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子計畫四：以 RFID 為基之半導體供應鏈監督與控制之研究

(1/3)

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行政院國家科學委員會專題研究計畫成果報告

RFID 系統發展及產業應用

子計畫四：以 RFID 為基之半導體供應鏈監督與控制之研究(1/3)

Monitoring and Control of Semiconductor Supply Chains with RFID-based Information (1/3)

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摘要

半導體產業本質上是結合高科技、高度資本密集的產業, 整個產業處於激烈競爭與快速變遷環境中，其供應鏈具有高度垂直分工的特性，上下游不同的企業所追求的目標不一, 導致整個供應鏈被分割為許多片段, 而無法對顧客的訂單進行有效的監控。因此，為滿足顧客準時交貨與產品品質及可靠度的要求, 半導體供應鏈中的廠商有必要進行前端與後端作業與資訊的整合, 以提昇顧客的滿意度與改善整體供應鏈的效率。隨著新技術的發展，例如 RFID 的導入，越來越多的資訊可以更即時的取得，使必要的資料交換更容易。因此如何運用這些即時的資訊來重新調整半導體供應鏈內成員的作為以提昇供應鏈內協同合作的績效便成為一個重要的研究課題。

本三年計畫旨在以半導體產業為研究平台進行三大研究議題：(1)建立以 SCOR 與 RFID 為基礎之供應鏈績效監督指標；(2)建構描述供應鏈行為的實證模式；(3)發展以 RFID 為基礎的控制機制。第一年重點為建立以 SCOR 與 RFID 為基礎之供應鏈績效監督指標，已完成之具體的工作成果分為(1)運用 SCOR 參考模式描述半導體供應鏈行為;(2)定義以 SCOR 與 RFID 為基礎的半導體供應鏈績效衡量指標;(3)定義以 RFID 為基礎的半導體供應鏈資訊需求;(4)研究半導體供應鏈績效衡量指標之間的關係;(5)擬定後續研究細部架構。

關鍵詞：供應鏈績效衡量指標、監督與控制、供應鏈作業參考模式、無線射頻識別

Abstract

Semiconductor industry in nature is a business with high capital investment and fierce competition and has a fragmented supply chain due to different ownership and interests of firms. Thus, there is a need to integrate the front-end and back-end in the semiconductor supply chain to meet customer on-time delivery and product quality and reliability. Nowadays, as more information will be made available instantly by new technology developments such as RFID, how the firms adopt the real-time information to readjust their behaviors to improve collaboration in semiconductor supply chain has become an important research area.

The goals of this three-year research are to: (1) design SCOR-based and RFID-based supply chain performance monitoring metrics; (2) construct a supply chain behavior model; and (3) develop RFID-based control schemes. In the first year, we have completed five major tasks: (1) utilize SCOR model to model semiconductor supply chain; (2) define SCOR-based and RFID-based semiconductor supply chain performance monitoring metrics; (3) define RFID-based semiconductor supply chain information requirements; (4) research on the inter-relationship among different metrics; and (5) define next-year monitoring and control framework.

Keywords: Supply chain performance metrics, monitoring and control, SCOR model, RFID

1. Motivation and objectives

Semiconductor industry in nature is a business with high capital investment and fierce competition and has a fragmented supply chain due to different ownership and interests of firms. Thus, there is a need to integrate the front-end and back-end in the semiconductor supply chain to meet customer on-time delivery and product quality and reliability. Nowadays, as more information will be made available instantly by new technology developments such as RFID, how the firms adopt the real-time information to readjust their behaviors to improve collaboration in semiconductor supply chain has become an important research area.

Recently, RFID was promoted by EPC (Electronic Product Code) Global and ISO (International Standard Organization), respectively. By applying the technology of radio frequency and utilizing the property of mass storage, RFID has capability to provide enough information timely and has been used in sales promotion, inventory management, transportation & logistics, and tracing & tracking. In addition, Supply Chain Operation Reference Model (SCOR), developed and endorsed by Supply Chain Council (SCC), provides the definition of supply chain, performance metrics, and standard operation flows. The SCOR model which has been widely used to define the supply chain, reengineers the business process, performs the benchmarking, and evaluates process performance can be applied to monitoring and controlling the supply chain.

Due to the complexity of semiconductor supply chain, it is more difficult to perform the monitoring and controlling tasks in semiconductor supply chain. Thus, it is worth to pay more attention to research issues such as how to apply RFID to obtain timely and sufficient information in the semiconductor supply chain; how to describe the semiconductor supply chain and define performance metrics to monitor and control the supply chain by utilizing the concept of SCOR.

The objectives of this three-year research based on semiconductor industry are to: (1) design SCOR-based and RFID-based supply chain performance monitoring metrics; (2) construct a supply chain behavior model; and (3) develop RFID-based control schemes.

Therefore, the major focus in the first year is to build up the supply chain performance indices based on SCOR and RFID. The accomplishments in the first year are listed as follows: (1) utilize SCOR model to model semiconductor supply chain; (2) define SCOR-based and RFID-based semiconductor supply chain performance monitoring metrics; (3) define RFID-based semiconductor supply chain information requirements; (4) research on the inter-relationship among different metrics; and (5) define next-year monitoring and control framework.

2. Literature reviews

2.1 SCOR models

SCC is an organization promoting cross-industry standard for supply chain management (SCM). Also, SCC has developed and endorsed SCOR to provide standard terms and symbols for defining supply chain. SCOR is structured around five distinct management processes: Make(M), Source(S), Delivery(D), Return(R) and Plan. SCOR contains 3 levels of detail, and each level has its distinct performance measures as Figure 1 shows.

In Figure 1, level 1 metrics are high-level measures which define the performance goals of enterprise; level 2 metrics are related to performance measures for different process categories; at the 3rd level, process elements are analyzed in more details including process performance metrics.

Until now, more than 1,000 global companies (including HP, NEC, Hitachi, IBM, Intel, Philips) have become the members of SCC, and actively promote and apply the concept of SCOR to improve supply chain management for better supply chain performances. (Supply Chain Council, 2004).

2.2 Performance measurement in semiconductor supply chain

Performance measurement for supply chain management has become an interesting issue in recent years. In addition to 5 performance attributes (reliability, responsiveness, flexibility, costs, and asset management efficiency) for different processes under 3 levels defined in the above SCOR model by SCC (Supply Chain Council, 2004), many scholars also research on performance measurement in supply chain. Tian et al. (2003) argued the performance measurement of supply chain should be evaluated from the perspectives of time, quality, cost and flexibility, and they not only proposed performance metrics for each category but also provided aggregated performance measurement. Wu (2005) discovered the important properties of variations in the fab and discussed the relationship between product cycle time and WIP. Martin (1998) pointed out that capacity utilization is the only concern to fab due to the cost and lack of capacity in semiconductor manufacturing. Besides of the methodology provided by Constraints Theory traditionally, he also proposed to utilize the concept of X-Factor to identify the most effective way to add capacity for processes without enough capacity. Delp et al. (2003) further showed that X-Factor and the Constraint Theory both can improve system output under certain circumstances. But one drawback of X-Factor is that the system can only be monitored and improved after the production run is completed because X-Factor measures product cycle time. Therefore, Johnishi et al. (2002) proposed another performance index, Dynamic X-Factor, to monitor product cycle time instantly by observing the amount and the states of WIP. He demonstrated that this index has the same meaning as X-Factor in the long run.

2.3 The meaning and standards of RFID

RFID is one of the most frequently discussed issues in SCM. According to the Association of Automatic Identification and Data Capture Technologies, an RFID system is the one that carries data in transponders generally known as “tags”. These tags retrieve the data by machine-readable means. RFID is the technology that will allow us to leverage the power of information, and it also provides supply chain partners a look at where the materials and finished products are at any point of time (Caltagirone, 2004).

The benefits for implementing RFID for manufacturing includes building intelligence into the product, improving control surrounding configuration processes, reducing risk of counterfeiting, improving manufacturing process integrity, ensuring right employees doing right tasks, and managing contractors on site (Accenture, 2004).

There are two types of RFID, direct read-write and network-retrieval. For network-retrieval RFID, it can only write the corresponding ID number of objects to RFID tag. Once the ID number of objects is read, the corresponding attributes of products are retrieved by the network. But direct read-write RFID not only carries extra memory space to store tag or object ID but also records some related product attributes by users. Our research has been based on the applications of direct read-write RFID. This type of RFID tag can store the amount of data from 96 bits to 2k bytes, but the RFID tag with 1k bits memory is the major tool for planning the contents of RFID information in our research. (蕭榮興&許育嘉,2004).

The tag of RFID must communicate with reader or writer initially. Then, information needed based on different application requirements are sent back and wrote into the tag after reader receives the RFID messages and the messages are processed by computer. The current infrastructure and standards of RFID are shown in Figure 2.

2.4 The applications of RFID

RFID projects the statements in the real world to the virtual world of Network. It uses the characteristics of real time information refreshing and the detail databases to connect the virtual world to the real world, and then has various powerful applications. This means that the RFID has big potential applications in the hyperlink of network system. It could be used in manufacturing, logistics, medical, transportation, retailing, and national defense fields and so on. Here are few cases of the applications RFID (周湘琪, 2004). Table 1 lists RFID related applications in different industries.

Table 1 RFID applications

	Company	Application	Benefits
Retailing	Wal-Mart MARUSTSU	Warehouse management Shelves management	1.Reducing the labor Cost 2. Increasing the track ability of goods. 3. Reducing the inventory cost 4. Improving the visibility of SC 5. Theft control
IC card	TRCT	Ticket management	1. Reducing the labor Cost 2. Saving the passing time
Library	library	1.Shelves management 2. Management of borrowing and lending book	1. Reducing the labor cost 2. Improving the track ability
Airline	Delta Air HK Airport Boeing Airbus	1.Tracking the baggage 2. Components tracking	1. Improving baggage identification 2. Components tracking
Defense	DoD	Material control	Comparing the two battles of Iraq, it saves 30% human resources and reduces 90% of containers
Semi-conductor	IBM tsmc	Inventory control	1. Improving inventory tracking rate and accuracy

2.4.1 The application of RFID in semiconductor manufacturing

Major manufacturers in semiconductor industry such as TSMC, and IBM, all introduce the technology of RFID and apply in the warehouse management. The main reason is that warehousing is the most difficult part to be controlled in entire production processes. For instance, IBM has used RFID in the warehouse system at FishKill factory. The purpose, it hopes, is to know exact amount of inventory in the warehouse quickly and accurately, and can locate the stocking position of wafer correctly. The benefits of utilizing RFID system are: capable to find the exact number of inventory in warehouse; lower the effort of counting process at each checkpoint; locate the correct stock position of goods (IBM, 2004). But the applications of RFID to monitoring and controlling the semiconductor supply chain are still missing.

We believe that fab itself can utilize the technology of RFID to obtain newly updated information from manufacturing process, and quickly respond to all kinds of changes in the dynamic environment by readjusting production schedules to meet their customer's needs more effectively and efficiently. Furthermore, if the upstream and downstream manufacturers in semiconductor supply chain, especially for the firms with capacity or other constraints (for example, fabs and final testing), can share timely, newly updated information beforehand by utilizing FRID information, the entire supply chain not only can quickly respond to the changes under dynamic environments but also help the upstream and downstream manufacturers to cooperate tightly to raise higher level of customer satisfaction and further reduce supply chain cost.

2.4.2 The applications of RFID in SCM

Although many applications of RFID in SCM are still in the early experimental stage, it can be expected that these applications will have great significant impact on the practices of SCM. For instance, retailing firms such as WalMart、Metro Group、Maruetsu has begun test on running intelligent shelf management system, intelligent shopping cart, and inventory management based on RFID technology. Besides, airline industry uses the property of RFID to track and trace passenger's luggage. On the other hand, IBM and TSMC apply the technology to manage their warehouses. All the current applications in supply chain are summarized and shown in Figure 3. These applications are spread on the following areas: product identification and protection, production and manufacturing, distribution, transportation, retailing and service after sales (周明佩, 2004).

Based on the above literature reviews, although several researches has investigated the applications of RFID on product sales, inventory management, transportation & logistics, and track & tracing, the researches on the monitoring and controlling of supply chain performance measurement are still insufficient. On the other hand, more than 1,000 global companies (including HP, NEC, Hitachi, IBM, Intel, Philips) have become the members of SCC, and actively promote and apply the concept of SCOR to improve supply chain management for better supply chain performances. But how to apply the concept of SCOR to monitor and control the performance measurement is still missing in the literature. Thus, it is worth to pay more attention to research issues such as how to apply RFID to obtain timely and sufficient information in the semiconductor supply chain; how to describe the semiconductor supply chain and define performance metrics to monitor and control the supply chain by utilizing the concept of SCOR.

3. Accomplishment 1:Utilize SCOR model to model semiconductor supply chain

One of the purposes to develop and endorse SCOR by SCC is to provide a common mechanism to describe operations and performance metrics in supply chain. Based on this common mechanism, different people can understand, analyze and improve the supply chain performance more conveniently and less ambiguously. Thus, our research adopts SCOR model to describe the behavior in semiconductor supply chain.

Semiconductor supply chain mainly composes of four tiers: Fabrication, Circuit Probe, Assembly, and Final Test. The relationship among these four tiers can be represented by Figure 4.

The production process of semiconductor supply chain in the mode of Make to Stock is driven by Integrated Device Manufacturers (IDM). The production procedure of semiconductor products is as follows:

1. Fabrication: to manufacture wafer
2. Circuit Probe: to produce die
3. Assembly: based on product requirements to produce packaged circuit
4. Final Test: test whether packaged circuit has met customer requirements
5. After Final Test, the passed finished products will send back to IDM for further assembly.

The production process of semiconductor supply chain in the mode of Make to Stock described by SCOR can be represented in Figure 6. In Figure 6, the number "1" indicates the related activities in Source、Make、Delivery and Return are based on the mode of "Make to Order", but the number "2" indicates the related activities in Source、Make、Delivery and Return are based on the mode of "Make to Order." In the Plan process, P2 represents plan source; P3 represents plan make; P4 represents plan delivery; and P1 represents plan supply chain. In Figure 6, the semiconductor supply chain is driven by the Fabs, and the Fabs perform planning jobs for entire supply chain. Figure 6 also demonstrates the activity relationship among different levels in semiconductor supply chain.

4. Accomplishment 2: Define SCOR-based and RFID-based semiconductor supply chain performance monitoring metrics

Considering SCOR model and the performance metrics proposed in the literature, we can define SCOR-based and RFID-based semiconductor supply chain performance metrics as shown in Table 2. In Table 3, we show the how these performance metrics can be provided by RFID information. The SCOR-based and RFID-based semiconductor supply chain performance metrics are classified into several categories:

1. Cycle time：cycle time is one of the important factors needed to be considered in semiconductor industry. There are two performance indices, actual cycle time and cumulated waiting time belonging to this type of metrics. But the raw process time for different products under different processes are totally different, thus, cycle time is no longer a best choice for performance metric. Therefore, X-Factor is adopted to look into product's standardized production cycle. Of course, we not only hope to have better average performance but also have relative small variations. Therefore, we also adopt the performance metrics from X-Factor variability to easily monitor the variation in supply chain.
2. Delivery: On-time delivery is another important factor needed to be considered in semiconductor industry. One of the reasons to choose cycle time related performance metrics mentioned above in our performance metrics is to indirectly monitor delivery process. Thus, the metrics in this category mainly considers whether the product's delivery process can be monitored and controlled or the remaining production time is longer enough to accommodate the rest of production processes before the customer's due date.
3. WIP：the quantity of work in process. WIP and cycle time and cost are closely related. Therefore, we can utilize the WIP related metrics to indirectly monitor other performance indices in supply chain. The WIP distribution and the status of WIP can be used to derive the cost of WIP. Also, dynamic X-Factor which is derived from WIP distribution and the status of WIP could be a reference for the future cycle time.
4. Cost：metrics in this category are mainly derived from WIP related metrics.

The SCOR-based and RFID-based performance metrics for semiconductor supply chain are described in more details as follows:

1. Actual cycle time：It mainly records the production cycle for a product. This index can be measured in different levels, such as production cycle for entire supply chain, or production cycle in different production stages, or production cycle in different production flows. In order to obtain this index, the information of entry time at the very beginning, different stages or different production flows for each lot needs to be recorded.
2. X-Factor：X-Factor is defined as cycle time / raw process time, which is a measurement for evaluating standardized production cycle. Because X-Factor itself is decomposable, this index can be treated as cycle time which is measured in three different levels, operation level, stage level and supply chain level. The information needed for calculating this index includes: raw process time for entire supply chain under different stages and different production flows and actual cycle time.
3. X-Factor variability：Since X-Factor can be obtained from three different levels, the X-Factor variability can be obtained from three different levels. This index can be derived from X-Factor of each lot.
4. Cumulated waiting time： Since cycle time in X-Factor mainly consists of raw process time and waiting time and raw process time is fixed, cumulated waiting time can be used to monitor semiconductor supply chain. By utilizing the information of entry time at the very beginning, different stages or different production flows for each lot, we are able to calculate this index.
5. Delivery performance for each order lot: This measurement is used to evaluate whether the customer's due date can be met or the remaining production time is longer enough to accommodate the rest of production processes before the customer's due date. This measurement can be decomposed into two levels: supply chain level and stage level. Based on the

definition of Table 2, we use the value of remain raw process time to check whether the lot can meet customer's due date or the remaining production time is longer enough to accommodate the rest of production processes before the customer's due date. Therefore, we need the information of remain raw process time for this stage and the following stages and the customer's due date.

6. Delivery rate：If we sum up the delivery performance for each lot, we are able to obtain the total delivery rate. Also we may extend this concept to obtain order's delivery rate. As the same property as the previous one, this index can be decomposed into two levels: supply chain level and stage level. Since the delivery rate can be directly calculated from delivery performance of each order lot, there is no other information needed.
7. Received on time： the percentage of order lot can be delivered on time to the next production process.
8. Total number of wafers：the total number of WIP in each production stage and in entire supply chain. This measurement needs the information inputs from the location of each order lot, the current status of each order lot, and the lot size of each order lot.
9. Total number of wafers in process：This index is very similar to the previous one. The only difference is that we only count the lot whose lot status is still in process. Therefore, we still need the information inputs from the location of each lot, the current status of each lot, and the lot size of each lot.
10. Dynamic X-Factor：This measurement, derived from the total number of wafers and the total number of wafers in process, could be a reference for the future cycle time. Dynamic X-Factor can be decomposed into two levels: supply chain level and stage level. Since this index is derived from the above two performance metrics, there is no additional information needed.
11. WIP cost：WIP cost can be computed periodically or simply from the total number of WIP in supply chain. This index can be obtained from the total number of wafers.

Table 2 SCOR-based and RFID-based performance metrics for semiconductor supply chain

Cat.	Metrics	Definition of the metric
CT	Actual cycle time	$Current\ time - order\ entry\ time$ Current time - Process entry time Current time - Stage entry time
	X-Factor	$\frac{Actual\ \text{Cycle Time}}{Raw\ \text{Process Time}}$
	X-Factor Variability	Standard Deviation of X-Factor
	Cumulated Waiting Time	Sum of waiting time in the process
D	Delivery performance for each order lot	$LateLot$: $Current\ time + Remain\ process\ time > Due\ date$ $On\ Time\ Lot$: $Current\ time + Remain\ process\ time \leq Due\ date$
	Delivery rate	$\frac{\text{Lot Delivery on Time}}{Total\ \text{Order Lot}}$
	Received on time	$\frac{\text{Lot received on Time}}{Total\ \text{Order Lot}}$
WIP	Total number of wafers	The wafers in the plant (process) to be processed and in processing
	Total number of wafers in process	The wafers in the plant (process) in processing
	Dynamic X-Factor	$\frac{The\ \text{Total Number of Wafers}}{The\ \text{Total Number of Wafers in Process}}$
Cost	WIP cost	Total number of wafers at the end of a time period x unit inventory carrying cost
	Cumulated Direct cost	The Cumulated Direct cost in the process till current time

Note:
1. CT: Cycle Time
2. D: Delivery
3. Most of the metrics can be viewed in different levels: supply chain level and stage level.
4. Raw process time includes the theoretical transportation time if the transit between different stages (processes) is necessary.

Table 3 Information provided by RFID for calculating supply chain performance

Metrics	RFID Direct	RFID Derived	Required information from RFID
Actual cycle time	✓		Order Entry Time Process Entry Time stage Entry Time
X-Factor	✓		Order Entry Time + Raw Processing time →X-Factor of the Supply Chain stage Entry Time + Raw Processing time →X-Factor of the Supply Chain Process Entry Time + Processing time →X-Factor of the Process
X-Factor Variability		✓	The X-Factor Derived from above
Cumulated Waiting Time	✓		Process Entry Time (Order Entry Time)→cumulated waiting time
Delivery performance for each order lot	✓		Remain Process Time (for supply chain) Due Date Remain Process Time (for stage) Process Due Date
Delivery rate	✓		The aggregation of the metric of Delivery rate for each order lot
Received on time	✓		Expected Process Entry Time
Total number of wafers	✓		Lot Number Machine Number Lot Status
Total number of wafers in process	✓		Lot Number Machine Number Lot Status
Dynamic X-Factor	✓		From the metrics result above
WIP cost		✓	Lot number Machine Number
Cumulated Direct cost	✓		Cumulated direct cost

5. Accomplishment 3: Define RFID-based semiconductor supply chain information requirements

Based on the above discussions, we propose to the following information requirements of RFID for semiconductor supply chain as shown in Table 4. Here, we define the information needed to be stored in RFID, the storage type (fixed or updated), and the corresponding related performance metrics.

Table 4 Information requirements of RFID for semiconductor supply chain

RFID Information	bits	Type	RFID related metrics
Object ID	96	Fixed	
Priority	8	Updated	
Route	16	Updated	
Lot Number	16	Fixed	All the metrics
Order Number	16	Fixed	Delivery performance of the order Delivery Rate
Due Date	96	Fixed	Delivery Performance of each lot(supply chain level)
Stage Due Date	96	Fixed	Delivery Performance of each lot(stage level)
Location	16	Updated	Total number of wafers Total number of wafers in process
Order Entry Time	96	Fixed	Actual Cycle time X-Factor
Process Entry Time	96	Updated	Actual Cycle time X-Factor
Stage Entry Time	96	Update	Actual Cycle time X-Factor
Raw Processing Time (supply chain)	16	Fixed	X-Factor
Raw Process Time (stage)	16	Update	X-Factor
Processing time	16	Updated	X-Factor Update the information of the remain raw process time
Remain Raw Process Time	16	Updated	Delivery Performance of each lot (supply chain level)
Remain Raw Process Time (stage)	16	Updated	Delivery Performance of each lot (stage level)

Expected Process Entry Time	16	Updated	Received on time
Cumulated Waiting Time	16	Updated	Cumulated Waiting time
Cumulated Direct Cost	16	Updated	Cumulated Direct cost
Lot Status	4	Updated	Total number of wafers Total number of wafers in process

Note:

1. Stage: the different stages of the supply chain- Fab, C/P, Assembly, F/T
2. Process: the different operations and processes
3. Current used memory: 780 bits

The contents of information stored in RFID are described in more details as follows:

1. Object ID: identify the object where RFID is attached to. It may follow the standard of EPC or ISO, and it should be fixed.
2. Priority: store the information of the production priority of each lot. Once the priority of production lot is changed, it should be updated.
3. Route: store the route information of each production lot.
4. Lot number: store the corresponding number for each lot.
5. Order number: store the corresponding order number belonging to each production lot.
6. Due date: store the due date information of each customer order.
7. Stage due date: store the theoretical due date setting for the lot at each stage in order to fulfill customer order on time. Once the lot moves from one stage to another stage, this number needs to be updated.
8. Location: store the current location information for each lot. Once the lot is moved from one location to another, this information needs to be updated.
9. Order entry time: store the entry time of each production lot at the first stage in the supply chain.
10. Process entry time: store the entry time for each production lot once it enters a new process. This information is used to calculate the waiting time of each lot. When the lot is moved to a different process, this information needs to be updated.
11. Stage entry time: store the entry time of each production lot at each stage. This information is used to calculate the production cycle of each lot in different stages. When the lot is moved to a different stage, this information needs to be updated.
12. Raw process time of entire supply chain: store total raw process time required to finish one product in the entire supply chain.
13. Raw process time of stage: store total raw process time for all operations required to finish one product in a stage. Once the lot is moved to a different stage, this information needs to be updated.
14. Processing time: store the processing time of each lot in each production flow. Once the lot is moved to a different production flow, this information needs to be updated.
15. Remain raw process time in supply chain: store remain completion time of each production lot in supply chain. Once the lot is finished in one operation, this information needs to be updated.
16. Remain raw process time (stage): store remain completion time of each production lot in each stage of supply chain. Once the lot is finished in one operation, this information needs to be updated.
17. Expected process entry time: store the theoretical entry date for the lot at each stage in order to fulfill customer order on time. Once the lot moves from one stage to another stage, this number needs to be updated.
18. Cumulated waiting time: store cumulated waiting time of a production lot once it enters the first stage of supply chain. This information will be updated and the cumulated waiting time is re-calculated when the production lot is moved to another production flow for processing.
19. Lot status: store the current status of each production lot. The status may include waiting for process, in process or finished, etc.

6. Accomplishment 4: Research on the inter-relationship among different metrics

In order to build up the monitor and control mechanism for supply chain, it is necessary first to clarify the relationship among performance metrics. At this moment, the relationship among performance metrics is only discussed in each category. For instance, for the performance metrics in the category of delivery, we can compute the total delivery performance from delivery performance of each production lot, or from delivery performance of each order. The relationship among these metrics is shown in Figure 7. For the performance metrics in the category of cycle time, initially, we should be able to obtain the actual cycle time of each production lot from RFID. The cycle time of a production lot is mainly composed of raw process time and waiting time. By using raw process time and actual cycle time, we can calculate the X-Factor at different levels of supply chain. The relationship among these metrics is shown in Figure 8. For the performance metrics in the category of WIP, we can derive the metrics for dynamic X-Factor by using the distribution and the status of WIP. Once the metrics is derived, we will be able to figure out the relationship between the metrics and the cost through WIP distribution. The relationship among these metrics is presented in Figure 9.

7. Accomplishment 5: Define next-year monitoring and control framework

With the performance metrics of SCOR-based and RFID-based semiconductor supply chain, the monitor and control functions for a semiconductor supply chain can be designed as shown in Figure 10. This system will contains 3 sub-functions: (1) to obtain the distribution of cycle time by performing simulations of a semiconductor supply chain; (2) to determine the upper and lower production control limits for WIP and tolerant false alarm rate; (3) to monitor semiconductor supply chain and determine the timing for updating control limits.

The information needed for these sub-functions are shown in Figure 11. By utilizing the performance metrics of cycle time, delivery rate, and WIP, we can obtain the most robust supply chain configuration. Based on this configuration and scenario settings and constraints, we can perform simulations of a semiconductor supply chain. From the simulation results, the distribution of cycle time under the most robust supply chain configuration can be found. By considering the distribution of cycle time with scenario constraints, the upper and lower production control limits for WIP and tolerant false alarm rate are derived. Finally, with upper and lower production control limits for WIP and tolerant false alarm rate and constraints, the control chart of production control is developed and the timing for updating control limits is determined.

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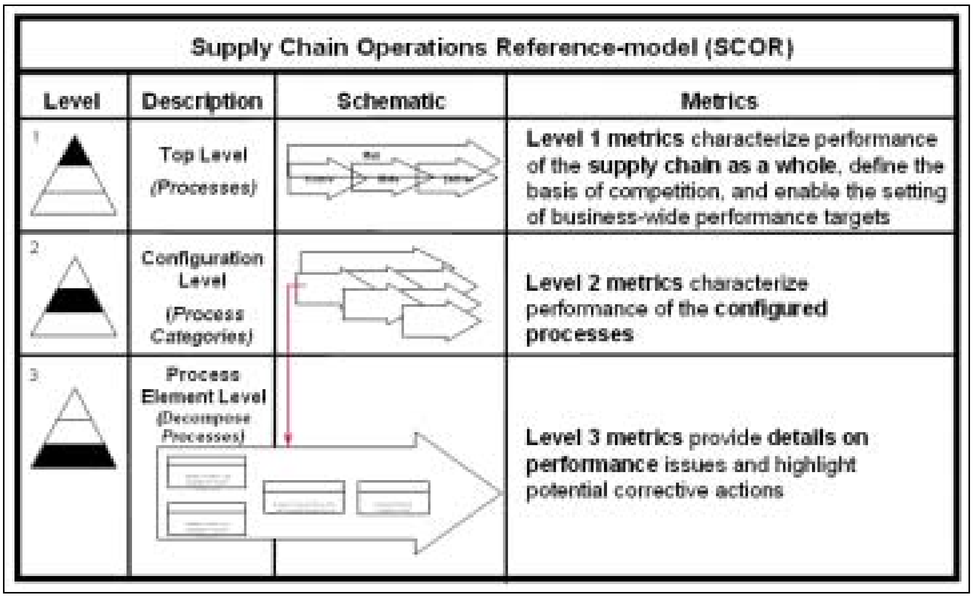

Figure 1 SCOR model

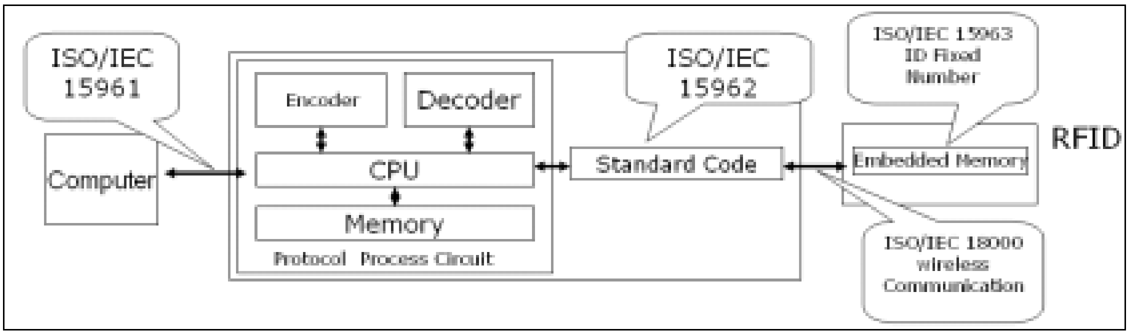

Figure 2 The infrastructure and current existing standards of RFID

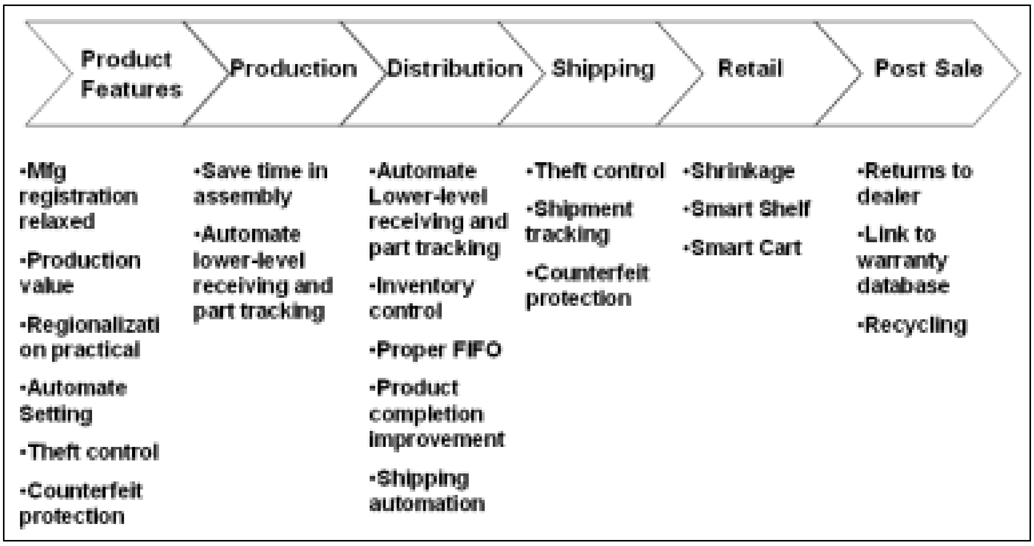

Figure 3 The applications of RFID in supply chain

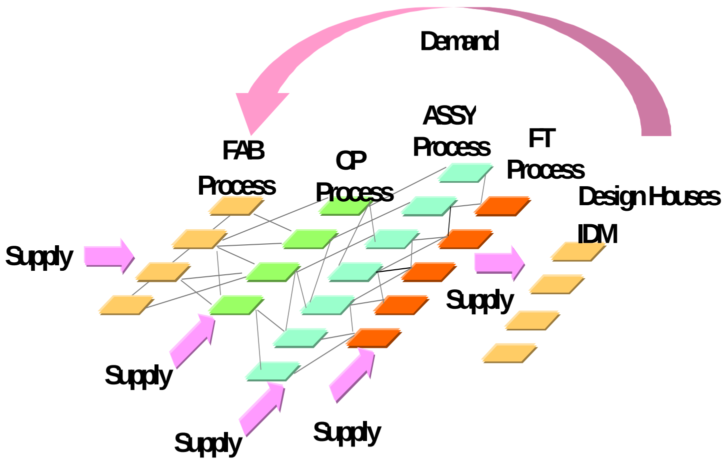

Figure 4 Semiconductor supply chain

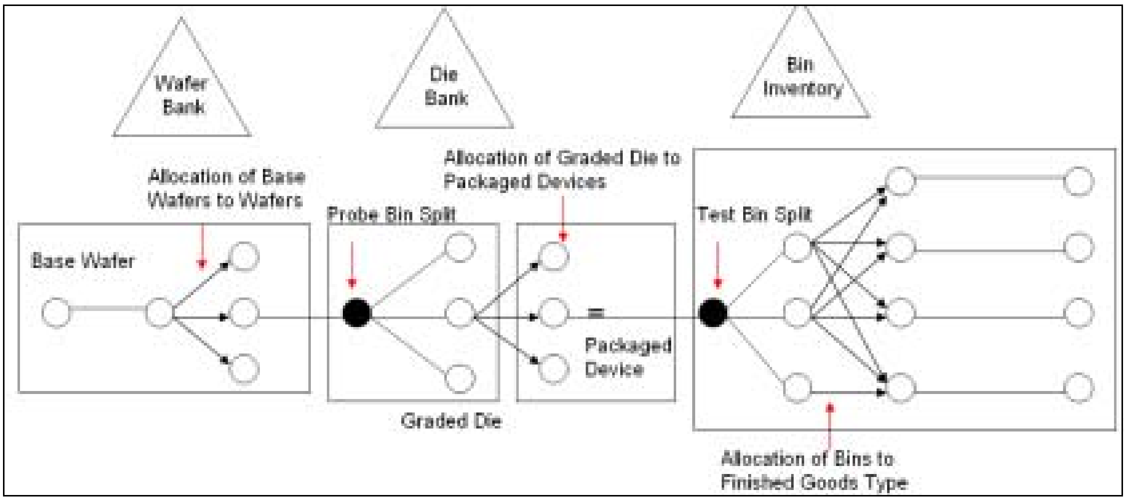

Figure 5 Production flow in semiconductor supply chain

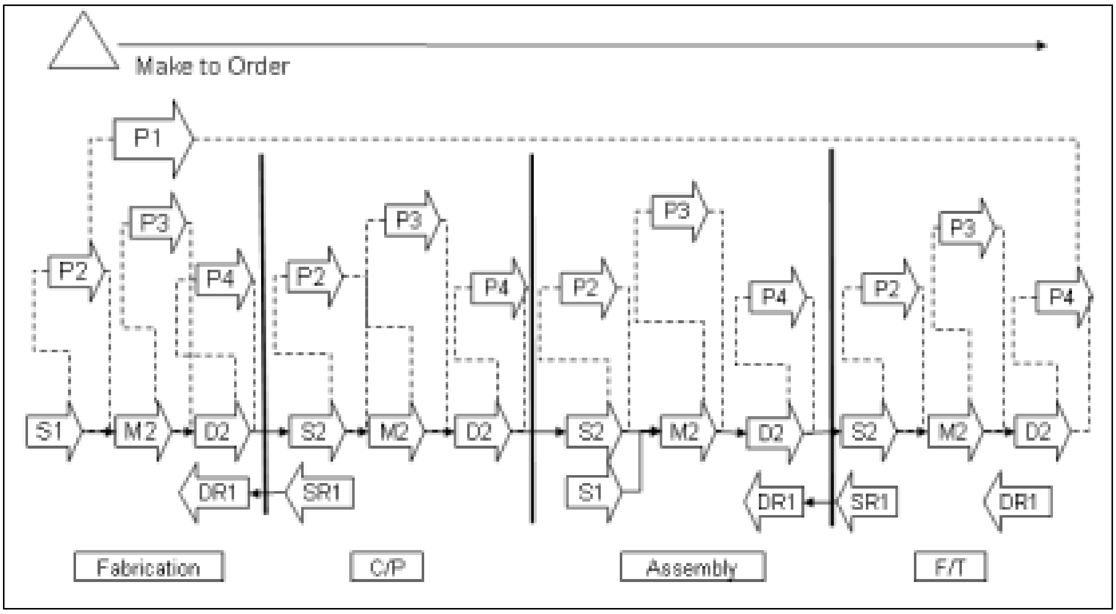

Figure 6 SCOR model for semiconductor supply chain

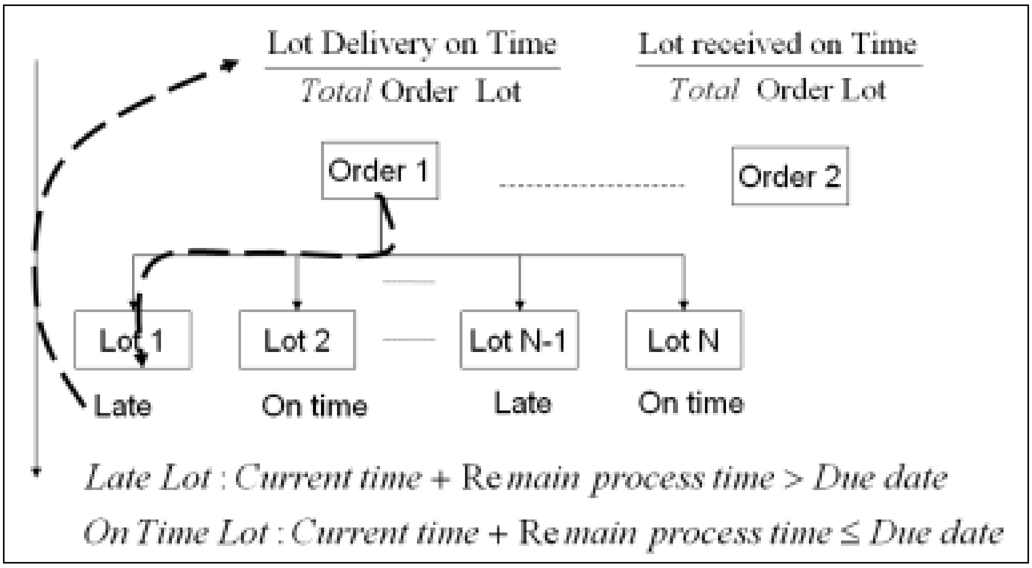

Figure 7 The relationship of the performance metrics in delivery category

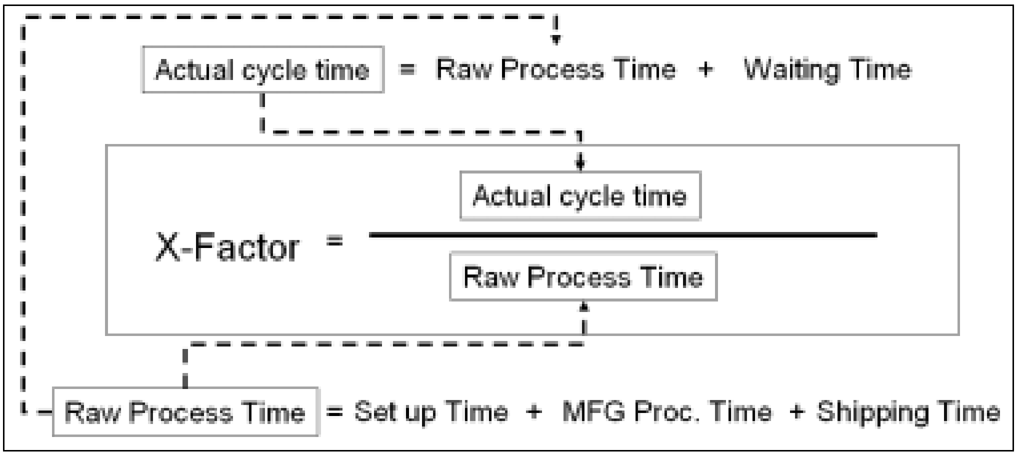

Figure 8 The relationship of the performance metrics in the cycle time category

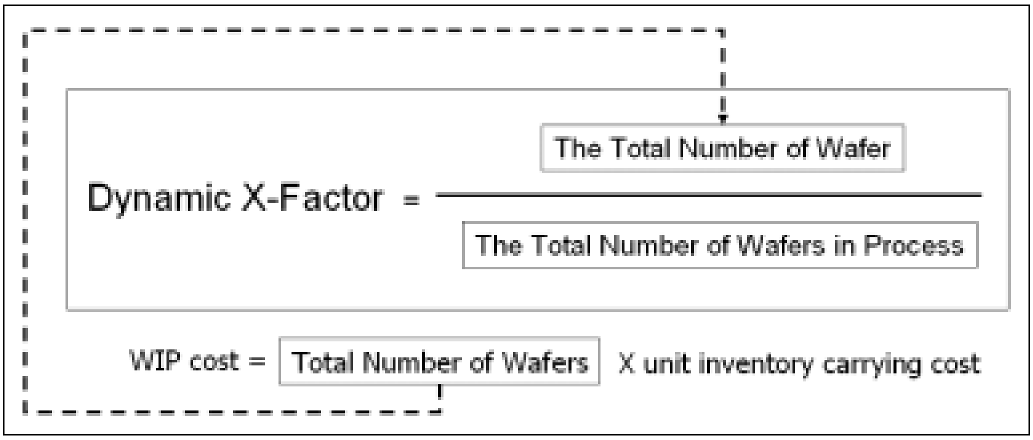

Figure 9 The relationship of the performance metrics in the WIP category

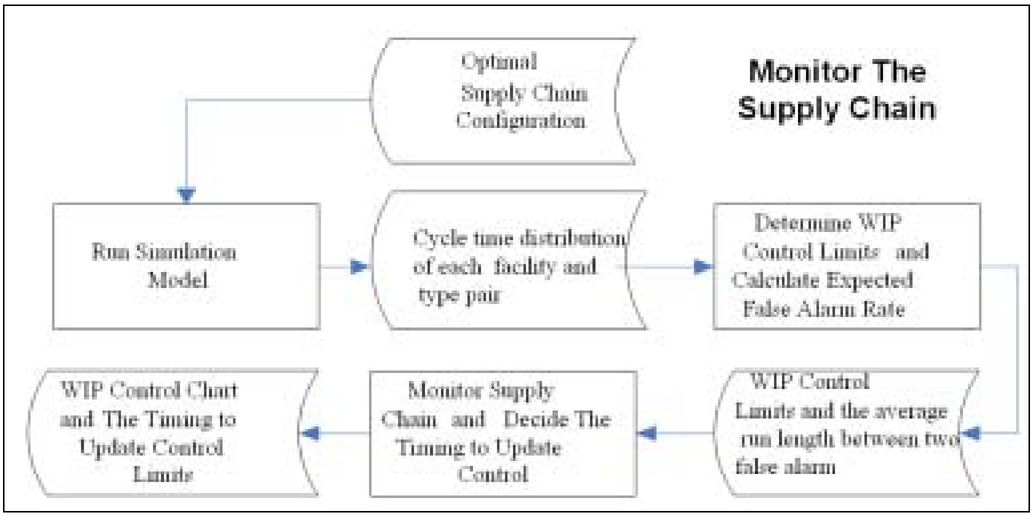

Figure 10 Monitor and control functional flowchart for semiconductor supply chain

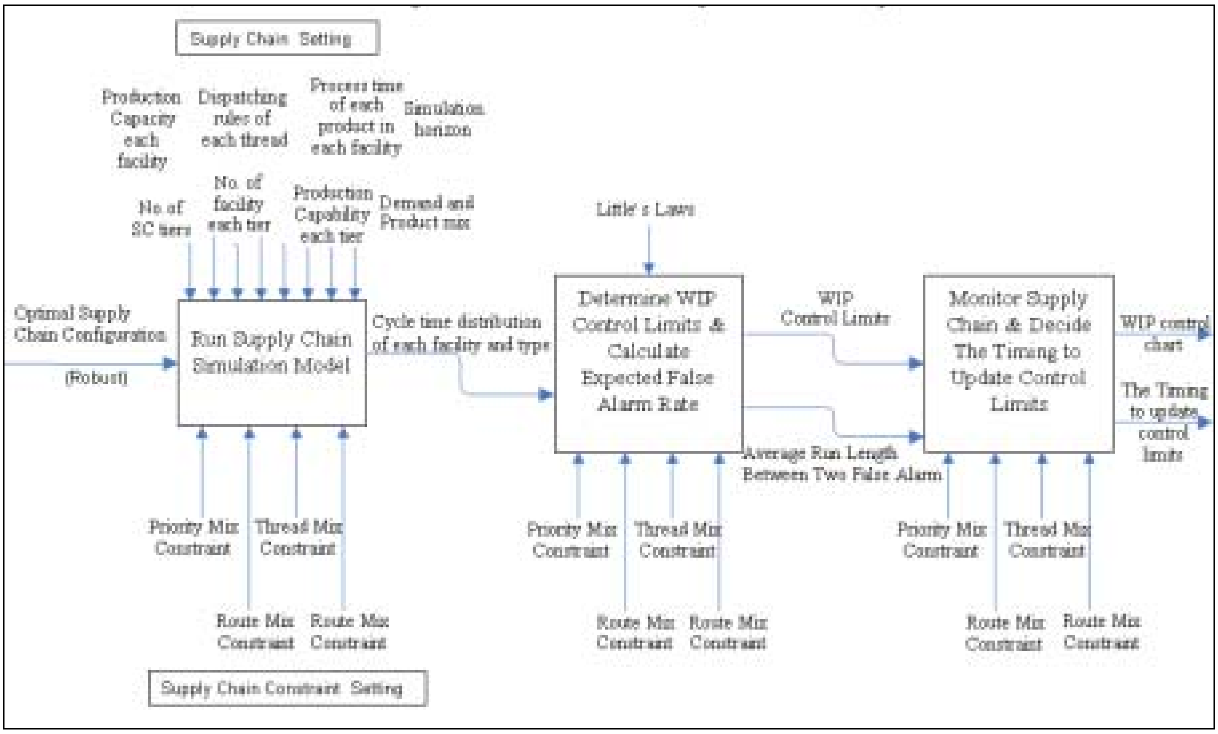

Figure 11 Monitor and control data flow diagram in semiconductor supply chain