THE CROSS FERTILIZATION OF CONSTRUCTION AND MANUFACTURING THROUGH COMPUTER INTEGRATION

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ABSTRACT

This paper compares the process similarities between the manufacturing and construction industries and identifies areas for cross fertilization through techniques that have been effectively applied to solving productivity problems.

An extensive comparison of manufacturing and construction describes basic functional similarities, indicates similar problems facing both industries, and defines similar solutions being applied with varying degrees of success. The computer integrated solutions in manufacturing are clearly more advanced than construction's efforts. Potential benefits of this system are illustrated by the strides that manufacturing has made in their integrated approach to providing a product.

The paper develops an integrated process model that identifies specific activities in construction and relates the model to an existing integrated manufacturing model. A general discussion compares the similarities and differences of the functions and levels of integration in manufacturing and construction activities. Finally, the paper describes and defines areas for cross fertilization of techniques and tools for automation of the construction industry. A strategy for using Group Technology based coding and classification schema to foster Computer Aided Process Planning for reinforced concrete structures is presented.

1 INTRODUCTION

This paper focuses on defining ways to improve and integrate the provision of a constructed facility through better use of computers. It is based on a common abstract understanding of the fundamental processes required to construct a facility, viz. the Integrated Building Process Model, IBPM (Sanvido, 1988). This abstract model is then compared to a similar model developed for the processes required to manufacture a product to identify similar functions where cross fertilization can occur with meaningful results.

2 A COMPARISON OF MANUFACTURING AND CONSTRUCTION INDUSTRIES

Construction in the U.S. is a $300 billion per year industry that has experienced declining productivity over the previous two decades. Owners are becoming more educated and are demanding "More Construction for Their Money." (Business 1982). The construction industry is fragmented. Many organizations and standards exist. The average contractor and subcontractor provides services for a small portion of the facility's total life.

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The significance of these problems are demonstrated through the intrusion of foreign competition into the US construction and manufacturing markets.

2.3 Solutions to Problems

Both industries have tried to address these problems using the following three similar techniques:

1 Design for Manufacturability/ Constructability;
2 Simultaneous Engineering/ Fast Track Construction; and
3 Computer Integrated Manufacturing (CIM)/ Computer Integrated Construction, (CIC) which is the subject of this work.

The first two techniques have been the norm in construction over recent years, while being relatively new to manufacturing. On the other hand, the third, has been implemented over the last decade in manufacturing and is new to construction. Thus it is important to look closer at CIM to explore techniques that have helped to improve the manufacturing industry and apply them to construction. The next section examines process modeling and integration in each industry.

3 PROCESS MODELING AND INTEGRATION

3.1 Modeling and Integration of the Manufacturing Process

Major contributions in modeling manufacturing systems were made by the Air Force ICAM program. This program resulted in the development of several modeling tools, including IDEF-0 [ICAM 1983],which is used for functional models. A further contribution was an architecture of manufacturing, developed in IDEF-0, which encompasses activities from initial planning and design through maintenance and repair of the product (Integrated 1978). Harrington [1985] discussed and extended this work, and reports utilization of similar models in various manufacturing applications.

3.2 Modeling and Integration in Construction

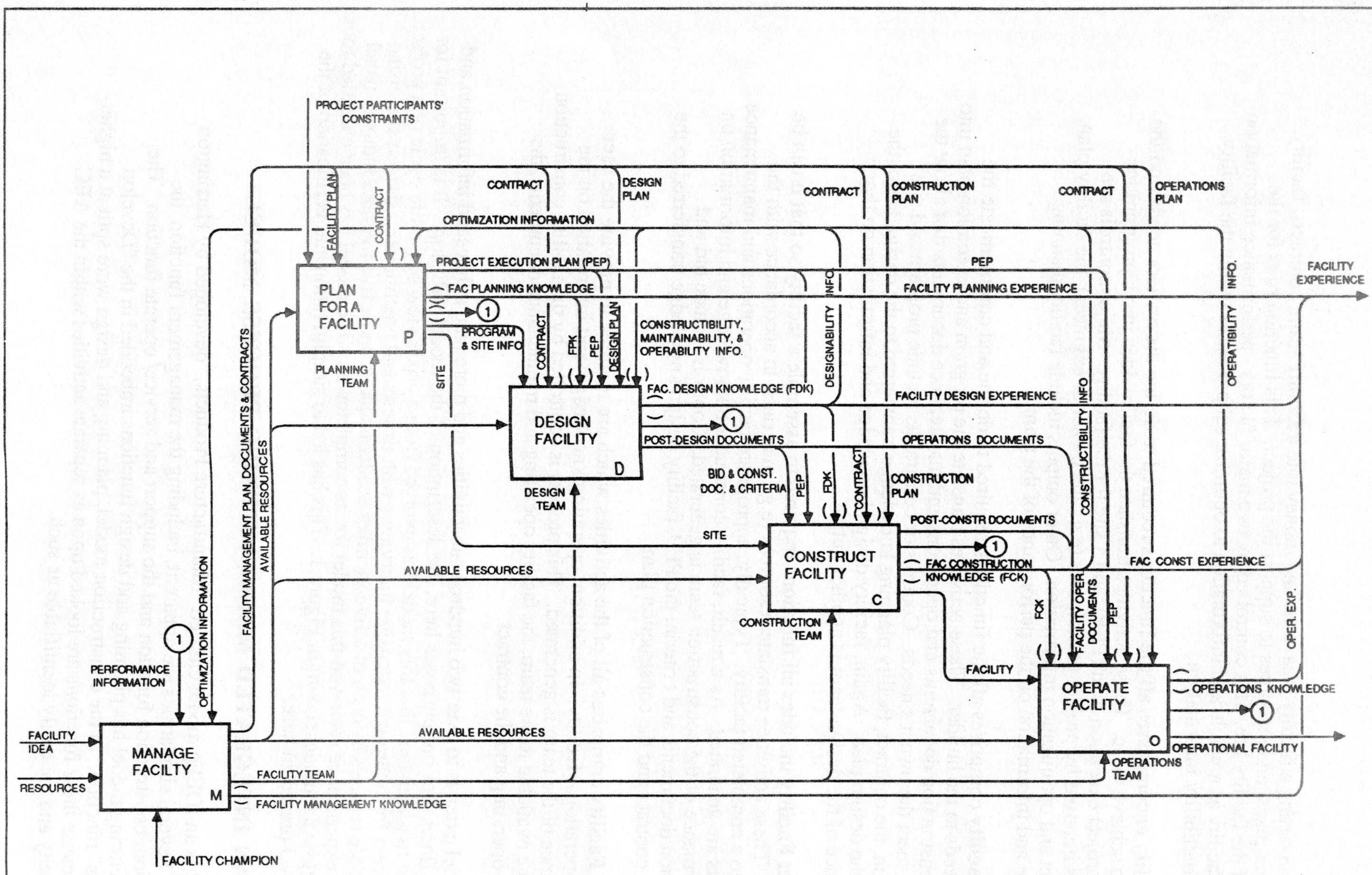
The first step in integrating is to develop a process model of the functions that are generic to all facilities over their life. There have been several attempts by researchers to model the functions in the life of a construction project (Sanvido 1987). None of these models cover generic functions for the entire life of a facility. They either cover portions of the project functions or are oriented to activities associated with a segment of the industry. However, they supplied a good background for the development of the Integrated Building Process Model (IBPM).

In all, five design process models were found, two construction process models, and three life cycle models. While many more models were reviewed, the authors determined that only ten of these had merit for their generic model building purposes.

4 AN INTEGRATED BUILDING PROCESS MODEL

The Integrated Building Process Model (IBPM) was developed by using IDEF-0 modeling methodology to five levels of detail. This explanation focuses on the first level only.The model was drawn from the perspective of the owner of the facility.The model breaks down the process of "Provide Facility" into the five subprocesses shown in Figure 1. These are: Manage Facility, Plan Facility, Design Facility, Construct Facility, Operate Facility. Detailed definition of these subprocesses follow.

Manage Facility includes all the business functions and management process required to support the provision of the facility from planning through operations. These activities



NODE: F.	TITLE: PROVIDE FACILITY	BY:	CHECKED BY:

Figure 1. Provide Facility

focus on converting a facility idea, time and money into a facility team, contracts, facility management plans, and resources to support the project. This function runs for the duration of the facility life. It is controlled by two major factors - performance information about the facility as a whole and information to optimize subprocesses within the facility e.g., constructibility information.

Plan Facility encompasses all the functions required to define the owners needs and the methods to achieve these. These activities translate the facility idea into a program for design, a project execution plan (PEP), and a site for the facility. Major controls are constraints imposed by project participants (e.g., the owner or engineer), the facility plan, the contract and optimization information. Other outputs include facility planning knowledge and information on the performance of the team.

Design Facility comprises all the functions required to define and communicate the owner's needs to the builder. These activities translate the program and execution plan into bid and construction documents and operations and maintenance documents that allow the facility to meet the owner's needs. Controls or constraints include program and site information, the contract, facility planning knowledge transferred to the design team, the PEP and the design plan. Again, facility design knowledge and information on the performance of the design team is another output.

Construct Facility includes all functions required to assemble a facility so that it can be operated. These activities translate resources (e.g., materials) in accordance with the design into a completed facility. Typically, appropriate facility operations and maintenance documents are generated. As a result, facility construction knowledge and information on the performance of the construction team is generated. Controls include bid and construction documents and criteria, the PEP, facility design knowledge transferred to the team, the contract and the construction plan.

Operate Facility comprises all of the activities which are required to provide the user with an operational facility. In addition, operating knowledge, and information on the performance of the team is generated. This process is controlled by the facility construction knowledge available to the team, the facility operating and maintenance documents, the PEP, the operating and the contract.

This model extends to over two hundred subactivities and more than a thousand information and physical flows. For our purposes here, the description of the model will stop. It is important for the reader to understand that this model has evolved from a crude view of the life cycle of a project to its current form through extensive interviews with experts and practitioners; sixteen site visits; and multiple reviews by each of a five member academic panel and a five member industry panel. Over 40 experts have reviewed this model for its completeness. The model has been extended four levels below the model shown in Figure 1. This has led to simplification and verification of the upper level presented here.

5 AN INTEGRATED MANUFACTURING PROCESS MODEL

Figure 2 is an $IDEF_0$ model entitled "Manufacture Products," developed by Harrington (1985). Several similarities are apparent, including the management function, the production/ construction function and the support and service/ operate function. The manufacturing model has planning and design functions imbedded in the "Develop Products" function. In the construction model, planning and design were split at a higher level because these functions are looked upon as separate activities within the AEC community and are easily identifiable as such.

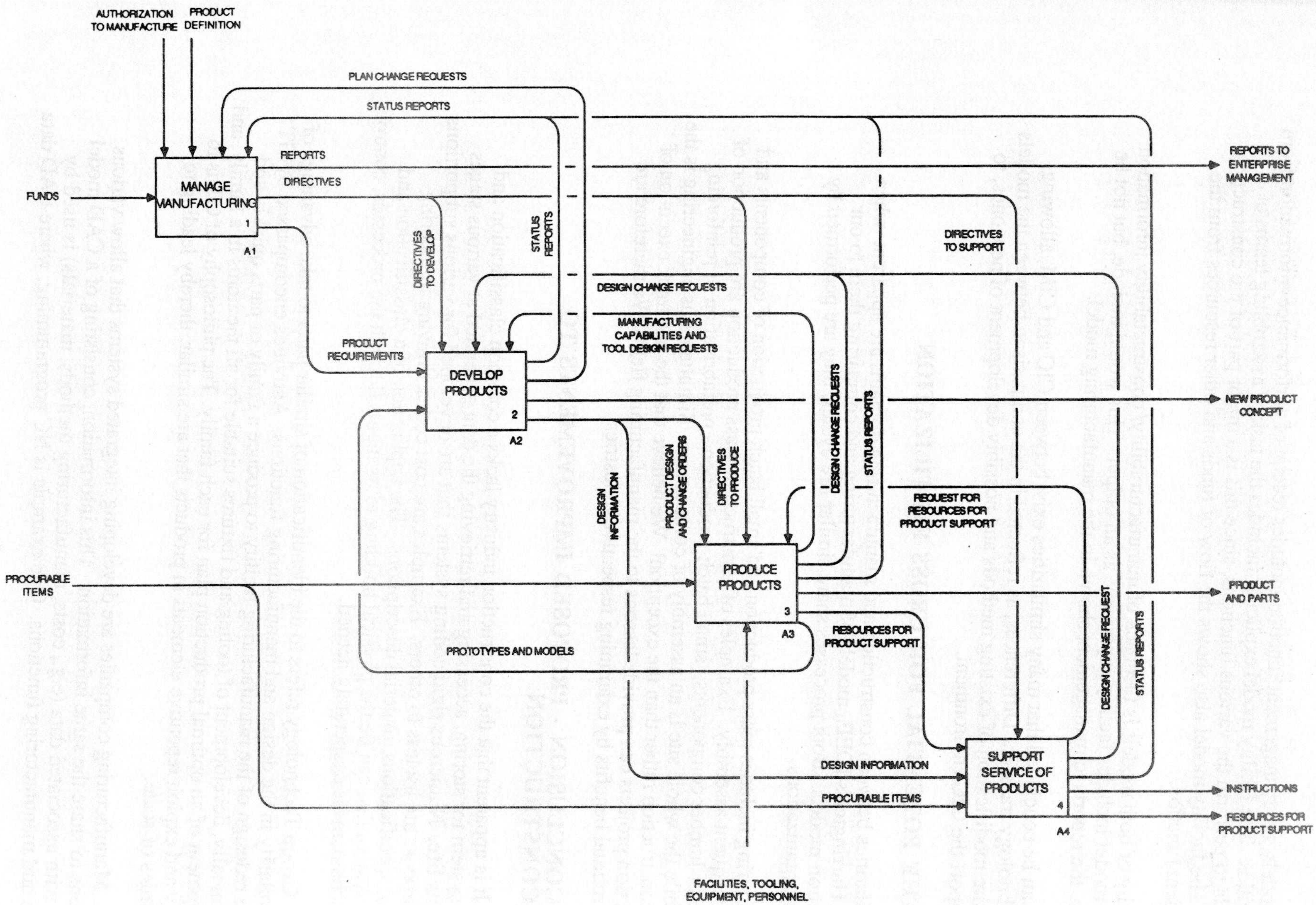


Figure 2. Manufacture Products (Adapted from Harrington, 1985)

In both models, the management function includes receipt of performance information from later activities. The facility model explicitly includes the task of assembling teams of individuals to perform the various functions, since this is a major part of the construction activity. The facility model also shows the flow of funds and other resources from the management function.

A similarity of both models is feedback of manufacturability/ constructability information. The CIC model includes facility experience as an output. This would include, but not be limited to, the reports to management shown in the manufacturing model.

Thus, it can be concluded that many similarities exist between CIC and CIM, allowing some technology transfer. Differences, as reflected in the comparison between the models will require modification of existing methods and possibly development of new ones, to fully support the CIC environment.

6 THE POTENTIAL FOR CROSS FERTILIZATION

The similarities between construction and manufacturing domains are apparent when viewing Harrington's IDEF$_0$ models of manufacturing and comparing them to our construction models. Both processes share similar life cycles, they are performed by different organizations.

Manufacturing includes mass production and small batch production of components and their subsequent assembly. Examples of construction mass production are production of concrete or lumber components; small batch production - prefabrication of reinforcing steel, while the whole site is an assembly of components. Simultaneous engineering is the rule in construction rather than the exception! We believe that the fast track execution of construction projects can provide lessons to the manufacturing field. We therefore are finding mutual benefits by examining respective industries.

7 CONCLUSION - PROPOSED IMPROVEMENTS TO CONSTRUCTION

1 It is apparent that the construction industry lacks a common classification and coding system for storing, accessing and retrieving the data generated at various stages during its life. Numerous rigid coding systems that are developed for various subportions of the process are useless to others. Examples are cost codes, drawing numbering systems, specifications, material descriptions. The application of a classification and coding system that can tie the physical building to its inputs through the processes, controls and mechanisms is desperately needed.

2 Group Technology refers to the identification of similar parts to take advantage of this similarity in the design and manufacturing functions. Activities encompassed by GT include redesign of the manufacturing facility to produce a family of parts quickly and economically, development of tooling and fixtures suitable for all the items in a family, and development of an optimal production plan for each family. The philosophy of GT is to identify and exploit repetitive elements in products that are similar, thereby leading to economies of scale.

3 Manufacturing companies are developing integrated systems that allow various functions to share the same information. This information, consisting of a CAD model along with associated data (e.g., costs, manufacturing methods, materials) is used by design and manufacturing functions. One example is NC programming, where CAD data

is used as a basis for programming machine tools to create the product. Similar links between design and construction should be developed.

4 Computer Aided Process Planning involves automating the generation of instructions to produce a product, including operations, sequence, and timing. This technology leads to process standardization, and simplifies monitoring and cost control.

5 Production planning and scheduling methodologies such as MRPII, include tracking products through production and feedback of production information to later planning functions. Technologies for monitoring the progress of work, such as point of use terminals, bar coding, etc. are in wide use. Information thus collected is automatically fed back to the planning system, and problems identified in the form of exception reports.

The key to successful implementation of these computer based tools is the existence of a common set of integrating data. The applications described above rely on a central information source designed to support the process. Hence, the process models previously described will serve as the basis for developing an information architecture for Computer Integrated Construction.

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