A Continuous Improvement Project to Increase the Fulfillment Level in a Wire and Cable Company

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Abstract
A continuous improvement project (CIP) is a structured project using a team of people during a relative short period of time to improve a work area or process metric. An international wire and cable company had 51% orders delayed, which affected the fulfillment level of on-time orders, placing it on monthly average of 88%. The purpose of this project is to improve the fulfillment level indicator. In order to achieve this paper's goal, the research team used a Plan-Do-Check-Act (PDCA) problem solving methodology to address the main and action research methodology to document the results of this paper. Although this CIP is ongoing, after one week of implementing a pilot test in information transparency, the fulfillment level increased 3.5%. The content of this paper is relevant for professionals in the field because it shows the process of applying a continuous improvement methodology in the analysis, design and implementation of a solution to a very common issue for many companies. The benchmarking that the team made showed that other companies solved the problem by centralizing information, which was the option selected as "core" of the project. Despite the company's willingness to cooperate with the CIP, a key limitation was present: the lack of unified information.

Keywords
PDCA, action research, fulfillment, continuous improvement.

1. Introduction

A CIP is a structured project using a team of people, from different departments/units, working to improve a work area or process metric (Gonzalez Aleu and Van Aken, unpublished) in a relative small period of time, such as days or months. Some of the problem solving or improvement methodologies used in CIPs are Kaizen events, Six Sigma projects, Lean projects, and plan-do-check-act (PDCA). CIPs have been used in manufacturing and service organizations addressing different problems, such as, Health service improvement through diagnostic waiting list (Lodge, 2007), Lean Six Sigma and marketing: a missed opportunity (Chaplin, 2013), and Implementing lean methods in the Emergency Department (Timmons, 2014). Unfortunately, most of the publications related to CIPs has an practitioner focus, instead of an academic focus (Gonzalez Aleu and Van Aken, 2016), limit the quality of the knowledge generated (Nissen, 1996) On the other hand, Order fulfillment involves aspects such as, generating, filling, delivering and servicing customer orders (Croxton, 2002). The order fulfillment or fulfillment level integrates three metrics: orders delivered on time, orders delivered completed, quality of order delivered. Although order fulfillment has been studied from different perspectives, such as Managing product variety in quotation processes (Bramham, 2004), IT-enhanced order and delivery process of a fast moving consumer goods (FMCG) company (Chung, 2007), and Supplier selection and management strategies and manufacturing flexibility (Ndubisi, 2005), the research team considers that there is a lack of academic publications documenting successful CIPs on order fulfillment. Therefore, the purposes of this paper are (1) to improve the order fulfillment level in an international wire and cable manufacturing organization, using structured methodologies to increase the quality of knowledge in this research field.

Adapted from Creswell (2012) and Stringer (2007), a three-step action research methodology was conducted to address the aim of this paper: identify a problem to study, locate resources, and intervention. These steps were documented in this paper as follow: methodology (steps one and two) and results (step three). Additional, in the section of conclusion the research team summaries the major findings, describes the limitations of this projects and propose future lines of research.

2. Methodology

Action research is "a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this historical moment. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and theirs communities" (Reason and Bradbury, 2001 p.1). A three-step methodology was used in this investigation as follow.

2.1 Identify a problem to study

An international company dedicates to manufacture and supply different kinds of wires and cables (e.g. energy cables, construction cables, magnetic wire, and electric cables) with more than 700 employees, represent 40% of this industry. Although this company is a world-class organization, it has some opportunities for improvement. The procurement of raw material is the core of the supply chain, and when the steel cable line of product represents 51% of your total fulfillment failure, there is a problem on your process. During 2015, the organization averages an 88% of order fulfillment.

2.2 Locate resources

In order to identify the resources (people, financial, data), the research team creates a rich picture (Checkland and Scholes, 1999) of the process under study (see Figure 1), beginning in order reception and finishing with the shipment of the order.

1. Order Reception: An arrangement is done with the customer and the sales department generates an order with all the specifications made by the client.
2. Planning: First the order is received by the sales department, after that is sent to production planning, where the size of the order is checked manually with pen, paper and calculator, and then is approved, if correct a promise date for the customer is established and the order is sent to the Acquirements department. In case the client request is consider stock, the order is sent directly to the Acquisitions department. Those considered to be direct, follow the same path as a direct product, but they need to be quoted on the moment.
3. Production Program: the production line program manager states the date in which the raw material is needed in the production line to fulfill the order on time, this taking in account the average four weeks taken by the supplier to deliver the steel wire.
4. Acquirements: Once the production date is agreed the acquirements department makes the requisition to the supplier, once received in factory the steel is inspected and approved. When needed it is taken from the steel's warehouse by the production plant lifts and taken into the cable machines in which it is use as core for cable wired with aluminum wired previously stretched. When finished it is taken to the shipment patio, where the finished product awaits departure.
5. Raw Material Inspection: When the raw material is unloaded from the supplier truck, quality department ensures the diameter of the wires is met and the reel is in optimum conditions, these measurements are done with micrometer.

6. Drawing: In the drawing machine the aluminum wire is run through several rings at a high speed that reduces the wire diameter according to the necessity of the finished product. The wire is collected in reels at the end that are taken to the stranding machines to continue the process.
7. Stranding: once the aluminum is ready, the forklift looks for the raw steel in the warehouse and takes it to the stranding machine. In this process the machine takes several aluminum threads and strand them with a steel wire as the core of the cable.
8. Finished Product Inspection: consists in the final revision by the quality department, if the product is accepted a green label is pasted, in the case it is rejected a red label marks the reel.
9. Shipment: it is the final inter client for the finished product.

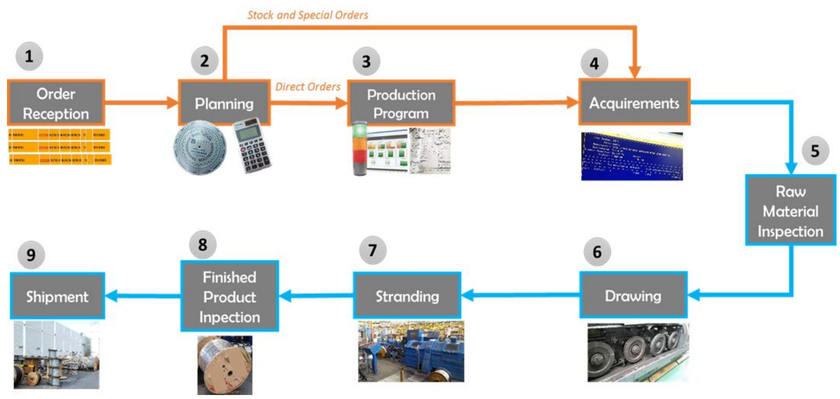

Figure 1. Rich Picture of the process under study.

Additional, a turtle diagram (Figure 2) was used to identify inputs, general process, and outputs. Both rich picture and turtle diagram help to identify the following resources: people, financial, data. The research team was integrated with people from two different organizations: Universidad de Monterrey, and wire and cable organization (see Figure 3). Two groups are part of Universidad de Monterrey. Three Industrial and Systems Engineering (ISE) senior students have role of consultants; they are responsible to diagnostic an organizational problem, identify cause-effects, propose solution designs, test solutions designs, implement best solutions, and document results. All these activities should be conducted in less than five months. Because the potential lack of expertise of the ISE senior students, they have an advisor and two co-advisors with more expertise in the problem that they are addressing in the organization. On the other hand, the wire and cable organization participated with six employees: internal customer, five internal suppliers, and one management team member. The internal customer and internal suppliers worked with the ISE senior student developing solution designs, testing solutions designs, and implementing best solutions. The management team member was the responsible to authorize any financial resource required from the solutions designed.

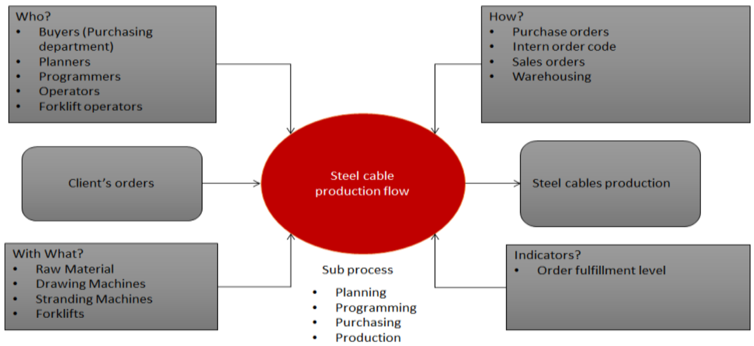

Figure 2. Turtle Diagram of the entire process

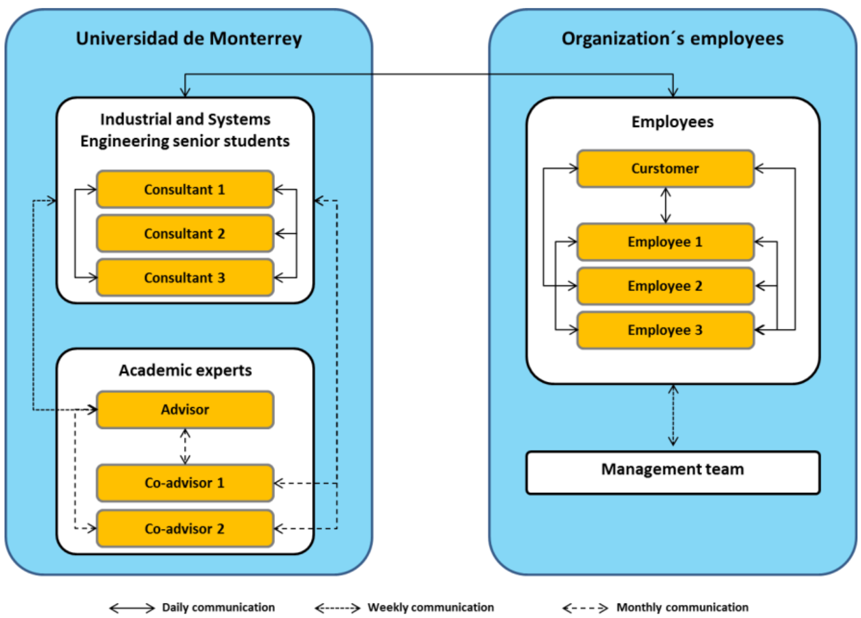

Figure 3. Action research team

In order to conduct this action research, the following data was collected. First the team needed to know the difference between the produce products, as well as the time each took from the order reception to the order fulfillment. Once notion of the entire process was well established and every single person involved in it was known, the investigation for the problem root causes started. For this we gather different data bases that stored the detected causes by the employees, as well as the information gathered from watching the procedures on the production line. The last step of the action research methodology is the intervention, which was documented in the next section of this paper.

3. Results

Based on research team's previous knowledge, the intervention process was conducted as CIP; using plan-do-check-act (PDCA) problem solving methodology. The first phase is to plan, during this phase it is necessary to establish the goals, define potential root causes, and propose potential solutions. Second, to do, which consist in test the solutions designed. Third, to check, the results from the implementations are verified and analyzed. If the results were not what research team expected, then new solutions should be taken. Fourth, to act, the solutions are full implemented and additional actions are took in order to standardize the results. Each of these four phases were described as follow.

3.1 Plan

In 2015, the production flow was of 526 orders considering the full catalog of products regarding aluminum, copper and steel wired cables. The steel wired cable orders represent the 59% of the total orders produced or 46% of the total amount of tons produced. by the wire production plant. In the steel segment or products, the company has three types of orders:

- Stock (36% steel orders production): Are the products that its raw materials are already in the company's stock.
- Direct (58% steel orders production): All the products that need to take into account the supplier's lead-time.
- Specials (6% steel orders production): The products that it's raw material need to take into consideration the direct negotiation with the supplier.

Because of a lack of reliable and traceable records, ISE senior students integrate information from different databases in order to identify the causes of order fulfillment failures (see Figure 4), highlight waiting and quantity as the most important causes. Unfortunately, 12 out of 142 orders were unable to be traceable. A depth investigation showed (see Figure 5) that the causes from the main problems are lack of raw material (Steel), production program, production line, external factors, and no data. Of these 5 subgroups can impact the first three, which are: Lack of raw material, Production program and line

Figure 4. Division of fulfillment causes in groups

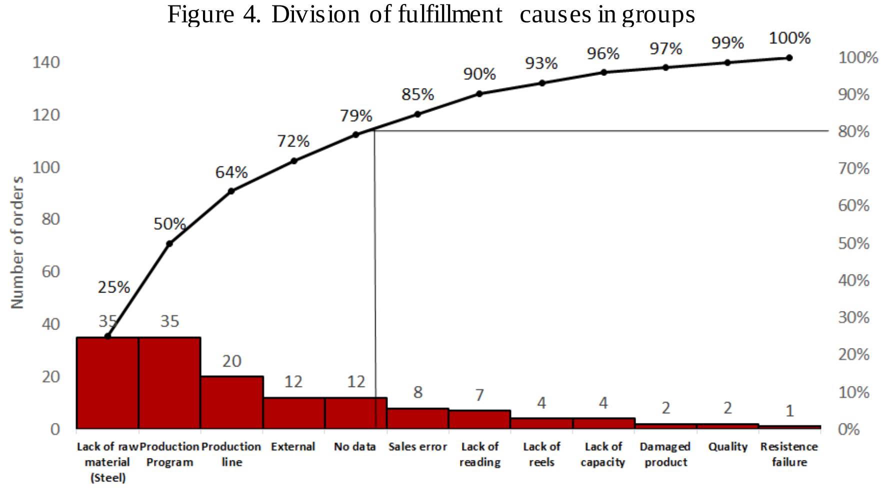

Figure 5. Pareto diagram of the fulfillment causes subgroups

After this was done, ISE senior students made the overview of the subgroups for each main group (see Figure 6), concluding that for Waiting, our focus cause group, the 39% of its failures belong to the subgroup Production Program, as well as in Quantity with a 78%. Which means that all the calculations made by hand are a big part of the problem.

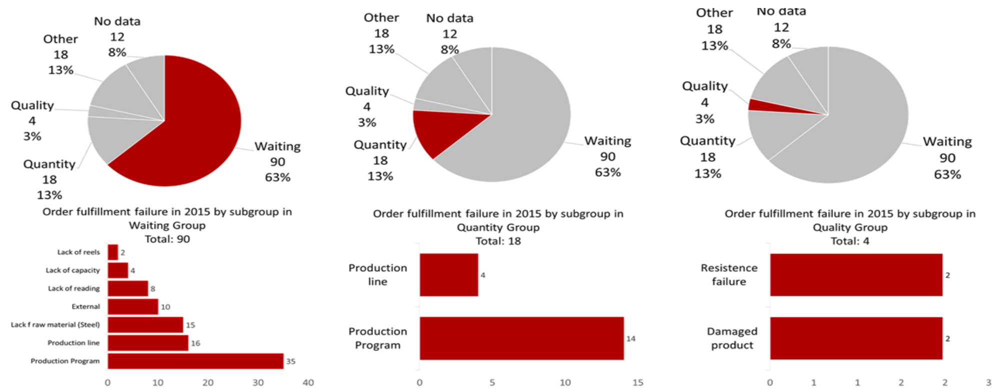

Figure 6. Unfulfilled order division in groups and subgroups.

After this analysis we conclude that the project need to have a special focus in the causes grouped as Waiting. With an impact of the 77% of the problems. With already defined the project mail group, we needed to decide which system was more important, either hard or soft. With the following chart (see Figure 7) we discovered that 72% of the causes of order fulfillment failure items were due to problems with the soft system, therefore the system is the main target the project.

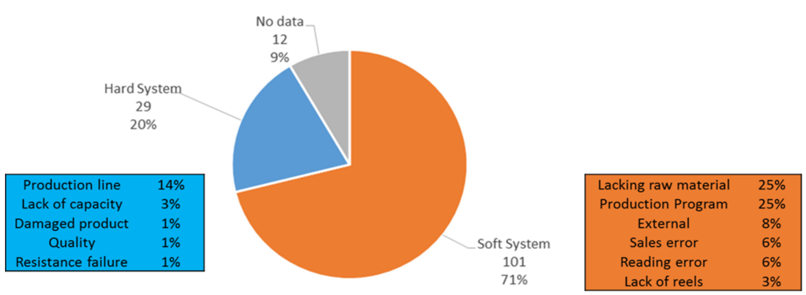

Figure 7. Root causes classification according to the figure 6.

To differentiate the approach of the future solutions used to solve the root causes founded in the analysis, the ISE senior students and the organization's employees used two different approaches to identify the root causes. A structuring diagram was used to identify failures for the soft system and its information flow, while the current reality tree (CRT) which is based in the philosophy of the five-whys, was used for the production system and the machines analysis. According to the structuring diagram, the root cause for the soft system was lack of standardization of processes (each sales order is communicated differently), the activities per area are not properly defined, and lack of alerts to send a sales order at the right time. The main root cause found in the soft system was related to the process suffered by the information in the order displayed by the sales department to become raw steel wire in the warehouse. That information flow between departments was taking 7 days and had high risk of being incorrect, because of the high presence of human intervention. Normally, the information exchange between the departments were done through e-mail, which could get lost in a vast sea of unread mail, by the time information reached its final destination about 45 hours had passed. Additional, all the calculations and metric conversions were done by hand and a pocket calculator. Therefore, new process that includes acknowledgment of a steel order and all its specifications was proposed, as well as, automatic calculations.

On the other hand, the CRT indicate four root causes: there's no alert system that notice when a process is complete, employees do not work together, the labeling system is not user friendly, the warehousing control is not the proper one. In the production line the forklifts had several problems related to the communication, forklift operators did not know when to move reels from one machine to the other, they were scouting the floor for work, and the data displayed in label on reels was small and incapable of reading from the forklift seat. In order to counterattack the teamwork deficiency in the procedures and the labeling inefficiency towards communication, an Andon system was in order to improve communication between machine operators and forklifts operators, this allowed the machine to signal the forklift when a process was done and when it needed to be filled up. For the labeling a rearrangement of data was needed, an increase of the size of the reel destiny was planned so the lift operator could easily establish where should the reel be taken to.

After two solutions were designed between ISE senior students and organization's employees (see Table 1), the others action research team members (advisor, co-advisors, an organization management team member) participated in a feedback process in order to rich the potential solutions. Three of the main contributions from this feedback process was to include weekly meetings between departments involve in the order flow, to create an Excel application to reduce waiting time (instead of the participation of IT department to develop a software application), and the authorization of buy recharge batteries for tablets.

Table 1. Summary of solutions designed

Solutions	Problem	Root cause	Actions	Time required	Benefits
System design to improve information flow	There's no control over the steel orders information flow	- Lack of standardization of processes, each order is made differently	Excel application		- Decrease probability of human mistakes by hand calculations - Waste activities removed - Trustworthy information registration
		- Lack of standardization of processes, each order is made differently - Employees do not work together	Weekly meetings		- Improvement of intern communication between administration and the manufacturing plant - Failure cases analysis and feedback - Solution proposals
Warehouse controls	Ineffective Warehouse controls	- The labeling system is not user friendly	Labels redesign		- Forklifts operators do not need to get off the truck to check the labels - Security risks and errors are reduce
		- There is not alert system that notice when a process is completed - Lack of alerts to send and order at the right time	Andon system		- The forklift operators do not waste time looking for who needs its service - Improvement in flow communication between manufacturing line and forklift operator
		- Lack of	Steel		- Delivery time reduction of all

	standardization of processes, each order is made differently - The warehousing control is not suitable	requirement by system	raw materials - Distance and time reduction - Elimination of daily steel count activity in stock

3.2 Do

During this step in the PDCA problem solving methodology, two solutions were tested and full implemented: system design to improve information flow and warehouse controls.

3.2.1 System design to improve information flow

This improvement implies the creation of a complete system in Excel (see Figure 8 that helps the communication between the areas of the soft system: Planning, Programming, and Raw Material Purchasing. It is a database shared by the three departments in order to have the information in one place. This system automates the calculations that used to be done by hand and converts the order to the need units (Kg, Lbs., M and Ft), informs that a promise date of delivery to the client and most of all makes lean the flow of the orders through the supply chain management, easy to identify and share.

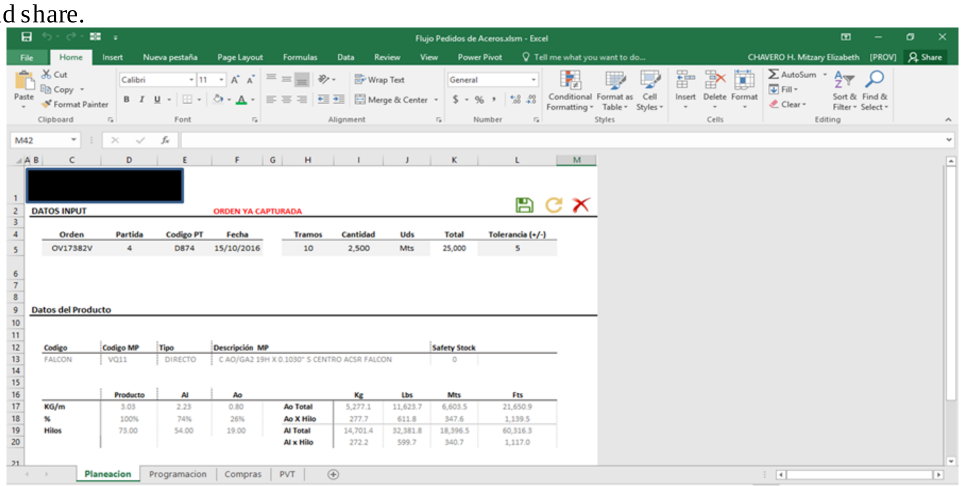

Figure 8. Information flow Excel system design.

In order to success in the implementation of the Excel system design and increase the communication flow between departments involved (production, planning, programming and raw material purchasing), a weekly meeting was established to talk about on time delivery failed orders and the reason of these incidences. This meeting was designed considering six thinking hats (de Bono, 1985), where each participant contributes in a different way to the meeting: white hat (production; objective), green hat (acquirement; creative), black hat (raw material acquirement; negative), red hat (planning and feedback; positive), and blue hat (planning and input; organization), yellow hat (programming: emotional). Additionally, the ISE senior students structured the meeting flow, which includes: following up previous actions (5 minutes), orders failed and causes (20 minutes), solution designs or kaizen (20 minutes), next orders vs. inventory (10 minutes), closing meeting (5 minutes).

3.2.2 Warehouse controls

The forklift operators had the necessity to step down the cockpit and read the labels on the reels and determine the destination, in the best case scenario the machine operator would tell the driver where to take the material or finished product. By reorganize the information in the labels used to identify the reels, and make the size of the destination or next step in the process larger (see Figure 9), the forklift operator could easily read and quickly identify the place the reel needed to be deliver

Figure 9. Finished product label redesign.

On the other hand, while reviewing the possibility to install an Andon light system, the supervisor mentioned there used to be a system where machine operators would request reels to feed the wiring machines, indicating the quantity, time, and which machine it is coming from, after which the forklift driver would see and bring to the corresponding machine: this system allowed the supervisor to monitor the forklift activity. It was left aside because, the tablet that served as medium between the forklift operator and the system itself, needed to be taken of to be recharge. To bring back the system a brainstorm session was made, and the simples less costly and eligible solution came up, using external batteries to charge the iPad when in need.

To improve the annexation of the steel products to the requirement system needed to be made, the procedure would be as every other material (see Figure 10). It was needed to instruct and train the programming department to do the requirements. Once this was done, the warehouse forklifts were instructed to leave the steel reels in a specific area, called steel patio, where during the day and as needed production forklifts would come and take the correct material.

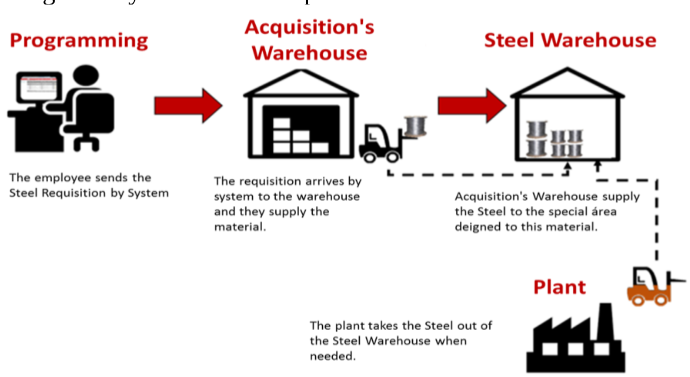

Figure 10. Raw materials requisitions process.

3.3. Check

Follow up activities were conducted during 10 weeks in order to monitor the implementation and the results obtained for each solution.

3.3.1 System design to improve information flow

The benefits of the excel system were a reduction of a 75% in order fulfillment failure by wrong information feed through the administration channel. This impacted as well the Kaizen#4 about the redesign of the job profile; this will be explained in the correspondent Kaizen.

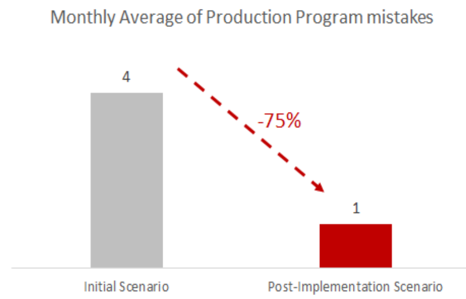

Figure 11. Results of kaizen number 1

Once the excel system was implemented, the team decided to use the time previously taken to check the veracity of the orders to be made, and instead organize a meeting in which the Production, Planning, Programming and Acquirements, analyze the orders failed for every product material by its causes and define a kaizen for them; as well check the next orders in line to verify everything is in the right time and place to process it without any trouble (See Figure 12).

In order to give a systematic approach to the meeting and to avoid that the different participants take advantage of the moment to look for guilty, it was decided to approach the meeting with a methodology based on the book "Six Thinking Hats" from the writer Edward de Bono (See Figure 13). The meeting leader (White hat) was trained about the methodology and also the rules that the team should follow depending the "hat they are wearing" were given. Initially the meeting was with the hat their personality consist of, but in the next ones the hats are changing depending the instructions of the leader to force the people to think out of the box and take assertive decisions.

Meeting topics	Duration
• **Orders failed** • Copper • Aluminum • Steel • **Causes** • Groups • Subgroups	20 min
• **Kaizen/Feedback** • Action taken • Person in charge • Due date	25 min
• **Next orders vs Inventory**	10 min
• **Closure**	5 min

Figure 12. Meeting Program

Hat	Quality
Green	Creativity
Black	Negative
White (Meeting leader)	Data and objectives
Red	Positive
Blue	Organization and Control
Yellow	Emotional

Figure 13. Qualities per Hat

The results that the meeting showed was that there was a better communication flow between the members of the chain, all the "bad vives" were cleared. This result was also influenced by the Excel System because it made the process more transparent, and everyone had a way to prove their work was done; not to look for culpabilities, but to find the problem and a solution.

3.3.2 Warehouse controls

This Kaizen, together with the Kaizen #1 brought two main benefits: for the steel requisition system, a reduction of 96% in muda related to time spent in activities related to steel, this meant saving 109 minutes. Also the forklifts traveled about 669 mts daily to find the raw material, now there is a specific place nearer, this made the forklift travel around 580 mts, which it involves a 13% of distance reduction with a mean of 5 reels per order.

Remembering the general objective of the action research, when it started on the first days of June 2016 the indicator of the order fulfillment percentage was of 90% (see Figure 14). On September 2016 the implementation took effect (Do-step) and the indicator rose to 98%, which means 2 orders failed on time deliveries. Lastly, on October there was only 1 failed on time delivery.

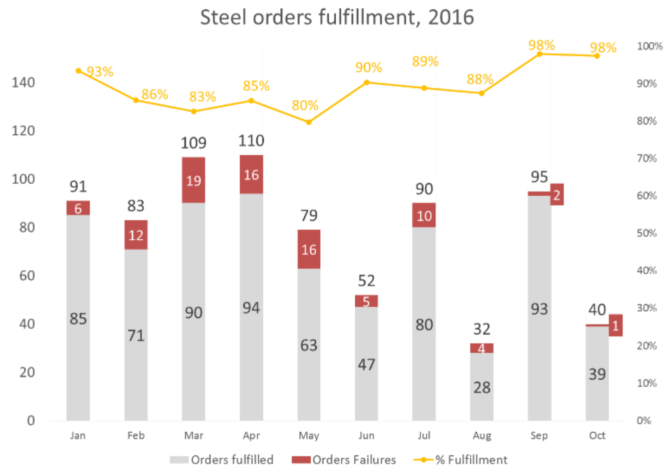

Figure 14. Steel orders fulfillment order indicator

3.4 Act

The final step for the project is to establish the steel requirement system made in excel, into the company's IT system, allowing the orders information to be filtered automatically. This will enable a faster and more reliable information flow between the relevant areas. The Excel System is going to be left for them to copy the code into the system. For the Meetings the leader is already trained, and its being working well, we left the memorandum format and every presentation from the training so they can keep using it. To improve the design in all labels related to the wire plant, this means to standardize the labels that go into the plant and those that go outside of it. As well the establishment of manuals that would take step by step the user of the systems, and the final trainings needed for the team and the employees for the correct usage of the implementations and for their continuous improvement.

4. Conclusion

Because of the development of the solutions for Information Flow and Warehouse Control the fulfillment level went from an 88% average of fulfillment level at the beginning of the project to a 98% on September and a 95% on October, reaching the main objective of the project. The key elements for the success was the deep analysis made as well as the data gathering, despite the hard work, it made the design easier. Change resistance was a main limitation during the analysis and design: the employees involved in this action research are mainly above 50 years old and really drowned into the way they used to do things. Despite this, the solutions worked; communication helped a lot, showing the benefits of this new way of processing information.

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Biography

Mitzary E. Chavero Hidalgo is a fourth year industrial engineering student at the Univesidad de Monterrey in San Pedro Garza García, Nuevo León. Currently she has a 90% academic scholarship and is part of UDEM's Honors Program "Líderes Plus" where only the 1% of the entire class is admitted, this program requires a social development project on benefit of a local community. Won first place in General Electric's Lean Challenge in the Electrical Distribution Equipment S.A. plant with a manufacturing project. Also she is doing an internship in Ternium México S.A. de C.V.

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