

Case Study: Improving Production Planning in Steel Industry in Light of Lean Principles

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Abstract

Lean manufacturing has been applied in many companies in different sectors. The steel industry has many challenges for the implementation of lean manufacturing due to some constraints that are related to the nature of the industry such as large lot production. This paper describes the application of lean principles in the production planning of a flat steel plant. Pull Production, Mixed Model Production, elimination of waste, and creating flow are among the lean manufacturing principles that were applied in this case. The results show more than 40% reduction in work in process and cycle time, reduction in cycle time variability, and less chaos. This case shows that it is possible to implement, at least, several lean principles in steel industry and achieve positive results.

Keywords

Lean manufacturing, production planning, steel industry, mixed model production

1. Introduction

Lean manufacturing (Toyota Production System) has got the researchers and practitioners interest in the last two decades. Many companies around the world tried to implement lean manufacturing (e.g. Huson and Nanda, 1995, Sakakibara, Flynn, and Schroeder, 1997) to realize the gains that have been reported by many researchers.

Lean manufacturing consists of many elements that support each other (e.g. Schonberger, 1982, Liker, 2004). Those elements include: set up time reduction, pull system, production leveling (Heijunka), small lot size, quality control circles, group technology, total quality control, and total productive maintenance. Lean manufacturing elements are implemented through a culture of waste elimination, root cause analysis, mistake proofing, visualization (visual plant), respect for employees, simplification, focus on shop floor (Gemba), and standardized work. Fahmi and Hollingworth (2004) showed that lean manufacturing principles are interdependent and support each other.

Many studies have reported the gains from lean manufacturing (e.g. Fullerton and McWatters, 2001; Fullerton, McWatters, and Fawson, 2003; Huson and Nanda, 1995; White, 1999) such as: less cycle time (sometimes called throughput time), less work in process, less rework and defects, less plant troubles, shorter time to respond to market changes, increase in on time delivery, increase in employees morale, and improvement of financial measures on the long term.

Abdallah (2003) explained how steel industry could benefit from the application of lean manufacturing. He used a simulation model to show the estimated reduction in lead time and work in process when lean manufacturing is applied. Abdelmalek and Rajgopal, (2006) suggested that some lean principles are probably inapplicable or partially applicable while others are applicable. They suggested that 5S, visual systems, and value stream mapping are applicable in steel industry, while set up time reduction, production leveling, total productive maintenance, and just-in-time are partially applicable. Roy and Guin (1999) suggested a model for just-in-time purchasing at an integrated steel plant. Dhandapani, et al. (2007) showed how a steel plant at India can reduce production cost and lead time by applying lean principles.

This study shows how several lean principles have been applied at a steel plant (EZDK) in Egypt and presents the results of applying those principles. Those principles were applied mainly by the production planning team but the effect was obvious at the shop floor. In the next section EZDK flat steel plants and the production planning

challenges are described. Section 3 describes the implementation of several lean principles. In the next sections the results are presented and discussed. Finally, a brief introduction to future work is presented.

2. Production Planning of Flat Plants

EZDK Flat production planning is affected by the nature of demand and production process. Flat contracts are usually between hundreds of tons and several thousands of tons. Each contract has a specific steel grade, width, thickness, and type of processing.

EZDK Flat production consists of one Electric Arc Furnace (EAF), One Caster, and One Hot Strip Mill (HSM). The three steps are parts of a continuous process. If any trouble occurs in one of those steps it will affect other steps as well. It means, also, that whatever is produced in the electric arc furnace will be cast and rolled in the caster and hot strip mill. The raw material are melted in the electric arc furnace, and then the molten steel is cast in the caster into slabs with the required width and a thickness of 52 mm, and finally the slabs are rolled to reduce the thickness into the required thickness (1.2 mm to 12.7 mm). The final product of the mill is coils with the required width, thickness, grade and weight.

The electric arc furnace capacity is 160 t which means that it operates with batch production of 160 t of molten steel known as “heat”. The continuous process (sequence) lasts for more than 10 heats then the caster has to stop to get prepared for the next sequence.

The flat steel is produced in the form of Hot Rolled Coils (HRC) at a high temperature (around 600 °C) and then left for few days to cool down naturally. More than 60% of the coils will need further processing after the cooling period. There are several downstream plants: Skin Pass (SKP), Pickling (PKL), Slitting (SLT), Light Cut To Length (LCTL), and Heavy Cut to Length (HCTL). The coil will take one route or another through those different plants based on the customer demand.

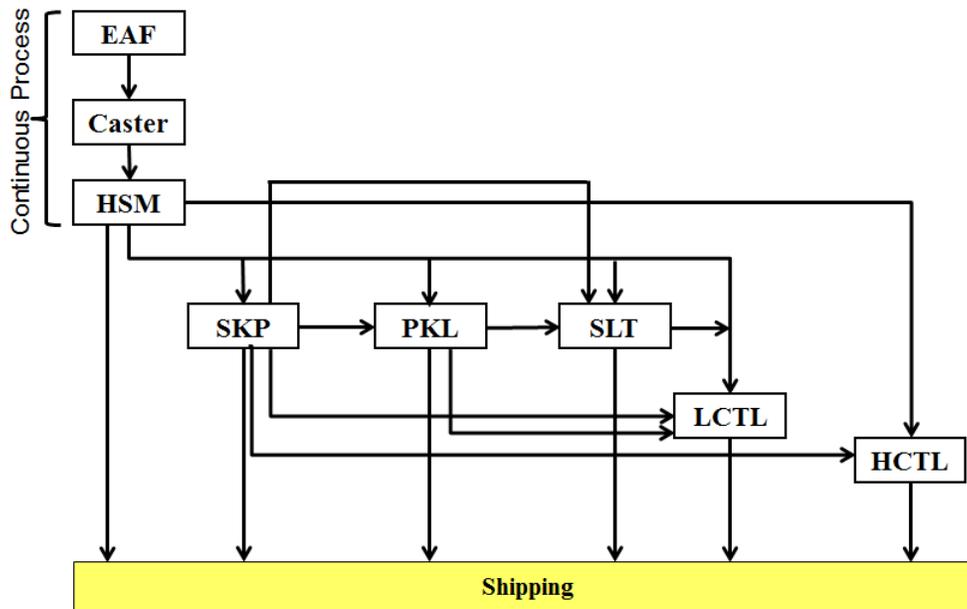


Figure 1: Flat products routes through flat plants

Flat Production planning is a complex process because it should consider:

- Customer specific requirements: grade, thickness, width, processing, packing type, and weight range
- Delivery time
- Plants constraints which are related to the nature of the process such as: it is not possible to produce a grade with quantity less than 160 t because this is the electric arc furnace capacity, the width change during the sequence should start from larger to smaller, The sequence should start with a high thickness

- 3 or 4 mm and then the thickness can be reduced from coil to the next through certain steps, and the fact that not all grades can be produced in the same sequence.
- Cost of production: for example: short sequence of two or three heats increases the production cost
- Plants' capacities

The flat production planning team at EZDK consists of several engineers who are working during the day time for five days a week. During the last 12 years they have developed an information system that helps them in issuing new production and processing orders, and in contract tracking.

Although the production planning team was improving from one year to another, the team decided to make changes by applying some lean principles in the last year. The rest of this paper explains the implementation and results of this case.

3. Implementation of Lean Principles

3.1 Heijunka (Production Leveling)

Production leveling by volume has been applied, for several years, at the Electric arc furnace, caster and hot strip mill because those plants are working 24X7 except during planned maintenance or troubles. However, production leveling by mix was not applied and the large batch philosophy was dominant. This led to large batches of the same product route and huge quantities waiting for processing at different stages and uneven production load at the downstream processes. Figure 2 describes the traditional planning which produces large quantities of pickled products, skin passed products, and slitting products in the first, second and third day respectively. This will lead to two or three days of waiting time at each of those plants.

Day 1	Day 2	Day3
Pickled Product	Skin Passed Product	slitting Product

Figure 2: Traditional production planning by large batches

In order to minimize work in process, the mixed model production was applied. It was not an easy task to apply mixed model production in steelmaking, but the planning team learned how to apply it. Instead of producing products with the same product route on the same day, the production was a mix of different routes. Although it was not possible to keep the same product mix everyday due to industry constraints, it was possible to produce variety of products every day and this was supported by pull production. Figure 3 shows the daily production plan which aims at producing a mix of product types each day.

Day 1				Day 2				Day3			
Pickled Product	Skin Passed Product	Slitting Product	Sheets	Skin Passed Product	Skin Passed Product	Slitting Product	Pickled Product	Sheets	Sheets	Skin Passed Product	Skin Passed Product

Figure 3: The application of mixed model production in flat Production planning

3.2 Pull Production:

Push production used to be applied in flat production planning which means that any type of product will be produced from the mill with any quantity regardless of the downstream rate of processing. This led to long waiting times and crowded coil yard. Moreover, this was a reason for delay of inspection and late discovery of defects. Consequently, the on time delivery was negatively affected. Figure 4 shows the long waiting time before processing. The waiting time used to be much longer than the processing time and thus the coil may take 5 or 6 days in average

to get processed after the cooling period.

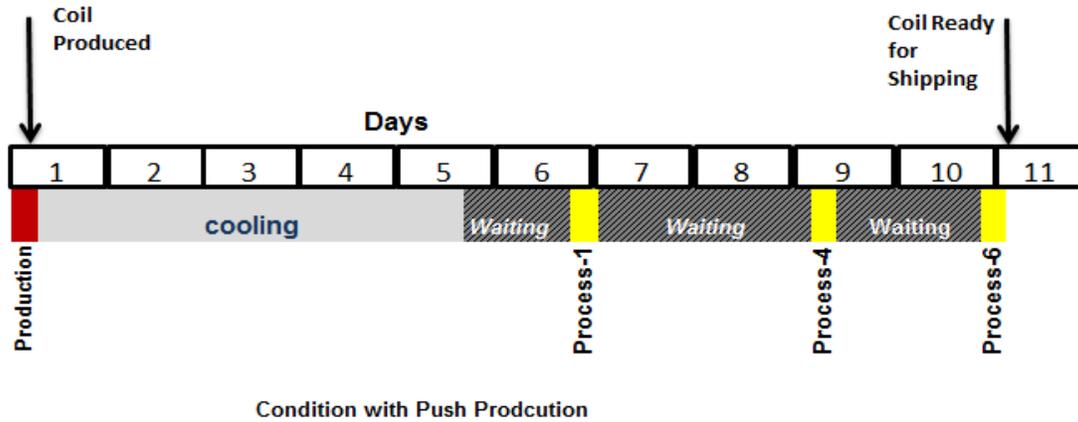


Figure 4: Push production effect on the waiting time before processing

Pull production means that downstream processes issues order to upstream through Kanban. This is still not possible to implement at EZDK because of the variety of product route and the complexity of creating upstream production order. However, pull production spirit was applied through considering downstream plants' capacity when planning the upstream production. No coil will be planned for production at the upstream unless the next process will be available when this coil is ready for processing.

In order to achieve this, the production of the upstream for any product route is constrained by the least process capacity in this product route. For example, if product A will pass through processes 1, 4, and 6, and the daily capacities of these processes are 1000 t, 500 t, 700 t, then the maximum production of product A at any day will be 500 t. In other words, the maximum daily production plan of any product that needs processing at processes 1, 4, 6 should not exceed 1000 t, 500 t, 700 t respectively. By applying this rule, any coil will be processed as soon as it passes the natural cooling time.

Figure 5 shows how pull production planning eliminated most of the waiting time. The coil needs one or less than two days to get processed after the cooling period.

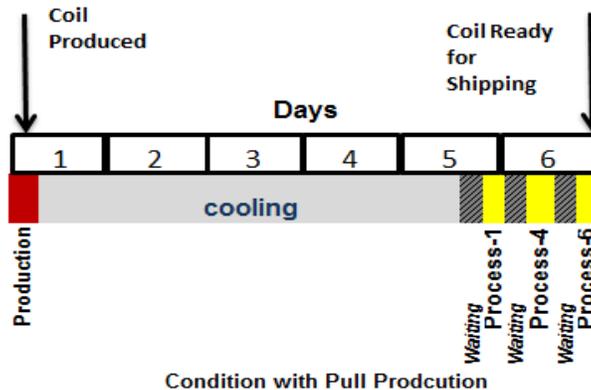


Figure 5: Minimization of waiting time through Pull production

3.3 Creating Flow through Automatic Processing Order:

Due to the centralized production planning, coils cannot be moved to the next process until production planning engineer issues an order for the next process. This means long waiting hours during night hours and weekends because planning engineers are not available. In order to create a flow and minimize the waiting time, the order issuance was carried out through the information system automatically during day and night. The information

system checks every four hours for new orders and issues them. Each plant is informed electronically about the new orders. This allowed processing a coil in three processes on the same day instead of three days, and created a flow of coils.

In light of Kanban spirit, employees empowerment, and production planning on the shop floor, the operators at any downstream plant at any time can use the information system to check for new orders.

3.4 Estimation of Cooling Time:

In order to have more accurate plan and decrease the waiting time, it is important to process the coil as soon as it reaches the processing temperature (less than 40 °C). The coils' temperatures were tracked during the natural cooling time in different seasons. Based on these measures it was possible to have a defined accurate period for the cooling time. It was found that the natural cooling takes 4 days in the winter, 6 days in the summer, and 5 days in fall and spring. This allowed production planning engineers to have an accurate plan for the downstream processing.

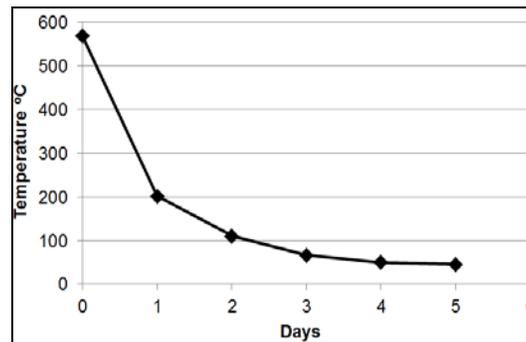


Figure 6: Cooling curve of the Hot Rolled coils from ~ 600 °C to 40 °C

These measures helped specifying the factors affecting the cooling period length. Although everyone in the plant had a belief that thickness, width or grade affects the cooling time, it was found that the weight is the only dominant parameter. This result was used in designing the coils with less weight, which is not always preferred, in case of urgent requests. The relation between weight and temperature was considered in estimating the coils cooling period.

3.5 Problems Should be Visible:

Lean manufacturing aims at finding problems in order to eliminate them. This principle was applied at EZDK by showing any delays in the production plan. This was not welcomed by the production people but it was a necessary step to see the problems.

This principle was applied in the production planning information system by creating simple screens to see any delays in coils' processing or any problems in coils' specifications. By allowing everyone in the planning team to see those problems, the action to resolve the situation was fast.

3.6 Customer First

The production planning team started shifting from the traditional thinking of “producing as much as you can with minimum cost” to Taiichi Ohno's saying (1988) “making what you need only in the quantity you need when you need it ...and as inexpensively as you can”. Whenever there are many production planning alternatives, the one which will produce the contracts in the proper time is selected. This is different from the traditional way of trying to minimize the cost of production by producing large batches of the same product regardless of the negative effect on the delivery time and customer satisfaction.

3.7 Gemba (Observing the Situation at the Plant)

Lean production focuses on going to the plant and seeing the problems. To some extent, the production planning team increased their site visits which allowed them to discover many problems and to find many points for improvement. The site visit gave them the basis for many planning improvements. For example, the planning engineers discussed and implemented, with the coil yard manager, many improvements that helped in decreasing the coils cooling period. In other instances, planning engineers noticed possibilities for increasing the productivity of

certain plants. In some cases, planning engineers found that production people did not follow their orders for a practical reason, and then the planning engineers tried to include that in their order preparation.

3.8 Elimination of Waste in Coil Assignment

Based on lean culture of elimination of waste (Muda), the production planning team worked on eliminating the waste of coil assignment task. Some of the contracts for flat steel are based on buying the existing inventory which is called traders contracts. Whenever a trader contract is issued, the sales representative sends an e-mail with a list of certain coils to be assigned to that contract, then the production planning engineer will try to assign those coils to that contract. The production planning engineer will have to type each coil number and may refuse to assign some coils because they are needed for another contract. A series of e-mails and phone calls between sales and planning will be going back and forth until the task is done. According to a time study, this task was the longest task and, as described, it was one of the most disturbing tasks.

Production planning team worked with IT engineers to develop an advanced system to get this task carried out in very short time without any disturbance for sales or planning. The new system allows the sales representative to pre-assign coils for a contract and the system will inform the production planning team electronically whenever this pre-assignment needs checking and approval from the production planning. Then, the planning engineer checks the pre-assignment and approves/rejects it in seconds.

By eliminating the waste from this process, the production planning engineers have time to focus on more critical planning tasks, the sales representatives get their assignment in very short time with less effort, and the customer enjoys shorter delivery time.

4. Results:

By applying those principles, the production planning team was able to realize the following results:

4.1 Reduction of Work in Process by More Than 40%

Due to the application of Mixed Model Production and Pull Production, the work in process decreased by about 43%. Moreover, the variability in the work in process became less than before. The standard deviation of the work in process quantity decreased from 6,700 to 2,900. The maximum work in process in the last twelve months is equal to the average work in process in previous years. The reduction in work in process saved space in the coil yard which allowed for better coil stacking that reduced the cooling time. The less work in process, the easier it is to check that no coil needs a quality decision or planning action is forgotten for days or weeks. Figure 7 shows the changes in work in process from August 2009 till May 2012.

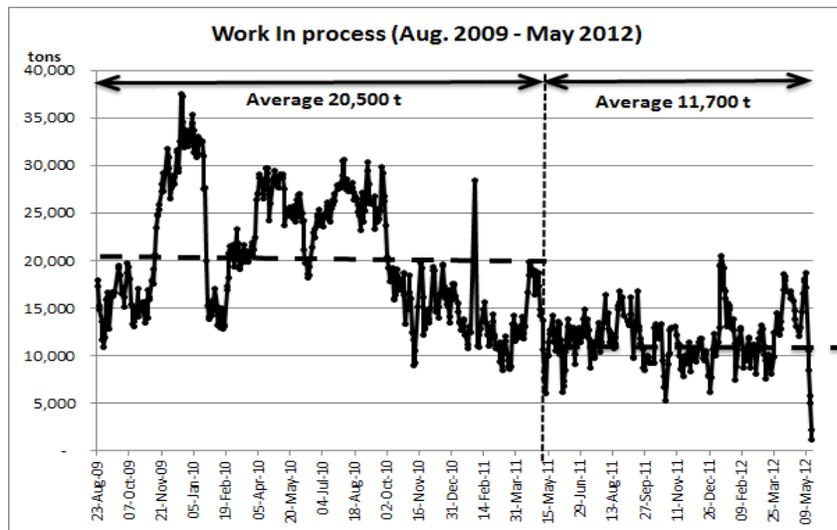


Figure 7: Work in process quantities from Aug. 2009 till May 2012

4.2 Reduction of Cycle Time by More Than 40%

The cycle time (time from coil production at the mill until the coil is ready for shipping after processing) decreased by the same percentage: 43%. Obviously, this is due to the linear relation between work in process and cycle time (Hopp and Spearman, 1996).

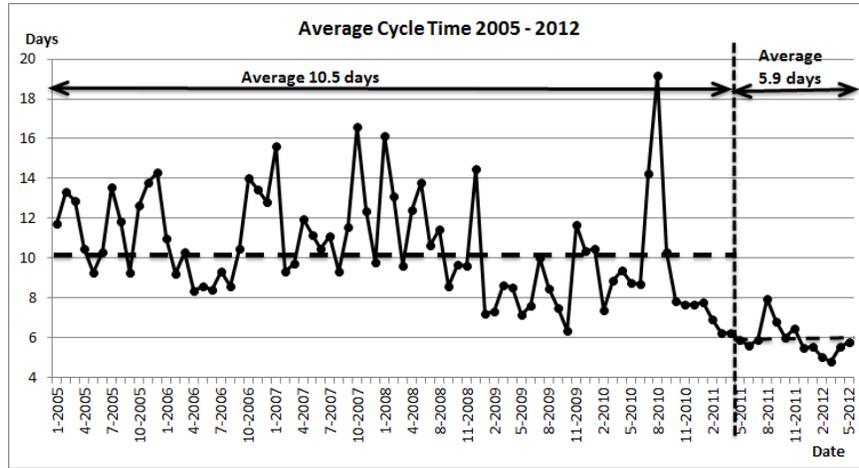


Figure 8: Average monthly cycle time from Jan. 2005 till May 2012

Lean manufacturing aims at decreasing variability, and this was achieved for the cycle time. Figure 9 shows the change in the standard deviation of the cycle time. The standard deviation decreased from an average of 7.8 days to 3.5 days.

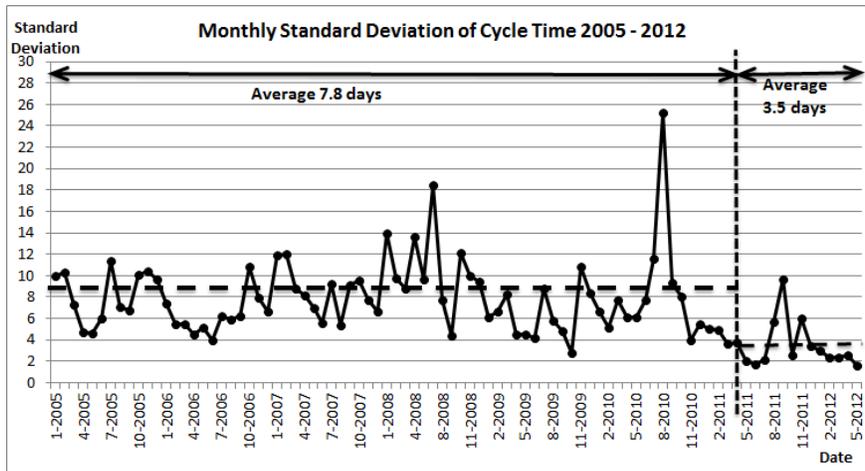


Figure 9: Monthly standard deviation of cycle time from Jan. 2005 till May 2012

4.3 Increasing Planning Accuracy

Due to the reduction in the variability in the cycle time and since the cooling time was estimated based on the cooling time study, the accuracy of the delivery time increased because the production planning team is able to forecast the processing time with less deviation.

4.4 Decreasing Chaos

Large quantities of work in process result in chaos because sales managers would always expedite the processing of specific coils. That means several phone calls and e-mails from sales to planning asking for expediting the processing of specific coils, then several phone calls from planning to production plants asking for processing specific coils first. On the next day, some of those coils may still not being processed because of any reason. Then a

second wave of calls among sales, production, and plants occurs asking why those coils were not processed. This is a repeated situation which makes production planning team act as a call center.

With more than 40% reduction in work in process and with a pull production planning, each coil will find the next process ready to process it when the coil is ready for processing. No one needs to expedite the processing of any coil and no one will ask why the coil was not processed. At any day, the plant will process the coils that are ready for processing which does not exceed that plant daily capacity.

4.5 Discovering Problems

The reduction in work in process and cycle time helped discovering many deficiencies. For example, the delay in product packing after processing was notified. The delay in coil transfer to the next process or the delay in quality decision was visible. On the other hand, any quality defect is being discovered earlier than before.

4.6 Less Variability in Downstream Plants Loading

Pull production and mixed model production besides the automatic work order led to a reduction in the variability of loading of the downstream plants. For example, if we compare the standard deviation of the production of the slitting plant during March and April of 2012 with the same period in 2011 we find a reduction of 30%.

5. Discussion and Future Work:

One of the main challenges to this case was to get people believe that mixed model production, minimization of work in process, and pull production are better than the traditional way of large batch push production. During the implementation, it was obvious that traditional performance measures make people reluctant to accept lean manufacturing. In addition, the belief that steel industry is very special industry is one of the reasons people will mention when they refuse to change from the old ways to the lean way. All those challenges need to be addressed through training, discussions and gradual implementation.

The production planning team had to work against large batch production culture not only in the production plan but also in the data entry, packing, and coil handling. It was found that all those processes have to cope with the shorter cycle time by working with one piece flow or at least small lots.

The implementation can be extended by applying those principles not only in the production planning but also at the production plants by the production people. For example, single minute exchange of die (SMED) should be applied to improve the application of Mixed Model Production. Total Productive Maintenance is very essential to have reliable production plants. Quality Control Circles are needed to solve both quality and equipment problems to decrease rework and sudden stoppage.

In order to decrease the cycle time beyond the current levels, forced water cooling for the coils is being studied. If this succeeds, it will decrease the cycle time to 1 day only, which means shorter delivery time.

6. Conclusion

Several principles of lean production have been completely/partially implemented at a flat steel plant in Egypt. Those principles include: pull production, production leveling, Gemba (work place) visits, waste elimination, creating flow, and problems visibility. The production planning was the focus of those lean principles' implementation. The results show that the work in process and cycle time decreased by more than 40%. The variability in cycle time- measured by the monthly standard deviation- decreased by 55%. The production leveling created free spaces in the coil yard which helped in standardization and minimization of the cooling time. The improvement of the coil assignment process decreased the effort and time. All these improvements decreased the chaos and improved the planning accuracy.

This case shows that many of lean principles can be applied in steel industry, but they may have a special form in order to face challenges in the steel industry. The principles that were not applied in this case may be applicable in steel industry and may be tried in the future.

Acknowledgements

The authors would like to thank Mr. Mohamed Said, Mr. Haitham Mohamed, Mr. Ahmed Ragab for their efforts that made this case study and improvement possible. The authors appreciate Mr. Hamdy Fathy support during the implementation of those changes. The great IT support from Mr. Mohamed Ali and Mr. Motaz Sanad were essential success factor in this case. Finally, the authors would like to thank production and quality people who participated in these changes.

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