the user-friendly interface (Web application) was designed (Fig. 5) as a part of the DEPROCIM project.

Table 1 – Improvement variants (alternatives) with their cost, reliability, and other attributes (criteria)

Improvement variant (alternative)	Variants' attributes (criteria)					
	Price EUR/year (10 runs)	Reliability (1-10)	Upgradeability (1-10)	Functionalities (1-5)	Resources for analysis (workers)	Time to delivery (worker- days)
Variant 111	172	6	4	2	4	1
Variant 122	304	8	6	2	4	4
Variant 123	212	8	6	2	4	2
Variant 125	244	8	6	2	4	2
Variant 132	204	6	4	2	4	2
Variant 134	238	6	4	2	4	3
Variant 135	222	6	4	2	4	3
Variant 222	268	8	7	3	1	9
Variant 223	176	6	7	3	1	7
Variant 225	208	6	7	3	1	7
Variant 322	265	4	7	3	1	11
Variant 323	173	4	7	3	1	9

Variant 325	205	4	7	3	1	9
Variant 422	496	9	10	5	1	10
Variant 423	404	9	10	5	1	8
Variant 425	436	9	10	5	1	8
Variant 432	394	7	10	5	1	8
Variant 434	418	7	10	5	1	9
Variant 435	412	7	10	5	1	9
Variant 532	444	6	7	3	1	20
Variant 534	462	6	7	3	1	21

In this research, the didactic game in LLF is used for testing the presented approach for the improvement variant selection. First of all, a table with possible improvement variants and their implementation type, cost and other attributes is made (Table 1). The variants are possible developed concepts approved by brainstorming, that they are feasible. The attributes are selected by the decision maker, and the values for every variant is done by observations, calculations and simulations. Both variants and attributes can be changed or updated. In this case, six attributes represent six criteria for multi-criteria decision-making procedure: price EUR/year (10 simulation runs are planned annually in LFF), reliability (1-10), upgradeability (1-10), functionalities (1-5), resources for analysis (workers), and time to delivery (worker-days). The HUMANT algorithm takes these criteria into analysis together with decision-makers preferences (criteria weights) defined by using the user-interface (Fig. 5).

The algorithm selects optimal improvement and the following variant or variants with the highest priority. Decision-maker is enabled to select the final one among these two variants in this case.

However, some additional attributes are also taken into account as criteria. For instance, the “RFID sensors” have been selected as the variant type and aluminum was preferred as the construction material (Fig. 6). But for both of these additional attributes a preference level (weight) has been also defined. It is a kind of approach already used for the product configuration optimization (Veza et al., 2018).

So, in the end, the HUMANT algorithm selected two variants with highest priorities (Fig. 5): “Variant 423” and “Variant 425”. The “Variant 423” has a lower price, but it also has a steel construction, and, since the decision-maker preferred aluminum construction, nevertheless the steel is cheaper, the “Variant 425” is selected as the improvement variant for this case.

It is important to note, that selected improvement variant doesn’t represent the best solution, but rather the best compromise based on the preferences of the decision-maker. In the multi-criteria decision-making, it is always a search for the best compromise.

The future work will include system realization, programming and procurement of electronic parts. Already, appropriate RFID tags are procured, which can be glued to car chassis. Its size is appropriate and just slightly changes the design of the car (Fig 6). RFID sensors and background software represents Industry 4.0-based improvement, which will be additionally upgraded by more Industry 4.0-based components in future work.

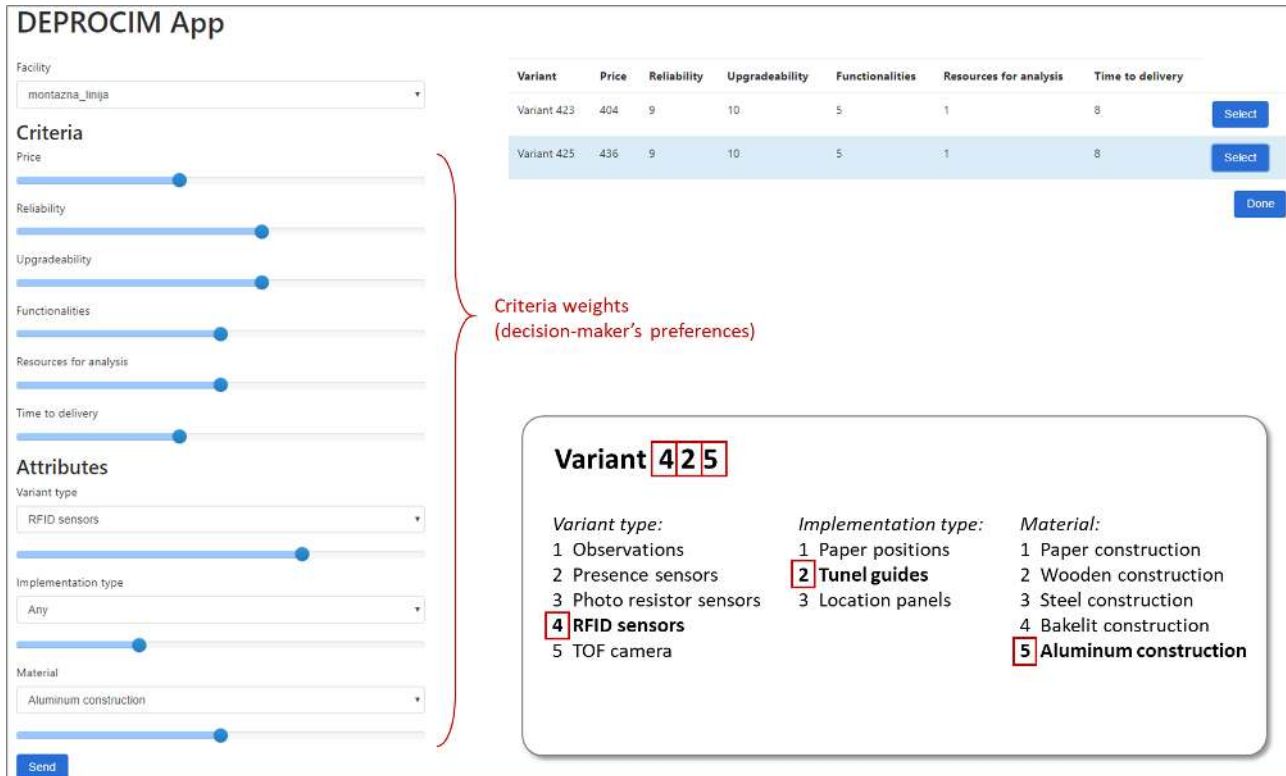


Figure 5 – Web application for the definition of the criteria weights with the results of the priority selection

Nevertheless, of the time frame for the realization of this case study improvement, DEPROCIM procedure is tested and will be implemented in the industry case studies. As seen in for this case study, generalization process of procedure has to be done, to fit to different case studies. In this case study, some simplification is done to first two procedure steps, while the other two were as planned in the project. The procedure itself attend to be iterative. While it will be able to propose the list of activities that should be done one by one, discarding options that are not suitable after preceding improvement steps, it can be used for selecting a one-stage improvement process, as shown in this paper.

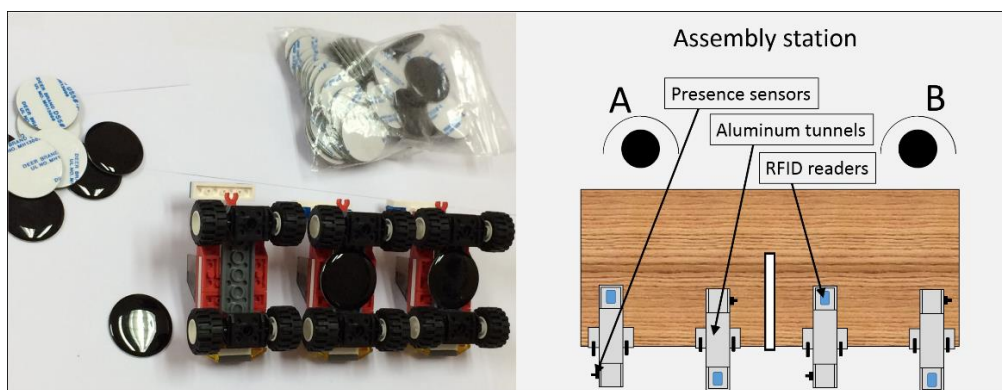


Figure 6 – Position of RFID tags on toy cars and position of tunnel guides on table

Conclusion

Despite the feasibility of didactic game simulation in current form, with one or more trainers, problems with all necessary data gathering on four-stage assembly process and preparation of those for presentation, shown need for improvement. In this research, within LLF environment, the didactic game case study was used. The DEPROCIM procedure solution presented was used to evaluate and select the optimal improvement variant. The variants were evaluated and ranked (prioritized) by using the HUMANT algorithm. The selected Industry 4.0-based variant will be implemented which will improve the education process using this didactic game.

Furthermore, specialized Web application was developed as user-interface. The variant with among the highest priorities is selected, based on the preferences of the decision-maker. These preferences represent criteria weights for the HUMANT algorithm, and improvement variants' attributes represent criteria: price, reliability, upgradeability, etc. The presented approach helps decision-makers to select the improvement variant which is, for instance, the most cost-effective, or the most reliable, or whatever the decision-maker prefers.

Acknowledgement

This work has been fully supported by the Unity Through Knowledge Fund (UKF), 1C My First Collaboration Grant, under the project 11/17 Development of integrative procedure for management of production and service improvement process.

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Industry 4.0: Knowledge and capabilities needed for workers, middle-managers and top managers

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Abstract

Throughout the several industrial revolutions, the evolution of technology and of the production operations was huge and evident. Following this evolution, it was imperative an adaptation from all the participants in the value chain, from the closest levels off the shopfloor to the top managers, both in terms of knowledge and competencies needed to carry out each position and work.

Currently we are facing a new industrial revolution, the well-known era of Digitalization, the Revolution Industry 4.0. We are facing a revolution where all processes and equipment's will communicate with each other autonomously, new manufacturing and support technologies will emerge, where paper will be replaced by IT-flows and man's influence on manufacturing processes will change radically.

An important question that arises is related to the new need for adaptation by the workforce. Is the existing knowledge enough to deal with such Revolution Industry 4.0? Are the competencies required of employees currently suitable? What new knowledge and capabilities should be required to future professionals?

There is no doubt that adaptations will have to happen. Therefore, this research is focused in the study of the new needs of knowledge and capabilities that come with the Revolution Industry 4.0 in the several hierarchical levels, from the workers in the shopfloor, passing by middle and top managers, through the application of a case study.

Keywords: Industry 4.0; Digitalization; Industry 4.0 workforce capabilities

Learning Lean in High-Variety/Low-Volume: Lessons Learned from the EuroLean project and the learning model in the Lean4.0 project

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Abstract

Looking at learning Lean and understanding and solving problems, it seems that between Industry and Academia is a wide gap. The Lean philosophy of flow and continuous improvement is developed in the Low-Variety/High-Volume context of car manufacturing. Most Lean tools are especially applicable in highly repetitive environments. The recently finished EuroLean+ project focused on Lean principles and tools that can be applied in High-Variety/Low-Volume environments. This resulted in a learning platform for operations managers and scholars in operations management. The platform consists of a dynamically extendable collection of best practices and a number of key instruction video's and other educational content on Lean tools that can be used in High-Variety/Low-Volume companies. We will present results from the Erasmus project Eurolean+, it also provides a preview of the just started Erasmus project Lean European Action Learning Network 4.0 (Lean 4.0). The Eurolean+ project was a collaboration of 4 academia: NTNU (Norway), the HAN University of Applied Sciences (the Netherlands), the Hochschule Osnabruck (Germany) and the University of Gent (Belgium), and several industrial partners.

In Lean 4.0, the same academia and a network of industry partners will use the outcomes of EuroLean as a starting point and focus on the question: How to organize a network learning community between industry and academia for the development of the operations function in a High-Variety/Low-Volume environment?. We will focus on the linkage between Lean methods and Industry 4.0 technologies in companies, as the use of (Smart) information technologies will play an important role in future companies.

Our basic premise is that Industry 4.0 solutions will have an important impact on the development of the Lean philosophy and methods (Khanchanapong, et al., 2014; Kolberg & Zühlke, 2015; Gilchrist, 2016). Currently, however, there is no satisfactory framework combining these two areas (Kolberg & Zühlke, 2015). We will develop such a framework in the project Lean 4.0, using the learning platform of EuroLean+ and develop it further to provide a framework for exchange of knowledge. In Lean 4.0 we will also provide a model (a double learning cycle) to bridge the knowledge & application gap between academia and industry. This will improve the cycle of identifying the right issues, developing knowledge, putting the knowledge into practice and learn, and evaluating the developed knowledge. The use of information technology plays a pivoting role.

In the presentation, we will explain the development and results of Eurolean+ (framework as well as learning content). We will also discuss the Network-Action-Learning- model that will be developed and tested in Lean 4.0.

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3.3 Lean Applications

A literature review of Operations Management and Lean Production

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Abstract

The interest in Lean Production in the field of Operations Management (OM) has been increasing. This communication has the objective of characterizing OM from the perspective of Lean, based on papers published in journals indexed in Scopus. The study is based on the combination of a bibliometric analysis of papers from the Scopus database, using terms related to Operations Management, Lean production and the intersection of the resulting sets of papers. Additionally, the papers were analysed based on keywords, analysis of content, and qualitative interpretation from outcomes of text mining and Principal Component Analysis. The analysis confirm a large set of contexts and subjects of Operations Management from the perspective of Lean Production. The countries with the higher number of publications in the intersection between OM and Lean Production are US, UK and Brazil. Using predefined dimensions of Operations Management, the top related dimensions found were 'Planning and Control', 'Strategy', and 'Processes'.

Keywords: Operations Management; Lean Production; Production Planning and Control; Scoping review.

Acknowledgments: This work was partially supported by projects COMPETE-POCI-01-0145-FEDER-007043 and FCT-UID-CEC-00319-2013, from Portugal.

Application of Kaizen philosophy to increase productivity: a case study in an electronics industry

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Abstract

The production line studied is part of a company, located in Polo Industrial de Manaus, being the second largest Contract Manufacturing in the world in the manufacture of equipment for large telecommunications and computer companies. The quotation of the production line of the product under study was elaborated considering the metric of Units Produced per Person per Hour (UPPH) equal to 5.33, that is, the production of 80 pieces per hour using 15 direct employees in the line. However, the line was operating with 2.5 UPPH, producing 53 pieces per hour and using 21 employees. So, the goal of the project reduce the number of line workers by 21% and increase capacity by 29%. With this, the project development methods were based on Kaizen philosophy, the leading lean tool that allowed maximum reach of the goal in just four weeks. For this, on the first stage, data collection and analysis were made and, in the second phase, the action plan was drawn up and the improvement actions implemented. Once established targets were met, the results obtained allowed the elimination of the divergence between labour costs and expected costs, eliminating delays in deliveries caused by low productivity.

Keywords: cost reduction, kaizen, lean manufacturing, takt time.

Introduction

Increasing productivity has become an important goal in almost all organizations and is the key to global competitiveness (Robbins and Coulter, 1998).

According to Gonçalves (1997), companies that are seeking to organize themselves by processes seek greater efficiency in obtaining their products or services, better adaptation to change, better integration of their efforts and greater learning capacity.

The principle of the concept of lean production was derived from the evolution of the concept created by Ford, the production line, which was widely diffused in all parts of the world. In 1921, Ford already stated that something could change in the concept of the development of production, especially when he pointed out that having stock was a waste, what would later be known as just in time, or simply JIT.

Looking at the work of Shigeo Shingo, Neto (2016) argues that the term "just in time" suggests more than focusing solely on delivery time, as this could encourage early overproduction and result in unnecessary waiting.

Lean production has several tools and methodologies, including Kaizen, which consists of continuous improvement efforts, and its central focus is the search for the elimination of waste (Ohno, 1997).

The improvement of the productive processes is necessary because, at present, it is not through the increase of prices that the expected profit is reached, on the contrary, the supply of products is high and the competitive advantage occurs in the price of the final product. To avoid this advantage, companies are working to reduce

costs, at which point high productivity as well as efficient production are gaining importance (Corrêa e Corrêa, 2004).

Literature Review

Lean Productiona

Efficiency in the industry has been addressed since the studies of Ford and Taylor. Efficiency can be achieved by reducing waste and generating maximum transformation into available final products (Prates and Bandeira, 2011). In addition, Japan also made an important contribution, since after the Second World War, the Japanese automotive industry, due to its socioeconomic reality, developed the model of lean production, in order to minimize waste. Eiji Toyoda and Taiichi Ohno were responsible for the implementation of the model and it presented a significant advantage compared to the mass production proposed by Ford (Womack and Jones, 2004).

On the one hand, efficiency can be understood as the efficient use of resources, that is, better utilization of resources, reducing waste and generating the maximum transformation in available final products (Prates and Bandeira, 2011). On the other hand, Maximiano (2006) states that efficiency is the word used to indicate that the organization productively uses, or economically, its resources. The higher the degree of productivity or economy in the use of resources, the more efficient the organization is.

Lean thinking aims to do more and more, with less and less. It is at this point that it resembles efficiency, since they have concepts that induce the same goal. Therefore, in order to eliminate these wastes, lean production is based on the five principles of lean thinking, Womack and Jones (1996), and can be observed in the sequence: value, value flow, continuous flow, pulled output and perfection (Lean Institute Brazil, 2010).

Kaizen

The Japanese use the term kaizen to refer to continuous improvement. Continuous improvement, in turn, is the philosophy that seeks to perfect all the factors related to the process of continuous conversion of inputs into outputs. It covers equipment, methods, materials and people (Stevenson, 2001). Kaizen can help from product quality improvements and productivity. Productivity would be a consequence of improved activities, reducing idle time in certain equipment, especially in activities that demand greater manual needs, where prevails the lack of standardization and lack of technique.

Kaizen also proposes continuous improvement throughout the process chain. Companies would need to cooperate in shifting their methods by forming a lean company to determine the product. Finally, it can be said that kaizen predicts focus on the operation, but also observes the whole process. Womack and Jones (2004) argue that "kaizen is the continuous and incremental improvement of an activity in order to create more value with less change, also called kaizen of the point and kaizen of the process.

According to TBM Consulting (2000), the kaizen philosophy relies on three great concepts, just in time, jidoka and production balancing. According to Sharma and Moody (2003), "JIT is a manufacturing system that produces what the customer wants, in the quantity that the customer wants and when the customer wants, using the minimum raw material, equipment, work and space".

Jidoka is a Japanese word that literally means "automation with a human touch" (TBM Consulting, 2000). Automation is the separation between the machine and the operator, ie the ability of the machine to work without human intervention.

Line balancing allows the optimization of the application of resources, greater efficiency in the processes, guiding the division of tasks according to their execution times, taking into account Takt time and previous tasks. According to Moreira (2004), "the function of line balancing is to assign the tasks to the workstations in order to achieve the production rate so that the work is divided equally among the workstations".

Cycle Time

Cycle time can be summarized as the duration of execution of a given activity. Lean Production seeks equality between itself and takt. Takt is the ideal cycle, based on the need of the market. Womack and Jones (2004)

conceptualize takt time as the available production time divided by the customer demand index. For example, if the customer orders 240 pieces a day and the factory operates 480 minutes a day, takt time will be two minutes; if the customer wants two new products to be designed per month, takt time will be two weeks.

The takt time defines the production rate according to the customer demand index, becoming the pulsation of any lean system.

Operator Balancing Chart

The operator balance graph (OBG) is also known as Yamazumi board. It is used to determine which tasks each operator must perform at his or her job. The activities are divided into operations that add value and operations that do not add value to the product. The takt time line is present as a reference for task distribution and balancing (Gomes *et al.*, 2008).

To build the OBG, the first step is to time each work element separately from the entire work sequence performed by the operator. An example of OBG, in Figure 1, in which it is possible to check the takt time line, the cycle times below takt (operator A, B, C and D), the cycle time above takt (operator E), proving to be a visual tool for verification and analysis of waste.

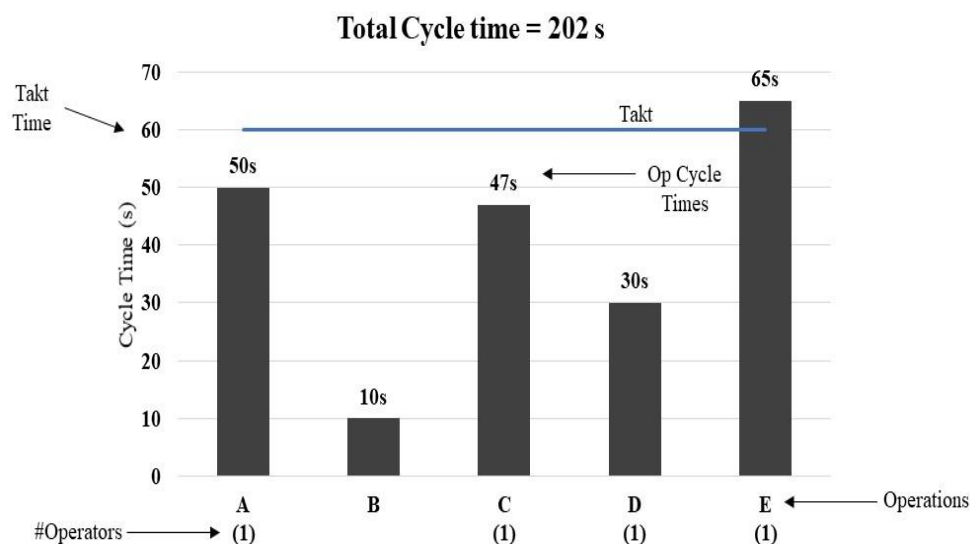


Figure 1 - Operator Balancing Chart, (Tapping *et al.*, 2002).

After the mapping and analysis of the "current state", it is necessary to start the kaizen of all the activities that do not add value in the production line, in order to redistribute the work. When designing the "future state" of the line, one should take into account the improvements proposed during the kaizen phase (Rother and Harris, 2002).

Methodology

The case analyzed was an electronic product manufactured by the company of this study, exclusively in the final assembly part.

The line consists of 8 automatic screwing stations, 1 selective welding station, 10 manual assembly stations, 4 functional testing stations and 3 manual packing stations. The layout of the line is contemplated in Figure 2, and 19 people perform the activities.

The study was conducted during an internal event in the company focused on Kaizens applications and splitted in two phases: process analysis and data collection; preparation of action plan and implementation of improvements.

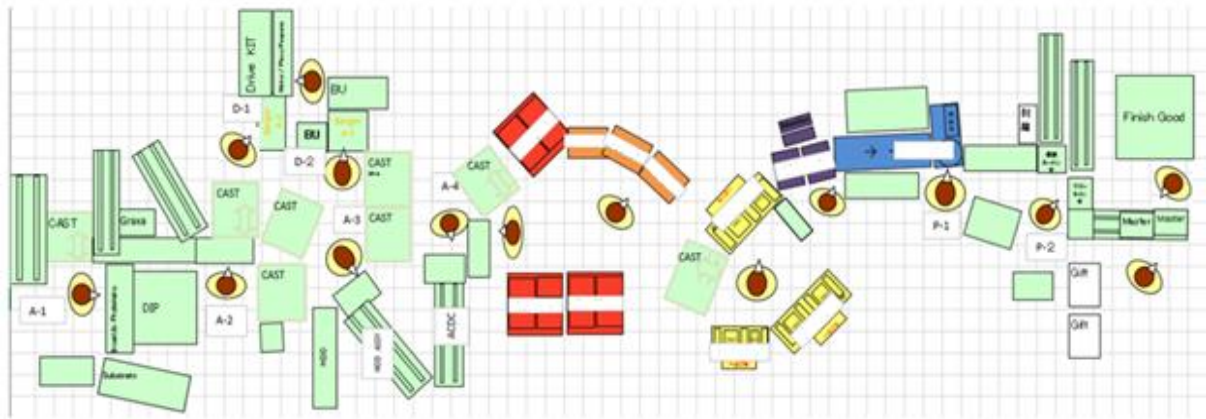


Figure 2 - Layout of production line.

During the data collection phase, all the operations were filmed to facilitate the definition of the individual times of each activity within the same operation and to verify if the activity that was being executed met the criteria of value used by the company:

- **Add value:** the activity adds some indispensable part to the product;
- **Does not add value:** the activity does not change any characteristic of the product and is not indispensable to meet your requirements;
- **Does not add value, but is required:** activity does not add any characteristic to the product. However, it is necessary to evaluate whether the product conforms to specifications, usually test stations.

The chronoanalysis of all line operations was also performed to measure the average cycle time of each operation. We took 10 times of each operation, discounting the times where there was some external punctual interference that did not fit the activity described in the standard working instruction.

All activities performed by the same operator were considered and data from two different operator groups were used, half of the data was measured in the morning group and the other half was measured during the afternoon shift of production.

With this data, the average time of each operation was calculated, and it was then possible to construct the line-balancing chart, considering the cycle times, divided into activity classifications by value, assessing if the balance was adequate and identify the activities.

After identifying the improvement points, a brainstorming with the Kaizen multifunctional team was conducted and the information collected was used to structure an Ishikawa diagram and identify the main offenders. These offenders were quantified and from these data, a Pareto diagram and a plan of action for the correction of them were elaborated. With this, after the implementation of the action plan, the line was monitored for 1 week to assess if the actions taken were effective and if there was support.

Applying Kaizen

Planning Phase (Plan)

During the initial weeks of the project, the data needed to collect and analyze the inefficiencies and waste of the process were collected. The chrono analysis of all the workstations of the line and the balancing study of the operators were carried out. The activity balancing chart was elaborated stratifying which activities add value, which do not add value but are necessary and which activities do not add value.

Based on the Figure 3, it was possible to identify that the activities A0 and A1 could be optimized and unified if the times that do not add value were eliminated and the required times were reduced which would result in the reduction of an operator.

It was also evidenced that station A3 and A3.1 should be unified and the necessary times should be reduced which would also result in the reduction of one operator.

Another significant improvement point would be to remove D2 and D3 from the line that used two operators and to mount a sub-assembly cell with these two combined operations that would be able to provide parts for the two existing lines at the factory, which would result in the reduction of more two operators in the process and would achieve the goal of reducing labor.

In this operation, the opportunity of damage reduction was also identified the printed circuit boards that most of the time had to be discarded. With regard to the low productivity of 51 pieces per hour, it was identified that the biggest offender was the times of equipment stoppage of the production line, from that conclusion an action plan was drawn up to reduce the line stop times.

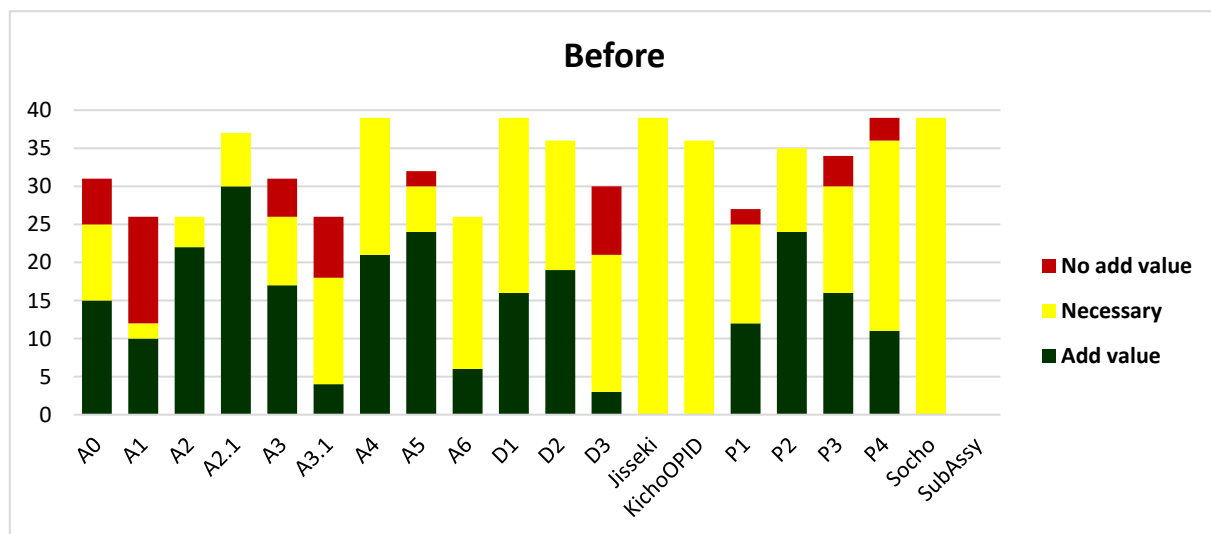


Figure 3 - Balance chart before improvement.

Execution phase (DO)

After the planning and preparation of the action plan needed to make the improvements, a meeting was held with the team to define the disjointed actions of the plan, which team members were responsible and the implementation period, which could not exceed the limit of one week. The follow-up of the activities was carried out in two daily meetings, one in the morning and the other in the afternoon at the end of the day.

The actions implemented at stations A0 and A1 to eliminate the time that did not add value and reduce that one did not add value but was necessary were to reduce the amount of shorts welds that arrived at the station after the selective welding process, for that activity were 3 retouching per plate. However, an average of 8 retouching per plate was performed due to inadequate machine operation conditions. To solve this problem the maintenance team acted directly in the correction of parameters of the machine.

As for stations A3 and A3.1 it was identified that the root cause of the wastes was lack of balancing and excess defects due to the lack of thermal paste that was applied manually in the product.

The actions implemented were the definition of a new standard procedure reducing parts handling and a new layout that allowed to decrease the operator movement and the addition of an automatic dispenser of thermal paste for the line, which ensured the application repeatability and shortened the time operator's manual.

The D2 and D3 stations were removed from the process, and a sub-assembly cell was mounted near the line. The activities were also rebalanced with the D1 station, and a support was developed for products with twice the positions of simultaneous manual welding, which allowed developing the operation more times per cycle and thus decreasing the time of handling and chance of damages the plates. With these modifications, the new cell had its capacity doubled and became able to produce subsets to accommodate the two production lines.

In order to reduce downtime, preventive and corrective maintenance actions were defined in some equipment, better technical qualification for the maintenance team because the product was new and used a differentiated construction structure and stabilization of the compressed air compressor that constantly presents technical problems.

Verification phase (CHECK)

According to company methodology, indicators were stipulated to measure each of the actions taken and to verify if they had been effective during the last week of the Kaizen event.

Hourly monitoring of the occurrence of short welded defects, lack of thermal grease and damaged plate was monitored. It was also checked if the line was running with the 15 people in the new job setup and balancing. These metrics should monitor whether the goal of achieving a UPPH of 5.33 was effective and would demonstrate sustainability throughout the week, with results being reported daily.

Action phase (ACT)

The Kaizen event happens in a very dynamic and speedy way to meet the deadlines, during the action phase it was necessary to proceed with all layout changes, labor mapping and machine specifications that were performed, as well as update all the work instructions altered after the rebalances and create a new working insight for the new subassembly cell.

At this stage, the presentation of the project, as shown in figure 4, was also prepared for presentation at the closing of the event. The payback to the company was calculated and the validation was obtained from the financial sector.

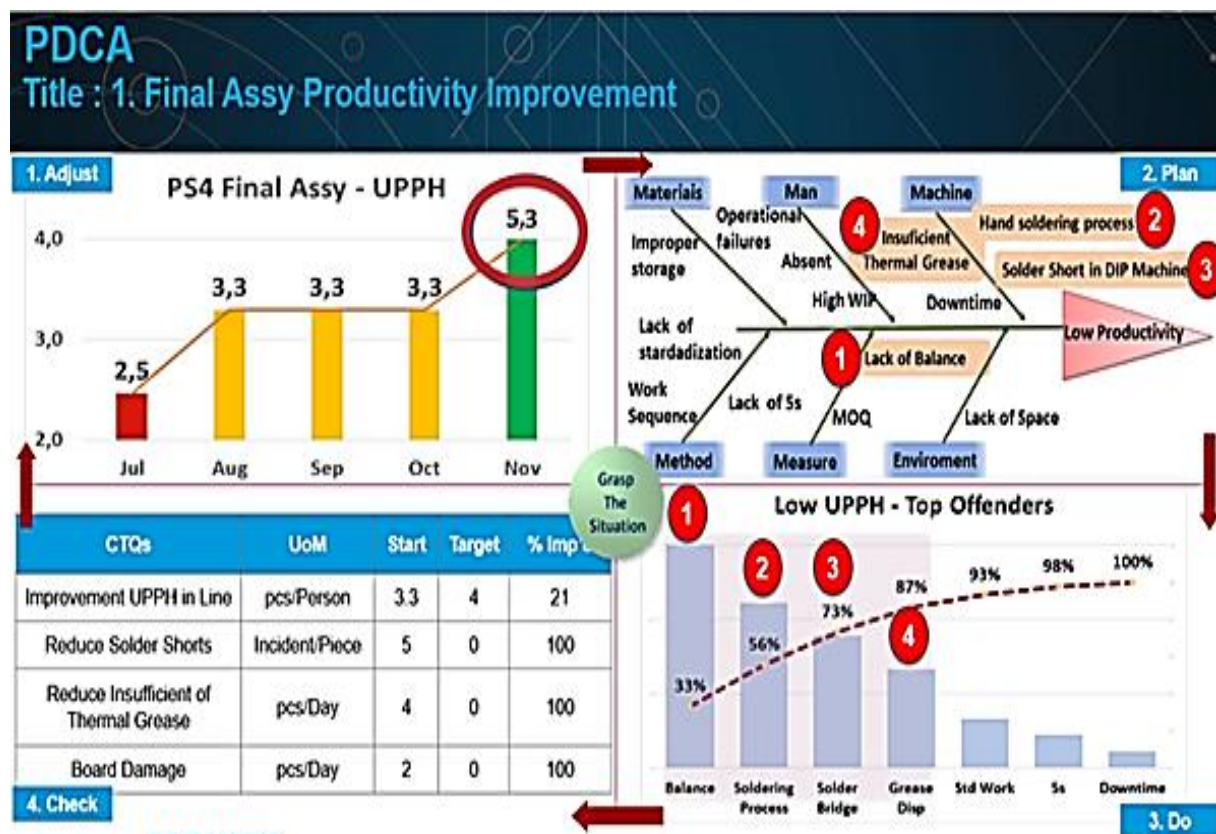


Figure 4 - PDCA.

Conclusions and results analyses

After the adjustments made in the production line, both balancing and identifying losses and completing the actions of the action plan, besides setting up a new layout for the line, we were able to reach the expected: to reach a UPPH of 5.3.

Figure 5 shows the line-balancing chart after implementation of the improvements and the reductions of jobs and activities that do not add value in relation to the initial chart.

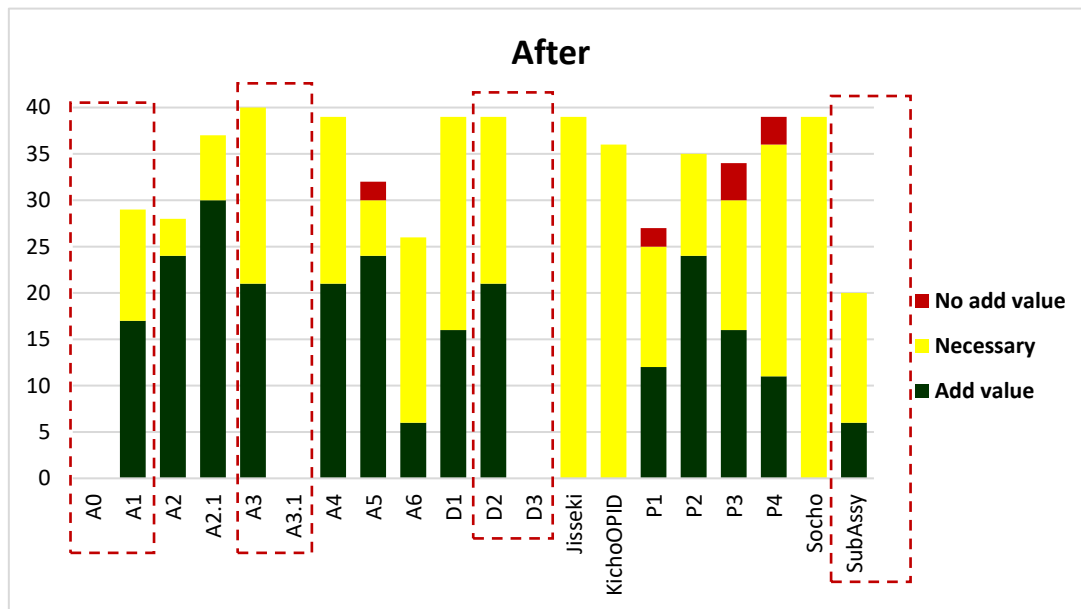


Figure 5 - Balance chart before improvement.

Times that did not add value were eliminated and times were optimized. Stations A0 and A1 were consolidated in a single operation, stations A3 and A3.1 also had their operations added and reduced to a single operation, and the D2 and D3 stations of the two mirror lines were shifted to a cell out of the continuous process which made possible the optimization of labor.

There was a direct labor reduction of 21% and a 29% increase in the number of pieces produced per hour on the production line. These results support the end of the divergence between labor costs incurred with the costs predicted during the quotation of the product and took the company from the delay of deliveries due to the low productivity.

The interventions performed on the machines were very significant for the stability of the process and for achieving the goals of the production plan. It was observed that the actions that involved reduction of defects also contributed to the increase of productivity considering that they reduced the number of pieces that left the normal flow of the process to be reworked.

Implementing a project is always a challenge and teaches us the importance of teamwork, synergy and focus on the result as a whole. This project also provided the incredible opportunity to develop leadership skills during project implementation coordination. It was observed that the correct use of a methodology of continuous improvement has as main result the potentialization of the results before the cases that do not use specific methodology.

It was observed that there are still many stations with significant activity times that do not add value, but are necessary to be objects of future continuous improvement projects, thus seeking to reduce costs within the quoted in order to provide a competitive advantage for the company.

The deadline for carrying out the project was a major challenge and risk for its completion due to the purchase and authorization requirements that have complex and time-consuming corporate procedures and because it is not a time dedicated exclusively to the project, where it was necessary to manage the execution in with day-to-day activities.

The work developed reinforces the strategy of the adoption of tools to improve performance by organizations, particularly those related to lean culture. Based on the results achieved, it is important to create and maintain a lean culture within organizations, as steps to achieve goals more effectively.

Acknowledgments

The authors wish to thank the project partner Amazonas State Foundation for Research Support (FAPEAM - Fundação de Apoio à Pesquisa do Estado do Amazonas) for facilitating this work.

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Improving healthcare quality in an oncology public day hospital

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Abstract

Lean manufacturing has been widely used in service companies even in hospital environments. However, in Spain, and in the public sector it is not widespread, despite the fact that the benefits of the implementation are perfectly documented. The paper explains the implementation of improvements using lean tools that arise from training courses in lean tools. The case presented is about the use of VSM in a day hospital for the care of oncological patients who come to the hospital for treatment with chemotherapy. The current VSM and its analysis and a proposal for a future map, not ideal, but implantable, are presented. As a result of the implantation arising from the use of the tool, there was an important improvement in the quality of patient care, as well as waiting times for patients in the hospital.

Keywords: lean manufacturing, value stream map, lean healthcare

Lean practices to improve the learning process and production document control: a case study

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Abstract

The advent of lean practices has driven changes in organizations, especially by seeking systematic practices to identify and improve processes, helping organizations to consolidate a culture focused on knowledge management, training, capacity building, and discipline, aiming at the achievement of organizational results and to the members of the different teams of the company. The case study developed in this work intends to share the practical results of the adoption of automated document control systems within the productive processes, as a component associated with lean practices adopted by the company studied, which is based in the industrial center of Manaus. The work developed was aimed at disseminating lean practices to better control the process, as well as introducing a culture focused on the adoption of good management practices, from the development of automated work instructions to productive process, allowing the teams' self-development, facilitating the training stage of the respective teams that act in the process. As an additional contribution to the organization, it allowed easy access to information, agility to the document management system, ease of updating versions and elimination of physical documents in the production line, giving contributions to the organization's results in the field of quality management, production and teams.

Keywords: computerized document control, lean culture, lean training, organizational culture, team management.

Acknowledgments: This work was partially supported by projects COMPETE-POCI-01-0145-FEDER-007043 and FCT-UID-CEC-00319-2013, from Portugal.



3.4 Lean Games

An Educational Game for Mixed Model Assembly Line Design Using Lean Concepts

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Abstract

An educational game is developed for assembly line design using lean concepts. The game aims to show the participants that using lean techniques improves the line efficiency. LEGO® parts are used as educational material to simulate the assembly process of a selected product.

The game has four phases: In Phase 1, the participants assemble the entire product individually to get used to doing assembly operations; in Phase 2, working as a team, they design an assembly line with workstations that ideally have equal workload, while in Phase 3, they are introduced to lean concepts (yamazumi, takt time, pull, built in quality, team leader concept) and then they are allowed to redesign the line. Finally in Phase 4, participants create an mixed model assembly line (MMAL), introduce MMAL balancing concepts and enhance Just in Time (JIT) production system in order to use SPS (set part system) material replenishment system.

At the end of the session Key Performance Indicators of Assembly Lines designed in phases 2,3 and 4 are compared to see the effectiveness of lean concepts on line efficiency. This game has been played by several teams from different manufacturing sectors. KPI (key performance indicators) analysis of the results shows that the performance of the simulated assembly lines has improved after applying the lean techniques and material replenishment system.

Keywords: Lean production; mixed model assembly line; educational games; production simulation

The contribution of simulation games for the learning process of Lean Education in Production Engineering undergraduate course.¹

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Abstract

This research study aims to study how the simulation games in Lean Education can contribute to the learning process of undergraduate students of Production Engineering, from the students' point of view. For this, two educational games that work with the pull production approach, GP3 and LSSP_PCP3, are applied in a public high education institution. At the end of the course, the students' perception on their own development is evaluated by a questionnaire. The results show that the use of simulation systems makes classes more dynamic, providing an environment that stimulates a problem analysis and the decision-making process, which can contribute to the increase of students' learning.

Keywords: Lean Education, Simulation games, Industrial engineering, Active Learning.

1. Introduction

Over the years, in the face of a series of changes (globalization, fierce competition, demands for flexibility and quality, internet, etc.), organizational environments have become complex, interrelated and more dynamic (Indezeichak, Leite, 2005). In order that the organization can survive, it is important for them to become effective learners and to be able to adapt itself to the rapid changes of conditions in their environment. For both individuals and organizations, learning to adapt to new situations is becoming as important as having a good performance in the old situations.

In order to face these new situations individuals fundamentally need a support of knowledge, after all knowledge can be seen as the process by which the information is elaborated from the environment, how it acts on it and, with this, it acquires experience to restart the cycle. (LSSP, 2010)

In this context, some higher education institutions have sought to use business games in educational environments. Business games are simulated games with the particularity of portraying specific situations of the business area, such as marketing, production, finance or association between functions. They are based, in general, on mathematical models developed to simulate certain business environments considering the main

¹ This research was supported by FAPDF. Process number 00193.00001650/2018-53.

variables that act in those environments [Schafranski (2002, p. 26) apud Kopittke (1992)]. They originated in war games, designed to develop strategies used in military operations and in the training of officers through simulations of military situations.

During games people reveal facets of their personality that are not usually exhibited for fear of sanctions. Due to the permissive environment, the experiences are spontaneous and some assertive and non-assertive behaviors arise, worked through post-game analysis. Findings serve as a basis for reformulations or for reinforcement of attitudes and behaviors.

Real-world experiences teach through the stimuli that are sent to the human organism. The senses of the human organism perceive these stimuli and store them, recording them in their memory. Each stimulus represents a unit of information, and therefore, the more stimuli are received, the more complete will be the perception, that is, the learning. In traditional teaching, two stimuli are frequently worked: the visual and the auditory. Unless you can reconstruct the whole scene of the event that is spoken and written about, there would be very difficult to make the process more engaging. Simulation is an alternative that offers the possibility to create scenes like real ones, but in a simplified way, copying from the original event its fundamental principles, developing them as if they were true to the eyes, ears and other senses of the participants.

In this context, this article aims to investigate how business simulation games can contribute to the development of behavioral skills in the learning process. When two business games were applied to students of the Production Engineering undergraduate course of the University of Brasília (UnB), it is sought to identify, through a questionnaire, the students' perception of the development of twenty-six soft skills selected in this research.

2. Research Methodology

Research like this that emphasizes the discovery of ideas and insights can be classified as exploratory. In addition, Zirkmund (2006) states that this type of research is developed with the objective of understanding the ambiguous nature of certain problems, seeking a better understanding of the dimensions involved without, however, producing conclusive evidence.

The games were applied to two disciplines, with 50 students in each. The game LSSP-PCP3 was used in the discipline *Planning and Control of Production*, while in the discipline *Special Topics in Business Simulation* the game GP-3 was used. In each class, the students were divided into teams formed by 10 students.

A structured, and non-disguised, questionnaire-type data collection instrument performed data collection. All respondents were informed of the study objectives. The use of a structured questionnaire aimed at standardization in the data collection process.

Based on the twenty-six soft skills selected in this research, shown in 3.2, a questionnaire entitled "Evaluation of the Development of Behavioral Skills (Soft Skills)" was build, considering each soft skill as a research variable.

This questionnaire was structured in a way to list twenty-six soft skills with a brief concept to help the students' response, whose alternatives of answers followed the Likert Scale of 5 points, 1 (very weak), 2 (weak), 3 (reasonable), 4 (good) and 5 (very good). Likert Scale is one of the most used in perception research to evaluate the degree of agreement with certain assertions. In the scale proposed by Rensis Likert, respondents are asked to state their degree of agreement with an assertive statement on a scale of 1 to 5. Each response is assigned a number that reflects the respondent's attitude toward the statement. This approach finds support in Malhotra (2001)

The questionnaire was applied in June 2018 in 2 classes of the Production Engineering undergraduate course of the University of Brasília (UnB), 80 students in total, with spontaneous participation.

The Descriptive Statistics, in special the descriptive analysis, was adopted for data treatment. The main objective of descriptive analysis is to synthesize a series of values of the same nature, thus allowing an overall view of their variation.

To represent students' average perception of each variable, the arithmetic mean was calculated from the total set of responses for that variable.

3. Referencial Teórico

3.1. Business Games

Business simulation games are presented as a great tool for education, as they bring great pedagogical value, as well as capturing students' attention and enabling them to learn through interactions with the game (Silva; Morais II, 2011). Schwarz (2006) states that games contribute to students learning concepts and developing skills that will serve their professional life. With the use of business simulation games students feel stimulated in an environment that challenges and welcomes them, combining moment of dispute and cooperation, with that the group work is strengthened (Moreira; Montanari; Pilatti, 2017).

Libâneo (1994) and Saviani (1998) argue that the application of business games to the training of future managers can be used as a teaching technique, that is, a set of procedures adopted by the teacher to lead the students to achieve the educational objectives through the learning of the various contents needed for their professional training. In the sequence there are 2 business games used in this research:

3.1.1. GP-3 Game

GP-3 game (Production Management 3) is part of the GP series of games, developed by the "Laboratory of Simulation of Productive Systems" (LSSP) of the Federal University of Santa Catarina (UFSC). Within the production planning and control (PCP) line, two other business games are also part of GP series of games (GP-1 and GP-2), which deal with medium and short-term PCP issues, being that in GP-2 the simulated company (*Cia Industrial de Móveis*) has a push production system with departmental physical arrangement.

GP-3 was created with the aim of transforming the dynamics of the push programming of *Cia Industrial de Móveis* from the GP-2 game into a dynamic of pull programming, with the introduction of the cellular layout and of the Kanbans pull productive system. As the Kanban system is a component of the JIT / TQC production philosophy, another modifications in the batch production system of *Cia Industrial de Móveis* become necessary, mainly the change in the production layout, previously departmental, to cell of manufacturing and assembly (LSSP, 2010).

3.1.2. LSSP_PCP3 Educational Games

LSSP_PCP3 game is part of the series of educational games LSSP_PCP, developed in Access by the "Laboratory of Simulation of Productive Systems" (LSSP) of the Federal University of Santa Catarina (UFSC). The simulated company produces three distinct families of knitwear, called Colmeia, Piquet and Maxim, in various colors, with knitting, dyeing and finishing sectors. The demand for these kitwears may show trend, seasonality and random variations. The games have didactic purpose and do not characterize competition among the players. (LSSP, 2009).

LSSP_PCP1 game aims to build a strategic production plan, based on demand forecasting. The LSSP_PCP2 game aims to study and discuss the characteristics of a system within the PCP hierarchy focused on pushed

programming. LSSP_PCP3 game has the same objectives as the LSSP_PCP2, but it is focused on the push and pull programming simultaneously, approaching Kanban system concepts (Tubino, 2009).

3.2. *Soft Skills*

Soft skills mean the set of personal, interpersonal and cross-functional behavioral competencies in various areas and professional activities. Soft skills are currently essential not only to enter the labour market but mainly to keep a job; they are non-technical behaviors necessary for the development of the professional career (Klaus, 2007, p.1); they are traits of personality, attitudes and intangible behaviors that emphasize the qualities of an individual as leader, facilitator, mediator, and negotiator (Parsons, 2008, cit in Dabke, 2015, pp. 2-3); and they are necessary tools that help the individual achieve his or her potential (Muir, 2014, cit in Dabke, 2015, p.3). Considering the objectives of this research and the literature review, mainly the works of Bernotavicz (2002); Oderich (2005); Gramigna (2004); Vidal (2000); Neto (2005) and Baldwin et al. (2008), twenty-six soft skills were identified, which were used in the application of the questionnaire, whose relationship and summary description is presented below:

1. **Agility:** Ability to be rapid, fast, speedy in the development of an activity or a thought, in solving problems or in their application.
2. **Concentrated Attention:** Capacity of attention and concentration, keeping focus on activities, even when influenced by external factors.
3. **Distributed Attention:** Capacity to distribute attention to more than one objective and/or activities, simultaneously.
4. **Analysis and Synthesis Capacity:** Use and application of logical rules in gathering and analyzing facts and data, as well as the capacity for synthesis and objectivity in the activities inherent to its performance.
5. **Learning Capacity:** Acquisition of knowledge, skills, values and attitudes, made possible through study, teaching or experience.
6. **Capacity to Take Decision:** Decision-making is a process that includes identification of the problem, the criteria, how to elaborate, analyze and choose alternatives, verifying the effectiveness of the decision.
7. **Ability to Work Under Pressure:** Capacity to meet requested demands in an adequate time and with quality, maintaining satisfactory levels of quality of results and work relations, without prejudice to their biopsychosocial balance.
8. **Communication:** How people relate to each other, sharing and exchanging experiences, ideas, feelings, information, mutually modifying the society where they are inserted in. Without communication, each of us would be an isolated world.
9. **Creativity:** Innovative attitude to solve problems, to deal with lack of resources, to manage unforeseen situations and practicality in managing routines.
10. **Determination:** It is the inner certainty of direction. Being determined is having clear, defined goals and a full conviction that you will achieve them.
11. **Dynamism:** Capacity to act in an active, intense, diligent manner in a high degree.



12. **Entrepreneurship:** Capacity to identify new opportunities for action, to propose and to implement solutions to problems and needs that are presented in an assertive, innovative and appropriate way.
13. **Flexibility:** Capacity to adapt easily to new situations and/or working pressures. Quickly assimilate changes of anykind.
14. **Verbal Fluency:** Capacity to transmit and express ideas, feedback, rapport, thoughts, emotions and diverse information, in order to guarantee that the receivers learn the contents in their fullness, without noise or distortions.
15. **Focuson the Result:** Ability to conduct work processes in order to achieve and / or exceed pre-established results.
16. **Conflict Management:** Function of specialized governance in the management of conflicts between individuals, between individuals and groups within the organization, between groups belonging to the organization or conflicts with other organizations through the use of techniques, practices and processes.
17. **Time Management:** It is one of the main challenges that managers must face. Therefore, managers must know how to manage the time available with great effectiveness, setting priorities, planning, organizing their agendas and delegating what is possible to delegate.
18. **Leadership:** Capacity to catalyze the energies of the team to achieve or surpass the objectives, through a cooperative relationship with the people, stimulating them the self-development and self-actualization, within a high motivation and moral climate.
19. **Negotiation:** Capacity to negotiate various issues with internal/external clients, suppliers and/or various entities, seeking to achieve balance of interests between the parties.
20. **Planning and Organization:** Capacity to plan and organize activities in the different phases of the evolution of a task, determining objectives, procedures, priorities, deadlines and adequate use of resources to achieve the goals and results.
21. **Proactivity:** Capacity to take initiative in the face of situations by assuming responsibilities in decision-making in order to realize ideas, to develop and to anticipate solutions.
22. **Interpersonal Relationship:** Capacity to express and to listen to the other, seeking a balance of satisfactory solutions in the proposals presented by the parties, when there are conflicts of interest, as well as the exchange system that surrounds the context and to act based on the "win-win".
23. **Troubleshooting:** It consists of the ability to use methods, in an orderly manner, to find solutions to specific problems.
24. **Critical Sense/Thinking:** Capacity to analyze and create conclusive own opinion about a certain subject, independent of common sense.
25. **Teamwork:** Working in a team is not just working together, but sharing is need. Results are never achieved only by one person, it is necessary to share with the other to achieve the ultimate goal.
26. **Systemic Vision:** Capacity to understand the business and visualize how your actions, activities and attitudes can influence or interact with other areas of the organization and/or suppliers and/or customers.

4. Results

As explained in Methodology, a questionnaire was structured in a way to list twenty-six soft skills with a brief concept to help the students' response, whose alternatives of answers followed the Likert Scale of 5 points, 1 (very weak), 2 (weak), 3 (reasonable), 4 (good) and 5 (very good). In the scale proposed by Rensis Likert, respondents are asked to state their degree of agreement with an assertive statement on a scale of 1 to 5. Each response is assigned a number that reflects the respondent's attitude toward the statement.

The questionnaire was then applied in 2 classes of the Production Engineering undergraduate course of the University of Brasília (UnB), 80 students in total, with spontaneous participation.

The responses were processed and the mean results for each soft-skill perception is presented in Figure 1.

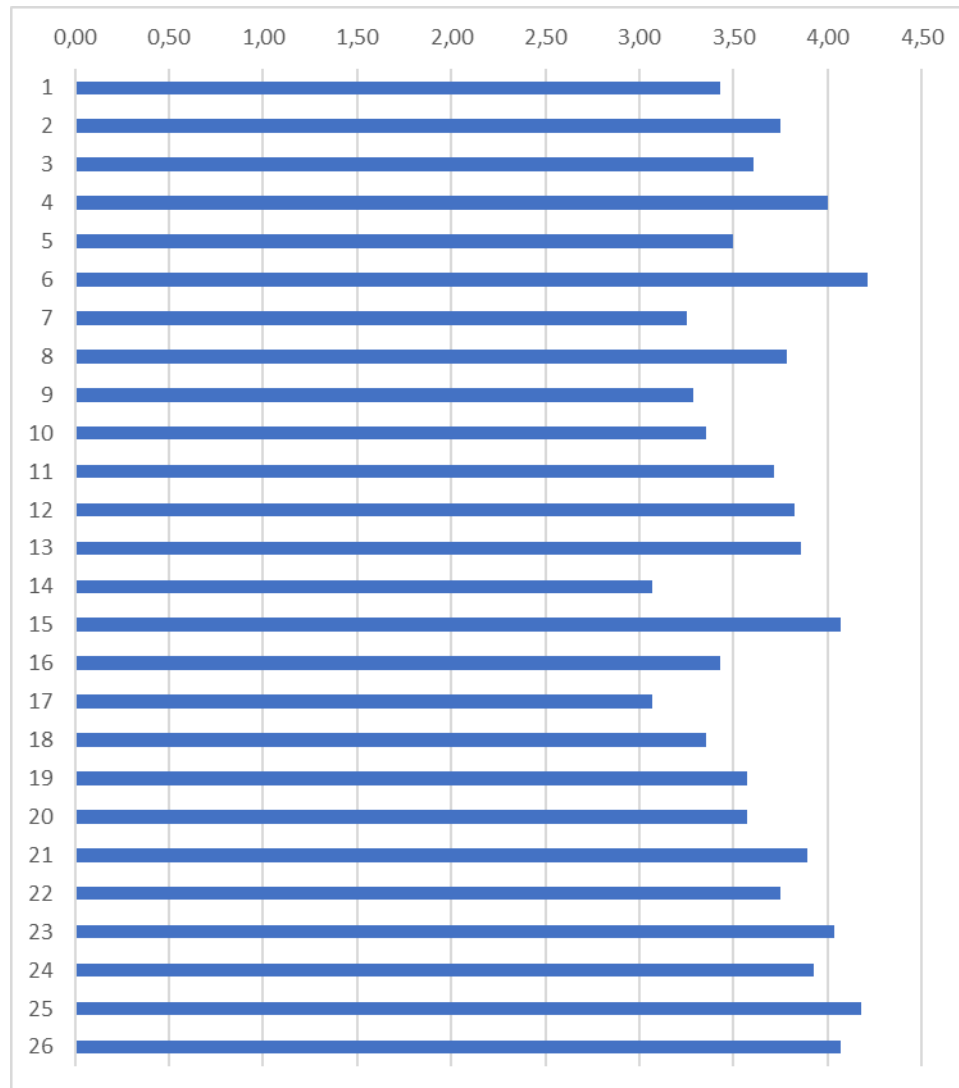


Figure 1 – Average result for each variable

It is observed that among the twenty-six soft skills only five had the average of the students' perception greater than 4.00. They are respectively in descending order: The Capacity to Take Decision; Teamwork; Focus on the Result; Systemic Vision and Troubleshooting. On the other hand, seven soft skills had a average of students' perception smaller than 3.50. They are respectively in increasing order: Conflict Management; Agility; Determination; Leadership; Creativity; Ability to Work Under Pressure and Verbal Fluency.

In the interval between 4.00 and 3.50 average, the students' perception resulted in 14 soft skills, which are respectively in descending order: Analysis and Synthesis Capacity; Critical Sense/Thinking; Proactivity;

Flexibility; Entrepreneurship; Communication; Concentrated Attention; Time Management; Interpersonal Relationship; Dynamism; Distributed Attention; Negotiation; Planning and Organization and Learning Capacity.

The variable with the highest degree of agreement was the variable 6, *Capacity to Take Decision*, with a result 4,21. This evidences a high degree of agreement among respondents that participation in simulation, games, developed in the participants the ability to identify a problem, criteria for solution, elaboration, analysis and choice of alternatives as well as verification of the effectiveness of the decision.

The second variable with the highest degree of agreement was the variable 25, *Teamwork*, with a degree of agreement of 4.18. From the analysis of the data it was possible to deduce that the ability to work in a team was also developed in a significant way.

Next, the variables 15 and 26, *Focus on Results* and *Systemic Vision*, with a degree of agreement of 4.07, appear. This result highlights the role of Simulation in developing the ability to conduct work processes to achieve and/or overcome pre-established results as well the ability to understand the business and to visualize how their actions, activities and attitudes can influence or interact with other organization sectors, suppliers or customers.

The variables with the lowest degree of agreement, that is, the competences less developed were *Ability to Work under Pressure* with degree of agreement 3,25, followed by *Verbal Fluency* and *Time Management* with degree of agreement 3.07.

5. Conclusion

The present study aimed to identify and analyze, through a data collection instrument based on the spontaneous structured questionnaire, the students' perception on the development of twenty-six soft skills selected for this research, in the performance of business simulations in the Production Engineering undergraduate course of the University of Brasília. For the response to each of the assertions, Likert Scale was used.

From the study developed it was possible to verify that the accomplishment of entrepreneurial simulations in the subjects of the Production Engineering undergraduate course enabled to the students the development of diverse behavioral skills generally not worked in the other subjects of the course.

It was also possible to observe that all the behavioral abilities contemplated in the study were reasonably stimulated and developed in the students' perceptions throughout the disciplines although in the result of the study it indicates that some of them were more developed than others.

During the games, students revealed aspects of their behavior that often do not show up in conventional classes. Due to the non-hierarchical environment, the experiences were spontaneous and assertive and non-assertive behaviors emerged, worked through post-game analysis.

This study is important once as increasingly behavioral skills are valued by companies, since these skills contribute to the establishment of a more dynamic, harmonious, organized and humane work environment. In addition, professional positions based on these types of skills help in the continuous increase of the productivity and the competitiveness of the companies.

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Use of gamification as a tool for developing competences - a proposal of application for analysis and prevention of failures

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Abstract

This article proposes the development of an analysis and failure's prevention system that makes use of gamification as a strategy for employee engagement. This approach allows the users involvement with some aspects, such as the narrative of the game, continuous reflection and competition, which is directly linked with the recognition in the industrial organization, that occurs under the form of awards, materials or not. Beyond that, works contributing to the personal motivation regarding the fulfillment of the goals pre-established by the company's sectors. Therefore, a study was carried out through a bibliographical research that allowed the formation of the system and its instructional methods to employees. The design was developed on Canvas platform and simulates the gamification system through interactive illustrations, using features to hold the employee's attention, such as pastel colors, simple language and an assistant robot character. Moreover, as an example, the process presented a methodology called TOPS 8D (Team Oriented Problem Solution/8 Disciplines), showing how the evaluation can be elaborated. Finally, the developed model allows a more effectively interaction of employees with their leaders and with the tools used in industry, contributing to improve the level of training, adding value and giving it a qualitative scope, and avoiding wasted time with ineffective training.

Keywords: active learning, gamification, failure analyses, people engagement.

Introduction

The global workforce is slowly changing and giving room to the new generation. By the year 2030, about 75% of our global workforce is expected to be represented by generation Y (born between 1980 and 1997) (Montes, 2017). Thus, it is imperative that the contemporary market adapts to the new workforce that seeks independence, transparency, immediate gratification and social connection.

In this way, organizations have attempted to improve the technological functions in supporting knowledge sharing among employees, identifying domain experts in an attempt to facilitate access to specialization (Yuan *et al.*, 2007) and incorporating corporate social networks (Leonardi, 2014). Despite significant advances in knowledge management in the last decades, organizations are still struggling to improve the involvement of their employees in creating and maintaining it (Heisig *et al.*, 2016; Wang *et al.*, 2014).

In an attempt to gain employee engagement, gamification emerged as a label fabricated for the intersection of the game with non-game-related elements and activities. A general definition of gamification identifies it as "The process of adding game mechanics to processes, programs, and platforms that would not traditionally use such concepts" (Swan, 2012, p. 13).

The use of gamification to encourage people to participate in targeted activities is gaining the attention of academics and industry (Deterding, 2011; Suh et al., 2015). As said by Sarangi and Shah (2015), they are the elements rooted in the gamified process - a sense of shared purpose, challenge, and reward - that make it attractive and engaging, decoding the mechanics do the gamification work (Ryan *et al.*, 2013).

In this way, gamification creates significant scenarios to engage and reach the full potential of this new generation that is entering the market, as it allows employees to feel engaged through the recognition of the same within the industrial organization. It takes the way of awards, and of the immediate social recognition that the game has, with transparency prevailing and providing real-time feedback from employees and the team as a whole in meeting pre-set goals by the company's sectors. Thus, quantifying employee contributions, gamification helps to identify "who knows what" and "who contributes to what" (Mashhadi *et al.*, 2016).

Besides that, the new era of digitalization helps the employees to see the methodology changes on trainings as non-radical changes. It happens because, as said by Gangadharbatla (2016), the gamification of everything (Rolland e Eastman, 2011) responds to a general shift onto digital natives (Bennet *et al.*, 2008) that not only have grown with the internet and network technologies, but that have been born into a world filled with digital games within the context of home and everyday life.

There are several tools available within the corporate environment such as 5S, Failure Mode and Effect Analysis (FMEA), Root Cause Analyzes (RCA), Fault Tree Analysis (FTA) and 8D methodology, which are used for fault investigation and analysis. One of those that stand out are that called Team Oriented Problem Solving - TOPS 8D or simply 8D, which was developed to be an auxiliary tool for the understanding of a fault-breaking phenomenon, which results in the loss of function of a machine or process (Oliveira, 2017).

As quoted by Oliveira (2017), Tarartuch (2009) defines the methodology 8D (eight Disciplines) as a complementary methodology and simultaneously integrating all the methods that have proven most effective, introducing means that seek to ensure the manufacture of the products and that provide the protection to the client. According to Rambaud (2011), the methodology is useful in improving products and processes, establishing a standard practice with an emphasis on facts that focuses on the origin of the problem by determining the root cause. From this, it is possible to apply gamification concepts in a tool as important as 8D, creating an environment with singular aspects, such as a game narrative, continuous reflection, competitiveness, teamwork, challenges, emotion, rewards, fun and pleasure, which stem from the interaction between employees through healthy competition to make everyday tasks more exciting.

Literature Review

Gamification

Gamification is the practice related to the application of game mechanics in several areas of knowledge, such as business, health, social life, education and, more recently, has been widely used in productive processes as part of the generation and propagation of knowledge in organizations (Hammedi, Leclercq, & Van Riel, 2017; Harman, Koohang, & Paliszkievicz, 2014; Insley & Nunan, 2014; Paravizo, Chaim, Braatz, Muschard, & Rozenfeld, 2018; Sarangi & Shah, 2015; Suh & Wagner, 2017).

Through the pillars associated in the creation of a game, the proposal to make use of gamification is related to the goal of increasing engagement, arousing people's curiosity and, through the recommended challenges, achieving results, receiving compensation and recognition for the success achieved. The set of key elements of gamification comprise storytelling, tasks, level of progression, feedbacks, characters, multimedia elements, goals and objectives as well as punctuation and reward.

Burke (2014) defines that gamification "is not just about applying technology to old engagement models, but about creates entirely new engagement models, targeting new communities of people and motivating them to achieve goals they may not even know they have." An important factor, given that, according to Anitha (2014), engagement can represent better performance and ultimately the fulfillment of a company's goals.

Besides that, Freitas (2015) says that gamification has the power to shape behavior and cause a positive influence on people's psychology (Hamari, 2014; Herzig, 2014). With this, the gamification can be understood

how an integral technique of many applications since this approach could help achieve promising results when integrated into any application (Khaleel *et al.*, 2016).

For this, some authors refer to important points for an effective and engaging gamification, more specifically, to increase the success on implementation of a gamification system it should consider the user profiles (Marache-Francisco *et al.*, 2013).

Learning Organization Culture

According to Jiménez (2016) "If an organization's culture is oriented on learning, and its structure permits collaborators within the organization to impact knowledge, then the working force is more inclined to feel entrusted to learn." Besides that, the author refers to an order to support knowledge creation: organizations have to harvest a learning culture that gives satisfactory conditions for employees to learn. This concept is a point in the development of gamification systems, which can be seen how these conditions.

In this way, the learning through gamification allows the user to do things that they, commonly, do not like to do. An example from Groh (2012) is solving mathematical equations in the context of games, what is fun for many people, who disagree to denote the identical task as fun in the context of school, where most of the tasks seem to be boring and repeating? Thus, it is important to confront the user with interesting challenges, what explain that same conditions can be applicable to companies in the specific case of formal trainings.

Methodologies and tools for analysis and fault prevention

To attend the complexity of production systems and improve then constantly, many tools were developed specifically to analyses and prevention of failures. Oliveira (2017) indicates five technics (or tools) that can be used how good practices: 5S, Failure Mode and Effect Analysis (FMEA), Root Cause Analyses (RCA), Fault Tree Analysis (FTA) and 8D Methodology.

These tools are the center of the proposed gamification model because the trainings are supposed to happen focusing on them. Thus, the simulation uses, initially, 8D methodology or Team Oriented Problem Solving – TOPS 8D (Oliveira, 2017). The same author refers to 8D's how a tool that was developed to help the understanding of a phenomenal that results on function loss of a machine or process.

Moreover, this method follows an application's sequence that can be seen in the next figure and represents the sequence used in the gamification process design.

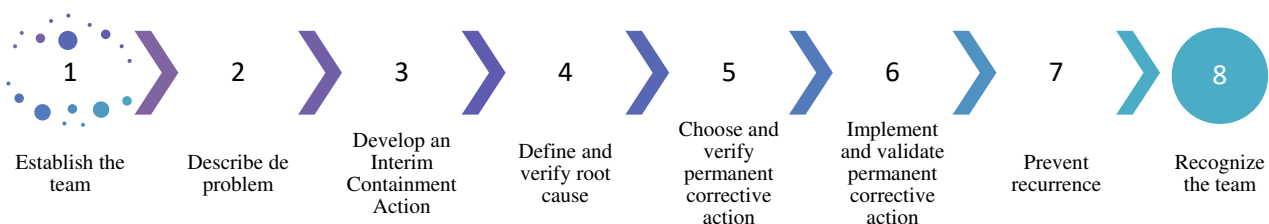


Figure 1 – 8D Methodology Sequence

Model's development and analyses

The gamification model was developed on Canvas platform, a web tool used to create designs. This feature allows access images, graphics, text and forms models, as well as providing the sharing of the created designs in two versions: web (.PNG) and print (.PDF). Beyond that, the system was designed on the "presentation" mode, simulating the real size used in computers and, finally, was provided in the formats (.PDF) and (.PNG), following the structure bellow:

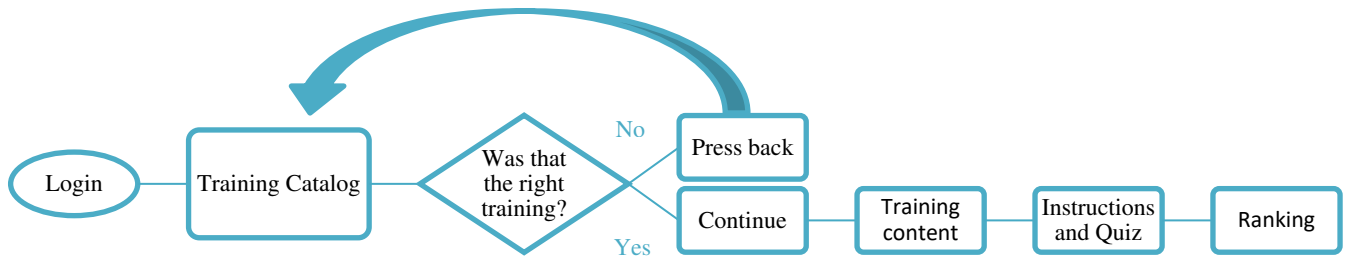


Figure 2 – Model's structure

System Screens

The first system screen represents the Login screen, where the user receives a robot support, which indicates the steps that must be followed to access the learning game.

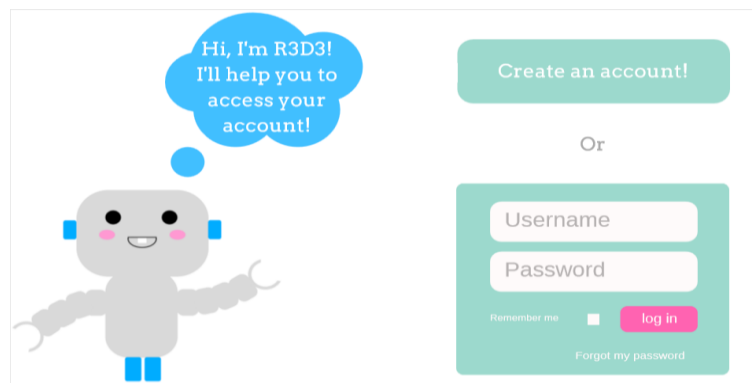


Figure 3 – Login screen

The next screen shows the process start, where the user must choose what tool wants to learn. From the moment he makes his choice, he has access to the confirmation screen.

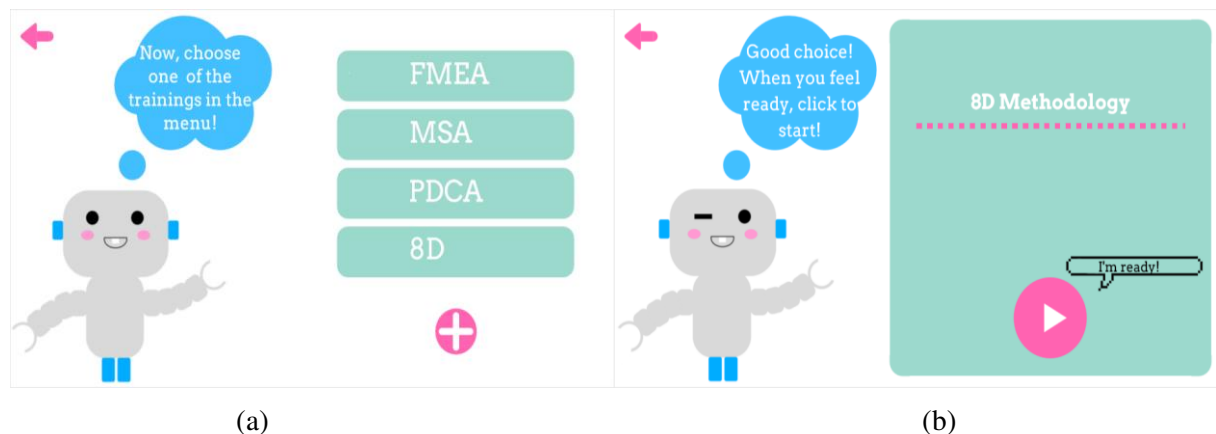


Figure 4 – (a) Initial screen and (b) Confirmation screen

Among several tools that can be available for simulation, the user chose the 8D methodology, for instance, a method of analyses and resolution of problems composed by eight structured steps. Thus, the training starts showing the concept of the tool, as can be seen in the following screen. The button - "Got it!" - allows the passage to the next concepts.

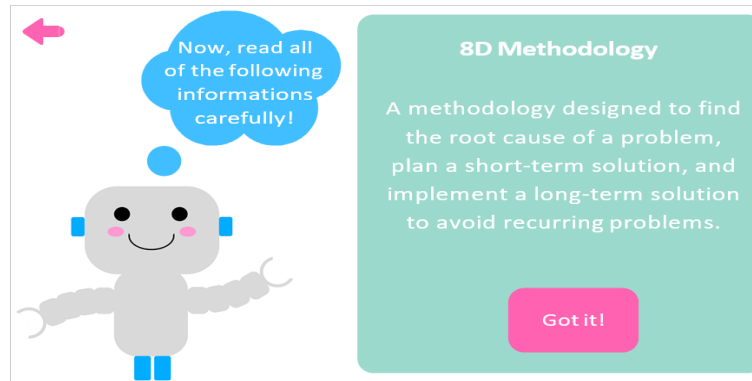


Figure 5 – Training screen

The next screens allow the visualization of the eight disciplines studied in the tool. For example, some of the disciplines are shown in the pictures' bellow.

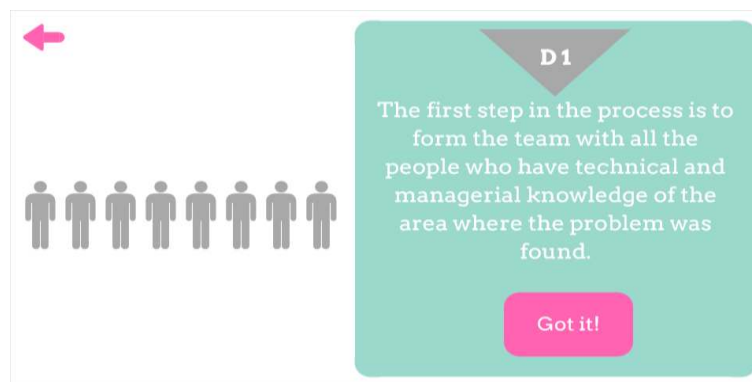


Figure 6 – D1 screen

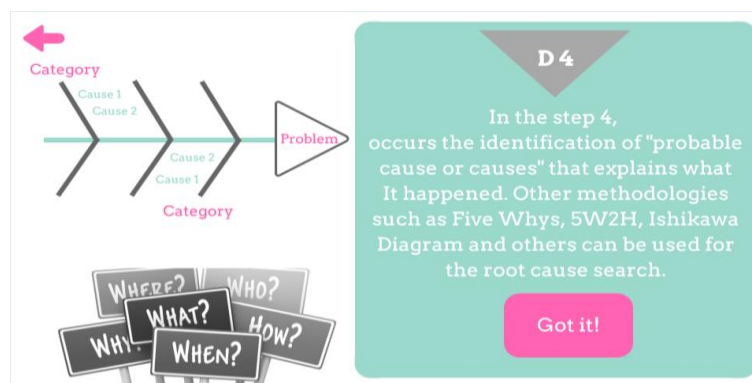


Figure 7 – D4 screen

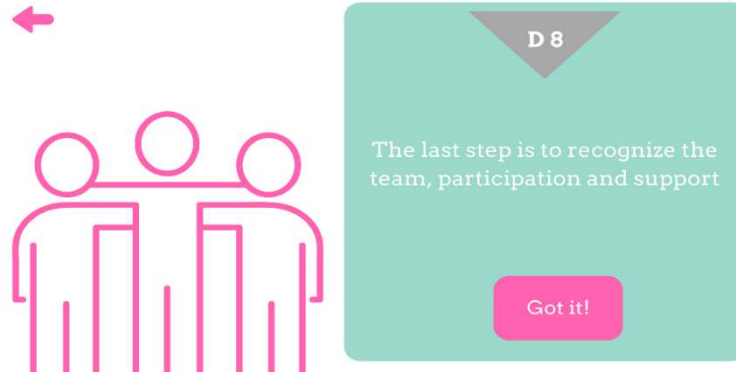


Figure 8 – D8 screen

Finalizing the training, the user has access to the Quiz screen, in order to answer questions about the conducted training. The following screen brings basic instructions to complete this step.

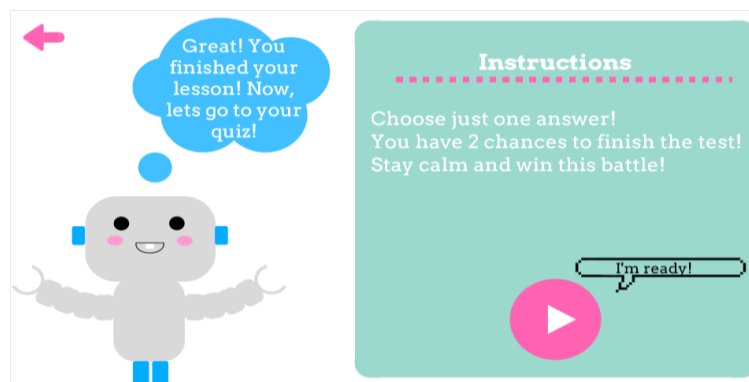


Figure 9 – Quiz instruction screen

At the end of the Quiz, the user has access to the Score screen, where the Quiz punctuation is displayed.



Figure 10 – Score screen

This score is computed in a way that the user's Ranking can be fed with these information's, allowing that, when he clicks on the bottom right button (the medal), he can visualize your position in relation to the others company collaborators. The next screen simulates this process.

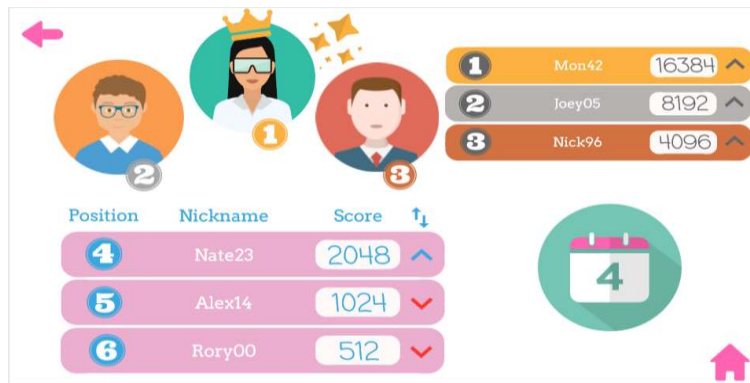


Figure 11 – Ranking screen

The presented gamification strategy is based upon the establishment of a competition among the company employees, which results in greater engagement, especially when coupled with bonuses and recognitions, whether material or not. Thus, the system does not approach gamification as an obligation, establishing rules and use limits, but rather as a way to drive continuous learning, bringing returns to both employees and company.

In addition, the methodology has a unique approach that can be applied to many other tools, not particularly those focused on fault analysis and prevention, thus allowing the training of employees in several areas, such as ergonomics and human resources.

Conclusions and future work

Considering the system based on gamification principles to analysis and prevention of failures that were proposed for this study, it was perceived that the structure used involves different mechanisms to improve the employee learning, with this, the engagement of the employees has the resources to be effective and brings back improvements to the organizations that use the created tool.

These mechanisms involve the combination of colors, presenting a continuity and harmony of tones in each screen of the process. The language used is often represented by signs of colloquially, which brings the computer system closer to human language, making communication more interactive. The formation of a self-explanatory tool, which makes use of a robotic character to accompany the development through the training together with the employee transmitting security and support in cases of doubts to proceed with the proposed activity. In this way, the developed methodology allows the training to the employee regarding the tools that can help him daily in a practical and interactive way, since the employee is no longer restricted only to formal trainings that happens at specific times and demand hours that could be destined for production.

Thus, the system allows the reduction of available hours for conventional training and adds interactive and continuous learning to the employees' daily routine, being also aligned with the benefits destined to the best employees, resulting in increasing competitiveness and the consequent engagement of the organization's teams. Moreover, the developed model has brought illustrations to be used in real computer systems, which involve not only computers, but also physical ergonomic structures that meet the technical norms of safety and allow the comfort of the employee when using them.

As said, it should be applicable to be integrated into a physical unit that is also ergonomically pleasant to the user, bringing privacy and comfort at the learning moment, besides presenting a strategic layout for easy access to the organization spaces.

Therefore, later work has the alternative of exploring the possible structures for the system installation, as well as applying it in web development software such as Visual Studio, which allows the creation of computational platforms through the C # (C sharp) programming language.

Acknowledgments

The authors wish to thank the project partner Amazonas State Foundation for Research Support (FAPEAM - Fundação de Apoio à Pesquisa do Estado do Amazonas) for facilitating this work.

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Would you like some Wine? Introducing Variants to the Beer Game.

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Abstract

The beer game is a well-known game to demonstrate the bullwhip effect in supply chains. However, this game mechanics offers so much more potential for teaching the effects in supply chains. We extended the beer game to include additional variants. In the spirit of the game (pun intended), these additional variants are wine and schnapps. The original beer game has two rounds, the first to show the bullwhip effect, and a second one to demonstrate how pull production can reduce this effect. In a third round, we introduce wine and schnapps. In a fourth round the pull system is adjusted, and the participants learn about the increase in inventory needed if the same demand is split across variants. In a fifth round, levelling is introduced. The participant's effort to maintain the pull system despite contrary information from the supply chain will worsen the bullwhip effect once the system breaks the levelled approach. In a last and final sixth round the students learn that even a levelled system requires flexibility, and has to be adapted if the demand leaves the range of the levelled system.

Keywords: beer game, levelling, variants, fluctuations, inventory, bullwhip effect

A Game to Understand the Effect of Utilization and Fluctuation on the Waiting Time

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Abstract

Two of the main influences on the waiting time in a system are the workload (the utilization) and the fluctuations of the arrivals and processes. For single arrival single server processes there are a few approximations, the most famous one being the Kingman formula. The presented game is an extension of an existing dice game to experience the Kingman formula. This game uses simple dices to explore the effect of utilization on the waiting time; the effect of fluctuations on waiting time; and the effect of a combination of both. The first round sets the baseline with low utilization and low fluctuations. A second round increases utilization, a third round increases the utilization again to 100%. The increase of the utilization is highly nonlinear, which surprises the participants. In a fourth and fifth game, the utilization is reduced again to the baseline, but the fluctuation is increased using dice with 12 and 30 sides. In a final sixth game both the utilization and the fluctuations are increased. The nonlinear effects continue to surprise the participants. Hence, this game can leave a lasting impact for its participants.

Keywords: Kingman equation, utilization, variation, waiting time

1. Introduction

In manufacturing, or actually in most processing systems, the waiting time for the objects to be processed is often significant. In a supermarket, the waiting time of the customer is relevant for customer satisfaction (Tom and Lucey 1997). In manufacturing, the waiting time of parts is a major contributor to the lead time. Most real live systems have a network of multiple processes and parts with varying utilizations and fluctuations. Often, the distribution of the inter-arrival time is the result of the output behavior of the preceding processes. Such complex systems can be simulated, but their relations are often difficult to grasp by humans and usually also difficult to analyze in queueing theory.

However, to understand the principles behind it, it is helpful to look in more detail at single-arrival single-departure processes, also known as single-server queue. Such a system is visualized in Figure 10.



Figure 10. Illustration of the arrivals, waiting objects, and server

For the general queue, there exist different approximations. The most common one is the Kingman approximation as shown in equation (2). Here, p stands for the utilization of the server (i.e., the mean arrival

time μ_A divided by the mean service time μ_S). C_A and C_S are the coefficients of variation (standard deviation divided by the mean) of the arrival distribution and the service distribution (Kingman 1961).

$$E(W) = \frac{p}{1-p} \cdot \left(\frac{C_A^2 + C_S^2}{2} \right) \cdot \mu_S \quad (1)$$

Please note that this is only an approximation, with the restrictions that it is only valid for higher utilization, that the utilization is below 100%, and that the arrival and service times need to be independently distributed. Other approximations exist like (Marchal 1976) or (Krämer and Lagenbach-Belz 1976), but for our purposes, the Kingman equation will suffice, especially since it shows the main effects clearly.

1.1 Effect of Utilization

The effect of utilization on the waiting time is represented by the first part of equation (2). As the utilization p approaches 100%, the waiting time approaches infinity. Please note that this is not a linear effect. This is also graphically visualized on the left side of Figure 11. Please note that the y-axis has intentionally no units, as this would depend on a specific situation. Please also note that the Kingman equation is not very accurate for low utilization.

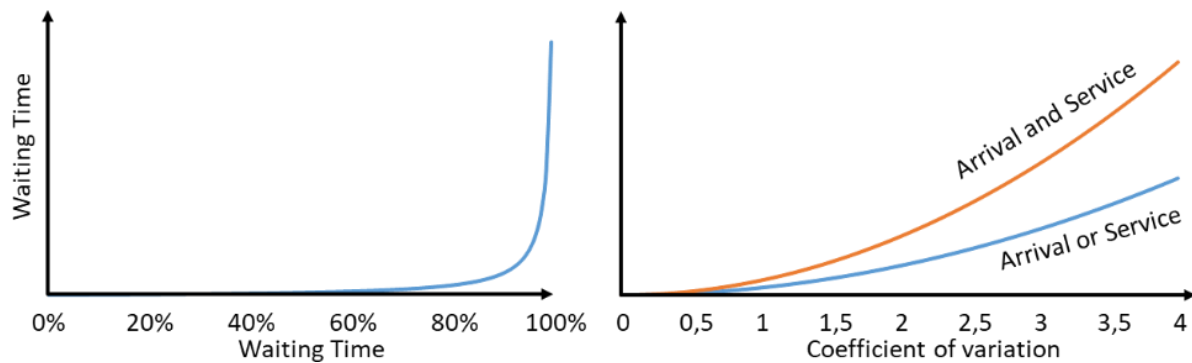


Figure 11. Illustration of the general behavior of the effect of utilization and coefficient of variation on the waiting time

1.2 Effect of Variance

The middle part of equation (2) represents the effect of the variance of the arrival and service times. The increase of the waiting time is also not linear but squared to the coefficient of variation. The right side of Figure 11 shows the effect of increasing the coefficient of variation of either the arrival or departures in the lower line. The effect of increasing both arrival and departure variation simultaneously is shown in the upper line, which is simply double of the lower line.

1.3 Joint Effect of Utilization and Variance

Please note that the joint effect of utilization and variance is not the sum but the product of the two individual effects. Hence, if both utilization and variance increase, the waiting time will increase significantly more.

2. Game Objectives

It is one thing to know the Kingman equation in theory. It is something else to experience this relation in practice. The exponential behavior of increasing either the variation or the utilization, and especially the multiplicative behavior of a joint increase, is hard to internalize for practitioners.

The target group is people who are working or will be working with process systems. This includes shop floor supervisors, production planning staff, managers, and students of engineering or management. The game aims to teach its participants the severity of the problem of having both high utilization and high fluctuation. During

the game, the participants will guess the magnitude of the change due to an increase in utilization or variation. The resulting actual outcome usually far exceeds these estimates, improving the learning experience.

3. Game Outline

The game is an extended version of the number game found in (Bicheno 2014), which shows the effect of utilization. In this original game, the effect of increasing utilization onto the system is experienced using normal six-sided (D6) dice. This game extends the original game to also show the effect of variation and the combined effect.

The game can be performed within thirty minutes and is hence a good warm-up for, as an example, a full-day or multi-day training. The game can handle a wide range of participants but ideally has around six to thirty participants split into groups of two. In each group one person represents the arrival, the other represents the service. Depending on the industry, these can be renamed as supplier and customer for manufacturing, customer and check out for supermarket cash registers, etc. as needed. The randomness is represented by dice throws. To model different variations, dice with different numbers are needed as shown in Figure 12. The game will be explained using four-sided, twelve-sided, and thirty-sided dice, abbreviated as D4, D12, and D30, but this can easily be adapted to other dice sizes. The largest dice, however, should be at least D20. Ideally, there is one dice of each type available per person, but if there are not enough dice, one dice per team is also sufficient.



Figure 12. Dice with different numbers. Top row from left to right D4, D6, D8, bottom row D10, D12, and D20. A D30 is shown on the right.

1.4 First Game: Baseline System

The game is played in a total of six games, each with twenty rounds between the arrival and the service. In the first game, the player uses D4 dice. Since not everybody may be familiar with the unusual shape of the dice, inform the participants on how to read the throw. In Figure 12, this would be a 4. Both the arrival and the service process throw the dice. The arrival adds 13 to the throw, and the service adds 15. This is a Δ of 2. Since the average throw of a D4 is 2.5, this means that in each round, 15.5 items are arriving and 17.5 items can be processed. This gives an average utilization of 88,6%.

If by chance more parts are arriving than can be serviced, the remaining parts are added to the queue. This is written down on a data sheet as shown in Figure 13 on the left. In the first round, the service exceeded the arrival. In the second round, arrival threw a 4 and service a 1, hence one item remained in the queue to be processed at the next round. Since arrival and service threw 4 and 2 respectively, the queue remained at length 1. Only in the fourth round was the service able to reduce the queue to zero again. This is repeated for twenty rounds, and the sum, as well as the average of the queue length, is calculated.

Dice Game Queue AllAboutLean!

Round	1	2	3	4	5	6
Dice	D4					
+Arriving	13					
+Check Out	15					
1	0					
2	1					
3	1					
4	0					
5	0					
6	0					
7	0					
8	0					
9	0					
10	1					
11	1					
12	0					
13	0					
14	0					
15	0					
16	1					
17	0					
18	0					
19	0					
20	0					
Sum	5					
σ	0.25					

Figure 13. Datasheet for the dice game with the first column filled out.

The expected outcome based on two hundred simulations is around 0.06 with a standard deviation of also 0.06. The results of your game will, of course, be a different number for each team, and the mean and standard deviation gives only an indication of the range of the expected results. In the game, however, you do not know the exact numbers but merely get a slightly different result from every team. The results of every team are marked on a chart to convey an idea of the range of expected results, and an estimated mean of the results is highlighted. Please be aware that the numbers will become quite high as indicated in **Figure 14**. Yet, adding a scale from the beginning gives participants clues on the expected result and diminishes the learning experience.

1.5 Second Game: Increase Utilization

In the next round, we keep the D4 dice but reduce the Δ to 1. Arrival adds 13, but service only adds 14. The expected utilization is now 93.9%. Repeating the twenty rounds will result in an average queue length of 0.54 with a standard deviation of 0.46. Again the results of the different teams are added to the chart.

1.6 Third Game: Increase Utilization to 100%

In the next game, we keep the D4 dice but reduce the Δ to 0. Both arrival and service add 13. The expected utilization is now 100%. Before playing this game, the participants should guess the expected outcome. Most will assume some linear relationship and guess around 1, vastly underestimating the true outcome. In the long term this would result in an infinite queue, but since in this game we play only twenty rounds, we expect an average queue length of 3.1 with a standard deviation of 2.3. Emphasize the nonlinear relationship by adding a curve through the tree means.

1.7 Fourth Game: Increase Variation by using D12

In this game, we now use a D12 dice and add 9 to the arrival and 11 to the service. The Δ is now again 2 as in the first game. The expected mean value of a D12 is 6.5, hence there will be in average 15.5 parts arriving and 17.5 serviced. Please note that these averages are identical with the first game, and the utilization is therefore also 88.6%. Only the variation around the mean has increased. After twenty rounds again, the results of the teams are added to a chart. The results are expected to have a mean of 2.9 with a standard deviation of 2.3.

1.8 Fifth Game: Increase Variation by using D30

The fifth game uses a D30 (a D20 is also possible, although the expected standard deviation would differ). To get the same average arrivals of 15.5 and service of 17.5 with a utilization of 88.6% as in game 1 and 4, we

add nothing to the arrivals and 2 to the service dice throw. Before playing the game, have the participants guess the expected outcome. Most of them again would assume a linear relationship and vastly underestimate the actual results, which are expected to have a mean 15 with a standard deviation of 12. Again, highlight the nonlinear relationship in the graph.

1.9 Sixth Game: Increase Variation to D30 and Utilization to 100%

In the last game, we combine the high variance with a high utilization. Both the arrival and the service get a D30 dice and cannot add anything to their dice throw, giving a Δ of 0 and hence a utilization of 100%. The participants should guess the expected outcome. Again, the participants vastly underestimate the outcome due to the multiplicative relationship of the effects. The results are expected to have a mean of 23 with a standard deviation of 16.

4. Expected Results

Table 2 shows the settings and expected results for the different games.

Table 2. Expected results for the six games using D4, D12, and D30

Game	1	2	3	4	5	6
Dice	D4	D4	D4	D12	D30	D30
+ Arrival	13	13	13	9	0	0
+ Departure	15	14	13	11	2	0
Utilization	88.6%	93.9%	100%	88.6%	88.6%	100%
Mean Length	0.06	0.54	3.1	2.9	15	23
StDev Length	0.06	0.46	2.3	2.3	12	16

Figure 14 shows on the left a graph with the expected mean and standard deviation for each of the six games from Table 2. For didactic reasons, however, it is recommended not to print a single chart, but rather prepare multiple A3 pages that create a consecutive chart (i.e. a page with a chart from 0 to 9, another page continuing from 10 to 19, a third from 20 to 29, and a fourth from 30 to 39). Only the first page should be attached to the wall so as not to indicate to the participants the range of the results. Whenever the added values exceed the range of the chart, the page should be attached to the wall above the previous one (or adjacent if the wall is “not high enough”). See the right side of Figure 14 for a photo of the results of an actual game on four A3 pages.

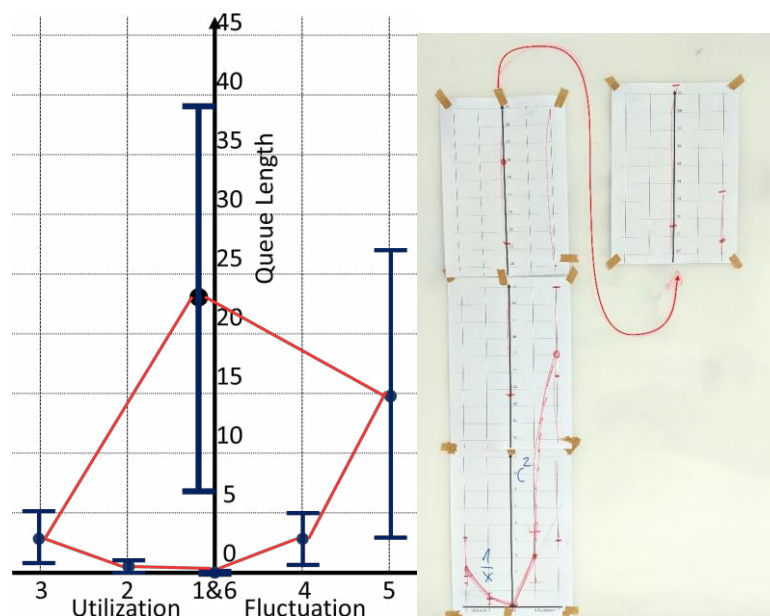


Figure 14. Graph with the expected range of results as well as actual game chart on multiple pages.

5. Discussion

To emphasize the key learnings of the nonlinear effect of both the utilization and the fluctuations and especially the multiplicative effect of both the game is closed with a discussion and review round. The moderator should emphasize and point out this nonlinear effect, and how the continuously larger numbers surprised the participants. Depending on the mathematical skills of the group, the Kingman equation can be introduced (see equation (1)). Emphasize the nonlinear relation of the utilization due to the inverse $1/p$. Emphasize the nonlinear quadratic relation of the coefficient of variation. Emphasize the not additive but multiplicative combined effect. Understanding this behavior is important for practitioners to define a production system. Often, inexperienced planners plan for a utilization of 100% and ignore the effect of variance. As a result, waiting times increase and therefore costs go up.

6. Participants Experience and Outcomes

This quick exercise is usually a surprising eye-opener for the participants, as shown by comments like “*I never thought it would get so high*”. After the initial first game, participants consistently underestimate the effect of the changes. The participants usually assume a linear relation and underestimate the effect of the third game by estimating a queue length of less than 1 instead of the actual 3. The fifth game is usually also underestimated with a predicted value of around 6 instead of the actual 15. For the combined effect of the sixth game, participants merely add the two effects and predict a queue of around 18, whereas the actual average result is around 23, and the largest queue length of a single team can easily exceed 40.

7. Summary

The game lets the participants experience the nonlinear effects of utilization, variation, and the nonlinear combination of both. Depending on the qualification of the participants, the Kingman equation may be introduced, but this is optional. We have played this game with different groups on different continents and have obtained consistent results of the participants being surprised by the magnitude of the effect. This game is a good warm-up for many trainings in the field of process optimization or lean manufacturing. Datasheets and more statistics can be downloaded at <http://www.allaboutlean.com/dice-game-kingman-formula/>.

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POSTERS

Application of the Toyota Kata method in a training simulator for industrial painting

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Abstract

The Toyota Kata method distinguishes itself from production techniques, since it only concerns the behavior of the people, and is carried out to develop the way of thinking and the ability of each operator of the organization in uncertain situations to be able to develop systematic and scientific solutions (Rother, 2010). This work aims to reduce ink consumption by 20% in a painting process using the Toyota Kata method. This is a plastic painting process of motorcycle parts, in a two-wheeled company in the industrial district of Manaus. Revisions to the operating instructions have been carried out including standard operations with the electrostatic pistols (equipment used in the manual painting process). It was created through a specific training need for painters a simulator with led panel in levels and modules. The development of the Paint Simulator has been studied in every detail, as well as the standard speed of application that is 500 to 700 mm / sec. The changes made throughout the development were made to improve the learning of painters, especially in the creation of difficulty levels, as this allowed to classify the levels of each painter, as well as their evolution according to the training. The results are expressed in the indicators, the index of defects caused by bad application decreases, the generated rework also becomes smaller, because the improvement with the new way of understanding the principles of painting through the simulator becomes easier.

Keywords: Toyota Kata, Lean manufacturing, Industrial painting, Training.

Specification of a Debureaucratization Model in Teaching: Case Study

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Abstract

Nowadays data is crucial for any organization and its success depends on how it is managed. The management's information process of the education system in general, and of an education institution, in particular, is a complex and bureaucratic process, where occurs information's fragmentation. In order to counter this reality, people should be encouraged to simplify procedures by adopting a culture of continuous improvement. On the other hand, it is suggested an appropriate infrastructure that enables not only data integration but potentiates its transformation into knowledge. The data simplification and computerization will remove the bureaucracy associated with the management of processes, streamlining and translating them into the creation of value in the education sector. It should be noted, however, the importance of ensuring that the proposed solution is based on the needs and characteristics of each education institution, and the education system, in general. There is also the need for the involvement of all participants, as well as the recognition of their perceptions because these are influential factors in the successful implementation of the change process.

Keywords: Value Creation in Education, Lean Philosophy, Re-engineering Process, Integrated Information System, Waste Reduction.



A Game to Understand the Effect of Utilization and Fluctuation on the Waiting Time

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Abstract

Two of the main influences on the waiting time in a system are the workload (the utilization) and the fluctuations of the arrivals and processes. For single arrival single server processes there are a few approximations, the most famous one being the Kingman formula. The presented game is an extension of an existing dice game to experience the Kingman formula. This game uses simple dices to explore the effect of utilization on the waiting time; the effect of fluctuations on waiting time; and the effect of a combination of both. The first round sets the baseline with low utilization and low fluctuations. A second round increases utilization, a third round increases the utilization again to 100%. The increase of the utilization is highly nonlinear, which surprises the participants. In a fourth and fifth game, the utilization is reduced again to the baseline, but the fluctuation is increased using dice with 12 and 30 sides. In a final sixth game both the utilization and the fluctuations are increased. The nonlinear effects continue to surprise the participants. Hence, this game can leave a lasting impact for its participants.

Keywords: Kingman equation, utilization, variation, waiting time

Development of Competences for Lean and Agile Project Management: combining PBL and Portfolios

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Abstract

Success of engineering projects require teams that apply technical knowledge working cooperatively with a suitable attitude and motivation. Thus, the development of competences for project management should integrate technical and transversal competences. The project management international associations have acknowledged the need for the integration of different types of competences. On the one hand, the International Project Management Association (IPMA) defined the IPMA Individual Competence Baseline, a framework of competences classified in three dimensions that the project management practitioner should develop. The dimensions are Practice Competences, People Competences and Perspective Competences. On the other hand, the Project Management Institute (PMI) association consider the need to give support to the teams of project management, in the processes included in the human resources knowledge area. The Master Program of Engineering Project Management of the University of Minho defined its structure partially inspired in the Project Management Body of Knowledge (PMBOK) structure. Based on this structure it defined two courses more related to human resources knowledge area. These courses were developed considering agile approaches for project management and the IPMA people competences as a framework to guide the planning of contents, activities, projects and individual portfolios. This work aims to analyze the results of the main outputs of these courses (projects and portfolios) focusing on competences developed in Lean and Agile project management. The research design is based in a qualitative analysis of three years of portfolios. The analysis is developed considering the IPMA framework. The preliminary results of the analysis of the evidences show that the competences that students most develop is communication and teamwork. Additionally, there are evidences that students develop critical thinking competences and value the semi directed teaching approach implemented in the classes. Implications for Lean and Agile project management education will be also discussed in the final paper.

Keywords: Engineering Education; Lean Education; Lean Project Management; Agile Project Management; Project-Based Learning; Project Management Competences

Acknowledgments: This work was partially supported by projects COMPETE-POCI-01-0145-FEDER-007043 and FCT-UID-CEC-00319-2013, from Portugal.