CHAPTER 4

DEVELOPMENT OF PRODUCTION SCHEDULING METHOD

4.1 Scheduling System

Before moving forward to further analysis, it is necessary to understand the system and its environment. In this study, "system terminology" will be used to describe the current scheduling system.

4.1.1 System Terminology

The system can be described by using the system attribute shown in figure 15.

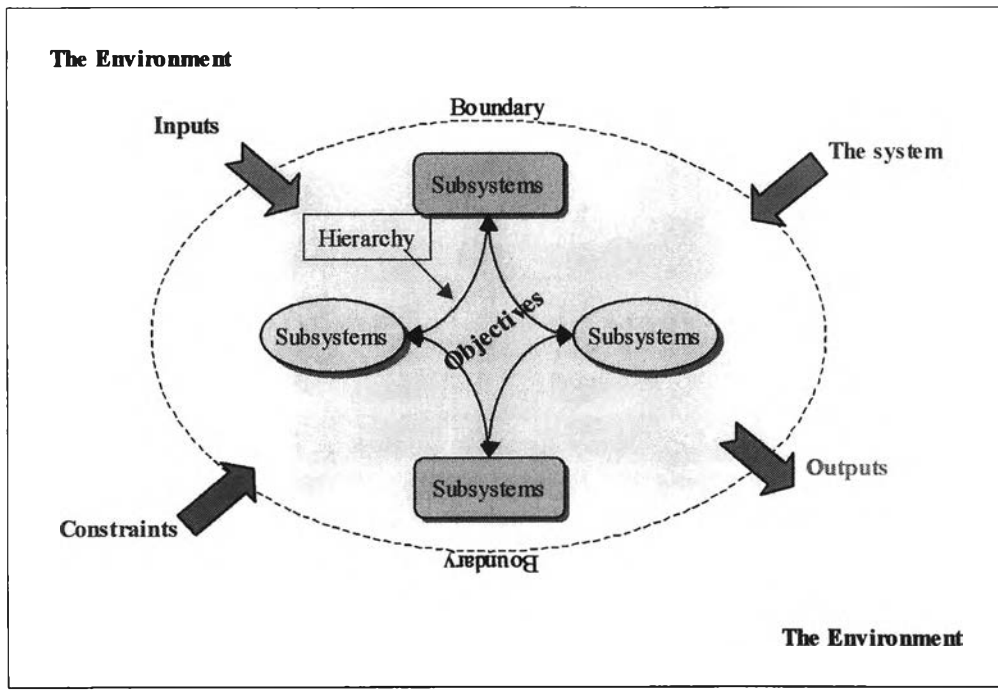

Figure 15 The system attribute. [WMG Module Note : BOD]

In the system attribute, there are eight elements that are environment, boundary, subsystem, hierarchy, objectives, constraints, inputs, and outputs.

System / Environment / Boundary:

At the starting point, it is necessary to identify which one is the system, which one is the environment, and what is the boundary of the system. Using below matrix can easily identify the environment and system.

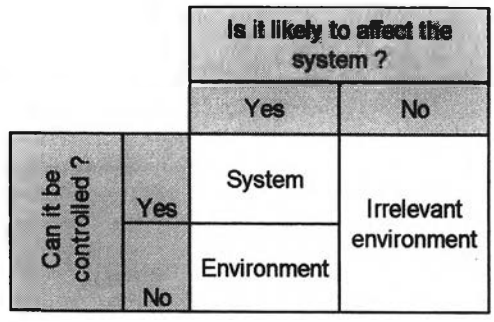

Figure 16 The system / environment identification matrix [WMG Module Note, 2004]

Based on this concept, the system and environment of scheduling process is as below.

Attribute	Scheduling Process
System	Machine Man Material Manufacturing infrastructure Manufacturing capacity Manufacturing capability
Environment	Legislation Material Availability Demand Shipment Plan Customer Requirement

Figure 17 System and environment in scheduling process.

As addressed earlier, the company is in the automotive supply chain. In this business, the time to market is one of the success factors. Moreover, high demand fluctuation is also one of the characteristic of this business. Thus, "demand" is the most important environment that the company has to concern. In other words, the dynamic market characteristic is a big concern in the environment point of view.

In term of system, in this case manufacturing capacity and capability are the major one because, most likely, the major concern in scheduling process is the production scheduling, not material scheduling. So, the boundary of this system is only the production scheduling. The material scheduling and transportation (for shipping) scheduling are assumed to have no issue.

Objective, Constrains & Conflicts:

The objective is to generate the optimum production scheduling in order to achieve,

- Minimum tardiness
- Minimize % missing shipment
- Maximum resource utilization

The major constrains in this system are,

- High demand fluctuation

This is the main constrain in scheduling system. Usually, customer will provide MPS plan by monthly. However, there is high demand fluctuation in the supply chain, so the customer will revise the MPS plan, normally, once or twice a week. This demand fluctuation directly impacts to production scheduling as well as raw material planning, resource planning, etc.

- Information through supply chain

The car manufacturing supply chain is huge and has high level of complexity. So information has not been shared through the chain. Thus, it is very difficult for all parties in the supply chain to understand the real requirement from end customer. In this case, it is not only the delivery schedule that has to be shared up front, but also the market situation. For instance, the market trend changes from one model to other models that required different components, if this information has not been shared, the suppliers in the chain will still focus on the old model and might not plan for the new one. This is one of the root causes of the high demand fluctuation.

- Manufacturing capacity

The manufacturing capacity is limited at 200 tons per day. This is based on the limitation at furnace operation. So, in case that there are many shipments at the same period of time, the company has to either build up inventory or delay the shipment.

- Cost

Same as other business, the company has to keep the cost as low as possible. In the scheduling point of view, it has to consider the inventory cost, over time cost, and penalty cost from customer in case that on time delivery cannot be achieved.

- Shop Floor Control System

As address earlier, the company does not have any shop floor control system. So, the company does not have capability of tracking the jobs' status as well as the detecting the problem in the process that can be impacted to the production schduling.

Subsystem:

Scheduling system can be broken down into subsystems aligned with the same objective in order to achieve the vision of the manufacturing. These subsystems composed of many different hierarchy levels as shown in figure 18.

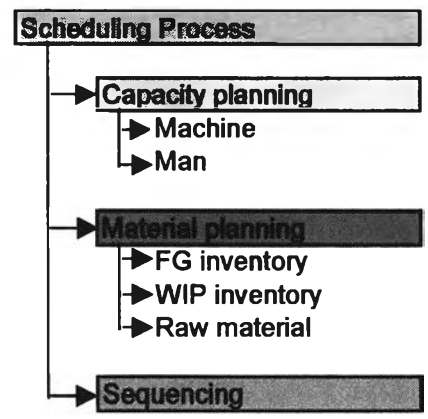

Figure 18 The hierarchy of subsystem of scheduling process.

Inputs & Outputs:

Input of this system consists of

- Master Plan Scheduling (MPS) from customer

This plan will be provided from customer by monthly. However, the company has to consider this plan as a dynamic input since it might be adjusted due to high demand fluctuation in the car business. On top of the MPS, customer also set the priority for some special jobs. This priority has to be taken into the consideration when generating the production scheduling.

- Manufacturing Capacity

Mostly, this input is fixed, however, in some case, the manufacturing capacity might be changed due to maintenance schedule, machine break down, etc.

- Raw Material Availability/Quality

This is also an important input. So far, company rarely has this kind of problem because the company mostly operates with full capacity so the raw material availability is fixed.

- Product Inventory

This will directly impact to production quantity. If that product has high enough inventory to cover the shipment, that product will have last priority in the production.

The expected outputs are

- Effective production scheduling: This can be measured by
- Tardiness
- % Missing shipment

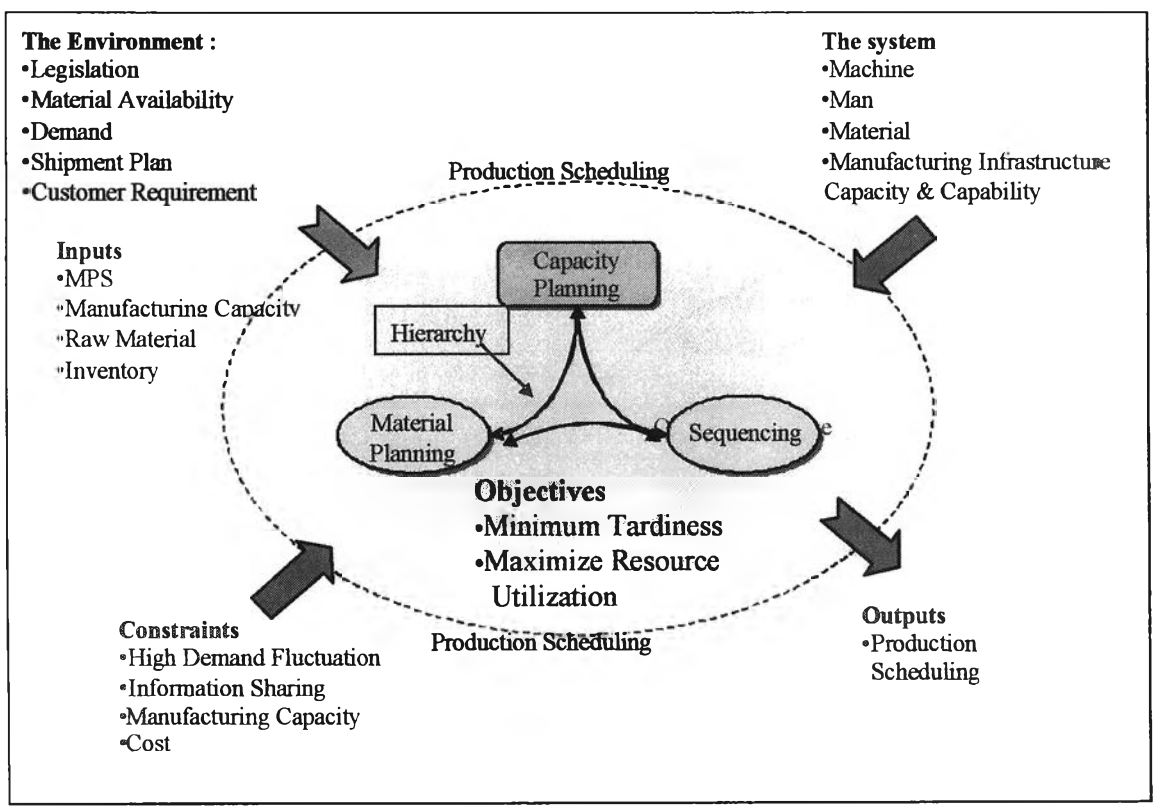

Figure 19 The system attribute of production scheduling.

4.2 Scheduling Objective

As addressed in the beginning, there are many various objectives for scheduling depended on the manufacturing's goal and strategy. For this case, there are two mains objective for scheduling:

- Minimum Tardiness

Since the company is in the car manufacturing, the time to market and product availability are very important in this supply chain. Higher tardiness cause not only the penalty but also the trust from the customer. To be able to success in this business, time to market is one of critical to function factor. So, the company has to improve the production scheduling in order to deal with the high complexity of product ranges and also the high fluctuation in demand. Thus, minimum mean tardiness is the main objective of this study.

- Minimize the % missing shipment

This will be a consequence of better production scheduling. Currently, the missing shipment parts are cancelled by the end of that month. They might or might not be included in the next month MPS. So, this is not only a loss of opportunity for the company, but also a decreasing in customer satisfaction that might be a problem in the long run.

4.3 Scheduling Strategy

First of all, the company has to have "short term" and "long term" scheduling strategy, so that it will be easier for company to develop its own strategy in the future. In this case, the strategic implications are

- On time delivery: Good scheduling will be a competitive advantage in this business.
- Flexibility: Effective scheduling will help the production line to deal with high demand fluctuation.
- Lower cost: By optimize the scheduling, the company will use all resources more effectively casing the low cost.

Short-term strategy:

In this case, since the company never has any scheduling system and the product range is not very high yet, the simple scheduling system is introduced by using dynamic programming and backward scheduling. Moreover, the company has to starting thinking about shop floor control system in the production line.

The shop floor control system is used for inventory tracking as well as a snap short of the plant floor at any time. Having real time information will help to identify the bottleneck and other problems.

The benefits of the shop floor control are:

- Improve on time delivery performance.
- Improve throughput by improving operator efficiency and supported operation such as transportation of WIP (work in process).
- Improve process control due to more timely information that will help supervisor managing the production line.
- Reduce down time due to improving on machine maintenance and machine control.

Long-term strategy:

- Implement the shop floor control system: This will help company to get the real time data in the production line as well as to detect the production problem. This system should,
  - Tracking all the production lots staring from the first process until FG (finish good). This will help company to get the correct information about inventory. This kind of information is directly impact to the production scheduling.

  - Focusing on the yield of each lot, if there is some problem that might impact the production output, the production scheduling should be adjusted, and manufacturing team has to find out and fix the problem before starting the process.

- Develop the supply chain management: This is the final state that needs the collaboration through the chain. Supply chain management involve in three main flows:
  - Material flow: The movement of product from supplier to customer. It also includes the return parts from the customer back to the supplier.
  - Information flow: It is not only the transmitting of delivery, but also the customer requirement from the end user. This is to improve the customer satisfaction through the flow.
  - Financial flow: This is a credit term, payment schedule and consignment and title ownership arrangement.

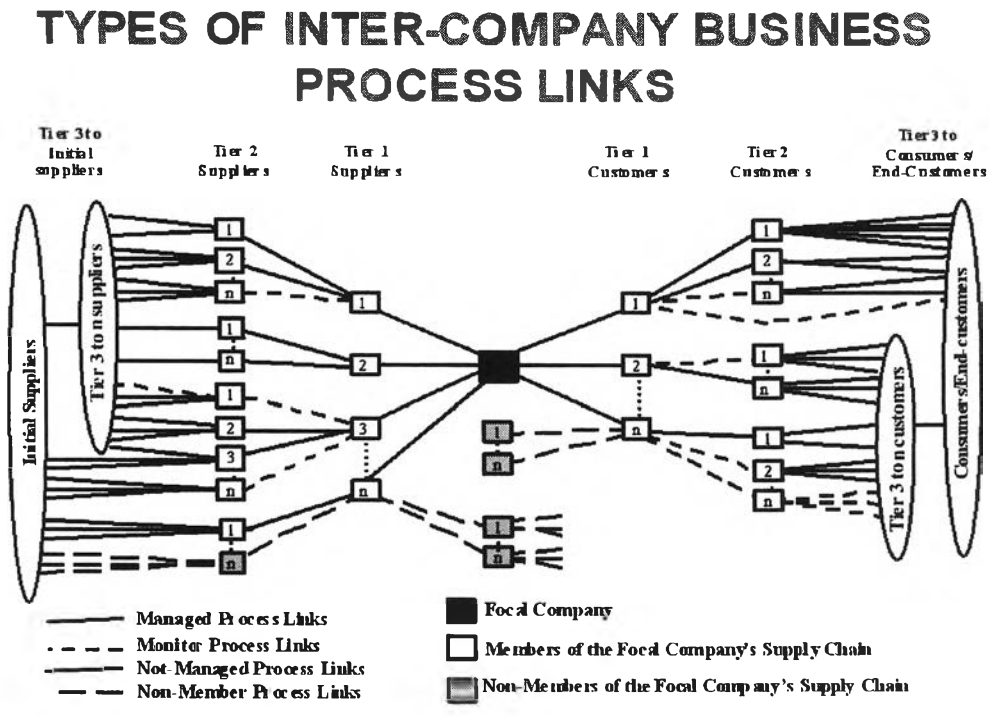

Figure 20 Types of inter-company business process links [Dale S. Rogers, 2004]

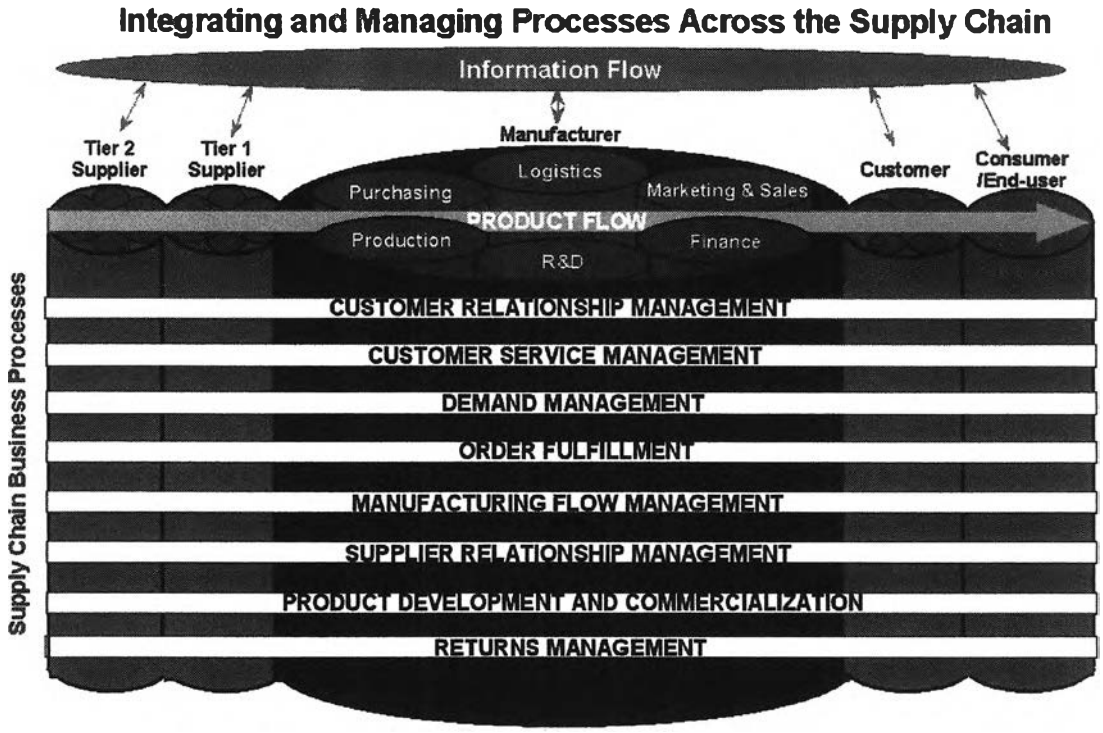

Figure 21 Integrating and Managing Processes Across the Supply Chain

The main advantages to whole the supply chain:

- Lower inventory and production cost
- Maximize the utilization of production capacity
- Reduce error regarding to poor communication throughout the chain
- More margin for product customization and improve the end user satisfaction

4.4 Development of Production Scheduling

Short Term

As address in the short term strategy, the company has to start with the simple system for scheduling. In this case, dynamic programming and backward scheduling are considered.

Regarding the process flow, it can be divided into two groups.

- Group # 1: Including furnace operation and molding line.
- Group # 2: All the back end process such as NRR (Non Repeatability Run out), grinding, etc.

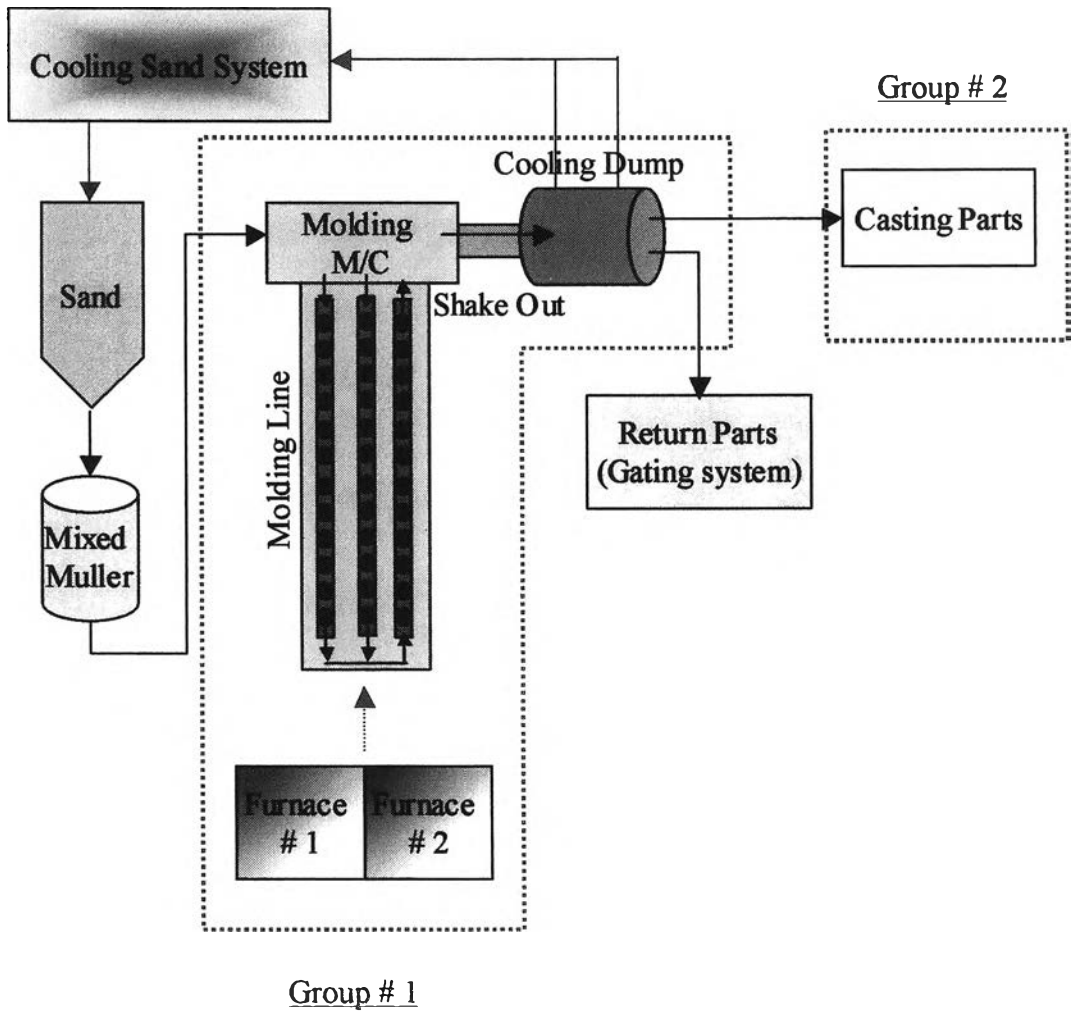

Figure 22 The production processed can be grouped into two groups.

Considering the process flow, furnace operation and molding operation can be considered as one operation because of two main reasons.

- After melting the raw material, it is supposed to pass to molding operation immediately. Or else, the material characteristic will be changed.
- The setup time (from product-to-product) at molding operation is insignificant.

For the back end process, there are many small operations. Each product requires different flow at the back end process. The characteristics of the back end process are

- Fast process time (per operation)
- Flexible process flow: That means if the first operation is not available at that time, it is possible to switch to other available operations before back to the first operation again.

Regarding the problem analysis, the main bottleneck is occurred at the furnace operation considered as group 1. Thus, for this group the dynamic programming technique is applied because this technique will try to generate an optimum scheduling based on the tardiness condition. Moreover, it allows the company to set the priority of each job. In this case, the priority is set based on the margin of that particular job.

For group 2, since the process is not very complicate. The backward scheduling technique is applied. At the beginning, since the company never has any system before, the company will assume that all the back end operations are fixed. This is to reduce the level of complexity and to make the model more simple.

From this logic, once the company gets the MPS plan from customer. The company has to use "backward scheduling technique" to get the starting date of the back end process. This date will be set as the final due date of the group 1 process. Once the due date is set, the " dynamic programming technique" will be applied to minimize the tardiness.

The supported system is needed in order to improve the efficiency of scheduling. The shop floor monitoring is the most important one. The main objective is to get real time information including WIP and inventory. The high inventory parts will have low priority. Moreover, this system will also alert when some problems are occurred in the production line that might cause the company to miss the plan.

4.4.1 Development of Dynamic Programming

First of all, it is necessary to transform quantity unit from product (piece) to mold quantity (mold). Each product has different mold cavity and each mold cavity require different metal weight per mold. Table will give an idea of this. For example, item 1 flywheel ZE0 required 11.4 kg per mold, and one mold has three cavities, means 3 pieces of flywheel ZE0. One furnace has a capacity for two ladles, 400 kg per ladle. Thus, one furnace can produce flywheel ZE0 210 pieces (2*400/11.4*3) without any failure. The number of ladle using to product that product will be an input for the parts. In reality, it might have some failure during the process, so the company has to have some yield factor. The yield factor depends on product design and process capability. Using too low yield factor results in inadequate output. However, using too high yield factor will end up with inventory and longer process time that might delay the schedule of other products.

Other factors that have to be considered are:

- Switching to another product required different kind of raw material has to clear all of old material from the furnace. New raw material cannot be mixed or modified from the left over old material. After mixing the material, the chemical characteristic has to be checked.

- In case that we need only one ladle to produce that product and switch to other products required different raw material. The manufacturing cannot mix the raw material for only one ladle because of financial reason – the overhead cost will be very high.

- Setup time at either furnace or molding is insignificant. So, setup time does not constrain in the process.

Item	Part No	Part Name	Material	Machine	Weight	Cavity	Weight/Mold	Yield (%)
1	32001	FLYWHEEL ZE0 (35)	FC250	AMF	2.06	3	11.38	54.30
2	32002	DRUM BRAKE MN (27)	FC250	AMF	4.4	2	15	58.67
3	32003	FLYWHEEL FCC. (28)	FC250	AMF	8.26	1	14	59.00
4	32004	CRANK P-CAR 052 (20)	FC250	AMF	3	4	21.6	55.56
5	32005	HUB P-CAR 02. (28)	FC250	AMF	1.8	5	14.7	61.22
6	32008	DRUM JT (30)	FC250	AMF	7.9	1	13.3	59.40
7	32009	PULLEY PROTON. (30)	FC250	AMF	1.8	4	12.8	56.25
8	32012	INERTIA RING KD (26)	FC250	AMF	3.5	3	15.34	68.45
9	32015	HUB KD. (30)	FC250	AMF	1.75	4	13	53.84
10	32016	HUB NOK. (26)	FC250	AMF	2.5	4	16	60
11	32017	RING NOK (35)	FC250	AMF	2.9	3	12.86	67.65
12	32018	RING NZ (35)	FC250	AMF	1.7	3	10.7	48.11
13	32019	FLY WHEEL ZE7 (30)	FC250	AMF	2.95	3	13.2	67.04
14	32020	FLY WHEEL ZE1 (30)	FC250	AMF	2.95	3	13.2	67.04

Table 5 The metal weight and cavity per mold.

Checking inventory has to be considered at the beginning. Usually, the company will pile up some inventory. This is to be a buffer giving more margined and more flexibility in the production line. However, be kept in mind that the higher the inventory, the higher the cost is. The product that has more profit, less inventory and faster shipment will be set as "high priority" in the production line.

Since the dynamic programming technique has the sample size limitation, the company cannot calculate the whole month shipment at the same time. So, the company has to group the shipment by sorting from the due date. This is most likely the EDD technique, but the major different is that the dynamic programming can set the priority of each job. Grouping the shipment like this does not be constrain because, normally, customer frequently revise the MPS plan so there is no point to generate the production plan by monthly. However, in term of raw material management and ordering is a different story.

4.4.2 Development of Backward Scheduling:

Besides of to make a scheduling at the back end process, the other objective of backward scheduling is to calculate the "latest due date" for the prior operation (furnace and molding). In general, processing time of back end operation is fast and has no bottleneck. By the way, having a good scheduling will help company to improve the resource utilization.

In the backend process, there are two main operations and other two optional operations.

Main operation: Surface finishing process.

- Shot Blast (2 M/C) :
- Grinding 18" (2 M/C) :

Optional operation:

- Runout (2 M/C) :

Items	Part No.	Part Name	Metal	Shot Blast (2 M/C)	Grinding 18" (2 M/C)	Fiber (3 M/C)	Runout 2 M/C)
1	32001	FLYWHEEL ZE0 (32)	FC250	Yes	Yes	Yes	
2	32002	DRUM BRAKE MN (27)	FC250	Yes	Yes		Yes
3	32003	FLYWHEEL FCC. (28)	FC250	Yes	Yes		
4	32004	CRANK P-CAR 052 (20)	FC250	Yes	Yes		
5	32005	HUB P-CAR 02. (28)	FC250	Yes	Yes		Yes
6	32008	DRUM JT (30)	FC250	Yes	Yes		
7	32009	PULLEY PROTON. (30)	FC250	Yes	Yes		Yes
8	32012	INERTIA RING KD (26)	FC250	Yes	Yes		
9	32015	HUB KD. (30)	FC250	Yes	Yes		Yes
10	32016	HUB NOK. (26)	FC250	Yes	Yes		Yes
11	32017	RING NOK (35)	FC250	Yes	Yes		
12	32018	RING NZ (35)	FC250	Yes	Yes		
13	32019	FLY WHEEL ZE7 (28)	FC250	Yes	Yes	Yes	
14	32020	FLY WHEEL ZE1 (28)	FC250	Yes	Yes	Yes	

Table 6 The backend process requirement of each product.

To maximize the resource utilization, the company has to train their employee for every operation. The outputs of the backward scheduling are

- Production scheduling for backend process: Most likely it will follow the front process.
- The latest start date of backend process is an "due date" for the front operation. All the calculation in previous process (with dynamic programming) will be based on this date, not the actual due date from customer.

Regarding the historic data, in some cases, it is impossible for the company to achieve "on time delivery" for every shipment because the demand during that period exceeds the manufacturing capacity. Thus, the company has to set "priority" of each product build by build. The dynamic programming has this function. The priority has to be set, case by case, based on either customer or from the company itself.

4.4.3 Customer priority

This is from the negotiation between company and customer. The company should be able to estimate whether it can produce the product on time or not. If the company cannot produce the product on time, it should inform to customer and negotiate the shipment date or shipment quantity. So, the priority will be set from the customer. Some times, customer will raise the flag to tell company that which shipments have high priority. Most likely claim products will have this flag.

In the high priority case, the company cannot be delay or missed the shipment because the penalty will be very high. This will become a problem when the company has many jobs with high priority flag. This make the dynamic programming become a useful model to solve this problem.