Decrease of the rates of rupture, in a brick company, during the transport of the product to the client, by using Lean Six Sigma methodologies

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Abstract

This paper presents a six sigma project, and therefore, has the main objective of improving the quality management in order to reinforce the value creation process of the company. It was conducted at a brick manufacturer corporation in Bogotá Colombia where bricks are distributed to customers by trucks around the country. The rates of rupture, during the transport of the product to the client, represent a high negative cash flow for the business. Through the use of DMAIC methodology (Define, Measure, Analyze, Improve, and Control) and some engineer tools like measurement analysis, design of experiments and Pareto graphs, this project was able to find new alternatives to the way that the final product was packed and transported in Ladrillera Santafé. The whole project was centered on the reference LEPVD, of the structural family of products, because of its high rate of rupture that represent around 60% of the total losses of the company related to this concept. By the end of the project it was possible to find a way to reduce the rate of rupture during transport of the LEPVD bricks from 0,62% to 0,31%.

Keywords
Rupture, Design of experiments, Quality management, Six Sigma, Claims

1. Introduction

The six sigma methodology is new in Colombia but has been emerging recently. It is all about tools to reach as good quality management as possible having bases in the continuous improvement (Kaizen). The main objective is to reach even better levels of quality than the expectations of the client. From this methodology comes the term "sigma level of quality" used as an indicator of the quality level that processes have at companies. A low sigma level means high chances of defective units but also good opportunities of improvement, while a high sigma level means low chances of defective units but less opportunities of improvement and a more standardized process. If the sigma level of a process gets to be qualified as six sigma it is assumed that its value of defective units is 3,4 PPM or less. To get to this sigma level in a process, even following the parameters of the methodology and using its tools properly, is really hard, it also requires leadership, correct utilization of the tools and great infrastructure among other factors, but it brings much greater benefits than the effort invested in almost all of the cases. (Gutiérrez Pulido H., Control estadístico de calidad y Seis Sigma, 2004)

In every company, quality has a cost that can be divided between tangible and intangible costs. The tangible part, such as the inspection or assembly of a product, represent usually between 10 and 15%, while the intangible part represents between 85 and 90% of the total costs. From this high percentage of opportunity of improvement, represented by the intangible costs, comes the importance of applying six sigma methodology and other methodologies that include the continuous improvement (Kaizen) at companies (M. Soković a, 2006).

Ladrillera Santafé produces construction materials based in red clay as the main raw material. It counts with 6 families of products, each one with several references assuring a large catalog to the potential client. It is a company with around 1000 employees and with more than 50 years since its foundation. Ladrillera Santafé is known as one of the most important corporations, in the field of the construction industry at Bogotá, and has an important status due to its level of service, commitment, and quality of its final product. In 2015 the company reported losses of 395 million COP for the concept of rupture of the product during the transportation to the client. In order to reduce this negative cash flow and to further enhance the image of the company in front of customers and its competitive advantage over competitors, it was decided to undertake this Six Sigma project in which it could standardize and improve processes related with this rate of waste and money leak.

2. Six sigma methodology

This project was carried out following the DMAIC methodology in order to reduce the high intangible costs in the process of delivering the product to the client. More specifically the costs associated with the ruptures that occur during transport of the product from the factory to the place indicated by the customer.

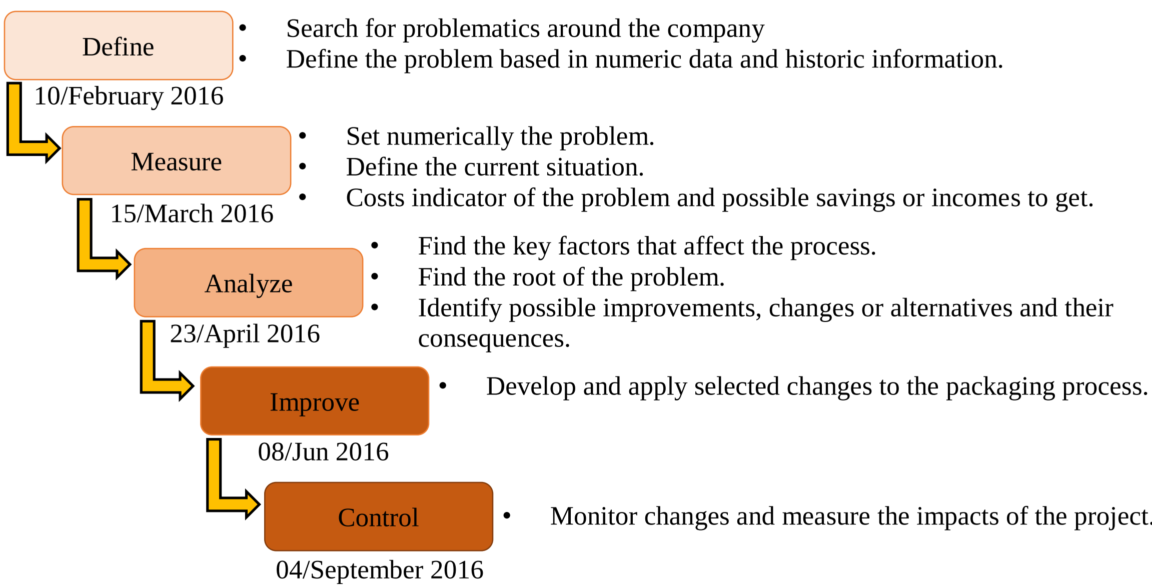


Figure 1: DMAIC methodology and time planning of this six sigma project

2.1 Define Phase

Ladrillera Santafé annually loses about 400 million COP due to rupture of units of all the references during the transportation from the factories to the customers. It is an important opportunity to reduce negative cash flows that the company has. But analyzing this situation more thoroughly, not all product families have the same behavior in the indicator: rupture rate during transport. (See figure 2)

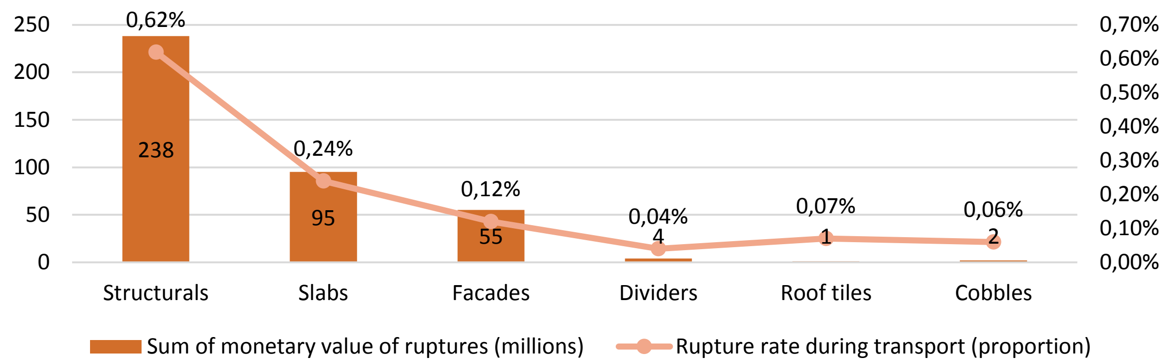


Figure 2: monetary representation and rate of rupture by family year 2015

In figure 2, it can be seen that out of the 6 families of products that the company manages, the family of structural bricks concentrates most of the ruptures during the transportation of the product to the client, 238 million COP and a rate of 0,62%. In Figure 3, the pie chart shows that not only in terms of units, but also in monetary terms, the structural family represents the largest percentage of this problem. In 2015 the structural family represented 60% of the losses due to this concept, that is to say 238 million of the total 395 million COP of the year. This is because structural bricks are products with a CTQ (critical to quality) quite high in terms of ruptures. From the VOC (voice of the costumer) which the company monitors constantly, it has been noticed that in the case of product families as facades or cobbles, the product does not need to be in perfect conditions to be classified as a non-defective product because it does not play a role within the structure of the building, it means a low CTQ in terms of rupture. But this does not happen with structural products; this family of references fulfills the function of holding the construction and therefore tends to have quality checks, by customers and by the company itself, much more comprehensive than other products of the corporation.

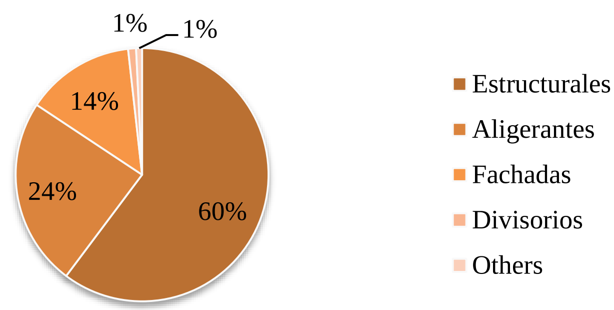


Figure 3: percentage by family of the total economic loss

The behavior of the rate of rupture, not by families but breaking it down by references (see figure 4), shows the references from the structural family (LEPVD, LEPVDMFRS3, LEPVDS3, LEPVDS2) located always in the top positions. It can be seen that the ruptures during the transport to the client do not depend on the production plant of the company where the structural brick was made. This can be concluded because the LEPVD, LEPVDS2 and LEPVDS3 references represent the same reference LEPVD, but the first one is produced in the factory Soacha 1, the second one in the factory Soacha 2 and the third one in the factory Soacha 3, and looking at figure 4 it is easy to see that the reference LEPVD, regardless of the factory that made the brick, shows higher rates of rupture during the transport to the client than any other reference in the company.

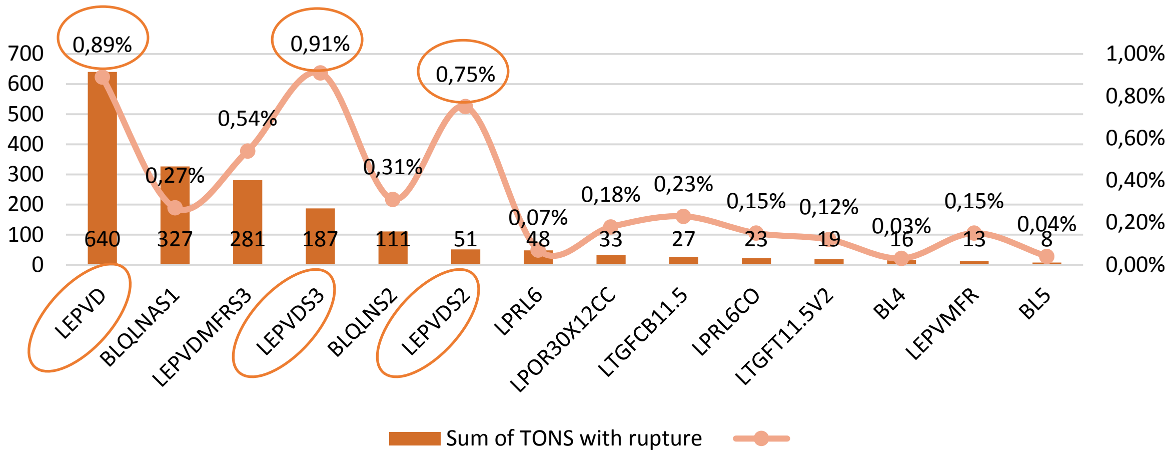


Figure 4: Ruptures by references in TONS and % of the total transported (Rate)

On the other hand, it is important to analyze the behavior of this variable with relation to time to understand if it has a growing, stable, or decreasing trend. All this in order to be able to contrast this with the results obtained under proposed changes, and later, be available to make accurate conclusions. In figure 5 the values are detailed in COP, it presents the total transported units in bars and with the orange line the value of the total units with rupture after the transportation to the client. By calculating the linear regression, it is possible to conclude that the problem has a growing trend with an increase of 672 thousand COP monthly. All of this only gives more strength to the problematic, and allows to base this project with better foundations, since it is not a stable but is also a growing over time problem.

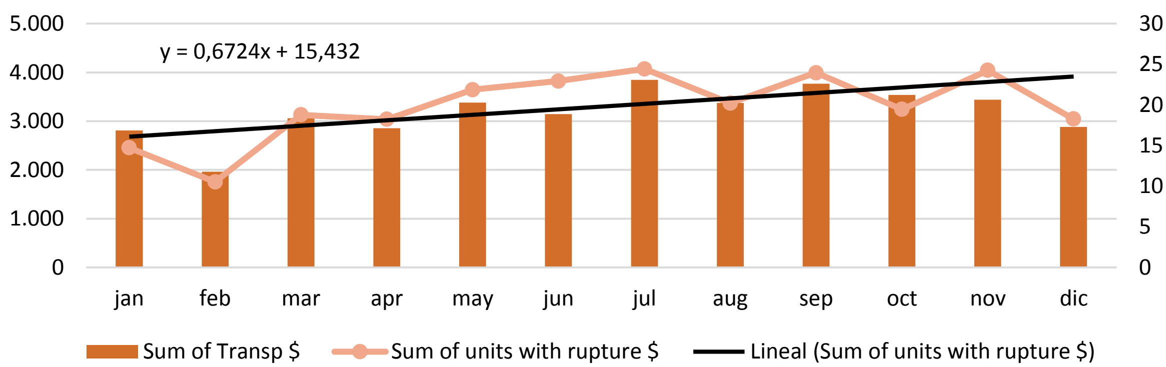


Figure 5: monetary value transported of LEPVD in bars and in line monetary value with Ruptures of this reference for 2015

Based on all of the above, this project will focus on reducing the rate of ruptures during the transport to the client of the reference LEPVD (see Figure 5), and seek standardization of a more efficient and effective type of packaging. It is not intended to look for causes before the packing station, indeed, it will be assumed that existing a quality control after production, 100% of the product that receives the packing section will be qualified as good product.

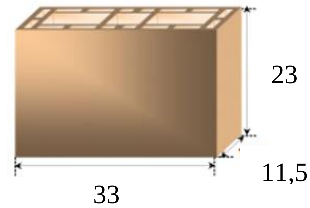


Figure 5: LEPVD and dimensions in centimeters

Knowing that the indicator of ruptures during the transport to the client, for the structural family, is currently 0.62% of the total transported, and represents losses of 238 million COP a year, the goal of this project will be to reduce it to a value of 0.50%. This reduction will mean savings for the company of 46 million COP a year by reducing the negative cash flow of this concept from 238 to 192 million COP (see Table 1).

Table 1: indicator and its economical representation

TON with ruptures / TON transported	Economic value
0,62%	238
0,50%	192

Those 238 million represent 60% of the total 395 million that the company lost in the year 2015. As seen in figure 3, the family of structural bricks represents 60% of the losses due to this cause. It is important to notice that this is a project that can be later adapted to other references getting even better results for the company.

2.1.1 Summary of the production process:

The main raw material for the production process of this product is red clay, additionally fireclay (cooked crushed brick) or degreaser, water and dyes. At the beginning of the production process the mixer adds the exact percentages of clay, fireclay and dyes for this reference. The mixture is then moistened and molded by extrusion. Subsequently the separate units are cut up into the final brick shape, the units are dried, and after it, baked for about 8 days under high temperatures until it gets fully cooked and leaves the production process. After production, a quality selection of the final product is done to give the packing process 0% defective product. In the packing section, 4 levels of 24 units each are installed on pallets one over the other, which means that each packed pallet has 96 units stacked in total. With the 4 levels installed over the pallet, the load is packed with plastic layers around. Finally, the pallets are stored in the stockyard by forklifts and delivered to the logistics area.

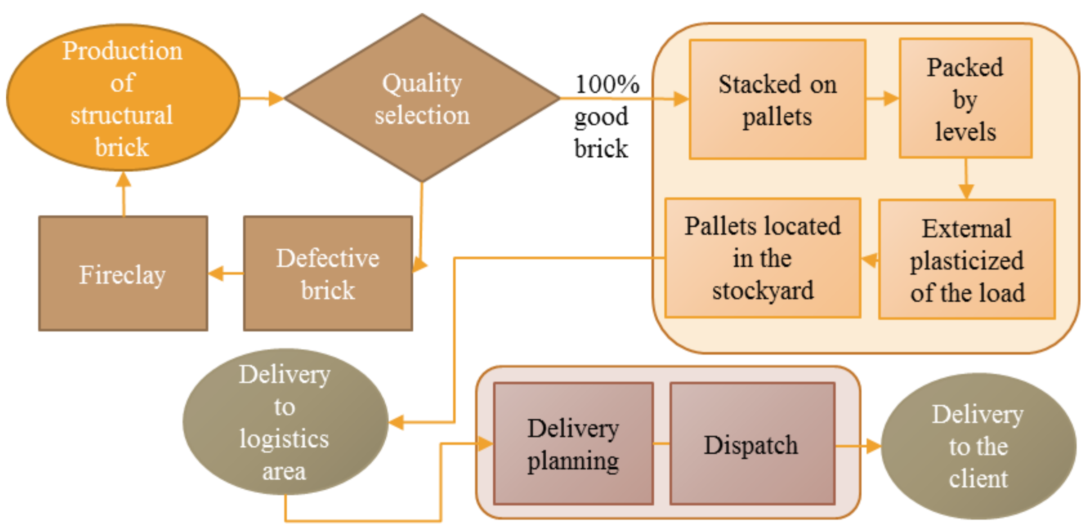


Figure 6: flowsheet

2.1.2 Project Charter

Project Name: Decrease of the rates of rupture, in a brick company, during the transport of the product to the client, by using Lean Six Sigma methodologies.	
Problem Statement: Last year Ladrillera Santafé had a waste due to ruptures of product during transport of 395 million pesos. 60% of these ruptures are attributed to the reference of structural bricks representing 238 million pesos in loss. Reducing this indicator of ruptures by 0.12% would represent savings of 46 million pesos per year for the company. **Scope of the project:** This project seeks to modify the way that the structural bricks are currently being packed in order to reduce the number of ruptures per package during the transportation to the client process.	**Business Impact:** Description of the benefit: Decrease in the rate of ruptures for the structural brick transportation to the client Expected savings: COP 46 million Reduction rate of structural brick ruptures: 0.12%
Main Objective: Reduce the indicator (% of bricks with ruptures / total bricks transported) from 0.62% to 0.50% in order to eliminate negative cash flows due to the loss of sales. **Secondary objectives:** • Improve the level of service of the company. • Improve the image of the company.	**Project Team:** Kaizen Leader: Camilo Otoya Project Champion: Javier Eslava Extended Team members: Jeiber Gallo, Emanuel Castillo.

2.2 Measure phase

The Rupture Rate indicator is calculated as follows:

$$= \frac{\text{(Tons with rupture after transport)}}{\text{(Total Tons transported)}} = \frac{1.310}{211.818} = 0{,}62\%$$

The responsible for determining how many units arrive with rupture to the location of a customer is an employee of the costumer itself. When a trip of structural bricks reaches the construction of a client, the supervisor counts how many bricks arrived with rupture and generates a compliment. If there are too many defective units in a delivery, at the discretion of the supervisor, it is not a compliment but a claim that the supervisor generates. Because of this supervisor being an employee of the customer and not one of Ladrillera Santafé, every time that a claim is received instead of a compliment starts supervision by the company to check that the client is making a proper quality check of the product.

The current value of the indicator, rupture rate during transport, is 0,62% and represents 6200 defective parts per million or PPM, while our objective of 0,50% would mean 5000 PPM. And under the standards of sigma level of quality (see table 2).

Table 2: current value of the rate compared with the objective value of this project

	Rate	PPM	Sigma Level
Actual	0,62%	6200	2,73
Objective	0,50%	5000	2,80

The current process is close to be in a 3 sigma level of quality but has to be qualified as a 2 sigma level process any way as it is shown in table 2. With the objective of this project accomplished the process will be even closer to 3 sigma but won't get there either. In the future, if it is wanted to get to a 3 sigma level of quality in this process, it is going to be necessary to get the indicator of rupture rate during transport at list as down as 0,27%.

2.2.1 Data collection:

When either compliments or complaints arrive to the company the information is stored in a database. This is a binary, or acceptance and rejection concept, scilicet no midpoints exist and it is an attribute not a variable kind of concept; this generates a rate of proportion between the total tons of structural bricks transported and the ones with rupture after the transportation. The company manages an EDE (company specification), or a report of quality requirements for their products, and this report is fully distributed among the construction supervisors of the clients, in the place of the construction, for the proper application of quality inspections. Customers who present claims instead of compliments receive training regarding these requirements to ensure that quality inspections are being done properly.

2.2.2 Measure system analysis (MSA)(R&R)

To validate the measurement system of acceptance or rejection among quality supervisors a measure system analysis was made. This statistical analysis was done with 3 quality supervisors, and 8 LEPVD units 5 of them acceptable and 3 non acceptable. Each of the supervisors made a quality check of the 8 units twice but every time the bricks where arranged randomly. With the results of the 6 quality checks, 2 for each supervisor, was possible to determine statistically the percentages of consistency between the decisions of the 3 supervisors with the real status of the bricks, also the consistency between the 3 of them, and the consistency within their own decisions from one quality check to the other.

The results were favorable for the measurement system, not a rejectable unit was listed as acceptable by supervisors, only 3 acceptable bricks were listed as rejectable and only 1 of the 3 supervisors contradicted once in their judgment. The error of the entire system was calculated at 10.4% and with a level of 89.6% was determined that the system is acceptable (see figure 7).

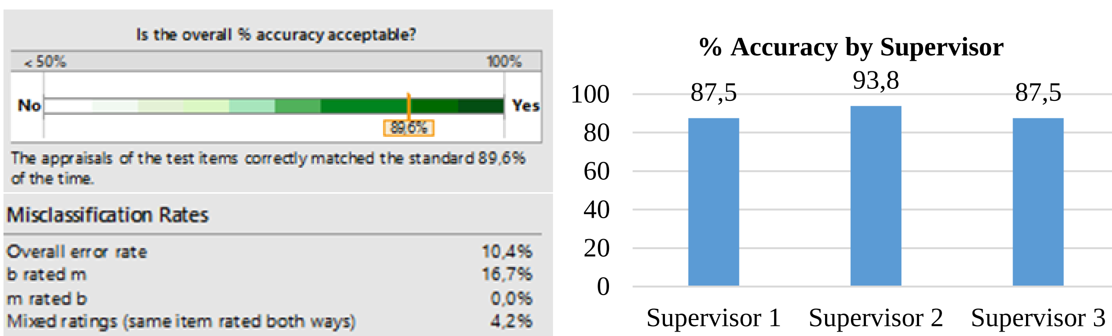


Figure 7: Minitab results for the MSA

2.2.3 Analysis of the existing data of the problem

By analyzing historical data, it is wanted to find two basic indicators of the process: first if the model behaves stably, that is to say, if is under control or not, is accurate or not. And secondly if the capability of the process is close to the target and could meet the expectations of the company. To determine if a process is under control or not, control charts are usually used. As it is an attribute and not a variable matter, it was decided to build a P chart to understand the historical behavior of the data and the rate of rupture. These type of charts are made to monitor the behavior of the data, they are used to find the endpoints and determine whether the number of alarms show if the system is or not under control.

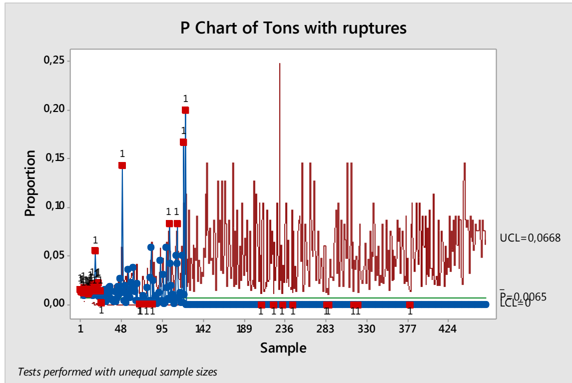


Figure 8: Minitab results for P Chart

From the graph obtained (Figure 8) is difficult to establish any kind of conclusions, the blue line represents the proportion of defective tons per customer and this line, in the costumer number 120 approximately, goes to the floor and thereafter remains at zero. Because of those results of the P chart, it was decided to make a Pareto analysis before starting the system stability analysis because there are many customers who have zero in their rate of rupture during transport.

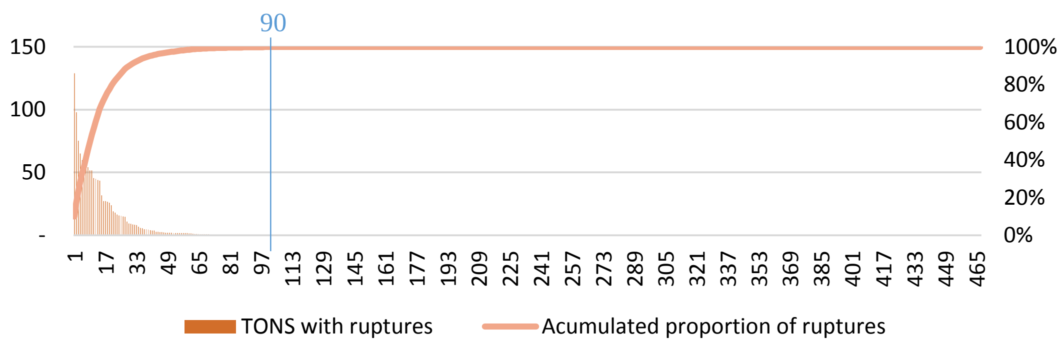


Figure 9: Pareto of the complete data

In this Pareto (figure 9), and as predicted before, the accumulated percentage of ruptures in TONS reaches 99,78% in the client number 90. Having this in mind, it was decide to remove from the analysis the rest of the clients, because from the client 91 onwards is only concentrated the 0,22% of the ruptures, and to make a new Pareto with the first 90 customers. This will allow an easier understanding of the situation and a project that has a better focus in the real generator of the problem that is the first 90 clients.

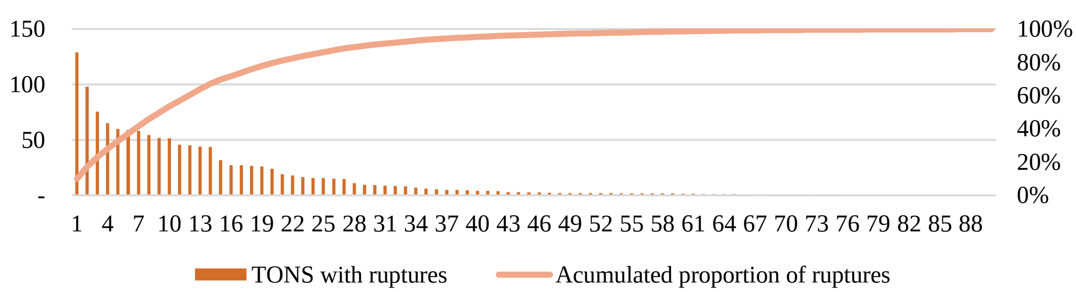


Figure 10: Pareto of the first 90 clients in order of TONS with ruptures

By reducing the number of clients to only the first 90, the project have to be rethought. The total tons transported is less than the number the project had before. But the tons of product with rupture stay almost in the same value because the rest of the clients represent almost nothing in this concept (0,22%).

Table 3: translation of the objective of the project into the new group of analysis

	Rate	TONS transported	TONS with rupture	Requirements for the objective	Objective
Complete population	0,62%	211.818	1.310	1.059	0,50%
Subgroup	0,92%	141.590	1.308	1.057	0,75%
Difference	0,30%	-70.228	-2	-2	0,25%

The project now has a rate of 0,92% of rupture during the transport to the client. And to keep the value of the objective in 0,50%, it has to go down from 0,92% to 0,75% in the subgroup to be able to accomplish the 0,50% in the complete group. Now the project is in a better position to make a P chart with better results than the ones above.

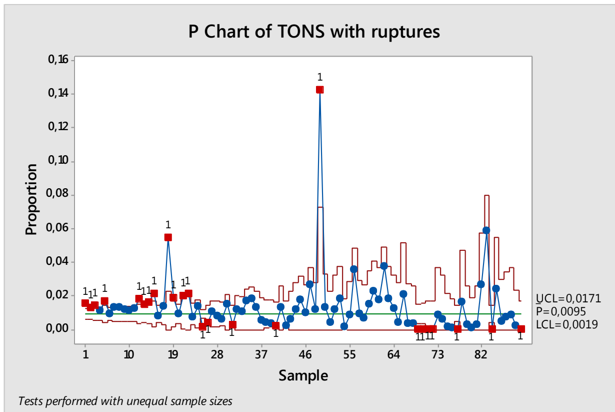


Figure 11: Minitab results for P Chart subgroup

Now it is easier to analyze the P chart and to make better conclusions (see figure 11). There are a lot of red points representing alarms, more than 10% of the them, and the process should be catalogued as out of control. Anyway, this chart could be wrong because of the big variation that there is between the sizes of the deliveries, a diagnostic for the P chart should be done.

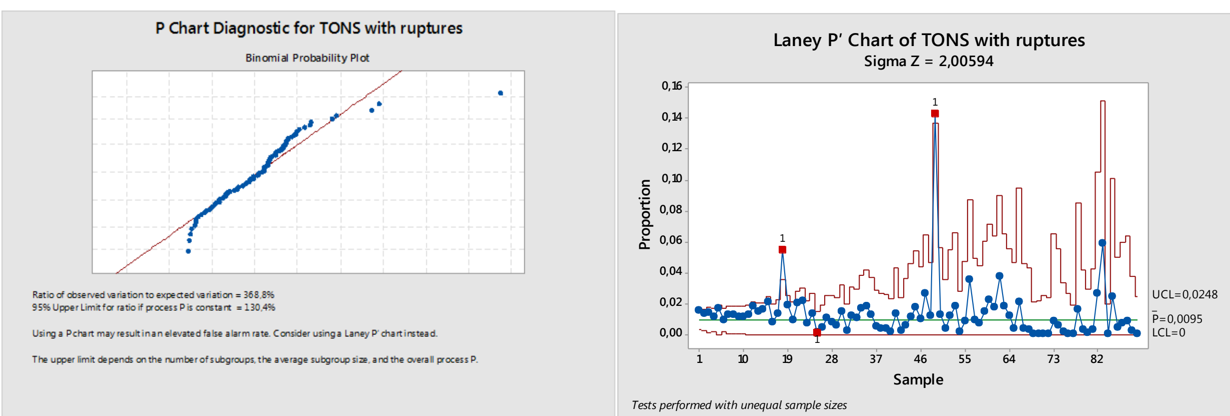
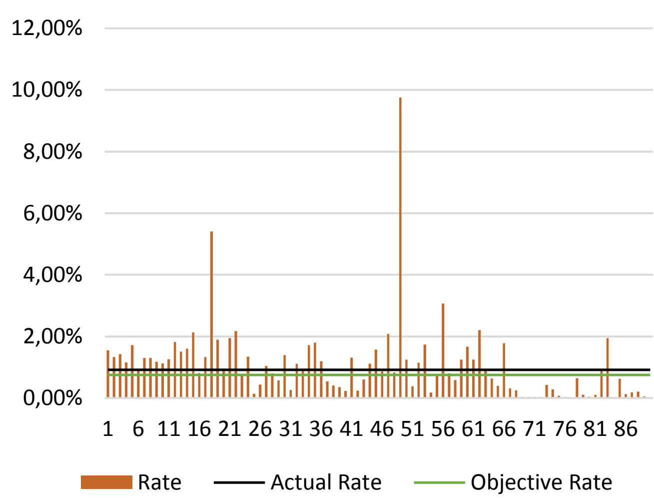
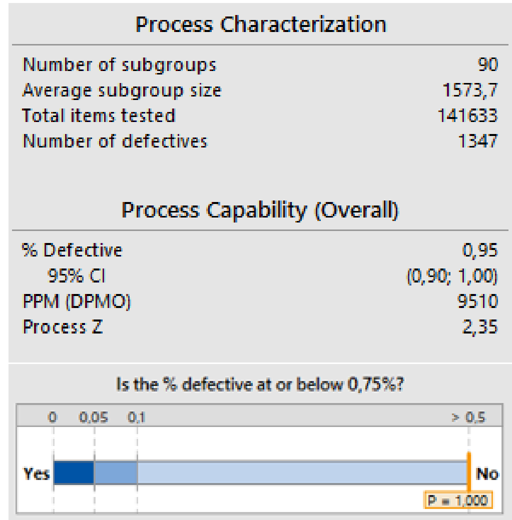


Figure 12: P chart diagnostic and Laney P chart

Because of the diagnostic for the P chart giving the results that it gave (see figure 12 left), a blue line that is close to the red one (mostly in the center), a rate of observed variation to expected variation equal to 368,8% and a 95% upper limit for ratio if process P is constant equal to 130,4%, it was decided to build a Laney P chart to avoid all of the false alarms that it could have. Anyway, even when the Laney P chart shows a lot less alarms (see figure 12 right), there still enough alarms to catalogue the process as one out of control.

Now that it is known that the process is out of control, it has to be determined if the process has the capability to take down the rate of ruptures during the transport from 0,92% to 0,75%. This is an attribute matter that counts defective items per delivery so the correct analysis to make is the binomial capability analysis for TONS with rupture during the transport to the client.





Process Characterization

Number of subgroups	90
Average subgroup size	1573,7
Total items tested	141633
Number of defectives	1347

Process Capability (Overall)

% Defective	0,95
95% CI	(0,90; 1,00)
PPM (DPMO)	9510
Process Z	2,35

Figure 13: binomial capability analysis for TONS with rupture during the transport to the client

Even when in the graph with bars (see figure 13 left), the actual rate and the objective rate seem to be really close to each other, and could be concluded that the process could easily accomplish the objective rate, the table right beside it contradicts this affirmation. The P vale of the statistical analysis is 1, it means that the process has absolutely no capability for the objective established by this project. In deed with a certainty of 95% the value of the rate is going to be between 0,90% and 1%.

So finally it can be concluded that the process of transporting the product LEPVD from the factories to the clients is not under control and does not have the capability to accomplish the objective established by this project.

2.3 Analysis phase

At this phase is necessary to understand the roots of the problem, propose ways to get improvements, and make a design of experiments (DOE) to establish ways to improve the process in the most efficient and effective way using the most significant factors of the problem.

2.3.1 Ishikawa diagram

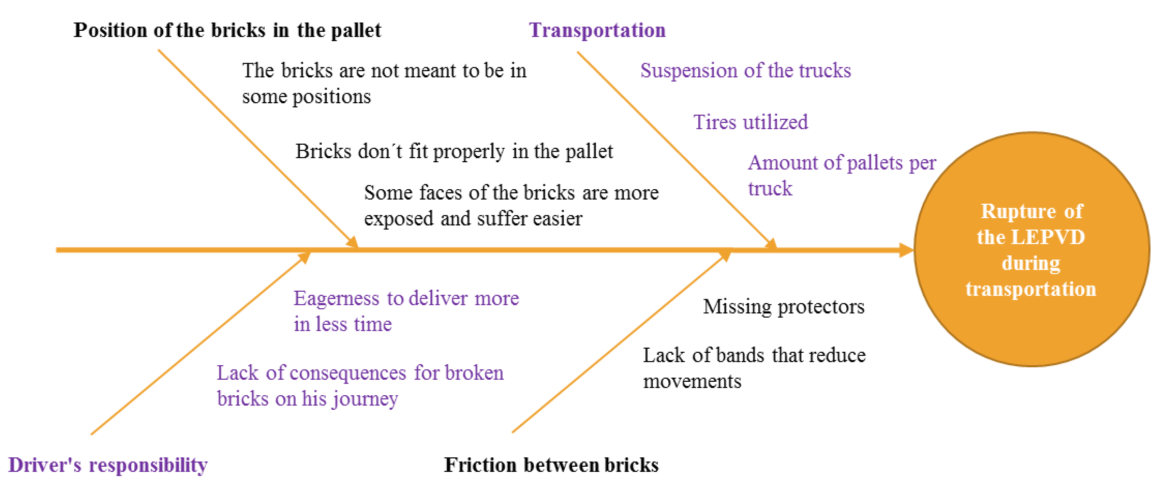


Figure 14: Ishikawa diagram

In the search for possible solutions, for the problem in question, it is first necessary to understand the causes of the problem. This Ishikawa diagram (see figure 14) was constructed with 4 main roots of the problem: position of the bricks on the packed pallet, transportation, driver´s responsibility and friction between the bricks. As you can see in figure 14 transportation and driver's responsibility are in purple, that is because this two roots are not going to be taken into account in the analysis. Transportation will not count for this project because it would mean changing the truck fleet for a more modern one or fixing the pavement around the city, or transporting only 1 or 2 pallets per truck, and all these "solutions" are not feasible in practical terms.

Regarding to the responsibility of the driver, Ladrillera Santafé has policies indicating that for every unit that gets to the client with rupture a percentage of the driver's payment is going to be deducted, thus the company makes sure that this root of the problem is kept at its minimum level. Never the less, regarding the responsibility of the driver, besides de politics of Ladrillera Santafé it was important to make a hypothesis testing to check if it has an important influence in the rate of rupture. The initial idea was to check if there were significant differences between the means of the drivers, in terms of the indicator of ruptures during the transport of the product, but there is not historical information about who was the driver of each trip. Never the less, thinking that the distance that the truck has to travel from the factory to the client most be a totally determining factor, and that this distance is different for every travel, it was decided to check with a linear regression the correlation between the distance of the travel and the rate of rupture that the travel gets. If there is a high correlation it would mean that the rate of rupture would be more correlated with the distance of the trip than with which the driver is, solving our problem.

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Pearson correlation of Distance (Km) and Indicator () = 0,443
P-Value = 0,000
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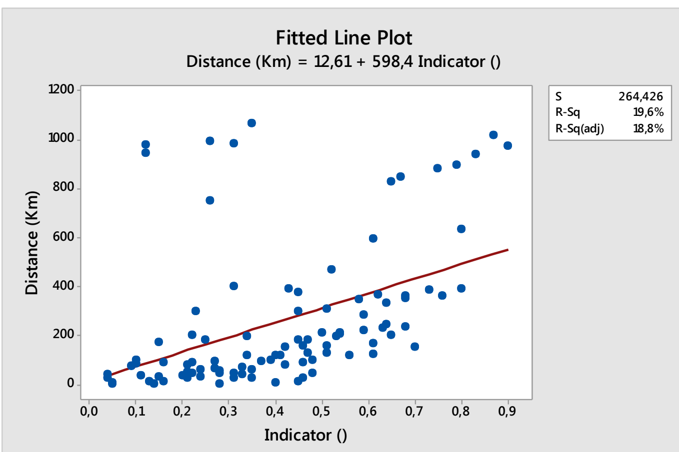


Source	DF	SS	MS	F	P
Regression	1	1670666	1670666	23,89	0,000
Error	98	6852244	69921		
Total	99	8522910			

Figure 15: Linear Regression and Correlation

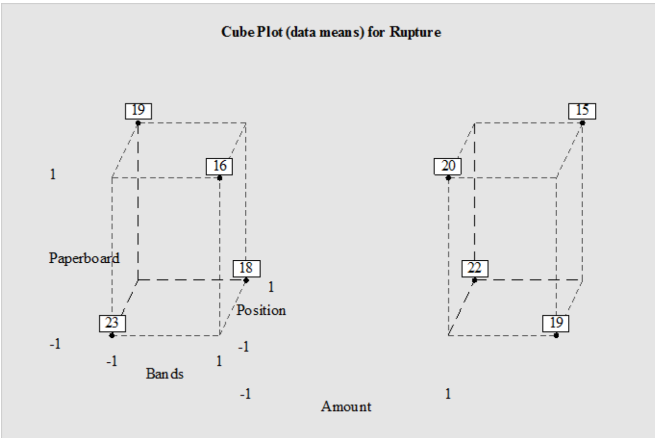
With a P-Value of cero for the linear regression and a correlation of 0.443, it was possible to determine that the distance of the trip had a highly significant influence in the rate of ruptures that the delivery was going to have. Almost half of the value of the indicator was explained with the distance of the trip and the other half was explained with the rest of factors such as the weather, the road, the traffic, the pressure of the air in the tires, and between all this other factors the driver.

From the other two roots, position of the bricks in the pallet and friction between bricks, emerge 4 key factors in the quality of the process that could improve the quality of the process if implemented:

- Using packaging bands to secure the load vertically or horizontally.
- Use of paperboard to avoid friction.
- Position of the brick in the packed pallet.
- Amount of bricks per pallet.

2.3.2 Design of experiments (DOE)

With this four factors selected above, now is necessary to check its real relevance over the rate of rupture during the transport to the client, a design of experiments was made. This DOE had 4 factors, 2 levels per factor (2^{4-1}) but with (-1) representing 8 experiments in total.



		Levels	
		Level -1	Level 1
Factors	Packaging Bands	With out	With
	Paperboard	With out	With
	Position	Horizontal	Vertical
	Amount	88	96

Figure 16: DOE Cube plot and Table with meanings

Each of the 8 experiments is a pallet to be packed with different combinations of the factors in order to, in a statistically robust manner, determine the impact of each factor over the rate in question. Eight pallets were transported in a truck from the factory in Soacha to the store of Ladrillera Santafé in Suba, round trip, to simulate a transport of about 50 Km, approximately the average trip that the brick has to take. The table in the figure 15 shows that the (-1) level means that the factor is not applied while the level (1) means that it is applied. Level 1 means 4 packaging bands and 4 paperboards while level -1 means none of both of them. The eight examples made for the DOE are marked in de cube plot of the figure 15 with a square, and inside of it, the number of bricks with rupture after the experiment in that specific pallet.

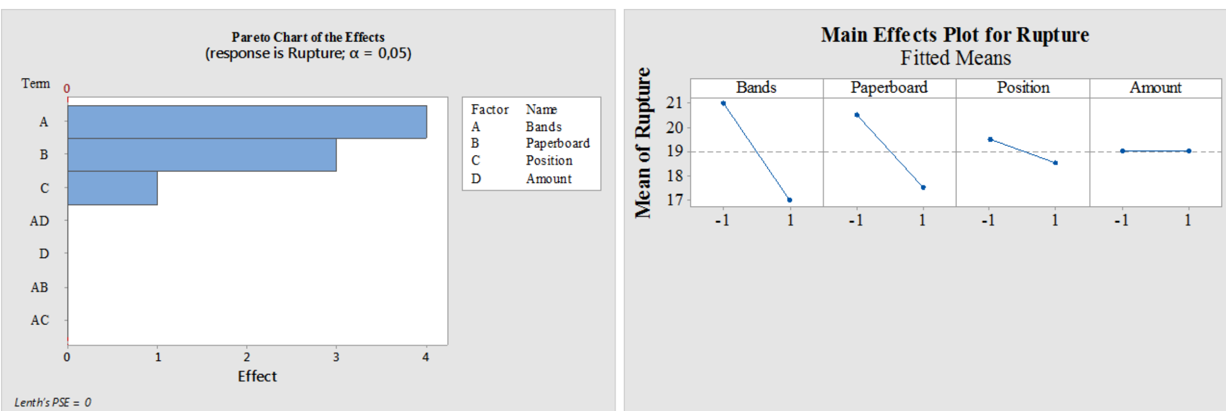


Figure 17: Results of the DOE

The figure 16 represents in two graphs the results of the DOE, the most significant factor is the use of packaging bands, the second one the use of paperboard, and the third one the position of the bricks in the pallet. The amount of bricks in the pallet did not present any kind of relevance in the rate of rupture during the transport. Also it can be said that the factors are not correlated and what has an influence in the rate are the factors by themselves.

2.4 Improve phase

2.4.1 First test of the proposed alternatives

Based on the results of the DOE, and with the 3 factors that were significant: packaging bands, paperboards and position, it was decided to build 3 prototypes of packaging modes. Twelve pallets of each of the alternatives and twelve more pallets of the original method of packaging, for a total of 48 pallets, were made. All this with the goal of running a final test that yielded definitive results to take decisions about a way to improve the process. Two trucks, each loaded with 24 pallets, and shipped from the factory in Soacha went to the store in Suba, round trip, about 50 Km. Upon returning, a quality selection was made to all the 48 pallets, and the rates of rupture during the transport of each of these modes of packaging were calculated.

Table 4: Costs associated to every way of packing

	Original			Alternative 1			Alternative 2			Alternative 3		
	Quantity	Unit Cost	Total Cost	Quantity	Unit Cost	Total Cost	Quantity	Unit Cost	Total Cost	Quantity	Unit Cost	Total Cost
Stretch Pelex (gr)	120	$ 6	$ 720	120	$ 6	$ 720	120	$ 6	$ 720	120	$ 6	$ 720
Paperboard				2	$ 700	$ 1.400	2	$ 700	$ 1.400			
Packaging band										3,8	$ 29	$ 110
Grappa										2	$ 6	$ 12
Corner Paperboard										4	$ 112	$ 448
Total			$ 720			$ 2.120			$ 2.120			$ 1.290
Cost per brick	$ 8			$ 22			$ 22			$ 13		

The table 4 shows the costs associated to every way of packing that was used in the final test. Also it can be seen the cost per brick and the total cost per pallet.

Table 5: results of the final test with the benefit – cost

	Extra cost per pallet	Rupture rate	Benefit	Benefit - Cost
Historical	$ -	0,62%	$ -	$ -
Original	$ -	0,79%	-$ 272	-$ 272
Alternative 1	$ 1.400	0,39%	$ 367	-$ 1.033
Alternative 2	$ 1.400	0,44%	$ 288	-$ 1.112
Alternative 3	$ 570	0,21%	$ 655	$ 85

Table 5 shows the test results in terms of cost-benefit. The cost is calculated as the extras that have to be paid for the alternative in question compared with the original way of packaging, so the original one has a value of zero in this column just as the line of the historical packaging. The benefit is calculated as the number of less units with rupture compared with the historical one, multiplied by $ 1.664 COP which is the price of a brick in front of the client, this is the value used because the bricks with rupture are bricks that are not going to be sold, and represent exactly the monetary loss of its selling price. The cost-benefit value is the difference between these two values. The rate of rupture during transport of the original packaging gave a value 0,17% higher than the historical for 2015 with this same packaging mode, this might be because the quality control in the test was made rigorously regarding the specifications of the EDE. However, even with a rigorous quality control, the 3 alternatives dropped rates of rupture during transport quite low as expected. For alternative 1 and 2 the cost- benefit was negative, that is to say, even when this modes of packaging are saving units, the investment is too high and absorbs the gains in monetary terms. Alternative 3 gave positive results in every way. The rupture rate for this mode of packaging was only 0.21% reaching a sigma level of 3.07 and 2100 PPM with rupture, and its cost-benefit value was positive.

Getting results, where the original packing gave even higher rates of rupture than the historical rates, suggests that it was a rigorous quality control the one applied. This gives even more strength to positives results of the alternative 3. It was expected that this alternative was going to be the most beneficial one. Applying packaging bands, that represents the most influential factor on the rate of rupture during transport according to the DOE, and the paperboards in the corners of the pallet, assured a reduction in the friction and an increase in the stability of the units inside the packaging.

2.4.2 Pilot implementation plan

The first full application of the changes was performed for an entire work shift of 8 hours in which 100% of the pallets were packed with this new method of packaging. All of this with the aim to monitor the performance of the whole system with the changes implemented. It was expected that the costs associated with the packing station were clearly going to increase. But it was also expected that the reduction in the negative cash flow due to rupture was going to be enough to pay for the new costs and even start generating additional revenue for the company.

During this work shift 140 tons were packed in 176 pallets. After the delivery of all this pallets it was possible to measure the rates of rupture in 0.207%:

$$= \frac{\text{(Tons with rupture after transport)}}{\text{(Total Tons transported)}} = \frac{0{,}29}{140} = 0{,}207\%$$

Table 6: results of the implementation plan

	Extra cost per pallet	Rupture rate	Benefit	Benefit - Cost
Historical	$ -	0,620%	$ -	$ -
Alternative 3	$ 570	0,207%	$ 660	$ 89
Pallets	Total extra costs	Total Benefits	Benefit - Cost	
176	$ 100.355	$ 116.075	$ 15.719	

Table 6 shows the final economic benefits that the project brought to the company in only one work shift. Implementing this for the normal operations of the factory would bring benefits of around 24 million COP if scaled to the almost 212.000 tons that the factory produced in 2015.

2.5 Control phase

The collection of the data to stablish a new historical rate of ruptures for the LEPVD reference has already started but has not enough information yet. The expectations for the year 2017 have a total production of 230.000 Tons for the LEPVD reference and an expected value in the rate of rupture of 0.21%. As seen in the first test of the proposed alternatives, and in the pilot implementation plan, those are totally feasible values to get.

Never the less, and with the intention of assuring the fulfillment of the objectives, the company has had a rigorous training of all the workers in the new way of packaging to reduce the variation in order to get a standardized process.

In the project charter of this project the objective was to reduce the rates of rupture from 0.62% to 0.50% achieving savings of 46 million COP a year, this was calculated with the price of 2015 for LEPVD of $1,504 COP. With the alternative 3 and the new price for 2016 of $1,664 COP, and knowing that it has the potential to throw a rate of 0.21%, if the company produces the same 211,818 tons of LEPVD reference of 2015, the savings are going to be around the 175 million COP. But the costs of the alternative 3 are going to be around 151 million COP so the final cost benefit expected for 2017 its going to be earnings of 22.5 million COP. (See table 7)

Table 7: Expected year 2017 vs. objectives of Project charter

Rate of rupture	Tons 2015	Pallets 2015	Saved Bricks	Benefit	Cost
0,62%	211.818	265.836	0	$0	$0
0,50%	211.818	265.836	30.624	$50.958.817	$0
0,21%	211.818	265.836	104.633	$174.109.292	$151.579.598

$$174´109.292 - 151´579.598 = \mathbf{22´529.694}$$

3. Conclusions and discussion

- Ladrillera Santafé loses annually 400 million COP approximately. LEPVD reference, because of its CTQ, represents 60% of it, and this is indifferent of the factory that produces the LEPVD.
- It is a problem that is growing with the time, 672 thousand COP a month.
- The objective of this project was stablished in reducing the rate for the LEPVD from 0,62% to 0,50% representing savings for the company of 46 million COP a year.
- The measure system of this process has been validated and it can be trusted.
- Out of the 467 deliveries made in 2015 only 90 of them concentrate the 99,78% of the ruptures but only represents the 66,84% of the total transported during the year. The project had to be readjusted to this focus group of clients.
- The process has a great level of variation and because of that a Laney P chart should be used in order to reduce the false alarms.
- The capability of the original process does not reach the objectives of the project; changes have to be made to be able to achieve the proposed results.
- There is a correlation of 0.443 between the distance of the trip and the rate of ruptures. This means that almost half of the rate can be explained with the distance of the trip, and knowing that Ladrillera Santafé has policies indicating that for every unit that gets to the client with rupture a percentage of the driver's payment is going to be deducted, it was possible to understand that the driver of the truck did not have a big influence in the rate of rupture of the trip.
- Out of the factors: use of packaging bands, use of paperboards to avoid friction, position of the bricks in the pallet and amount of bricks per pallet the only one that does not have any effect over the rate of rupture is the amount of bricks per pallet, the rest of them have a positive effect.
- With the 3 factors described above was possible to find one combination with a positive cost-benefit for the company. This new alternative of packaging has a rate of rupture during transport of 0,21% with 2100 PPM defective and a sigma level of 3,07.
- With a positive cost-benefit it can be concluded that this project has an efficient and effective result. The expected savings for the year 2017 are around the 22.5 million COP with a correct application of the control phase.

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Biography

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