CHAPTER 5
EVALUATION

After implementation, measuring and evaluating performance should be recognised. However, there is limitation faced during evaluation. These would be discussed as follow.

5.1 Limitation

According to the nature of product and business operation of the case study factory, result measurement is difficult for representation. Many limitations concern in comparison the result. The list of limitation and impact on measurement are detailed below.

1. Majority of ordered model changes in each month.
2. Number of order and quantity is varied depending on customer requirement.
3. Flow process in manufacturing is uncertain depending on product design.
4. Each model involves with different level of difficulty in manufacturing.
5. There is more than one order being process at a time in order to optimise resource utilisation.

As results of those, comparability is hardly provided regarding to the study objective of improves process flow and reduces delivery.

5.2 Results

As consequences of the mentioned limitations, measurement is difficult in terms of comparability. Therefore, result is measured in terms of both subjective and objective as following:

5.2.1 Objective Result

The objective result is used to indicate meeting the objective of this study. The detail of result is as following:

5.2.2.1 Process Flow

The traditional process flow shown in Figure 5.1 is developed by reducing non value-added activities so that it is ultimate with the new process flow shown in Figure 5.2 that can be shorten the workflow and reduce work of coordinator.

Role of coordinator is reduced. The detail of eliminated functions are identified as:

1. Function as the center to transfer job to productive shop.
2. Function to inspect quality of received work from productive shops.
3. Function to manage rework occurred within production process flow. Opening rework document, distributing and receiving rework object, and inspecting reworked object are cut.
4. Function to check conformation to the production order such as size, color, quantity, characteristic, etc.

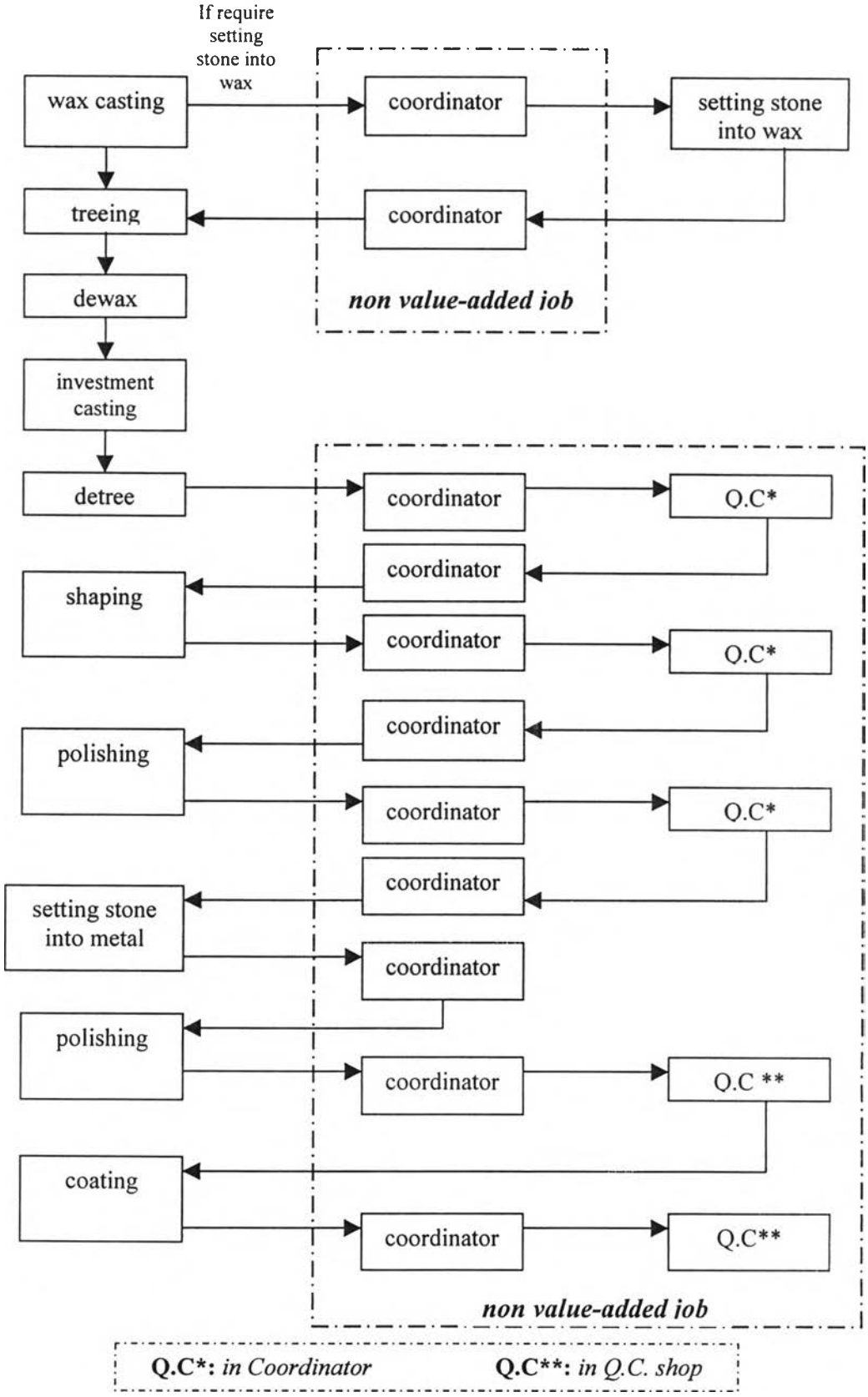
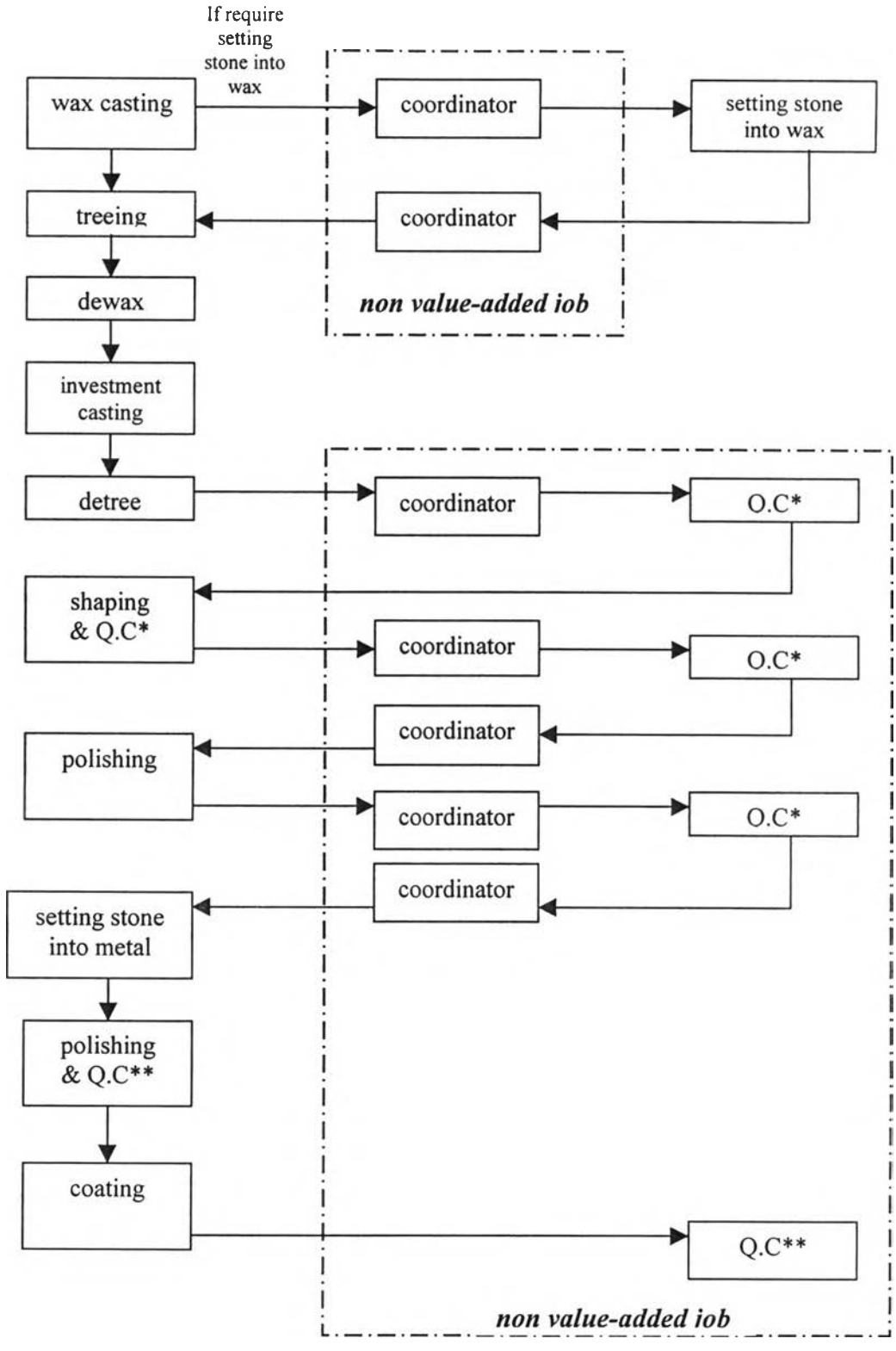


Figure 5.1: Process Flow Diagram (Before Improvement)



Q.C*: *in Coordinator* **Q.C**:** *in Q.C. shop*

Figure 5.2: Process Flow Diagram (After Improvement)

- **Flow Process Chart**

The summary of activity concerns with traditional process flow shown in Table 5.1. After improvement flow of process, some activities are reduced and summary of activity result is shown in Table 5.2.

Table 5.1: Summary of Flow Process Chart (Before Improvement)

Summary (Before Improvement)			
Activity		Number of steps	Distance (m)
Operation	○	17	
Transportation	⇨	21	282
Delay	D	13	
Inspection	□	21	
Store	▽	0	

Table 5.2: Summary of Flow Process Chart (After Improvement)

Summary (After Improvement)			
Activity		Number of steps	Distance (m)
Operation	○	17	
Transportation	⇨	18	247
Delay	D	11	
Inspection	□	12	
Store	▽	0	

Table 5.3: Improvement Result of Flow Process Chart

Summary									
Activity		Before Improvement		After Improvement		Improvement Result			
		Number of steps	Distance (m)	Number of steps	Distance (m)	Number of steps	% of improvement	Distance (m)	% of improvement
Operation	○	17		17		0	0		
Transportation	⇨	21	282	18	247	-3	14.3	35	12.4
Delay	D	13		11		-2	15.4		
Inspection	□	21		12		-9	42.9		
Store	▽	0		0		0	0		

From the improved process flow, non value-added activity has been reduced. The improvement is summarised as in Table 5.3. That is transportation, delay, and inspection decrease by 14.3%, 15.4%, and 42.9% respectively. Moreover, distance of transportation concerning on the process flow is shortened by 35 meters or 12.4%.

- **Travel Chart**

In another view, movement between shop of the old process flow can be illustrated by Travel Chart shown in Figure 5.3. Since the improvement is implemented, the movement has been changed and represented in Figure 5.4.

From the Figure 5.3, there are high as eight movements concerning on coordinator shop which is non-productive shop. This supports the reason behind selecting improvement area focused on coordinator shop.

In Figure 5.4, it indicates the reduction of movement relating to coordinator shop caused by the improvement result.

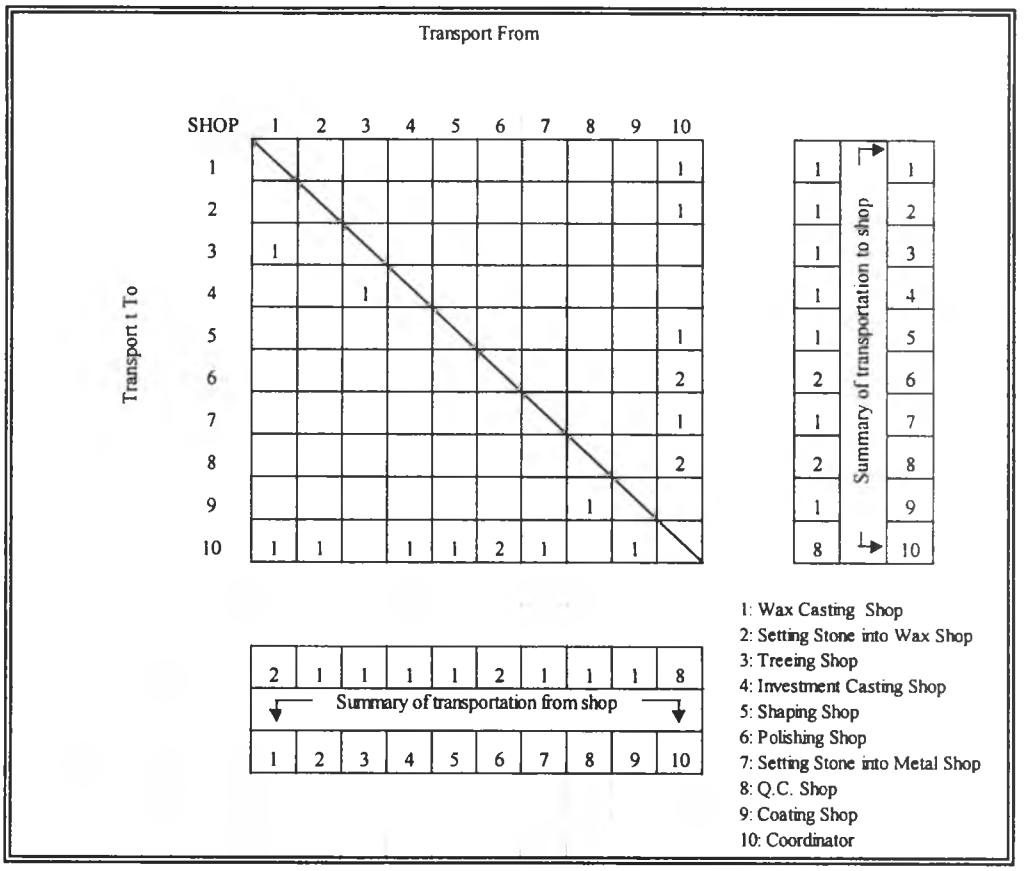


Figure 5.3: Travel Chart (Before Improvement)

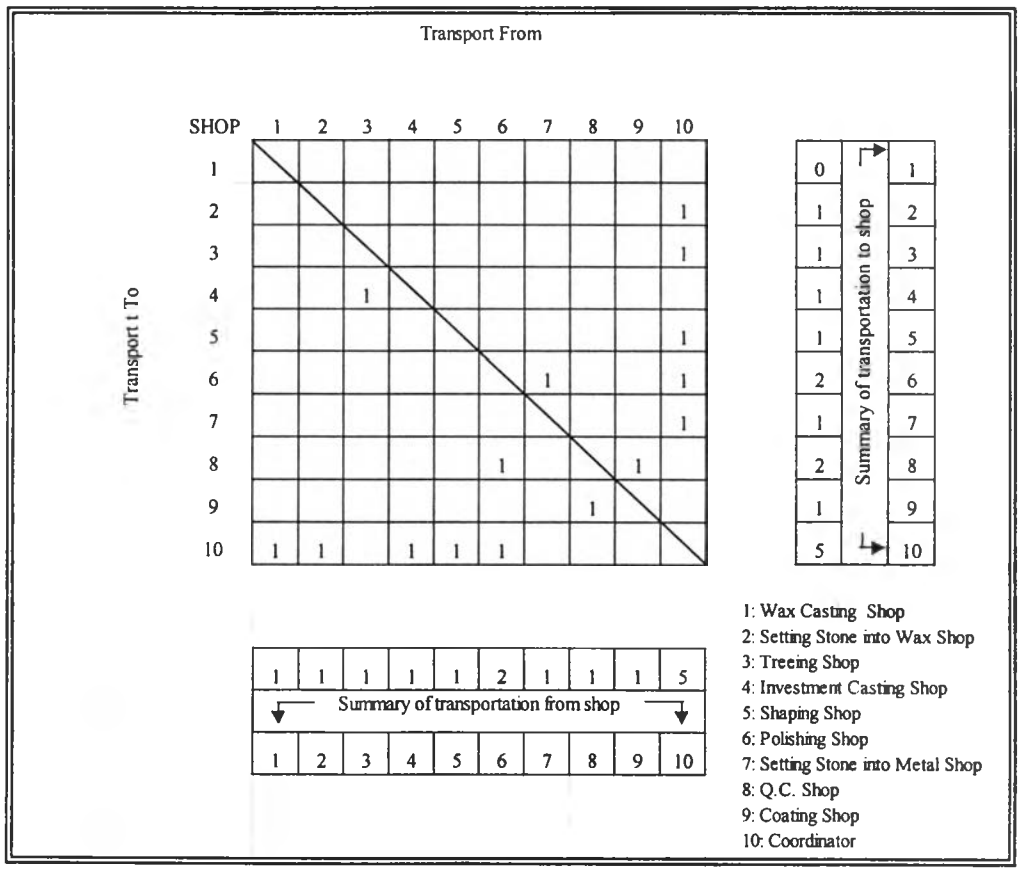


Figure 5.4: Travel Chart (After Improvement)

- **Manufacturing Flow Efficiency**

Because of the mentioned limitations, the selected order has constraints in measuring performance as following:

1. The orders in each comparison number must have the same process flow.
2. The quantity of orders compared in each comparison number should be close.
3. Flow of each order must be in one lot in order to avoid synchronisation of lot.
4. The orders in each comparison number must have similar difficulty in manufacturing.

In order to evaluate result, the observation has been collected for two weeks from 8th to 20th May 2000.

Table 5.4: Comparison of Manufacturing Flow Efficiency [per one lot]

Comparison No.	Before Improvement					After Improvement				
	Product No.	Qty.	Process-sing Time (hr.)	Manufac-turing Flow time (hr.)	**Manufac-turing Flow Efficiency**	Product No.	Qty.	Process-sing Time (hr.)	Manufac-turing Flow time (hr.)	**Manufac-turing Flow Efficiency**
1	10177	55	58	73	0.79	18059	50	56	60	0.93
2	10207	58	31	39	0.79	10802	60	32	35	0.91
3	10232	45	38	46	0.83	11348	50	40	43	0.93
4	10256	50	50	62	0.81	12415	45	30	33	0.91
5	11459	60	44	51	0.86	11347	50	40	42	0.95
6	10460	78	30	35	0.86	10717	85	31	32	0.97
7	11468	50	34	43	0.79	10035	48	34	36	0.94
8	10724	30	26	32	0.81	10117	33	25	27	0.93
9	10626	30	22	27	0.81	10130	35	23	24	0.96
10	11346	55	38	47	0.81	10173	59	39	43	0.91
Average					0.82	**Average**				0.93

Table 5.5: Improvement of Manufacturing Flow Efficiency

	Comparison No.										Ave-rage
	1	2	3	4	5	6	7	8	9	10	
% Manufacturing Flow Efficiency Improvement	17.5	15.0	12.6	12.7	10.4	13.0	19.4	14.0	17.6	12.2	**14.4**

From Table 5.4, it can be observed that the processing time per lot, time spent in material transforming excluding transportation, inspection, and waiting time, of each pair is approximately the same. On the other hand, the manufacturing flow time, time spent in production process including transportation, inspection, and waiting time, of each pair has been decreased after improvement.

Before improvement, manufacturing flow efficiency, indicates efficiency of time spent on processing product, is 0.82 on average. After improvement is implemented, average manufacturing flow efficiency increases to 0.93.

Manufacturing flow efficiency per lot is determined by

Processing time of lot / manufacturing flow time of lot

From Table 5.5, improvement of manufacturing flow efficiency, it can be described that the result of implementation is 14.4% increase of manufacturing flow efficiency in which that is caused from the reduction of manufacturing flow time. That means efficiency of time spent on processing product is improved.

Rework

Due to that rework causes the complexity within process flow, this can be improved in terms of rework flow by changing external rework to internal rework.

From Figure 5.5, there are eight possibilities of rework flow. By the improved process flow, the possibility of rework flow is reduced to five as shown in Figure 5.6.

Rework Rate

Rework rate is used to represent the number of rework found comparing with ordered quantity. Due to the mentioned limitations, selecting evaluated order involves with constraints. The criteria used in selecting compared order is as following:

1. The orders in each comparison number have the same process flow.
2. The orders in each comparison number must have similar difficulty in manufacturing for comparable of rework occurrence number.

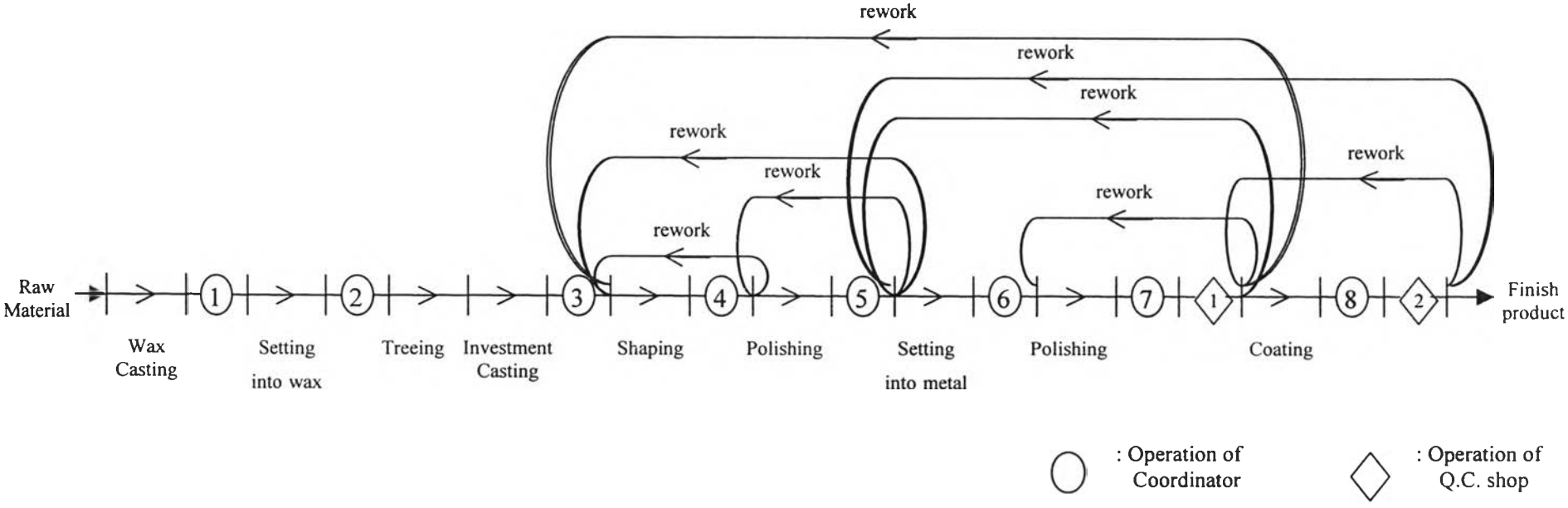


Figure 5.5: Rework Flow (Before Improvement)

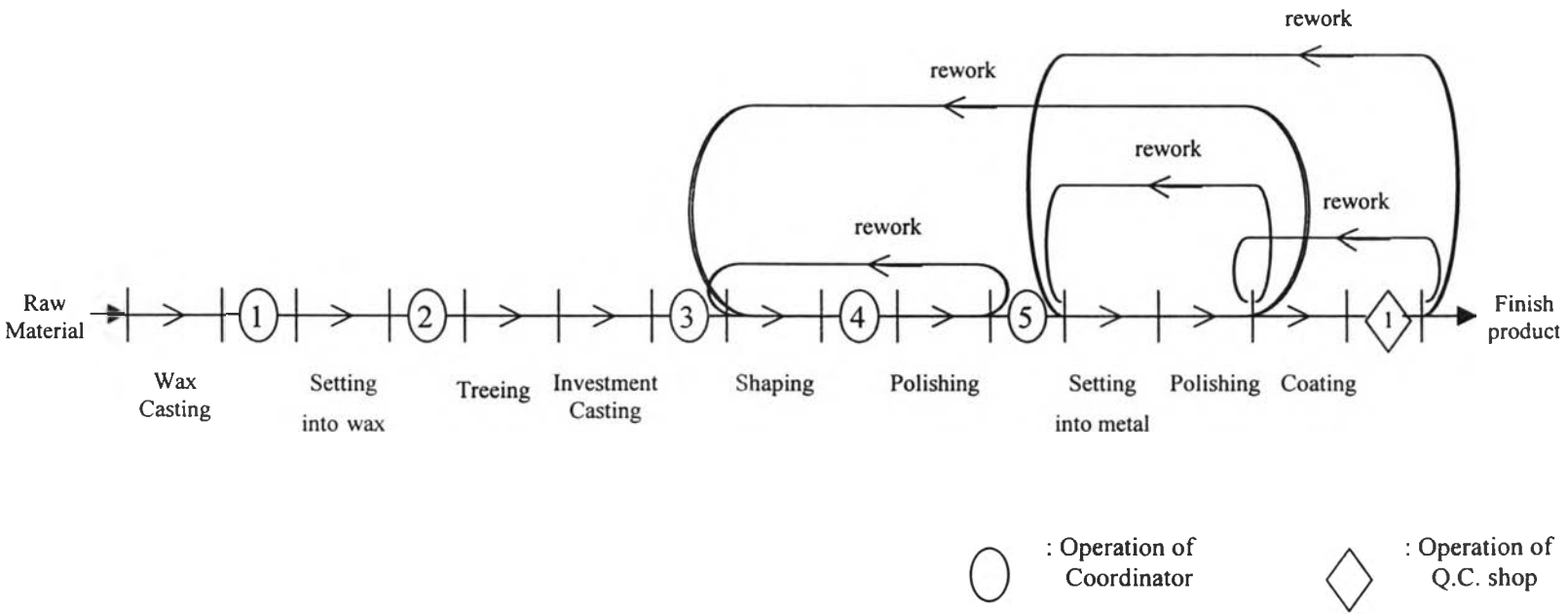


Figure 5.6: Rework Flow (After Improvement)

In order to evaluate result, the observation has been collected for two weeks from 8th to 20th May 2000.

Table 5.6: Comparison of Rework Rate

Comparison No.	Before Improvement				After Improvement			
	Product No.	Qty.	Rework Qty.	**Rework Rate (%)**	Product No.	Qty.	Rework Qty.	**Rework Rate**
1	11354	200	178	**89.0**	10873	250	130	**52.0**
2	11258	150	102	**68.0**	10802	60	22	**36.7**
3	10898	100	106	**106.0**	11348	50	35	**70.0**
4	10993	80	69	**86.3**	10873	100	41	**41.0**
5	11259	100	88	**88.0**	11347	50	28	**56.0**
6	10911	200	135	**67.5**	11244	150	46	**30.7**
7	10992	750	360	**48.0**	10633	100	19	**19.0**
8	10984	1200	692	**57.7**	14101	770	181	**23.5**
9	10692	500	271	**54.2**	10692	800	193	**24.1**
10	10888	2500	720	**28.8**	10621	1500	285	**19.0**

Table 5.7: Improvement of Rework Rate

	Comparison No.										Ave-rage
	1	2	3	4	5	6	7	8	9	10	
% Rework Rate Reduction	41.6	46.1	34.0	52.5	36.4	54.6	60.4	59.2	55.5	34.0	**47.4**

From Table 5.6, rework quantities are relatively high. This quantity also includes the parts that are repeated rework. After implementation, the rework quantities are dramatically reduced since internal rework is introduced.

From the improvement result, the rework found drops around 47.4%. That indicates corrective action of rework change to be made within shop. Therefore, reduction of time used in transportation for rework job is implied.

❑ Document Flow

The document flow is improved to support the improved process flow. The flows of document before improvement and after improvement are illustrated in Figure 5.7 and 5.8 respectively. The documents are change to support the changed process flow. The detail of document change is summarised as in Table 5.8.

Table 5.8: Summary of Production Document System Improvement

SHOP	Document List		Operation on the document			
	Before	After	New	Adapt	Cancel	Same
1.Coordinator	1. Production order 2. Job order 3. Note	1. Production order 2. Job order - 3. Basket control 4. Rework order	 X 	 X	 X 	X X
Total	3	4	1	1	1	2
2. Setting stone into wax shop	1. Job order	1. Job order				X
Total	1	1	-	-	-	1
3. Treeing shop	1. Investment casting job order	1. Investment casting job order				X
Total	1	1	-	-	-	1
4. Investment casting shop	1. Investment casting job order	1. Investment casting job order				X
Total	1	1	-	-	-	1
5. Shapping shop	1. Job order	1. Job order 2. Basket control 3. Rework order	 X 	 X	 	X
Total	1	3	1	1	-	1

6. Polishing shop	1. Job order	1. Job order 2. Basket control 3. Rework order	 X 	 X		X
Total	1	3	1	1	-	1
7. Setting stone into metal shop	1. Job order	1. Job order 2. Basket control 3. Rework order	 X 	 X		X
Total	1	3	1	1	-	1
8. Q.C.	1. Job order	1. Job order 2. Basket control 3. Rework order	 X 	 X		X
Total	1	3	1	1	-	1
9. Coating shop	1. Job order	1. Job order 2. Basket control 3. Rework order	 X 	 X		X
Total	1	3	1	1	-	1

Table 5.8 summarises change of document used within process flow. Some new documents are introduced whereas some are adapted to match the improved process flow. However, some are given up of use since the flow is shortened.

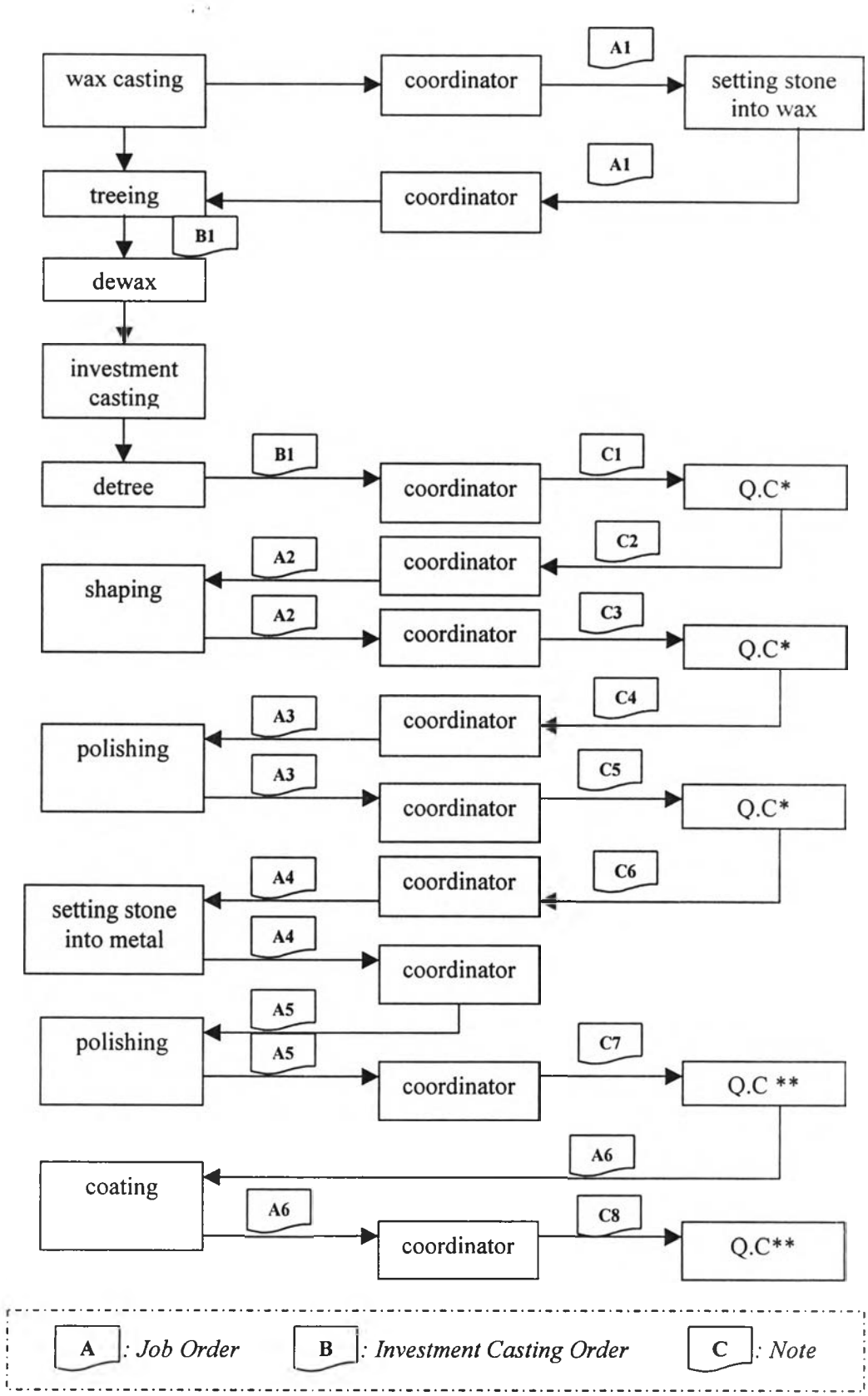


Figure 5.7: Production Document Flow System (Before Improvement)

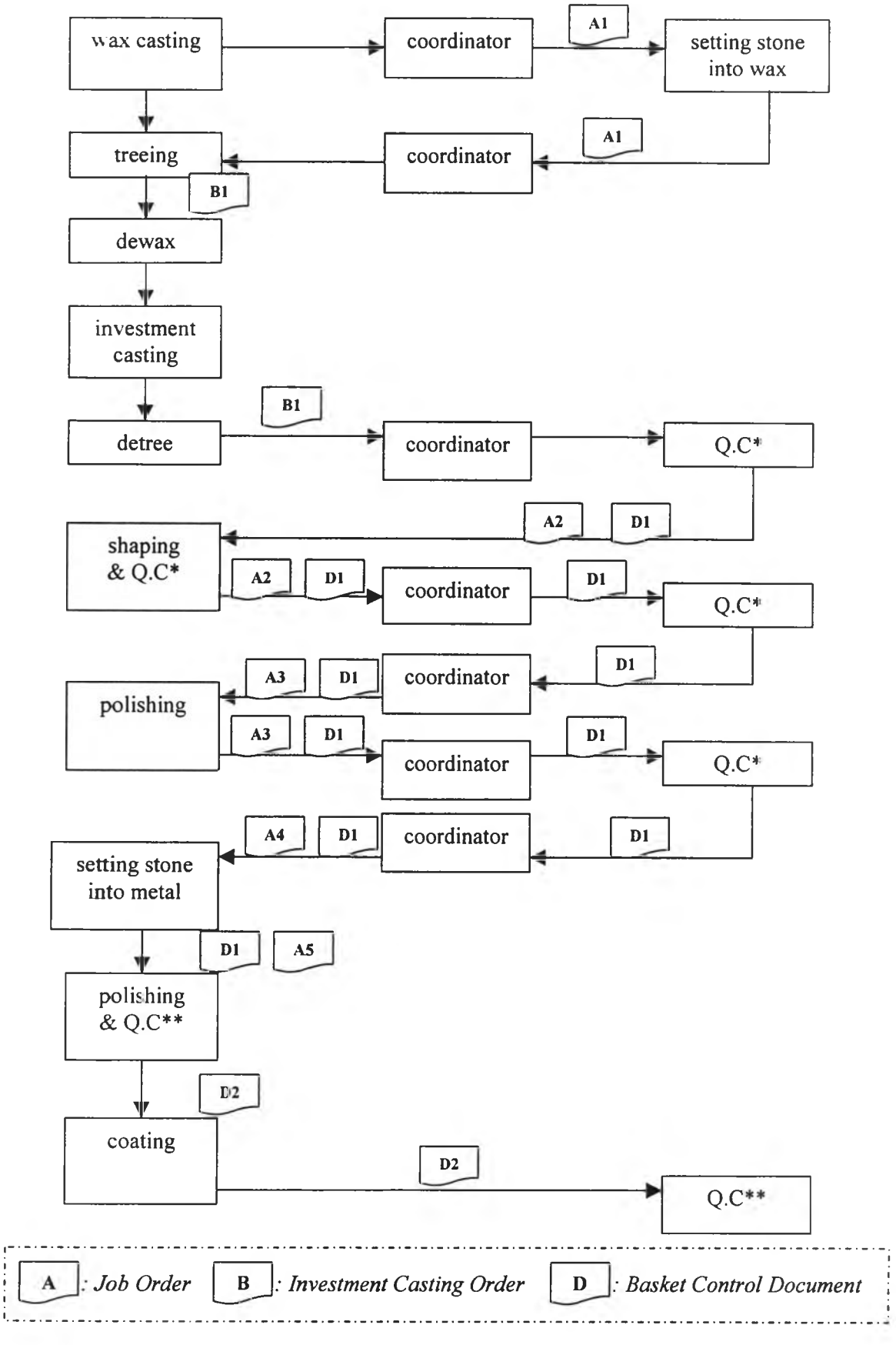


Figure 5.8: Production Document Flow System (After Improvement)

- **Delivery Data**

For delivery result, it has found that delivery delay has been improved. Number of delay decreases. However, same as other results, measurement has not been performed completely. Limitation of measurement provides the difficulty of comparability. Thus, measurement of delivery delay result can be provided partially via some comparable orders which are selected under the same criteria as in manufacturing flow efficiency. The comparison is shown in Table 5.9.

Table 5.9: Comparison of Delivery Data

Comparison	Before Improvement			After Improvement			Improvement (day)
	Product No.	Qty.	Delivery Variation (day)	Product No.	Qty.	Delivery Variation (day)	
1	10177	55	-2	18059	50	-1	+1
2	10207	58	0	10802	60	0	0
3	10232	45	-1	11348	50	0	+1
4	10256	50	-1	12415	45	-1	0
5	11459	60	-1	11347	50	0	+1
6	10460	78	0	10717	85	+2	+2
7	11468	50	0	10035	48	0	0
8	10724	30	0	10117	33	+1	+1
9	10626	30	+1	10130	35	+1	0
10	11346	55	-1	10173	59		+1
	Average Delay		*0.6*	*Average Delay*		*0.2*	*66.6 %*
	Lagging due date rate		**0.5**	**Lagging due date rate (%)**		**0.2**	**60 %**
	Leading due date rate		**0.1**	**Leading due date rate**		**0.3**	**200 %**

From Table 5.9, before improvement, delivery delay is 0.6 day per order on average. After improvement, the delivery delay has been reduced. The average of the delay decreases to 0.2 day per order. In the terms of improvement, delivery delay has been improved up to 66.6 %.

According to the delivery in Table 5.9 concerns with earliness and lateness so that leading and lagging due date rate is another index to represent delivery performance.

Lagging due date rate is determined by

Number of late delivered order / Total number of order

Leading due date rate is determined by

Number of early delivered late order / Total number of order

Before improvement, it can be observed that the lagging due date rate is approximately 0.5. That means a half of number of orders is delivered after due date. On the other hand, the leading due date rate is 0.1 in which indicates only 10% of total order that is delivery before due date.

After the improvement is implemented, lagging due date rate has been reduced to 0.2. There is an increase of 0.3 of lagging due date rate. When compare with before improvement, 60% improvement of lagging due date rate has been achieved from the implementation. That represents the result of reduction of delivery delay. Decrease in delivery product after due date has been met. On the other hand, the leading due date rate increase to 0.3. The result of implementation in terms of early delivery is identified by 200% improvement. Handling product before due date is also achieved from the improvement.

As results of previous result discussion, the objective to reduce delivery delay is partially fulfilled.

However, the overall delivery result should not be ignored. The graphical results of delivery of before and after improvement is summarised and shown in Figure 5.9 and 5.10 respectively.

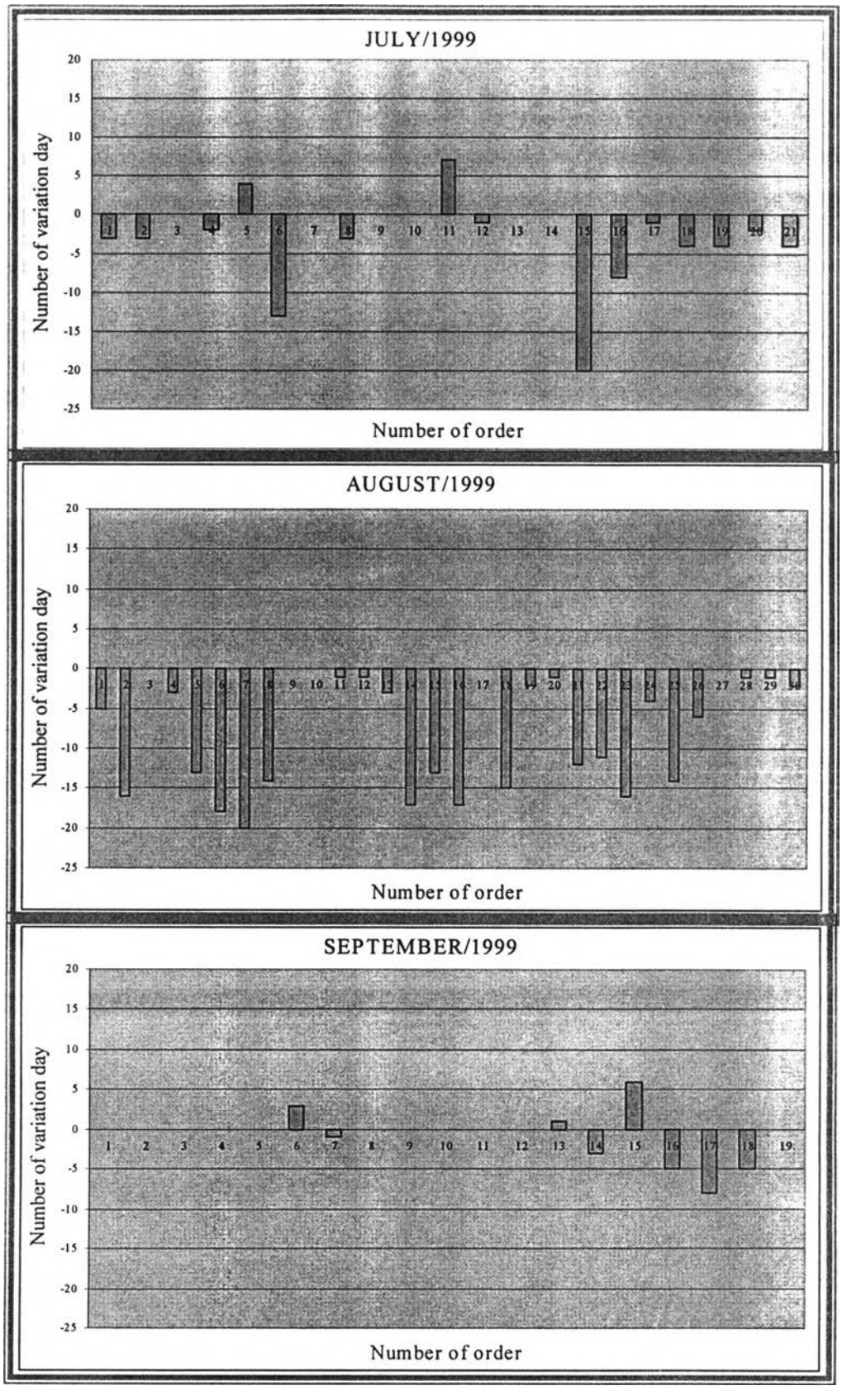


Figure 5.9: Delivery Summary (Before Improvement)

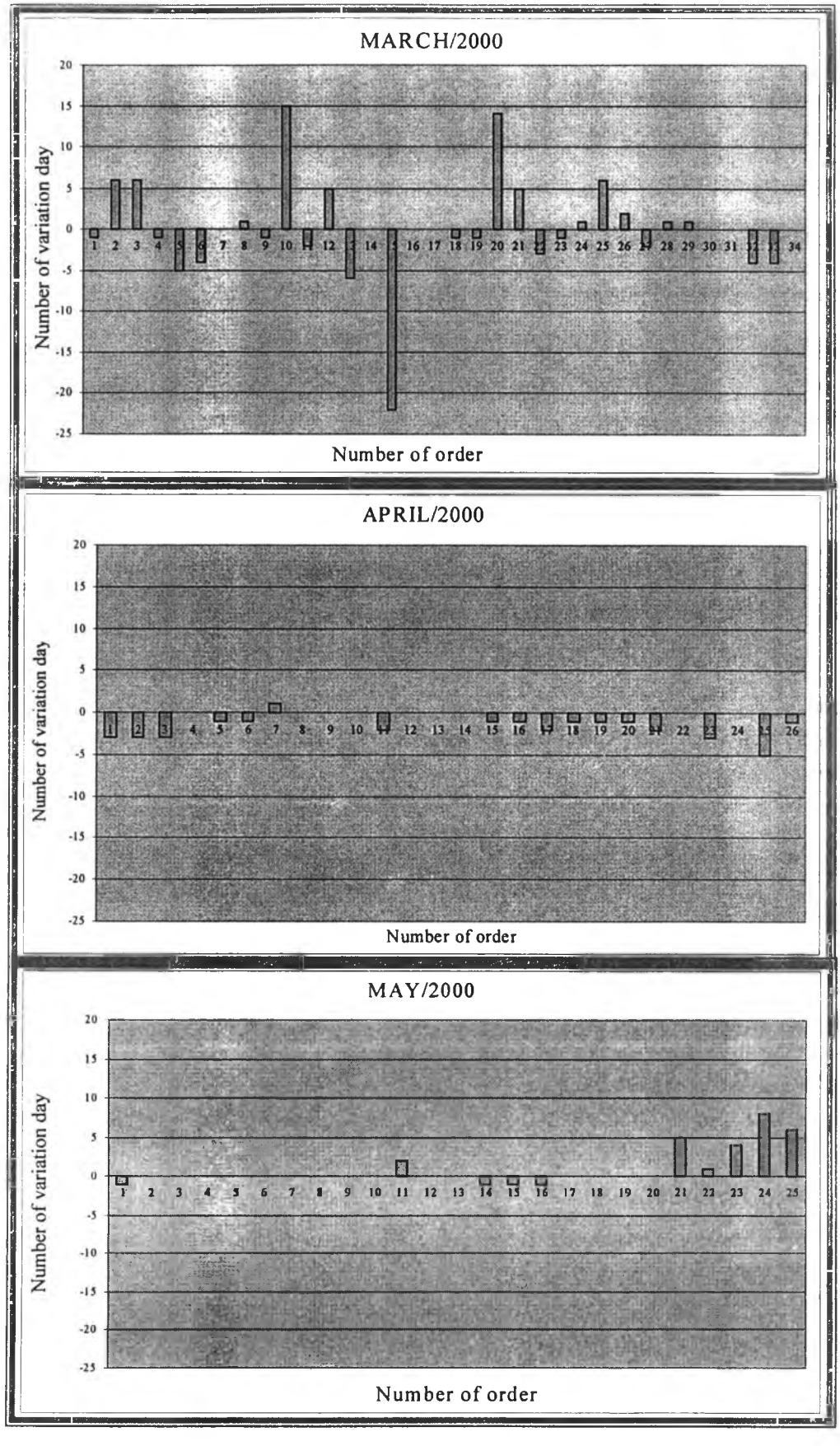


Figure 5.10: Delivery Summary (After Improvement)

To decrease the number of delivery delays after improving the process flow that is the ultimate objective of this thesis, the delay time of before and after improvement taken are recorded. For the data of before improvement, they are collected from July 1999 to September 1999 shown in Figure 5.9 while data of after improvement are collected from March 2000 to May 2000 shown in Figure 5.10. It can be obvious that the overall delay time has been reduced as indicated by the shortened negative bars after improvement. However, some orders still show long delay time since it is the local order. From investigation, local order will be last priority because no penalty is in charge and it can be negotiated for expanding delivery time.

5.2.2 Subjective Result

The method used in gathering this result is interview many related production staff including sale staff. The interview result is represented as following:

- *Production Manager*: the Production Department has more systematic. Effective manufacturing is gained. Managing and control becomes easier. Problems from rework flow can be manipulated faster. Production lead time is shorter. Complain of not finish order on schedule from Sale Department is lower.
- *Coordinator Supervisor*: responsibility is reduced. Process flow becomes more automatic. Consequently, there is more time available to spend on necessary functions such as controlling overall flow, solving technical processing problems.
- *Each Production Shop Supervisors*: Urgency in manufacturing the near due date order is less than previous. Team working resulting from pull system increase. Operation between shop becomes easier. Operational discipline is stronger.
- *Sale Manager*: the production department can manufacture products faster. That impact Sale Department on customer complains caused by delivery late. Number of the complain reduces whereas customer satisfaction increases. Furthermore, greater number of order received is reached. Consequently, factory's sale is higher.

From interviewing, it comes out in the same direction of positive results. In the view of factory staffs, the improvement has been succeeded. Satisfaction of staffs is emerged. Therefore, it can be summarised that the intention of this study has been reached in subjective aspect.