CHAPTER 4
IMPLEMENTATION

4.1 Background

A case study company is a jewelry factory established in 1989. The size of the factory is a small enterprise. It has around 200 employees. Capacity in manufacturing is about 3,000,000 units per year. The company manufactures for only made to order. The markets of the company's product are both local and export but mostly for export market.

4.1.1 Company Products

The types of products that the factory manufactures are:

1. ring
2. necklace
3. bracelet
4. earrings
5. brooch
6. pendant

4.1.2 Business Process

The business process of the company for a customer order consists of 6 stage: Receiving Customer Order, Making Mould, Making Sample, Production Planning, Manufacturing, and Handling.

1). Receiving Customer Order

Firstly, the desired designs from customer are sent to Sale Department. Those desired designs are then translated into perspective drawings by Design Department. In the design

process, the specification of gems and related production specification are also detailed in order to provide right products within set schedule.

2). Making Mould

After the drawings and related specification are made, making sample products are commanded to making sample section in Production Department. Similar to other products, making mould is the first stage of producing product. Core mould is made manually and has physical appearance as an actual object except material used. The core mould is made by metal because it will be used in making elastic cavity mould which require high melting point of core mould. Then the particular elastic cavity mould is used to make the sample products.

3). Making Sample

This stage involves test run production. Due to that the sample products must be the same quality as the incoming order, thus making sample product is passed through production processed as same as production of the incoming ordered lot. Particular material and gems also must be the same between the sample product and the incoming ordered product. That can indicate taking into consideration and maintaining of the company's product quality. That also provide the production foreseeing problems which will occur in running actual process and prepare taking action to response them.

4). Production Planning

In an event that the sample product submitted is met with satisfaction and the customer decide to place the order to the company, the Sale Department is who responsible for receiving customer order. When customer placing the order, the required due date is mostly specified by customer which normally 60 days for production lead time is used as standard of the company. Then the temporary order document with the required due date is issued by Sale Department and copied for Production Planning Department. After the receipt of the order document, the Production Planer will check the in hand order, the production capacity, and available resources and consider the possibility of manufacturing and finishing this order on the required date with the high quality. If the

required date is possible, the order will be confirmed to the Sale Department and order acceptance will be replied back to customer. At the same time, Production Planning Department has to update the production schedule and order or prepare particular material which may require certain time for ordering. In the case of that the required date is unreachable, the appropriate due date will be set by the Production Planning Department and confirmed to the Sale Department to negotiate with customer and inform the final appropriate due date through Production Planning again in forms of permanent order document.

5). Manufacturing

After the order is confirmed, the production order is copied and handed to all production lines in order to prepare themselves for manufacturing. The manufacturing processes begins at preparing rubber cavity mould, then moves to waxing, treeing, investing, setting gem, tumbling, polishing, Q.C., and finishes at coating. However, the sequence of process is variable depend on the type and design of product.

6). Handling

The Sale Department is in charge of this stage. Packing is also counted as a part of this stage and performed by marketing staff. Final Q.C. made by non-production staff is the important process within this stage and must be done before packing in order to keep high quality of product and prevent customer dissatisfaction. Due to that the company's customers are mostly foreign; therefore, handling is done via shipping and handling service provider.

However for the product models which have been ordered, the making mould and product sample are cut out from the business process. The detail of business flow can be illustrated by Figure 4.1

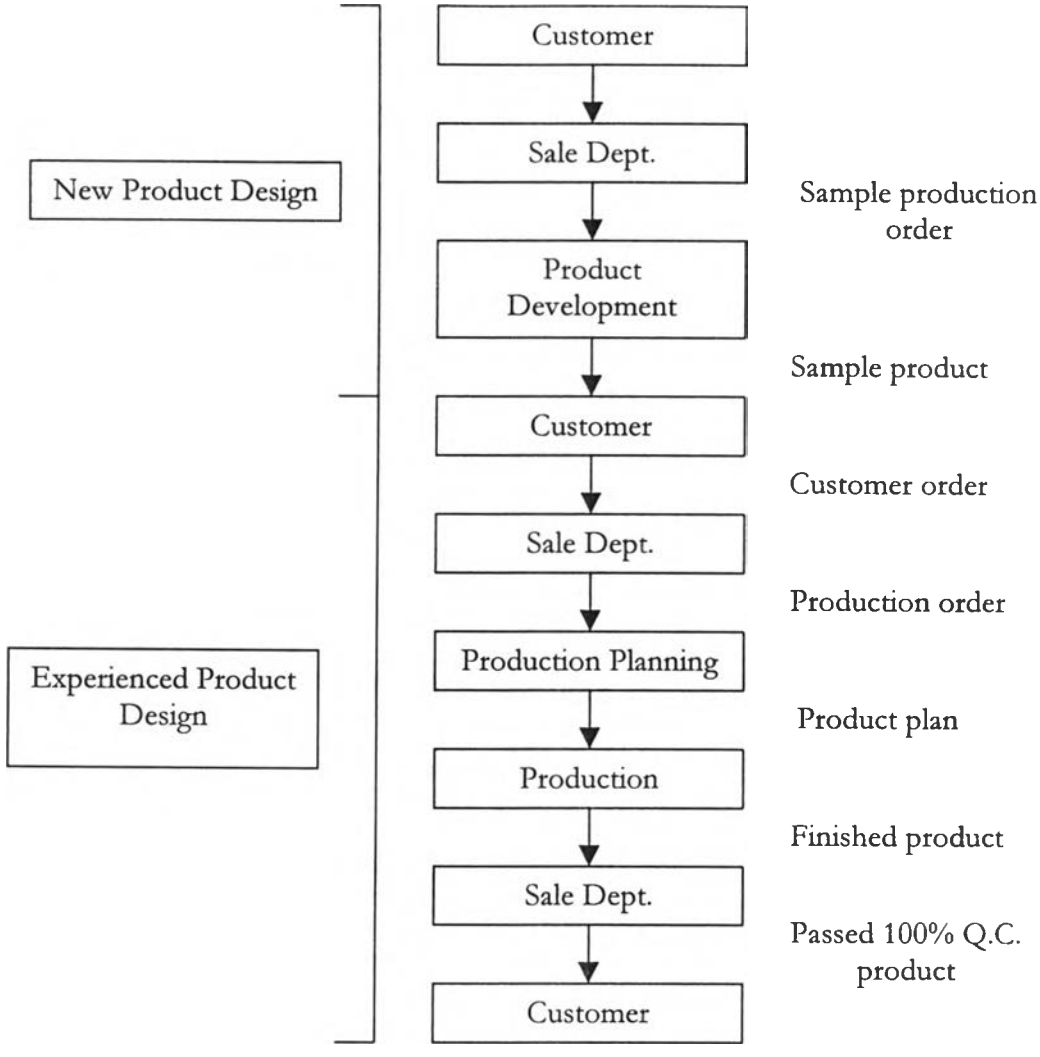

Figure 4.1 Business Flow Chart

4.1.3 Production Layout

The production of layout of the factory is shown in Figure 4.2

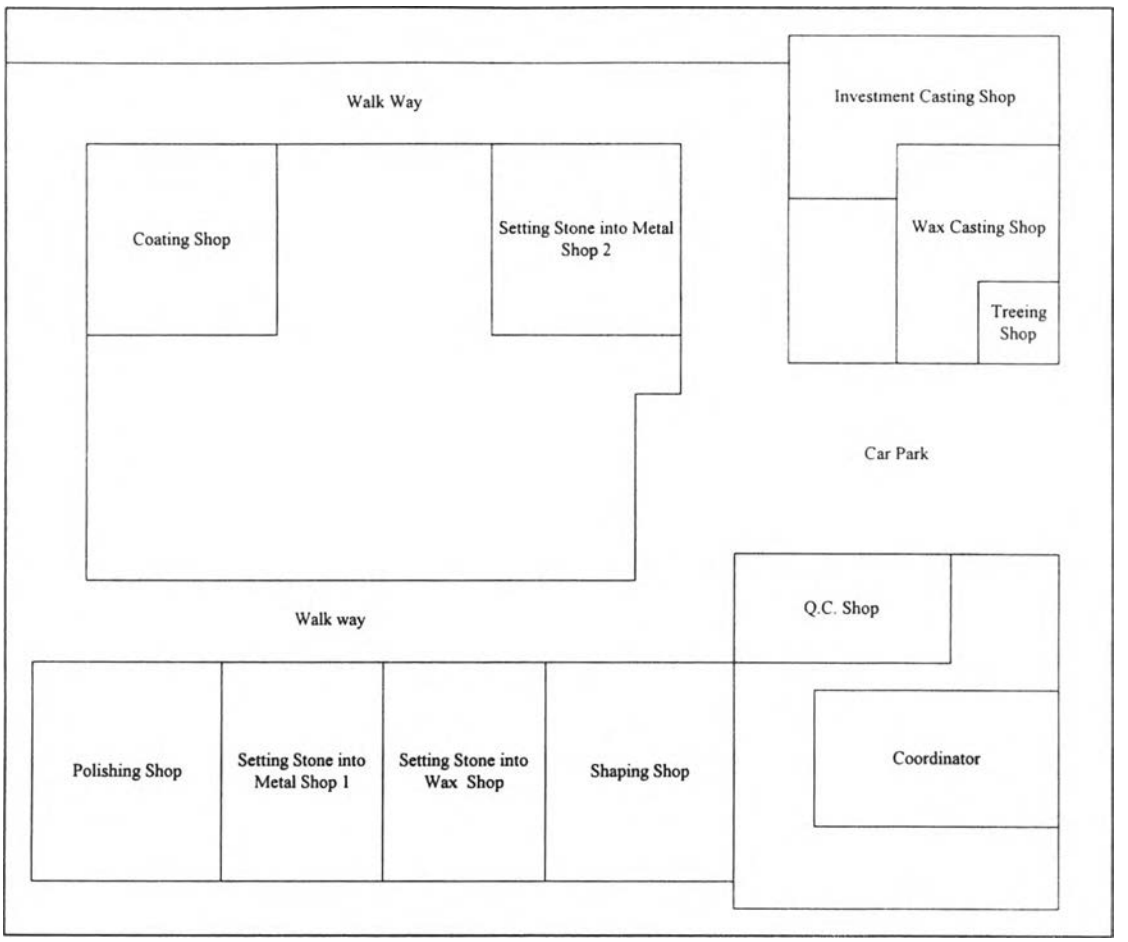

Figure 4.2: Production Layout

4.1.4 Production System

The current production system of the factory consists of 9 shops as following:

1. Wax Casting

Wax casting shop functions to make wax in which the finished wax from this shop will be transformed to a metal replica of piece of jewelry. The finished waxes have exactly the form of the objects we are trying to achieve. In this shop, wax is shaped by melting method. All products have to begin with wax casting shop.

The wax casting process starts from melting wax. Then inject the melted wax into the elastic cavity mould, mother mould. The injected mould is left for a while until the injected wax is rigid. The last process of wax casting is that the rigid wax is detailed. Before handling the finished wax object to the next shop, Q.C. the finished wax is necessary. If the shape or detail is missing while the wax is transformed into metal status,

that means wastes of such resource, time, money, involve. The wax object has to be inspected piece by piece carefully.

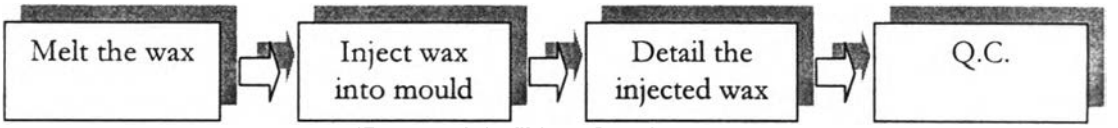

Figure 4.3: Wax Casting Process

2. Setting Stone into Wax

This shop function is to set the wax object with stone(s). Not all of product design has to be set stone in wax object, before investment casting. There is only for some designs decided to be set into wax. It provides ease and fast for setting stone when compare with doing after investment casting process, setting stone into metal object. In addition, it allows ease for correction and yields benefits in terms of saving cost, time because correcting or reworking on the metal object costs the factory much more than doing it in the wax form. This shop requires skill to perform the job.

Decision of setting stone into wax is normally based on

1. *Size of stone*. The small stone size is mostly set into the wax object form because setting into the wax form concerns with high chance of damage or broken of stone caused by heat. Due to that after finish setting stone into wax, the finish object will be sent to investment casting process which concern directly with heat. Large stone size involves with high cost, thus, is not selected to be set before investment casting, in wax form.
2. *Type of setting method required.* This is another factor for deciding of setting. If the type of setting is not difficult, it is preferable to set into wax form as the results of saving cost and time. However, if particular type of setting is likely hard work, setting after investment casting, into metal form, is preferable in order to avoid breaking or loosing of stone and providing better, neat, and more detail than doing in the wax form.

3. Treeing

This is also called spruing process. Treeing concern with using a wax rod to secure the wax model to a specifically configured rubber base that is called a sprue base. In the center of the base is a wax insert to which is attached waxes that are to be cast. Thus the

function of this shop is providing the wax model ready and easy to be cast by treeing the wax model to the wax rod. The product of this shop is the treed wax model ready for casting. However, second inspection of wax object before attaching is also responsibility of this shop. If there is any bubble, hole, or misshape of the wax, corrective action must be made in this shop before sending to investment casting; otherwise, imperfection of product will arise and lead to starting over process since the wax casting.

4. Investment Casting

This shop is responsible for making metal object. The process of this shop starts from inserting carefully a stainless steel flask inside the outer lip of sprue base, so as to surround the waxes. Then pour the mixed powder, around the wax models that are supported inside the stainless steel flask. This has to be made carefully because if investment containing air bubbles is poured around the waxes, many of these bubbles will cling to the wax and will translate to small metal bubbles on the piece once it is cast. The next step is wax elimination, sometimes called dewax. Waxes are removed by melting in high temperature. After that the flask must undergo a heat treatment process to eliminate any remaining wax. Then the flask is placed inside of a kiln. This process is called the burn out. The temperature of the kiln is slowly brought up to well in excess of one thousand degrees Fahrenheit over a period of several hours. Then the flask is moved out and metal material is cast into the flask. Next, leaving the flask to cool down for a while is needed in order to stiffen the invested metal. Then leaching the powder out and the rest is the metal object tree. The last function of this shop is detree the invested metal from its tree to piece form for processing of the next shop. This shop can be made in high volume and consume less time.

5. Shaping

The metal object piece is shaped by abrasion according to the design because mostly the detreed object pieces have low in conformance shape quality. Thus this process concerns with rough tumble, primary skin polish. In addition, functions of primary preparation the particular shape and skin that simplify for setting stone, includes in this shop.

6. Inserting Stone into Metal Object

This shop is responsible for setting stone which is the rest of setting into wax shop. For the case that stone is set into wax, the set object still has to get in this shop in order to

recheck and correct. This shop is the real labor intensive stage in which consume a lot of time and required high skill.

7. Polishing

This is the step of detailing the metal object. It involves making the product skin shiny. In this shop, there are 2 types of polishing:

1. Sand Polishing. The level of skin gloss from this type is not high. This polishing type is mostly done when rhodium coating is required.
2. Glossy Polishing. The level of skin gloss from this type is high. After polishing of this type, coating with rhodium is not necessary.

The type of polishing depends on customer requirement.

8. Q.C.

O.C shop is responsible for final inspection. It concerns overall inspection: stone, skin, shape, etc. If the product does not pass the quality standard, sending to concerned shop for rework of correct is the responsibility of this shop. And if the correction is made, the particular product will be sent back to inspect in this shop again. All the products that pass inspection in this shop will be transferred to the coating shop.

9. Coating

This shop is not high in labor intensive and does not concern with time consuming. There are 4 types of coating.

1. Rhodium Coating with nickel-copper. This process takes about 30 minutes.
2. Rhodium Coating without nickel-copper. This process takes about 5-10 minutes.
3. Gold Coating. This process time consumption depends on thickness required. The normal thickness is around 3 to 5 micron in which takes about 3 to 5 hours respectively.

Goal Coating with white color face. This type consists of two steps. First is coating goal as the same as type 3. Then painting white color, silver, onto the particular area. For time, it will depend on the required thickness and area for white painting.

4.2 Existing System Analysis

To analyse process flow, there is not only process flow route to be analysed but also other areas related with process flow must include in analysis. Those areas are as follow:

1. Process flow
2. Document flow
3. Material handling

The relationship of these factors can be represented as in Figure 4.4.

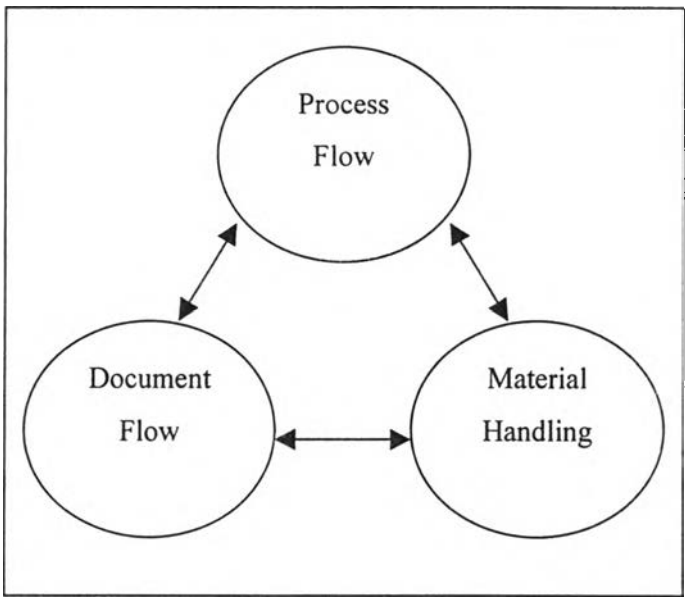

Figure 4.4: Process Flow Analysis

From the figure, these three factors have interrelated to each other. Changing in one has affected to the others.

4.2.1 Process Flow

For process flow aspect, the consideration can be catagorised into two cases as:

1. *Normal production flow*. In this case, it is the process flow in manufacturing the product.
2. *Rework flow*. In this case, the flow of process concerns with flow backward to the related shop for correct the product or work-in-process required reworking.

4.2.1.1 Normal Production Flow

There are two conditions of normal production flow. The difference of them is the method of setting stone into object. The detail of these two conditions are as following:

1. *Setting stone into wax* (before investment casting process). After wax casting, if setting stone into wax required, the process will flow to setting stone into wax shop and flow back to the main flow route at treeing shop. Product set into wax, still requires to pass through the setting stone into metal shop in order to recheck problem related with stone again.
2. *Setting stone into metal only* (after investment casting process). The process flows as the main process.

According to majority of productions are operated in job shop system, process flow is uncertain. The flow depends on type and design of product. In addition, the factory manufactures various types of product. Identifying flow of process related with each product type is difficult. Thus in order to provide clearly explore the detail of process flow the most ordered product type, ring, is chosen to be explored in this study. However, within the ring product, there is variety design in which results in uncertainty of process flow in manufacturing ring product. As consequence, the typical process flow of manufacturing ring product shown in figure 4.5 is chosen for exploring in this study.

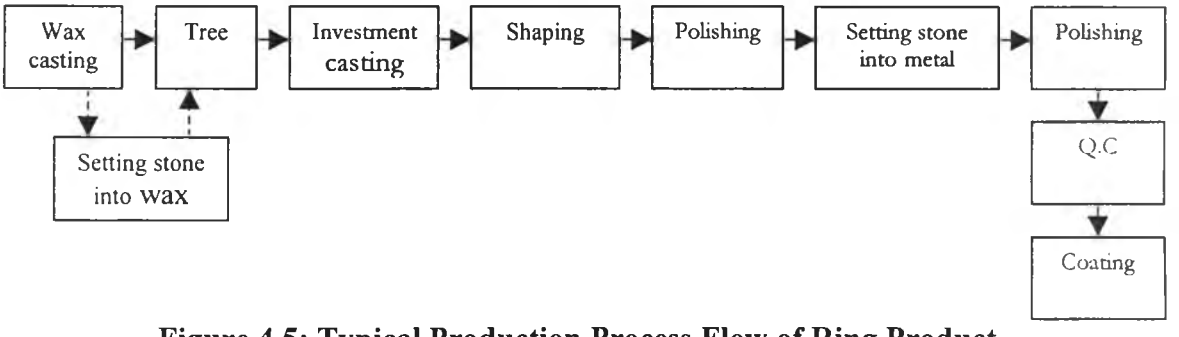

Figure 4.5: Typical Production Process Flow of Ring Product

The previous flows represent only manufacturing process. In practice, controlling flow of the process and quality of work is necessary. Thus, Q.C shop and Coordinator shop must be inside the flow route. The entire process flow for making ring is shown in Figure 4.6

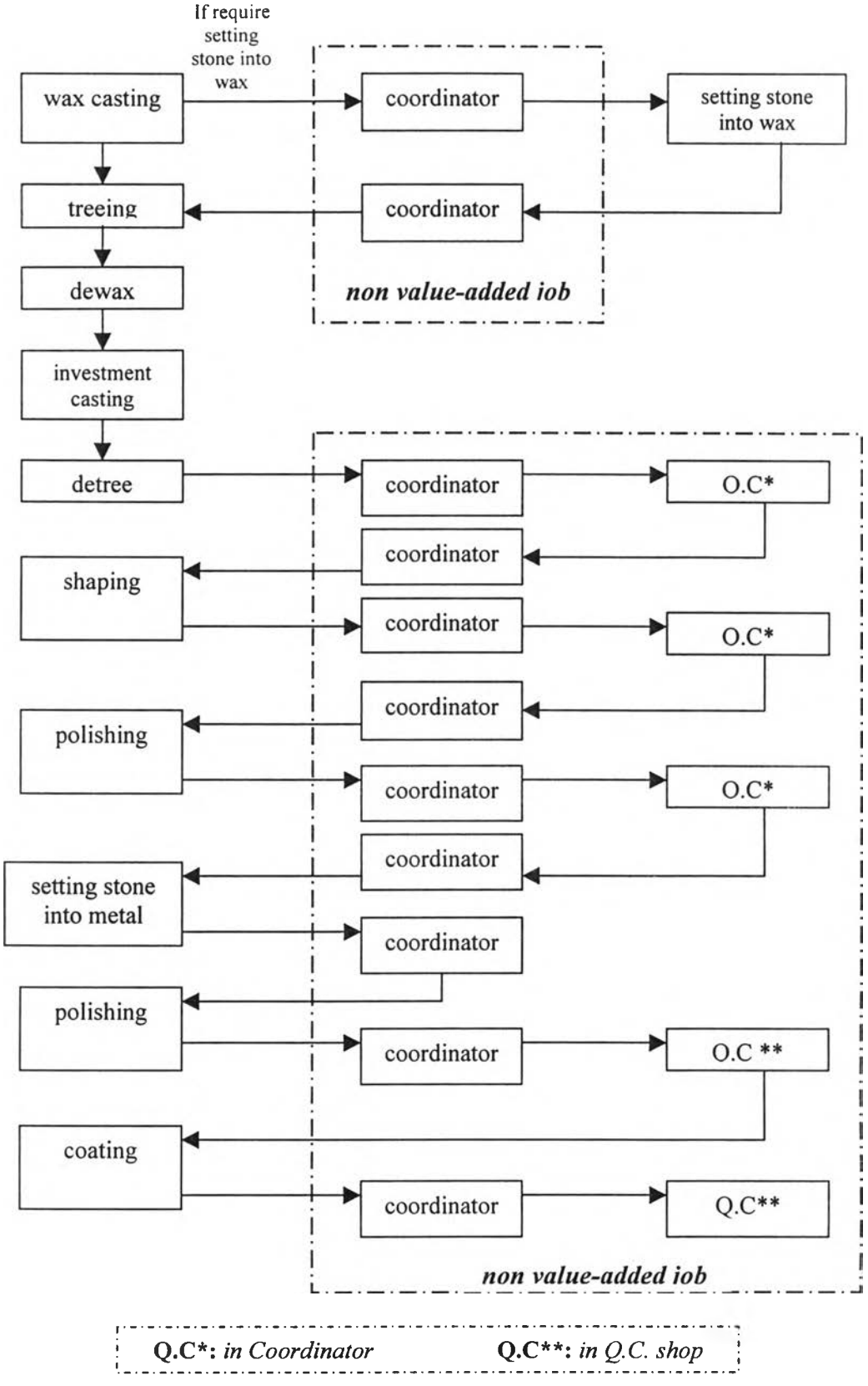

Figure 4.6: Typical Process Flow Diagram of Ring Product

From the represented flow, it contains two types of job.

1. ***Value-added job***. This is the job that involves with transforming from raw material to finish product. Consider value in view of production, the product which comes out from this type of job must has higher value than before it gets into the shop. In the studied process flow, shops that provide value-added job are wax casting shop, setting stone into wax shop, treeing shop, investment casting shop, tumbling shop, setting stone into metal shop, and coating shop.
2. ***Non value-added job.*** This job does not concern directly with transforming product but it functions to support generating quality product and control processing. In the studied process flow, there are two shops fall in this type of job.

   2.1) Q.C shop. Work provided by Q.C shop is counted in this type. Q.C functions to inspect both work in process and finished product for controlling the quality to be within set standard. No transforming product in this Q.C shop. In physical term, value is not added into raw material or product. However, in order to provide quality product, Q.C job is still required because it is necessary process for producing quality product. Without Q.C job, assuring to meet customer satisfaction may lack.

   2.2) Coordinator shop. This is another shop that falls into this area. Coordinator's functions concern with controlling and managing flow of process between shops.

- **Role of Coordinator Shop**

The coordinator shop has many functions as:

1. It has to control production flow.
2. It is the middleman to receive and distribute job to each shop.
3. It has to inspect quality of the received work from investment casting shop and other shops.
4. In the case of when problem occurs, it is responsible to coordinate between top production management level and the particular shop to find out solution and solve the problem.
5. It is responsible to manage rework occurred within production process flow. It has to open rework document, distribute the work required rework, receive the reworked work, inspect the reworked work, and control rework rate.

6. It is responsible to check conformation to production order such as size, color, quantity, shape, characteristic etc., in order to keep the right amount conform the production order.
7. It functions to control overall flow and schedule of production department.
8. It is the middleman who coordinates with external department, between marketing and production.
9. It is a distributor of material required controlling such as stone (diamond, opal, emerald, etc), raw metal (silver seed, goal bar), etc. That because these mentioned materials concern with high cost, controlling in terms of amount, volume, and weight is required. Otherwise, stealing can be done easily. That also provides the problem of difficulty for tracking.

- **Flow Process Chart Analysis**

From the mentioned typical process flow, analysis of flow process is represented by the Flow Process Chart as illustrated in Table 4.1. In the chart, it summaries the detail of activity related with manufacturing flow.

This chart is made from observation one lot production. As a result, it is found 17 operations, 21 transportations, 13 delays, 21 inspections, and 0 store. It contributes totally 282 meters in distance of transportation.

4.2.1.2 Rework flow

The processing within the flow mostly concerns with labour intensive, rework is inevitable. However, rework have a critical impact on the flow of process. It makes flow to turn backward and repeat processing. Rework can occur at any shop depending on design, raw material, skill, etc.

Rework flow of the mentioned typical process flow is illustrated in Figure 4.7. From the figure, there are eight possibilities for rework activity involved with this typical process flow. Reworking is ordered to related shop by coordinator and Q.C. shop who are responsible for inspection activity. The shops required rework are shaping, polishing, setting stone into metal, and coating shop.

Table 4.1: Flow Process Chart (Before Improvement)

FLOW PROCESS CHART : Material Type — sheet 1 of 2

Process: Making ring product

Beginning: Inject wax into elastic cavity mould

Ending: Handling finish product to export division

Method: Present

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

Description	Distance (M)	Symbol				
		○	⇨	D	□	▽
1. Inject wax		X				
2. Finishing wax object skin		X				
3. Inspect finished wax object					X	
4. Taken to coordinator	8		X			
5. Waiting for making out job order				X		
6. Taken to setting stone into wax shop	14		X			
7. Set stone into wax		X				
8. Brought the finished setting to coordinator	14		X			
9. Waiting for receiving ordered job process				X		
10. Sent to treeing shop	8		X			
11. Tree the wax objects		X				
12. Await untreeing				X		
13. Sent to investment casting shop	10		X			
14. Making powder mould around the wax tree		X				
15. Dewax		X				
16. Kiln the power mould		X				
17. Cast metal material into the flask		X				
18. Leached the powder out		X				
19. Brought the invest tree to weigh at coordinator	10		X			
20. Weigh the metal tree					X	
21. Brought back to investment casting shop	10		X			
22. Detree the metal object		X				
23. Sent to coordinator	10		X			
24. Inspect the skin					X	
25. Measure size					X	
26. Count quantity of each size					X	
27. Waiting for making out shaping job order				X		
28. Taken to shaping shop	10		X			
29. Shaped		X				
30. Brought back to coordinator	10		X			
31. Waiting for receiving ordered job process				X		
32. Inspect the shape					X	
33. Measure size					X	
34. Count quantity of each size					X	
35. Waiting for making out job order				X		

Table 4.1: Flow Process Chart (Before Improvement)-(continued)

FLOW PROCESS CHART : Material Type — sheet 2 of 2

Process: Making ring product

Beginning: Inject wax into elastic cavity mould

Ending: Handling finish product to export division

Method: Present

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

Description	Distance (M)	Symbol				
		○	⇨	D	□	▽
36. Taken to polishing shop	20		X			
37. Polished		X				
38. Brought back to coordinator	20		X			
39. Waiting for receiving ordered job process				X		
40. Inspect the skin					X	
41. Measure size					X	
42. Count quantity of each size					X	
43. Waiting for making out job order				X		
44. Taken to setting stone into metal shop	16		X			
45. Sealed with wax for setting process		X				
46. Set stone into metal object		X				
47. Leached wax out		X				
48. Brought back to coordinator	16		X			
49. Waiting for receiving ordered job process				X		
50. Measure size					X	
51. Count quantity of each size					X	
52. Waiting for making out polishing job order				X		
53. Taken to polishing shop	20		X			
54. Polished skin		X				
55. Brought back to coordinator	20		X			
56. Waiting for receiving ordered job process				X		
57. Count quantity of each size					X	
58. Taken to O.C. shop	3		X			
59. Inspected quality					X	
60. Measure size					X	
61. Count quantity of each size					X	
62. Waiting for making out coating job order				X		
63. Taken to coating shop	25		X			
64. Coated skin		X				
65. Brought back to coordinator	25		X			
66.. Waiting for receiving ordered job process				X		
67. Count quantity of each size					X	
68. Taken to Q.C. shop	3		X			
69. Inspect detail for final inspection					X	
70. Measure size					X	
71. Count quantity of each size					X	
72. Sent to export shop	10		X			
TOTAL	282	17	21	13	21	

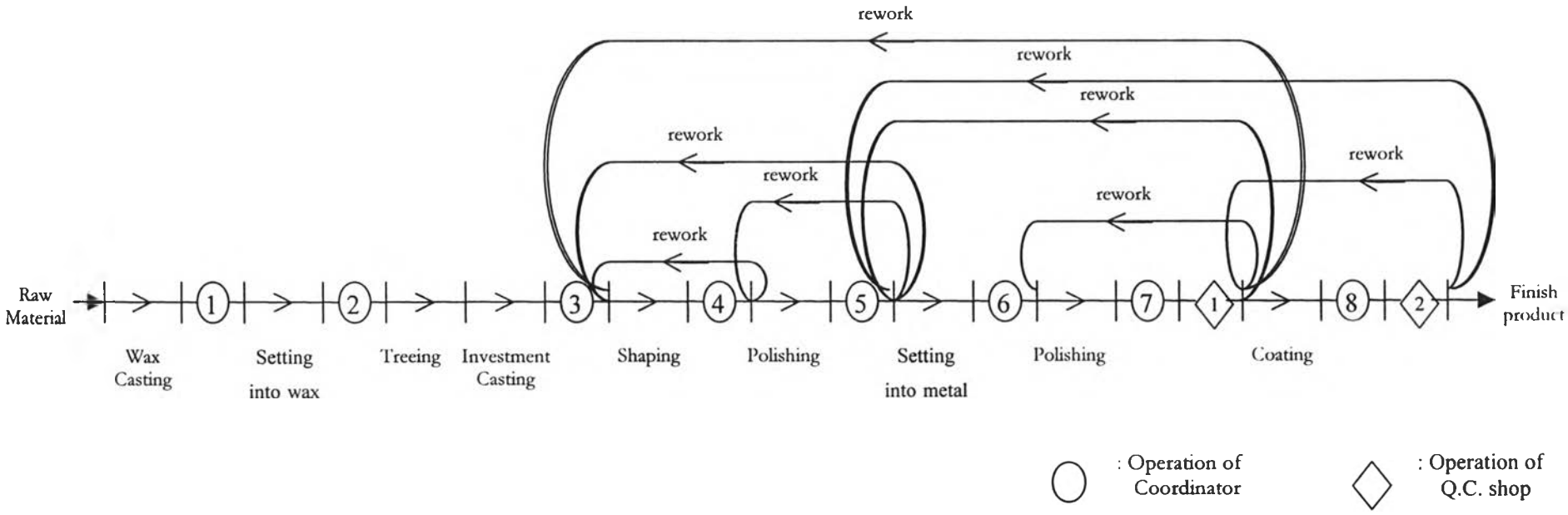

Figure 4.7: Rework Flow (Before Improvement)

- **Problem related with existing process flow**

1. Process flow is complicated causing from passing many shops.
2. The process flow is long. The longer flow means the higher time consumed in producing product.
3. Coordinator shop holds many responsibilities and that comes out with unable to provide effective controlling and managing flow of process.
4. Rework flow causes difficulty in controlling flow of process. Tracking work becomes more difficult because flow is split: rework flows backward and the rest flows forward. Although most of the products in one order are finished, waiting for the rest reworked still required and leading to delivery delay.

4.2.2 Document Flow

Clearly, without supporting from good document system, flow of work between process can not move smoothly in this job shop production system. Document system of job flow has to serve flow of process. Thus, when analysing one, consideration about impact on the other one can not be ignored. This helps to identify their relationship in operation.

The documents used in process flow are summarised as in table 4.2.

- **Problem related with document flow system**

1. There is no overall or summary document within process flow of any product model.
2. The existing document system does not simplify the process to flow fast and easily.
3. The existing document system does not support rework condition effectively. That results in the difficulty of controlling and tracking rework job.

Table 4.2: Document Flow Description (Before Improvement)

Document Name	Flow of Document	Objective	Copy	Figure
1.Coordinator 1. Production order	Coordinator ------→ every shop	To inform production order and product specification and use as reference in processing	10	4.8
2. Job order	Coordinator ------→ setting stone into wax shop	To order setting stone into wax job and give related specification	2	4.9
	Coordinator ------→ shaping shop	To order job in shaping shop, give related specification, and record weight of ordered job	2	4.11
	Coordinator ------→ polishing shop	To order polishing job and give related specification and caution	2	4.12
	Coordinator ------→ setting stone into metal shop	To order setting stone into metal job and give related specification and caution	2	4.10
	Coordinator ------→ related shop	To order rework job and give caution area	2	4.13
3. Note	Coordinator ------→ Q.C shop	To order inspection job and give related amount information	-	

2. Setting stone into wax shop 1. Job order	setting stone into wax shop ------→ Coordinator	To return ordered setting stone job	1	4.9
	setting stone into wax shop ------→ Coordinator	To return ordered rework job	1	4.13
3. Treeing shop 1. Investment casting job order	treeing shop ------→ investment casting shop	To order metal casting job and to record related weight for coordinator in checking weight of metal material	2	4.15
4. Investment casting shop 1. Investment casting job order	investment casting shop ------→ Coordinator	To provide detail of weight related in metal casting process.	1	4.15
5. Shapping shop 1. Job order	shaping shop ------→ Coordinator	To return ordered shaping job	1	4.11
	shaping shop ------→ Coordinator	To return ordered rework job	1	4.13
	shaping shop ------→ Q.C.	To return ordered rework job	1	4.13

6. Polishing shop 1. Job order	polishing shop ------→ Coordinator	To return ordered polishing job	1	4.12
	polishing shop ------→ Coordinator	To return ordered rework job	1	4.13
	polishing shop ------→ Q.C.	To return ordered rework job	1	4.13
7. Setting stone into metal shop 1. Job order	setting stone into metal shop ------→ Coordinator	To return ordered setting stone job	1	4.10
	setting stone into metal shop ------→ Coordinator	To return ordered rework job	1	4.13
	setting stone into metal shop ------→ Q.C.	To return ordered rework job	1	4.13
8. Q.C. 1. Job order	Q.C. ------→ coating shop	To order coating job and give related specification	2	4.14
	Q.C. ------→ related shop	To order rework job and give caution area	2	4.13

9. Coating shop 1. Job order	coating shop ------→ Coordinator	To return ordered coating job	1	4.14
	coatingshop ------→ Q.C.	To return ordered rework job	1	4.13

From the table, document flow can be shown as in figure 4.8-4.15

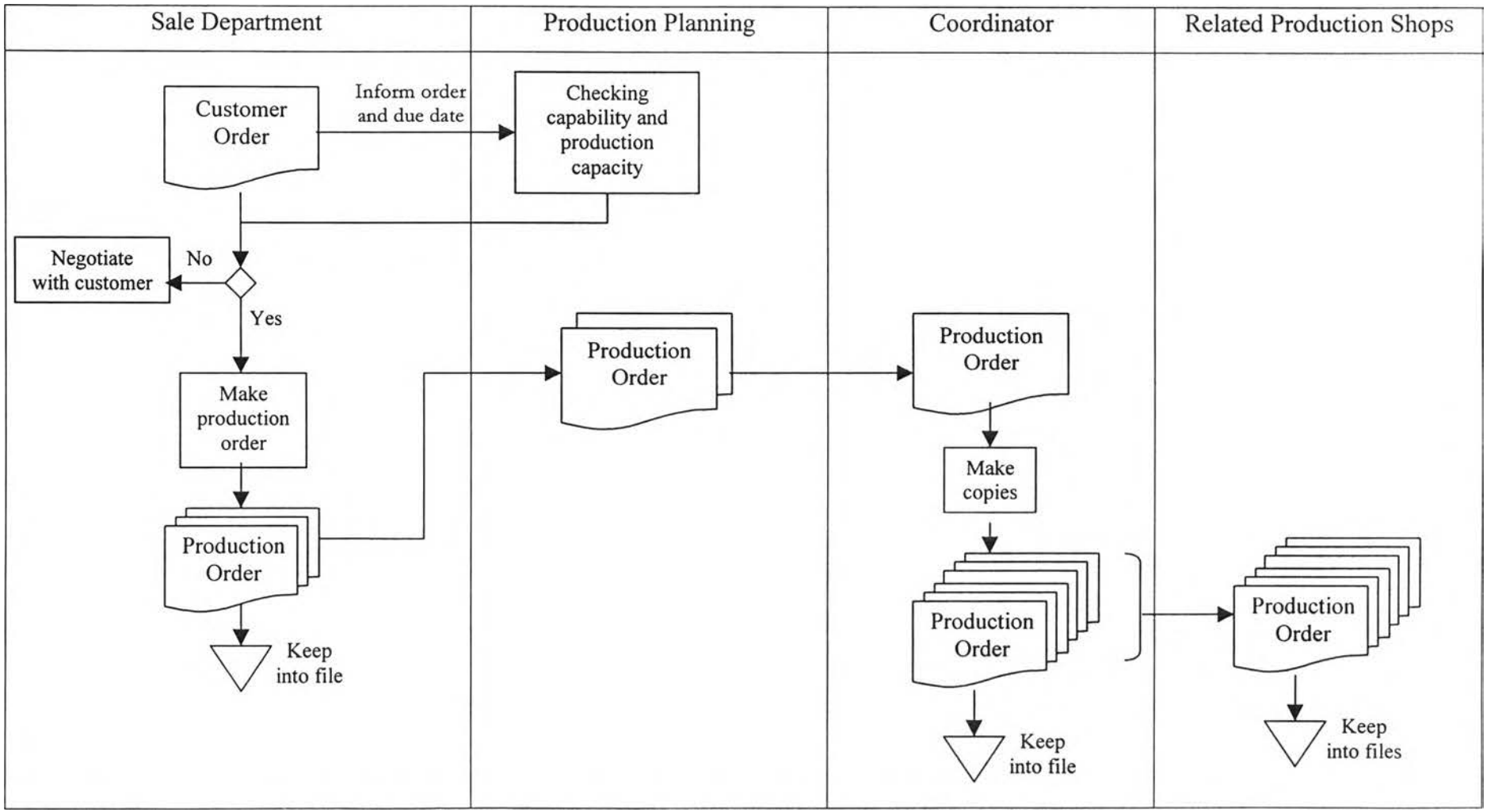

Figure 4.8: Document Flow of Production Order (Before Improvement)

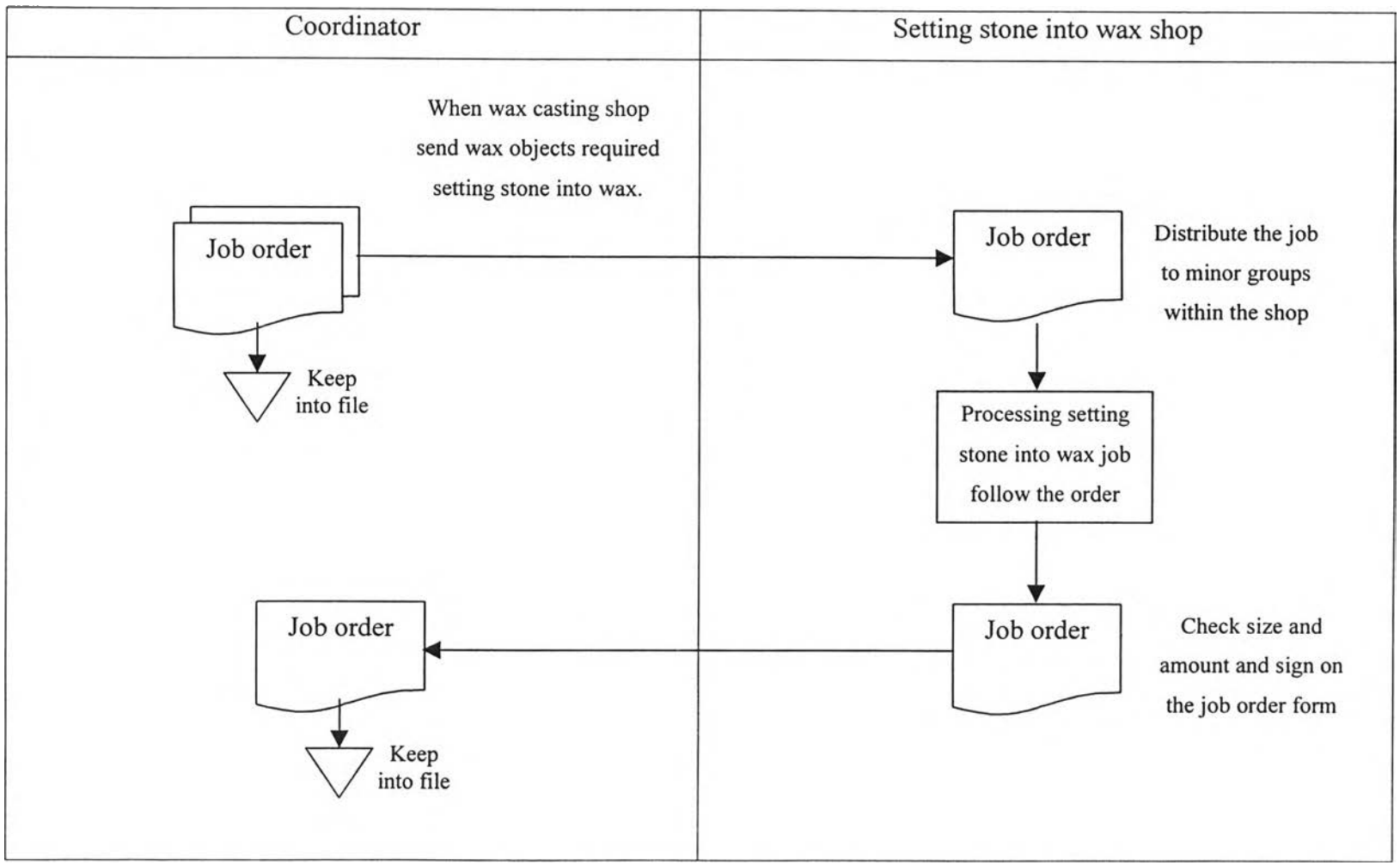

Figure 4.9: Document Flow of Job Order for Ordering Setting Stone into Wax Job (Before Improvement)

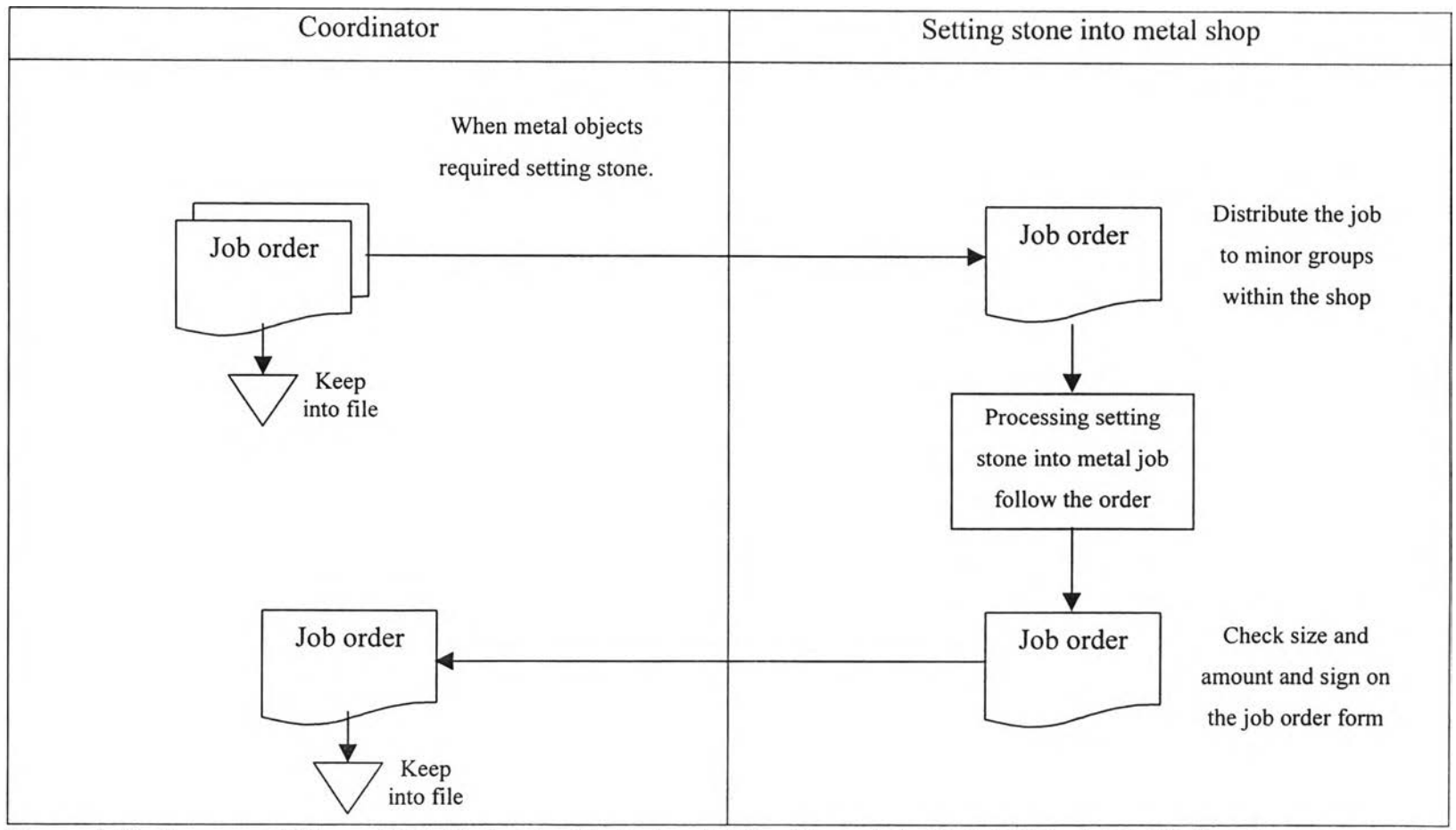

Figure 4.10: Document Flow of Job Order for Ordering Setting Stone into Metal Object Job (Before Improvement)

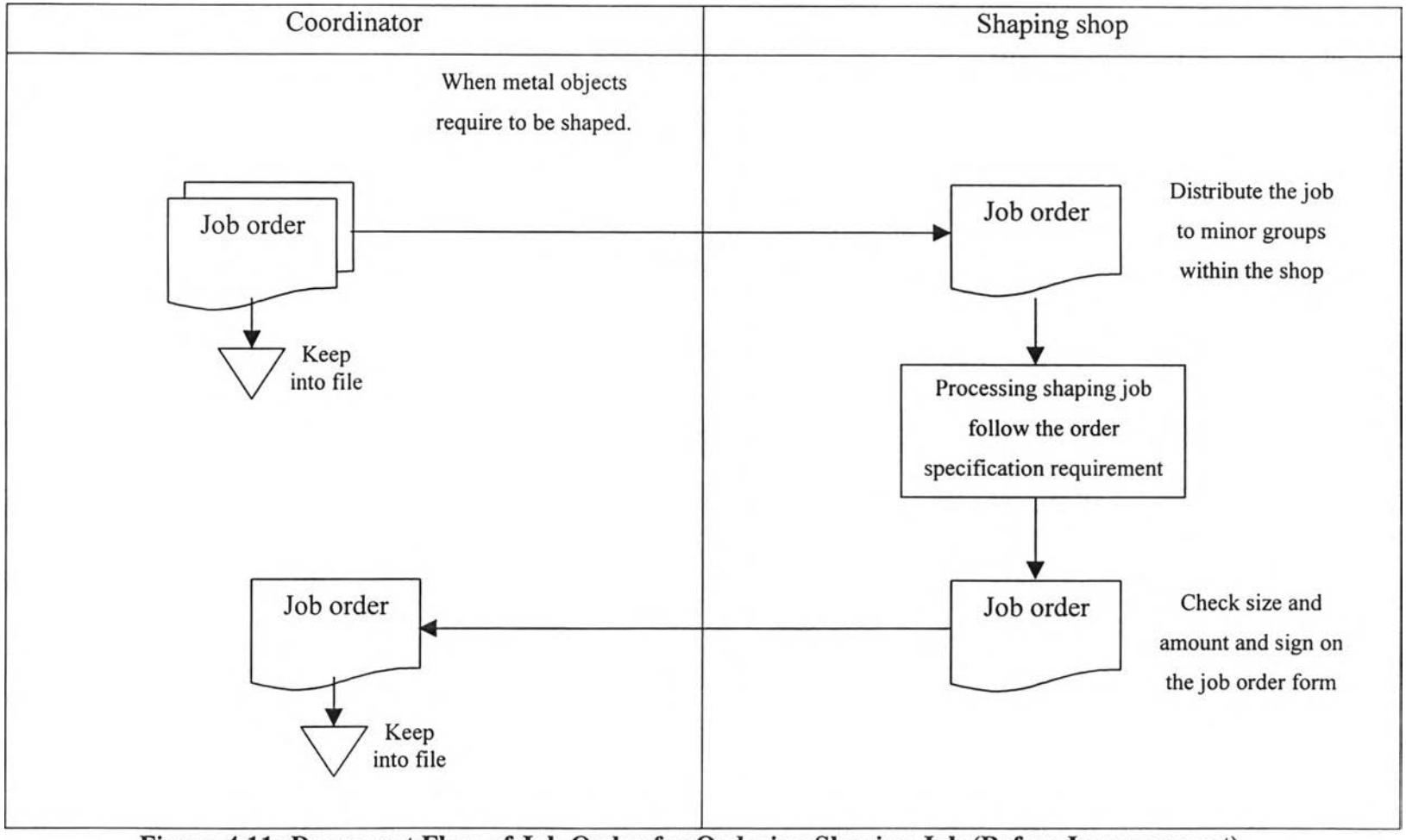

Figure 4.11: Document Flow of Job Order for Ordering Shaping Job (Before Improvement)

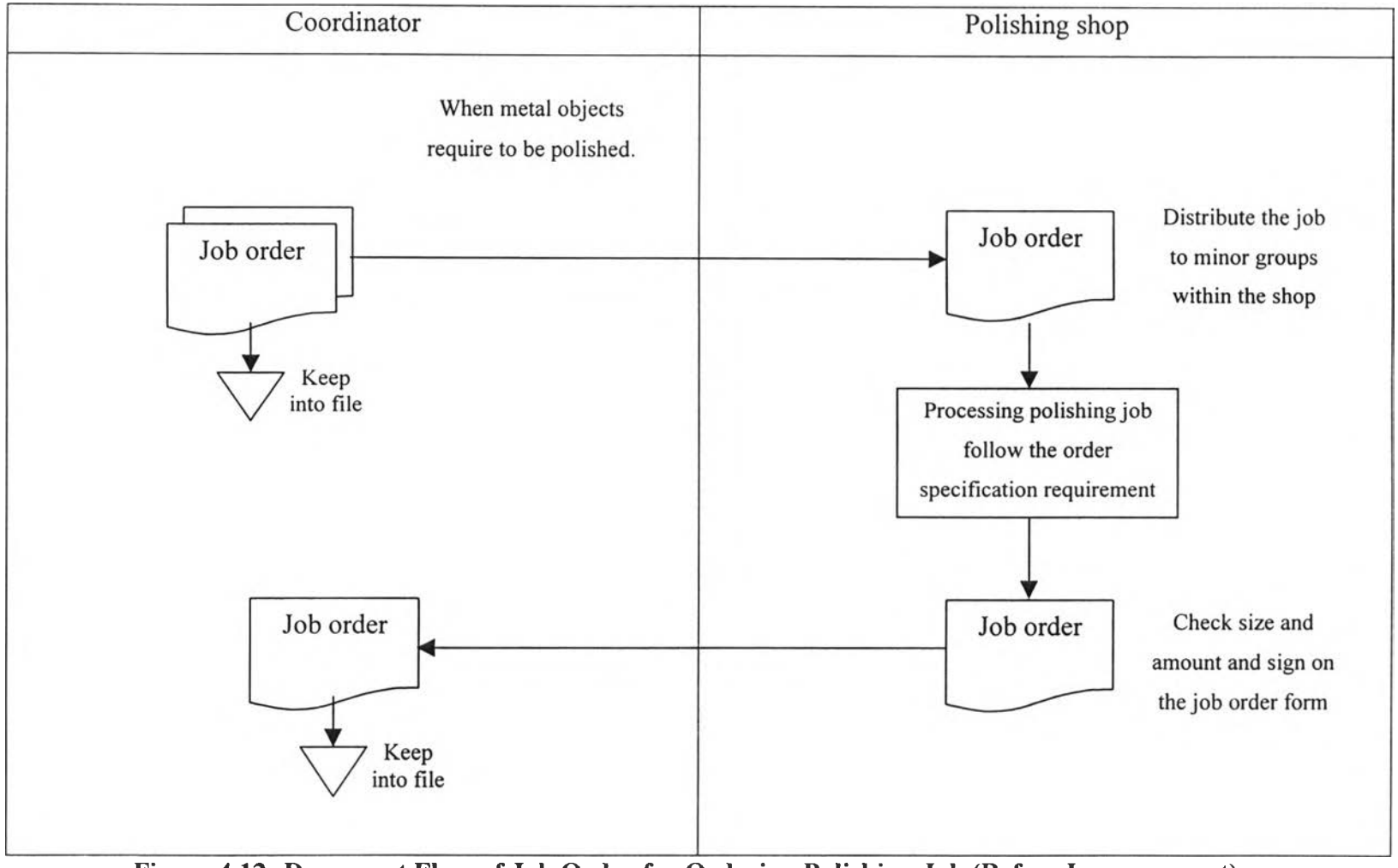

Figure 4.12: Document Flow of Job Order for Ordering Polishing Job (Before Improvement)

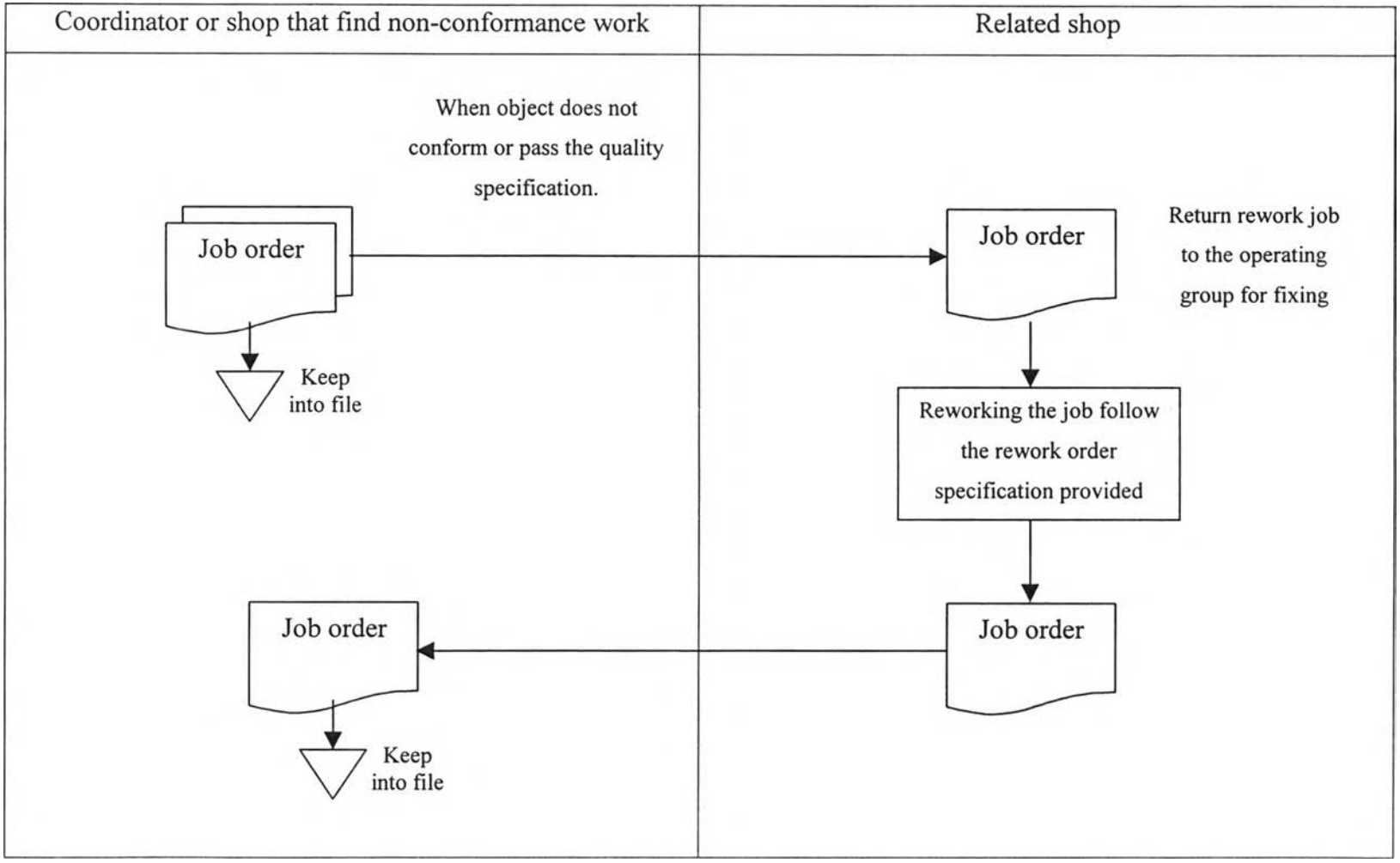

Figure 4.13: Document Flow of Job Order for Ordering Related Rework Job (Before Improvement)

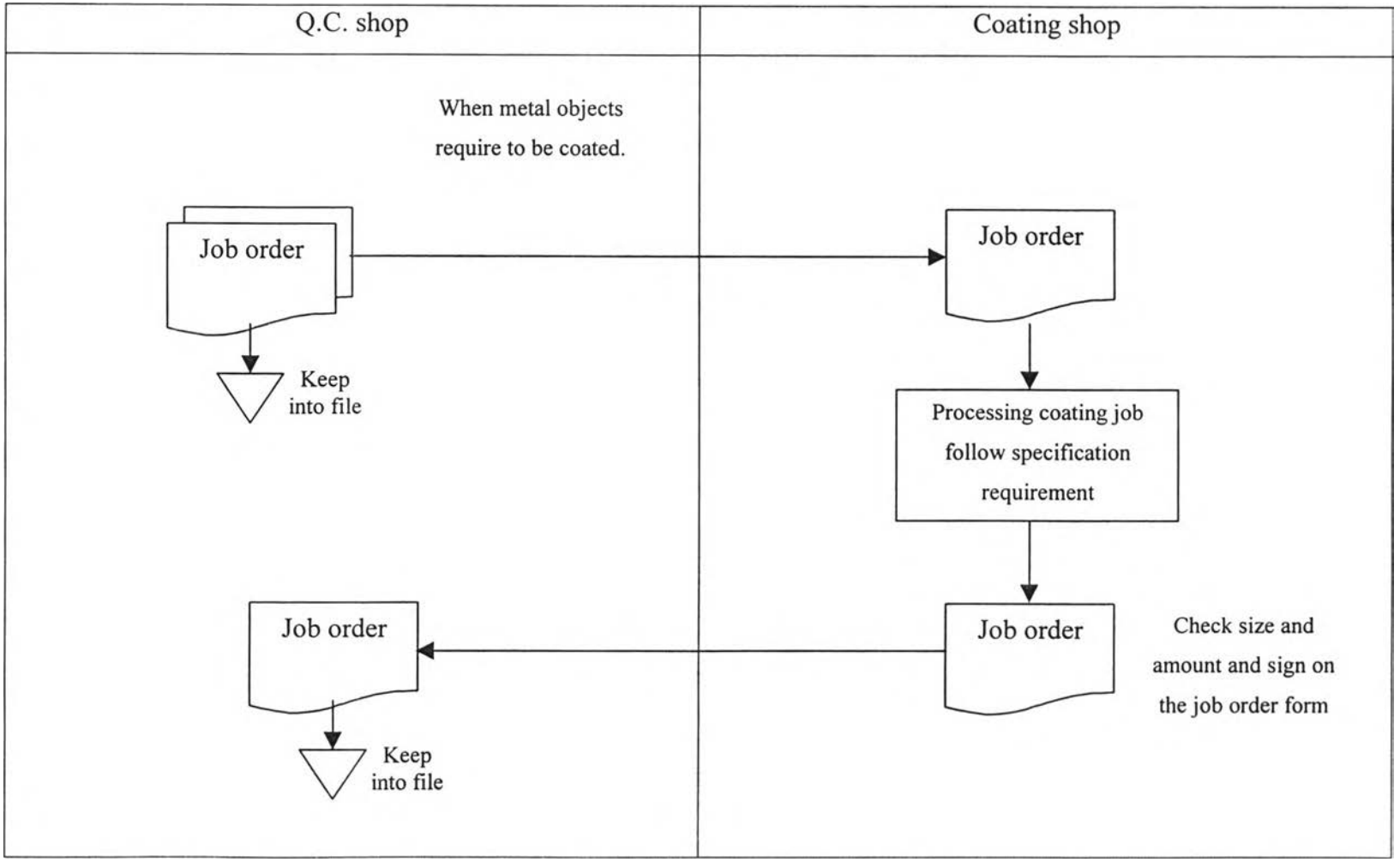

Figure 4.14: Document Flow of Job Order for Ordering Coating Job (Before Improvement)

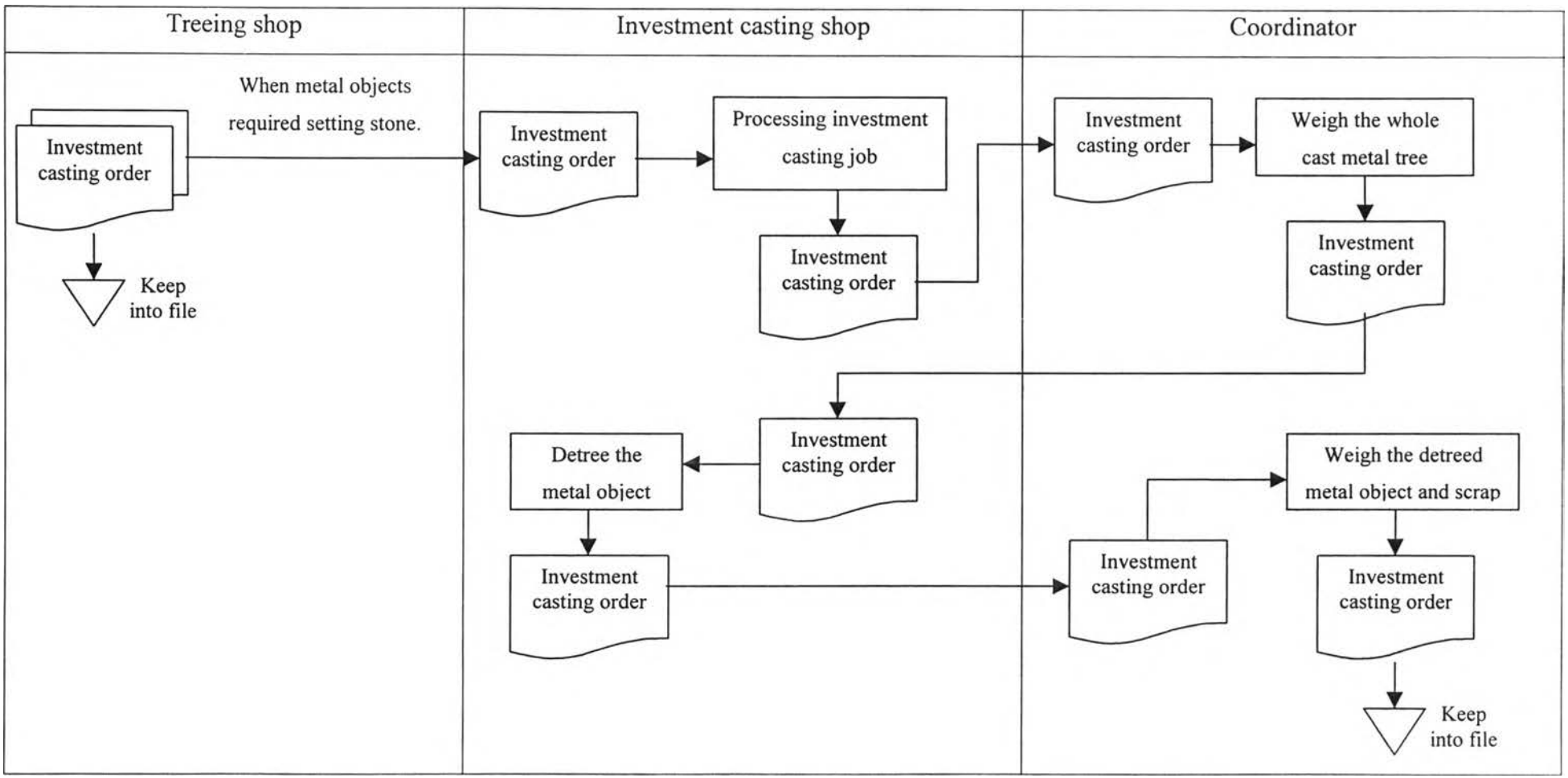

Figure 4.15: Document Flow of Job Order for Ordering Investment Casting Job (Before Improvement)

The entire production document flow system is shown in Figure 4.16.

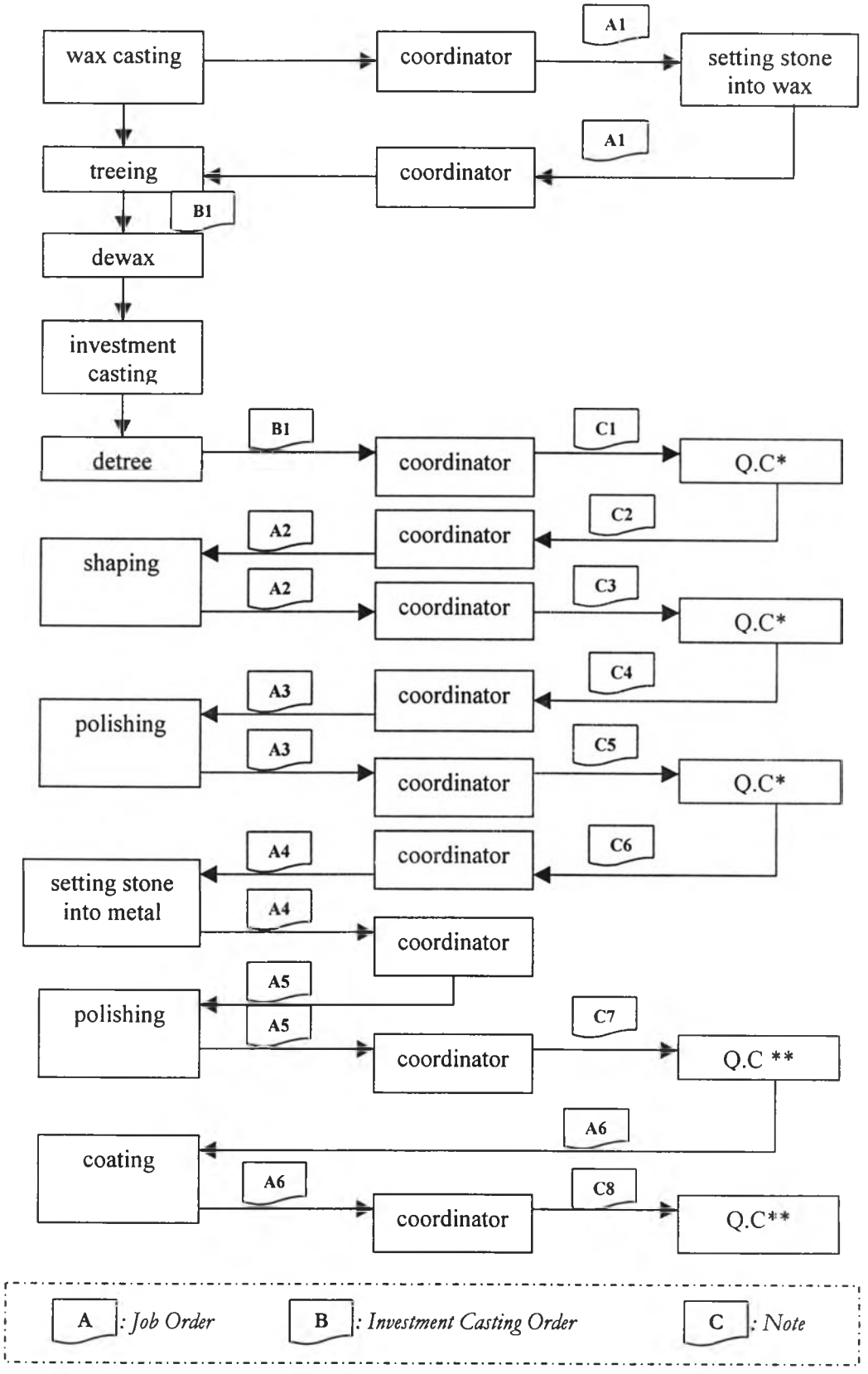

Figure 4.16: Production Document Flow System (Before Improvement)

4.2.3 Material Handling

The two types of material handling are used in process flow.

1. *Box*. This type of material handling is used to transport object which is in wax form. Because the box has lid to cover for protecting the wax object which is sensitive with air.
2. *Tray*. This type is used in transportation of object in metal form. One tray consists of 4-6 holes depending on tray size. Each hole has capacity for containing around 5 -10 pieces of ring.

- **Problem related with material handling.**

1. Tray that part put into the hole causes quality problem. Scratch between part often occurs.
2. Tray is easy to fall down when stacking tray is performed.
3. Part put in hole does not simplify counting quantity of part. In addition, discipline of specifying quantity for each hole has not been conformed from using the tray.
4. When size of part is separated by hole, mixing problem of size sometimes happen because they slip to others hole easily.
5. While transporting to too many shops, steeling part is found but tracking can not be accomplished.
6. It is difficulty for tracking in terms of who made each lot.

4.2.4 Production Planning

In planning, there is no systematic method applied. Estimation by based on experience of planner is used. Furthermore, there is no production plan and schedule document available.

There is no formal rule for scheduling. Scheduling is based on experience in which can be summarised as:

1. *Due date*. This is the first priority used to consider in scheduling.

2. *Difficulty*. Level of difficulty is decided by based on experience of experts and the higher difficulty level has the higher priority to be processed.

- **Problem related with production planning and scheduling**

1. There is no master production plan.
2. There is no production plan available for each shop.
3. Finish date for each shop is not specified. As a result, each shop can not know their status, especially for the shops in the middle of process in which result in urgent working and over time of shops around the end of process and causing delay in delivery.
4. When previous order delay, it impact flow of the rest orders in processing and can lead to the same delay problem.
5. No summary of workload is shown.

4.3 Improvement

Before improving the process flow, area of improvement should be specified. The possible areas for improvement are listed below.

1. Process Flow
2. Document Flow
3. Material Handling
4. Production Planing

While determine improvement method, there is not forming individual. They are developed along together for providing the effective support and match among them.

4.3.1 Process Flow

As in process flow analysis, analysing concerns with two cases of flow.

4.3.1.1 Normal Production Flow

After analysing process flow, the coordinator and Q.C. shop are the potential areas for improvement. This is supported from result of analysing Flow Process Chart. It is indicated that the operation activity comprises 17 steps from 72 steps within one lot process flow. The rest are 21, 13 21, and 0 for transportation, delay, inspection, and store activity respectively. Considering together with process flow diagram, coordinator and Q.C shop is the obvious area concerning with non-productive activity. However Q.C shop function is still necessary and highly impacts to support processing product. On the other hand, coordinator functions are found that some functions can be cut out and shorten the process flow by pushing the flow pass through without stopping at coordinator shop as previous. Nevertheless, the cut functions are still considered. Replacement of those functions is contributed by new material handling system, basket system.
The unnecessary roles of coordinator cut are listed below.

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

The improved typical process flow is shown in figure 4.17.

Figure 4.17 illustrates the improvement of entire process flow. When compare with the typical traditional process flow, shown in Figure 4.6, three movements to coordinator has been cut. Whereas, functions of the remain coordinator are diminish. The reasons for not to cut the out are:

1. It concerns with high value material such as metal, gems, etc. Preparing and distribute is still required control of coordinator. Thus the flow from coordinator to shaping and setting stone into wax and metal shop, in Figure 4.17, still remains.
2. It involves with checking quantity of part from investment casting. That is important for tracking conformance production order.

3. It has to control production flow and overall flow.
4. It is responsible to coordinate between top management level and shop floor.

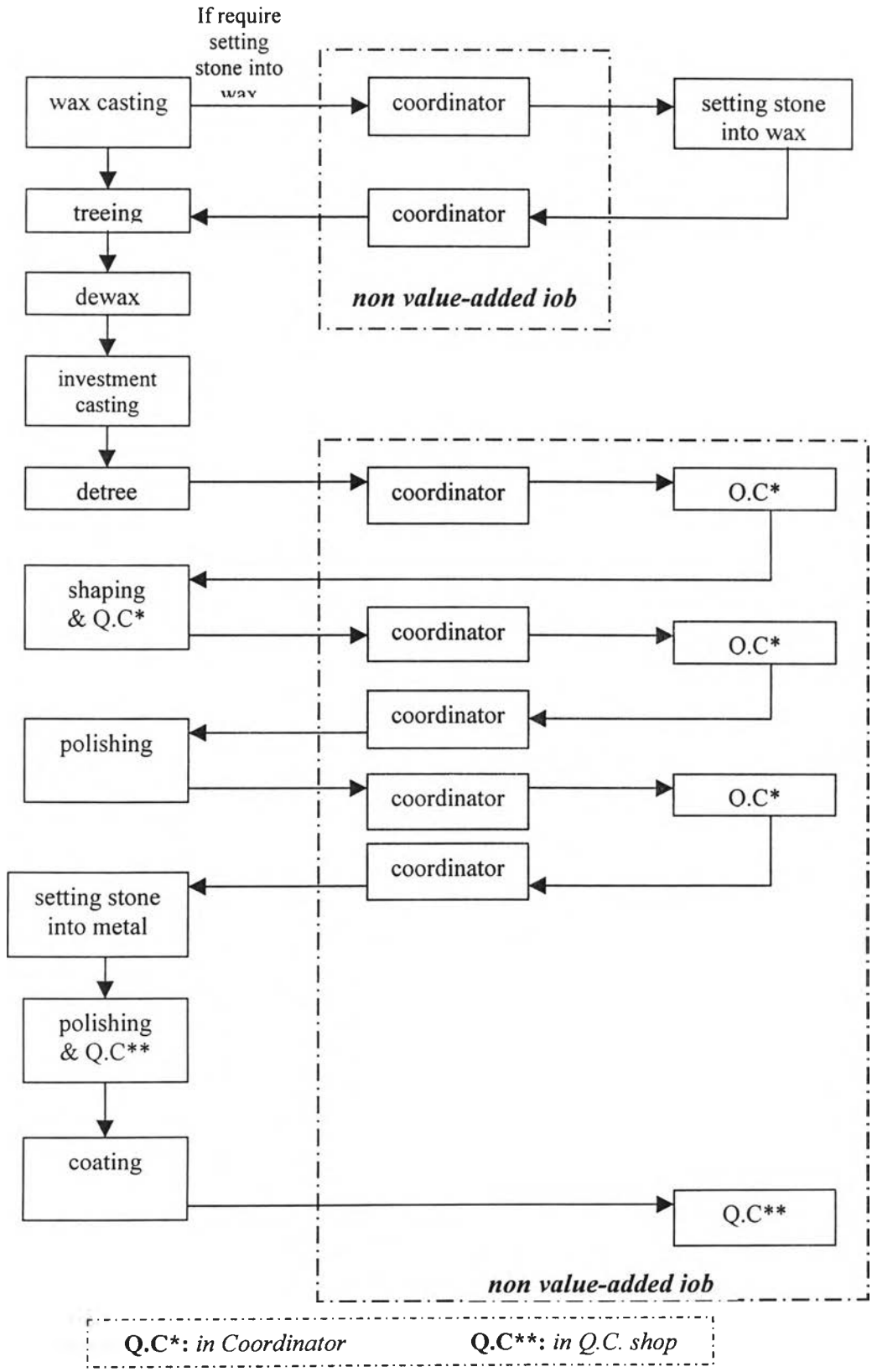

Figure 4.17: Typical Process Flow Diagram (After Improvement)

- **Flow Process Chart**

From the improved process flow, analysis of the flow process is represented in another view by the Flow Process Chart as illustrated in Table 4.3. In the chart, it summaries the detail of improved flow activity.

This chart is made from observation one lot production having the flow as typical. As consequence of improvement implementation, it is found 17 operations, 18 transportation, 11 delays, 12 inspections, and 0 store. It contributes totally 247 meters in distance of transportation.

4.3.1.2 Rework Flow

Since process flow has been improved, that has affected the flow of external rework. Rework flow of typical process flow is illustrated in Figure 4.18. From the figure 4.18, there is a reduction of five possibilities for rework activity involved with the process flow. Shops who are responsible for ordering rework job are Q.C. and polishing shop. Q.C is still the same for this respond whereas polishing has been replaced coordinator of this function. After processing in polishing shop, this outlet is the most points required reworking. That because processing polish normally contributes damage on other shops' finished work. Thus polishing shop is chosen for improved flow to be a distributor of external rework.

Table 4.3: Flow Process Chart (After Improvement)

FLOW PROCESS CHART : Material Type — sheet 1 of 2

Process: Making ring product

Beginning: Inject wax into elastic cavity mould

Ending: Handling finish product to export division

Method: Proposed

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

Description	Distance (M)	Symbol				
		○	⇨	D	□	▽
1. Inject wax		X				
2. Finishing wax object skin		X				
3. Inspect finished wax object					X	
4. Taken to coordinator	8		X			
5. Waiting for making out job order				X		
6. Taken to setting stone into wax shop	14		X			
7. Set stone into wax		X				
8. Brought the finished setting to coordinator	14		X			
9. Waiting for receiving ordered job process				X		
10. Sent to treeing shop	8		X			
11. Tree the wax objects		X				
12. Await untreeing				X		
13. Sent to investment casting shop	10		X			
14. Making powder mould around the wax tree		X				
15. Dewax		X				
16. Kiln the power mould		X				
17. Cast metal material into the flask		X				
18. Leached the powder out		X				
19. Brought the invest tree to weigh at coordinator	10		X			
20. Weigh the metal tree					X	
21. Brought back to investment casting shop	10		X			
22. Detree the metal object		X				
23. Sent to coordinator	10		X			
24. Inspect the skin					X	
25. Measure size					X	
26. Count quantity of each size					X	
27. Waiting for making out shaping job order				X		
28. Taken to shaping shop	10		X			
29. Shaped		X				
30. Inspect shape and related detail					X	
31. Brought back to coordinator	10		X			
32. Waiting for receiving ordered job process				X		
33. Sampling inspect					X	
34. Waiting for making out job order				X		
35. Taken to polishing shop	20		X			

Table 4.3: Flow Process Chart (After Improvement)-(continue)

FLOW PROCESS CHART : Material Type — sheet 2 of 2

Process: Making ring product

Beginning: Inject wax into elastic cavity mould

Ending: Handling finish product to export division

Method: Proposed

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

Description	Distance (M)	Symbol				
		○	⇨	D	□	▽
36. Polished		X				
37. Inspect skin					X	
38. Brought back to coordinator	20		X			
39. Waiting for receiving ordered job process				X		
40. Sampling inspect					X	
41. Waiting for making out job order				X		
42. Taken to setting stone into metal shop	16		X			
43. Sealed with wax for setting process		X				
44. Set stone into metal object		X				
45. Leached wax out		X				
46. Waiting for making out polishing job order				X		
47. Taken to polishing shop	5		X			
48. Polished skin		X				
49. Inspect skin					X	
50. Taken to O.C. shop	22		X			
51. Sampling inspect overall quality					X	
52. Waiting for making out coating job order				X		
53. Taken to coating shop	25		X			
54. Coated skin		X				
55. Brought back to Q.C. shop	25		X			
56. Waiting for receiving ordered job process				X		
57. Inspect detail for final inspection					X	
58. Sent to export shop	10		X			
TOTAL	247	17	18	11	12	

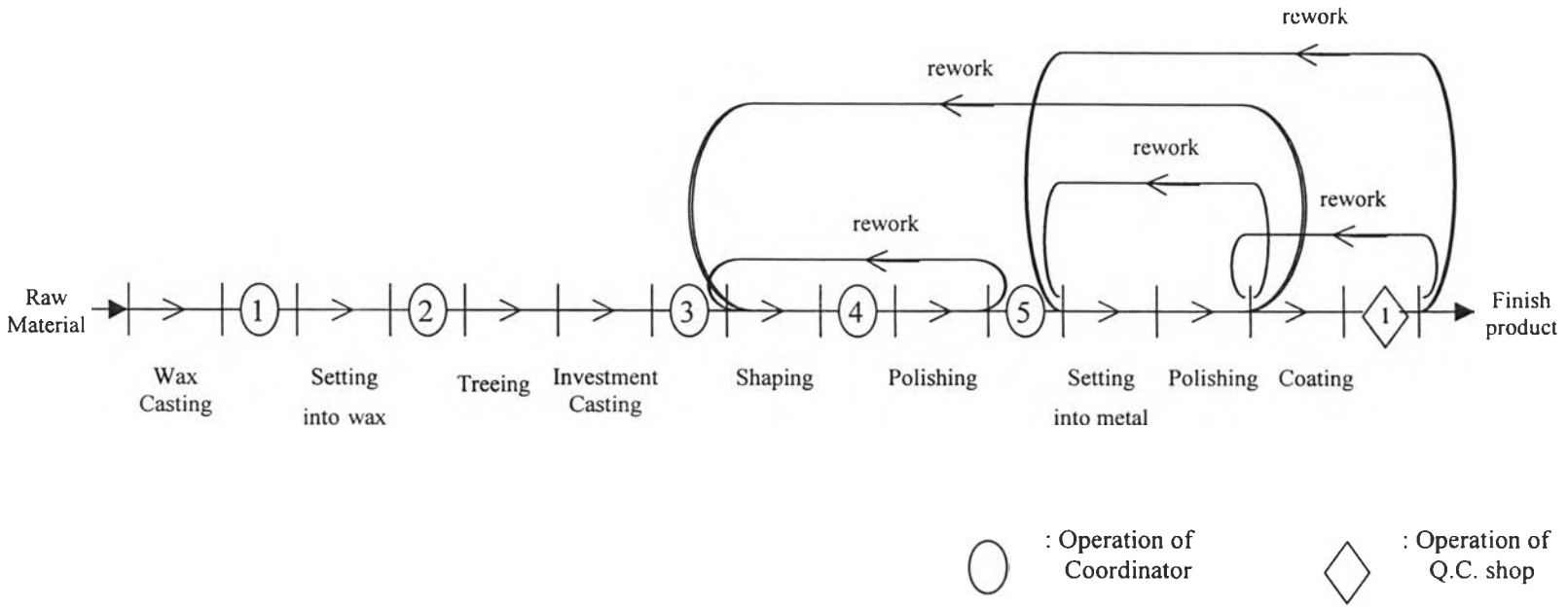

Figure 4.18: Rework Flow (After Improvement)

- **Improved Production Layout**

As a result of improved process flow, the change can be represented by Figure 4.19.

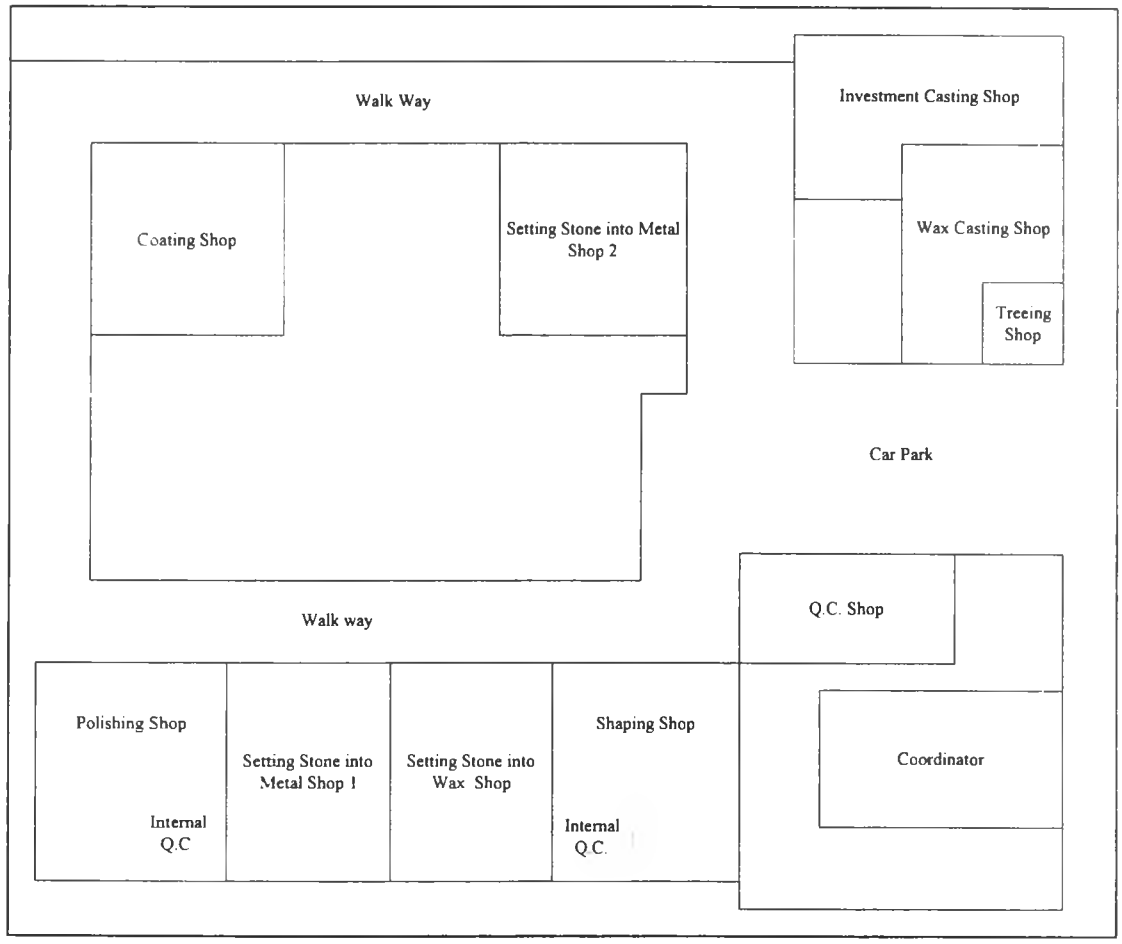

Figure 4.19: Improved Production Layout

As the process flow change, Q.C. work from polishing and shaping shops is required in order to cover the cut role of coordinator shop. Internal Q.C. is established. Figure 4.19 illustrates the layout of internal Q.C. in both shops.

4.3.2 Document Flow

Since the process flow has been changed, basket system is introduced, basket control document and rework document are created in order to support operation of those improvement. Moreover, some ineffective documents are improved. The details of improved document system are summarised in Table 4.3.

Table 4.4 Document Flow Description (After Improvement)

Document Name	Flow of Document	Objective	Copy	Figure
1.Coordinator 1. Production order	Coordinator ------→ every shop	To inform production order and product specification and use as reference in processing	10	4.20
2. Job order	Coordinator ------→ setting stone into wax shop	To order setting stone into wax job and give related specification	2	4.21
	Coordinator ------→ shaping shop	To order job in shaping shop, give related specification, and record weight of ordered job	2	4.13
	Coordinator ------→ polishing shop	To order polishing job and give related specification and caution	2	4.24
	Coordinator ------→ setting stone into metal shop	To order setting stone into metal job and give related specification and caution	2	4.22
3. Basket Control	Coordinator ------→ related shop	To detail of production flow in terms of amount, size, rework, basket no., etc.	1	4.28
2. Setting stone into wax shop 1. Job order	setting stone into wax shop ------→ Coordinator	To return ordered setting stone job	1	4.21

	setting stone into wax shop ------→ Coordinator	To return ordered rework job	1	4.25
3. Treeing shop 1. Investment casting job order	treeing shop ------→ investment casting shop	To order metal casting job and to record related weight for coordinator in checking weight of metal material	2	4.27
4. Investment casting shop 1. Investment casting job order	investment casting shop ------→ Coordinator	To provide detail of weight related in metal casting process.	1	4.27
5. Shapping shop 1. Job order	shaping shop ------→ Coordinator	To return ordered shaping job	1	4.23
2. Rework order	shaping shop ------→ Q.C.	To return ordered rework job	1	4.25
3. Basket Control	shaping shop ------→ Coordinator	To detail of production flow in terms of amount, size, rework, basket no., etc.	1	4.28
6. Polishing shop 1. Job order	polishing shop ------→ Coordinator	To return ordered polishing job	1	4.24
2. Rework order	polishing shop ------→ Q.C.	To return ordered rework job	1	4.25

3. Basket Control	polishing shop ------→ related shop	To detail of production flow in terms of amount, size, rework, basket no., etc.	1	4.28
7. Setting stone into metal shop 1. Job order	setting stone into metal shop ------→ Coordinator	To return ordered setting stone job	1	4.12
2. Rework order	setting stone into metal shop ------→ Q.C.	To return ordered rework job	1	4.25
3. Basket Control	setting stone into metal shop ------→ polishing shop	To detail of production flow in terms of amount, size, rework, basket no., etc.	1	4.28
8. Q.C. 1. Job order	Q.C. ------→ coating shop	To order coating job and give related specification	2	4.26
2. Rework order	Q.C. ------→ related shop	To order rework job and give caution area	2	4.25
9. Coating shop 1. Job order	coating shop ------→ Q.C.	To return ordered coating job	1	4.26
2. Rework order	coatingshop ------→ Q.C.	To return ordered rework job	1	4.25

3. Basket Control	coatingshop ------→ Q.C.	To detail of production flow in terms of amount, size, rework, basket no., etc.	1	4.28

From the table, document flow can be shown as in figure 4.20-4.28

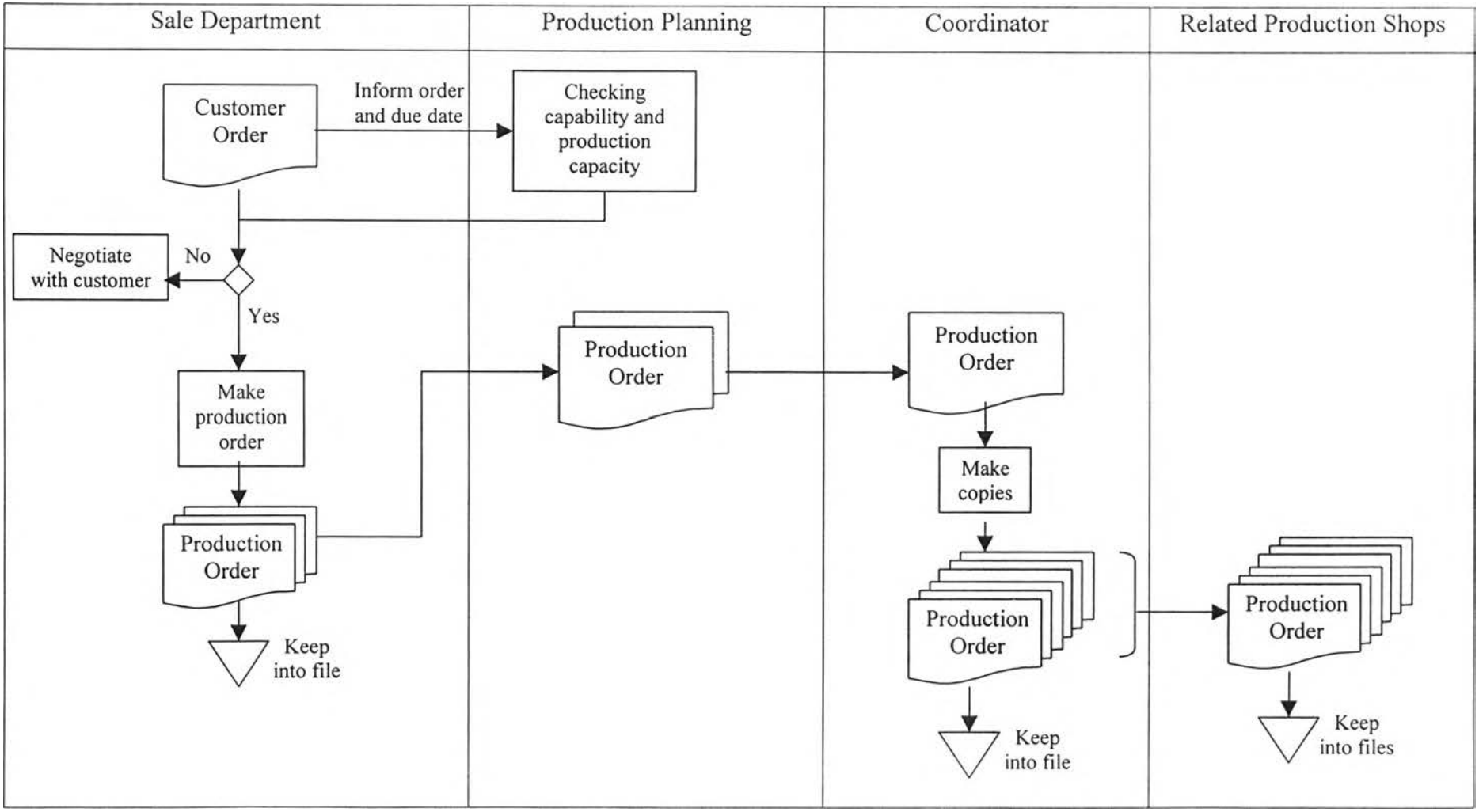

Figure 4.20: Document Flow of Production Order (After Improvement)

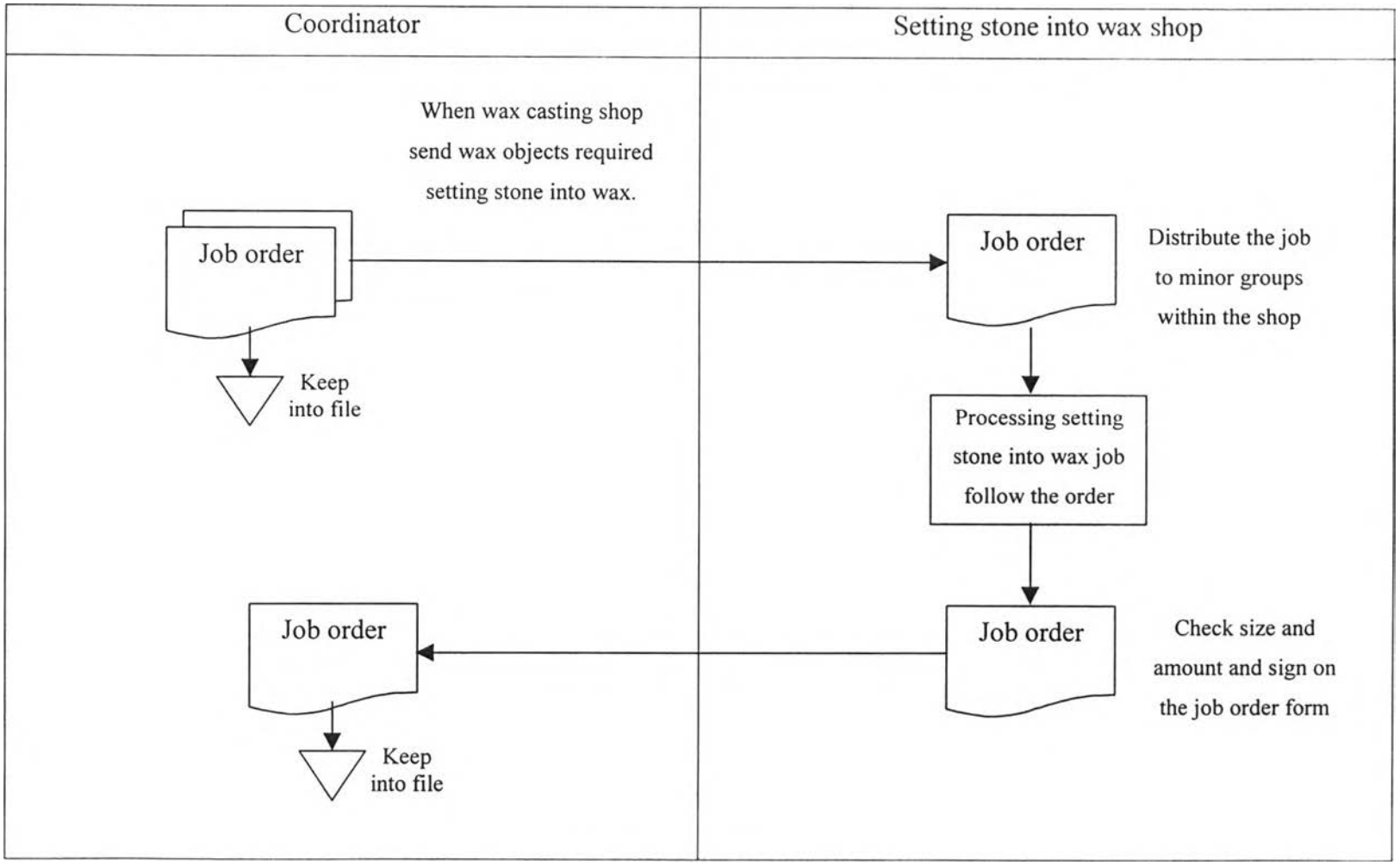

Figure 4.21: Document Flow of Job Order for Ordering Setting Stone into Wax Job (After Improvement)

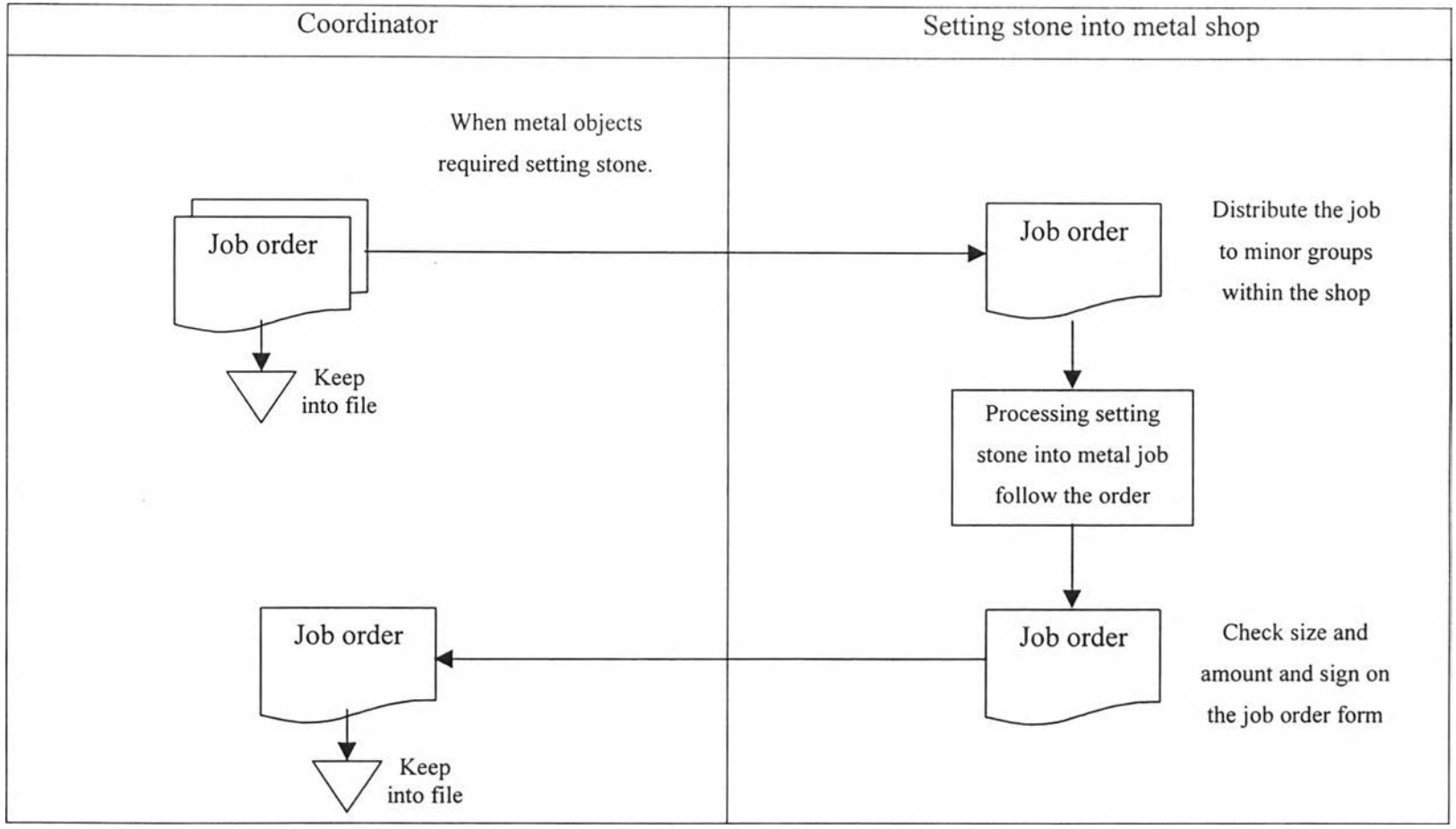

Figure 4.22: Document Flow of Job Order for Ordering Setting Stone into Metal Object Job (After Improvement)

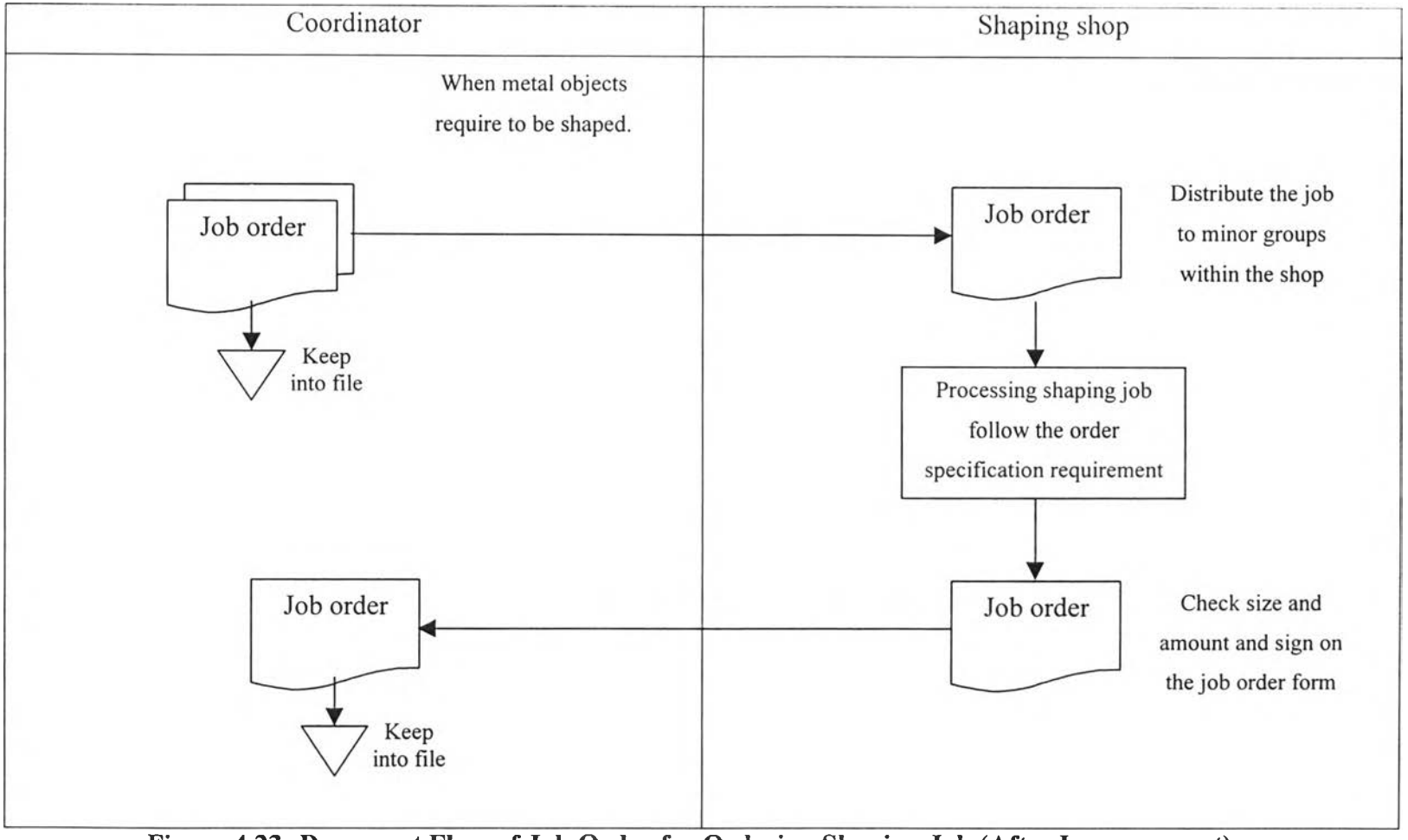

Figure 4.23: Document Flow of Job Order for Ordering Shaping Job (After Improvement)

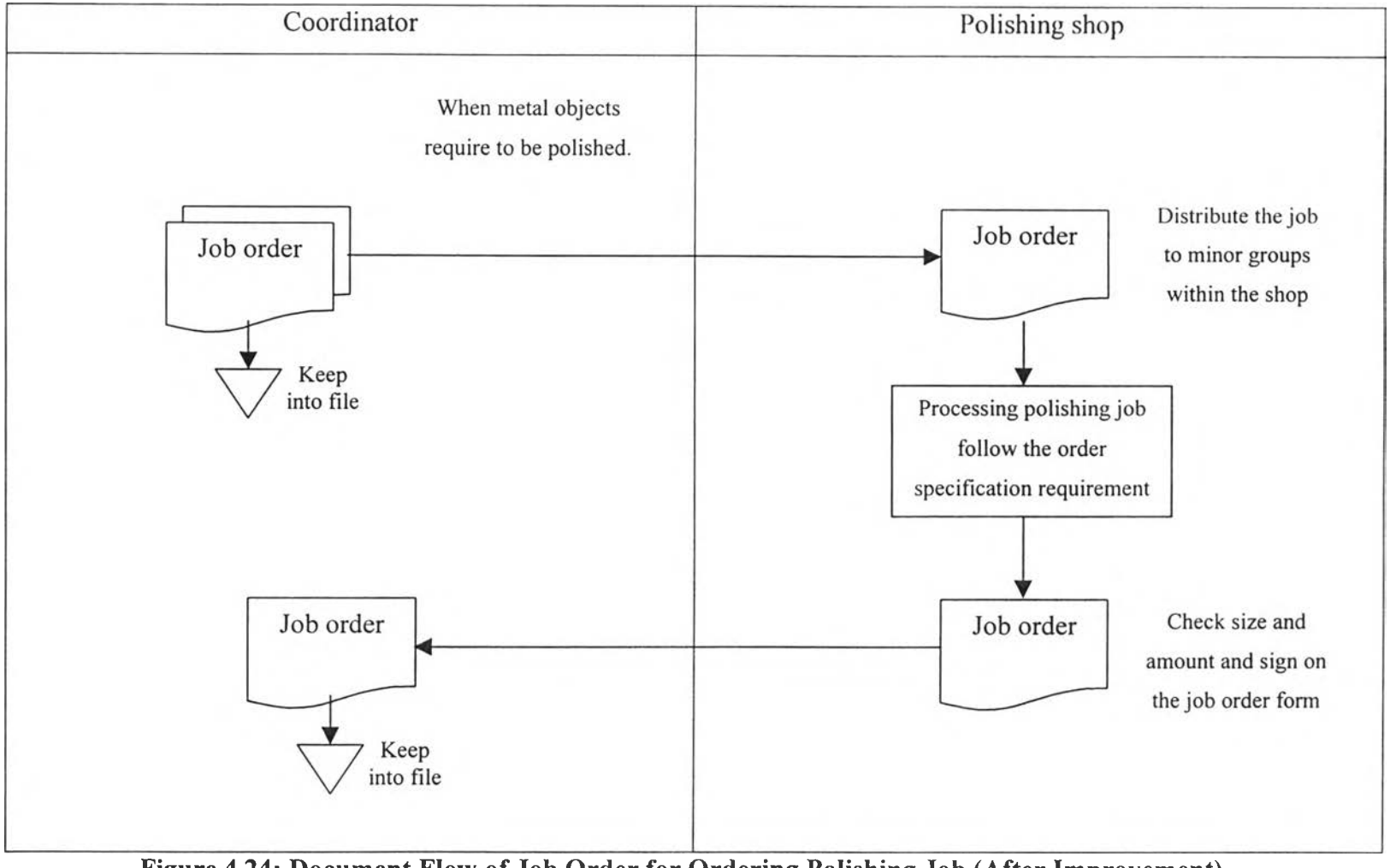

Figure 4.24: Document Flow of Job Order for Ordering Polishing Job (After Improvement)

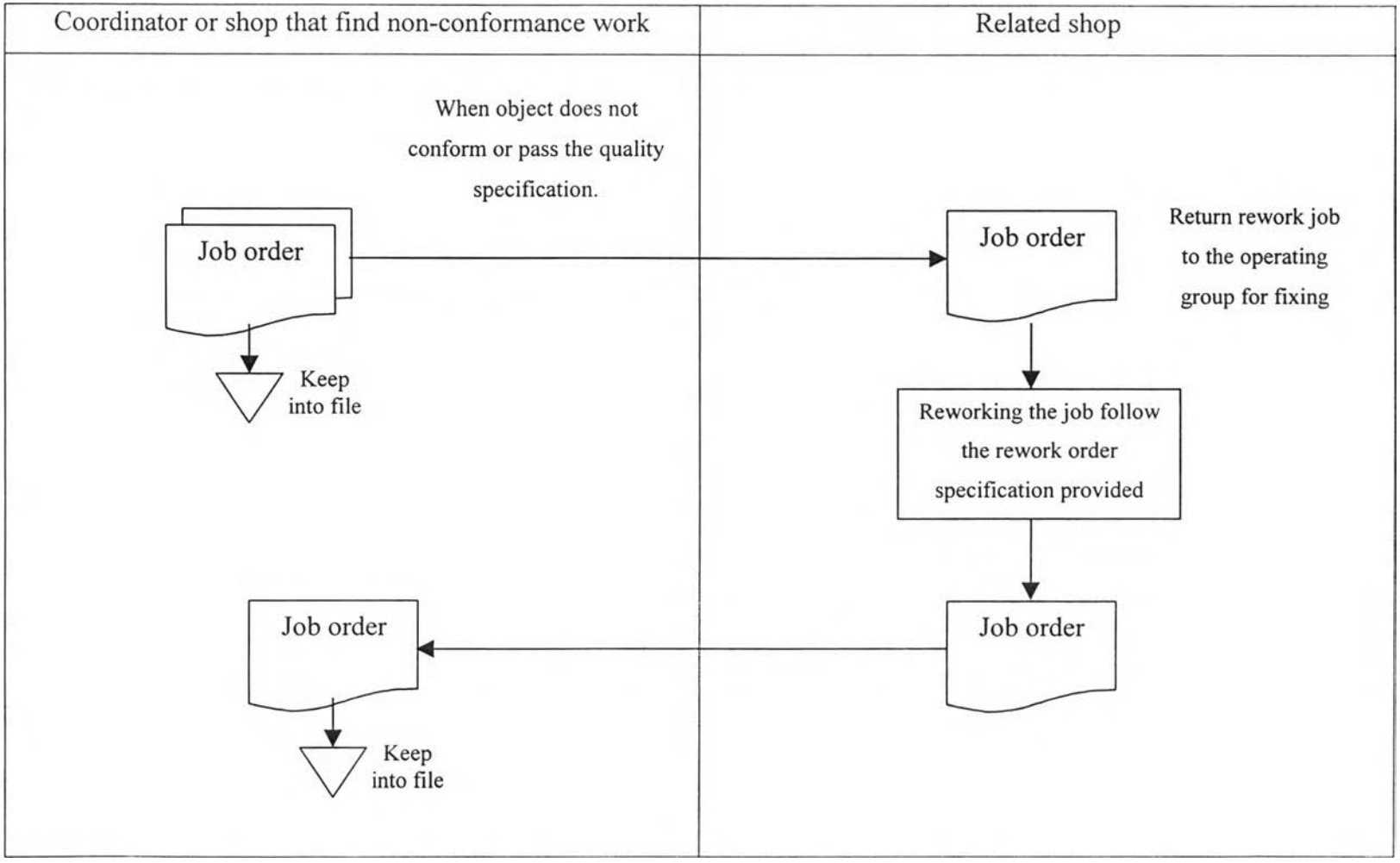

Figure 4.25: Document Flow of Job Order for Ordering Related Rework Job (After Improvement)

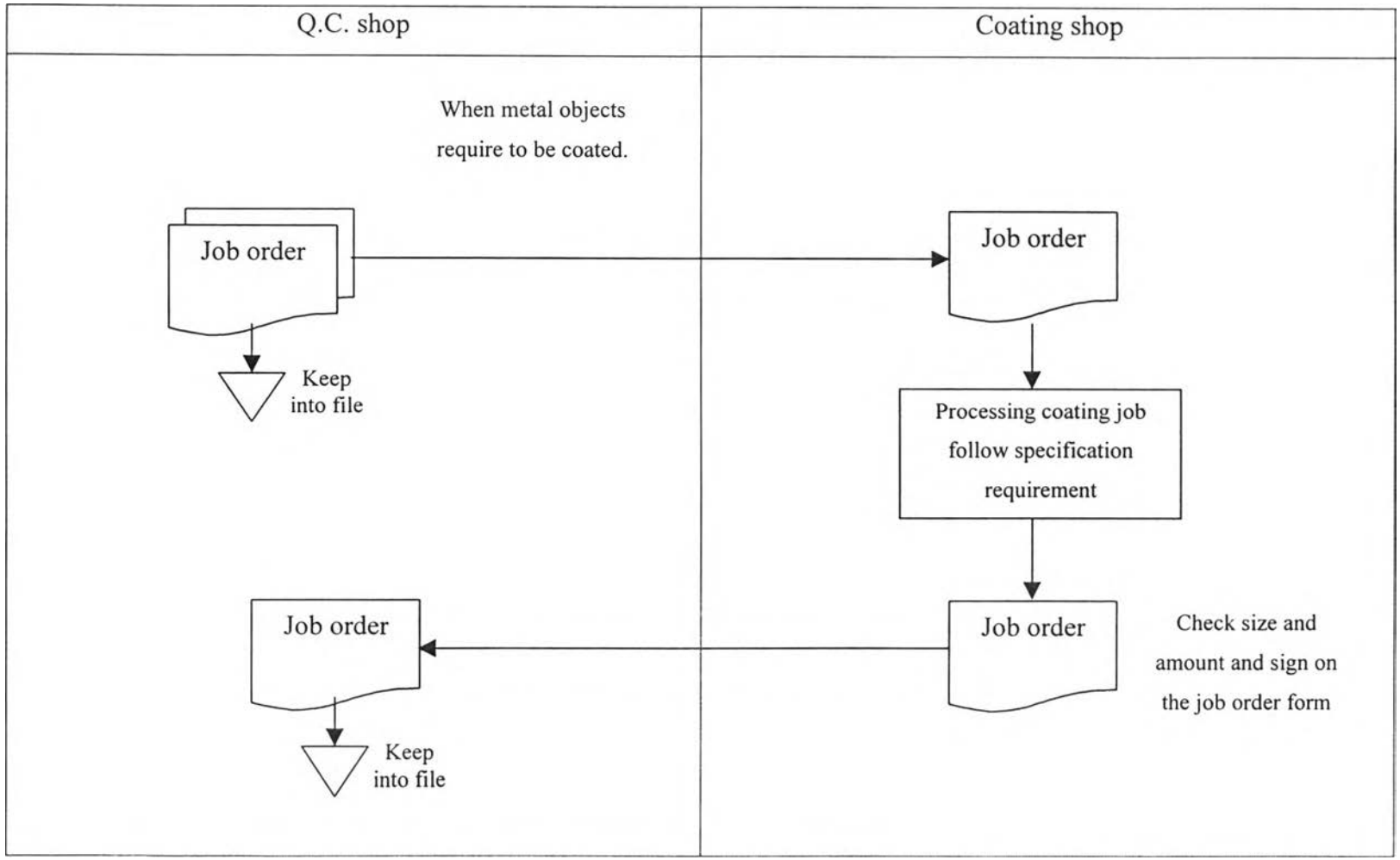

Figure 4.26: Document Flow of Job Order for Ordering Coating Job (After Improvement)

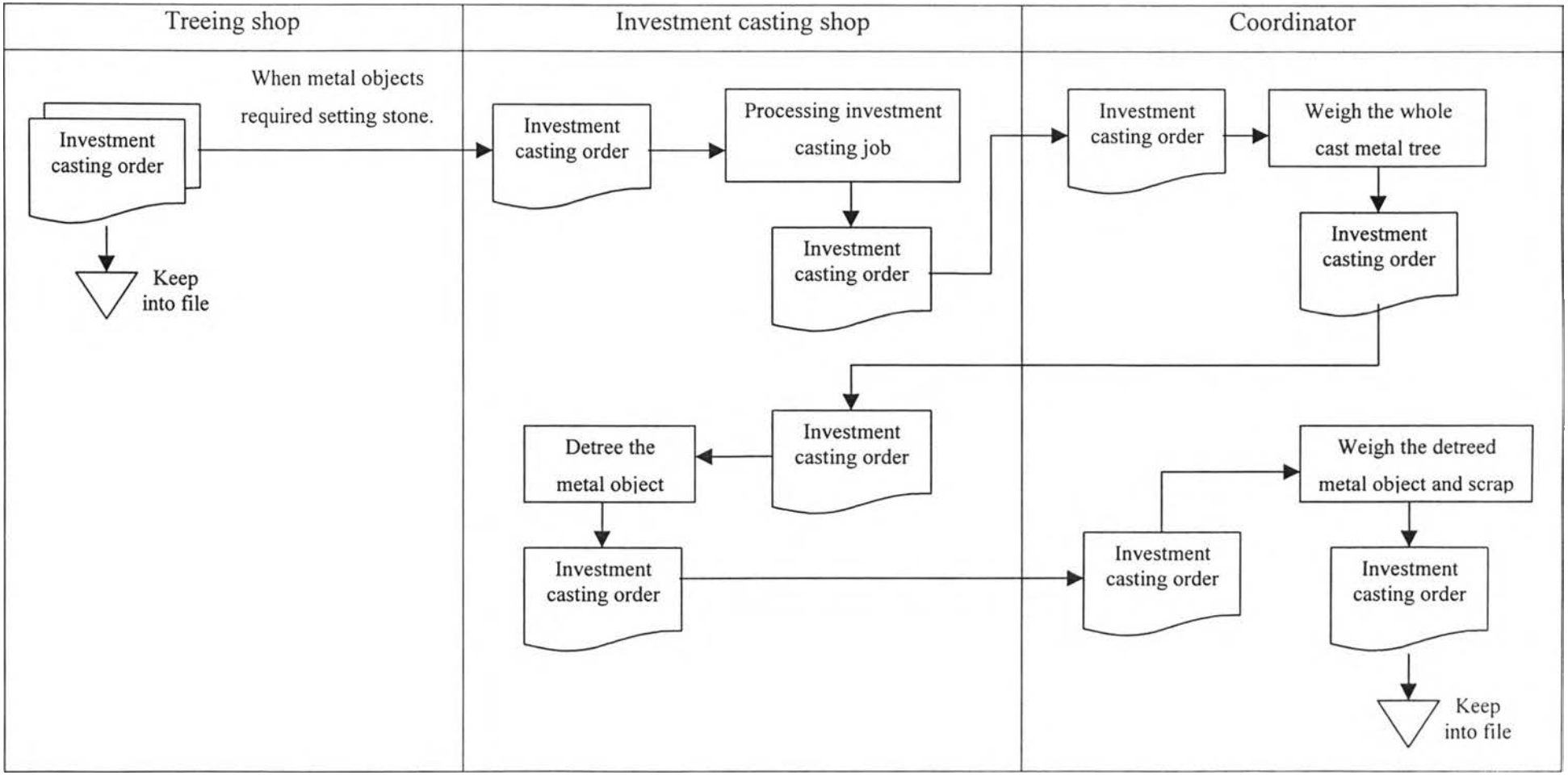

Figure 4.27: Document Flow of Job Order for Ordering Investment Casting Job (After Improvement)

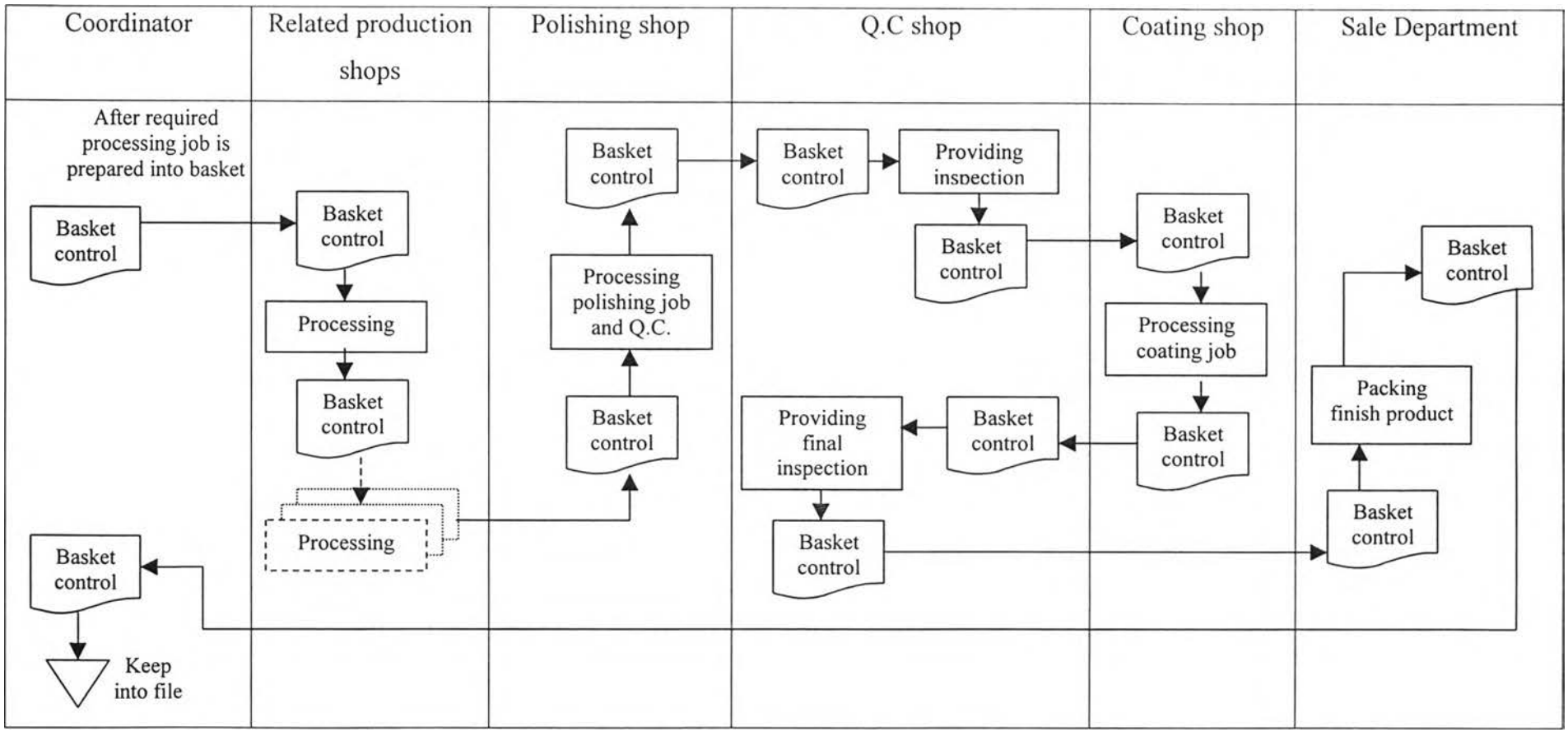

Figure 4.28: Document Flow of Basket Control Document (After Improvement)

The entire production document flow system after improvement is shown in Figure 4.29.

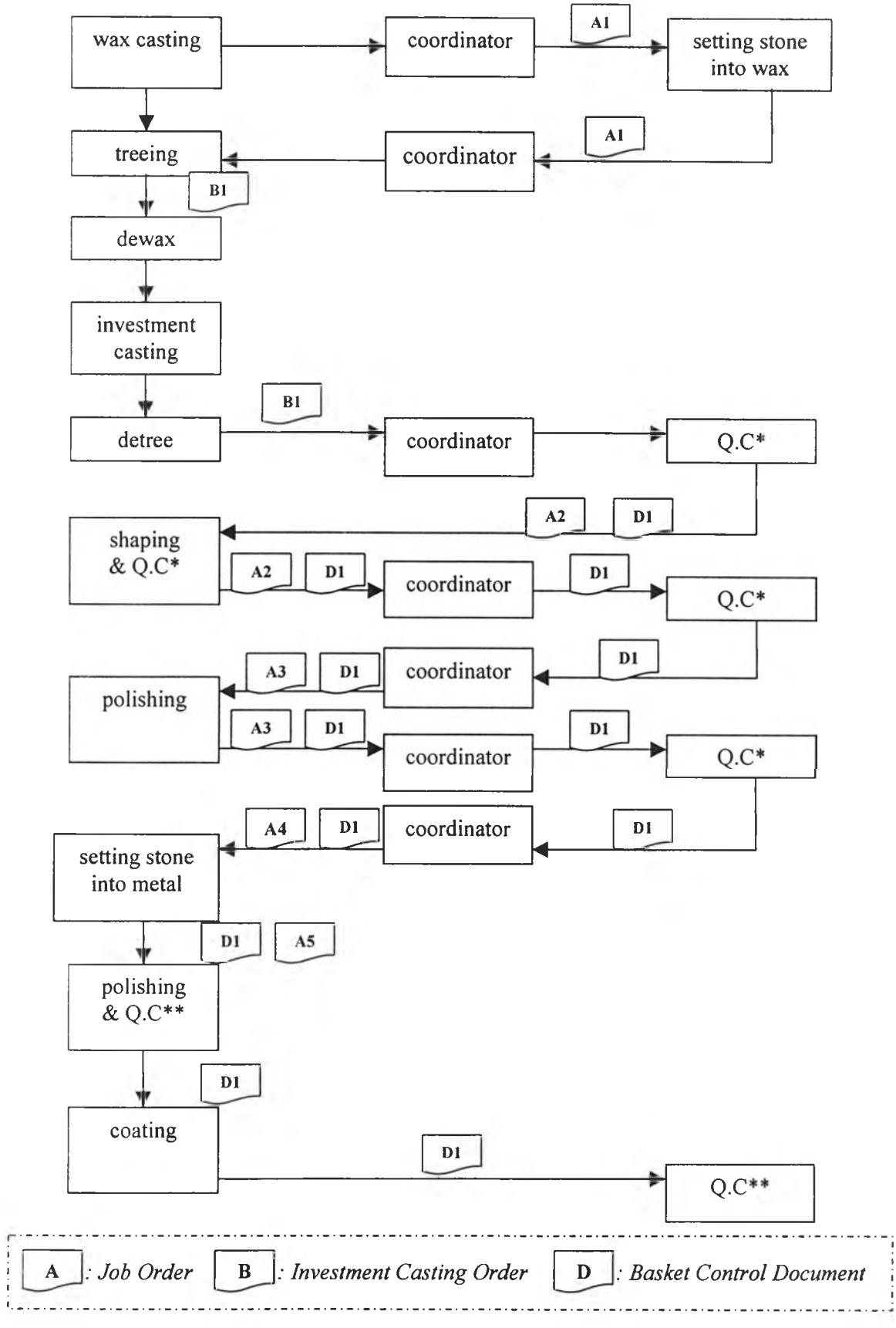

Figure 4.29: Production Document Flow System (After Improvement)

From the figure 4.29, number of document related with process flow has been decreased as consequence of the basket system. In addition, majority of process flow data is collected in the basket control document. That yields benefit in terms of ease to track back the information related with process flow.

4.3.3. Material Handling

After analysing existing, it is found that many problems caused by the material handling and affected flow of process. Good material handling characteristic is identified. That can be described as following:

1. Allow stacking store in order to save space without providing damage to part.
2. Not put many parts into one hole because that leads to scratch of part.
3. Ease for tracking job of what shop it comes from, who making this lot.
4. Suit for variety size of piece of product.

Improvement of material handling should support the improved process flow. Therefore, basket system is introduced for flow of work-in-process and product. It is used to replaced the tray whereas, the box still remain in use because it does not provide problem on process flow and there is no better material handling suited with wax object.

In basket system, each basket is filled with a sponge sheet which has fixed capacity holes with specific mark shows the number of hole.

There are three types of basket used in the process flow system.

Type A: Coordinator's basket. This basket type belongs to coordinator.
Type B: Polishing shop's basket. This basket type belongs to polishing shop.
Type C: Rework basket. Every shop has this basket type. It is used to transfer rework job to related shop.

The details related with basket types are provided in Table 4.5.

Table 4.5 Basket Type Description

	Type A	Type B	Type C
Own	Coordinator	Polishing shop	Related shop
Label ("_" denoted for one digit of number)	"A-_ _ _"	"_ _ _"	"rework"
Colour	Red	Blue, yellow, green	Red
Size	12"*10"	12"*10"	10"*6"
Fixed capacity	50 holes	50 holes	25 holes
Flow to	▪ Shaping shop ▪ Setting stone into wax shop ▪ Setting stone into metal shop ▪ Polishing shop	▪ Q.C shop ▪ Coating shop ▪ Export	Required rework shop

The flow of basket system along with the improved process flow is shown in Figure 4.30

In Figure 4.30, basket type A is used for transport from the point that coordinator receives work from investment casting in which after object tree is detreed, the objects are inspect and check size and quantity. Then they are put into basket and open basket control document and sent to the next processing shop. The coordinator basket is used for transporting object through the process until the last process of polishing shop. Transferring basket from coordinator basket to polishing basket is occurred. Changing basket is set for the reason of that the coordinator basket passes through many processing shops. Dust and some scrap may be stuck in the basket or sponge. Thus when process almost reaches last processing process. Consideration of clean and quality should be taken into account seriously. Putting object into non-clean basket can cause in to rework requirement such as need to be repolished.

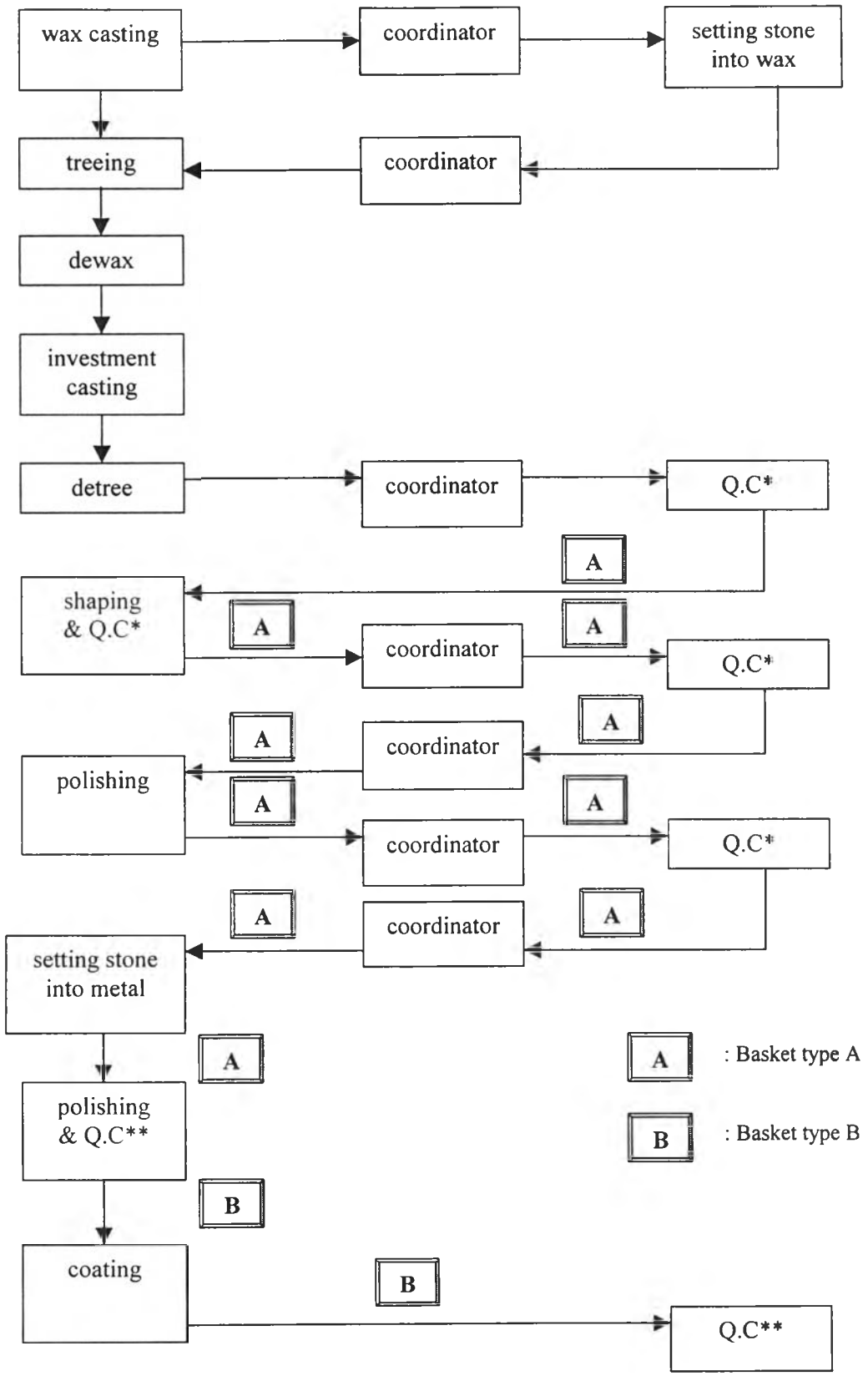

Figure 4.30: Basket Flow

4.3.4 Production Plan

Pre-production plan is developed for guide status of production. Gantt chart and Critical Path Method (CPM) concepts are adapted in developing the plan.

4.3.4.1 Objective

The objectives of the pre-production plan chart are:

- The major purpose of the chart is to provide foreseeing of workload and peak time of each production shops. As consequence of that, managing workload and time in order to cope the identified peak period of each shop can be prepared effectively. For instance, if the overwork load of tumbling shop is show, balancing workload by working overtime may be necessary for tumbling shop in order to maintain balance of process flow.

- The pre-production plan chart does not aim for high level result. Strictly practice follow the plan is not expected in the first usage of the plan. The reason behind this is that in the factory, manufacturing process is based on labors' skill, a lot of rework involves in which that provides unpredictable in production process time for rework order. In the first step of problem solving, it is difficult to control process flow following the developed plan.

- The chart aims to be a reminder about start and finish date for each shop. Push & pull work concept is gained from this application. In a chart, it consists of forward and backward schedule, which represent early and last date for starting and finishing of each production shop. If the last finish date that any shop must done the job is near, that shop can be reminded by the chart and the work will be tried to finish and push out of that shop. On the other hand, if it is reminded by the chart that the next job must pass into the shop but in fact the previous shop still working on that job. Pulling job from the previous shop will occur in order to keep the finish date on time.

4.3.4.2 Procedure

The procedures for developing of the production plan chart are as follow:

1. **Select Order**

According to that the factory operates in made to order, the volume of order is open. It ranges from a couple pieces up to more than ten thousand pieces for a model. That provides different impact on production. The higher volume has higher chance to affect production flow and processing time. As consequence, priority level of order must be defined. Amount of volume is used as criteria in catagorising priority level.

The level of priority defined by volume is shown in Table 4.6 below.

Table 4.6: Priority Level Defined by Amount of Order

Amount (pieces)	**Priority level**
1-99	1
100-999	2
1000 up	3

The table represents level of priority. The higher priority is ranked by the higher number of level. This helps to classify group of order for developing the chart easily.

In addition, there are more than a hundred orders per month, consideration can not cover all the order. Consider order in terms of group for the low priority level order is the used. Group technology concept is applied for this case. For the orders that fall in level 2 and 3 are picked up to be developed in the production plan chart individually.

The reasons of why order must be grouped and catagorised in to priority level are:

1. The importance of each order to production is different.
2. Lower order volumes normally require shorter processing time for finishing the whole order.

3. In developing the production plan chart, importance of order must be taken in to account.
4. Only level 2 and 3 are selected to be considered individually.

2. Determine Flow of Manufacturing Process

Workflow process of the selected order from step 1 is identified. Only manufacturing process is considered. The process of flow is determined by interview experts because the process flow is not fixed. It is varied depending on the difficulty and complexity of product design regarding to best manufacturing approach and producing high quality of product.

The form used in collecting flow process data is shown in Table 4.7.

Those flow process information can be used as database for next time use in developing the production plan chart. In the case of that product has different flow process from those information, interview is still required and the results will be added in the historical database for further development.

3 Estimate Processing Time

The workflow procedure information from the step 2 is developed further. Data of estimated time spent in each shop for processing is collected by interview supervisors of each shop. At a time, there is not only one product being process in each shop; therefore, assumption for estimating time must be set up in order to make ease while collecting data.

The assumptions for estimating are:

1. There is no overtime allowance.
2. There is no interrupting from other work.
3. Allocating workload to worker is based on actual condition.

4. Develop production plan chart

The all collected data from step 1,2, and 3 is utilised together in developing the production plan chart. In the chart, one product model consists of 3 conditions.

Table 4.7: Form of Flow Process Data Collection

Manufacturing Process Form

Production Order No. _____

Customer Code _____ **Due Date _____**

Product Code _____ **Quantity _____**

Manufacturing Process	Estimated Time for processing	Previous Process	Note
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

1. Earliest Production

Forward pass rule computation is applied in this area. The purpose of this is to show earliest start time and earliest finish time of each manufacturing process for each product model.

2. Latest Production

This is developed under backward pass rule computation. It aims to illustrate the latest start time and latest finish time for each manufacturing process that still allow manufacturing finish on time.

3. Actual Production

This is the black area for each related shop to fill in actual production. It aims for collecting actual data for further development and analyse performance result of the chart. It also yields benefit for assessing performance of each shop.

The chart is developed interms of 2 types as:

1. *Overall production plan*: this represents a broad view of production throughput time for each product. Start date and finish date is contained in the chart. This type of chart allows production control in realising of workload.
2. *Each shop production plan*: this is developed under consideration of each shop work. It provides detail of each product for each shop. Early and late start and finish date is shown. Each shop can realise their workload from this plan. Action taking can be prepared in the case of over workload seems to occur.

The examples of Pre-production plan are in appendix C.