Production planning optimisation and challenges in steel production: SSAB process review

Ville Isoherranen*

Oulu Southern Institute,
University of Oulu,
Pajatie 5, FI-85500 Nivala, Finland
Email: ville.isoherranen@oulu.fi
*Corresponding author

Pekka Kess

Department of Industrial Engineering and Management,
University of Oulu,
P.O. Box 4610, FI-90014 Oulu, Finland
Email: pekka.kess@oulu.fi

Abstract: This research investigates the production planning challenges in steel production. The strategy for steel manufacturing by the case company has changed in response to the pressure of the global markets. The original strategy resulted mostly in a push type of production planning that took the customer’s orders into account at a certain point in the production line. Currently, the company is driven by customer’s demand, which has resulted in more dynamics and larger variations in the production runs. The theory is built upon operations management, with a focus on production planning. The results indicate that the special nature of the production planning environment, which includes multiple variable process components in steel manufacturing, therefore contributes to the challenges in achieving a balanced production flow. The study evaluates the reasons for production scheduling challenges and examines the overall flow of steel production from an operation’s optimisation point of view. This study brings forward the new data on measurement done in one critical production phase of steel production, thus giving example on variation at the single-process phase yielding to total variation of the system.

Keywords: continuous improvement; operations management; production planning; SSAB; steel production.


Biographical notes: Ville Isoherranen (Dr. Sc. (Tech.)) is the Director of Oulu Southern Institute (OSI), University of Oulu. He has international and cross-functional industrial management experience from Sales and Marketing, Product Management and Supply Chain Management. He has worked as a Consultant for several companies for sales development, operational excellence and business growth. His research interests are strategic management, operations management, product management and customer-focused enterprises.
1 Introduction

The process of production planning is focused on management of production flow in an optimal way. The target for the production planning process is to optimise different variables in the production flow and drive towards effectiveness in resources usage. This means to minimise the total time and costs, within the context of the constraints in the system. The production system is always subject to dynamic disturbances (Long et al., 2014). The complexity of the planning and scheduling of highly integrated steel plants have been widely discussed by Tang et al. (2001).

A steel plant production planning process has always been an interesting research field and many approaches have been put forward for establishing and optimising production planning and scheduling (Long et al., 2014). In Northern Finland, the steel manufacturing has been very important source for employment for a long time. This research is motivated to secure and further develop the knowledge on steel manufacturing, to further strengthen the competitive advantage of local steel manufacturing capabilities. Attempts to optimise steel production have used various common optimisation and scheduling techniques. For example, Tang et al. (2000b) studied various applicable methods and identified the following categories:

1. operations research-based methods
2. artificial intelligence-based methods
3. expert system-based methods
4. constraint satisfaction methods
5. human-machine coordination techniques.

They proposed “a multiple travelling salesman problem model for hot rolling scheduling”, based on the results from research, to provide a significant improvement in a steel company case.

Significant amount of research has also investigated steel production planning, with subsequent generation of good theoretical foundations but very little information of practical use. Körpeoglu, Yaman and Aktürk (2011) has studied a multi-stage stochastic programming approach in master production scheduling. The research of Tang et al. (2000a), which included a mathematical model for scheduling steelmaking and
continuous casting production, also falls into this same category. The research of many scholars (As’ad and Demirli, 2010) on production planning process in steel mills with demand variation clearly shows that the current state of methods provides results with many compromises.

The strategy of steel manufacturing used by the present case company has changed because of the pressure of the global markets. The original strategy resulted mostly in a push-type production planning that took the customers’ orders into account at certain points in the production line. Currently, the company is driven by customer demand, which has resulted in more dynamics and a larger variation in the production runs. The production planning challenges now lie in providing:

− shorter delivery times
− better delivery accuracy
− better yield
− better utilisation of the production resources (physical, human and financial)
− improved productivity.

This research can be addressed by the following research questions (RQ):

RQ1: What are the challenges in steel production planning?

RQ2: What is the current state of the case company in terms of meeting the challenges of production planning?

The research process to answer these research questions is described briefly in Chapter 2. The challenges of the steel production in general will be addressed in Chapter 3. The second research question will be answered in the subsequent chapters.

2 Research process

The research process is described in general terms and is shown in Figure 1. The research started with the definition of the research questions and theme. This was followed by a literature study and then synthesis of the theory relevant to build a framework for this study. The case was then examined in detail to discuss the production planning challenges in the case company. Conclusions are presented at the end as well as a plan for future research.

Figure 1  The research process (see online version for colours)
3 Challenges in steel production

The current main challenges within the steel production industry can be shortly presented as follows: (Manser, 2013)

− overcapacity
− high raw material/energy costs
− price volatility

Based on this research done by Manser (2013), the steel production industry has overinvested in new capacity for several reasons. This trend does not seem to be changing any time soon:

− Capacity increases are driven by technology upgrades.
− The investment costs are low, especially in China.
− Steel production plants delivering local markets can succeed when they have large domestic markets.
− The steel producers in, e.g. India and Russia have low production costs due to the low raw material costs.
− In the open international trade, the steel manufacturers can export their overproduction easily.

When looking at the steel market as a whole, the weak demand in the developed markets, such as Western Europe and USA has resulted in the slow market size growth, which has been different scenario than the one to which capacity increases have been planned. Some measures have been taken to reduce capacity, but not in large context (Manser, 2013).

The main energy source for a steel production furnaces are coking coal, these prices have constantly risen. Iron ore costs have also risen as well as the power costs. This has been especially problematic due to the fact that many steel producers have long-term raw material contracts, but they are not able to transfer the price increases in their raw materials to the prices of end products (Manser, 2013).

High-performance companies have risen to the challenge and they take into account the various aspects (customers, costs, agility and stakeholders), as described in Figure 2 (Challenges Facing the Steel Industry, 2015):
4 Production planning

4.1 Push production

In production planning, the most common approach for solving the production optimisation challenge is the "push production" approach (Haverila et al., 2009). Push production is based on the detailed scheduling of each of the production steps from the first processing step to the last. The flow of production starts from the first processing step and the following step is initiated when the previous step is finished. This requires confidence in long-term forecasting from the company using this approach, so production can be adjusted to the actual demand, without overproduction. Naturally, the company can also suffer from stock-outs, if the production volumes are underestimated. The challenge of push production is also the accumulation of intermediate stock and work in progress for the production process; in many cases, this is due to the variation in the process steps and mismatch between the actual demand and the produced quantities (Mann, 2015).

4.2 Pull production

Pull production is manufacturing of products or parts to meet only the actual immediate demand. In the manufacturing process, the signals to trigger processing travel from the end of the process towards the beginning. Typical signals are Kanban cards, which indicate the need to start processing. The pull production approach has become famous, its origins on the Toyota production system and the lean philosophy, that is, the essential fabric for sustaining a pull production system and its benefits (Haverila et al., 2009; Liker, 2004).
4.3 Material requirements planning

Material requirements planning (MRP) was first published by Joseph Orlicky in 1975 (Pitkänen, 2010). The idea of this system is to have stock when needed and to have none when it is not needed. The focus is not just to look the reorder point for the items but identifying the size and timing requirements from the master production schedule. In other words, nothing materials will be ordered before these items are needed to produce something for the master schedule. This method is widely used in manufacturing because several levels of dependent demand can exist for a product such as assemblies made from subassemblies made from components made from purchased materials (Muller, 2003; Wild, 2002).

Normal stock control handles an item as completely independent, unaffected by usage of any other item, and the demand is assumed to be random. The MRP approach is quite different, based on (Wild, 2002):

- Dependent usage between stock items.
- Ordering for the demand.

Efficient practice of MRP requires that sufficient, timely and correct information be available (Wild, 2002; Frazelle, 2002), as follows:

- A master schedule of planned delivery for each product with a planning view long enough to handle the lead time for purchased parts and the total consumed manufacturing time.
- The bill of materials (BOM) which is a list of parts and components which is clearly defined.
- Actual purchasing and manufacturing lead times for all items.
- Stock records which include work in progress (WIP) and items already ordered.

The master production schedule (MPS) and the BOM are the essential parts of the MRP. The MPS defines what will be produced and delivered and in what quantities. The BOM is the receipt of items required to produce something. It describes the dependencies between materials. Using both types of information, MRP systems calculate when, what and how much material needs to be purchased and/or produced to meet the requirements (Muller, 2003).

The biggest advantage in an MRP system is that it is a forward-looking system; in other words, the system takes all the available data into account when making decisions and proposals. At the same time, MRP systems are highly data dependent. Data like production schedules, purchasing lead times and on-hand inventory need to be correct and accurate; otherwise, MRP gives wrong suggestions.

The largest problems related to MRP are (Aiello, 2008):

- Inventory accuracy: without accurate inventory records, MRP will make wrong proposals and may cause stock-outs.
- BOM accuracy: if the BOM is not correct, the MRP will propose supply in the wrong quantities or wrong materials.
• Manufacturing and purchasing lead time: MRP creates supply proposals based on the delivery; therefore, if delivery times in the system are too short, MRP proposes too late a replenishment and can cause stock-outs.

• Lot-size rules: MRP uses the lot-sizing rules for proposing the correct order quantities; if the rules are wrong, then MRP may suggest too much or too little replenishment.

In steel manufacturing typically, and in the case company especially, the first problem does not apply, whereas the rest are very relevant problems and therefore represent challenges.

5 Improvement approaches

5.1 Plan-do-check-act

The plan-do-check-act improvement wheel (Figure 3) is the most famous quality improvement approaches. It is based on Deming’s quality thinking. The plan phase is all about planning, the do phase is for executing the items which were planned in the previous step, and the check phase means evaluation of the results achieved by activities in the previous step. The act phase’s purpose is then to implement corrective actions based on the findings of the previous step. The cycle then closes, and the activities start again from the planning phase (Sokovic, Pavletic and Pipan, 2010).

![Figure 3 The plan-do-check-act improvement cycle](image)

5.2 Six Sigma

The fundamentals of Six Sigma thinking originates from Motorola in the 1980s. The set quality program aimed to reduce variability in the processes and products. The improvement approach is based on the identification of the reasons for variability, and then influencing these variables by designing experiments aimed at reducing variability and increasing predictability (Karjalainen and Karjalainen, 2002). The Six Sigma process is a well-known D-M-A-I-C (define-measure-analyse-improve-control) process. This
gives a rigid framework for an improvement approach and relies heavily on collection and statistical analysis of the data.

5.3 Lean thinking

Lean thinking philosophy, officially defined by Jim Womack, has been a successful approach in the context of manufacturing, especially in the pioneered automobile industry (Takala, 2011). According to Monden (1983), the origins of lean thinking are result of the Toyota Production System. Womack and Jones (2003) compressed the idea of lean thinking into five principles, described in Figure 4.

Figure 4 Lean thinking (see online version for colours)

The seven-waste framework originally defined by the Toyota family is one of the key concepts of lean thinking. These are described in Table 1 (Hines and Taylor, 2000).

Table 1 The wastes defined for lean thinking

<table>
<thead>
<tr>
<th>Waste</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overproduction</td>
<td>Producing too much or too soon, resulting in poor flow of information or goods and excess inventory</td>
</tr>
<tr>
<td>2. Defects</td>
<td>Frequent errors in paperwork, product quality problems or poor delivery performance</td>
</tr>
<tr>
<td>3. Unnecessary inventory</td>
<td>Excessive storage and delay of information or products, resulting in excessive cost and poor customer service</td>
</tr>
<tr>
<td>4. Inappropriate processing</td>
<td>Going about work processes using the wrong set of tools, procedures or systems, often when a simpler approach may be more effective</td>
</tr>
<tr>
<td>5. Excessive transportation</td>
<td>Excessive movement of people, information or goods resulting in wasted time, effort and cost</td>
</tr>
<tr>
<td>6. Waiting</td>
<td>Long periods of inactivity for people, information or goods, resulting in poor flow and long lead times</td>
</tr>
<tr>
<td>7. Unnecessary motion</td>
<td>Poor workplace organisation, resulting in poor ergonomics, e.g. excessive bending or stretching and frequently lost items</td>
</tr>
</tbody>
</table>
6 The case SSAB steel manufacturing process

Rautaruukki Oyj, until 2014, was a listed international company. In 2014, it was merged with SSAB. The merger process is still underway in 2015. Rautaruukki, now a part of the SSAB, produces steel and metal production and solutions for construction and the engineering and metal industries. The former Rautaruukki Group had operations in over 20 European countries. The core marketing area was the Scandinavian countries and the Baltic area. Of the turnover, over 90% came from Europe (Raahe Steel Works Environmental Statement, 2003).

The steel producer, Raahe Steel Works, is the largest steel works in the Nordic countries and one of the largest industrial sites in Finland. Steel production is based on the use of iron ore concentrates. The finished products are hot rolled plates and strips (Raahe Works Environmental Report 07, 2007).

A schematic of the production facilities at the Raahe Works is shown in Figure 5.

Figure 5 The production scheme of the SSAB Raahe Works’ Environmental Report 07 (2007) (see online version for colours)
The production and the production systems have been developed throughout the more than 50 years the works has existed. IT systems have been utilised extensively in managing the production as well as the whole business of the company.

The IT systems architecture has become rather complex through the years, representing various production paradigms as well as IT technologies. Figure 6 presents a rough picture of the IT systems architecture of the case company.

Figure 6 System architecture of the case company (see online version for colours)

Figure 7 shows an overview of a part of the case company SSAB steel manufacturing process. The process starts at the raw iron mixer, followed by sulphur removal, which is done for a certain quantity of raw iron, and then in the following step, the recycled iron is added together with raw iron to the converter. There, the iron is exposed to oxygen, until the carbon ratio drops under 0.04%. The material is then called steel. After the converter, the next step depends on the required material values. The subsequent step can be CAS-OB (Composition Adjustment by Sealed argon bubbling - Oxygen Blowing) or a ladle furnace with or without a vacuum until the casting phase.

In this study, the production planning challenges are focussed on the CAS-OB processing phase. Figure 8 shows the deviations in the processing times in this process step, based on measurements done in the CAS-OB processing phase.
The processing times in the CAS-OB phase clearly show variation. This ranges from below 0.36 s to over 0.56 s. The root causes for variation can involve many factors.

This cumulative variation from several process steps then results in variation in the subsequent delivery time, as illustrated in Figure 9. This can then be perceived by the customer as a lack of quality in operations and product service. Ultimately, this can lead to loss of this customer to competitors.
6 Conclusion

Literature research and empirical study lead to the conclusion that the challenges in steel production planning are related to the challenges of steel production more generally. These challenges include the continuous pressure and new demands placed by customers and the need to drive costs down, to improve all operations for better agility and to manage the company so that it meets the needs of all stakeholders in a balanced way.

6.1 Theoretical implications

The literature clearly shows that integrated steel production is so complex that mathematical modelling for production planning purposes is extremely challenging. Thus far, a global model has not been developed. The steel production remains with a great potential for further research, especially for modelling the customer and market drivers, and their implications to operations management field, in the special context of highly integrated steel manufacturing operations. System modelling and variation linkages analysis should be supported by proven frameworks.

6.2 Managerial implications

The empirical research showed that the current state of the case company is insufficient with regards to meeting the challenges of production planning. The complexity of the production line needs a much better understanding for better planning. The current complexity and variation in operations of the case company’s process results to less than
Production planning optimisation and challenges in steel production

optimal usage of the key resources in the case company. This can be seen in the operations floor level with appearance of waste, such as waiting times, excess stocks and lower productivity. For management, this should be a signal for the need of comprehensive operational excellence program to enhance the production flow and moreover, deployment of lean approach to operations.

References


media/Files/Corporate%20responsibility/Ruukki%20Raahé%20Works%20Environmental%20
report%202007.ashx (6.4.2015).

cycle, RADAR matrix, DMAIC and DFSS’, Journal of Achievements in Materials and

Takala, A. (2011) Lean Thinking in the Context of Transactional Processes, Master’s Thesis,
University of Oulu.

scheduling steelmaking-continuous casting production’, European Journal of Operational

hot rolling scheduling in Shanghai Baoshan iron & steel complex’, European Journal of


p.265.

Corporation, Revised and Updated, Free Press, New York, United States.