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Planning of Integrated Interior Finishing Work System —WASCOR IV Research Project Report (Part I)—

Kinya Tamaki*, Hisashi Matsuda**, and Yukio Hasegawa**

* School of Business Administration, Aoyama Gakuin University, 4-4-25 Shibuya, Shibuya-ku, 150 JAPAN (Associate Researcher of System Science Institute, Waseda University)

** System Science Institute, Waseda University, 1-21-1 Nishi-waseda, Shinjuku-ku, Tokyo, 169 JAPAN

ABSTRACT

For automatizing building construction systems with robots, the WASCOR (WASeda COnstruction Robot) research project has been organized since 1982 by the 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 the research results of the first year for the period of three year WASCOR IV project started in autumn of 1992. The results treat the following three issues: 1) research methodology for designing an automated interior finishing work system, 2) development of new construction methods suitable for robotization, and 3) research of a computer-assisted information system for construction management and machinery control. 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 computer-assisted system in the future automated building construction. This paper also describes the POP concept and how to apply it to build this framework.

1. INTRODUCTION

In the construction industries, Japanese general constructors and construction machinery manufacturers are in the forefront of the world in having developed various types of construction robots. However, part of the already developed robots numbering over one hundred kinds cannot be put to practical use with the desired labor savings at conventional construction sites. The reasons why many construction robots cannot attain full-scale utilization are not only the immature capabilities of their own hardware and software systems, but also the luck 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.

Therefore, the WASCOR IV research project aims at developing the new construction methods adaptable to robotization in interior finishing work. In the project we have approached these issues with a proposed systematic design methodology, started from the comprehensive level of a total system design down to the detail level of component systems. At the same time, the fundamental specifications of robot hardware systems will be defined in response to the construction methods.

Furthermore, even if some fleets of robots are introduced into a site, without such a total construction management and control system they cannot contribute to a remarkable improvement of the total productivity by comparison with traditional manual construction work. Although the direct workmen's tasks are decreased by using robots, system engineers and mechanics have to be engaged in further set-up operations before and after utilizing these diverse kinds of robots and machinery. The excessive burden prior to construction preparation and indirect set-up tasks for operating the machines undoes the merits of the direct labor saving. The robot fleets can hardly be used effectively within traditional sites based on the conventional management and control environment, for example, verbal instructions within the site.

For this reason, the research and development of a computer-assisted information system for construction management and machinery control are indispensable for future automated construction work. The concept of the "Point of Production (POP)" information management and control system already being operated in the manufacturing industries is a useful tool for establishing the framework of a computer integrated management system for future automated building construction. In addition to the above-mentioned research methodology for developing the new construction methods and the robotized system, this paper describes the concept of POP concept and how to apply it to build this framework.

2. PROJECT THEMES AND RESEARCH SCOPE

As shown in Figure 1, the WASCOR IV research project has treated of the following three themes:

1) Development of the innovative construction methods adapted to robotization in the interior finishing work. The main research scope covers the ceiling, wall, and floor work systems, and besides, the construction facility work associated with these particular work systems. Additionally, when developing these construction methods, part of structural work such as beam erecting and slab footing should be also included within the research fields.
2) Development of an automated construction system including the following research subjects; robotized systems, peripheral equipment, and automated material handling systems.
3) Development of the "POP" information management system, consisting of construction management and machinery control function, in the automated construction site.

3. SYSTEMATIC DESIGN METHODOLOGY FOR INTEGRATED INTERIOR FINISHING WORK SYSTEM

Figure 2 shows the research methodology to pursue the previously described three themes

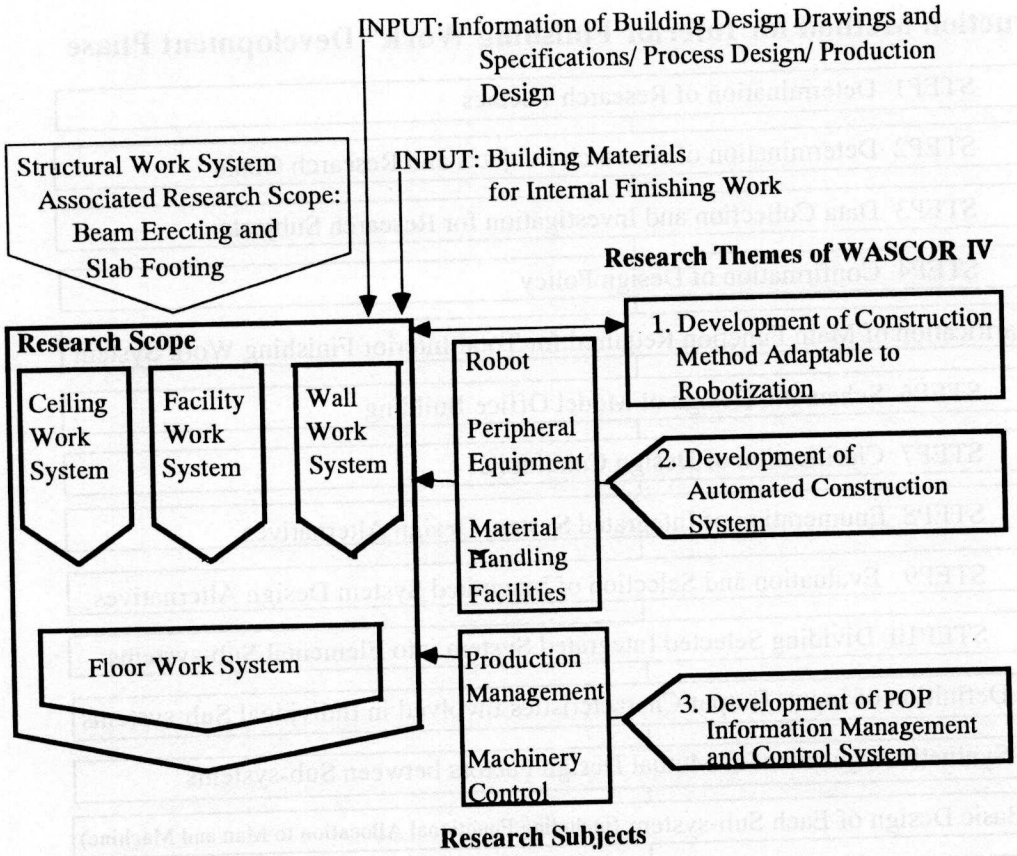

Figure 1 Research Themes and Scope in Interior Finishing Work System

associated with STEP1 and STEP2. Firstly, STEP3 to STEP14 are the research phase for developing the construction methods. Based on a statistical survey, a model office building is set up in order to prescribe concrete design conditions in STEP6. This type of the building is one of the most common in JAPAN: building area/ approximately 960m^2, middle story/ 10~20F above ground (steel structure) and two under ground (steel reinforced concrete), floors/ full or half precast floor deck, exterior wall/ curtain wall, and so on. In STEP7 the design conditions are confirmed before commencing the conceptual design of desired total interior finishing work system. At the end of the first year for the period of three year research project, we completed until STEP9 of the development phase. Seven alternatives of the total systems are proposed and categorized on several groups. Currently, these alternatives are evaluated from the point of the proposed estimation criteria suitable for robotization feasibility of the automated construction system.

Secondly, regarding the development phase of the automated construction system, Figure 2 focuses on a research process for designing the robot hardware systems. The robot modularization is one of the effective means overcoming the difficult problems existing in the development of construction robots. Because distinctive task processes in construction sites are performed by cooperative group efforts of works and varied types of skilled workers, the application of conventional limited types of robots to construction systems would not be economically feasible.

Thirdly, the concept of the "POP" information management and control system in future automated site is described in the following "Chapter 5".

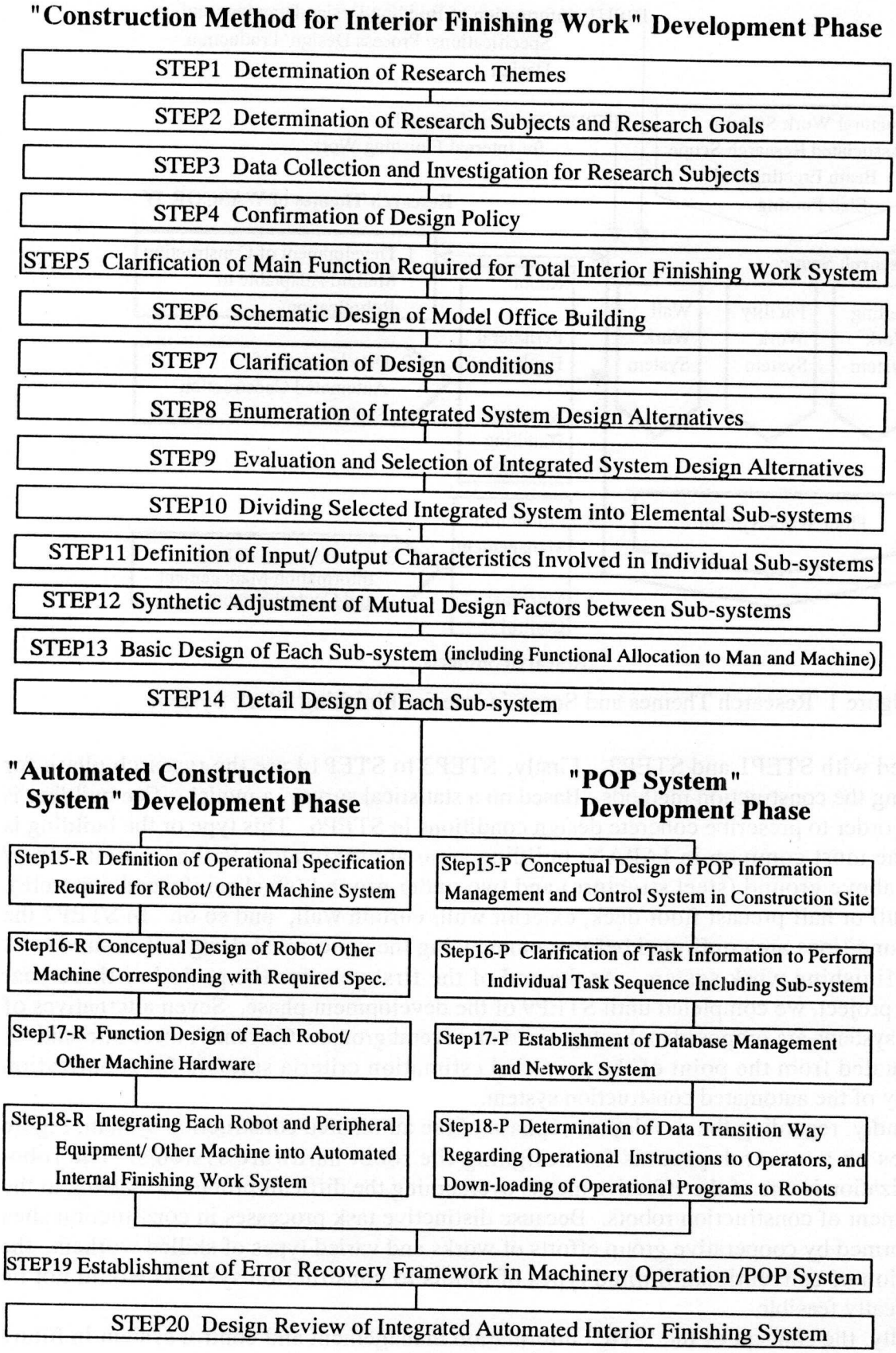

Figure 2 Research Procedure for Designing Automated Interior Finishing Work System

4. THE POP SYSTEM IN MANUFACTURING INDUSTRIES

The POP information management and control system is defined as follows [2]: "the ever-changing production information from the shop floor is directly collected from machines, facilities, operators, and workpieces by using the POP network. This information is immediately processed and the results of processing that concern production progress are provided to the shop floor manager in real time. Based on the real-time production information, he can flexibly control the current production progress and give the proper operational instructions according to the alterations in the external and internal situation." Since he is released from time-consuming of office work, for example, the collection and analysis of daily production performance reports from individual workmen, he can concentrate on rapidly accomplishing his primary management tasks with correct decision-making based on exact information reflecting the actual situation of the current production processes, dealing appropriately with various troubles caused inside or outside his shop, and giving the proper operational instructions in accordance with the ever-changing working environment.

As mentioned above, the POP system is a useful tool that assists the shop floor manager in performing significant tasks. Additionally, another of its functions is the "down-loading" of operational instructions to individual operators or automated machines. For instance, instructions for the machines, operating programs, and control conditions are directly transferred from the CAD/CAM system to each POP terminal connected with individual NC (Numerical Control) machines. In the case of operational instructions for manual labor, the relative operational standards corresponding to each of the jobs involved in the daily production schedule are automatically represented on the indication screens of the POP terminals installed at their work places. The significance of such a way of instruction resides not in the giving of only paper-less instructions to them instead of using the conventional instruction sheets, but also in the fact that the shop floor manager is not required to collect and analyze performance reports.

The main aim of the introduction of POP system is to reduce the indirect manufacturing costs. The POP system effects a reasonable reduction of these costs by means of improving the following items [3]: 1) reduction of the period of delay in processes and warehouses, 2) decrease of the work-in-process, 3) improvement of the net working rate, 4) increase of the net yield ratio, and 5) the saving of maintenance costs. Without installing the POP system on the shop floor, such items have been often disregarded because it is very difficult to recognize quantitative data in real time on account of the frequent changes in the production processes.

5. APPLICATION OF THE POP CONCEPT TO AUTOMATED CONSTRUCTION SYSTEM FOR THE NEXT GENERATION

Since the majority of the construction activities on a site concerns production preparation and set-up operations, the degree of accuracy of previous planning and preparation before the commencement of work greatly affects the total productivity and efficiency. At present, foremen guide their teams by using verbal instructions and architectural drawings at the work places. In the case of future construction work which applies the various types of robots and automated machinery, double the content of operational information will be required for production preparation in comparison with conventionally manual tasks.

For this reason, an information management and control system which reflects the peculiar nature of the construction tasks will need to have been studied so that the introduction of robots into the automated site can result in the advantage of saving direct man-power and machine-power. To undertake the innovative robotization of the whole building construction site as compared with the conventional limited mechanization, we must solve new problems which include the following unique characteristics of the construction production system [4]:

1) Most robots require a locomotion function by reason of the frequent removal from one work places to another in a huge building.
2) Great numbers of robots and other automatic facilities have to be transferred from one site to another in response to the mobility of construction sites.
3) Construction robots require a versatile function to perform multiple motions and tasks, as compared with conventional industrial robots engaged in repetitive motions and tasks in manufacturing factories.
4) The existence of divers construction methods.
5) The use of various types of construction materials and workpieces ranging, for example, from big and heavy steel columns to small screws.
6) In the construction sites many skilled workmen are necessary for constructing a building, for instance, more than 100 kinds of technicians in the case of a medium-size office building.

Figure 3 illustrates a conception of the information management and control system for construction production in the next generation. The construction POP system, which deals with the information generated within the actual building site, corresponds to the system levels from "process planning and production preparation" to "information resources" consisting of construction machines, facilities, robots, materials, skilled workmen and so forth. At the first stage in starting the POP researches, the technological factors involved in developing the information management and control system are listed as follows:

1) A computer-aided system for completing production preparation of the automated machinery by using the design data and the planning data created in the head office. These data are transferred through the backbone network.
2) Automatic operational instructions to operators and mechanics manipulating the machinery at their individual work places. Development of a CAPP (Computer-aided Process Planning) system.
3) The supervision of production progress and quick action in response to modifications of the original schedule and planning, and variations of design.
4) The collection, analysis, and application of production performance data.
5) Direct program down-loading to each numerical control machine. Development of a CAD/CAM system.

As expectations of the future sites, the automated work-cells involved in individual construction works will consistent of multiple robots, automatic machines, peripheral equipment, and technicians. A total automated construction will be integrated with respective sub-component works to process and fabricate workpieces automatically transferred between each other's work-cells. The performance of the control systems in the work-cells greatly influences reliability and safety for the total construction system. For instance, the research on the group control of multiple automated machines is one of the most essential issues in relation to the POP control system.

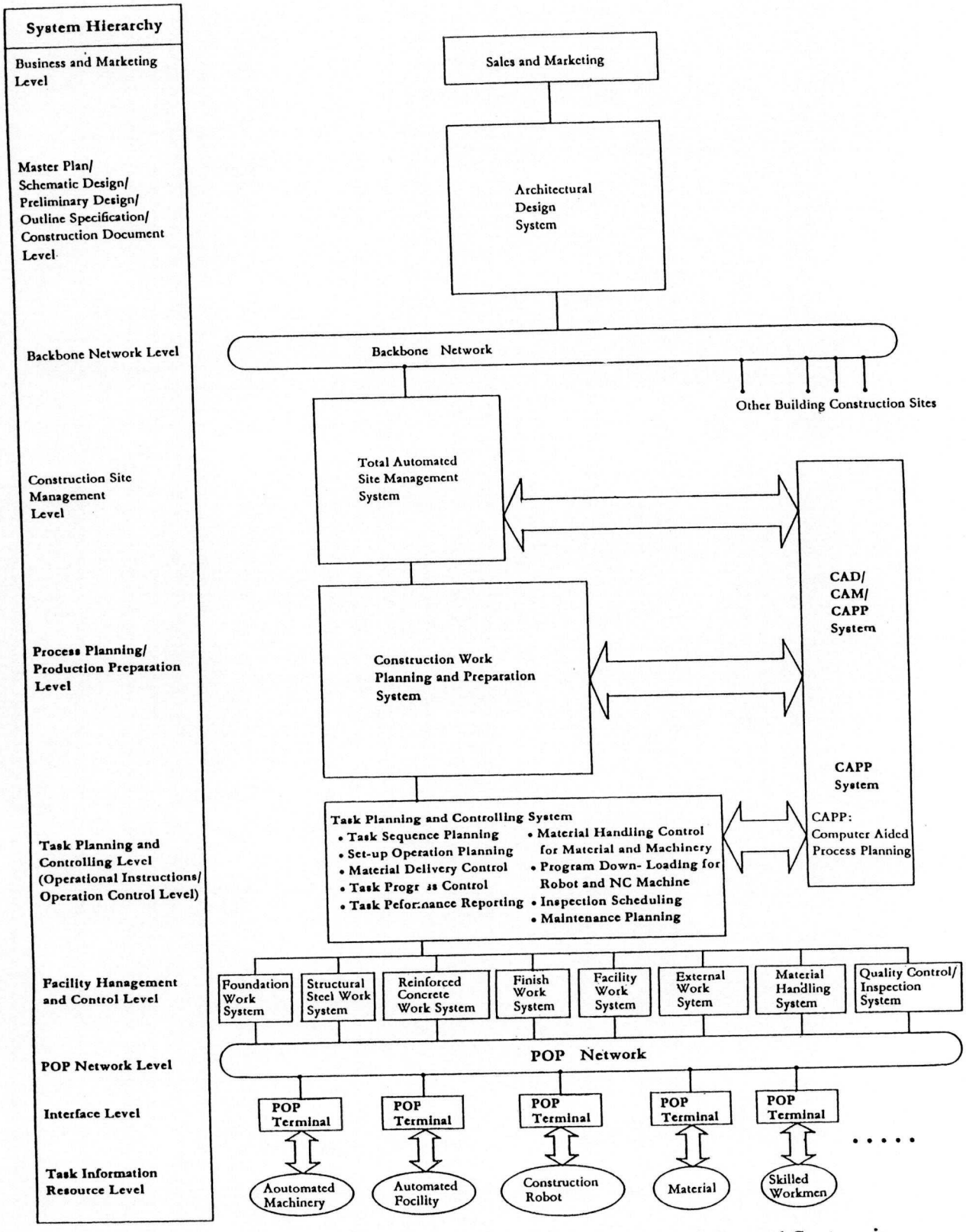

Figure 3 Conception of The POP Information Management and Control System in Automated Building Construction Site [1]