AN IDEF0 REPRESENTATION OF A GARMENT MANUFACTURING SYSTEM DESIGN PROCESS

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CHAPTER 1
INTRODUCTION

1.1 Manufacturing System Design Background

Manufacturing system design is becoming increasingly complex due to new manufacturing processes, greater product variety, higher product quality standards, shorter product life cycles, etc. All of these factors are contributing to an increased demand for more sophisticated manufacturing systems (Judd, Vanderbok, Brown & Sauter, 1990). Judd et al. (1990) also mention that many manufacturing systems, once they are operating, never meet their designed goals as they were planned.

Major reasons for these shortcomings in current complex manufacturing systems design are:

1. improper system design criteria, that lead to inefficient and ad hoc implementation;
2. inadequate integration of system designs, resulting in an incomplete manufacturing system design;
3. inflexibility in system design criteria that lead to inflexibility and poor performance in the implemented system;
4. individualized and localized system design processes that lead to inconsistent, improper or suboptimal systems; and

5. individualized and localized implementations that lead to an inconsistent, improper or suboptimal implementation scheme (Kumara, Ham, Ohsuga, Tsatsoulis, Ramesh, Frost, & Kashyap, 1992).

Incorrect, inconsistent and unclear requirements for the system in turn result in a faulty system design and the fact that one must develop a correct and complete set of system requirements before designing a system (Bravoco & Yadav, 1985).

Communication among the different designers of a manufacturing system such as the control system design, robot system design, material handling system design, etc. are not well established in the designing phase. The viewpoint of each design discipline is different. When the entire system is going to be implemented, conflicting assumptions in the various design models create implementation problems.

For the last several years, the entire textile industry, particularly the garment manufacturing segment, has been under pressure for improved quality and productivity. Increasing wages in this relatively labor-intensive industry is a major force behind this pressure. Rising costs for energy, materials and capital equipment, along with growing imports of garments from developing countries are other forces behind the
need for greater productivity (Parker, Dubey, Paul, & Becker, February 1983).

1.2 Problem Statement

Proper understanding of the system requirements and the system design processes can result in a correct manufacturing system design. The problem that is addressed in this thesis is the identification of the required design process or activities, design tools or mechanisms and how the design information from one design activity relates to another. The process of designing a garment manufacturing system will be considered for addressing the problem and developing a suggested solution.

1.3 Research Objectives

The objective of this thesis is to develop a generic activity model for designing a garment manufacturing system by using the IDEF0 modeling technique. This activity model will show: (1) the design activities that are needed to get a set of garment manufacturing design specifications; (2) the information that flows from one design activity to another; and (3) the tools or mechanisms that are used in designing a garment manufacturing system.
1.4 Research Method

This IDEF0 model for "designing a garment manufacturing system" has been developed through reviewing literature regarding garment manufacturing systems and other manufacturing system design techniques and system design tools and their applications in different areas of the manufacturing system design process.

Before developing the IDEF0 model for the garment manufacturing system design process, an existing function model for apparel manufacturing was studied. It was based on a project done by Dr. Sundaresan Jayaraman and Rajeev Malhotra for the U.S. Defense Logistics Agency to better understand garment manufacturing operations (Jayaraman & Malhotra, 1990). In addition to that, the author also utilized his own experiences from visiting several garment factories both in the U.S.A. and Bangladesh and working for the garment factories in Bangladesh.

After having reviewed the literature and manufacturing function model of the garment manufacturing system extensively, the manufacturing system design issues were determined, and an IDEF0 model for designing a garment manufacturing system was developed. The model also includes textual explanation of each model component.
1.5 Research Benefits

This generic IDEF0 model can be used as a reference model for designing a new garment manufacturing system or similar kinds of manufacturing systems. Moreover, this model will help to identify the design issues that should be considered in the early stage of design procedures.

1.6 Research Validation

In order to achieve the desired integration objective, top-down planning considers how all aspects of the system will eventually function together to optimize performance (Mitchel, 1991). Since the manufacturing enterprise consists of a large number of interacting functional components, an IDEF0 function model provides a structured representation of the functions that a system performs and the interconnections that exist between these functions (Malhotra & Jayaraman, 1992). In defining the general information flow between the subfunctions, each subfunction needs to be further broken down into several activities reflecting the tasks of the subfunction (Zhang & Alting, September 1991).

This model will identify the design functions of a garment manufacturing system and the points of interaction of the design functions, so that the new manufacturing system models can be well integrated, and changes can be made before
1.7 Research Verification

Developing a model allows a modeler to answer a set of questions that modeler has in mind (Marca, 1988). Therefore, results of this research effort could be judged by developing a functional model (IDEFO) for designing a garment manufacturing system and how well the following set of questions are answered about designing a garment manufacturing system:

1. What activities have are performed in a garment manufacturing system design process?
2. What are the relationships between these activities?
3. What information flows between these activities?
4. How will information from one activity constrain another activity?
5. What tools could be used to support the activity in designing a garment manufacturing system?
6. What inputs, outputs, controls and mechanisms are required for the activities in designing a garment manufacturing system?
7. How is the garment manufacturing design process hierarchically decomposed into tasks and sub-tasks?
CHAPTER 2
REVIEW OF LITERATURE

An understanding of the different manufacturing system design approaches, the apparel manufacturing process and its currently available technology and system modeling methodologies were essential for carrying out this research. Thus, the literature review has been divided into the following categories:

1. A review of different approaches to manufacturing system design.
2. The problems and nature of apparel manufacturing.
3. A review of Computer Integrated Manufacturing (CIM) and its application in the garment industry.
4. A review and analysis of system modeling methodologies.

2.1 Different Manufacturing System Design Approaches

It was found that different manufacturing system design approaches were used by the system designers to design a manufacturing system. Most of the designs were done for some manufacturing operations or to design part of the total
manufacturing system design. The manufacturing system design processes were done on the basis of designing the manufacturing system from the viewpoint of individual design expertise, not as a whole system design team.

Judd et al. (1990) discuss an improved method for designing manufacturing systems by using the method called "XSpec" and the tool called "XFaST". "XSpec" focuses on designing manufacturing workstations, cells or individual production line rather than designing the entire factory which are the lower level of system design activities. "XSpec" design method is the actual conducting of the system design after the manufacturing system has been specified.

Biemans (1990) describes the architecture of a manufacturing production and planning system to show the relationship between the different levels of the manufacturing system as a whole organization, such as the manufacturing cells, the manufacturing workstations, the product and process design etc. Ranky (Winter 1991) shows a systematic approach to designing a flexible manufacturing system within a CIM environment, using the IDEF0 modelling techniques, but he did not show the total manufacturing system design activities.

models discuss designing the manufacturing system operations and the manufacturing processes, rather than designing the total manufacturing system.

While there has indeed been progress made in the area of manufacturing system design, there is still a need for a total manufacturing system design approach. The current design methods or models have approached designing parts of the total manufacturing system, not the "total manufacturing system", which is the goal of this presented manufacturing system design approach.

2.2 Problems and Nature of Apparel Manufacturing

Throughout its long history, the clothing industry has gone through many changes because garment fashion changes are dramatic and frequent, and they are coupled to an unending variety of clothes (Cooklin, 1991). The international competitiveness of American industries has become a major concern to the U.S. government and to the business and labor communities because of low domestic and export growth, and rising imports (Arpan, 1982).

Apparel products fall into the category of piece part goods like automobiles, ships, airplanes, appliances, etc. The production process involves the manufacture of numerous discrete parts that are then assembled into finished products (Malhotra, 1991).
2.2.1 Lack of Communication From Design to Manufacture

The apparel industry is currently facing many problems because of a lack of communication between different points in the design to manufacturing process (Willett, 1990). According to Willett (1990), the difference between the apparel industry and virtually any other industry is the apparel industry's lack of a common language to represent its products. Willett (1990) describes the following problems between design and manufacture:

1. There is no feedback from consumer to retailer, and therefore no feedback to the manufacturer and designer. Consequently, consumer demands for better quality products are not recognized.

2. Quality control is performed primarily at the point of shipping (very little during the manufacturing process). Quality assurance is performed merely at the point of design (P.O.D.).

3. There is no communication of production requirements to stitchers, pressers or other production workers, though the tasks they perform are dependent upon appropriate visualization of the production goal.

4. There is a severe lack of qualified pattern design technicians. For a pattern to be of value it must provide product information, as well as represent an aesthetically pleasing product. While some useful
technology has been developed for grading (sizing), marking (layout for cutting) and cutting, the ideal shape of a garment is not easily quantified; as the "old masters" and those who trained under them are dying out, the artistic background necessary to produce appropriate patterns is being lost. Existing CAD systems, which take their ideal shapes from body measurements are ignoring esthetic considerations which can only be addressed by an expert pattern maker or an expert system.

5. The production pattern maker and creative designer have no means of communication.

6. There is poor resource information for designers on textiles, supplies and trims, and no source of information in understanding the aesthetic or functional relationships of materials to styles. Expert systems, libraries and software on textile design or computer guidance tools for resourcing and evaluation do not exist at the P.O.D.

7. Retailers are increasingly setting their own requirements for products (private label) with little or no consideration for the implications of changing technical design specifications. The resulting products are often of poor quality, adding to the psychological rift between manufacturers and retailers.

8. There are no image communications tools for reinformation between managers, stylists and designers.
Willett (1990) also discusses communications tools which need to be useful to design management in the industry as a whole and must be based upon:

1. a language that supports standardization of representation;
2. linkage of production information and product requirements to product representation;
3. use of basic building blocks to avoid repetitive effort; and
4. incorporation of syntactical information to aid in the understanding of the represented product.

2.2.2 Apparel Production Systems

Sewing fabric is a large segment and the most labor-intensive process involved in the production of garments. The sewing room has also undergone changes to improve the productivity and responsiveness in sewing (Malhotra, 1991). The most commonly used manufacturing system for the sewing room in the 1960s and 1970s is the bundle system. In this system, the work pieces move in bundles, creating larger inventory, increasing the space requirement and creating material handling problems. One of the popular variations of the bundle system is the skill center bundle system, where the sewing room operations are grouped into sub-assembly sections. Each sub-assembly section can accommodate style variations to
some extent, giving the system flexibility for style changes. This system is currently in use in a large number of plants. The slow response time of the bundle system, however, makes it unsuitable for quick response production.

Other flexible and faster ways of physically moving the fabric through the plant have also been developed through the following types of apparel manufacturing systems.

2.2.2.1 Unit Production System (UPS)

The unit production system (UPS), as shown in Figure 2.1, moves the fabric pieces for one garment on a single hanger through the factory. A computer balances the line by routing garments to sewing operators with higher performance and lower inventory (Albrecht, 1989). According to Albrecht (1989), UPS addresses the problem that a bundle system generates, where 80% of the production operators' time is devoted to material handling. It also helps to eliminate time spent labeling and moving fabric pieces. This system also helps improve quality by spotting the sewing errors sooner, and thus corrections can be made on them before large quantities of garments are affected. Another benefit of UPS is lower work-in-process, which means fewer capital and labor dollars are tied up on the factory floor. With this system, throughput is quicker and the garment can be shipped to the customer sooner (Albrecht, 1989).
Unit Production Systems (UPS) are good for large garments like pants, coats, skirts, dresses etc., because large parts are normally difficult to handle in the conventional way when they are in bundles (Lokiec, March 1990). According to Lokiec (March 1990), under the UPS the parts can be better pre-positioned before they are fed into the machine.

2.2.2.2 Modular Manufacturing System (MPS)

Another system for moving fabric quickly through the factory is called the Toyota Sewing System (TSS), synchronized, or the more popular term, Modular Manufacturing System (MPS) as shown in Figure 2.2. In the Modular Manufacturing System, the layout for modular manufacturing
includes smaller groupings of machines in a U-shape to complete parts of a garment or a total garment (Albrecht, 1989). According to Albrecht (1989), in a modular layout the number of operators is less than the number of machines. Each operator is cross trained on two or more machines and moves from machine to machine to balance the line as necessary.

Albrecht (1989) also suggests that modular manufacturing provides small manufacturers with short lead times while producing high quality garments under good management control. Of course, larger manufacturers can also benefit from it. Quality can be achieved in modular manufacturing through team work to keep the line balanced or fabric pieces moving through smoothly. Modular manufacturing means sewing a variety of garments within a module. To accommodate some garments, machines in the module are changed rather than trying to fit various garments into the production line.

Figure 2.2 Modular Manufacturing System (Albrecht, 1989).
Modular manufacturing can be compared to the Just-In-Time (JIT) management system which works toward a zero inventory buffer and total quality control (Albrecht, 1989). According to Albrecht (1989), flexibility via modular manufacturing is important for a company to remain responsive to the market. Flexible manufacturing includes the ability to quickly produce quality products in the quantities needed.

The Modular Production System (MPS) approach is more like a culture, concept or philosophy, rather than a technology that requires a total company commitment throughout the organization (Gilbert, March 1990). Gilbert (March 1990) suggests that the modular manufacturing is a process, not a program.

2.2.3 Labor Intense

Vought (February 1990) describes the apparel industry as the most labor intensive of all industries. It has the most Standard Allowed Hours of direct labor or number of direct employees per wholesale dollar of all industries. Probably another way of stating this is that it requires more people to add a dollar of value to the materials put in than any other industry. As a result, it is an industry of individual manual skills, supervision and training.
2.3 Computer Integrated Manufacturing (CIM) and Its Application in Apparel Manufacturing

Computer Integrated Manufacturing (CIM) involves integrating computers into the various operations of an enterprise to produce the right product at the right price and at the right time (Jayaraman, May 1990). Jayaraman (May 1990) describes these operations as fashion and product design, marketing and sales, merchandising, production planning, material requirement planning, manufacturing, materials handling, quality control, administration and financial and business management.

Increasing productivity, eliminating waste, improving quality standards and achieving greater consistency are some of the benefits from automating apparel manufacturing (Albrecht, 1989). Computerized manufacturing support systems have been available for some years covering various areas of management control, like factory loading, production planning, inventory control, work-in-progress/bundle flow control and labor cost/payroll (Nilsson, 1983).

Steward (February 1990) discusses other benefits that computer technology makes available to the apparel industry. These advantages result from the computer's capability to provide information in a timely manner. This information can be invaluable in the day-to-day operations of an apparel company. According to Steward (February 1990), certain
investments have been made in computer-assisted automation where the specific operation has benefitted. One example of this automation would be computerized marking and pattern grading and a Local Area Network (LAN), which provides the ability for each device to communicate to another, as needed, to perform the overall task. A second example would be in the cutting room, where several programmable spreading machines and cutters exist. A third could be an island of automated sewing machines for a particular operation or even automated pressing and finishing machines and shop floor control systems. The following are some examples of Computer Integrated Manufacturing (CIM) applications in apparel manufacturing.

2.3.1 Computer Aided Design

In the apparel industry, CAD systems, which have been well established for approximately 20 years, serve the primary role in pattern grading and marker making (Gray, January 1994). CAD systems include the capability to produce realistic pictures of various garments, alter pattern pieces for design features, size, grade patterns and make markers (Albrecht, 1989). According to Gray (January 1994), these systems work in two dimensions and produce output in the form of paper plots or in computer form (disk, tape, memory chip, etc.) for direct machine control. The modeling system accepts
input from most of these systems and uses the data that describes the geometry of the individual pattern pieces as its primary source.

The CAD vendors began to introduce new software for product specification handling (Kosh & Deirdre, August 1993). Kosh and Deirdre (August 1993) suggest that this is toward the goal of implementing a PDM (Product Data Management) in the context of product development. This allows concurrent review and changes to new product ideas, product development and design information by all the necessary people or departments involved in the product life cycle.

A CAD system can have a major impact on Material Utilization (MU) programs by setting procedures that include checkpoints for pattern/grading and marking quality (Kosh, August 1990).

2.3.2 Product Data Management (PDM)

Bridging multiple and diverse systems across distributed environments is a top priority today, and Product Data Management (PDM) has become the single most important and fastest-growing segment of computer integrated manufacturing (Kosh & Deirdre, August 1993). According to Kosh and Deirdre (August 1993), developing a product information infrastructure that can handle the increasing demands imposed by today's complex business scene is vital not only to maintaining a
competitive edge, but also to future survival. Linking product information with the marketing information and business systems to revise merchandising calendars for line development and planning and to evaluate volumes, resources, final costing and margins is crucial if deadlines and profit and quality goals are to be met. In summary, PDM is cross-industry technology to control all the information systems linked to the entire product life cycle. Its purpose is to provide the right version of the right data at the right time to the right person.

2.3.3 Computer Aided Manufacturing

Mechanized manufacturing techniques aided by computers and microprocessors include the spreading and cutting of fabric and the assembling of the fabric pieces (Albrecht, 1989). According to Albrecht (1989), automation to some extent has been achieved with sewing and other machines and with the way the fabric moves through the factory.

2.3.4 Management Systems

Management systems are fairly well developed for apparel manufacturing. Computer programs available for in-house use include manufacturing resource planning (MRPII), garment costing, cut-order planning, piece rate, Method Time
Measurement (MTM) and inventory and production control, to name a few (Albrecht, 1989). Albrecht (1989) suggests that these systems help manufacturers control functions, such as styling, forecasting, distributing, work-in-process, inventory, securing raw materials and scheduling.

2.3.5 Quick Response

Quick Response (QR) is a program whereby a relationship is developed between the manufacturer, the retailer and the supplier of raw materials to encourage a quick response to consumer demand (Albrecht, 1989). It provides information faster to facilitate faster product movement via EDI linkage. According to Albrecht (1989), QR's strategy is based on customers "pulling" the desired products through the system, as opposed to the textile and apparel manufacturers and retailers "pushing" products through. QR affects quality by proving the customer with what they want, when they want it. QR helps the U.S. industries remain viable by helping prevent waste due to overstock and mark-downs, freeing up capital and up to tripling Return On Investment (ROI). According to Mitchell and Cedrone (February 1994), Quick Response (QR), Computer Integrated Manufacturing (CIM) and Electronic Data Interchange (EDI) are the keys to success of the apparel manufacturing business of the '90s.
2.3.6 Robotics Fabric Handling

The class of garment at a sewing machine station may change several times in a year, due to seasonal and fashion requirements. Also, similar garment shapes may require several different types of materials in a production run. Robotics fabric handling could be useful in such flexible production scheduling with changes in fabric type or pattern shape (Parker et al., February 1983). According to Parker et al. (February 1983), the flexibility of the robotic manufacturing cell makes it an attractive prospect for improving garment manufacturing productivity. In most common garment sewing operations, the basic job of the operator is to load the pieces of fabric into a sewing machine. Usually these pieces of fabric have been cut into a pattern from a large stack of fabrics and are removed from the stack at the sewing machine or work station. The pieces of fabric vary widely in shape, thickness, stiffness and surface texture, and the extremely sensitive fingers of a human have been necessary to separate the fabrics from the stack. Parker et al. (February 1983) suggests that using robotics end-effector for acquiring single plies from a stack of fabrics can solve the problem.

2.3.7 The A-CIM Center
The Apparel CIM (A-CIM) Center is a research center at the University of Southwestern Louisiana. This research center demonstrates an effective CIM network that includes marking/grading/PDS systems, automated cutting systems, unit production systems, automated sewing equipment, computer controlled pressing equipment and shop floor control systems (Steward, February 1990). In this facility, the pattern design and fabric data, as well as pertinent engineering data, will be directly communicated to each device for preparation of new style introduction. For example, the pattern geometry will be automatically downloaded to a programmable stitcher. During operation, the appropriate stitch pattern, cut file and pressing information will be selected as a garment arrives for an operation. In addition, feedback will be achieved from both operator and equipment to better monitor, control and balance the overall operation.

All these available CIM technologies can be used in improving the apparel manufacturing system operations. It will not only facilitate the production of quality products but will also solve the current problems of apparel manufacturing.

2.4 Review and Analysis of System Modeling Methodologies

A system model is necessary in designing any manufacturing system. A suitable modeling methodology is also
essential to understand the system modeling process. The modeling methodologies for developing the presented model have been studied before developing the model.

2.4.1 IDEF0 Generic Modeling

A generic model is one that represents the generally accepted or intrinsic activities that exist within a defined function and can be universally useful in understanding a manufacturing enterprise (Baines & Colquhoun, August 1990). An IDEF0 model of a manufacturing activity is comprised of generic sub-activities, each of which is an identified unique activity related hierarchically to the top level generic manufacturing activity (Colquhoun, Gamble & Baines, 1989).

The development of an IDEF0 generic model is based on an initial design by an 'author' followed by an 'author reader cycle' where experienced IDEF0 practitioners analyze, criticize and refine the model (Ross, April 1985). Ross (April 1985) also suggests a continuous peer review of all work to ensure quality and reduce errors. The generic modeling application provides the users with a reference frame or system architecture (Baines & Colquhoun, August 1990). Manufacturing system design needs an integrated systems approach to converging its main functions, subfunctions and activities. A system approach would provide a top-down design information flow architecture enabling a bottom-up
implementation (Zhang & Alting, September 1991).

2.4.2 Need for IDEF0 Functional Model

A graphical model is helpful in understanding and representing the structure of a manufacturing system (Harrington, 1984). According to Harrington (1984), a model is not the real world; it is just a simplified representation of it, but it grows naturally out of the real world, and the purpose of a graphical model is to define and display the fundamental relationships of the many component functions which work together to accomplish manufacturing.

System modeling techniques have been used to represent the operations and activities that occur in increasingly complex manufacturing systems (Ranky, Winter 1991). Ranky (Winter 1991) suggests that system modeling is primarily to facilitate the study of existing systems and to aid in the design of new complex systems.

For a new system, a functional model can be utilized to identify and describe the types of activities, actions, processes and operations that must be performed to achieve the goals of the system under study (Goldman & Cullinane, 1987). Goldman and Cullinane (1987) also state that the function models describe how the activities are performed in the support of some high level functions which relate to each other.
2.4.3 Design Methodology, Technique and Tool

To create a model, three separate aspects are required: a methodology, a technique and a tool (Bancroft, 1989). Bancroft (1989) discusses methodology, technique and tool as follows:

2.4.3.1 Methodology

The methodology defines the management process of the modelling activity. It describes who the sponsor should be, at what organizational level the modeling activity should start, and whether the model should be built from the top down or from the bottom up. It also helps to establish a reasonable scope for the model. With the scope defined, an estimate can be made of the resource, time and commitment required to build a thorough model. The methodology also establishes what skills are needed on the modeling team and how the team should gather the needed information.

2.4.3.2 Technique

A technique describes how the diagrams should be drawn. It defines what symbols should be used and what the symbols mean. If the technique is hierarchical in nature, then it establishes the rules for decomposition.
2.4.3.3 Tool

The tool puts the symbols defined in the technique down on paper. The tool could be paper and pencil, but it could also be software. The tool supports a particular technique. However, for any particular technique there could be multiple tools. For example, there are several software tools that support the technique part of IDEF0.
CHAPTER 3
IDEF0 MODELING TECHNIQUES

This chapter is a discussion of the IDEF0 modeling technique that is used for developing the garment manufacturing system design model.

3.1 IDEF0 Modeling Description

IDEF stands for ICAM (Integrated Computer Aided Manufacturing) DEFINition, which evolved from SADT (Structured Analysis and Design Techniques) developed by the U.S. Air Force and is designed to describe manufacturing organizations in a structured graphical form. IDEF0 is one of the three IDEF modeling techniques. IDEF0 is the process modeling, while IDEF1 is the data modeling, which has been extended to become IDEF1x. IDEF2 models the dynamics of the system.

IDEF0 is a hierarchical modeling methodology, as shown in Figure 3.1. The model starts with a very high level function which is systematically decomposed into subfunctions (Goldman & Cullinane, 1987).

SADT, the precursor to IDEF0 is based on three concepts:
1. A top-down modelling approach;
2. The adoption of a graphical approach as a means of highlighting specific sections in a hierarchy; and
3. Providing a method capable of distinguishing between data, people, devices and activities which could clearly show what is performed and how (Colquhoun et al., 1989).

![Functional Decomposition Concept](image)

**Figure 3.1** Functional Decomposition Concept (Haines & Evers, 1990)

### 3.2 IDEF0 Model Structure

The diagramming technique of IDEF0 is a series of boxes and arrows. The boxes represent activities or processes. The arrows between the processes represent the data. The top diagram consists of one box representing the entire process being modeled. All boxes except for the lowest level boxes or terminal boxes are decomposed into diagrams consisting of three to six boxes. A numbering scheme keeps track of the relationship and position of the boxes. Depending upon which side of the box the arrow touches, the arrow may be either an
input (things used and transformed by activities), control (things that constrain activities), mechanism (how activities are realized) or output (things into which inputs are transformed) as shown in Figure 3.2 (Bancroft, 1989). A collection of all the diagrams connected by ICOM codes is called a model (Ross, April 1985).

![Figure 3.2 IDEF0 Fundamental Building Box](image)

Each IDEF0 model must have a defined purpose and viewpoint, since these affect the way the model is developed (Arabshahi, September 1991).

3.2.1 Purpose

The purpose of a model is, by definition, to answer a set
of questions (Marca, 1988). According to Marca (1988), these questions remain in the designer's mind during analysis, and thus they guide and influence the development of a model.

3.2.2 Viewpoint

The viewpoint is the one and only one perspective from which the model is developed. The viewpoint is also best thought of as a place, person or thing one can stand in to view the system in operation (Marca, 1988).

3.3 IDEF0 Model Development Procedure

The following procedures are involved in developing an IDEF0 model:

1. Acquire knowledge through interviewing multiple information sources (e.g., documents, people and the system in operation);
2. Document properly the acquired knowledge; and
3. Validate the model through iterative review which takes place between the author and expert about the validity of the evolving model (Marca, 1988).
CHAPTER 4

GARMENT MANUFACTURING SYSTEM DESIGN
PROCESS IDEF0 MODEL

The modeling process begins by determining the orientation of the model. The orientation is stated in terms of the objectives of the modeling activity (purpose), the boundaries of the domain under consideration (context), and the perspective from which the domain is seen for modeling purposes (viewpoint) (Malhotra & Jayaraman, June 1990).

4.1 Model Purpose

The purpose establishes the intent of the model, i.e., the goal of communication it serves (Jayaraman, May 1990). This model will describe the sequence of design activities that are required to design a garment manufacturing system. Moreover, this generic activity model of designing a garment manufacturing system acts as a reference model for a system designer designing a garment manufacturing system.

4.2 Model Context
Associated with a functional model is the context that establishes the subject of the model (Jayaraman, May 1990). A primary consideration in the development of the model is that the model be representative of the general garment manufacturing design process. For this purpose, the approach will be adopted for modeling a new garment manufacturing system. Activities ranging from the design requirements of the system to the validation of the designed systems are included in the context.

4.3 Model Viewpoint

The viewpoint determines what can be seen within the context and from what slant (Jayaraman, May 1990). The manufacturing system designer's viewpoint will be used in the generic activity model of designing a garment manufacturing system. The system designer is also the key design mechanism in the overall design activity.

4.4 Model Stopping Criteria

The purpose of this model is to show the design activities for designing a garment manufacturing system to a level which ultimately will produce a set of specifications that will guide the construction of the system.

In the context of the system designer's viewpoint, the
design activities and the specifications that are required to design the garment manufacturing system up to the sub-system levels have already been produced. The further decomposition of each design activity (i.e. material handling system etc.) should be done individually under the guidance of a sub-system designer (i.e. material handling engineer). Of course, the communication will continue between the system designer and other sub-system designers until the total manufacturing system is designed and built.

4.5 Model Activity List

The IDEF0 activities of the "design garment manufacturing system" model are shown in Figure 4.1. The activities were then used to construct the model diagrams, consisting of the activities and the ICOMs connecting the activities. A description of all the activities and ICOMs are given in the Chapter 5 and the APPENDIX respectively.
A0  Design garment manufacturing system
A1  Determine manufacturing system requirements
A11 Analyze product requirements
A12 Select manufacturing processes
A121 Identify manufacturing operations
A122 Determine machinery & mach. operation requirements
A123 Determine operators & production Shift
A124 Document manufacturing operations
A13 Develop system design requirements
A131 Develop layout design requirements
A132 Develop material handling design requirements
A133 Develop control system design requirements
A2  Develop manufacturing system specifications
A21 Design manufacturing layout specifications
A211 Design workstation layout specifications by dept.
A212 Determine space requirements
A213 Design materials flow
A22 Develop material handling system specifications
A221 Establish material handling methods
A222 Define material handling operation sequences
A223 Select material handling equipment
A224 Design material handling operation layout
A23 Develop manufacturing control system specifications
A231 Determine control methods
A232 Define control operations
A233 Select control devices
A234 Configure control system
A3  Design manufacturing system
A31 Design manufacturing layout
A32 Design material handling system
A33 Design manufacturing control system
A4  Simulate and validate manufacturing system
A41 Set simulation and validation requirements
A42 Design simulation model
A43 Conduct simulation of manufacturing system
A44 Verify and validate model

Figure 4.1 Design Garment Manufacturing System
IDEF0 Model Activity List.
CHAPTER 5
GARMENT MANUFACTURING SYSTEM DESIGN PROCESS
ACTIVITY DESCRIPTION

5.1 A-O Design Garment Manufacturing System (CONTEXT)

As shown in Figure 5.1, the uppermost activity "design garment manufacturing system" establishes the subject of the model from which all other activities are decomposed. This top-level activity uses the "product specifications/information" given by the user/client as input to generate the "new garment manufacturing system specifications" accordingly, as the output of the activity. The activity is done under several controls (i.e. "user/client request for system design", "labor availability & cost", "garment manufacturing knowledge", "manufacturing system design data/knowledge" and "budget constraints", etc.) through the mechanisms of the "design team" and "design tools."

5.2 A0 Design Garment Manufacturing System

This model context is then decomposed into four top-level activities as shown in Figure 5.2:
Figure 5.1 Design Garment Manufacturing System "Context" (A-0)
Figure 5.2 Design Garment Manufacturing System "Top Level" (A0)
1. Determine manufacturing system requirements (A1);
2. Develop manufacturing system specifications (A2);
3. Design manufacturing system (A3); and
4. Simulate and validate manufacturing system (A4).

These top-level activities are then decomposed into additional levels to describe the sub-activities with respect to their top-level activities and ICOMs.

5.3 A1 Determine Manufacturing System Requirements

In designing a manufacturing system, the first step is to determine the requirements of the manufacturing system to be designed. The purpose of system requirements is to identify what the system is for and how the system will be designed according to those requirements. Judd et al. (1990) describe the requirements for designing a system are to list:

1. constraints;
2. process needs;
3. production capacity;
4. interface to other equipment;
5. relevant standards;
6. mechanical layout; and
7. general strategy for implementation of the system.

According to Blanchard and Fabrycky (1990), system requirements can also be described by answering questions for the system such as what the system is to accomplish in terms
of operations and functional performance characteristics (i.e. items processed per month, how the system is to be used in terms of hours of operation per day, etc.). Blanchard and Fabrycky (1990) also said that the system requirements content usually covers the following areas: operational requirements, performance characteristics, physical characteristics, effectiveness characteristics, etc.

A requirements specification is also important for several reasons. It can serve as a means of communication between the user and the system developer. It can also serve as a basis for the design, implementation, testing and maintenance of the target system (Tse, 1991).

The activity, "determine manufacturing system requirements" of the model, the output "manufacturing system requirements" becomes the control of subsequent design activities. Harrington (1984) says "at all levels, specific elements of the plans, designs, etc. and detailed information concerning the requirements necessary to meet the plan for production, become the controls for subsequent functions."

The following discussion decomposes the "determine manufacturing system requirements" activity into three activities as shown in Figure 5.3 in the next level:

1. Analyze product requirements (A11);
2. Select manufacturing processes (A12); and
3. Develop system design requirements (A13).
Figure 5.3 Determine Manufacturing System Requirements (A1)
5.3.1 All Analyze Product Requirements

Harrington (1984) describes production as the physical conversion of raw materials into product. Production plans describe how each product (i.e. the results of the manufacturing process) and each part of each product are to be made, and how they are to be assembled and tested (Harrington, 1984). Colquhoun and Baines (1991) describe the activity to produce a complete description of the processes required to produce each manufactured component, together with the methods of assembly necessary to produce the product. Colquhoun and Baines (1991) also added that resource requirements, such as plants and equipment, to produce the necessary quantities at the right time are also established at this stage.

Detailed statements of a product is required to analyze it's characteristics, performance parameters, cost, etc. (Harrington, 1984). The "analyze product requirements" activity starts from the given "garment style", "production volume", and other "labor availability & cost" to describe the product that is going to be produced well enough to specify the future designed factory. It is very important for the manufacturing system designers to be well informed about the product, so that the system designers can use the product detail while designing the system.

Product requirements will describe the beginning of the design processes, what kind of garment and how the product
will be manufactured (i.e. whether the system will perform only sewing operations or everything from garment designing to garment finishing, etc). Information, such as where the raw materials will be coming from and where the final product will be shipped to and all other product related information must also be described in this activity.

5.3.2 A12 Select Manufacturing Processes

The necessary operations, equipment, tooling, tools, personnel and technology necessary for the production can be defined as manufacturing process requirements (Harrington, 1984). In the "select manufacturing processes" activity, the manufacturing (operational and production) requirements will be determined. These include the sequences of manufacturing operations, required machinery and the machinery's operational requirements, as well as manufacturing operators and production shifts. All these "select manufacturing processes" will support or carry out the analyzed "product requirements" from the previous activity (A11).

The following discussion decomposes the "select manufacturing processes" activity into four activities as shown in Figure 5.4 in the next level:

1. Identify manufacturing operations (A121);
2. Determine machinery and machinery operation requirements (A122);
Figure 5.4 Select Manufacturing Process (A12)

1. General manufacturing knowledge
2. Identify manufacturing operations
3. Determine machinery & equipment
4. Operation requirements
5. Select machinery & equipment
6. Flow process data
7. Flow production data
8. Determine operators
9. Document manufacturing operations
10. Identify manufacturing process
11. Identify manufacturing equipment
12. Document manufacturing operations
13. Manufacturing process
14. Select manufacturing process
15. Select manufacturing equipment
16. Document manufacturing operations
3. Determine operators & production shift (A123); and

5.3.2.1 A121 Identify Manufacturing Operations

An efficient manufacturing operation results from minimum production cost and maximum profit. By using the "product specifications" according to the "product requirements" and "garment manufacturing knowledge", the manufacturing operations will be identified in this activity. These garment manufacturing operations to produce the garment can be the cutting operation, sewing operation, finishing operation, etc.

5.3.2.2 A122 Determine Machinery and Machinery Operational Requirements

The selection of manufacturing machinery occurs after the manufacturing operations are identified. The manufacturing machinery performs the manufacturing operations in the required manner. The selection of machinery will be according to the "production operators & shift" that the manufacturing system has been set to operate. The machinery will also be selected according to the management's "budget constraints", "labor availability & cost" and "production volume". All the necessary machinery for all required operations or processes that are needed to produce the garments will be determined in
this activity. Apple (1977) advises the following factors to be considered in selecting the equipment:

**Direct costs** - commonly associated with the operation of equipment, will include the fixed costs of depreciation and other items of overhead and variable costs, such as personnel, power and maintenance.

**Indirect costs** - will include such equipment and method related cost as space, inventory, repair parts, downtime, and such management related cost as re-layout and training.

**Indeterminate costs** - costs not easily pre-determined or vague might include such frequently overlooked costs as space lost or gained, savings from inventory or production control, changes in overhead or in product or material quality and costs relating to installation and scheduling.

**Intangible factors** - will include whatever applies but nevertheless defies dollar-value calculation and must therefore remain outside the usual cost comparison, such as quality and availability of equipment or parts and the remote but vital aspects of personnel and financial policy.

After determining the required machinery, the operational requirements of those machines, such as who will be operating what machine, the accessories required to run those machines, etc. will be determined in this activity. The determination of machinery operational requirements is also important for deciding whether the selected machinery is appropriate for the manufacturing system or not.

5.3.2.3 A123 Determine Operators and Production Shift

Garment production operators are an important concern to
the apparel industry. To compete with other apparel manufacturers, especially those who have inexpensive labor, the selection of production operators should be done very carefully. Management should decide on the required operators and the production shift according to the available labor resource and their cost to meet the buyer's demand (i.e. the "production volume" from the buyer). The decision of the shift of operation will also be determined on the basis of the availability of labor, a major resource for operating the garment factory. The wage rate of the labor is very important in determining whether the management has the financial capacity to run the additional shift to meet the demand.

5.3.2.4 A124 Document Manufacturing Operations

All the identified manufacturing operations, the machinery that will be used to perform the operations and their operational supporting requirements will be documented as the "needed manufacturing processes" in this activity. These "needed manufacturing processes" will guide development of the whole system's design requirements and specifications.

5.3.3 A13 Develop System Design Requirements

In this activity all the manufacturing system requirements, such as designing the layout, material handling
of the system, etc. will be developed according to the "needed manufacturing processes." The sub-system design activities requirements need to develop in this level, so that the actual system building design activities can be initiated.

The following discussion decomposes the "develop system design requirements" activity into three activities as shown in Figure 5.5 in the next level:
1. Develop layout design requirements (A131);
2. Develop material handling design requirements (A132); and
3. Develop control system design requirements (A133).

5.3.3.1 A131 Develop Layout Design Requirements

This activity "develop layout design requirements" will develop the requirements of the layout to facilitate the manufacturing process. These requirements include a layout allowing all the manufacturing operations on the factory floor.

This activity also considers designing a good and an efficient layout for the manufacturing system as a part of manufacturing system requirements. The considerations of manufacturing system layout design, such as the type of factory building where the layout will be built, the size of the manufacturing facility, etc.

5.3.3.2 A132 Develop Material Handling Design Requirements
Figure 5.5 Develop System Design Requirements (A13)
This activity "develop material handling design requirements" will identify the requirements of a material handling system to support the manufacturing process. These requirements identify the required material handling operations needed on the factory floor. This activity is to determine "when", "where" and "what" material handling is essential in the garment manufacturing process.

The requirements of material handling include moving fabric to the cutting area, moving cut fabrics to the sewing area and moving sewn fabrics to the finishing and packaging area. Proper identification of the requirements of material handling will minimize the handling operation of the materials through the manufacturing system, which will result in a more efficient manufacturing operation.

This activity will also determine the importance of having a proper material handling system. The degree of automation of material handling system and whether the automated material handling system operation will cost tremendously will be other concerns of this activity.

5.3.3.3 A133 Develop Control System Design Requirements

This activity "develop control system design requirements" will develop the requirements for the control system according to the "needed manufacturing processes." The control requirements of the manufacturing equipment or
operations should be determined in the early stages of the control system development process. Control requirements include determining what specific equipment or manufacturing operations need to be controlled by the computer or other control devices.

5.4 A2 Develop Manufacturing System Specifications

For any design process, generally design means the procedure of determining the design functions, structures and specifications for the system (Ito, 1987). Ito (1987) suggests that the design procedure itself and the preparation of the design specifications show implicitly its effect on the corresponding design activities.

This activity "develop manufacturing system specifications", will develop the system specifications of all the sub-systems (i.e. manufacturing layout, material handling system, manufacturing control system, etc.) according to the "manufacturing system requirements." These manufacturing system specifications will generate the detail of each sub-system such as the manufacturing operation layout descriptions, material flow descriptions and system operation methods and equipment.

The following discussion decomposes the activity "develop manufacturing system specifications" activity into three activities as shown in Figure 5.6 in the next level:
Figure 5.6 Develop Manufacturing System Specifications (A2)
1. Develop manufacturing layout specifications (A21);
2. Develop material handling system specifications (A22); and
3. Develop manufacturing control system specifications (A23).

5.4.1 A21 Develop Manufacturing Layout Specifications

A manufacturing layout is the expression of a manufacturing or work process as applied to a particular area (Sims, 1968). The manufacturing layout design process is considered at the beginning in designing a manufacturing system and is the basis for the building the designed system (Apple, 1977).

According to Apple (1977), the major objectives for the design of a facility layout are:

1. Facilitating the manufacturing process, such as proper arrangement of machinery, equipment, and work areas so that materials are caused to move smoothly along in as straight a line as possible;
2. Minimizing material handling;
3. Maintaining flexibility of arrangement and of operations;
4. Maintaining high turnover of work-in-process so that the material is moved through the necessary processes in the shortest possible time;
5. Holding down investment in equipment by proper arrangement of machines;
6. Making economical use of building cube;
7. Promoting effective utilization of manpower; and
8. Providing for employee convenience, safety and comfort in doing the work.

This activity develops the manufacturing (production/process) layout specifications of the manufacturing system, according to the manufacturing layout requirements. The following discussion decomposes the activity "develop manufacturing layout specifications" activity into three activities as shown in Figure 5.7 in the next level:
1. Develop workstation Layout specifications by departments (A211);
2. Determine space requirements (A212); and
3. Design materials flow (A213).

5.4.1.1 A211 Develop Workstation Layout Specifications by Department

In this activity "design workstation layout specifications by department", the layout specification will be developed in terms of the manufacturing operations. These specifications will define the physical existence of the factory, individual machinery position and manufacturing operations of the manufacturing system. The layout specifications will be specified according to the material
Figure 5.7 Develop Manufacturing Layout Specifications (A21)
flow and the required space for manufacturing operation. All manufacturing departments layout specifications, such as the cutting department layout, sewing department layout, finishing department layout, garment packaging department layout, including its required or selected machinery or equipment setup layout will be developed of in this activity.

5.4.1.2 A212 Determine Space Requirements

When developing the layout specifications for all the workstations, it is necessary to make an estimate of the total space required for each operation in the manufacturing system (Apple, 1977). In this activity, the garment manufacturing operations space for all departments will be considered to determined where the manufacturing system will be built. These spaces include:

1. the machine/operation space, which is for manufacturing operations including the machinery, for each manufacturing operation area, such as cutting, sewing etc.;

2. the materials handling space for allowing material handling operations and it's equipment that are going to be used in the handling operations. The goal is always to have a free and convenient space for material handling system that will speed up the manufacturing operations; and
3. the WIP/storage space, which is required for manufacturing operations and storage purposes. The WIP/storage space should be considered according to the actual selected production and should not obstruct the material handling operations.

5.4.1.3 A213 Design Materials Flow

An efficient plan for the materials flow is a primary condition for economical production (Apple, 1977). Apple (1977) describes the material flow pattern as the basis for an effective arrangement of physical facilities and the entire plant design, as well as for the success of the enterprise.

There are also several advantages of well planned material flow in designing a manufacturing layout. According to Apple (1977), having a well-conceived and planned material flow pattern toward designing a manufacturing layout can:

1. Increase efficiency of production and productivity.
2. Utilize better of floor space.
3. Simplify handling activities.
4. Utilize equipment better and have less idle time.
5. Reduce in-process time.
6. Reduce in-process inventory.
7. Utilize more efficient work force.
8. Reduce product damage.
10. Reduce walking distances.
11. Reduce traffic congestion in aisles.
12. Be a basis for an efficient layout.
13. Ease supervision.
14. Simplify production control.
15. Minimize back-tracking.
17. Improve scheduling process.
18. Reduce crowded conditions.
19. Provide better housekeeping.
20. Make logical work sequence.

All types of material flow and where and what type of materials that need to move will be designed in this activity. In other words, this activity will design from where to where the raw materials or unfinished garments or semifinished or finished garments will move before shipment of the garments.

Designing materials flow includes:

1. the raw materials of garment parts which need to flow in such a fashion that they will accelerate other manufacturing operations. Raw materials include cut fabrics and other garment accessories;
2. the WIP materials, which occur after or in parallel with the unfinished materials flow. In any manufacturing operation, the more WIP materials, the more inefficient the manufacturing processes become. Maintaining less WIP process materials makes manufacturing operations more
productive; and
3. the finished materials, which takes place after both the raw materials and the WIP materials flow.

5.4.2 A22 Develop Material Handling System Specifications

Material handling has been defined simply as handling, storing and controlling material (Apple, March 1987). Apple (March, 1987) suggests material handling is providing the right amount of the right material in the right sequence, in the right position, at the right place, at the right time, at the right cost, safely and without damage.

Apple (1977) indicates the concept of "unit load", which is one of the principles of material handling, implies the maximum the load is handled, the lower the cost per unit handled would be. The unit load system has the basic characteristics of reducing handling problems to their common denominator (Sims, 1968).

The following expression can be helpful to represent the moves of material in a material handling system and the importance of the questioning attitude in a designing material handling system (Tompkins, 1984):

\[ \sum_{\text{material moves}} [\text{Why (Where + What + When + How)}] \]

This activity will design the required material handling system for the garment production and will answer "when", 
"where", "what", "how" the materials will be handled in order to be produced.

According to Taylor and Koudis (1987), in a typical sewing room about 80% of production time is spent handling the workpiece as opposed to joining. They describe this handling as the following:

1. separating the fabric ply from the stacks;
2. picking up and moving each piece;
3. orientating a piece with respect to the other(s) and bringing them to the sewing head;
4. guiding fabric during sewing; and
5. removing and stacking for the next operation.

Taylor and Koudis (1987) also suggests that only (d) involves joining, the rest are material handling operations and do not add value to the product and a large amount of available production time is wasted in fabric handling operations.

Material handling converts the static flow pattern into a dynamic reality, providing the means by which material is caused or permitted to flow (Apple, 1977). Apple (1977) suggests that an ideal system will consist of an integrated combination of methods and equipment designed to implement the flow of material.

From an engineering point of view, materials handling is defined as the art and science involving the moving, packaging and storing of substances in any form (Sims, 1968). Sims
(1968) describes materials handling as the portion of the business system which affects the relationship of materials and packaging to the product, facility or customer without adding usable worth or changing the nature of the product. Sims (1968) also suggests that in almost any industrial process, the greater part of the indirect labor employed is engaged in materials handling.

The following discussion decomposes the activity "develop material handling system specifications" into four activities as shown in Figure 5.8 in the next level:

1. Establish material handling methods (A221);
2. Define material handling operation sequences (A222);
3. Select material handling equipment (A223); and
4. Design material handling operation layout (A224).

5.4.2.1 A221 Establish Materials Handling Methods

This activity determines "how" the required materials will be moved or what handling operations will be performed in the manufacturing process. These methods include moving cut fabrics on a cart to the sewing area in a progressive bundle system or moving the cut fabrics on an overhead conveyor in a unit production system (UPS). Depending on the manufacturing system (i.e. bundle or UPS), the method of moving materials for every required move of the materials will be established in this activity.
Figure 5.8 Develop Material Handling System Specifications (A22)

1. Material handling methods
2. Material handling equipment
3. Material handling system specifications
4. Design material handling layout
5. Select material handling equipment
6. Establish material handling methods
7. General materials handling requirements
8. Material handling equipment and system specifications
9. Establish material handling requirements
10. Select material handling equipment

Node: A22
5.4.2.2 A222 Define Materials Handling Operations Sequences

After determining the handling methods, the handling operations need to be defined, such as, what are the sequential movements of the materials and who is responsible for each handling operation. A detailed description of each material movement will be established in terms of their pick and release points. This activity provides the materials flow information.

5.4.2.3 A223 Select Materials Handling Equipment

Apple (1977) suggests not to always consider materials handling equipment for solving a handling problem, because sometimes the simplest and most economical method will not require any equipment at all. According to him, after having accomplished the following procedure which suggests work simplification approach, the material handling equipment should be selected attempt to:

1. Eliminate the move.
2. Combine the move with some other function; such as processing, inspection, storage.
3. Change the sequence of activities, to shorten, eliminate, or alter the move requirements.
4. Simplify the move, to reduce the scope, extent, or distance to move based on the method or the equipment
5.4.2.4 A224 Design Materials Handling Operation Layout

In this activity, a layout of all the materials handling operations will be designed so that the handling operations can be seen physically on the factory floor. A material handling operation layout will also help to identify whether the handling methods and operations are appropriate for the garment manufacturing system before actually designing the materials handling system.

5.4.3 A23 Develop Manufacturing Control System Specifications

Manufacturing control plays an important role in a successful computer-integrated production (Bilberg & Alting, 1991). The design of manufacturing systems and the development of the manufacturing system controllers has become closely linked as the manufacturing environment has become more automated (Boucher & Jafari, 1992). Monitoring and control of floor level devices is essential for efficient manufacturing systems (Israni, 1987).

In this activity, the overall garment manufacturing operational control system specifications will be developed. This will be done by specifying a system which will control the automated or semi-automated manufacturing operations. The
control system is essential, especially in the unit production 

system (UPS) where an automated overhead conveyor operates as 
the major material handling equipment, and for an automated 
fabric cutter or fabric spreader.

The following discussion decomposes the activity "develop 
manufacturing control system specifications" into four 
activities, as shown in Figure 5.9 in the next level:

1. Determine control methods (A231);
2. Define control operations (A232);
3. Select control devices (A233); and
4. Configure control system (A234).

5.4.3.1 A231 Determine Control Methods

This activity determines how the machines, equipment and 
operations need to be controlled. In other words, what 
software, hardware or mechanical devices are necessary to 
control the system. Determination of the point and time of 
stopping and starting the overhead conveyor in the unit 
production system (UPS) is a good example of determining these 
control methods.

5.4.3.2 A232 Define Control Operations

This activity defines at what sequence the necessary 
equipment or machinery will be controlled by the control
Figure 5.9 Develop Manufacturing Control System Specifications (A23)
devices and determined control methods during manufacturing operation. In other words, control operations include a decision concerning at what stage of the operation the automated equipment will be activated.

5.4.3.3 A233 Select Control Devices

After determining the control methods and defining the control operations, this activity selects the control devices. The selection of control devices also follow the previously described rules for selecting manufacturing or materials handling equipment. The budget constraints also need to be considered as well.

5.4.3.4 A234 Configure Control System

This activity is to configure the control system according to the control methods, operations and selected devices. This activity will determine whether the specified control system will be appropriate for the manufacturing system and finalize the control system specifications.

5.5 A3 Design Manufacturing System

After developing the specifications for the manufacturing system, the manufacturing system is ready to be designed
according to the system specifications. This activity, "design manufacturing system" shows designing the garment manufacturing system according to the developed system specifications that were developed in previous activities for all sub-systems.

The following discussion decomposes the activity "design manufacturing system" into three activities as shown in Figure 5.10 in the next level:

1. Design manufacturing layout (A31);
2. Design material handling system (A32); and
3. Design manufacturing control system (A33).

5.5.1 A31 Design Manufacturing Layout

In this activity the manufacturing layout will be designed according to the developed layout specifications.

5.5.2 A32 Design Material Handling System

In this activity the material handling system will be designed according to the developed material handling system specifications.

5.5.3 A33 Design Manufacturing Control System

In this activity the manufacturing control system will be
Figure 5.10 Design Manufacturing System (A3)
designed according to the developed control system specifications.

5.6 A4 Simulate and Validate Manufacturing System

Suri, Diehl and Dean (1986) suggest simulation is an important tool and must be used before a design is finalized. In this activity, the overall system will be simulated to see how the individual system interacts with the rest of the system and what necessary alterations will be made before the final design is ready to implement.

The Oxford English Dictionary defines simulation as:

"the technique of imitating the behavior of some situation or system (economical, military, mechanical, etc.) by means of an analogous situation, model or apparatus, either to gain information more conveniently or to train personnel."

Werner and Profozich (January 1991) suggest that simulation has become an accepted methodology for solving many manufacturing problems in the apparel industry. Simulation has been used to address design problems as well as manufacturing operational problems of manufacturing systems (Elmaraghy & Ravi, 1992). Simulation gives the user a tool for quickly predicting the performance of the shop-floor activities as it is designed (Pargas, Peck, Kambekar & Dharmaraj, 1990).

Schroer (August 1992) discusses the increasing interest in using computer simulation for modeling modern apparel
manufacturing systems. He also suggests that simulation can increase productivity, improve quality and, at the same time, reduce costs. It is also a technology that can improve an apparel company's competitive edge, not only in domestic markets but also in international markets. According to Schroer (August 1992), in the apparel industry there is a continual effort to improve the process, minimize system variability, improve quality and reduce cost. Simulation provides an approach to support this effort.

With simulation, it is possible to manipulate the model rather than the real-world system and in an apparel environment, such real-world manipulation is often too expensive and impractical. Schroer (August 1992) suggests the following outlines for simulation in a manufacturing environment:

1. Understanding the operation behavior of a system;
2. Conceptualization of various system configurations and the comparison of these configurations or alternatives with the existing real world system;
3. Analyzing the behavior of the real world system in a controlled environment by selectively varying parameters;
4. Predicting the impact of various changes to the system; and
5. Studying various proposals during the system design stage, before actually purchasing equipment or starting construction.
The following discussion decomposes the activity "simulate and validate manufacturing system" activity into four activities as shown in Figure 5.11 in the next level:

1. Set simulation and validation requirements (A41);
2. Design simulation model (A42);
3. Conduct simulation of manufacturing system (A43); and
4. Verify and validate model (A44).

5.6.1 A41 Set Simulation/Validation Requirements

The requirements of the simulation and validation of the designed system are set in this activity according to the "manufacturing system specifications." The requirements of the simulation and validation include satisfying the conditions that were set in the beginning of the design procedure and the results that are to be expected after simulation is done. The requirements also include simulating each individual system, such as the material handling system and control system.

5.6.2 A42 Design Simulation Model

The design of the model will be done in this activity. The necessary simulation software or generating simulation program are the main activities done here.
Figure 5.11 Simulate and Validate Manufacturing System (A4)
5.6.3 A43 Conduct Simulation of Manufacturing System

This activity shows conducting the simulation of the designed system after designing the simulation model. The results of the simulation of the designed manufacturing system will be used to confirm the manufacturing system, and the design errors can be realized before finalizing the system design.

5.6.4 A44 Verify and Validate Model

The results of the simulation will be analyzed and verified with the requirements set earlier. This is the stage where the "ok" signal for the designed system can be given, if all the requirements for validating the system are met, according to the "manufacturing system specifications." If not, the individual system designs will be redesigned or modified and will be simulated again until they are matched according to the design goals.
CHAPTER 6
EVALUATION OF RESULTS

6.1 Model Accomplishment

The IDEF0 model for designing a garment manufacturing system which has been developed describes a generic garment manufacturing design process. The analysis of each activity level illustrates how a garment manufacturing system will be designed.

Jayaraman and Malhotra (1990) developed a model for "apparel manufacturing architecture", where they described the manufacturing operation activities which are required to manufacture the garments. In contrast, the model "design garment manufacturing system" was developed to show the design activities to design a garment manufacturing system. A good system design is the key to overall success of the manufacturing business. Therefore, designing should be conducted carefully and precisely to accomplish the goal.

6.2 Design Activities

The model describes the design activities for a garment
manufacturing system from creating factory requirements and specifications to simulating the designed system before building the system physically. The design activities are to fulfill the "client/user requirements" along with other considerations of such as "budget constraints", "labor availability and cost", etc.

6.3 Design Information

The model has also shown the information or data flow from one design activity to another. The information shown as an output from one activity has become either a control or an input for another activity.

6.4 Design Tools/Mechanism

The identification and usage of design activity mechanisms that are required to perform the design activities and to generate the outputs of design activities was one of the major concerns of this model. These design tools or mechanisms were used to convert the input to an output.

6.5 Use of IDEF0 Modeling Technique

The design of a garment manufacturing system has been broken down into the four top-level design activities:
1. Determine manufacturing system requirements (A1);
2. Develop manufacturing system specifications (A2);
3. Design manufacturing system (A3); and
4. Simulate and validate manufacturing system (A4).

These top-level activities are then further decomposed into additional levels according to their needs. The hierarchial design activities of the model in terms of their shared data and information flow simplified the overall design activity. The different levels of design activity were also useful for focusing on each part of the manufacturing system design process.

6.6 Use of Garment Manufacturing System Design

IDEFO Model

The model has been developed to show the design activities for designing a garment manufacturing system. This model could be used as a garment manufacturing system design reference model for the system designer to see what design activities are needed for a new system.
7.1 Accomplishment of Objective

A description of garment manufacturing system design activities has been developed. The specific problem addressed is the inadequate understanding of required design activities, tools and how the design information in one design activity relates to others. In this generic model of a garment manufacturing system design process, depth was limited to retain generic descriptions of the activities. The purpose of the model presented here was to show the garment manufacturing system design activity in designing a new garment manufacturing system.

This generic model also serves as an example of the capabilities of IDEF0 as a general purpose modeling technique to provide a clear picture of a complex aspect of a manufacturing organization. IDEF0 was found to be a powerful descriptive tool that offers a number of features which make it easy to apply and, more importantly, to understand (Colquhoun & Baines, 1991).
7.2 Future Research

This developed model was a generic framework of design activity for a garment manufacturing system, which also showed the identification of design tools to perform the activities and the information flow between the activities. This research of designing a manufacturing system can be extended further as follows by:

1. Modeling the sub-system, such as the material handling system or the manufacturing control system separately in detail with the same modeling technique for the garment manufacturing system;

2. Developing a common database for improving the information flow and structure for designing a garment manufacturing system; and

3. Developing a software using the Artificial Intelligence (AI) technique to generate the design activities that are required for designing a manufacturing system, especially for a garment manufacturing system.
References


APPENDIX

GARMENT MANUFACTURING SYSTEM DESIGN PROCESS IDEF0 MODEL
- Unrelated request for system design
- Manufacturing system design knowledge
- Budget constraints
- Garment manufacturing knowledge
- Labor availability & cost

Product spec info

Design garment manufacturing system

New garment mg system design specifications

System design team

- Design tools
Node: A1
Title: Determine manufacturing system requirements
Number: 1

1. Manufacturing system requirements

- Analyze product requirements
  - Production volume
  - Labor availability & cost
  - Current market

- Select manufacturing processes
  - Needed manufacturing processes
  - Design tools
  - Computer
  - Bid
  - Design constraints
  - Current manufacturing knowledge
  - Design request for system design

- Develop system design requirements
  - A11
  - A12
  - A13
Node: A12  Title: Select manufacturing processes  Number: 

1. Manufacturing operations
2. Selected machinery & machine operation requirements
3. Needed manufacturing processes
Title: Develop system design requirements

Node: A13

1. Manufacturing system requirements

- Computer
  - System design team
  - Manufacturing control system requirements
- Manufacturing layout design requirements
  - Material handling system requirements
  - Material handling system preference
  - Uncertain material handling system preference
- Uncertain factory layout preference
- General manufacturing knowledge
- Needs manufacturing processes
Node:A2  Title:Develop manufacturing system specifications  Number:  

1. Manufacturing system specifications  

- Develop manufacturing layout specifications  
- Manufacturing layout requirements  
- Layout design  
- Layout engineer  

2. Manufacturing layout specifications  
- Manufacturing layout requirements  
- Product specifications  
- Product design  

3. Manufacturing control system specifications  
- Material handling system specifications  
- Control engineer  

4. Material handling system specifications  
- Material handling system requirements  
- Material handling system design  
- Material handling engineer  

- Manufacturing control system specifications
Develop workstation layout specifications by dept.

1. Space requirements

Node: A21   Title: Develop manufacturing layout specifications

Computer

Design materials flow

A212

Manufacturing layout specifications

A211

Space requirements

M2

Flow process chart

M1

Form-0 chart

A213

Determine space requirements

Select machinery & mark operation requirements

Manufacturing layout requirements

Layout engineer

General manufacturing knowledge

Layout design for knowledge
Materials flow

C2 C3 C1

Rev.

Publications

Notes: 1 2 3 4 5 6 7 8 9 10

Project:

Draft

Recommended

Date: 6/5/994

Content

仁
1. Manufacturing control system specifications

Node: A23
Title: Develop manufacturing control syst. specifications
Number:
Node-A4
Title: Simulate and validate manufacturing system

1. Simulated manufacturing system
2. New general mfg. system design specifications
GLOSSARY OF ICOM TERMS

Budget Constraints:
This is the financial capability of the user/client that tells the designer to what extent the user/client is willing to invest in the project, so that the designer can limit selection of the equipment, automating the system and also the timeframe within which the system design work has to be completed.

Computer:
For the computation related activities, such as using SPREADSHEET, LOTUS 123 program or any other available computer software that will be used.

Computer Simulation Software:
The simulation software, such as SIMFACTORY II.5, TC-SQUARED, WITNESS, GPSS/PC, GPSS/H, etc. which are used for simulation purposes.

Control Devices:
The selected control hardware and software to operate control system in the manufacturing operations.

Control Engineer:
The person who is the head of designing the control system.

Control Methods:
The strategy of how the required manufacturing machinery, such as an automatic cutter, a spreader or the overhead conveyor system for material handling purposes, in a Unit Production System (UPS) will be operated.

Control Operations:
The description of the sequences of control operation of the manufacturing equipment or devices.

Control System Design Tools:
The computer software tools, such as SIMAN/Cinema, a discrete event simulation tool to model and animate simple mechanical systems and material flow and FLEXIS, a software design tool based on Grafcet to design the control logic.

Design Tools:
A set of design tools which will be used as the mechanisms for designing the system. These design tools range from the use of computer to the use of computer simulation software.
**Designed Manufacturing System:**
The designed manufacturing system which is done according to the manufacturing system specifications.

**Flow Process Chart:**
The flow process chart contains considerably more detail than does the operation process chart (see Operation Process Chart). In addition to recording operations and inspections, the flow process chart shows all the moves and delays in storage encountered by an item as it goes through the plant.

**From-To-Chart:**
The from-to-chart is a technique used in layout and materials handling purposes. It is especially helpful where many items flow through the manufacturing area. In from-to-chart, the numbers usually represent some measure of materials flow between the locations involved, such as the number of unit loads, distances, weights, volume etc.

**Garment Manufacturing Knowledge:**
The experience, data and knowledge that come from the existing garment factory, garment experts and garment related people about garment manufacturing processes and operations, garment factory technology and resources, etc.

**Garment Style:**
The style or the physical appearance of the any particular garment type.

**IDEF0:**
The IDEF0 technique is used to show the manufacturing operations that are required to perform sequentially and hierarchically.

**Labor Availability and Cost:**
The availability of labor and cost determines how easily labor can be hired for the production in terms of pay roll and work skill.

**Layout Design Changes:**
The necessary alterations according to the production system simulation results or analysis which need be done before confirming the final production system layout.

**Layout Design Data/Knowledge:**
The data and knowledge related to designing manufacturing layout.

**Layout Design Tools:**
The computer software which are used to designing manufacturing layout, such as LAYOUTMASTER, COFAD etc.
Layout Engineer:
The person who is the head of designing the layout of the production system.

Manufacturing Control Design Data/Knowledge:
The data and knowledge related to designing the manufacturing control system.

Manufacturing Control System:
The designed manufacturing control system according to the control system specifications.

Manufacturing Control System Changes:
The necessary alterations according to the control system simulation results or analysis which need be done before confirming the final control system.

Manufacturing Control System Requirements:
These requirements are created at the system design requirements planning activity level and represent the necessary control requirements of the machines or equipment for the manufacturing operations, according to the specified manufacturing operations.

Manufacturing Control System Specifications:
The determined manufacturing control system specifications.

Machinery Operational Requirements:
These machinery operational requirements are the necessary people and the supporting tools or accessories that are required to operate the manufacturing machinery.

Manufacturing Layout:
This is the designed layout according to the layout specifications.

Manufacturing Layout Requirements:
These requirements are created at the system design requirements planning activity level to design the manufacturing layout as a part of the system in the system design process. The manufacturing layout requirements control determining the manufacturing layout specifications.

Manufacturing Layout Specifications:
The determined manufacturing layout specifications.

Manufacturing Operations:
The necessary manufacturing operations that must be performed to produce the final garment, such as cut fabric, sew fabric, finish fabric, etc. These operations also include from where-to-where the unfinished or semifinished garment moves before completing the final garment.
Manufacturing System Design Data/Knowledge:
The experience, data and knowledge that come from the manufacturing system design experts, manufacturing system design journal and book, past manufacturing system design knowledge and current available manufacturing design technology etc.

Manufacturing System Requirements:
All the determined requirements of the manufacturing system including the sub-systems.

Manufacturing System Specifications:
All the determined specifications of the manufacturing system including the sub-systems.

Material Handling Design Tools:
The required computer software for designing material handling system, such as COFAD, for designing material handling layout and SIMFACTORY II.5, for simulating material handling operations.

Material Handling Engineer:
The person who is the head of designing the material handling system.

Material Handling Equipment:
Selected equipment to move finished or unfinished materials to and from manufacturing operation departments and to move finished or unfinished materials to and from storage.

Material Handling Methods:
The methods of material handling which tell how each type of materials (i.e. the unfinished parts, semifinished parts and final garment) will be carried or moved from one operation area to the another. For example, one of these methods involves carrying cut fabrics to the sewing area on cart or overhead conveyor or simply by the operator.

Material Handling Operations Sequences:
These operations described the required materials movement after each manufacturing operation is completed within the same operation area or between the different operation areas. The material handling operations are also the defining points from where the materials will be picked and to where the materials will be released, in terms of quantity or in terms of garment parts combination.

Material Handling System:
This is the designed material handling system which is designed according to the material handling system specifications.
Material Handling System Changes:
The necessary alterations according to the material handling system simulation results or analysis which need be done before confirming the final material handling system.

Material Handling System Design Data/Knowledge:
The data and knowledge related to designing material handling system.

Material Handling System Requirements:
These requirements are created at the system design requirements planning activity level. The handling requirements are the handling or moving description of the materials that need to be moved. These requirements include moving the fabrics from storage to the cutting room or moving cut fabrics to the sewing room, etc.

Material Handling System Specifications:
The developed material handling system specifications according to its requirements.

Material Volume/Size:
The total quantity of materials that are required, according to the factory specified production volume, that are going to be made during the manufacturing processes.

Materials Flow:
The movement of all kinds of materials including unfinished, Work-In-Process (WIP) and finished goods that are necessary to complete the final garment.

Needed Manufacturing Process:
The documented list of all the manufacturing requirements in terms of manufacturing operations, production labor and production shift, selected machinery and their operational resources in order to manufacture the product.

New Garment Manufacturing System Specifications:
The final output of the design effort which satisfies the client/user request. According to the design request, all the system design specifications are made to build the system.

Operation Process Chart:
The operation process chart shows the chronological sequence of all operations, inspections, time allowances and materials used in a manufacturing or business process from the arrival of raw material to the packaging of the finished product.

Product Requirements:
The product requirements are the description of the features that describe the construction of the garment according to the product specifications, garment style and production volume.
This description is similar to the bill of materials.

**Product Specifications/Information:**
The detail of the garment required characteristics, performance parameters, etc. These things control the manufacturing function are the mandate to conduct manufacturing in conformance with the product definition and specification received from the company's overall management (Harrington, 1984).

**Production Operators & Shift:**
The production operators are the personnel who are going to perform the manufacturing operations in the manufacturing processes. The management people are not included here. The production shift is the term of production that the factory will be operating in terms of hours in the production day.

**Production Volume:**
The quantity of the garment product that will be required to be produced in terms of daily or weekly or monthly manufacturing operations period to meet the customer's demand.

**Simulated Manufacturing System:**
After conducting the simulation of the designed system which is ready to be verified and validated.

**Simulation/Validation Requirements:**
The goals of the simulation model and the conditions that the designed system is to meet after conducting the simulation of the designed system.

**Simulation Engineer:**
The person who is the head of designing the simulation model of designed system. He/she is also responsible to simulate the individual simulation of the system, such as the material handling system, control system, etc.

**Simulation Model:**
The conversion of the designed system in computer codes or modeling the system with the aid of different icons and entering data by means of a simplified interface in the simulation software.

**Selected Machinery and Machinery Operation Requirements:**
The machinery that will be used in the manufacturing operations for all the manufacturing processes and the needed machinery operations supporting requirements, such as spare parts, services, etc.
**Space Requirements:**
The floor space for the whole manufacturing processes including the different operational departments. These space requirements also include the production, storage and Work-In-Process (WIP) for the individual operational department.

**System Design Changes:**
The changes that need to be made after verifying the simulation model.

**System Design Team:**
The system design team is comprised of representatives from all phases of system design, including representatives from client, garment industry experts and design engineers (i.e., layout, material handling, control, simulation, production etc.). The members are to work together, so that the design decisions comply until the development of the manufacturing system.

**User/Client Control System Preference:**
The specific preference that come from the user/client in designing the control system.

**User/Client Factory Layout Preference:**
The specific preference that come from the user/client in designing the factory layout.

**User/Client Material Handling System Preference:**
The specific preference that come from the user/client in designing the material handling system.

**User/Client Request For System Design:**
The user/client request for system design the first control in the garment manufacturing system design process. This request initiate the design process.