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SCHEDULING OF MOLDING PRODUCTION ON PRESS LINES

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ABSTRACT

SCHEDULING OF MOLDING PRODUCTION ON PRESS LINES

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This work presents a methodology for analyzing a production line of molding processes. A high quantity of products and diverse set up times have a great impact on the overall cost, which occurs at the end of the period. One of these optimization methods is GAMS, the system is tailored for complex, large-scale modeling applications and allows the user to build large maintainable models that can be adapted to new situations. The main objective of this study is to minimize the setup and stock costs of the production line.

1 INTRODUCTION

1.1 TOFAŞ

Tofaş is a Turkish automaker which was established in 1968. The founder was Vehbi Koç, who was also the initiator of Koç Holding. The company's manufacturing plant is located in Bursa, Turkey. It is jointly owned by Fiat Chrysler Automobiles and Koç Holding.

Tofaş manufactures passenger and light commercial vehicles. More than 6,500 employees work in the plant and 400,000 vehicles are produced annually. Tofaş manufactures for Fiat, Citroen, Peugeot, Opel and Vauxhall brands in Bursa. It has achieved for it the "Gold Level" within the scope of the WCM-World Class Manufacturing Program. Tofaş plays a leading role in Turkish automotive sector. It manages sales and after sales operations for Fiat, Alfa Romeo, Lancia, Jeep, Ferrari, and Maserati brands in Turkey.

Tofaş exported 160,000 units to 80 countries in 2013. It also recorded 7 billion TL net sales income and 434 million TL net profit. 1.6 billion euros export income were achieved by increasing its export volume by 4%. (Wikipedia, 2019)

1.2 TOFAŞ University-Industry Collaboration Projects 2019

The main purpose of the University-Industry Collaboration Projects is to contribute to the transformation of the scientific potential in the university to the industrial value and to transform the firms in the region into R&D and innovation studies. It also wants to ensure the sustainable cooperation and mutual trust between the academician and the industrialist.

Activities carried out in this direction are

- Presenting project consultancy services to academia and industry (writing, conducting and reporting projects
- Developing projects to benefit from national and international grants and support programs for industrial organizations based on R & D activities

- Presenting, implementing and commercializing the scientific studies of academicians to the sectors needed
- To direct the demands of industry from the industry to the right academician with the expertise of the subject and to provide consultancy services
- Construction of university-industry meeting platforms
- To create an industrial need analysis in accordance with the information obtained from regular industrial visits to determine the problems of industrialists
- Providing services on contract management, legal consultancy, follow-up of financial issues (Üniversite - Sanayi İşbirliği, 2015)

1.3 Scheduling

Providing customization of products is an important way of attracting customers, but it can increase the complexity of planning and scheduling processes in the order fulfilment system. Thus the question arises, how product variety, manufacturing conditions and managerial practices interact with the planning and scheduling functions of a firm. In the dynamic and competitive environment of the automotive industry, first-tier suppliers struggle to decrease costs, while improving delivery lead times and reliability and flexibility. In the automotive industry the power enjoyed by big car manufactures plays an important role in the whole supply chain settings and agreements. Using their power, these original equipment manufacturers (OEM) pressure their suppliers for lower prices, more flexibility in deliveries, higher reliability, and shorter lead times which can be achieved by efficient scheduling. Production scheduling in this sector, the problem of sequentially configuring a plant to meet its forecasted demands, is a serious problem throughout the manufacturing industry. The necessity of maintaining product inventories in the face of unpredictable demand and stochastic factory output makes scheduling models (Dangayach & Bhatt, 2013).

One of the most important aspects of planning and scheduling is to develop baseline standards of productivity and success. Without setting a specific plan in place with a specific desired outcome defined by a completion date, you won't know if you are meeting goals. This is most clearly seen in revenue goals, but goals permeate every aspect of the business. After all, revenues are the result of other activities such as marketing and advertising strategies as well as production and fulfillment capabilities.

1.3.1 Schedule Inputs

- *Project calendar;* Understanding working days, shifts, and resource availability is critical to complete an unimpeded a project schedule.
- *Description of project scope*; From this, key start and end dates can be determined, major assumptions behind the plan, and key constraints and restrictions.
- *Project risks;* You need to understand the risks to make sure to deal with identified risks and with unidentified risks, where doing a risk analysis is an important aspect.
- *Lists of activities and resource requirements;* It is important to determine if there are other constraints to consider when developing the schedule. Understanding the resource capabilities and experience you have available will affect the schedule.

1.3.2 Scheduling Tools

- *Schedule Network Analysis;* This is a graphic representation of the project's activities, the time it takes to complete them, and the sequence in which they must be done. Project management software is typically used to create these analyses – Gantt charts and PERT Charts are common formats.
- *Critical Path Analysis;* This is the process of looking at all of the activities that must be completed and calculating the 'best line' – or critical path – to take so that you'll complete the project in the minimum amount of time. The method calculates the earliest and latest possible start and finish times for project activities, and it estimates the dependencies among them to create a schedule of critical activities and dates. Learn more about Critical Path Analysis.
- *Schedule Compression;* This tool helps shorten the total duration of a project by decreasing the time allotted for certain activities. It's done so that you can meet time constraints and keep the original scope of the project.
- *Crashing;* This is where you assign more resources to an activity, thus decreasing the time it takes to complete it. This is based on the assumption that the time you save will offset the added resource costs.
- *Fast-Tracking;* This involves rearranging activities to allow more parallel work. This means that things you would normally do one after another are now done at the same time. However, do bear in mind that this approach increases the risk that you'll miss things, or fail to address changes.

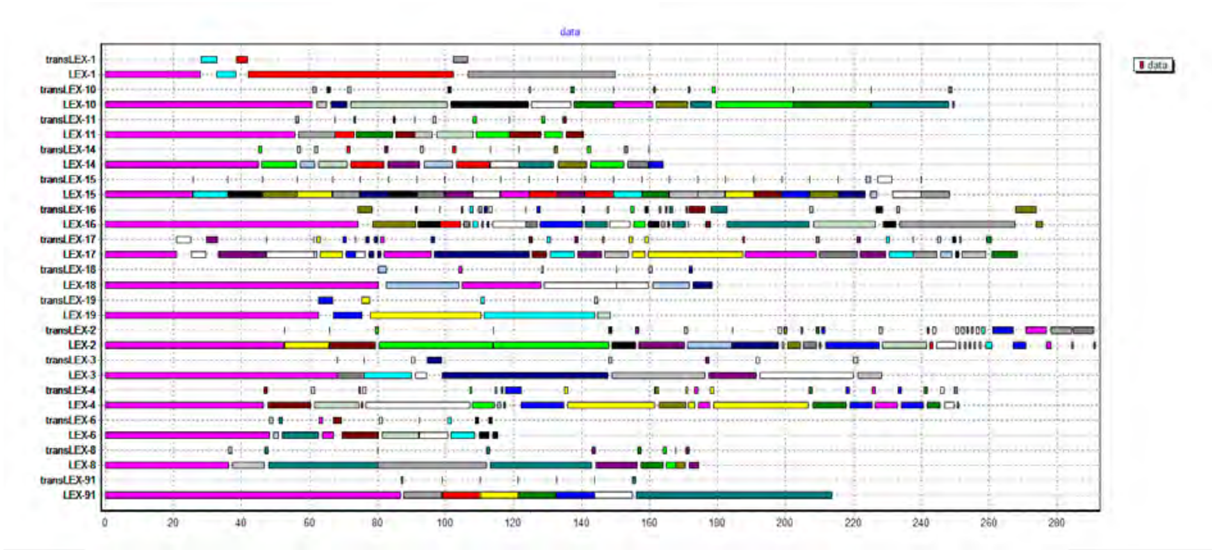

Figure 1.1: A Conference Scheduling Plan

1.4 Scheduling of Molding Production on Press Lines

The aim of the project is to schedule the forming process for the molding production press lines and therewith to minimize the setup and stock cost by creating an ordered production schedule.

Comprising the requirement in the body shop and the «make» part according to the stock status printed sheet planning is carried out in the workshop. Pieces which are cut, are pressed in one of 5 different lines. Pre-assignment of each track a printed / designated line.

According to the net requirement of the press printing sheet metal lines, it is necessary to schedule the molds by taking into consideration the technological constraints of the production line. While creating a weekly chart, the stock level will not be planned to stop the production of the body and the losses caused by the stock losses should be minimized. Creating a mold production schedule to minimize losses such as setup and inventory within the scope of the project it was targeted.

2 LITERATURE REVIEW

2.1 Capacitated Lot Sizing Models

Production planning is the process of determining indefinite plan for how much production will occur in the next time periods, during an interval of time called planning horizon. It is an important challenge for industrial companies because it has a strong impact on their performance in terms of customer service quality and operating costs. However, production planning often proves itself to be a very complex and compound task.

To minimize setups costs, the production should run with large batches but at the expense of high inventory costs. On the contrary, inventory levels can be kept low if production of a product is run many times at short intervals and small batches, but at the expense of high setup costs. Therefore, capacitated lot sizing models aim at finding a production schedule achieving an optimal trade-off between setup and inventory holding costs, while complying with given capacity constraints that demand for all products is satisfied without backlogging (Gicquel, 2008).

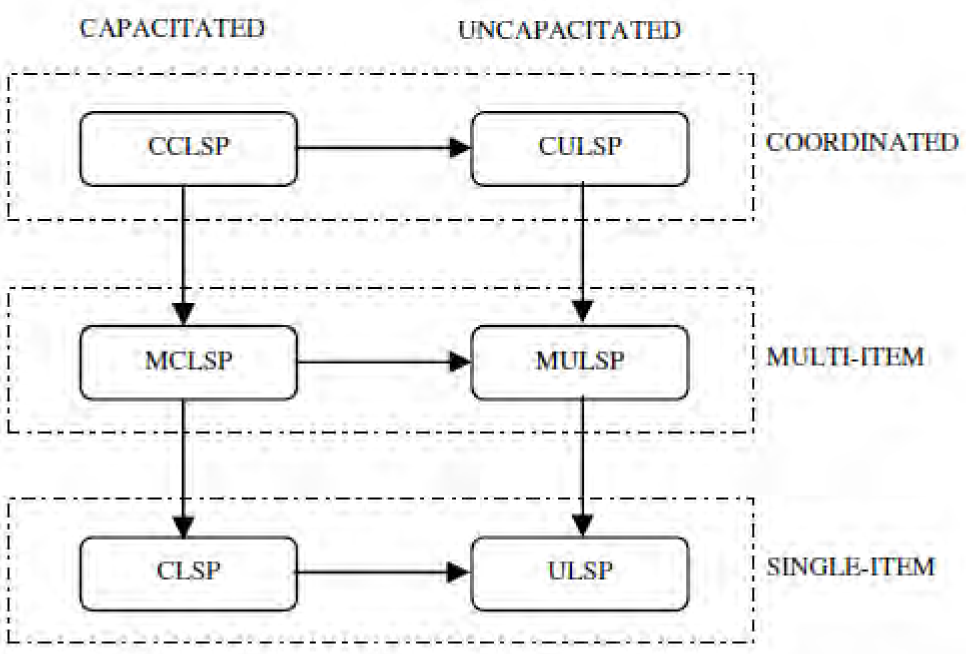

Figure 2.1: Taxonomy of Demand Lot-Sizing Problems

2.1.1 Single-level single-resource models

The capacitated lot sizing problem (CLSP) is a classic example of a big bucket problem, where many different items can be produced on the same resource in one time period. The typical CLSP consists in determining the amount and timing of the production of products in the planning horizon: the outcome is a production plan giving for each planning period the quantity of each item that should be produced. Nevertheless, detailed scheduling decisions are not integrated in the CLSP. The usual approach is therefore to solve the CLSP first and to find the key to a scheduling problem for each period separately afterwards.

2.1.2 Single-level multi-resource models

The lot sizing models assume that the products are processed on a single machine. Though in many cases a manufacturer has access to multiple machines or production lines, which can be used in parallel. We focus on the single level, parallel resources problem. A recent review on lot sizing problems involving parallel resources can be found in. Parallel resources further complicate the production planning problem. Namely, as an item can be produced on several machines, there is an additional decision to be made: the task of production lots to resources. As for the single-resource models, a distinction can be made between big bucket and small bucket models. A large time bucket typically represents a time slot of one week and the planning horizon is less than six months. Subdividing the macro-periods of a large bucket model into several fictitious micro-periods leads to the so-called small bucket models (Kacymarczyk, 2009).

2.1.2.1 Big bucket Models

First, we consider extensions of the classical CLSP. It is assumed that a lot cannot be split among several machines so that in one specific period, an item can be produced on one machine at most. This enable them to reduce the size of the mixed integer program to be solved and thus to save a significant amount of computing time while avoiding some drawbacks arising from a purely myopic approach. In a recent paper extends his GLSP model to the case of parallel production lines and uses a solution procedure combining local search strategies with dual re-optimization to solve real problems gathered from the consumer goods industry.

2.1.2.2 Small bucket Models

In small bucket models, the assumption is made that during each time period, at most one type of item can be produced on the resource. Thanks to this hypothesis, lot sizing and scheduling decisions can be made simultaneously: namely a unique item is allocated to each planning period and the resulting sequence of item-period assignments naturally defines the production schedule. Note that in small bucket models, the production of a lot may last several periods and setup costs should be sustained in a period only if the production of a new lot begins.

2.1.3 Multi-level multi-resource models

In a multi-level lot sizing problem, the production planning is not only considered for the final level, but also for the parts and subassemblies that are needed to make the end products. Because of the parent component relationship between items, production at one level leads to demand for components at a lower level, which is called dependent demand. At the highest level, production is triggered by market demand, the independent demand.

Most contributions on multi-level lot sizing problem use big bucket models and a general product structure. They can thus be anticipated extensions of the classical CLSP described in the previous section to the multi-level case. That is why we chose to classify the literature with respect to the type of solution approach used rather than with respect to the planning horizon discretization.

2.2 GAMS

The General Algebraic Modeling System (GAMS) is a high-level modeling system for mathematical programming and optimization problems. It is composed of a language compiler and a stable of integrated high-performance solvers. GAMS is modified for complex, large scale modeling applications, and allows you to build large rational models that can be adapted quickly to new situations. GAMS is specifically planned for modeling linear, nonlinear and mixed integer optimization problems. (GAMS, kein Datum)

A GAMS model is a collection of statements in the GAMS Language. The only command governing the ordering of statements is that an entity of the model cannot be provided before it is declared to exist.

GAMS statements may be set typographically in almost any style that is appealing to the user. Multiple lines per statement, embedded blank lines, and multiple statements per line are allowed.

The GAMS compiler does not differentiate between upper-and lowercase letters, so you are free to use either.

Documentation is determining to the usefulness of mathematical models. It is more useful if it is fixed within the model itself rather than written up separately. There are at least two ways to slot documentation within a GAMS model. First, any line that starts with an asterisk in column 1 is ignored as a comment line by the GAMS compiler. Second, possibly more important, documentary text can be inserted within particular GAMS statements. All the lowercase words in the modification model are examples of the second form of documentation (Rosenthal, 2007).

Many optimization problem forms exist. The simplest of these is the Linear Programming or LP problem. Imagine an optimization problem like the following (McCarl, 2008);

$$
\begin{array}{lccccccc}
Max & 109*X_{corn} & +90*X_{wheat} & +115*X_{Cotton} & & & \\
s.t. & X_{corn} & + \quad X_{wheat} & + \quad X_{Cotton} & \leq 100 & & (land) \\
 & 6*X_{corn} & +4*X_{wheat} & +\ 8*X_{Cotton} & \leq 500 & & (labor) \\
 & X_{corn} & X_{wheat} & X_{Cotton} & \geq 0 & & (nonnegativity)
\end{array}
$$

Figure 2.2: Optimization Model

where this is a farm profit maximization problem with three decision variables: X corn is the land area devoted to corn production, X wheat is the land area devoted to wheat production, and X cotton is the land area devoted to cotton production. The first equation gives an expression for total profit as a function of per acre contributions times the acreage allocated by crop and will be maximized. The second equation limits the choice of the decision variables to the land available and the third to the labor available. Finally, we only allow positive or zero acreage.

If we want to solve this in GAMS, the formulation of the mathematical model is

```
VARIABLES               Z;
POSITIVE VARIABLES    Xcorn ,    Xwheat , Xcotton;
EQUATIONS     OBJ,  land ,  labor;
OBJ..  Z =E= 109 * Xcorn + 90 * Xwheat + 115 * Xcotton;
land..             Xcorn +      Xwheat +       Xcotton =L= 100;
labor..          6*Xcorn +  4 * Xwheat +  8  * Xcotton =L= 500;
MODEL farmPROBLEM /ALL/;
SOLVE farmPROBLEM USING LP MAXIMIZING Z;
```

Figure 2.3: Mathematical Model

3 SYSTEM ANALYSIS

3.1 Information About the Project

3.1.1 Definition of the Project, Processes and Scheduling Problem

The aim of the project is creating a sequential production schedule that minimizes mold setup and inventory costs for the press line 3. Also, current process is wanted to change by this project.

First of all, roll sheet metal is taken from the roll sheet storage. This roll form sheet metal has to be opened to start the process. After that it goes to cutting process. Following the cutting process, it goes to the mold press operation. Our observation is handled in press line 3. So, in this line there are 52 mold and it means that there are 52 products which is produced. Therefore, all products are different from each other. Also, production time is different too for each mold. After these products is ready to go to the next process, it is on its way to body welding section. Sheet planning is carried out at the press workshop according to the needs in the body shop and the parts of the «make» parts. The cut sheet is worked on one of 5 different lines (3,4,5,6th of lines) according to the type of piece. Each piece can be processed on a predetermined line. (Scope of the project can be limited by a single line scheduling). According to the net requirement of the press printing sheet metal lines, it is necessary to schedule the molds by taking into consideration the technological constraints of the production line. During the preparation of the weekly chart, the stock level which will not stop the production of the body should be planned, and the losses caused by the setups and the stock losses should be minimized during this planning. Within the scope of the project, it is aimed to create a mold production schedule that will minimize losses such as setup and inventory.

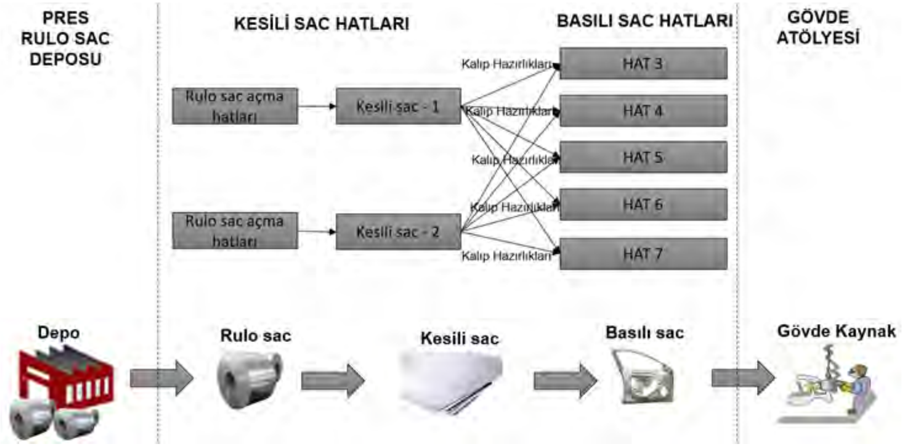

Figure 3.1: View of the Process

3.1.2 Components of the System

The main components of the system are as follows;

Press Line; Press machines use three different methods of processing metal: mechanical, hydraulic and forging. It includes parts transport within the press by means of feeder systems as well as material feed and removal of the finished parts.

Mold; For each lens produced in the factory, there are specialized molds that can produce in the injection presses specified. Maintenance of the molds is done in the factory maintenance workshop. The molds are heated prior to commissioning.

Setup Time; Period required to prepare a device, machine, process, or system for it to be ready to function or accept a job. It is a subset of cycle time. In our system we do have external and internal setup time.

Stock; products which are manufactured and sold that are sold as part of the business's daily operation.

Lot Size; refers to the total quantity of a product ordered for manufacturing.

Shift; Shift work can involve evening or night shifts, early morning shifts, and rotating shifts. Many industries rely heavily on shift work, and millions of people work in jobs that require shift schedules.

Demand; The mere desire of a consumer for a product is not demand. Demand includes the purchasing power of the consumer to acquire a given product at a given period. In other words, it's the number of products or services that consumers are willing and able to purchase.

Product; A product is the item offered for sale. A product can be a service or an item. Every product is made at a cost and each is sold at a price.

Product Capacity; Production Capacity is the volume of products or services that can be produced by an enterprise using current resources.

Cost; The company has cost items such as product processing, workforce, preparation, procurement, retention, raw material, maintenance-repair, poor quality and overtime.

Depot; a place for the storage of large quantities of equipment, food, or goods.

3.2 Current Method Analysis

3.2.1 KANBAN System

Kanban is a visual method for controlling production as part of Just in Time (JIT) and Lean Manufacturing. As part of a pull system it controls what is produced, in what quantity, and when. Its purpose is to ensure that you only produce what the customer is asking for and nothing more. It is a system of signals that is used through the value stream to pull product from customer demand back to raw materials.

Its literal meaning is that of a flag or sign, when you see that flag you know that it is time to manufacture the next part. Kanban's can take many forms but in most production facilities they will use Kanban cards or bins to control the process, although there are no limits to how you can control and design Kanban's; only your imagination.

Kanban cards are essentially pieces of paper which travel with the production item and identify the part number and amount in the container. Kanban cards serve as both a transaction and communication device. The following figure shows a Kanban card used between processes.

On Kanban cards; it can be seen where it is used, part number, track image, track name, definition of the part, Kanban number (Kanban card identification number), number of pieces / Kanban (the quantity of pieces that are ordered by this Kanban for each production unit of the main part), descriptive code number or name of the box in which Kanban is placed regularly, the location of the workstation (code number or description) of the workstation to which Kanban will be delivered (INDUSTRYLOG, 2018).

Part Description				Part Number	
Smoke-shifter, left handed.				14613	
Qty	20	Lead Time	1 week	Order Date	9/3
Supplier	Acme Smoke-Shifter, LLC			Due Date	9/10
Planner	John R.	Card 1 of 2			
		Location		Rack 1B3	

Stok Raf No : 5E215 Parça Arka No:A2.15	Önceki Operasyon
Parça No : 356 70 S 07	Dövme B-2
Parça Adı : Tahrik pimi	
Araba Tipi : S*50 BC	Sonraki Operasyon
	Talaşlı İmalat M-6

Kutu Kapasitesi	Kutu Tipi	Sayı
20	B	4/8

Figure 3.2: Examples for KANBAN cards

The main focus of JIT is to pull production through the process as the customer actually takes what they want. The ideal flow being a single part manufactured as required; although this is not always possible with many processes without significant redesign or investment. This is very different to what most companies have traditionally done.

Traditionally production processes are scheduled, raw materials ordered, and then manufactured to create stock based on a forecast of what the customer is expected to order. This is push production and is driven very much by the materials being fed into the start of the process and all processes being controlled through a schedule or MRP. This typically produces products in large quantities or batches and ties up a huge amount of your capital in stock and Work in Progress (Lean Manufacturing Tools, 2014).

3.2.1.1 Operation of Kanban System

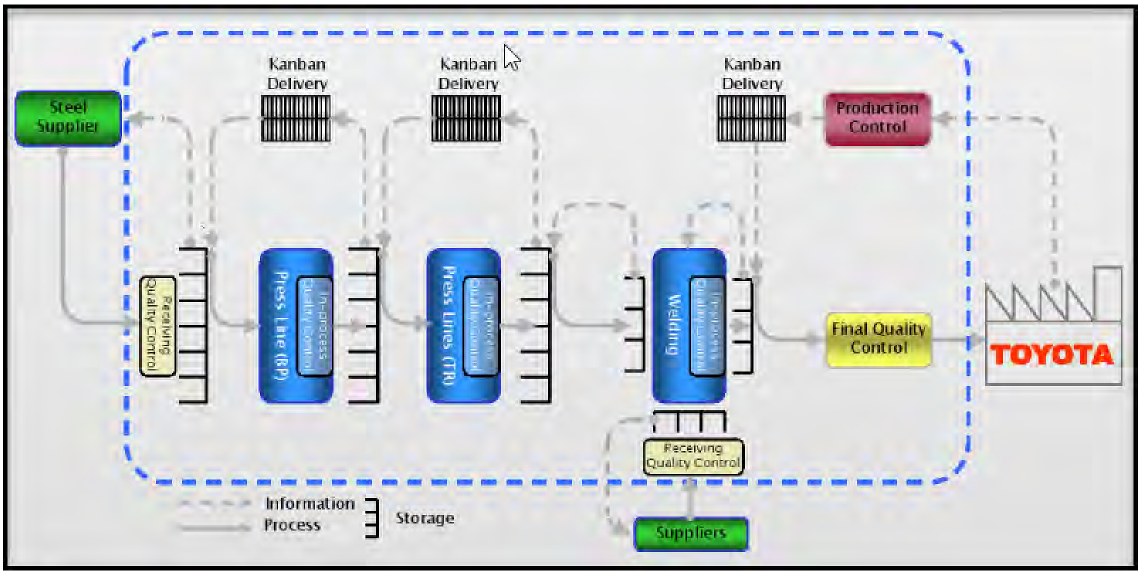

Figure 3.3: View of the Kanban Process

In Japanese manufacturing factories (Toyota, Toyotomi, Toyotetsu), this Kanban system is still being used and this system is not easily abandoned thanks to the understanding of Japanese culture. Because this system is applied in every stage of the human factor is completely manual and self-adopted so much that even if the whole digital system collapses production never stops.

According to the pulling system applied; demand coming from the customer goes to the trucker's welding lines with the delivery bag. In welding lines, the welding bladder removes the welding drum from the attached parts and attaches the shipping canvas. The parts coming from the welding lines are ready for shipment, if they pass the quality control. For this reason, the delivery canvas is shipped to the customer by taking the attached part to the manifesto area.

As the welding cannons are removed from the welding parts, the welding cannons are lost. The discharged source cannas are thrown into the Kanban stream. These processes are applied with Kanban and is included for reproduction. Parts of the welding lines come from the press lines and the sub-industry. On the parts coming from the press lines, the supplier Kanban is located on parts from the press. As the welding lines use these parts, these two Kanban’s are lost and the Hebanka process is applied by discharging into the Kanban River. In order to supply the parts in the welding lines, the forklift truck moves to the press lines or the waiting areas where the parts are kept by the conveyor. Here, the supplier takes the parts and transports the source lines by replacing the Kanban or the Kanban from the supplier. Finally, materials used for the parts produced on the press lines are used.

3.2.1.2 KANBAN system in the company

In Kanban system which the company uses to minimize the critical level has both many advantages and disadvantages. Thanks to this Kanban approach, current inventory, consumption and fix lot size can be determined. Also, criticality can be predicted for a short period. The disadvantages are that in Kanban system, all stages such as the number of pieces to be produced in production, the type of piece to go to the customer, which part will go to the customer are controlled by these pieces of paper. Therefore, these cards, which are considered as pieces of paper, are actually money. You must give this training to each employee. But even if you do not train it, wrong Kanban printing, the wrong part of the customer to go, problems such as missing over-over-production is encountered. Therefore, this system should be controlled very regularly and meticulously.

3.3 Company Goal

The current using method for this line is KANBAN. The firm main aim is to change the current method to the right scheduling. Because KANBAN method is not enough for this problem. It has many deficiencies. The main disadvantage is that there is no scheduling approach in Kanban system. Also, in the Kanban approach, both set up and workforce and maintenance planning cannot be done. In addition to these planning, cut sheet planning cannot be done. If scheduling can be done weekly in scheduling, mold and workforce planning can be done. It is easier to access with the scheduling system to know when and how much products to be produced. Because of that company wants to determine problem constraints and then build the right model. The aim is minimizing the setup costs, which in this problem, is setup costs divided by two costs. These are internal and external costs.

3.4 Sequential Production Scheduling

3.4.1 Definition of Sequencing and Scheduling Concepts

Scheduling is the allocation of resources over time to perform a collection of tasks and it is a decision-making function. The practical problem of allocating resources over time to perform a collection of tasks arises in a variety of situations. In most cases, however, scheduling does not become a concern until some fundamental planning problems are resolved, and it must be recognized that scheduling decisions are of secondary importance to a broader set of managerial decisions. The scheduling process most often arises in a situation where resource availability fixed by the long- term commitments of a prior-planning horizon. Sequencing is the order of processing a set of tasks over available resources. Scheduling involves sequencing " task of allocating as well as the determination of process commencement and completion times i.e., timetabling. Sequencing problems occur whenever there is a choice to the order in which a group of tasks can be performed. The shop supervisor or scheduler can deal with sequencing problems in a variety of ways. The simplest approach is to ignore the problem and accomplish the tasks in any random order. The most frequently used approach is to schedule heuristically according to predetermined "rules of thumb". In certain cases, scientifically derived scheduling procedures can be used to optimize the scheduling objectives (Bruker, 1995).

3.4.2 Sequential Production Scheduling the Company Wants

First of all, with sequential production scheduling, the aim of the company is to minimize setup and inventory costs. There are basic inputs and outputs to achieve this goal. The company intends to make weekly production schedules with current stock consumption and technological constraints inputs (external setup and pattern transition constraints). Criteria with this scheduling can be predicted for a weekly period. Maintenance schedule is also available.

4 APPLICATION

4.1 Definition of the Problem

There is no scheduling approach in the company and as mentioned in the system analysis section, Kanban system is used in the company and this system cannot meet the current needs of the company. With the Kanban system, setup planning, work planning, mold planning and maintenance planning cannot be done. If the company is able to switch to the scheduling methodology, it will be able to plan the planning of the planning of the planning and planning the planning of the work planning in a more efficient way. Criticality will also become predictable for the weekly period.

4.2 Aim of the Application

Our goal was to create a 6-day (1-week) production schedule of the press line (line 3) determined by the company. While creating the production schedule, we have determined the production, production quantities and production sequence by minimizing the setup and stock costs. We have determined the inventory level and production quantity so as not to stop the production of the body while performing our production schedule and we have also considered our constraints.

4.3 Data of the Problem

The data of the problem is provided by the company. The company shared the mold (product) names, demand quantities, beginning stock, safety stock, setup costs, total number of cases, internal setup and external setup times.

4.4 Developed Models and Solution Methods

For the companies given task a mathematical model is developed.

4.4.1 Mathematical Model

Developed scheduling model is considered as a sequence dependent, capacitated lot size and scheduling problem with single machine multi-product and optimizes the stock level and setup number, minimizing the cost of retention and setup costs. It also gives us the order of the products to be produced and the production quantities. The mathematical model suggested for the scheduling problem is given below:

Parameters:

N: The number of product(mold) i= 1,2…….,I

T: The number of period t=1,2…,T

h_i: Holding cost for each unit of product i (TL/unit)

p_i: Total production amount for product i per day.

r_t: Length of the working period for the day of t

b_i: External and internal setup cost for product i (TL/min)

bs_i: Beginning inventory amount for product i

f_i: Max total number of part for i product

e_i: Safety stock amount for product i

d_{it}: Demand amount for product i in period t

m_{ij}: Internal setup interrarrival time between product i and and j

mn_{ij}: External setup interarrival time between product i and j.

BIGM: Big Number

Decision Variables:

X_{it}: production amoun of the product i in period t

Y_{it}: $\begin{cases} 1, \text{ if product i will be produced in the period t} \\ 0, \text{otherwise} \end{cases}$

S_{it}: Production amount of the product i in the period t.

T_{ijt}: $\begin{cases} 1, \text{ if the product i produced before the product j in the period t} \\ 0, \text{otherwise} \end{cases}$

α_{it}: $\begin{cases} 1, \text{ if product i is produced first in period t} \\ 0, \text{otherwise} \end{cases}$

β_{it}: $\begin{cases} 1, \text{ if product i is produced first in period t} \\ 0, \text{otherwise} \end{cases}$

y_{it}: $\begin{cases} 1, \text{ the machine is setup for product i at the end of period t} \\ 0, \text{ otherwise} \end{cases}$

ω_t: is strictly positive when at least one product is produced in period t, and zero otherwise.

δ_t: is defined to be 0 if exactly one product is produced in period t, andan unrestricted non-negative number otherwise

Objective Function

Objective function (4.1) provides the minimization of the internal-external setup cost and holding cost.

$$\sum_i^N \sum_i^N \sum_t^T b_i m_{ij} T_{ijt} + \sum_i^N \sum_j^N \sum_t^T b_i mn_{ij} T_{ijt} + \sum_i^N \sum_t^T h_i S_{it} \qquad (4.1)$$

Constraints

Constraint (4.2) for t≥2, the balance of the inventory level is provided by this constraint.

$$S_{i,t-1}+X_{it}-d_{it} = S_{it} \qquad \forall t= 2\ldots\ldots,T \quad \forall i= 1\ldots\ldots,N \qquad (4.2)$$

Constraint (4.3) for t=1, the balance of the inventory level is provided by this constraint.

$$bs_i+X_{it}-d_{it} = S_{it} \qquad \forall t=1 \quad \forall i=1\ldots\ldots,N \qquad (4.3)$$

Constraint (4.4) for t≥2 ,the total number of maximum product is provided by this constraint .

$$X_{it}+ Si_{,t-1} \leq f_i \qquad \forall t= 2\ldots\ldots,T \quad \forall i= 1\ldots\ldots,N \qquad (4.4)$$

Constraint (4.5) t=1 için the total number of maximum product is provided by this constraint.

$$X_{it}+bs_i \leq f_i \qquad \forall t=1 \quad \forall i=1\ldots\ldots,N \qquad (4.5)$$

Constraint (4.6) Safety stock constraint is provided for i product.

$$S_{it} \geq e_i \qquad \forall t=1\ldots\ldots,T \quad \forall i=1\ldots\ldots,N \qquad (4.6)$$

Constraint (4.7) Internal setup time and total process time of the all products which produced in every period cannot exceed daily working time in the related time rule is provided by this constraint.

$$\sum_i^N piXit +\sum_i^N \sum_j^N mijTijt \leq r_t \qquad \forall t=1\ldots\ldots,T \qquad (4.7)$$

Constraint (4.8) With this constraint, it is provided that in case where Xit >0 ,the value of Yit is equal to 1 automaticaly.

$$X_{it} - BIGM*Y_{it} \leq 0 \quad \begin{array}{l}\forall t=1........,T\\ \forall i=1........,N\end{array} \tag{4.8}$$

Constraint(4.9) In case where i=j, the constraint provides that from i to j setup does not occur.

$$T_{ijt} = 0 \quad \begin{array}{l}\forall i=j =1....,N\\ \forall t=1........,T\end{array} \tag{4.9}$$

Constraint(4.10) In case where i≠j, if production of the product j will be produce after production i, this constraint prevents the production of product i, after the production of the product j in the same period. At the same way, if the production of j after i, this constraint prevents the production of j after i in the same period again.

$$T_{ijt}+T_{jit} \leq 1 \quad \begin{array}{l}\forall i\neq j =1....,N\\ \forall t=1........,T\end{array} \tag{4.10}$$

Constraint (4.11) ω_t is forced to be one if any itemis produced in period t

$$Y_{it} \leqslant \omega_t \quad \forall i,t, \tag{4.11}$$

Constraint(4.12) is forced to be positive of δ if more than one product is produced in period,

$$\sum_{i=1}^{N} Y_{it} - 1 \leqslant (N-1)\delta_t \quad \forall t, \tag{4.12}$$

Constraint(4.13) provide that α 1 for exactly one product in a given period

$$\omega_t \leqslant \sum_{i=1}^{N} \alpha_{it} \leqslant 1 \quad \forall t, \tag{4.13}$$

Constraint(4.14) provide that β 1 for exactly one product in a given period

$$\omega_t \leqslant \sum_{i=1}^{N} \beta_{it} \leqslant 1 \quad \forall t, \tag{4.14}$$

Constraint(4.15) provide that α 1 if no product is produced in period t

$$\alpha_{it} \leqslant Y_{it} \quad \forall i,t, \tag{4.15}$$

Constraint(4.16) provide that β 1 if no product is produced in period t

$$\beta_{it} \leqslant Y_{it} \quad \forall i,t, \tag{4.16}$$

Constraint(4.17) provides that if the α value for a product is 1, then the corresponding β value is 0, and vice versa.

$$\alpha_{it} + \beta_{it} \leqslant 2 - \delta_t \quad \forall i,t, \tag{4.17}$$

Constraint(4.18) provides only one product can be setup for at the endof each period which is modeled

$$\sum_{i=1}^{N} \gamma_{it} = 1 \quad \forall t. \tag{4.18}$$

Constraint(4.19) provides to apply whenever more than one product is produced in a single period.They force at least one $T_{ijt's}$ to be 1

$$\sum_{j=1}^{N} T_{jit} \geqslant Y_{it} - \alpha_{it} \quad \forall i, t, \tag{4.19}$$

Constraint(4.20) provides to apply whenever more than one product is produced in a single period.They force at least one $T_{ijt's}$ to be 1

$$\sum_{j=1}^{N} T_{ijt} \geqslant Y_{it} - \beta_{it} \quad \forall i, t. \tag{4.20}$$

Constraint(4.21) provides to force a setup that the machine at the end of the period t − 1 is not the same as the setup state at the endof period t,

$$T_{ijt} \geqslant \gamma_{i,t-1} + \gamma_{jt} - \omega_t - 1 \quad \forall i \neq j, t. \tag{4.21}$$

Constraint(4.22) provides to properly count setups between periods in which the machine is not idle.

$$T_{ijt} \geqslant \beta_{it} + \gamma_{jt} - 1 \quad \forall i \neq j, t. \tag{4.22}$$

Constraint(4.23) provides to properly count setups between periods in which the machine is not idle.

$$0 \leqslant \omega_t \leqslant 1 \quad \forall t, \tag{4.23}$$

Binary and non-negativity constraints was shown in below:

$0 \leq \omega_t \leq 1 \quad \forall t$

$X_{it}, S_{it}, \delta_t \geq 0 \quad \forall i,t$

$T_{ijt}, Y_{it}, \alpha_{it}, \beta_{it}, \gamma_{it} \in \{0,1\} \quad \forall i,j,$

4.4.2 Solution of Model

In the study, the results of the problem which modeled in GAMS program get from Neos server program. Because the characteristics of the program were too complex. The solution time was 0.125 seconds. GAMS outputs are shown in below:

Solve Summary

```
               S O L V E      S U M M A R Y

     MODEL   tofas               OBJECTIVE  z
     TYPE    MIP                 DIRECTION  MINIMIZE
     SOLVER  CPLEX               FROM LINE  322

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE             1697.8740

 RESOURCE USAGE, LIMIT       1041.879     50000.000
 ITERATION COUNT, LIMIT   4512847    2000000000

IBM ILOG CPLEX   25.1.1 r66732 Released May 19, 2018 LEG x86 64bit/Linux
--- GAMS/Cplex licensed for continuous and discrete problems.
Cplex 12.8.0.0

Space for names approximately 0.42 Mb
Use option 'names no' to turn use of names off
MIP status(101): integer optimal solution
Cplex Time: 1041.81sec (det. 291219.16 ticks)
Fixing integer variables, and solving final LP...
Fixed MIP status(1): optimal
Cplex Time: 0.03sec (det. 12.77 ticks)
Proven optimal solution.

MIP Solution:          1697.874000    (4512847 iterations, 98291 nodes)
Final Solve:           1697.874000    (0 iterations)

Best possible:         1697.874000
Absolute gap:             0.000000
Relative gap:             0.000000
```

Production Quantity

```
----     323 VARIABLE x.L
```

	1	2	3	4	5	6
1	732.000	2628.000				
2	1432.000			501.000	489.000	481.000
4			17.000	727.000		
5		77.000	754.000			
6	2637.000					
7	2256.000					
8	1406.000					
10		69.000				
12	160.000					
13	28.000					
18		781.000				
20	1581.000					
22				43.000		
23				112.000		
24				4.000		
26				730.000		

Inventory Quantity

```
----    323 VARIABLE s.L
```

	1	2	3	4	5	6
1	261.000	2316.000	1762.000	1254.000	756.000	261.000
2	1362.000	798.000	256.000	256.000	256.000	256.000
3	393.000	385.000	377.000	370.000	364.000	353.000
4	634.000	359.000	124.000	614.000	363.000	124.000
5	252.000	120.000	666.000	480.000	310.000	120.000
6	2437.000	1953.000	1493.000	1070.000	649.000	220.000
7	2437.000	1953.000	1493.000	1070.000	649.000	220.000
8	1681.000	1466.000	1252.000	1060.000	890.000	700.000
9	366.000	354.000	341.000	333.000	314.000	299.000
10	270.000	311.000	293.000	281.000	264.000	260.000
11	1452.000	1406.000	1341.000	1288.000	1239.000	1179.000
12	260.000	260.000	260.000	260.000	260.000	260.000
13	68.000	67.000	67.000	67.000	64.000	60.000
14	240.000	227.000	224.000	216.000	214.000	210.000
15	200.000	199.000	199.000	199.000	196.000	192.000
16	120.000	117.000	117.000	115.000	115.000	115.000
17	120.000	110.000	107.000	101.000	99.000	95.000
18	315.000	888.000	684.000	498.000	331.000	144.000
19	452.000	451.000	447.000	447.000	444.000	441.000
20	1726.000	1381.000	1054.000	749.000	436.000	156.000
21	170.000	159.000	148.000	138.000	129.000	115.000
22	500.000	405.000	298.000	281.000	217.000	84.000
23	439.000	338.000	246.000	232.000	125.000	84.000
24	96.000	96.000	92.000	91.000	88.000	84.000
25	920.000	813.000	704.000	598.000	501.000	389.000
26	758.000	473.000	176.000	630.000	379.000	135.000

Production Sequence

```
----    323 VARIABLE q.L
```

	1	2	3	4
1 .18		1.000		
2 .20	1.000			
4 .26				1.000
5 .4			1.000	
6 .13	1.000			
7 .2	1.000			
8 .6	1.000			
10.5		1.000		
12.8	1.000			
13.1	1.000			
18.10		1.000		
20.7	1.000			
22.23				1.000
23.24				1.000
24.22				1.000
26.2				1.000

Production Decision

```
----    323 VARIABLE y.L

             1           2           3           4           5           6

1        1.000       1.000
2        1.000                               1.000       1.000       1.000
4                                1.000       1.000
5                    1.000       1.000
6        1.000
7        1.000
8        1.000
10                   1.000
12       1.000
13       1.000
18                   1.000
20       1.000
22                                           1.000
23                                           1.000
24                                           1.000
26                                           1.000
```

Objective Function

```
----    323 VARIABLE o1.L                  =      130.944
            VARIABLE o2.L                  =      880.530
            VARIABLE o3.L                  =      686.400

----    323 VARIABLE z.L                   =     1697.874
```

5 CONCLUSION

In this project, the structure of the existing system has been examined and the problem has been identified. As a first step, the current problems of the firm are discussed for problem determination. The existing Kanban system, which the company uses for press lines, was wanted to transform into a system to work in the weekly scheduling logic. Therefore, the general definition of the current system, the Kanban system, was explained in the manufacturing sector and also its advantages and disadvantages has been investigated in depth. Then, the ordering and sorting concepts were explained. In the following phase, a large-scale literature search was conducted to determine the most appropriate system to obtain the outputs that the company wanted. The solution methods related to the problem determined by the literature research were examined. In the light of these investigations, it has been tried to establish a model that optimizes the inventory levels and internal and external setup times, by making the right press mold assignments and minimizing the cost. Due to the NP-hardness of the problem, a model was written in the Gams program and outputs were taken using the Neosserver program.

After developing the mathematical model in GAMS we conducted the model for 26 products and six days. In conclusion, we determined the lot size and which product will be produced on which day. However, the scheduling plan for daily production sequence could not be assessed.

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