https://dx.doi.org/10.22161/ijaers.6735 ISSN: 2349-6495(P) | 2456-1908(O)

Lean Production System Applied to a Liquid Fertilizer Industry

Fabrício Gomes Menezes Porto[1], Marcelo Bacci da Silva[2], José Roberto Delalibera Finzer[3]

[1,2]Institute of technological and exact sciences, Federal University of Triângulo Mineiro, Brazil
[3]Department of Chemical Engineering, University of Uberaba, Brazil

Abstract— *The reduction of production costs is currently a subject much sought after by companies. The Toyota Production System was the first program to be produced through a demand that was able to raise the quality level of the products, working with zero inventory, generating greater sustainability in the Japanese automotive business. The technology industry in plant nutrition has been growing in recent years in Brazil, with more than 450 companies in the segment and producing a turnover in the order of R$5 billion reals. The objective of this work was to apply the methodology of lean manufacturing in a liquid fertilizer factory. After application, the production time was reduced by 33% and the productive capacity was doubled.*
Keywords— ***Lean manufacturing, fertilizers, costs reduction, improvement process, Toyota Production System.***

I. INTRODUCTION

The implementation of techniques that provide higher productions with lower costs is of paramount importance for the survival of the business. The argument of lean production was adopted by Japanese organizations in the 1940, and generated new procedures for production excellence, which brought significant results: reduction of unit costs, variety of products, quality improvement and multipurpose employees. Several studies have shown that the lean production model introduced by Toyota is the successor to the traditional Fordist model of mass production, which can be applied in any business environment (FAVONI *et al*, 2013).

Lean manufacturing is one of the most widely adopted methodologies in the largest companies in the United States. In addition to increasing productivity, it can also make organizations more competitive on a ever-growing global market (ABDULMALEK & Page 5 In the academic environment, it has been identified that the total or partial implementation of some concepts or techniques of lean production, such as: Map of Value Flow, Standardized Work, Total Preventive Maintenance, Rapid Tool Change, Total Quality, Kaizen, among others, ensured better results and greater savings in production processes, as well as operational gains and business performance (FAVONI et al, 2013).

The application of LM consists in the union of continuous actions that aim to adequately specify the profit from the perspective of the final customer, excluding activities that generate waste and organizing the ones that generate value to happen in a flow driven by demand (SCHELLER, MIGUEL, 2014). For a better structuring of the scope of lean production, the use of the Kaizen methodology allows for a greater operational gain, which results in financial benefits (GONÇALES FILHO; PIRES, 2017).

Since the beginning of lean manufacturing practices, the program has usually been of interest to entrepreneurs and researchers. However, companies were not always successful in implementing lean production. Some essential points, such as the lack of guidance and planning, omitting the fact that LM is a long-term task, are highlighted by several authors, which is generally condensed in the absence of a strategic perspective for its implementation (MEDEIROS et al, 2016).

Initially developed and deployed in the automotive sector, many of the LM tools have been transplanted to other segments, such as the electronics and consumer goods industry (ABDULMALEK and RAJGOPAL, 2006). For the footwear sector, it was not different since it presents a manufacturing model and industrial environment consistent with the practice of lean production. (SANTOS et al, 2017).

The plant nutrition technology industry is a niche not yet explored by lean production systems. However, it represents a great participation in the development of the country having 459 companies in the segment that generated more than 17 thousand jobs and a turnover in the order of US$ 1,4 billion. In addition to US$ 78 million invested in R&D in 2016 (ABISOLO, 2017).

With the market rising with a growth rate of more than 26% between 2014 and 2016, the implementation of lean manufacturing in the production of special fertilizers can be a growth factor for companies of all levels. Therefore, the continuous improvement program based on the Toyota Production System, and carried out through tools such as Kaizen, can provide the industry with: reduction of waste and the ergonomic risk of employees, increased productivity and business competitiveness.

In this context, the objective of the present work is to apply the methodologies of Lean Manufacturing through the tools Brainstorming, diagram of cause and effect, chronoanalysis and 5W2H in a factory of liquid fertilizers that carry out hot process, in which there was a high investment for the increase of productive capacity. Nonetheless, with no real return, where current practices did not meet the expectation of volume expansion expected by the company's management.

The scenario before the investment had a reactor of 2.2 m³ coupled to a cooling tower that conditioned it to do 3 batchings per day, or 6.6 m³. With the high market demand, the company's board of directors invested in a 5 m³ equipment, expecting to produce 2 daily batches, 51% more than the previous model. However, without having modified the cooling system, the high temperature generated in the manufacturing process of liquid fertilizers couldn't be controlled efficiently causing a production 50% smaller than expected. Consequently, without financial support to acquire a new system, lean manufacturing was the best alternative to solve the problem.

II. LIQUID FERTILIZERS

For a production of fluid fertilizers, it is possible to highlight the processes that are most used for the manufacturing of solutions or concentrated suspensions, being themselves the mixing process (hot-mix) and the cold-mixing process.).

O-hot-mix is what known as a source of energy, like the energy of a heat source, this being an exothermic reaction, exemplified in Fig. 1 (BICHARA, 1990).

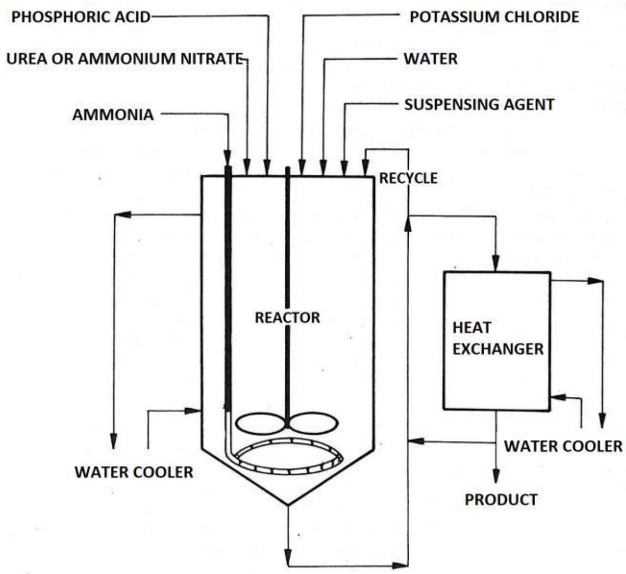

Fig. 1: hot-mix process.

The cold-mix, however, does not generate energy in the form of heat, contextualizing itself only in the mixture of components without exothermic reactions.

III. MATERIALS AND METHODS

3.1 Brainstorming

Brainstorming is a method of group work that assists in the emergence of new ideas about a certain subject (or problem). In addition, the tool can also stimulate the team's creativity, which generates a number of solutions to the issues in question.

The brainstorming structuring model consists of 5 main steps: presentation of the problem, free presentation of ideas, writing of ideas, reformulation of ideas, and evaluation of proposals.

Beyond this path, it is important to emphasize that a leader should be chosen to moderate the meeting and that the environment should be light, without excessive control by the coordinator (POSSARLE, 2014).

3.2 Cause and Effect Diagram (CED)

The DCE consists of a fishbone style chart, where the central axis (arrow) points to the consequence of the causes, which are represented by the ramifications of that axis. Commonly, the elements of the causes are: labor, environment, machinery, method, materials, and measure.

For elaboration, the following steps should be followed: definition of the problem to be analyzed, a survey of all causes and, finally, to present these data through the suggested model for this tool (COLENGHI, 2003).

Once you have the problem at hand, brainstorming is necessary, as it will ensure accuracy in determining the

https://dx.doi.org/10.22161/ijaers.6735 ISSN: 2349-6495(P) | 2456-1908(O)

causes. Along with others, organize them in their respective categories.

3.3 Study of AV and NVA times and activities

Time study is one of the most used methods in factories to measure work. This tool helps to measure individual efficiency, with the objective of establishing standards for production and greater control of industrial costs.

The application of this tool can be done through the letter of AV and NVA. An AV is an activity that adds value, that is, an operation that the final customer would pay the company for it. Therefore, NVA, defined as activity that does not add value, would be the one that the end customer believes is costly.

In the industry there is still the VSA activity, which would be the activity that has a semi-aggregate value. In this case, we would consider a VSA a task that can become VA by investing in machines and equipment that would reduce process time.

The presentation of this parameter can be performed through a chart or graph control, demonstrating the percentage or numerically the times of VA, NVA and VSA. This allows a strategic view of production and can serve as a basis for taking actions (MARTINS, 2005).

3.4 5W2H

This tool is a document that, in an objective way, defines actions and responsibilities of those who will perform, through questions (5W2H) that has the ability to guide the activities that should be implemented.

The 5W questions are: what, why, where, when, who, who, in Portuguese, represent: what, why, where, when, and who. And at 2H: how, and how much, what, the same way, how and how much it will cost (POSSARLE, 2014).

This method can be presented through a table, with the questions to be answered, actions to be taken, responsible for it, area in which they will be executed, when and how they will be executed and what the cost of this action will be.

3.5 Benefit / Cost Ratio

The benefit / cost ratio is an indicator to verify how much the company has obtained for each R$ 1 invested. This is will calculated by adding up all the financial returns that the company will achieve in 1 year divided by the sum of the investments made.

IV. RESULTS AND DISCUSSION

After the execution of the brainstorming process, a cause analysis was carried out through the cause and effect diagram, determining the root problem, being the low daily production, which is caused by the high time to formulate the product according to the activities described in Fig. 2.

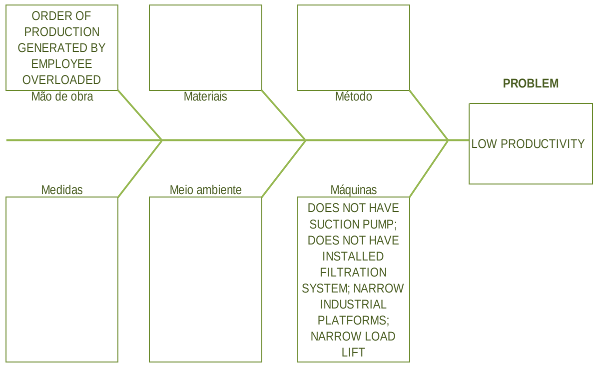

Fig. 2: Cause and Effect Diagram

For this time study, we used the tool applied cronoanálise determining NVA, and obtained the result shown in Figure 3.

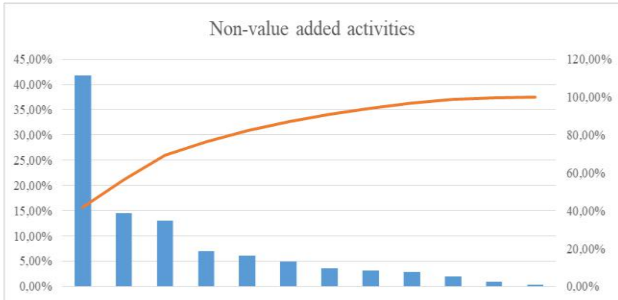

Fig. 3: Pareto chart for non-value-added activities

In this context, it is possible to verify that the activities that will take time for the formulation of the product are: filtration of the finished product and search and placement of sacks of raw materials. Figure 4 shows the activity mp1 positioning in the cargo elevator, which was performed manually by moving 25 kg bags, totaling 3 tons, which represented 15% of the NVA.

Fig. 4: sacks positioning mp1.

https://dx.doi.org/10.22161/ijaers.6735 ISSN: 2349-6495(P) | 2456-1908(O)

Table 1 describes all the activities of the product formulation process in question before the improvements implemented with their execution times. Thus demonstrating that the production stage is 63.4% of activities with value added (VA column), and a total percentage of 21.5% for no added value, (NVA column). In the industry and lean manufacturing projects, it is adopted a value of 88% to 12% for VA and NVA. The average times of standard deviation was 0.25.

Tab. 1: time formulation process before improvement

Sector	Activity description	activity time (min)	Before improvement		
			VA	VSA	NVA
Production	Making of Production Order	4.83			4.83
Production	Water supply	17.32	17.32		
Production	Installation of the water transfer pump	5.50			5.50
Production	Search reuse water container	0.50			0.50
Production	Pump Assembly Transfer MP	4.33			4.33
Production	MP Search	22,10			22,10
Production	MP weighing	9.26			9.26
Production	Addition of water to the solution mp1	10.66	10.66		
Production	Addition of water to the solution mp2	6.46	6.46		
Production	Search tools	1.50			1.50
Production	mp3 addition	15.62	15.62		
Production	sacks positioning of mp1	20.03			20.03
Production	mp1 Adding to the tank for preparing the solution	30.05	30.05		
Production	mp4 pumping	25.01	25.01		
Production	Mont. the siste. adding the solution to the reactor mp1	10.63			10.63
Production	MP2 adding to the solution preparation	7.00	7.00		
Production	Addition of the solution mp2 the reactor	115.75	115.75		
Production	Weighing the MP5	2.96			2.96
Production	Addition solution MP2 and MP5	6.32	6.32		
Production	Product cooling	30.00	30.00		
Production	Mount PA transfer pump	7.43			7.43
Production	Filtration and PA transfer	64.00		64.00	

The total measurement time was 6 hours for the formulation of a volume of 5 m³. Although the sum of the times has a value close to 7 hours of work, it is important to note that some activities occur simultaneously. Considering a shift of 8h45min, which is conducted by the company, the production is defined in that volume. So it was defined an action plan based on 5W2H methodology, where the goal was to reduce the times of the three items with greater delays in the manufacturing sector so that it is possible to produce at least 10 cubic meters per day, according to Table 2.

Tab. 2: Action plan

What?	Who?	At where?	When?	Because?	As?	How much?
Increase the lift platform	plant engineer	Production	Aug / 18	To facilitate the positioning of the sacks via forklift	Contact service provider	R $ 15,250.00
Adiquirir filter and pump with proportional flow the need	plant engineer	Production	Aug / 18	All in process	Contact pumps and filters suppliers	R $ 19,520.00
Redesigning the platform	plant engineer	Production	Aug / 18	To facilitate the positioning of the sacks via forklift	Contact service provider	Included in item 1
Perform production planning	Production manager	Production	Aug / 18	Plan a day before what will be produced the next day	Conduct training planning and production control	R $ 800.00

After the completion of the improvements, then given another the deadline, another cronoanálise was done with the results being presented in Table 3. The reduction of activity by 50% (22 to 11) by automation of some processes and also to reduce the time from other movements, caused a lean and without waste environment, focused exclusively on producing. It is observed that, with the changed process, the activities represent 84% VA (VA column), VSA, 14% (VSA column) and finally NVA (NVA column), only 2%.

Tab. 3: time formulation process improvement after

Sector	Activity description	activity time (min)	After improvement		
			GO	VSA	NVA
Production	adding mp1	15.33	15.33		
Production	Search materials	1.43			1.43
Production	rest of weighing mp1	1.49	1.49		
Production	preparation mP2	22.73	22.73		
Production	adding mp3	27.0	27.00		
Production	mp3 line cleaning	5.00			5.00
Production	Cooling the primary mixture	22.0		22.00	
Production	adding mp4	9.0	9.00		
Production	adding mP2	110.0	110.00		
Production	Cooling final product	44.0	44.00		
Production	Filtration and pumping	15.0		15.00	

Figure 5 shows the activity after new improved positioning mp1, where the pallet is placed feedstock directly via forklift in the cargo elevator, unlike what is shown in Figure 7, where the position was manual.

Fig. 5: sacks positioning mp1.

https://dx.doi.org/10.22161/ijaers.6735 ISSN: 2349-6495(P) | 2456-1908(O)

Figure 6 shows the comparison between the AC and NVA activities as a function of time (minutes), the formulation process before and after improvement.

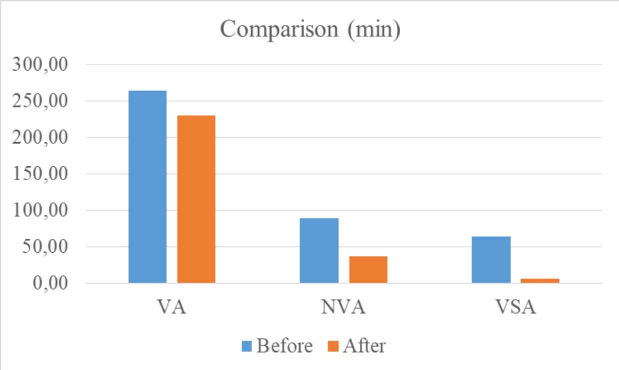

Fig.6: Graph comparison between VA and NVA VSA before and after the improvements

Thus, the total time for product formulation was increased to 4 hours, which allows the production of 10m³ per day, in turn 8h45min. The evaluation of the benefit / cost can be performed taking into account that 1 liter of product that generates an average income of R $ 3.00, a production 5m³ more than was installed per day, 20 days a month and 12 months a year, resulting in a return of R $ 101.20 for every $ 1.00 invested, as the following equation:

$$\frac{B}{C}=\frac{\left(averagerevenue\frac{product}{L}*production\ increase\right)*\left(\frac{days\ worked}{month}\right)*\left(\frac{month}{year}\right)}{project\ cost}$$

$$\frac{B}{C}=\frac{\left(\frac{R\$3,00}{L}*5000L\right)*\left(20\frac{days}{month}\right)*(12\ month/year)}{R\$35.570,00}$$

$$\frac{B}{C}=\frac{R\$3.600.000,00}{R\$35.570,00}=R\$101,2\ or\ US\$25,00$$

V. CONCLUSION

The present study showed lean manufacturing tools applied to a liquid fertilizer industry, which, until then, it comes as an innovation since it was not found in the literature reports of applying such a tool in this market segment.

Given the above, it is concluded that the lean manufacturing in plant nutrition technology industries is extremely feasible because culminated in the production achieving the goal of 10 m³ / day, reduction of non-value-added activities in 92.8% reduction production time by 33%, and consequently, in the cost / benefit analysis yielded a return of R$ 101.20 for every R$1.00 invested. You might even notice a better ergonomic working condition, since it has reduced the absolute number of activities, especially those weight transportation demanded by the employees.

REFERENCES

[1] ABDULMALEK, F. A; RAJGOPAL, J.; Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. Int. J. Production Economics, 107, 223–236. 2007.

[2] BICHARA, J. M; Tecnologia de produção de fertilizantes. Cap. 6. São Paulo: Instituto de Pesquisas Tecnológicas, 1990.

[3] COLENGHI, V. M; O&M e qualidade total: uma interpretação perfeita / Vitor Mature Colenghi – 2. Ed – Rio de Janeiro: Qualitymark, 2003.

[4] FAVONI, C; GAMBI, L.N; CARETA, C. B; Oportunidades de implementação de conceitos e ferramentas de produção enxuta visando melhoria da competitividade de empresas do apl calçadista de jaú/sp. Revista Produção Online, Florianópolis, SC, v. 13, n. 3, p. 1118-1142, jul./set. 2013.

[5] MARTINS, P. G; Administração da produção / Petrônio G. Martins, Fernando P. Laugeni – 2. Ed. rev., aum. e atual – São Paulo: Saraiva, 2005.

[6] MEDEIROS, N. C; SANTOS, L. C; GOHR, C. F; TOMÉ, F. S; Recursos estratégicos para a produção enxuta: um estudo de caso no setor de manufatura eletrônica. Revista Produção Online, Florianópolis, SC, v. 16, n. 4, p. 1309-1328, out./dez. 2016.

[7] GONÇALES FILHO, M., PIRES, S. R. I., 2015. Os principais passos adotados na aplicação de kaizen em fabricante de componentes industriais seriados. Revista Produção Online. Florianópolis, SC, v.17, n. 4, p. 1160-1178, 2017.

[8] POSSARLE, R.; Ferramentas da qualidade / Roberto Possarle. São Paulo: SENAI-SP Editora, 2014.

[9] SANTOS, L. C; GOHR, C. F; GONÇALVES, J. M. S; VILAR; F. M. M; ARNAUD, L. M; Identificação e avaliação de práticas de produção enxuta em empresas calçadistas do estado da Paraíba. Revista Produção Online, Florianópolis, SC, v. 17, n. 1, p. 176-199, jan./mar. 2017.

[10] SCHELLER, A. C., MIGUEL, P. A. C., 2014. Adoção do Seis Sigma e Lean Production em uma Empresa de Manufatura. Revista Produção Online, Florianópolis, SC, v.14, n. 4, p.1316- 1347, out./dez. 2014.