CHAPTER 5

TESTING AND ANALYSIS OF DEVELOPED SCHEDULING MODEL

5.1 Design of Test

There are two main factors considered during the design of test phrase, source of data and considered period.

Source of Data

There are three sources of data used in order to compare the efficiency of each scheduling model.

- Existing Data: This is an actual company's historical data for the last 6 months.
- The simulation data by using developed method and exiting production data for the same last 6 months (input data).
- The simulation data by using Johnson's method and exiting production data for the same last 6 months (input data).

Considered Period: The selected months for testing

Before selecting the considered months for evaluation, it is important to check the demand of each product over the year. This is to eliminate the "bias" which might be occurred when these products have some "demand pattern" or "seasoning demand".

Figure 23 shows demand by product by month on the year 2002 and 2003. There is no either demand pattern or seasoning demand for every product. Thus, the last 6 months of the year 2004 are selected because the company had implemented the new sand cooling system on July' 2004. The new sand cooling system enhances the capacity due to lower waiting time.

For more details, the trend chart by product by month by year, they are shown in Appendix I

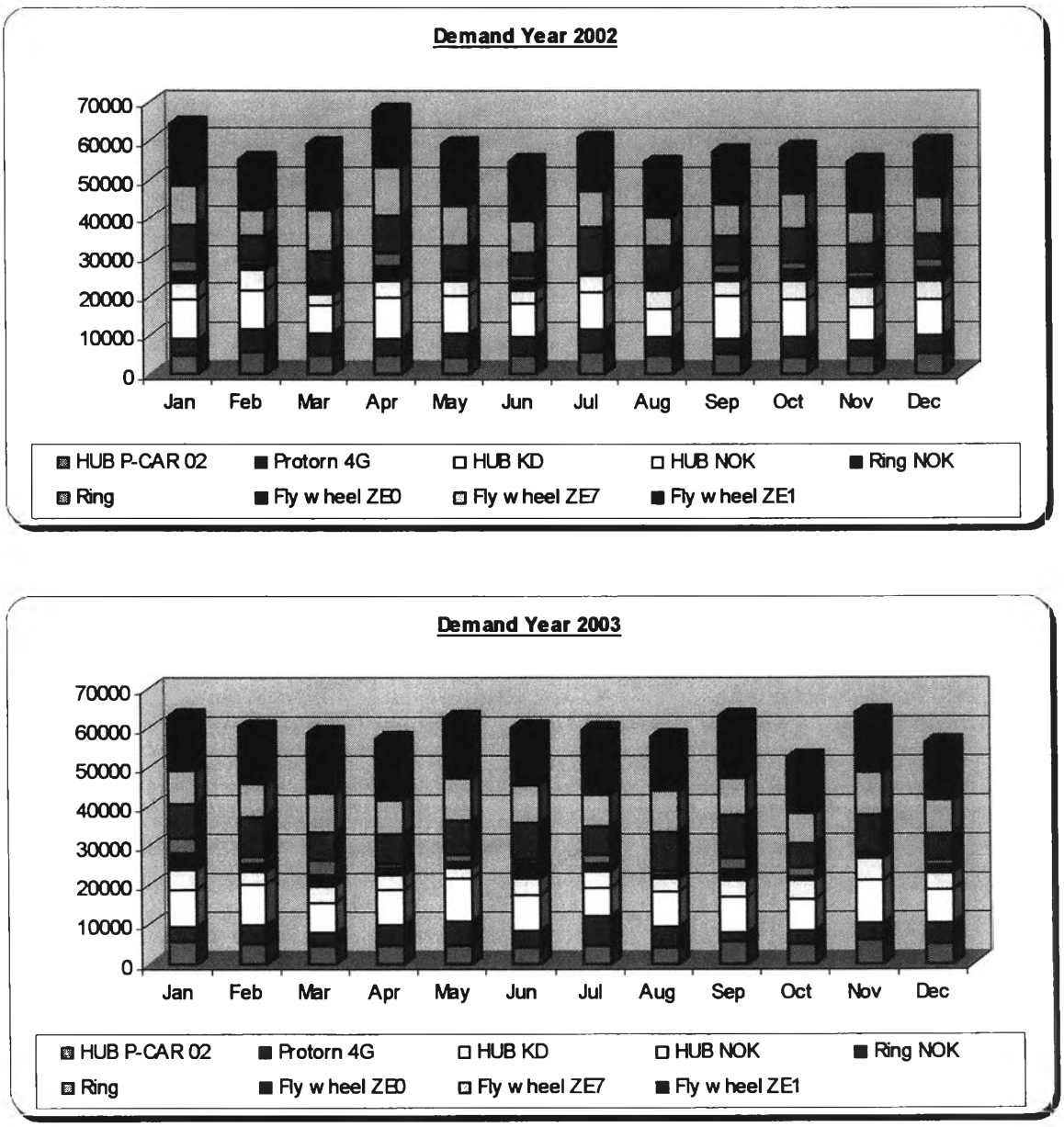


Figure 23 The demand by product by month on year 2002 and 2003.

5.2 Test Assumption

Below items are assumptions used for the developed scheduling model.

- Raw material is always available.
- Transportation for shipment is always available.
- No interruption in the production line.
    - Man power availability: This is only for backend process totally done by man. Normally, the company will plan resource matched with production plan. However, in reality, some employees might take leave without any notices in advance causing the resource limitation problem at backend process.
    - Machine breakdown: Actually, maintenance schedule is already counted in to the production capacity. So, in this model, it is assumed that there is no machine breakdown during the production run.

5.3 Test Measurement / Test Criteria

As addressed earlier, there are many "measurement" for in scheduling depended on the business they are in. In this case, since the company mainly focuses on the "on time delivery". Thus, the criteria based upon due dates as the following measurements are considered.

- Mean Tardiness:

This is a function of the lateness measured the conformity of the schedule to a given due date. So, the lateness can be both positive number when the job is completed lately and negative number when the job is completed early.

However, in many cases that the distinct penalties are associated only with the positive lateness, but no benefits are associated to negative lateness. Thus, the tardiness is considered.

$$T_i = \max \{0, L_i\}$$

So, the mean tardiness is

$$T = 1/n \sum_{J=1 \sim n} T_j$$

- Inventory: FG Inventory

This is an indirect measurement, however, it is a useful parameter used in the evaluation. This is because, basically, "on time delivery" and inventory are always "trade off" to each other. Building up some buffer at FG store can reduce pressure on delivery.

Since the company does not have the shop floor control yet, it is quite difficult to track inventory by daily. The existing process is to track the inventory by weekly.

- Missing Shipment

Normally, SBM will provide the MPS plan by monthly. If the company cannot make the shipments, that demand will be cancelled and might not be added into the next month MPS plan.

Thus, this is one of the critical parameter that the company has to keep an eye on because, it does not only relate to customer satisfaction, but also directly relate to company's profit.

5.4 Result and Data Analysis

Mean Tardiness:

Since the current method does not produce the product by job that means one shipment might separate into many production jobs produced in different time frame, so some shipment might not complete with in that month and cannot calculate the exact mean tardiness. In this thesis, Johnson' law will is used for evaluate the effectiveness of developed method in the mean tardiness point of view.

Month	Shipment	Developed	Johnson
June	46	-0.01	-6.30
July	43	0.00	-5.02
August	61	-1.08	-7.74
September	59	-0.22	-6.94
October	61	-1.57	-7.47
November	56	-0.14	-7.83

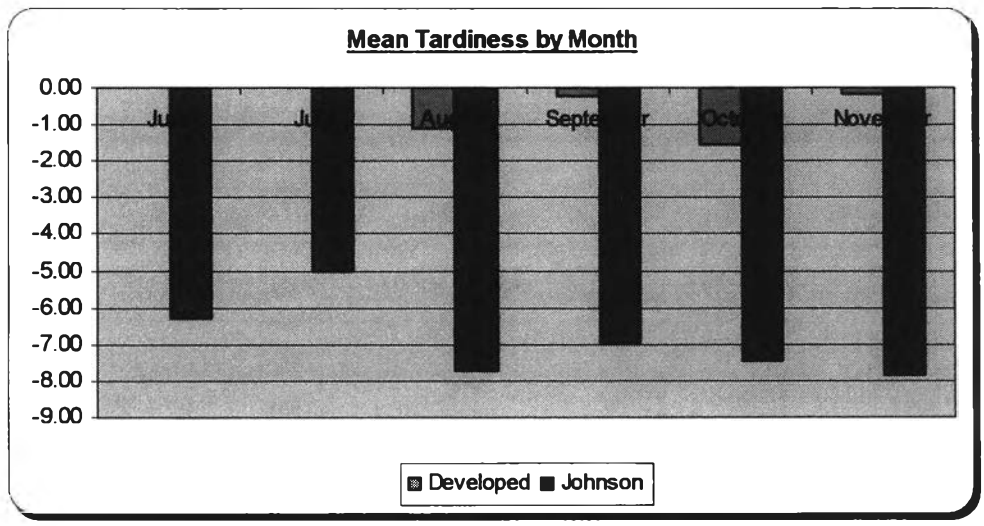


Figure 24 The Mean Tardiness comparing between developed method and Johnson's law.

Figure 24 clearly shows that the developed method has lower mean tardiness than Johnson's law for every month. Figure 25 shows the T-test result comparing between developed method and Johnson's law during these six months. It shows significant improvement in mean tardiness when using developed method.

Regarding to the cumulative plot shown in Appendix A, even though the mean tardiness of current method cannot be quantified, it clearly shows that the current method show much more worse than developed method in term of mean tardiness.

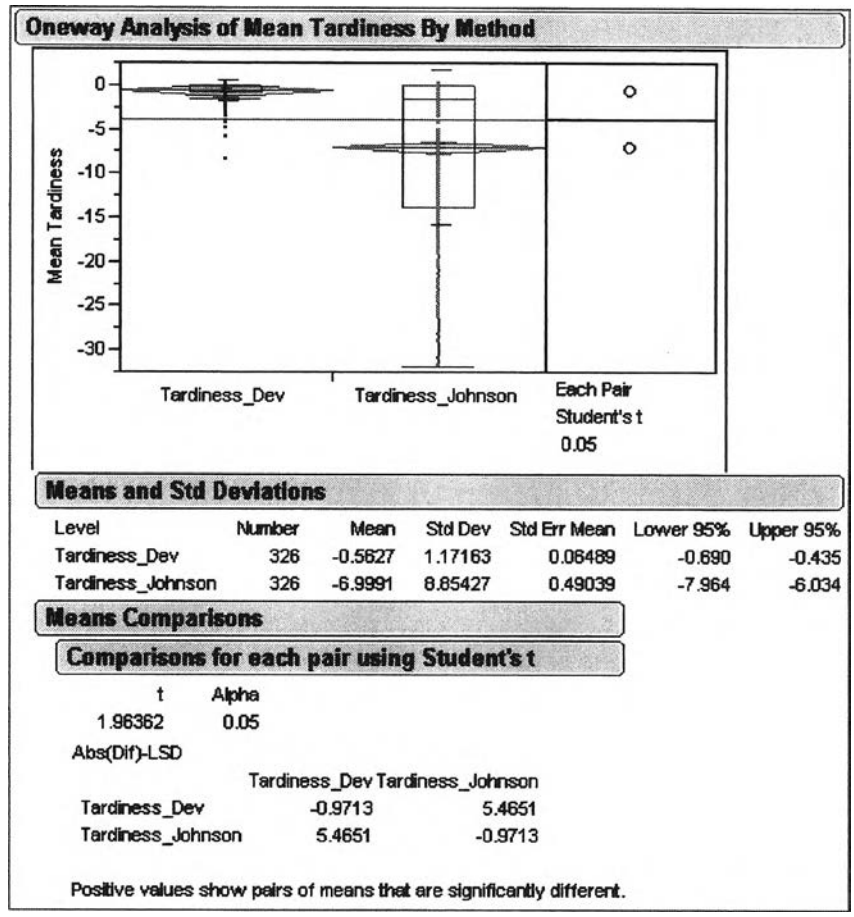


Figure 25 The Student's T- test between developed method and Johnson's method.

The output from Johnson's law also shows very good result in mean tardiness, however, it shows high inventory for many products. This can be observed from the cumulative plot. Below is an example.

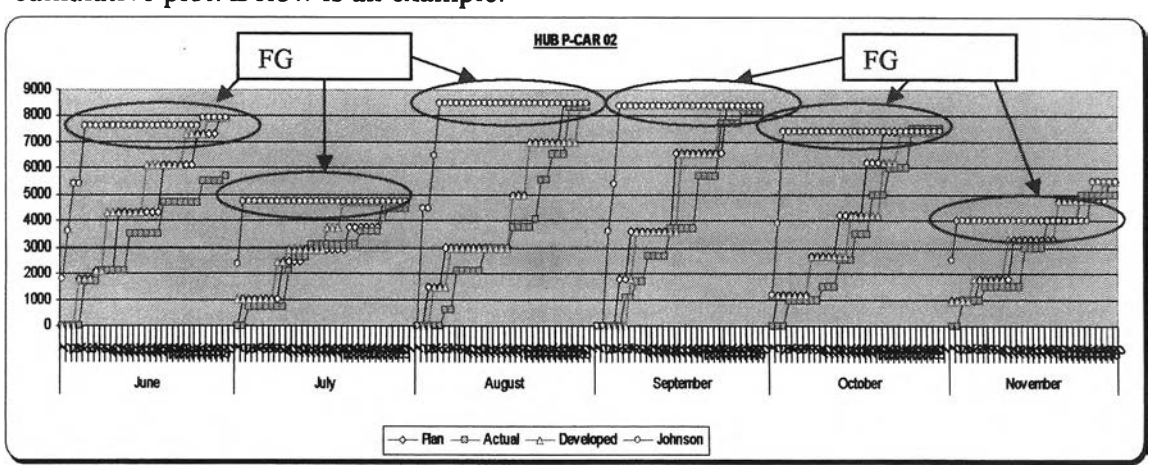


Figure 26 Cumulative Plot Comparing across three methods. Johnson's law shows the highest inventory within month.

Missing Quantity:

This is one of the most critical outputs because it directly relates to the profit and indicates the market opportunity for the company. Table 7 shows the % missing shipment by product by month comparing across three methods, current method, developed method, and Johnson's law. The positive number shows the % of the parts that over produce for that shipment, while the negative value show the % of missing shipment parts.

In general, Johnson's law shows the lowest % missing shipment and then followed by developed method. The current method shows the worst output. Moreover, some products have the excess inventory observed from the positive number in orange highlight.

		Month						
		June	July	August	September	October	November	Average
Fly wheel ZE0	Current	-6.90	0.74	-15.19	-0.71	-22.16	-20.56	**-10.80**
	Developed	0.00	0.00	0.00	0.00	-17.96	0.00	-2.99
	Johnson	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Fly wheel ZE1	Current	5.45	5.17	-13.89	-5.53	-50.00	-44.64	**-17.24**
	Developed	0.00	0.00	0.00	-12.77	-22.22	-21.43	-9.40
	Johnson	0.00	0.00	0.00	-12.77	0.00	0.00	-2.13
Fly wheel ZE7	Current	-0.10	2.94	-19.08	-11.02	-32.70	-28.08	**-14.67**
	Developed	0.00	0.00	-24.28	0.00	0.00	0.00	-4.05
	Johnson	0.00	0.00	0.00	0.00	-6.29	0.00	-1.05
HUB KD	Current	-8.33	6.31	4.09	0.00	-13.00	-22.29	**-5.54**
	Developed	0.00	0.00	0.00	0.00	-44.00	0.00	-7.33
	Johnson	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
HUB NOK	Current	-7.18	0.83	-0.79	-3.95	-24.55	-20.00	**-9.27**
	Developed	0.00	0.00	-7.94	0.00	0.00	0.00	-1.32
	Johnson	0.00	0.00	0.00	0.00	-10.91	0.00	-1.82
HUB P-CAR 02	Current	-27.85	-5.26	-1.76	-2.38	1.35	-9.09	**-7.50**
	Developed	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Johnson	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Protorn 4G	Current	-7.37	8.14	-1.67	-5.00	-28.00	-26.40	**-10.05**
	Developed	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Johnson	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Ring	Current	3.33	8.11	-11.11	-12.20	-13.64	-15.63	**-6.85**
	Developed	0.00	0.00	-16.67	0.00	0.00	0.00	-2.78
	Johnson	0.00	0.00	-9.26	0.00	-69.70	0.00	-13.16
Ring NOK	Current	12.52	-4.08	-1.56	-5.97	-33.70	-22.00	**-9.13**
	Developed	0.00	0.00	0.00	0.00	-23.91	0.00	-3.99
	Johnson	0.00	0.00	0.00	0.00	-54.35	0.00	-9.06
Average	**Current**	**-4.05**	**2.54**	**-6.77**	**-5.20**	**-24.04**	**-23.19**	
	Developed	**0.00**	**0.00**	**-5.43**	**-1.42**	**-12.01**	**-2.38**	
	Johnson	**0.00**	**0.00**	**-1.03**	**-1.42**	**-15.69**	**0.00**	

Table 7 The % missing shipment quantity by product.

Figure 27 shows the cumulative plot of % missing shipment of each method. It clearly shows that current method is the worst one. When comparing between developed method and Johnson's law, Johnson's law show longer tail than developed method. The % missing shipment is as high as 70%, while the developed method shows about 50 % missing. However, t-test shows no significant difference between developed method and Johnson's law at the 95% confidential.

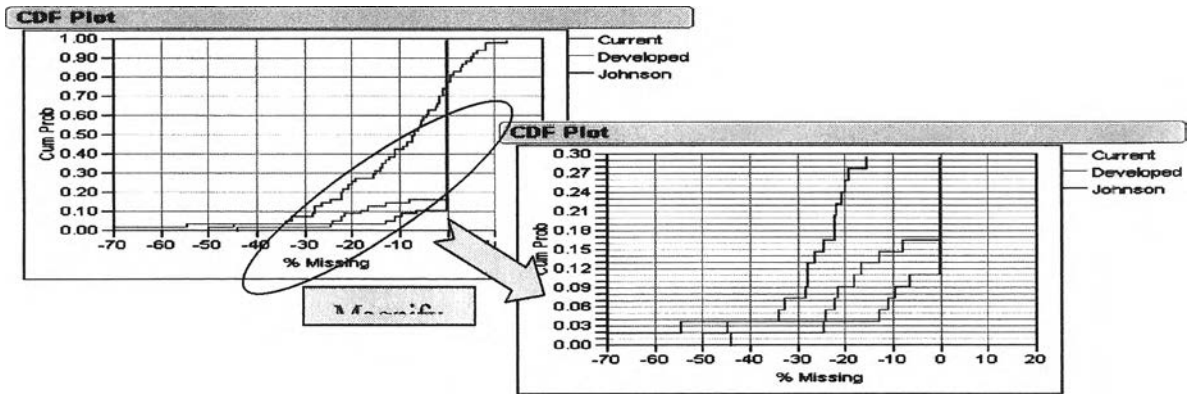


Figure 27 The cumulative plot of % missing shipment of each method.

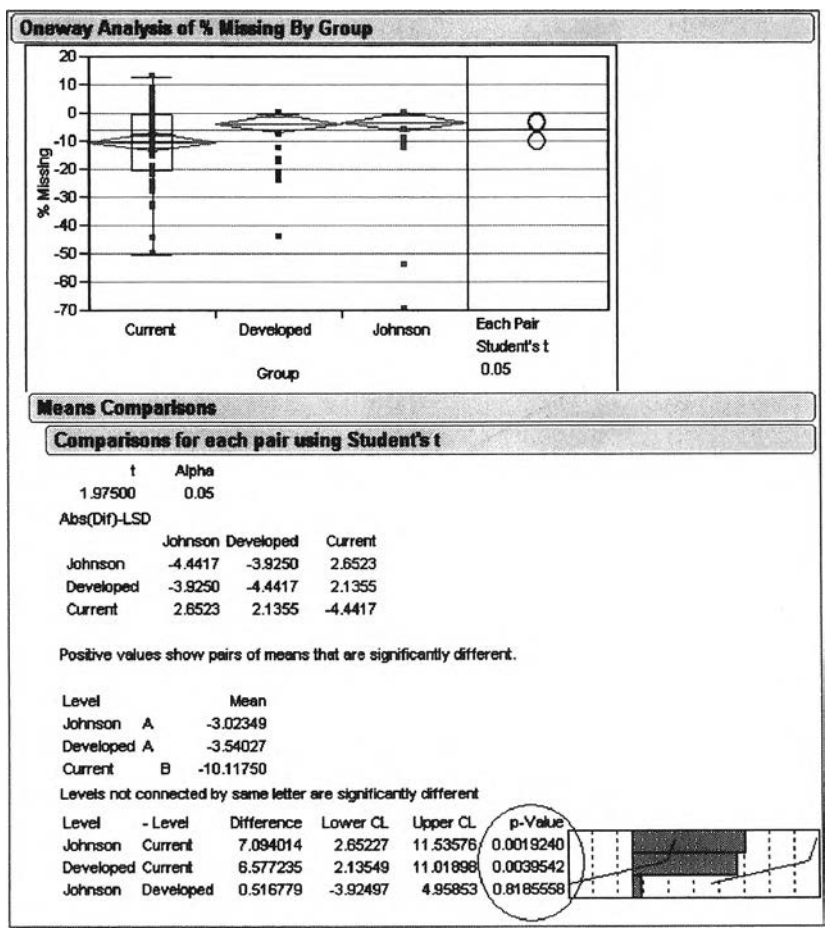


Figure 28 The T-test comparison across current method, developed method and Johnson's law.

5.5 Result Summary and Conclusion

The current method shows the worst result in term of % missing shipment. This directly impacted not only to company profit, but also the customer satisfaction that might be created a long-term problem. In term of mean tardiness, even the tardiness number cannot be quantified, the cumulative plot clearly shows that the current method has relatively higher tardiness than others.

Johnson's law shows the best performance in term of % missing shipment. However, the mean tardiness is significantly higher than the developed method. Thus, for Johnson's law, even though it can minimize the profit losses, the tardiness improvement is very low that might be impacted to customer satisfaction and, also, long term relationship.

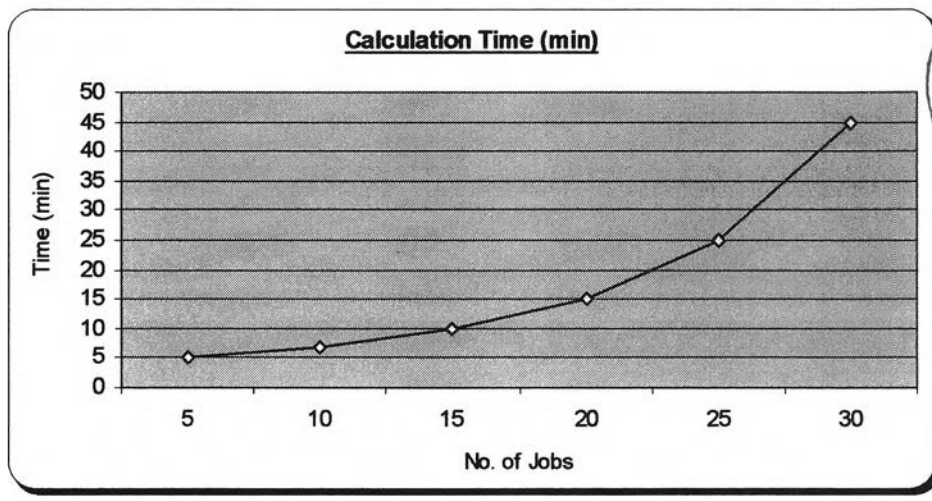
For the developed method, combining both mean tardiness and % missing shipment, it shows the most promising result. However, it still needs further improvement in order to minimize the mean tardiness and % missing shipment to achieve 0 mean tardiness and 0% missing shipment.

5.6 Analysis of Developed Scheduling Model

Comparison between Current Method and Developed Method:

As addressed earlier, the developed method is evaluated under certain conditions that might not be the same as what is exactly happened in the daily production such as material availability, transportation availability, and interruption in the production line. So, this result is the best-case scenario. The actual result after implementing this model might not be as good as the simulation result. However, it will give the better result than the current method. Besides, from the historical data, the material and transportation availability are not a major root cause of high mean tardiness and missing shipment. These problems are rarely occurred. For the interruption in the production line, this is not a scheduling model related problem, but shop floor control problem. That means, even with the same condition, the developed method tends to give better scheduling than current method. And if the foundry can improve the shop floor control system, the developed method will become more efficiency.

The another factor that has to be taken in the consideration is the difficulty when the plan is changed. Normally, from the historical data, the MPS plan is revised about once a week due to high demand fluctuation. The calculation time is a function of number of jobs. At this moment, the maximum number of jobs is 30.



No. Of Jobs	5	10	15	20	25	30
Time (min)	5	7	10	15	25	45

Figure 29 The calculation time as a function of number of jobs.

In term of resource utilization, the improvement is shown in backend process because the production manager will know ahead of time what is the plan at the backend. So, the foundry can arrange the manpower in this area more efficiently. However, the limitation is that workers cannot perform every operation at the backend. That means they have a specific group for specific operation. This is a big constrain in term of resource utilization because when considering the process characterization, the back end process is a flexible process and does not require 100% work load for every operation at the same time. So, it the foundry can enhance the workers' skill. The developed scheduling will give more benefit in term of resource utilization.

Advantages:

1. Having the "priority setting" option

Most of scheduling techniques with due date constrain such as Johnson's law, EDD, backward / forward scheduling, critical ratio and so on do not have "priority" function, but dynamic programming. Thus, this is a major advantage fitted to propose of the company since the company frequently changes job's priority according to customer's changes.

2. Minimize the mean tardiness

The result clearly shows significant improvement in mean tardiness as address earlier. This will help company to enhance the customer satisfaction especially for this business that is highly relied on the time to market.

3. Minimize the % missing shipment.

This is a consequence of lower tardiness. Normally, if the company cannot make the shipment within that month, the missing shipment demand will be cancelled and may or may not add into next month plan. So, improving the production scheduling will also help the company to minimize the % missing shipment. This is not only for customer satisfaction, but also company internal purpose – maximize the profit.

4. Standardization

Comparing to the current method manually generated the production schedule by production manager, the developed method clearly have more standardize. So, the result will be more consistent. More standardize method will help all concerned departments to work easier. For instance, the procurement department can predict for raw material availability as well as production department that can manage and utilize resources because all concerned department are relied on the same predictable system.

Disadvantages:

1. Sample size limitation

As address earlier, the dynamic programming has sample size limitation problem. High sample size will take very long time and go through complicate recursive algorithm. In this case, the maximum sample size is ten which is relatively too small comparing to the number of shipment per month. Moreover, even though it can be

used for now, it is not practical for the future because the company has a plan to expand to other customers.

2. Long calculation time

Comparing to other scheduling techniques, with the same sample size, the dynamic programming method has longer calculation time. Thus, it is not practical in case that the company has to re-adjust the plan. In this moment, since the company does not develop the supply chain management yet, the MPS plan from customer always changes, so that, the company has to regenerate the new production plan, most likely every couple days.

3. Under resource utilization at back end process

There are four operations in the back end process, short blasting, grinding, fiber, and run out as show in figure 29.

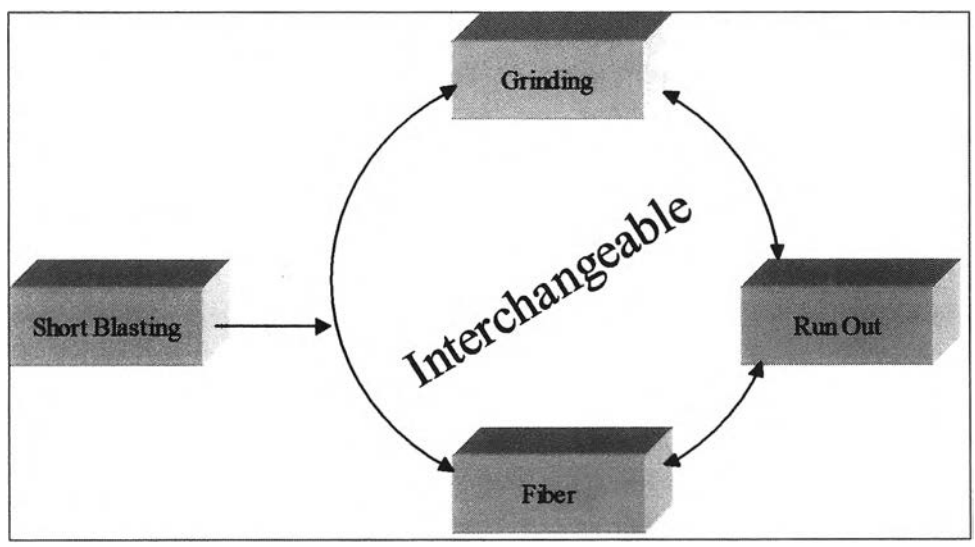


Figure 30 The back end process.

Regarding the back end process, grinding, fiber, and run out operations are interchangeable / flexible process. That means, for the best case, three jobs can be processed at the same time. However, the backward scheduling cannot support the flexible process like this. So, it can be claimed that the backward scheduling does not maximize the resource utilization at the back end process.

Constraint:

There are many different ways to identify constrain. There are two basic type of constrains:

- Physical constrain:

The physical constrain includes the raw material availability, the machine capacity limitation, resources limitation, and so on.

In this moment, the company does not have any problems with the material availability since it has a closed relationship with the suppliers. However, in term of manufacturing capacity, now the company is running with maximum capacity, so that the company has to start considering about increasing capacity to support high volume due to market growth in the future.

- Non-physical constrain:

The non-physical constrain includes the changes demand, corporate procedure, mission and vision of the company.

Now, the most constrain is an information from both upstream and downstream of this supply chain. Lacking of information make company has a difficult time to plan its production.

In the different point of view, constrains can be grouped into three main categories. In this thesis, both company constrains and model constrains will be discussed.

- Internal resource constrain:

This includes both manufacturing capacity and capability. The current situation shows that even the company is running with maximum capacity, it still cannot achieve on time delivery for all shipments. This problem might be able to solve by improve the scheduling process and manufacturing process. However, to support the future plan, company has to start considering about expand manufacturing capacity and capability.

As addressed earlier, the developed model is evaluated under the certain condition. However, it was very close to actual condition since the material and transportation availability is not a main problem and rarely occurred.

- Market constrain:

The main market constrain is a high fluctuation in this business. The demand and the customer requirement change rapidly. The high competition in this business makes the "time to market" becomes one of the critical factors for every company in the supply chain.

Since the real scheduling is dynamic, the scheduling model cannot handle this real time changes. Moreover, the model does not look at the upstream and downstream. Thus, constrains in other related function may not be recognized.

- Policy constrain:

This is related to Over Time (OT) policy, claim policy, plan change policy, etc. Currently, the company does not have any claim policy or plan change policy. That means customers can change the MPS plan any time even couple days before ship date. However, it is not easy to setup this policy with customer because they are highly depended on each other. Setting too strict policy might be a disadvantage in a long run.

Suggestions and Remedies:

- Real time shop floor control system

This system is highly recommended to implement into the production line. Nowadays, there is no shop floor control system in the production line. So, it is very difficult to track the status of each job. So, the supervisor will have no idea when some jobs are delayed or idle during the process. Moreover, in case that there is some problems occurred in the line, it will take a long time to detect and solve problems. Thus, many jobs might be processed during that period and be scrapped at the end.

Having shop floor control system will help the company to have better control in the production due to

- Be able to monitoring and control the progress of each job
- Be able to acquire current information and the status of each job

➢ Increase the capacity of bottleneck operation

Currently, furnace operation is the main bottleneck in the process. Increasing the capacity in this area will increase the overall manufacturing capacity. However, it has to consider the line balancing to make sure that after increasing furnace capacity, there are no other bottleneck operations.

➢ Developing other routings or subcontracts

This is just another option in case that increasing bottleneck capacity does not work. However, the company have to be very careful with this option because

- The subcontract might become a competitor.
- It is difficult to control.
- Business security.

➢ Well trained and cross trained for all employee

This is for the backend process only. Well trained and cross functional trained will help company to develop and enhance employee's skills that make them be able to work at every operation in the back end process.