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ANALYSIS OF LEAN MANUFACTURING KNOWLEDGE CORRELATION MODELS FOR INDIA AND THE USA

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Purpose: This article presents the findings of a statistical study that used surveys to collect data from English-speaking countries and India, where English is widely used as a common language. The surveys aimed to understand the knowledge, attitudes, and awareness of production management systems among employees at selected plants of a multinational automotive corporation. Statistical analysis was used to identify relationships within the "knowledge" subgroup of the data, and a detailed expert study was conducted based on the results. The study not only describes the identified correlations but also provides recommendations on how to enhance the performance of areas with low knowledge scores by leveraging these correlation.
Design/methodology/approach: Based on responses collected in a survey based on the Lickert scale in research groups. Using scale reliability analysis with the □ -Cronbach test and the Nunali criterion reliability, statistically significant pairs of correlations were defined and subjected to further expert analysis.
Findings: Based on the correlation analysis, a higher level of understanding of Lean Manufacturing issues was noticed in India than in the USA, and in both study groups there was a relationship proving that the use of Lean tools was perceived not as work improvement but as additional work.
Keywords: management systems, Lean Manufacturing, statistical analysis.
Category of the paper: Research paper.

1. Introduction

The benefits of implementing the Lean Manufacturing system include reducing losses in the process: The Lean methodology aims to eliminate stages of the production process that do not create added value. Lean Manufacturing leads to increased productivity. By streamlining processes, the repeatability and quality of products improves. The implementation of Lean

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Manufacturing focuses on improving the awareness and thus the involvement of employees, enabling them to use the full potential of their ideas for improvements. Reducing the amount of losses and waste and improving productivity lead to significant savings over time, and improving quality and efficiency clearly translates into increased customer satisfaction and reduced complaint levels. Lean Manufacturing can make a company more agile and able to change quickly in response to market demands or disruptions (Emiliani, 2006; Hafey, 2010; Hill, 2011; Jasińska, 2015; Koch, 2011; Liker, 1998; Netland, 2016; Prońko et al., 2008; Radeka 2013; Snee 2010; Tice, 2005; Womack et al., 2007).

However, implementing Lean Manufacturing is a transformational endeavor that comes with challenges, many of which involve changing deeply ingrained habits. One of the main obstacles is resistance to change. Employees, and sometimes management, may become comfortable with established processes and wary of new systems that change their routines or appear to threaten job security. Overcoming this resistance requires careful change management and clear communication about the benefits of the new approach (Bednarek, 2007; Dudek, 2016; Graupp, Wrona, 2010; Holweg, 2007; Koch, 2011; Netland, 2016; Nogalski et al., 2010; Nowacki, 2019; Shook, Rother, 2017).

Adopting Lean Manufacturing is not just about changing processes; it's about changing the workplace culture to one that values continuous improvement and efficiency and is able to implement improvement ideas from every crew member, regardless of their level in the organization. Creating this culture change requires ongoing commitment and can be difficult to sustain, especially with the daily pressures of running a business. Another significant difficulty is the need for extensive training and education. Both employees and managers must be trained in Lean principles and methodologies, which can require a significant investment of time and resources. After the initial, energizing period of implementing Lean principles, one of the challenges is maintaining momentum and focus. It is easy for organizations to fall back into old habits, especially if the ongoing benefits of a lean approach are not immediately apparent or if the company lacks strong leadership in lean principles. Production management is based on just-in-time (JIT) production, which reduces inventory costs (Deif, 2019; Duhigg, 2013; Garvin, 1986; Hofstede, 2000; Khaba, Bhar, 2016; Kull et al., 2014; Minkov, Hofstede, 2011; Netland, 2016; Pereira et al., 2017; Plum, 2008; Podloch, 2023, 2022; Wangwacharakul et al., 2014; Wiengarten et al., 2011; Wong, 2007).

In summary, moving to lean manufacturing requires significant effort and a shift in mindset, but the long-term benefits in terms of productivity, employee engagement, quality and cost savings can be significant. The dynamics of implementing and maintaining Lean principles in a company depends on many factors. One of them is employee attitudes resulting from cultural conditions. As the aim of the research, the development and comparative analysis of the knowledge models of the Lean area in the US and India as two countries with diametrically opposed cultural conditions was adopted (Bhasin, Burcher, 2006; Hill, 2011; Holweg 2007; Lewis, 2020; Murman, 2002; Nicholas, 2010; Prońko et al., 2008; Ward, Zhou, 2006).

2. Research methodology

The research was conducted using a proprietary questionnaire containing 18 questions on knowledge in the area of Lean Manufacturing, which is presented in Table 1. The set of questions was developed in cooperation with the Lean department of the company (a global automotive concern) where the research was conducted. Questions were answered on a 5-point Likert scale, where 1 meant definitely no, and 5 meant definitely yes.

Table 1.
Questions included in the research questionnaire

The content of the question	
How would you rate your knowledge of Lean principles? - my own	Q1
How would you rate your knowledge of Lean principles? - among the staff at your workplace	Q2
Do you think that the operator is responsible for the condition of the machine he works on?	Q3
Do you think that keeping records of machine parameters, activities, etc. on MAFACT boards is important?	Q4
Who do you think is responsible for safety in the area?	Q5
Who is responsible for ensuring product quality? (you can choose more than one answer)	Q6
Which problem do you think is more important? Scrap or Rework	Q7
Do you think that implementing and updating the Retooling Standardization can bring tangible benefits?	Q8
Should part of the responsibility for maintaining machines lie with the operator?	Q9
Is the role of the process engineer and/or setup person to speed up machine uptime at all costs?	Q10
Should a process engineer and/or production engineer analyze the layout of machines and stations and the number of operators in his area?	Q12
Is 100% Pull production possible regardless of the production type?	Q13
Should Maintenance be involved in detailed analysis of failures and the use of advanced systems for planning the replacement of parts?	Q14
Is Continuous Flow always possible?	Q15
According to Should your Finance departments be trained in Lean and MAFACT principles?	Q16
Should machines be grouped by? their uses? e.g. all CNC machines next to each other?	Q17
Do you think machines should be placed in neat rows facing the same direction?	Q18
Is it possible to achieve full replacement of operators? This means that all employees can be freely assigned to other positions?	Q19

The results were subjected to scale reliability analysis using the □-Cronbach test. The Nunali criterion was used to verify the reliability of the scale. Using the stepwise method, questions were removed from the scale, after removing which the □-Cronbach's value increased. After obtaining a satisfactory □-Cronbach's value (min. 0.7), Pearson's r test was used to analyze the correlation between pairs of questions. In each case, a significance level of □ = 0.05 was assumed. Based on the obtained correlation coefficients for pairs for which p <□□, LM knowledge models of India and the US were built.

The obtained results can be compared with the results of quality audits of the implementation of production management support systems, including, to a large extent, Lean Manufacturing. The audits evaluate individual issues on a point scale and are carried out by certified internal auditors. The auditors undergo regular calibrations so that their assessments can be comparable among themselves. The details of the auditing and calibration process are part of the company's "Know How", but at its core it was built on the well-known WCM (World Class Manufacturing) system - one of the systems extracted over the years from the basic Toyota Production System and later Lean Manufacturing and developed by Fiat Automotive, among others. Also for reasons of data confidentiality, the exact numerical results of the audits cannot be given. They will be compared on a percentage basis for the entire groups of regions studied.

3. Research results

The survey included 200 employees at various organizational levels from Canada, the US, India and the UK. Due to problems related to legal restrictions on conducting surveys in the UK and the resulting low percentage of completed surveys relative to the number of employees in the production facility, the UK was finally excluded from the analysis. Also excluded finally was Canada where, despite the collection of 18 surveys in relation to the number of employees, the survey return rate was about 1%. In Canada, in contrast to the UK where legal and internal company regulations hindered any initiative to spread the survey, the low response in Canada seems to be the result of a lack of need to share an opinion or possibly a lack of pressure from management for an information company that could be more visible to the workforce. In the US, 199 completed questionnaires were collected which represents 2% of the crew. In India, 70 completed questionnaires were submitted which represents 6% of the crew. The results of the analysis for India are presented in Table 2.

Table. 2.
Correlations between pairs of the India scale

	Q2	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	**Q18**	**Q19**
Q1	0,638	0,132	0,368	0,045	0,128	0,177	0,145	-0,136	0,32	0,449	0,017	0,34	0,317	-0,06	-0,107	-0,119	0,221
Q2	.	0,149	0,164	-0,005	0,061	-0,016	-0,027	-0,092	0,151	0,115	0,002	0,275	0,179	0,075	-0,215	-0,347	0,263
Q3	.	.	0,272	0,171	0,051	-0,06	0,267	0,446	0,489	0,334	0,468	0,449	0,469	0,193	0,019	-0,24	0,495
Q4	.	.	.	0,341	0,22	0,327	0,727	0,319	0,319	0,473	0,102	0,315	0,334	0,147	-0,046	0,018	0,200
Q5	.	.	.	.	0,369	0,286	0,289	0,227	0,091	0,192	0,204	0,074	0,015	0,194	-0,119	-0,164	0,233
Q6	.	.	.	.	.	0,455	0,223	0,07	0,136	0,225	0,025	0,205	0,067	-0,097	0,118	-0,152	0,25
Q7	.	.	.	.	.	.	0,136	0,064	0,022	0,308	0,108	0,227	0,085	0,069	-0,027	-0,012	0,054
Q8	.	.	.	.	.	.	.	0,385	0,396	0,479	0,22	0,392	0,43	0,158	-0,188	-0,079	0,211
Q9	.	.	.	.	.	.	.	.	0,322	0,313	0,397	0,282	0,322	0,616	0,079	0,207	0,319
Q10	.	.	.	.	.	.	.	.	.	0,547	0,475	0,494	0,749	0,009	-0,138	-0,1	0,434
Q12	.	.	.	.	.	.	.	.	.	.	0,23	0,417	0,555	0,168	-0,235	-0,138	0,265
Q13	.	.	.	.	.	.	.	.	.	.	.	0,333	0,546	0,321	-0,033	0,099	0,534
Q14	.	.	.	.	.	.	.	.	.	.	.	.	0,548	0,064	-0,069	-0,094	0,478
Q15	.	.	.	.	.	.	.	.	.	.	.	.	.	0,103	-0,201	-0,148	0,325
Q16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0,21	0,218	0,326
Q17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0,42	-0,051
Q18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0,124

Stepwise analysis of the scale's reliability, selected a homogeneous scale consisting of 18 questions for India with a α-Cronbach's value for the scale of 0.740 and 15 for the US with a α-Cronbach's value for the scale of 0.701. In the case of the USA, questions Q2, Q17 and Q18 were removed as not fitting the scale. In addition, question Q11 was omitted in both cases. A pairwise correlation analysis was conducted for the scale. Based on the analysis, 30 statistically significant pairs were selected for the USA and 46 for India, which were used to build the LM knowledge model. The results of the analysis for USA are presented in Table 3. Statistical significance was determined based on the p-value of α = 0.05.

Table. 3.
Correlations between pairs of the USA scale

	Q3	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q19**
Q1	0,258	0,172	0,041	0,059	0,174	0,169	0,207	0,125	0,188	0,133	0,108	0,02	0,262	0,036
Q3	.	0,042	0,043	0,157	0,277	0,041	0,205	0,049	0,009	0,248	0,106	0,088	0,207	0,147
Q4	.	.	0,204	0,194	0,106	0,3	0,097	0,042	0,223	0,068	0,257	-0,008	0,038	0,192
Q5	.	.	.	0,491	0,285	0,08	0,025	-0,027	0,136	0,079	0,035	0,005	0,063	0,05
Q6	.	.	.	.	0,196	0,037	0,125	0,203	0,053	0,077	0,043	0	0,057	0,106
Q7	.	.	.	.	.	0,07	0,118	0,074	0,027	0,125	0,12	-0,026	0,139	-0,093
Q8	.	.	.	.	.	.	0,38	0,163	0,548	0,125	0,451	0,095	0,375	0,083
Q9	.	.	.	.	.	.	.	0,185	0,255	0,157	0,275	0,085	0,316	0,147
Q10	.	.	.	.	.	.	.	.	0,167	0,311	-0,078	0,253	0,067	0,111
Q12	.	.	.	.	.	.	.	.	.	-0,061	0,396	0,151	0,188	0,154
Q13	.	.	.	.	.	.	.	.	.	.	0,092	0,259	0,07	0,085
Q14	.	.	.	.	.	.	.	.	.	.	.	0,038	0,213	-0,01
Q15	.	.	.	.	.	.	.	.	.	.	.	.	0,045	0,191
Q16	.	.	.	.	.	.	.	.	.	.	.	.	.	-0,001

4. LM Knowledge Model

The graphical construction of the knowledge model, due to the significant number of correlations, was built primarily based on the ability to build a consistent and graphically clear model, the second determining factor was the value of correlations between questions. The result was the graphical versions of the models shown in fig. 1 and fig. 2.

4.1. LM knowledge model for the US

The developed LM knowledge model requires expert verification and the determination of the possibility of indirect influence on individual questions through the formation of knowledge in the range corresponding to the individual pairs, which are the components of the model. The content analysis of individual pairs between questions was developed with the values of individual correlations, starting with the largest. Of the pairs of questions that were selected to build the LM knowledge model for the US, each has a positive correlation r, meaning that by raising awareness in one area we can simultaneously positively influence another related area.

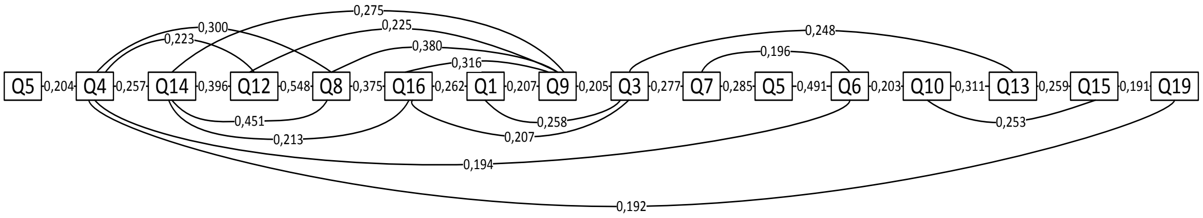

Figure. 1. LM USA knowledge model

Correlation analysis for the U.S. knowledge model was conducted from strongest to weakest among the selected pairs (Table 4).

Table. 4.
Correlations between pairs of the USA description

Q12 – Q8 (r = 0,548)	the connection between work standardization and LayOuts
Q5 – Q6 (r = 0,491)	issues of responsibility for safety and quality
Q14 – Q8 (r = 0,451)	questions regarding maintenance (analysis and standardization of changeovers);
Q15 – Q12 (r = 0,396)	questions about Continuous Flow and LayOuts
Q8 – Q9 (r = 0,380)	topics of standardization of changeovers and operators' responsibility for machines
Q8 – Q16 (r = 0,375)	the topic of standardization and training for non-production departments
Q16 – Q9 (r = 0,316)	issues of operators' liability for machines and training of non-production workers
Q10 – Q13 (r = 0,311)	the issue of using the Pull System and accelerating the cycle time
Q4 – Q8 (r = 0,300)	the issue of keeping records of parameters and standardizing changeovers
Q7 – Q5 (r = 0,285)	liability issues in the area and opinions on the importance of scrap/rework
Q3 – Q7 (r = 0,277)	issues regarding the importance of scrap/rework, operators' liability for machines
Q14 – Q9 (r = 0,275)	the topic of failure analyzes and responsibility for the condition of operators' machines
Q16 – Q1 (r = 0,262)	the topic of training of non-production departments and assessment of the level of knowledge
Q13 – Q15 (r = 0,259)	Continuous Flow and Pull system issues
Q1 – Q3 (r = 0,258)	issues of the level of knowledge and responsibility of operators
Q4 – Q14 (r = 0,257)	the issue of keeping records of parameters and analyzes after failures
Q10 – Q15 (r = 0,253)	the issue of using Continuous Flow and accelerating cycle time
Q3 – Q13 (r = 0,248)	issues of operator and Pull System liability
Q12 – Q9 (r = 0,225)	the issue of using the Pull System and accelerating the cycle time
Q4 – Q12 (r = 0,223)	tracking machine parameters and LayOuts
Q14 – Q16 (r = 0,213)	issues of maintenance analysis and training of non-production workers
Q16 – Q3 (r = 0,207)	issues of responsibility and training of non-production workers
Q1 – Q9 (r = 0,207)	the issue of assessing the level of knowledge and responsibility
Q9 – Q3 (r = 0,205),	both questions concern responsibility for the condition of machines
Q5 – Q4 (r = 0,204),	issues of responsibility and keeping records of parameters
Q6 – Q10 (r = 0,203)	liability issues and the role of the process engineer
Q7 – Q6 (r = 0,196)	issues of liability and materiality of scrap/rework
Q4 – Q19 (r = 0,192)	issues of maintaining parameters and skill matrices
Q4 – Q6 (r = 0,191)	issues of responsibility and keeping records of parameters
Q15 – Q19 (r = 0,191)	Operator Substitutability and Continuous Flow issues

From an expert analysis of the identified correlations, it can be concluded that correlations occur among questions mentioning individual Lean Manufacturing tools by name, sometimes with no direct connection to each other, may be indicative of a generally low level of awareness of what exactly the terms occurring in the survey are. In only some cases can correlations be unambiguously linked to the potential motivation of respondents. Such is the case with questions on maintenance issues, machine condition and post-failure analysis.

Other unambiguous correlations include links between the terms Continuous Flow, Pull System, cycle time work and LayOut analyses, questions that can be directly associated with optimizations conducted by the Lean Manufacturing team (Antosz, 2015; Wolniak, 2013; Żebrucki, Kruczek, 2011).

Another interesting group of links are questions related to accountability issues, Lean Manufacturing training for non-manufacturing departments and skill matrices. These linkages can be interpreted as associating Lean Manufacturing tools more with expanding responsibilities or additional work without necessarily ultimately improving the conditions of that work by optimizing it (Johansson et al., 2013; Koch, 2011).

4.2. LM knowledge model for India

Of the pairs of questions that were selected to build the LM knowledge model for India, most of the pairs have a positive r-correlation, meaning that by raising awareness in one area we can simultaneously positively influence another related area. The only pair of correlations with a negative coefficient is the pair Q2 and Q18. Respondents rating the level of knowledge among the general workforce as high in their subjective assessment also gave the most inappropriate answer to the question about how machines should be set up.

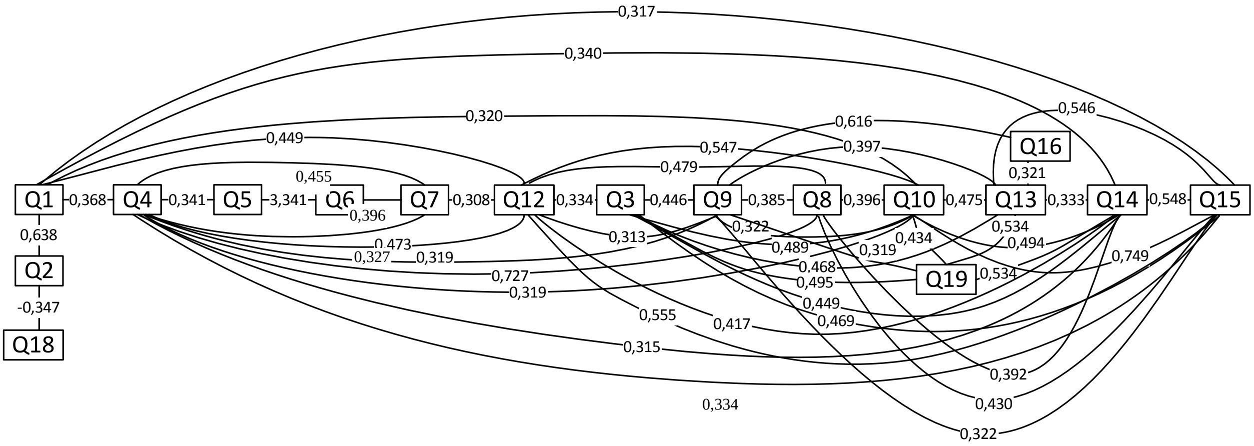

Figure 2. LM India knowledge model.

In a study group containing Indian manufacturing plants, the correlations of the various Lean Manufacturing tools are characterized by the logical relationship of these tools to the issues these tools are designed to address by design. Correlations such as Continuous Flow and cycle time. Standardization and station record keeping, Continuous Flow and LayOut, improving cycle time and working on LayOut. Repeated correlations are also noticeable in maintenance issues (Table 5) (Wong, 2007; Antosz, 2015).

Table. 5.
Correlations between pairs of the India description

Q10 – Q15 (r = 0,749)	issues of Continuous Flow and working on cycle time
Q4 – Q8 (r = 0,727)	keeping records of setting parameters and standardizing work
Q1 – Q2 (r = 0,638)	both questions directly concern the subjective assessment of the level of knowledge
Q9 – Q16 (r = 0,616)	issues of responsibility and training of non-production workers
Q12 – Q15 (r = 0,555)	issues related to Continuous Flow and LayOuts
Q14 – Q15 (r = 0,548)	the issue of Continuous Flow and Lean tools in maintenance
Q12 – Q10 (r = 0,547)	working on cycle time and LayOut
Q13 – Q15 (r = 0,546)	Pull System and Continuous Flow issues
Q3 – Q19 (r = 0,495)	issues of operators' liability and their substitutability (skills matrix)
Q10 – Q14 (r = 0,494)	improving cycle time and analyzing failure causes
Q3 – Q10 (r = 0,489)	issues of responsibility and role of the process engineer
Q12 – Q8 (r = 0,479)	issues regarding work standardization and LayOut
Q10 – Q13 (r = 0,475)	work on cycle time and Pull System
Q4 – Q12 (r = 0,473)	issues related to tracking setting parameters and LayOuts
Q3 – Q15 (r = 0469)	Continuous Flow issues and responsibility for the condition of machines
Q3 - Q13 (r = 0,468)	Pull System issues and responsibility for the condition of machines
Q3 – Q14 (r = 0,449)	issues of responsibility for the condition of machines and maintenance tasks
Q1 – Q12 (r = 0,449)	assessment of the level of knowledge and responsibility of process engineers for working on LayOut
Q3 – Q9 (r = 0,446)	both questions directly concern responsibility for the condition of machines;
Q6 – Q7 (r = 0,455)	both questions directly concern problems with the quality of details;
Q10 – Q19 (r = 0,434)	the issue of the role of the process engineer and skills matrix;
Q8 – Q15 (r = 0,430)	issues related to standardization of work and Continuous Flow;
Q12 – Q14 (r = 0,417)	issues related to conducting LayOut and post-failure analyzes and Lean tools in maintenance;
Q8 – Q10 (r = 0,396)	linking the issue of standardization of work and acceleration of cycle time
Q8 – Q14 (r = 0,392)	issues of work standardization and lean tools in maintenance;
Q9 – Q8 (r = 0,385)	issues related to responsibility for machine maintenance and standardization of work
Q1 – Q4 (r = 0,368)	issues of keeping records of parameters and assessing the level of knowledge
Q5 – Q6 (r = 0,367)	both questions directly raise issues of responsibility
Q2 – Q18 (r = -0,347)	issues related to working on LayOut and assessing the level of knowledge
Q4 – Q15 (r = 0,334)	issues of managing setting parameters and Continuous Flow
Q4 – Q7 (r = 0,327)	issues of maintaining parameter settings and assessing quality problems
Q9 – Q10 (r = 0,322)	issues of responsibility for maintaining machines and the role of the process engineer
Q9 – Q15 (r = 0,322)	issues of responsibility for maintaining machines and Continuous Flow
Q4 – Q5 (r = 0,341)	issues of maintaining setting parameters and liability
Q1 – Q14 (r = 0,340)	issues of using Lean tools by maintenance and assessing the level of knowledge
Q13 – Q14 (r = 0,333)	issues in the field of Pull System and Lean tools used by maintenance
Q12 – Q3 (r = 0,334)	issues of the operator's responsibility for machines and the role of the process engineer
Q16 – Q13 (r = 0,321)	the topic of employee training in the field of Lean for non-production employees and the Pull System
Q1 – Q10 (r = 0,320)	the issue of the engineer's role in working on cycle times and assessing the level of knowledge
Q9 – Q19 (r = 0,319)	issues of operators' liability and the possibility of replacing them (skills matrix)
Q12 – Q9 (r = 0,313)	issues of operator responsibility and the role of the process engineer regarding LayOuts
Q4 – Q9 (r = 0,319)	issues of maintaining setting parameters and responsibility for maintaining machines
Q4 – Q10 (r = 0,319)	issues of maintaining setting parameters and the role of the process engineer
Q1 – Q15 (r = 0,317)	issues of knowledge level and Continuous Flow
Q4 – Q14 (r = 0,315)	issues of maintaining setting parameters and maintenance responsibility for using Lean tools
Q7 – Q12 (r = 0,308)	issues of assessing quality problems and the role of the process engineer regarding LayOuts

In the knowledge model for Lean Manufacturing in the US, 30 statistically significant correlations were identified, when in the model for India, 46 were identified, which may lead to the belief that the smaller number of correlations are only those characterized by logical relationships. The complexity of the graphical representation of the knowledge model for India may lead to similar conclusions. However, analyzing the individual correlations separately, the correlations found in the Indian study group are more logical than those found in the US study group, in which correlations occur in issues when Lean Manufacturing analytical tools are linked to opinions on liability issues.

The groups of correlations found in the model for India are characterized by a higher awareness of the issues raised in the questionnaire by which one can infer an overall higher level of knowledge about production management systems in Indian plants than in plants from the US. The correlations in the India group occur in the linkage of specific Lean tools that are actually related to each other in a logical way.

5. Possible applications of the LM knowledge model

The results of correlation studies confirm the connections between individual areas of knowledge and can therefore be used to identify individual areas of knowledge on which work in individual plants may result in increasing the overall level of understanding of the Lean Manufacturing system.

The results of correlation analyzes for the two groups presented suggest the lack of training presenting the practical use of Lean Manufacturing tools in the group of plants from the USA. It would be valuable to conduct workshops proving that Len Manufacturing issues are not only training material that the company wants to provide to employees to improve their results, but that the working conditions after the workshops make the work more comfortable, we face fewer unexpected problems and at the same time we can be more efficient without extra effort.

Based on the identified correlations occurring in the US model of plants, it would be reasonable to conduct an extensive training program explaining the terminology of individual Lean Manufacturing tools so that employees would be able to identify the role of individual tools. The second stage would have to be conducting a series of workshops. Referring to the connections between issues related to responsibility and additional training, it would be reasonable to conduct not simulation workshops, but Kaizen workshops on selected production lines, involving mixed teams not only in production, so that the crew could see what effects the implementation of Lean tools can bring on a pilot line.

Training programs that could be carried out in Indian plants using the higher level of knowledge that was achieved there could be Value Stream Mapping analysis programs, which eliminated Work in Progress storage, Inventory Turns and the introduction of One Piece Flow wherever possible, advanced SPC programs focused on analysis production results to anticipate potential quality problems. The potential identified among the staff of Indian plants is worth developing and attempting to introduce advanced optimizations for the benefit of the company (Walentynowicz, 2015; Żebrucki, Kruczek, 2011).

6. Conclusion

According to the research, the created model can be used to study relationships and conduct additional statistical analyses. The article presents general models, however, by assessing the level of knowledge of individual people and previously defined groups using the model, it is possible to identify groups of employees that may require more attention. The results of the assessment of the study conducted on different groups of the study population were similar, although differences in the general and specific assessment of the area may appear in future studies.

The analysis clearly shows that increasing the level of knowledge in the field of Lean principles and improving production efficiency in the examined plant can be achieved through intensive training. This training should focus on simulating flow design, production planning, variances in planning systems, plant-wide part flow implementation methods, and planning and analyzing line-level optimization opportunities (such as LayOut and Line Balance) for specialists and operations engineers. This group is extremely important because it serves as a bridge between office and production employees, and their attitude significantly influences how leaders and operators perceive the Lean system tools. Moreover, transferring this positive attitude to the shop floor is crucial to raising the overall level of Lean knowledge throughout the plant.

A significant difference between the correlations indicated in the knowledge models in plants in India and the USA was verified by the results of corporate audits of the compliance of the plant's production management system with the expected level of implementation of Lean Manufacturing tools. The comparison of audit results confirms the observations made on the basis of correlation analyses, and the results of the plants from the Indian group are over 8.43% higher than the results of the US group.

References

1. Antosz, K. (2015). *Lean Manufacturing doskonalenie produkcji*. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
2. Bednarek, M. (2007). *Doskonalenie Systemów Zarządzania, nowa droga do przedsiębiorstwa lean*. Warszawa: Difin.
3. Bhasin, S., Burcher, P. (2006). Lean viewed as a philosophy. *Journal of Manufacturing Technology Management, 17*.
4. Deif v. Beek, A. (2019). *National culture insights on manufacturing competitiveness and talent management relationship*. San Luis Obispo, California: California Polytechnic State University.
5. Dudek, M. (2016). *Szczupłe systemy wytwarzania*. Warszawa: Difin.
6. Duhigg, Ch. (2013). *Siła nawyku. Dlaczego robimy to, co robimy i jak można to zmienić w życiu i biznesie*. PWN.
7. Emiliani, B. (2006) Origins of lean management in America. *Journal of Management History, 12*.
8. Garvin, D.A. (1986). Quality Problems, Policies, and Attitudes in the United States and Japan: An Exploratory Study. *Academy of Management Journal*.
9. Graupp, P., Wrona, R. (2010). *Podręcznik TWI*. Lean Enterprise Institute.
10. Hafey, R.B. (2010). *Lean Safety. Transforming Your Safety Culture with Lean Management*. New York: CRC Press.
11. Hill, A.V. (2011). *The Encyclopedia of Operations Management.* FT Press.
12. Hofstede, G. (2000). *Kultury i organizacje. Zaprogramowanie umysłu*. Warszawa: PWE.
13. Holweg, M. (2007). The Genealogy of Lean Production. *Journal of Operations Management*.
14. Jasińska, S., Żurek, M., Wyrwicka, M.K. (2015). Analiza efektywności wdrożenia Lean Manufacturing. Studium przypadku. *Economics and Management*, *1*. Politechnika Poznańska.
15. Johansson, P.E.C., Lezama, T., Malmsköld, L., Sjögren, B., Moestam, A.L. (2013). *Current State of Standardized Work in Automotive Industry in Sweden*. Forty Sixth CIRP Conference on Manufacturing Systems.
16. Khaba, S., Bhar, Ch. (2016). *Modeling the key barriers to lean construction using interpretive structural modeling*. Dhanbad, India: Department of Management Studies, Indian School of Mines.
17. Koch, T. (2011). Jak stosować metody Lean Manufacturing (Oszczędnego Wytwarzania) do wprowadzania innowacji. *E-narzędzia i technologie generatywne jako szybka ścieżka do innowacji, no. 1*. Warszawa: Politechnika Wrocławska.

18. Koch, T. (2011). *Minione 10 lat ruchu Lean w Polsce: wnioski i perspektywy*. X Międzynarodowa Konferencja Lean Manufacturing: materiały konferencyjne, Wrocław 2010. Lean Enterprise Institute Polska. za: Jak stosować metody Lean Manufacturing (Oszczędnego Wytwarzania) do wprowadzania innowacji, materiały, Warszawa.
19. Kull, T.J., Yan, T., Liu, Z., Wacker, J.G. (2014). The moderation of lean manufacturing effectiveness by dimensions of national culture: testing practice-culture congruence hypotheses. *International Journal of Production Economics*.
20. Lewis, M.A. (2020). Lean production and sustainable competitive advantage. *International Journal of Operations and Production Management*.
21. Liker, J.K. (1998). *Becoming Lean. Inside Stories of U.S. Manufacturers*. New York: Productivity Press.
22. Minkov, M., Hofstede, G. (2011). The Evolution of Hofstede's Doctrine. *Cross Cultural Management: An International Journal.*
23. Murman, E. et al. (2002). *Lean Enterprise Value. Insights from MIT's Lean Aerospace Initiative.* New York: Palgrave.
24. Murphy, M. (2002). Organisational Change and Firm Performance. *OECD Science, Technology, and Industry Working Papers, 14*. Paris: OECD.
25. Netland, T.H. (2016). Critical success factors for implementing lean production: the effect of contingencies. *International Journal of Production Research*.
26. Nicholas, J. (2010). *Lean Production for Competitve Advantage*. New York: CRC Press.
27. Nogalski, B., Czerska, J., Klimek, A. (2010). Wykorzystanie metod teorii masowej obsługi i lean management w usprawnianiu procesów w zarządzaniu organizacją publiczną. *Współczesne Zarządzanie, no. 1*.
28. Nowacki, K. (2019). *Modelowanie Bezpieczeństwa w Przemyśle*. Gliwice: Wydawnictwo Politechniki Śląskiej.
29. Shook, J., Rother, M. (2017). *Naucz się widzieć*. Lean Enterprise Institute.
30. Pakdil, F., Leonard, K.M. (2017). Implementing and sustaining lean processes: the dilemma of societal culture effects. *International Journal of Production Research*.
31. Pereira, C.M., Anholon, R., Batocchio, A. (2017). Obstacles and Difficulties Implementing the Lean Philosophy in Brazilian Enterprises. *Brazilian Journal of Operations & Production Management*.
32. Plum, E. (2008). *Cultural Intelligence*. Middlesex Universiti Press.
33. Podloch, I. (2023) Lean Manufacturing Knowledge Correlation Model, Advances in Production. *Intelligent Systems in Production Engineering and Maintenance, Lecture Notes in Networks and Systems, vol. 790*. Springer, p. 607, ISBN 978-3-031-45020-4.
34. Podloch, I. (2022). Zakres badań dotyczących świadomości zagadnień nt. systemów zarządzania i gotowości na ich wdrażanie. *Systemy Wspomagania w Inżynierii Produkcji, vol. 11, iss. 2,* pp. 1-7.

35. Prońko, J., Soboń, A., Zamiar, Z. (2008). *Zarządzania produkcją*. Kielce: Wydawnictwo Uniwersytetu Humanistyczno-Przyrodniczego w Kielcach.
36. Radeka, K. (2013). *The Mastery of Innovation. A Field Guide to Lean Product Development*. Boca Raton: CRC Press.
37. Shook, J., Rother, M. (2017). *Naucz się widzieć*. Lean Enterprise Institute.
38. Snee, R.D. (2010). Lean Six Sigma – getting better all the time. *International Journal of Lean Six Sigma.*
39. Tice, J. (2005). Lean Production and EMSs: Aligning Environmental Management with Business Priorities. *Environmental Quality Management, Winter*.
40. Walentynowicz, P. (2015). *Zakres zastosowania Lean Management w przedsiębiorstwach produkcyjnych.* Konferencje KZZ 2015, zebrane artykuły.
41. Wangwacharakul, P., Berglund, M., Harlin, U., Gullander, P. (2014). Cultural aspects when implementing lean production and lean product development experiences from a Swedish perspective. *Quality Innovation Prosperity*.
42. Ward, P., Zhou, H. (2006). Impact of Information Technology Integration and Lean/Just-In-Time Practices on Lead-Time Performance. *Decision Sciences, 37.*
43. Wiengarten, F., Fynes, B., Pagell, M., de Búrca, S. (2011). Exploring the impact of national culture on investments in manufacturing practices and performance. *International Journal of Operations & Production Management.*
44. Wong, M. (2007). *The Role of Culture in Implementing Lean Production System, Department of Industrial Engineering*. Taichung: Tunghai University.
45. Womack, J., Jones, D., Roos, D. (2007). *The Machine That Changed the World*.
46. Womack, J. (2001). *Odchudzanie Firm: Eliminacja marnotrawstwa - kluczem do sukcesu.* Warszawa: *Centrum Informacji Menedżera*.
47. Wolniak, R. (2013). *Metody i narzędzia Lean production i ich rola w kształtowaniu innowacji w przemyśle.* Konferencje KZZ 2013, zebrane artykuły.
48. Żebrucki, Z., Kruczek, M. (2011). *Doskonalenie struktury łańcucha dostaw z wykorzystaniem koncepcji Lean.*