Lean Practices Transfer in Developed Countries: A Practical Case in an Electrical Wires and Cables Company

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Abstract

Although Lean knowledge is widely spread worldwide bringing forth benefits to organizations, observable in the literature is that small-sized enterprises in developed countries do not usually apply this industrial management technique. Therefore, this article has sought to demonstrate that Lean Knowledge Transfer, through the university-enterprise cooperation, may reach expressive results in a wires and cables company. To achieve that, a product family largely impacting the production process has been selected in that company. Next, the tool Value Stream Mapping (VSM) has been used to visualize the current state and, in partnership with the company's managers, idealize a future state of the process. With that, wastes have been found in the production process and Lean tools have been pointed out to reach improvements proposed in the future state. The results have shown a significant reduction in wastes of: movement of operators (50 and 40% in distances traveled), inventories (44 and 22% of copper), lead time (60 and 53% of the time) and the number of operators (39% in total). Thus, the conclusion is that these results corroborate the literature, where one may apply Lean knowledge transfer in different-sized enterprises so as to seek the reduction of wastes and improve the production process efficiently with the cooperation of universities.

Keywords: Electrical wires and cables company; Value Stream Mapping; Lean knowledge transfer;

1. Introduction

Brazil has been experiencing an economic and financial crisis since the end of 2014 [16]. In fact, when analyzing the data of the Gross Domestic Product (GDP), it is possible to verify that in 2014 the value of the GDP was of 2.456 trillion dollars and the emergence of the crisis this figure fell to 1.802 US dollars rails in 2015 [48]. The implications of this resection had an impact in different sectors, mainly in the civil construction sector, which directly reflected in other industries that provided inputs to this sector, as is the case with the wire and cable industry. To overcome this situation, companies are looking for ways to reduce their processes and keep them competitive and survive. As an alternative to solving this problem, companies have the Lean Manufacturing (LM) technique.

The LM, according to [31], is the most widely used term in the West to refer to the production model proposed by Toyota (Toyota Production System – TPS). This production model is also found in the literature synonymous to "Lean production", "Lean thinking", "Lean enterprises" and "Lean consumption" [46, 6, 52, 33].

In accordance with [52], a catalyst that has been important to increase the popularity of Lean was the development of the International Motor Vehicle Program (IMVP). Corroborating the aforementioned, as per [40], the word Lean entered Industrial Management through a researcher from the Massachusetts Institute of Technology (MIT), called John Krafcik. Furthermore, this term has been chosen to represent the essence of TPS, as mentioned by [52], which is far less thirsty of resources in comparison to other Western traditional productions systems [40].

The systematic review undertaken by the authors [40] spans 25 years of Lean literature that has covered from 1989, its emergence, until 2013. Therefore, the authors demonstrate the increasing number of publications through graphs, where you may perceive a steep evolution of correlated works.

By observing the panorama described by the authors [40], easily notice the considerable boost in the number of publications as regards this theme from 2000 to 2013. This boost is likely due to, chiefly, the benefits generated in the production processes of its application, as well as in the extrapolation of application outside the automobile sector limits.

The benefits brought forth by implanting this industrial management technique, according to [4], are reduction of production costs, of lead time and improvement of production flow. Additionally, [30] stress that this technique has been shown as a good example of innovation in enterprises and one of its supports is the continuous improvement. However, so as to explore Lean, firstly, a current Value Stream Mapping (VSM) must be carried out in the production process aiming to show the wastes inherent to the process and then point out improvement opportunities in the future state or expected state VSM [12].

Corroborating the above-mentioned authors, [47] ratify that the VSM tool is the starting point to be followed in the application of Lean concepts. In addition, they attest that the automobile industry of Toyota was the first to use VSM and some authors who have employed this tool in their studies may be found in the literature [45, 42, 11, 36, 49; 2, 35, 50; 3,10, 34], as it visually outlines the information of the production process including value-added or non-value added activities to the good or service, besides clearly exposing the wastes and with that one may attain these cited benefits [5, 43, 27].

As per [29], the implementation of the Lean industrial management has occurred in a brilliant manner in the automobile sector and its principles and tools have been transferred to other companies of the manufacturing sector [7, 6, 41, 14] and one can observe that this knowledge has continuously been incorporated into the service sector [13, 1; 21, 23, 51; 39, 38, 19, 20, 32].

Despite this strong evidence, namely Lean enhances any production system by bringing forth benefits, the authors [17] report that knowledge transfer of this technique is a crucial point, albeit difficult, for enterprises. In accordance with these authors, this is related to multinationals in emerging countries. Regarding underdeveloped countries, note that in some of the major databases (Scopus, ScienceDirect,

Emerald, Web of Science and SciELO) this transfer has a high correlation in multinationals and low in local enterprises. This problem, or gap in the literature, is higher in poorer regions, as in the case of the Brazilian Northeast. Additionally, another gap found deals with scarcity of works published taking into account Lean knowledge transfer (LKT) in electrical wires and cables companies, which is the focus herein.
Another crucial factor with which this article is helping is to collaborate with researches referring to "Lean knowledge transfer", which according to [14], the literature on adherence to transfer of this industrial management technique is still embryonic and very fragmented. Thus, this article aims to demonstrate that LKT, through university-enterprise cooperation, may reach expressive results in a wires and cables company. For such, this survey is structured into five sections, in addition to the Introduction, namely: Section 2 – deals with the contextual antecedents and bibliometrics; Section 3 – outlines the methodology used; Section 4 – approaches the results and discussions; Section 5 – Discussion; and Section 6 – exhibits conclusions of the case study.

2. Contextual antecedents and bibliometrics

The gaps shown in the introductory section have been evidenced with the use of the literature review methodology used for designing this survey, which for its part has been based upon the combination of six keywords, as outlined in Chart 1, on five international databases, whose bibliometrics result is in Table 1.

Chart 1 Combination of keywords and operator

Keywords	**Operator**	**Keywords**
Wire Company	AND	Lean
Cable Company		Knowledge transfer
Wire and Cable		Value Stream Mapping
Keywords	**Operator**	**Keywords**
Lean	AND	Knowledge transfer
Value Stream Mapping		

As observed in Chart 1, the keywords have been combined in pairs by using the BooLean operator "AND" and by verifying Table 1, note that in all these databases accessed, the final bibliometrics result summed up 27 works, of which five are reviews [17, 46, 9, 24] and 22 are researches. Seven of these have drawn attention, as the authors have analyzed multi-cases or multi-plants [8, 17, 14, 22, 26, 25, 28, 24] where they have grouped several cases of LKT and synthesized them in their respective works.
Another noteworthy factor as regards this bibliometrics result analysis refers to the absence of works carried out at electrical wires and cables companies and which have not taken into account the following: knowledge transfer, Lean and Value Stream Mapping. This fact was previously discussed in the Introduction section above and makes this survey original and, due to that, it will be the largest literary contribution.
The result outlined in Table 1 has been reached by criteria of exclusions, duplicates and by the elimination of articles whose abstracts read have been outside the scope of the application theme of LKT in companies. Next, the remainder articles have been read thoroughly and served to support the methodology and find the

gaps of the Introduction section. As there have not been researches at wires and cables companies, the results have been discussed based upon articles which have shown similarity to the theme Value Stream Mapping and these have been surveyed on the aforementioned databases of the bibliometrics in addition to Google Scholar.

The systematic review method used herein was Methodi Ordinatio proposed by [37]. With that, the nine stages of this method have been used in addition to the software Medeley, JabRef and Microsoft Excel spreadsheets, student version, as recommended by the authors. Its use has aimed to order the major works found on the five databases of the Engineering literature: Web of Science, ScienceDirect, Emerald, Scopus and SciElo. Noteworthy is that the limitations of this study regard the following facts: the choice of works, which have been restricted to review articles and researches for analysis and discussion purposes; and the search of articles, which have been on these five databases.

Table 1. Bibliometrics result

Keywords		Data base					Total		
		Emerald	Scopus	Sciencedirect	Web of Science	SciElo	Found Papers	Check duplicates	Review of abstracts
wire company	Lean	0	0	0	0	0	0	0	0
	Knowledge transfer	0	0	0	0	0	0	0	0
	Value Stream Mapping	0	0	0	0	0	0	0	0
cable company	Lean	0	0	0	0	0	0	0	0
	Knowledge transfer	0	0	0	0	0	0	0	0
	Value Stream Mapping	0	0	0	0	0	0	0	0
wire and cable	Lean	0	1	0	0	0	1	1	0
	Knowledge transfer	0	0	0	0	0	0	0	0
	Value Stream Mapping	0	0	0	0	0	0	0	0
Lean	Knowledge transfer	7	41	10	20	1	79	52	27
Value Stream Mapping	Knowledge transfer	0	2	0	0	0	2	2	0
								Total	27

3. Methodology

3.1 Methodological procedures

The technical procedures employed herein consist of stages performed aiming to comply with the main objective of the survey. Importantly, in order to reach this objective, an LKT team has been created, made up of research professors, students from two university and the participants interested in absorbing this transfer on the part of the company studied. This transfer has occurred with the support of the stages outlined in Figure 1.

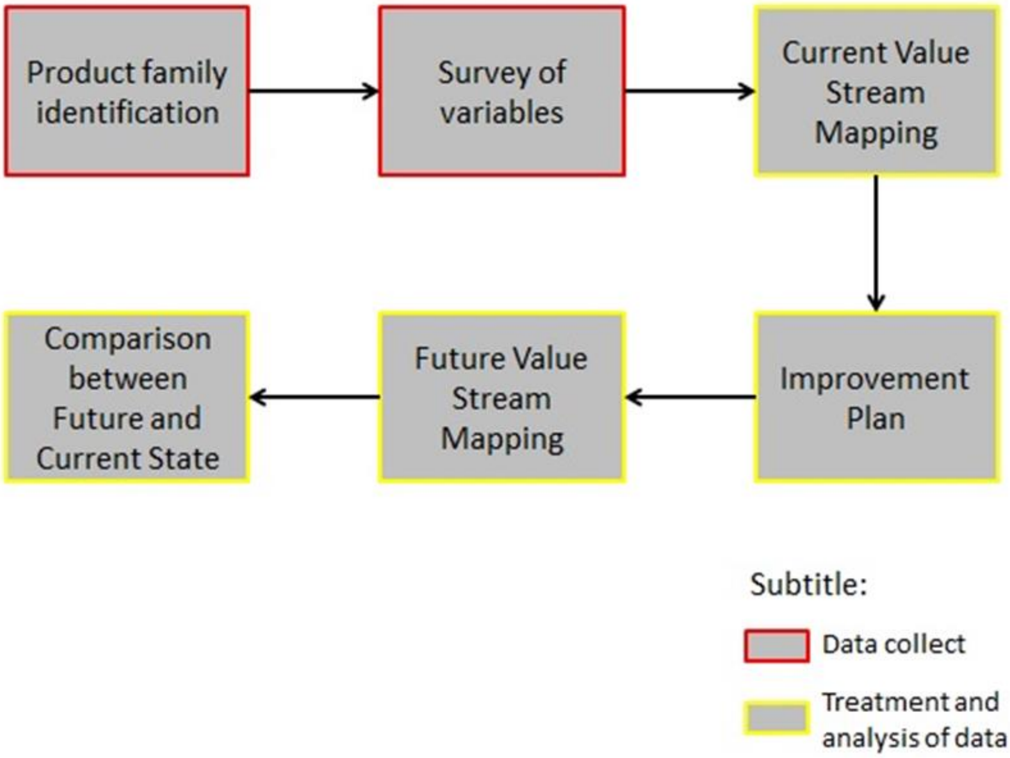

Figure 1. Stages of technical procedures.

Note that some of these stages of the research method employed herein (Figure 1) have been designed adapted as proposed by [15, 7]. Also note that, according to that Figure, the stages of technical procedures have been grouped into two macro stages: data collection; and data treatment and analysis. For such, the stages are explained in the following subsections of this Methodology.

3.2 Identification of the product families

The first stage has been based upon the works of [49], in which the author attests that one must choose the product family before executing the VSM. In this stage, the product family showing the highest production rate is identified in the company to serve as a base for the study. The data to elaborate and select the product family of this study have been collected by means of the company's Planning, Programming and Control of Production (PPCP) and Material Requirements Planning (MRP) regarding the actual demand of each product.

3.3 Raising the variables

After the identification of the product family, the variables of the production process referring to it have been collected. The stage of raising the variables is similar to the preparation phase presented by [15] seen that before raising them, the researcher has had to know which variables to collect and know the instruments to use for collecting the data. The variables presented in Figure 2 have been collected in a two-month period.

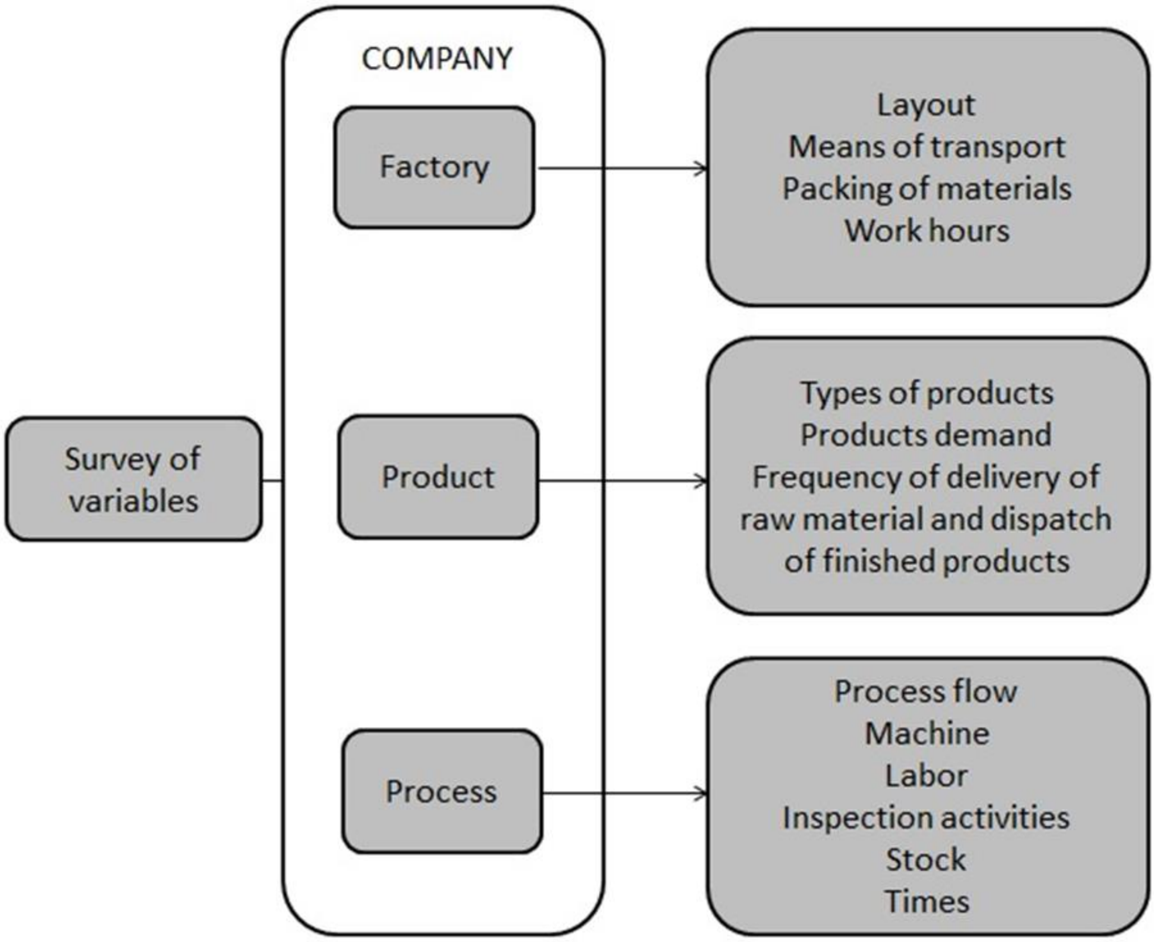

Figure 2. Sources of variables.

According to Figure 2, there are three Sources in the surveying of variables: the factory, the product and the process that generate the variables collected. The data collected regarding the factory have been layout of the floor (treated by means of AUTOCAD), the means of moving/transporting and storing the materials, as well as working shifts and hours. In regard to the product, data have been required on the types of products, the daily manufacturing demand, the frequency of the delivery of raw materials by the suppliers and dispatch frequency of finished goods to clients.

As for the production process of each product family, these have been collected: the process stream, the quantity of machinery and employees, inspection activities, WIP and inventories of finished goods, times (machine cycle time, time to load and unload the machine or manual time, setup time, inspection and waiting time). Finished the data collection, the data treatment and analysis have been started by the current physical modeling of the production process, explained in the following section.

3.4 Current value stream mapping

For carrying out this stage and that of subsection 3.1.5, some of the symbols have been used based upon the works of [18, 7]. These symbols have been developed by the Lean Enterprise Institute which, for mapping the production process, are extremely important.

For data treatment and analysis, as well as for accomplishing this stage, firstly, the takt time has been calculated and the structural part of the VSM elaborated via Microsoft Excel, based upon the works of [12]. For elaborating the current VSM, in each activity of the production process of the chosen family the averages of the following times have been calculated through statistical estimates: the machinery cycle, the manual work of operators, the setup, the inspection and the waiting times. Also, the following variables have been measured: the time in relation to the movement of the operator, inventory quantity, the production capacity of each machine, the quantity of operators in each activity. In the end, the lead time has been calculated (total time for producing the kg of copper) which served as a parameter for future comparisons amid scenarios.

Thus, the current VSM has guided the LKT team to identify the wastes present in the production processes of each product of the family, also helping them to identify which Lean tools should be proposed in the improvement plan, which is the following stage of the data treatment and analysis procedures.

3.5 Improvement plan

After the building of the current state VSM, this stage has been started, which demands skills and expertise about every Lean tool, requiring minute attention from the LKT team so as to identify the wastes and indicate which tool would help the company in reducing wastes and increasing production yield.

Observe that in this stage, the variables collected have also been treated through spreadsheets elaborated on Microsoft Excel serving as data treatment tools. Following the analyses and improvement suggestions, the future state VSM of the chosen production process has been performed.

3.6 Future State Value Stream Mapping

By finishing the improvement plan, the future state VSM has been built following the same steps used in elaborating the current VSM (section 3.1.3), though according to the improvement suggestions proposed by the LKT team when using the Lean tools. After elaborating the future state VSM, the results of the improvements have been compared with those of the current state of the production process.

3.7 Comparing the future and current states

In this stage, the results from the improved state have been compared with those of the current scenario, aiming to check the benefits brought forth with implanting Lean in the company's production process and to quantify the gains with these improvements.

4. Results

4.1 Identifying the product family

This company manufactures different types of electrical wires and cables, adding up 112 items in its product line. Therefore, defining the families in which the products may fit has been necessary. Thus, the product-process matrix has been elaborated, where products that have similar manufacturing stages have been observed and grouped, making up ten product families built, as shown in Table 2.

In Table 2, the acronyms TREF – wiredrawing, TOR – torsion, EXT – extrusion, MED – measurement and

EMBAL – packing indicate the stages of the manufacturing processes of all products, and note that in some families there are stages in their process that are not performed, that is, the stages with unchecked squares (no "X"). Also, the products have been fitted into ten families, from A to J, and for choosing the product family to be used as a research base, a manufacturing monthly summary has been elaborated, which has taken into account the measurement in kilometers (km) of manufactured cables per month, as demonstrated in Table 3.

After the analysis of Table 3, Family B has had the highest production rate within the company, corresponding to the flex mainstream cable, being one of the reasons for regarding this as the research base, as it has the highest production rate (84%), supposing that the majority of availability of the production process is intended for manufacturing this family. Due to this fact, the chosen family has the name "mainstream", from English, meaning main current or flow of the company, corroborating the idea of highest frequency shown previously.

Table 2 Product-process matrix

Product Family	TREF 1	TREF 2	TOR 1	TOR 2	EXT 1	TOR 3	EXT 2	MED 1	MED 2	MED 3	EMBAL
Family A - 11 items	x	x	x	x	x			x			
Family B - 4 items	x	x	x		x				x		x
Family C - 46 items	x	x	x		x		x	x			
Family D - 6 items	x	x	x	x	x		x	x			
Family E - 12 items	x	x	x		x	x	x	x			
Family F - 8 items	x	x	x	x	x	x	x	x			
Family G - 8 items	x			x				x			
Family H - 6 items	x	x	x		x	x	x	x			
Family I - 6 items	x	x	x		x	x				x	
Family J - 5 items	x				x					x	

Table 3 Production volume for each family of product

Months	Family A	Family B	Family C	Family D	Family E	Family F	Family G	Family H	Family I	Family J	Total
jan	147,61	6011,11	38,83	64,82	524,14	33,50	0,00	98,50	33,18	116,32	7067,99
fev	195,24	6849,43	223,28	148,64	420,77	7,75	67,52	74,06	55,42	2,34	8044,43
mar	202,76	5299,11	70,71	88,52	531,59	9,99	66,01	69,02	39,30	0,00	6377,00
apr	194,21	7843,19	60,52	52,32	572,08	15,03	20,51	40,09	52,19	0,00	8850,13
may	133,69	6445,52	39,93	50,35	430,53	9,21	8,33	115,25	2,01	37,45	7272,25
june	251,71	3797,18	74,01	109,12	517,44	10,67	46,91	125,37	32,64	0,00	4965,04
july	132,63	6537,87	218,34	203,50	520,73	1,58	78,03	0,00	28,23	0,00	7720,91
aug	181,91	5514,87	48,42	80,33	438,17	8,55	64,73	93,85	31,22	0,00	6462,05
sept	201,73	5503,32	305,68	160,52	825,79	18,40	0,00	55,43	0,00	19,15	7090,02
oct	305,65	6318,21	82,08	139,86	459,12	17,53	36,80	94,31	51,70	0,09	7505,33
nov	205,01	6218,21	233,45	165,35	628,38	15,07	52,33	94,82	40,31	0,00	7652,93
dec	252,01	6907,46	170,86	197,36	713,40	7,28	16,65	76,95	59,61	0,00	8401,57
Total	2404,15	73245,47	1566,10	1460,68	6582,14	154,54	457,80	937,65	425,81	175,34	87409,66
%	3%	84%	2%	2%	8%	0%	1%	1%	0%	0%	

4.2 Current state value stream mapping

After choosing the focus family for this survey, the next stage has been the elaboration of the current state Value Stream Mapping taking into consideration the data on working hours, demand, WIP, machinery involved in the manufacturing process, frequency of raw material receipt and dispatch of finished goods, stream of the products' process, machine cycle time, manual time of the operator, inspection and setup times, aiming to know in which current conditions is the production process of the family flex mainstream cable found, and thus identify other wastes inherent to processes 1 and 2. Figure 3 and 4 show the current mappings for these processes, respectively.

The Value Stream Mappings (Figure 3 and 4) exhibit the entire cycle for the production of the family "flex mainstream cable", representing the delivery of the raw material by the supplier as far as the dispatch of finished goods to the client.

Amid the stages of the production process are the quantities of intermediate inventories and in each machine are the times that have been raised in the data collection. By observing the VSM of Figure 3 and 4, the machinery involved in the production process of cables A and B are T2 (wiredrawer), B1 (buncher), E1 (extruder), M1 (measurer) and TE (shrink-tunnel); whereas, the ones used in producing cables C and D are T2 (wiredrawer), B2 (buncher), E1 (extruder), M2 (measurer) and TE (shrink-tunnel), as seen in Figure 3 e 4.

By means of the times collected, the individual takt time has been calculated for each machine taking into account their working shifts and the demand for products.

According to Figure 3, the lead time for process 1 registers approximately 28 days, and according to Figure 4, the lead time for process 2 is 19 days. Notable is that the lead times for the processes studied have been high, as the WIP has also been high amid the stages of the production process, and this ends up increasing the lead time of the finished good.

In the above-mentioned Figure, the wastes with intermediate inventories have been circled in blue, the total cycle times that do not comply with the takt time have been highlighted in red, and the lead time, in green. Observe, through these mappings, that the wastes are directly related to the high inventories amid operations and overproduction, once with these high intermediate inventories the company produces more than demanded daily, or more than the necessary, generating high inventories of finished goods.

Furthermore, note in the current mappings (Figure 3 and 4) that the cycle times of some machines are higher than the takt time, that is, machines (B1, E1 and M1) cannot fulfill the demand of flex mainstream cable programmed for the day. For fulfilling the takt time and reducing wastes found, some improvements have been suggested and are found in the next section.

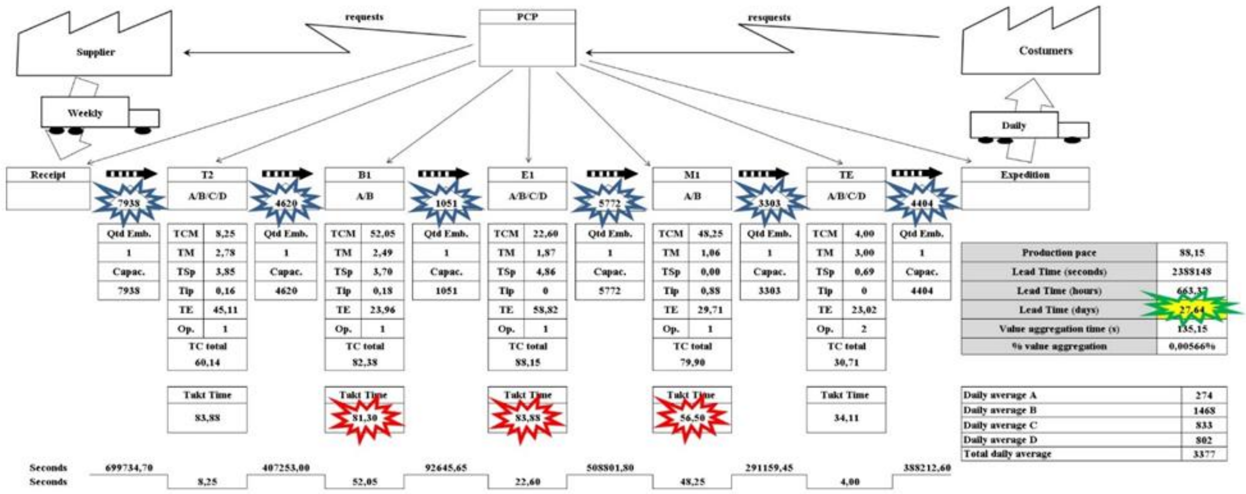

Figure 3. Current value stream mapping of process 1

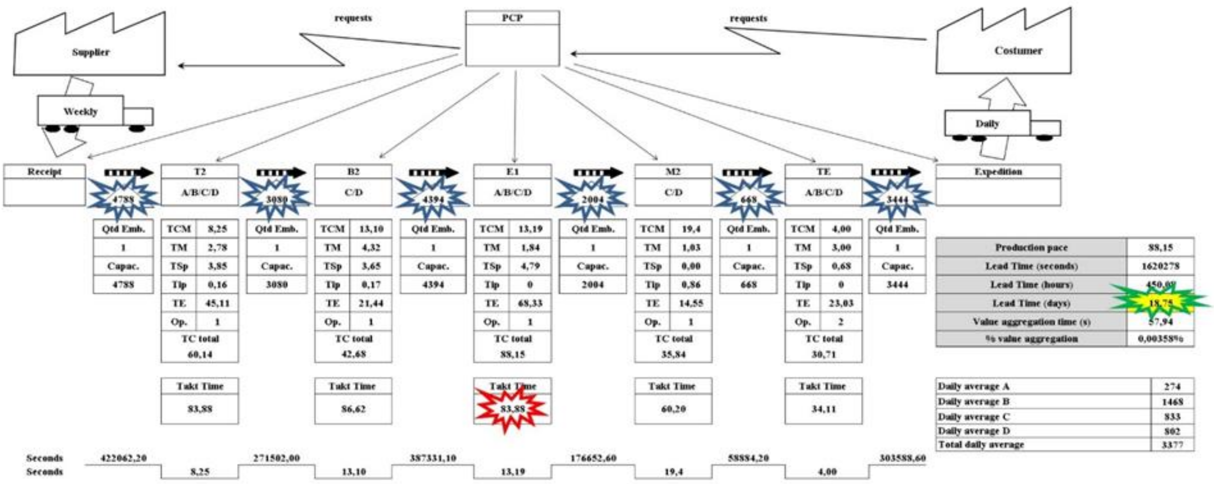

Figure 4. Current value stream mapping for process 2.

4.3 Improvement plan

After the analyses for identifying the wastes inherent to the production process of the family flex mainstream cable, improvements have been suggested so as to fulfill the objective of this research. Table 4 shows the problems found and the improvements proposed to solve them.

Table 4. Improvement plan

Problems identified	Improvements proposed
High inventories and overproduction	To produce as per the demand; to change the push to pull production flow; to implant supermarket inventories and the kanban system.
Cycle time B1	To transfer part of the demand to B2 or to reduce setup time through SMED.
Cycle time E1	To send to another extruder in the factory the production of cables C and D.

Cycle time M1	To transfer part of the demand for M2 and to implant the continuous flow between extrusion and measurement steps.
Unnecessary movements	To relocate machines B1 and B2 for the area of deactivated drawings.

As previously seen, the improvement opportunities in the Value Stream Mappings are reduction of inventories, amid operations, caused by overproduction, as well as some total cycle times higher than the takt time and unnecessary movements. As per Table 4, for reducing high inventories and overproduction a production according to daily demand is necessary, changing the production flow from the pushed to the pulled manner.

As for the cycle times higher than the takt time, by observing the current states shown by processes 1 and 2, a suggestion would be that a part of the demand intended for machine B1 be produced in machine B2, or reducing the setup time of B1 in 2s during the production of cable A, as well as the production of B through Single-Minute Exchange of Die (SMED), as shown in Chart 3.

As regards machine E1, it is intended for forwarding the demand to another extruder machine (E2), already existing in the factory, of the same standard of E1. Thus, E1 would be intended for cables of process 1 and E2 for cables of process 2. Thereby, a suggestion would be that two manufacturing cells be formed, one referring to process 1 and another to process 2.

M1, exhibited in Figure 3, does not comply with the takt time in 23.40s and M2, shown in Figure 4, has a lag time of 24.36s; then, by transferring a parcel of the demand from M1 to M2, ensures the requested demand to the machines to be fulfilled. Significant is that the measurement and the shrink-tunnel are within the limits of the takt time, in case there is any month in which the demand is higher than normal, M1, M2 and TE will not fulfill the demand, and improvement measures will be necessary in case this occurs.

So as to correct the deficit of measurement in high demands, and at the same time, reduce costs with collaborators, the continuous flow has been proposed between the extrusion and measurement stages, that is, E1+M1 and E2+M2, as extrusion already works three shifts and in each shift there is an operator; in this manner, with the continuous flow the work of measurement operators would not be necessary, and there would be a reduction of the existing 4 operators, as in the current measurement stage two machines are used and they work in two (2) shifts.

Additionally, grouping extrusion and measurement would bring changes for the factory floor layout by organizing it so as to fulfill the demand improving the production flow, also opening physical space to the factory.

Another matter worthy mentioning is to physically rearrange machine B2 closer to B1 and inserting a supermarket between them. This adjustment in addition to benefiting the process in itself would also reduce the non-value-added activity to the product, e.g. waste in unnecessary movement, intermediate transport and inventory. Reducing the quantity of operators to one (1) would be sufficient for handling the two machines, as these would be close to one another.

Hence, note that before the actual alterations in the factory layout, carrying out the study of operators' activities matching is important so that the working cells are sequenced the best manner possible; also, enlarging the Value Stream Mapping study is necessary for the remainder product families of the company.

4.4 Future state VSM

Based upon the proposed improvements and seeking to subsequently compare the future with the current state, the LKT team has designed future state mappings for processes 1 and 2, portrayed in Figure 5 and 6, respectively. Figure 5 exhibits the future state VSM for process 1 and Figure 6 exhibits the future state VSM for process 2.

Analyzing both future VSMs from Figure 5 and 6, observe the improvements of the new arrangement of the proposed layout with a continuous flow, and it is a Pull production based on the client's daily demand; additionally, there is the presence of supermarkets between the stages of the production process, and the order of production is pulled through kanban cards. Concisely, both production processes are Lean regarding the current state.

The lead time for process 1 is now 11 days (Figure 5) and for process 2 is now 9 days (Figure 6). After the compilation and explanation of results brought forth by the future state mappings, there has been a comparison between the current and future states both for process 1 and process 2.

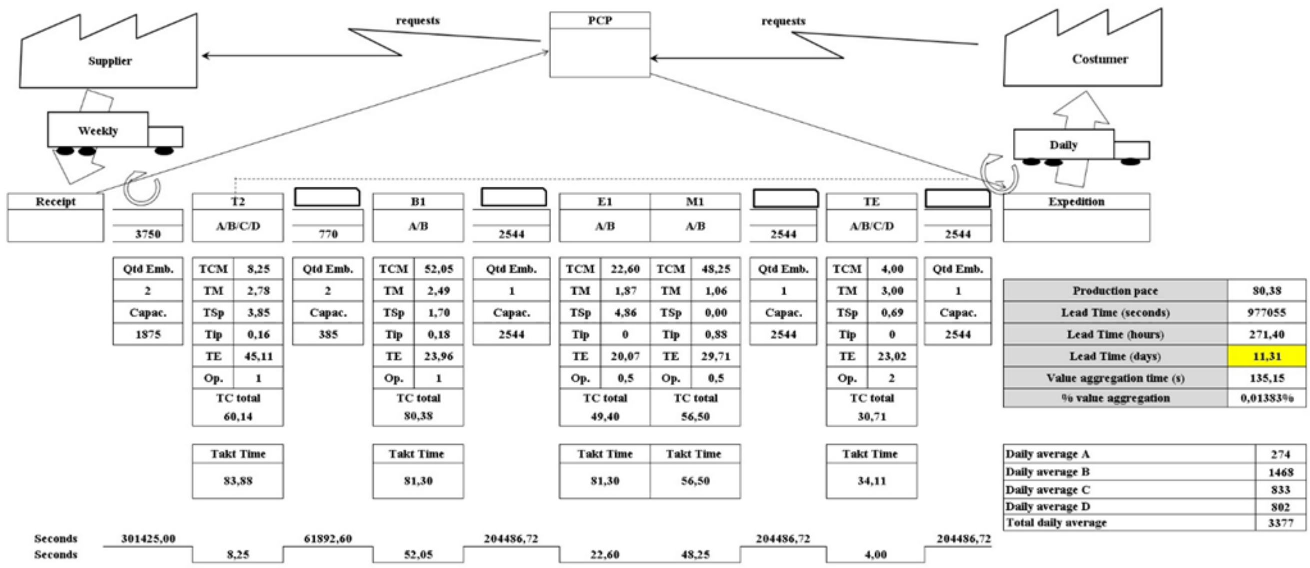

Figure 5. Future Value Stream Mapping for process 1.

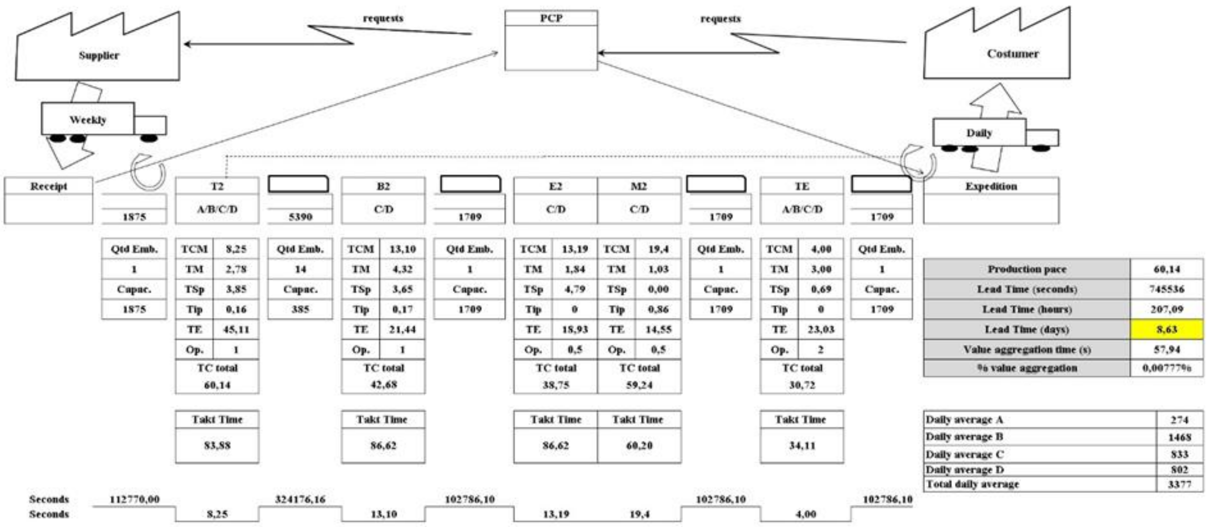

Figure 6. Future Value Stream Mapping for process 2.

5. Discussion

As mentioned by [30], the company has sought to innovate its production process by adopting the industrial management technique Lean Manufacturing. For such, this knowledge transfer has been efficiently established with the assistance of the LKT team, made up of collaborators from two Federal Higher Education Institutions and the company in this study.

In order to prove the efficiency reached by the LKT team, a comparison between the state in which the chosen process for analysis had been and the improved state has been carried out so as to explain the gains with this technique. Therefore, Table 5 exhibits the comparison of some productivity indicators of both states.

Table 5 Comparison between the current and future states

Indicators	Current state	Future state	Reduction
Distance traveled (process 1)	262. 4 m	131. 4 m	50%
Distance traveled (process 2)	225.14 m	129. 58 m	42%
Inventories (process 1)	27 tons	15 tons	44%
Inventories (process 2)	18 tons	14 tons	22%
Lead time (process 1)	28 days	11 days	60%
Lead time (process 2)	19 days	9 days	53%
Operators	18	11	39%

As shown in Table 5, various are the gains acquired with the improvements suggested. The changes in the factory floor layout enabled the distance traveled (unnecessary movement) by the product to decrease from 262.4m to 131.4m in process 1, which represents a reduction of 50% and from 225.14m to 129.58m in process 2, which is a reduction of 42%. The reductions in this indicator corroborate the results in the work of [44], where the company B.S. Spray Painting Works has reduced 44.18% and Kotla Auto Parts has attained a reduction of 50% in the distance traveled.

With the change of the production method from Push to Pull and working according to the daily demand, the inventories between operations for process 1 has reduced in 44%, and for process 2 they have decreased 22%. Through the reduction of inventories, the processing lead time has also decreased 60% (process 1) and 53% (process 2), making the process Lean as regards the current one. The reduction of lead times has been higher than the planned in the work of [7] and that reached in the work of [49], which has been 50%. The consequence of reducing the lead time is that the percentage of value-added time to the product increases and that may be observed when comparing Figure 3 with 5 for process 1 and 4 with 6 for process 2. In view of that, the percentage of added value in process 1 has moved from 0.006% to 0.014% and from 0.0036% to 0.0077% in process 2, approximately. This result is in accordance with that of [3], where the increase was 0.006% to 0.074% of the value-added time to the product.

Another indicator from Chart 4 is the quantity of operators. In the company studied herein, the quantity of operators is designed according to the quantity of machines working per shift, but it is known that for each machine there is one operator, except for the shrink-tunnel, which runs with two. Therefore, three (3) operators are intended for T2, B1, B2 and E1, as these run in 3 shifts adding up 12 operators. For M1 and M2 there are 2 operators for each machine, as these run in 2 shifts adding up 4 operators, and for TE 2 operators are required, being one to stay within the Source and the other at the machine's outlet, which works in the morning shift only. Thus, in the production of the family flex mainstream cable, 18 collaborators operate daily.

After the continuous flow proposal between extrusion and measurement, the work of four (4) measurement operators would not be necessary. Additionally, for machines B1 and B2, previously, the work of six (6) operators was necessary, being three (3) for each machine, but, with the relocation and proximity of these machines the work of only three (3) operators would be required, as one (1) operator per shift is able to handle them both. Thus, the quantity of 18 operators would now be 11 showing a reduction of 39%. Note that the quantity of operators above does not add the operators of E2, as these are a part of the company's staff.

Therefore, all these reductions explained above are in accordance with [4], as he reports that implementing Lean Manufacturing brings forth various benefits to the company, of which he has pointed out the reduction of lead time, of WIP and consequently there will be a reduction of costs.

6. Conclusion

As seen in the Introduction section, Lean Knowledge Transfer (LKT) may bring forth benefits for enterprises that plan to "dry" their production processes. Thus, this work has sought to demonstrate that LKT, through university students, has been able to achieve expressive results in an electrical wires and cables company. In order to achieve that, the LKT team has broken ground in this company by teaching Lean Manufacturing tools, e.g. by elaborating a Value Stream Mapping, how to identify the improvement opportunities, how to use kanban, just-in-time production, manufacturing cells and supermarket inventories. The improvement opportunities identified by VSMs of the chosen processes for analysis have been inventory wastes amid processes, overproduction, unnecessary movements, as well as some machines which have not complied with the takt time. In view of these wastes, the LKT team has designed improvements so as to reduce their incidence in the processes herein.

Through the results attained from the improvements proposed, gains have been acquired from eliminating non-value-added activities to the processes studied. These are among them: the reduction in the distance traveled by the product along the production process, in the quantity of inventories amid operations, in the lead times of the production processes of electrical wires and cables and the reduction of the working labor. These reductions have a direct relationship with the decrease of production costs, and in times of crisis, it may be a competitive distinction in front of the competitors of this company.

With that, the contribution of this work has been both for the company and the literature, as the company has learned a new industrial management technique through the LKT team, in addition to having attained significant reductions explained in the previous section. In the case of the literature referring to this theme, this research has filled gaps found in the databases from the Introduction section, such gaps are: the scarcity of works referring to Lean knowledge transfer; the scarcity of such works in developing countries and more precisely at small and medium-sized enterprises; and the originality of working with this theme in electrical wires and cables companies.

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