

**Framework of Production Information Management System  
for Automated Construction  
- WASCOR IV Research Project Report (Part IV) -**

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**ABSTRACT**

For automatizing building construction systems with robots, the WASCOR (WASeda CONstruction Robot) IV research project has been organized since 1992 by System Science Institute, Waseda University. This multi-client research project includes nine general constructors and one construction machinery manufacturer. The purpose of this paper is to report a part of the research results of the final year for the project period of three years. This paper presents a concept of "Production Information Management System (PIMS) based on real time monitoring for Automated Construction". In recent years, many construction robots have been developed with the goal of increasing the productivity in construction site. However, most of these robots numbered by a hundred or more types for various tasks can not be put into practical use with the desired labor savings at conventional construction sites. The reasons why these robots cannot attain successful utilization are not only the immature capabilities of their own hardware and software systems, but also the lack of the development of the new construction methods suitable for robotization, and total construction management and control systems for cooperatively operating multiple types of robots and automated machines in the sites. The concept of "Point of Production (POP)" information management and control already being operated in the manufacturing industries is a useful tool for establishing the framework of the PIMS in the future automated building construction. This paper also describes the POP concept and how to apply it to build this framework.

**1. INTRODUCTION**

Recently, Japanese general constructors have tried to develop and implement the several unique construction methods of mechanized structural steel work and precast concrete as the first strategy towards a future construction system by using some computer control technology. However, even if some fleets of various robots are introduced into a site without the total computer-assisted information system for management and control, they do not contribute on remarkable improvement of whole productivity in comparison of traditional human-oriented construction work. Although the direct craftsmen's tasks are decreased by using the robots, engineers and mechanics have to be engaged in further set-up operations before and after utilizing those diverse kinds of robots and machinery. The excessive burdens of preparation prior to production and indirect set-up tasks for operating the machinery undoes the merits of the direct labor savings. The robot fleets can hardly be used

within the traditional sites based on the conventional management and control environment, for example, verbal instructions and sensory inspection on the construction site by inspectors.

For this reason, the research and development on computer-assisted information system for production management and machinery control are indispensable for future automated construction work. As the first stage of the research, WASCOR has tried to develop a framework of "Production Information Management System (PIMS) based on real time monitoring for automated construction". The concept of "Point of Production (POP)" information management and control already being operated in the manufacturing industries is a useful tool for establishing the framework of the PIMS.

This paper mainly treats with the following issues. Firstly, the role and effects of the POP system in Japanese manufactures are described. Secondly, the influence on robotized construction, in view of characteristics of quantitative and qualitative production information managed by site managers, is appointed in comparison of the conventional type's construction. Thirdly, the project management for the automated construction is categorized and the management items covered with PIMS are described. Finally, as an example of a process management system among the management items, the flow of production information is illustrated within a hierarchial management structure for the site management.

## **2. Concept and Effects of POP System in Manufacturing Industries**

The POP system copes with two type of the production information, namely, "down-loading" information and "up-loading". Figure 1 illustrates the two type of the information according to individual system levels within the POP system. This figure also means that the CIM (Computer Integrated Manufacturing) system will be constructed on the basis of the POP information management in the future factories.

Firstly, the function of the POP system regarding "down-loading" production information is described as follows <sup>4),7)</sup>. The ever-changing production information at a shop floor is directly collected from machines, facilities, workpieces, and workers by using the POP network. This information is immediately processed, and the processing results concerning production progress are provided to the shop managers and foremen at real-time. Based on the real-time production information, they can flexibly control the current production progress and conduct the proper operation instructions according to the alternation of the external and internal situation.

Secondly, the another function is "down-loading" of operation instructions to individual operators or automated machinery. Significance of such instruction way does not imply only the paper-less instructions to them in stead of using conventional instruction sheet, but also no requirement for collecting and analyzing performance reports by the shop managers and foremen.

Generally, the POP system covers the following issues of information management control <sup>5),8)</sup>:

- 1) Production preparation,
- 2) Process planning,
- 3) Operation instructions for operators, and operational programs down-loading from CAD/CAM system to individual NC machines,
- 4) Real-time monitoring of process conditions,
- 5) Supervision of production progress and countermeasures to cope with abnormal production situation,
- 6) Collection, processing, and analysis of production performance data, and
- 7) Reporting of actual performance results, and inputting the results into database for data renewal.

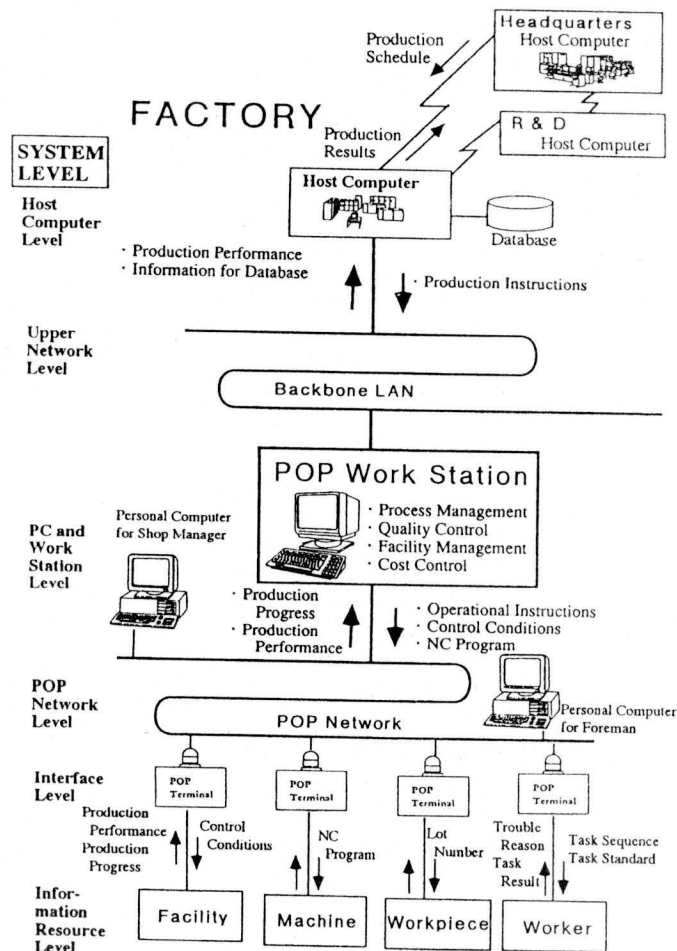


Figure 1 CIM System on the Basis of POP Information Management

The project teams, who are consisted of the foremen, shop managers, manufacturing engineers, production planners, and staff in charge of cost accounting, should have the periodical meeting for the positive KAIZEN activities in order to effectively utilize the results of the data processing and analyses through the POP system. Additionally, the POP system is also a useful tool for the workers to participate in the another KAIZEN activities at the bottom-up level such as the "QC circle" groups.

The Japanese manufactures have almost succeeded to reduce the direct manufacturing costs associated with the cost of man-power, machine-power, and materials, by means of KAIZEN activities, FA (Factory Automation), VA (Value Analysis), and so forth. In the case of the production style regarding the multi-products and small lot size, the percentage of the indirect cost involved in the total manufacturing cost tends toward relatively rising up in comparison of the direct cost. As previously described, the main aim of POP introduction is to absolutely reduce the indirect costs.

POP system executes the reasonable reduction of the indirect manufacturing cost by improving the following items. Generally, without installing the POP system in the shop floor, such items have been often disregarded because it is very difficult to recognize the real-time quantitative data on account of frequently changing situation of production processes.

- 1) Reduction of the indirect management tasks,
- 2) Minimization of work-in-process (WIP), or inventory in warehouses,
- 3) Shortening of production lead-time by minimizing the WIP,
- 4) Improvement of net working rate in relation to workers and machines,
- 5) Increase of product quality and net yield ratio,
- 6) Savings of maintenance cost by improving productive maintenance efficiency, and
- 7) Exact recognition of the real cost of production.

The POP system mainly covers the following types of information management: process management, quality control, facility management, and cost control.

### **3. Influence on Construction Management by Robotized Construction**

As mentioned above, several Japanese general constructors have carried out actual construction systems of the mechanized structural steel work and precast concrete. The results of implying such systems expand feasibility for future automated construction methods by using automated machinery and construction robots. At the same time, the constructors recognize that enhancement of the computer-assisted production information system are crucial issues for the mechanized construction, because diverse of preparation prior to production, indirect management, and set-up before and after tasks increase contrary to their expectations. This implies that the automated construction requires more quantitative and higher qualitative characteristics of the product information compared to the conventional construction methods. The main management operations for superintendents and supervisory staff in general construction sites are described as follows:

- 1) Master process schedule for the construction project, and the arrangement of the schedule.
- 2) Production progress control of the construction projects and feed back to the process schedule.
- 3) Orders for labors, materials, and machines. The arrangement of the orders according to progress of the project.
- 4) Operational instructions to site foremen of subcontractors and field engineers. The additional arrangement instructions for progress control.
- 5) Accident prevention and proper countermeasures against accidents.
- 6) Inspection at the site and instructions for adjustment and repair.
- 7) Report and communication related to production performance and results management.

In the case of robotized construction, Table 1 illustrates the alternation of quantitative and qualitative characteristics of management information, according to above mentioned each conventional management operation.

### **4. Management Categories Associated with PIMS**

As shown in Figure 2, the project management for the robotized construction covers wide areas. WASCOR chiefly deals with the following three management categories: process management, the machinery set-up planning and working rate analysis involved in facility management, and management of material and machinery handling, for the first framework of PIMS.

### **5. Process Management System in PIMS**

Figure 3 illustrates an example of the flow of production information within the "Process Management System" in PIMS. The process management includes three main management items: "task planning", "operational instructions", and "progress management".

Table 1 Alternation of Quantitative and Qualitative Management Information In the Case of Robotized Construction  
(Individual items are associated with each number of the conventional management operations.)

No.	Characteristics of Production Information for Robotized Construction
1	Accurate and detailed schedule planning. Diverse of preparation planning prior to starting the construction work. For example of a task by using robots, set-up planning before and after the task, task sequence planning, and preparation for robot programing.
2	Automated collection and analysis of the actual "up-loading" progress results based on real time. Frequent re-scheduling function in response to variances between the previous plan and the performance results.
3	When task planning and task loading, necessity of operational standard for role assignment between robots and craftsmen. Just-in-time provision for materials and robots into the site and the construction work-section.
4	More detailed and sophisticated operation instructions. Increase of supplemental operation conditions involved in the operational standard, especially, in the case of robotized tasks.
5	Supervision and monitoring of robot conditions during a task. Abnormal warning and absolute shutdown of robot's task system against accidents. Recovery function after the shutdown.
6	Paper-less report and communication directly connected with the computer network to the external or internal construction site.

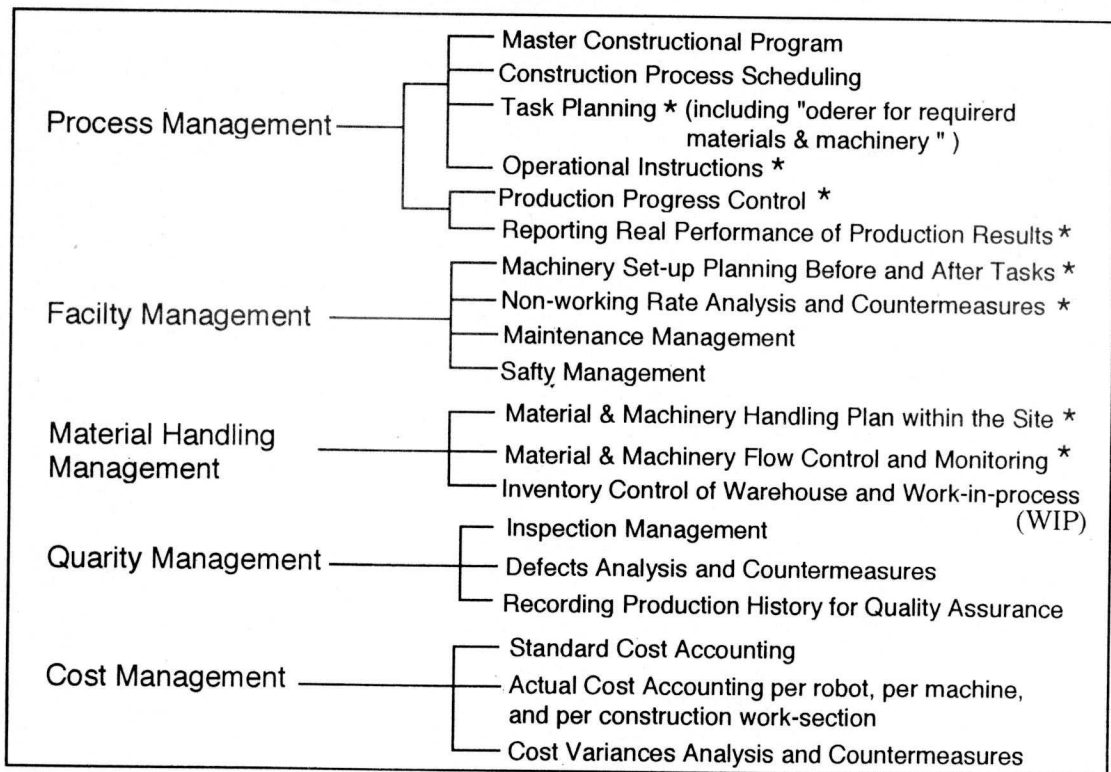


Figure 2 Management Categories for PIMS within Project Management in Construction Site  
(\*: management categories and items for PIMS)

### **5.1 Hierarchal Management Level in Process Management System**

As shown in this figure, the system consists of the following hierarchal management structure:

- 1) Integrated management level; planning and control for master process schedule to the whole extent of each construction work such as structural steel work, internal finishing work, and so on.
- 2) Construction work management level; monthly process planning and control for each work.
- 3) Task management level; weekly process planning and control for each "construction work-section" or "task lot".
- 4) Robot management level; operational planning and control for individual machines and craftsmen.
- 5) Resources level of production information; each element of information resources such as work-pieces, machines, facilities, and craftsmen at the lowest level in the hierarchal management structure.

### **5.2 Flow of Production Information in Process Management System**

In this figure, "task planning" and "operational instructions" copes with the production information concerning "down-loading" information.

#### **1) Task Planning and Operational Instruction**

The "task planning" and "operational instructions" are implemented at individual management levels as the following procedure. The planning function at each level has also re-arranging and re-planning function based on the results of "production progress" which is processed by the "up-loading" results of production performance.

Firstly, the master process schedule to the whole extent of each construction work is planned based on master constructional program installed in the computer workstation in the site. This workstation in the site, which is linked together the host-computer including the data base at the design department and the production design department in headquarters, has accumulated the basic information associated with the CAD data for this building during construction, and the past reference information, for example of construction period and production lead-time regarding completed buildings in the past.

Secondly, the phase of the monthly process, at the management level of the "construction work management", comprises the process schedule for each building story, the task loading and leveling, and preparations for arranging subcontractors, and for ordering materials, and robots and construction machinery.

Thirdly, the phase of task management level includes the weekly construction process for each construction work-section and operational preparations. The weekly construction process corresponds to the standard cycle process for a week. The operational preparations are to check the situation of material inventories and machinery carried in the site according the results of the production progress.

Fourthly, the operational planning for individual machines and craftsmen, at the robot management level, is prepared for the task sequence and operational program of each robot, and set-up preparation before and after the task.

Finally, the operational instructions are given from the robot management level to the lowest level of the information resources such as the robots and construction machinery, and the foremen of each subcontractors.

#### **2) Production Progress Management**

By using the "up-loading" results of production performance based on real time from the lowest level of the information resources within the site, the management of the production progress is executed at individual management levels. The production information of the

Management Level	task planning & operational instructions	collected actual production results	production progression	data base
Integrated management level 	-master process schedule		-recording history of production results -reporting production performance	-CAD data of shop drawing -reference D/B for the past completed buildings
Construction work management level -monthly process	-task loading & leveling -preparations for subcontractors -order for materials and machinery		-balancing construction period between related construction works -countermeasures for faulty works	-subcontractor D/B -material D/B -machinery D/B -lead-time D/B -PERT scheduling D/B
Task management level -weekly process	-weekly cycle process schedule -operational preparations for materials and machinery	-lot number of materials -ID number of craftsmen -ID number of robots and machines	-production progress control -man/ machine-power control -inventory control: materials & WIP	-standard work process D/B -standard task loading D/B
Robot management level -daily process	-task sequence planning -machinery set-up -operational instructions	-production yields -actual task loading -working time	-material flow control -real-time feedback of process conditions	-task process D/B -machine specifications D/B
(site network level) Resources level of production information		-information of real-time task situation -reasons of non-working time		-dispatching rule D/B -robot program D/B

Figure 3 Flow of Production Information between Hierarchical Management Levels for Process Management System

performance includes the following items for each type of robot and machinery and craftsman in the site: production yields, cycle time, required man-power and machine-power, net working time and set-up time, reasons of non-working time, quantity of used materials, contents of defects and countermeasures, and so on. The results of the progress management at each level feed back to re-arrange and re-plan the "task planning" phases.

## 6. Conclusions

WASCOR IV has dealt with the research themes to design an automation system of the whole interior finishing work, including facility work and part of structural work. This paper has mainly described the framework of "Production Information Management System (PIMS) based on real time monitoring for Automated Construction". The information management and control system in the construction site such as POP (Point of Production) is crucial factors for the success of the introduction of a variety of robots and automated machinery within an innovative building construction site.

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