The Analysis of the Role of Information for Production Control System
— 생산통제시스템을 위한 정보의 역할 분석 —

Kim, Hyun-Soo*
김 현 수
Choi, Jin-Yeong*
최 진 영

요 지

무한대의 경쟁체제로 급속히 변해 가는 현실에서 생산통제시스템은 고객의 만족도를 극대화하며 최적의 합리적인 경영을 할 수 있도록 생산환경을 뒷받침할 수 있어야 한다. 이를 위해서는 생산시스템 전반에 걸친 정보 및 통신 기술의 중요성이 다른 어느것 보다도 더욱 더 강조되며, 그리고 중요한 역할을 담당해 나가고 있다. 본 연구에서는 이러한 최근의 환경을 나타낼 수 있는 제조환경에서 중추적인 역할을 담당하는 생산통제시스템에 사용되고있는 정보기술에 관하여 기존의 생산통제방식(납기일결정방식, 생산입력통제방식, 우선순위결정방식)에서 사용되고있는 정보의 내용을 분석하여 생산환경의 어느 부분의 어떤 정보가 생산통제시스템에서 중요한 역할을 담당할 수 있는지를 연구하고, 생산시스템 각 부분에서 반드시 고려되어야 하는 정보의 내용을 제시하고자 한다.

1. Introduction

The success of future, or even current, manufacturing system requires high quality products, low cost, high performance in meeting the customer's expectations, and high satisfaction in delivery time performance for customers[1]. Accomplishing these goals requires a lot more information from the manufacturing system, and particularly, information plays a key role in the production control of manufacturing systems. The control system must have proper information about the current state of the system and must use proper information technologies and communication technologies in order to make a timely and effective decision. Unfortunately, however, little has been studied about the role of information technology in production control system. Only the following assumption has been applied implicitly throughout most research: Information is available at the right time at the right place.

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* Department of Industrial Engineering, Kyonggi Univ.

Identification of useful information needed for production control will improve the quality of the research in manufacturing environment. For this purpose, first, we discuss about the role of information technology in production control system in manufacturing environment including customers and raw material suppliers to support the evolution of manufacturing, especially its evolution toward Agile Manufacturing. Next, the appropriate elements of information needed for each element of production control(due-date assignments, production input control, and priority dispatching rule) system are discussed. And finally, the conclusions are provided.

2. The Role of Information Technology (IT)

The control system must have proper information about the current state of the system and must use proper information technologies and communication technologies in order to make a timely and effective decision. Therefore, the performance improvement of the manufacturing system will really depend on the quality of information(i.e., real-time, accurate, complete) and the quality of the technologies used.

Jaikumar[2] mentioned that in manufacturing "now the emphasis is on versatility and intelligence, the substitution of intelligence for capital, and economies of scope." Therefore, most of all, communication and information sharing are the most important aspects manufacturing should be seeking for. National Research Council[1] reported that "more, and more timely, information will be needed for decisions on the shop floor and in executive suites alike; information-intensive programmable processes and automated on-line control can improve product quality and manufacturing flexibility; greater integration among design, production, and marketing will lead to a greater need to share information."

With recent drops of prices and advances of performances in personal computers(PCs), wireless communications, and business software, manufacturing is now fast entering a new age of industrial excellence that is being called "Agile Manufacturing." The goal of Agile Manufacturing is to link customers, suppliers, and manufacturing system into a super-efficient confederation to produce a variety of products quickly and at a low cost[3]. A recent Computer Sciences survey of information system at U.S. and European corporation found that "Customer service is the No.1 focus of their companies's investment in technology[4]."

Manufacturers who tie customers, suppliers, and the manufacturing system into an equation for speed and agility can create a "time gap" between them and their competitors[5]. Through Agile Manufacturing, a customer can order his or her products over a phone-line, choosing features by describing them in whatever language they want. The specifications of the order can then be automatically entered into a CAD/CAM system to design, translated into the data the manufacturers needs, stored on a computer, and sent to the shop floor for production - while the customer is still on the line[6].

Close customer-supplier relationships help reduce costs in today's world economy, and particularly, boost speed which is very important in a world of ever faster product cycles [7]. Youssef[8] insisted that timeliness in creating products is an essential element of competition in 1990s and will continue in 21st century. Figure 1 illustrates typical structure of Agile Manufacturing.

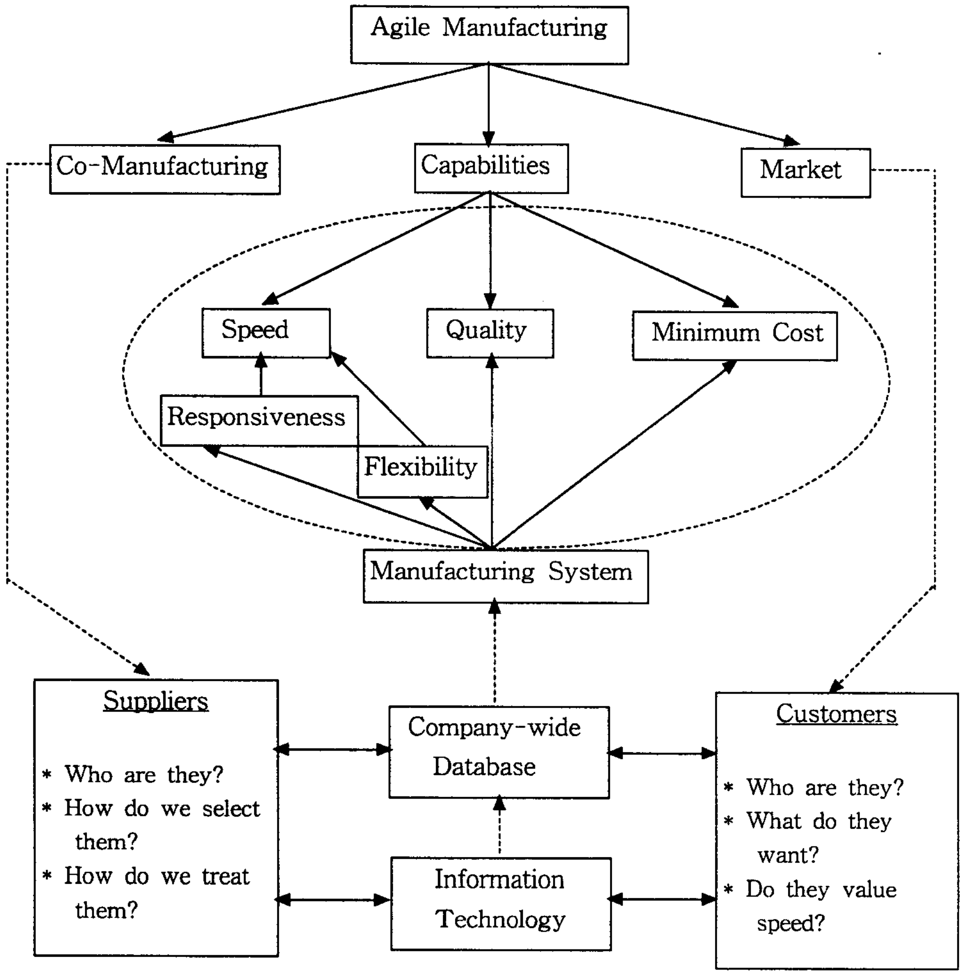

Figure 1. Typical structure of Agile Manufacturing[8]

Through Agile Manufacturing, flexible production manufacturing, changed from mass production manufacturing, is now changing toward mass customization manufacturing. "Customized products will be made as fast and as cheaply as mass-produced product[2]." Therefore, the performance improvement of the manufacturing system will depend greatly upon the quality of information technologies and communication technologies applied.

The subject of information technology(IT) in this study is only limited to the role and effect of information technology in production control system in manufacturing environment including customers and suppliers.

Stark[9] mentions that the role of IT is to help the manufacturing enterprise gain competitive advantage. Table 1 illustrates some of the differences between the IT environment and non-IT environment.

Table 1. Differences between IT and non-IT environments[9]

IT environment	Non-IT environment
* The key technology is the application in the computer at the work place of everyone in the company. * The key people are the "end-users" of computers, not the support staff. * IT helps link the manufacturing enterprise to the rest of the world. * IT focused on gaining competitive advantage. * IT plays an important role in all departments including engineering, manufacturing and marketing. * IT investment justification based on increased revenues from increased market share and reduced time to market as well as reductions in direct costs. * IT is a strategic weapon.	* The key technology is the mainframe computer in the computer center. * The key people are the support staff. * Computers only used for internal application of manufacturing enterprise. * Computers used to reduce direct costs and provide information to management. * Departmental use of computers. Use focused on Finance and Administration Department. * Investment justification for computers based on dollar savings in direct costs. * Computers and communications are not strategic tools.

IT can help to improve the performance of manufacturing system by using the most appropriate elements of information and of information technologies and communication technologies. Particularly, IT can affect the relationships with key customers and suppliers. As one of the most important benefits, IT can help the manufacturing enterprise gain competitive advantage as manufacturing is fast entering a new age of industrial excellence, Agile Manufacturing. Parsons[10] identifies six general opportunity areas in which IT can make major contributions to the manufacturing enterprise's competitive posture. They are:

1) IT increases customer switching costs: networking with customers by placing terminals at the customer site and allowing them to place orders and query order status provides a service that can only be replicated by another competitor at increased customer cost.
2) IT decreases one's switching costs against suppliers: using IT can reduce the dependence on a single supplier.
3) IT supports product innovation: using IT can increase product quality at the same cost or decreasing cost without affecting the quality.
4) IT cooperates with selected rivals by sharing IT resources.
5) IT substitute human labor: using IT can replace the human labor which reduce the production and/or distribution costs at the same time reduce the human error.
6) IT improves the customer service: using IT can obtain the accurate data which increase customer's satisfaction.

Among the above six areas, the elimination of human involvement from information collection by employing IT is really important aspect which allow the reducing human error caused by inaccuracy and reducing time spent in data entry. Through the recent study[11] regarding the role of production input control in a job shop manufacturing environment towards Agile Manufacturing system, we learned that the production input control should be carefully designed to obtain the best balance of performance measures. Carefully designed production input control(PIC) requires the involvement of more elements of information, which eventually emphasizes the role of IT more.

When a production control is composed of three sub-phases (due-date assignment(DDA), production input control(PIC), and priority dispatching rule(PDR)), information plays a key role in the production control of manufacturing systems. Unfortunately, however, only the following information related assumptions have been applied implicitly throughout the most research:

- Information is available at the right time at the right place.
- Enough raw materials are available always.
- Customers place orders without consideration of order waiting time.

The production control system must have proper information about the current state of the system in order to make a timely and effective decision. Therefore, it is necessary to improve and modify above assumptions intensively. Moreover, the assumption of enough raw material without explicitly modeling the supplier is not realistic in current manufacturing systems that are seeking for Just-In-Time(JIT) inventory systems.

In order to investigate the useful elements of information needed for each element of the production control(DDA, PIC, and PDR), we collected previous studies from literatures and studied what kinds of information are used for each element of the production control system specifically. After that, we analyzed which elements of information are frequently employed for each element of the production control system.

3.1 Due-date Assignment(DDA)

Whenever a new order is arriving, we have to find a due-date for each arriving order. In order to decide the proper due-date for each arriving order, many information should be needed. A total of 11 different due-date assignment(DDA) rules were selected from previous literatures. Table 2 summarizes the elements of information used for each of due-date assignments at previous studies. Based on Table 2, we analyzed the frequency of each information employed for the due-date assignments. Table 3 presents the summary of the frequency of each information for the due-date assignments.

As we can see from Table 3, the information regarding the characteristics of the order itself is most frequently used as elements of information for due-date assignments. However, other elements of information regarding the status of manufacturing system, the shop floor and raw material availability are also necessary to provide more accurate estimation of due-dates.

One reason why only one side of information (the characteristics of order itself) was employed for estimation of due-date in previous studies may be the lack of understanding about the role of information technologies and communication technologies.

Table 2. Information applied for previous due-date assignments

Due-date Assignment Rule (DDA)	Information
Constant (CON)	Order arrival time in the system, Constant flow lead time
Processing Time (PT)	Order arrival time in the system, Total processing time of order
Processing Time and Constant (PTC)	Order arrival time in the system, Total processing time of order, Constant flow lead time
Processing Time and Variable (PTV)	Order arrival time in the system, Total processing time of order, Variable flow lead time
Processing Time with Planning Stage (PTPS)	Order arrival time in the system, Total processing time of order, Time until next scheduled release from planning stage
Operation Number (OPN)	Order arrival time in the system, Total number of operations of order
Operation Number and Constant (OPNC)	Order arrival time in the system, Total number of operations of order, Time until first day of next week
Processing Time and Operation Number (PTOPN)	Order arrival time in the system, Total number of operations of order, Total processing time of order
Processing Time and Operation Number with Constant (PTOPNC)	Order arrival time in the system, Total number of operations of order, Total processing time of order, Constant flow lead time
Processing Time and Number of Orders in the Queue of Route (PTNOQR)	Order arrival time in the system, Total processing time of order, Routing sequence of order, Number of orders waiting in the queues of its route
Processing Time and Number of Orders in the System (PTNOSYS)	Order arrival time in the system, Total number of orders in the system currently, Total processing time of order

Table 3. Frequency of information used for the due-date assignments

Rank	Information	Frequency*
1	Order arrival time in the system	11/11
2	Total processing time of order	8/11
3	Total number of operations of order	4/11
4	Constant flow lead time	3/11
5	Variable flow lead time	1/11
5	Time until next scheduled release from planning stage	1/11
5	Time until the first day of next week	1/11
5	Number of orders waiting in the queues along the route	1/11
5	Routing sequence of order	1/11
5	Total Number of orders in the system currently	1/11

* Frequency: Number of appearance/total 11 Due-date Assignments

As we discussed previously, IT allows the collections of more accurate information from the shop floor and linkage of each workstation to other workstations, management department to shop floor, and management department to raw material suppliers more quickly and easily. Therefore, information from the manufacturing system, the order itself, and from raw material suppliers should be considered as elements of information for the due-date assignments. Based on the above analysis regarding information applied at literatures, suggested elements of information for the due-date assignments are:

Manufacturing System

* Pre-shop Stage:
  - number of orders waiting at Order Release Pool, and
  - total workload of orders waiting at Order Release Pool.
* Shop floor:
  - WIP(Work-In-Process) level at each work center,
  - queue load at each work center, and
  - total WIP level of shop floor.

Characteristics of order itself

- arrival time in the system,
- due-date,
- route,
- total number of operations, and
- total processing time.

Raw Material Suppliers

- raw material availability, and
- raw material delivery date.

3.2 Production Input Control(PIC)

After an order's due-date is assigned, each order is transferred to the Order Release Pool immediately. Orders wait at the Order Release Pool until released into the shop floor by a PIC. A total of 20 different production input control(PIC) rules were selected from previous literatures. Table 4 summarizes the elements of information used for each of PICs at previous studies. Based on Table 4, we analyzed the frequency of each information employed for the PICs. Table 5 presents the summary of the frequency of each information for the PICs.

As we can see from Table 5, the elements of information regarding the status of the shop floor are most frequently used and the elements of information which characterize the order itself are next frequently used as the elements of information for the PICs.

Table 4. Information used for the production input controls

Production Input Control (PIC)	Information
Immediate Release (IMR)	No information is used
Maximum Workload (MWL)	Order arrival time in the system, Current amount of unfinished work in the shop floor including the processing work, Pre-defined maximum workload in the shop floor
Maximum Workload with Least Work in Next Queue (MWLWNQ)	Routing sequence of order, Current amount of unfinished work in the shop floor including the processing work, Amount of work waiting in the queue of each work center, Pre-defined maximum workload in the shop floor
Minimum Workload (MIWL)	Order arrival time in the system, Current amount of unfinished work in the shop floor including the processing work, Pre-defined minimum workload in the shop floor
Minimum Workload in Queue of Work Center with Earliest Due-date (MWQWEDD)	Due-date of order, Routing sequence of order, Amount of workload waiting in the queue of each work center, Pre-defined minimum workload
Minimum Workload in backlog File with First in First Out (MWBFFIFO)	Order arrival time in the system, Current workload in the backlog file, Pre-defined minimum workload in the backlog file
Minimum Workload in Backlog File with Smallest Ratio (MWBFSR)	Total Processing time of order, Weight information, Current workload in the backlog file, Pre-defined minimum workload in the backlog file.
Maximum Number of Orders (MNO)	Current priority dispatching rule (PDR) used, Current number of orders in the shop floor, Pre-defined maximum number of orders in the shop floor
Bottleneck Workload (BWL)	Order arrival time in the system, Location of bottleneck work center, Current amount of workload in the bottleneck work center, Pre-defined minimum workload in the bottleneck work center
InOut Quantity (IOQ)	Order arrival time in the system, Daily output produced, Simple moving average of output for previous 10 days
Fixed Quantity (FQN)	Order arrival time in the system, Pre-defined target throughput rate of the system
Bottleneck Workload with Shortest Processing Time (BWLSPT)	Total processing time of order, Location of bottleneck work center, Current amount of workload in the bottleneck work center, Pre-defined minimum workload in the bottleneck work center
Backward Infinite Loading (BIL)	Due-date of order, Total number of operations of order, Planning value

Table 4. Continued

Production Input Control (PIC)	Information
Bottleneck Workload with Least Time to Bottleneck Work Center (BWLLTBW)	Processing time of each operation for order, Routing Sequence of order, Location of bottleneck work center, Current amount of workload in the bottleneck work center, Pre-defined minimum workload in the bottleneck work center
Modified Backward Infinite Loading (MBIL)	Due-date of order, Routing sequence of order, Total number of operations of order, Number of orders waiting in the queue of each work center, Planning value
Backward Finite Loading (BFL)	Due-date of order, Routing sequence of order, Processing time of each operation for order, Time-bucket information of planning horizon, Current status of work center capacity
Forward Finite Loading (FFL)	Due-date of order, Total number of operations of order, Processing time of each operation for order, Current workload profile for each work center, Current status of work center capacity, Estimated order completion time
Mixed Integer Programming (MIP)	Due-date of order, Current workload for each work center, Pre-defined desired workload for each work center
Kanban Method (KM)	Routing sequence of order, Current status of work center capacity, Current status of kanbans at each work center

Through the recent experimental study[11] regarding production input control in a job shop manufacturing environment, we learned that the PIC which consider a more variety of detailed elements of information can help to produce good performance measures in a job shop manufacturing environment considering customers and suppliers. Therefore, the elements of information from the order itself, the shop floor, and raw material suppliers should be considered together for the PICs. They are:

<u>Characteristics of Order itself</u>

- arrival time in the system,
- due-date,
- route,
- total number of operations, and
- total processing time.

Shop Floor

- WIP level at each work center,
- queue load at each work center,
- work load at each work center,
- total work load of shop floor,
- total WIP level of shop floor, and
- desirable maximum WIP level of shop floor.

Raw material Suppliers

- raw material availability, and
- raw material delivery date.

Table 5. Frequency of information used for the production input controls

Rank	Information	Frequency*
1	Current workload for each work center and its total	13/20
2	Order arrival time in the system	12/20
3	Due-date of order	11/20
4	No information is needed (Immediate Release)	11/20
5	Routing sequence of order	8/20
6	Total number of operations of order	7/20
7	Pre-defined maximum workload in the shop floor	6/20
8	Location of bottleneck work center (fixed)	4/20
8	Current workload for the bottleneck work center	4/20
8	Pre-defined minimum workload in bottleneck work center	4/20
8	Processing time of each operation for order	4/20
12	Current number of orders in the shop floor (WIP)	3/20
12	Pre-defined minimum workload in the shop floor	3/20
12	Number of orders waiting in the queue of each work center	3/20
15	Amount of work waiting in the queue of each work center	2/20
15	Current workload in the backlog file	2/20
15	Total processing time of order	2/20
15	Pre-defined minimum workload in the backlog file	2/20
15	Pre-defined target WIP level in the shop floor	2/20
15	Planning value	2/20
21	Weight information	1/20
21	Pre-defined maximum number of orders in the shop floor	1/20
21	Pre-defined target throughput rate of the system	1/20
21	Time-bucket information of planning horizon	1/20
21	Estimated order completion time	1/20
21	Current status of kanbans at each work center	1/20
21	Daily output produced	1/20
21	Simple moving average of output for previous 10 days	1/20

* Frequency: Number of appearance/total 20 Production Input Controls

3.3 Priority Dispatching Rule(PDR)

Once orders are released into the shop floor, order's movement through the shop floor is controlled by the PDR. A total of 8 different Priority Dispatching Rules(PDRs) were selected from previous literatures. Table 6 summarizes the elements of information used for each of the PDRs at previous studies. Based on Table 6, we analyzed the frequency of each information employed for the PDRs. Table 7 presents the summary of the frequency of each information for the PDRs.

Table 6. Information used for the priority dispatching rules

Priority Dispatching Rule (PDR)	Information
First In First Out (FIFO)	Current work center number, Arriving time of order at current work center
Shortest Processing Time (SPT)	Current work center number, Processing time of operation at current work center
Earliest Due-date (EDD)	Current work center number, Due-date of order
Modified Due-date (MDD)	Current work center number, Current time, Due-date of order, Remaining processing time of order
Minimum Critical Ratio (MCR)	Current work center number, Current time, Due-date of order, Total processing time of order, Remaining processing time of order
Minimum Stack Time (MST)	Current work center number, Current time, Due-date of order, Total processing time of order, Remaining processing time of order
Slack per Remaining Operation (S/OPN)	Current work center number, Current time, Due-date of order, Number of operations remaining of order, Total processing time of order, Remaining processing time of order
Due-date and Processing Time (DDPT)	Current work center number, Current time, Due-date of order, Processing time of operation at current work center

As we can see from Table 7, both elements of information regarding characteristics of the order itself and information at the shop floor are frequently used as the elements of information for the PDRs. This is because the PDRs mainly employ the elements of information regarding the order itself and the characteristics of orders at each work center.

From the recent experimental study[11], we learned that characteristics of information for PDRs are suggested as simple but well enough to represent the order itself at each work center. Suggested elements of information for the PDR are:

- due-date,
- arrival time at each work center,
- processing time at each work center,
- remaining total processing time,
- total processing time.

Table 7. Frequency of information used for the priority dispatching rules

Rank	Information	frequency*
1	Current work center number	8/8
2	Due-date of order	6/8
3	Current time	5/8
4	Remaining processing time of order	4/8
5	Total processing time of order	3/8
6	Processing time of operation at current work center	1/8
6	Arriving time of order at current work center	1/8
6	Number of operations remaining of order	1/8

* Frequency: Number of appearance/total 8 Priority Dispatching Rules

4. Conclusion

The success of future, or even current, manufacturing systems really requires high quality products, low cost, high performance in meeting the customer's expectations, and high satisfaction in delivery time performance for customers[1]. Accomplishing these goals emphasizes the role of IT more because equipment and workstations within the manufacturing system, entire manufacturing enterprises, networks of suppliers, and customers located throughout the world can be more efficiently networked and controlled through the use of information technologies and communication technologies.

Furthermore, the role of IT is more emphasized recently as manufacturing is fast entering a new age of industrial excellence that is being called "Agile Manufacturing," where the goal of Agile Manufacturing is to link customers, suppliers, and the manufacturing system into a super-efficient confederation to produce a variety of products quickly and at a low cost[3].

Stark[9] mentions that the role of IT is to help the manufacturing enterprise gain competitive advantage. Therefore, proper usage of the elements of information and of information technologies and communication technologies needed for production control system in manufacturing environment considering customers and suppliers is essential to compete successfully in a rapidly changing world full of competitors, customers, suppliers, and others that affect the manufacturing environment.

Based on the result of recent experimental study[11], we learned that the production input control should be carefully designed to obtain the best balance of performance measures. A carefully designed PIC requires the involvement of more elements of information, which eventually emphasizes the role of IT more.

Through the studies from literatures about what kinds of information are used for each element of information specifically and how frequently, we can list the suggested elements of information for each element of production control(DDA, PIC, PDR) system. Table 8 illustrates the summary of suggested elements of information for each element of production control system.

Table 8. Summary of suggested elements of information for each element of production control system

Information Element	DDA	PIC	PDR
Order Itself			
· arrival time in the system	X	X	
· arrival time at each work center			X
· due-date	X	X	X
· route	X	X	
· total number of operations	X	X	
· remaining number of operations			X
· processing time at each work center			X
· total processing time	X	X	X
· remaining total processing time			X
Shop Floor			
· WIP level at each work center	X	X	
· total WIP level of shop floor	X	X	
· queue load at each work center	X	X	
· work load at each work center		X	
· total workload of shop floor		X	
· desired maximum WIP level		X	
Pre-Shop State			
· number of orders waiting at Order Release Pool	X		
· total workload of orders waiting at Order Release Pool	X		
Raw Material Suppliers			
· raw material availability	X	X	
· raw material delivery date	X	X	

X: suggested element of information

Table 8 shows the interesting results that we recommend the use of more information for the PIC than for the PDR and also shows that different kinds of information are used for each. These results are matching with the result of recent study regarding the role of production input control in job shop manufacturing environment[11].

Information suggested through this study will help to manage overall production control system and to produce better performance from each element of production control (DDA, PIC, and PDR) system in a manufacturing environment.

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