

AN ADAPTIVE QUOTATION SYSTEM FOR WEB-BASED MANUFACTURING

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DECLARATION

I declare that this dissertation is my own unaided work except where due acknowledgement is made to others. This dissertation is being submitted for the Degree of Doctorial of Technology to the Durban Institute of Technology, Durban and has not been submitted previously for any other degree or examination.

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ABSTRACT

Increased global competition is challenging manufacturing industries to bring competitively priced, well-designed and well-manufactured products into the marketplace as quickly as possible. Manufacturing companies are responding to these challenges in their industry by extending current internet trends to create virtual marketplaces where factories, suppliers, and customers are part of the solution. Pressing demands to reduce lead-time by providing a suitable manufacturing price for a product has become an important step in the current competition age. This thesis presents an approach for providing a quotation for a product via the web, automatically and autonomously.

The objective of this project is to design a manufacturing quotation system that can generate a quotation (and estimated delivery time) for a part to be manufactured using Computer Numerical Control (CNC) manufacturing equipment, after the potential customer has submitted a suitable Computer Aided Design (CAD) model of the part via the Internet. The quotation should be generated automatically, and displayed by the system for on-line viewing by the potential customer. In addition, if the customer then wants to place an order, he should be able to do so via the same on-line system. The system should then log the order and the accompanying order number. Nothing like this exists presently.

Currently, this project uses CAD/Computer Aided Manufacturing (CAM) software, together with Artificial Intelligent (AI) and in-house generated data, to automatically provide an estimated machining time. To construct such a system, there are three main technical problems, namely cost calculation, profit margin expectation, and system integration.

Machining time is the basic for cost calculation. To generate machining time automatically, this project has adopted the latest technology advancement in the CAX field, which is STEP-NC (ISO 14649). By using this technology, the related CAD drawing information is queried, and then the related machining time can be generated. This research also has targeted quotation generation issues, which are centered around profit margin expectation. By adopting the concept of 'part complexity', the uncertainty factors related to the quotation processes have been dealt with. This is achieved via AI, which is enhanced by a self-learning function.

Thus, this system has been divided into three parts. The costing sub-system provides a basic foundation for quotation, which is integrated with profit margin expectation to provide a state of the art quotation solution. Actually, the result has been tested in reality for the concepts outlined. In addition, this approach has proven to be practical, and can be embedded into Web-Based Manufacturing (WBM) technologies easily.

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ABBREVIATIONS

CNC:	Computerized Numerical Control
CAD:	Computer Aided Design
CAM:	Computer Aided Manufacturing
AI:	Artificial Intelligent
STEP:	Standard for Exchange of Product Model Data
STEP-NC:	STEP application interpreted model for NC (AP238)
NC:	Numerical Control
ISO:	International Standards Organization
IGES:	Initial Graphics Exchange Specification
AP's:	STEP Application Protocols
WBM:	Web-Based Manufacturing
XML:	eXtensible Markup Language
AQS:	Adaptive Quotation System
RFQ:	Request For a Quote
DSS:	Decision Support System
NN:	Neural Network
FLC:	Fuzzy Logic Control
ERP:	Enterprise Resource Planning system
DNC:	Direct Numerical Control
IBM:	Internet-Based Manufacturing
VM:	Virtual Manufacturing
WIW:	Web-based Individual Workshop
HMI:	Human Machine Interface
ONC:	Open Network Controller
SCADA:	Supervisory Control And Data Acquisition
NC:	Numerical Control
SESAME:	Simultaneous Engineering System
IMS:	Intelligent Manufacturing Systems
MDICM:	Model-Driven Intelligent Control of Manufacturing
NIST:	ISO TC184/SC4 develops International Industrial Data Standards
DCOM:	Distributed COM
CORBA:	Common Object Request Broker Architecture
SQL:	Structured Query Language
RDBMS:	Relational DataBase Management System
ABC:	Activity-Based Costing
RPM:	Revolutions Per Minute
SFM:	Surface Feet per Minute
DIS:	Draft International Standard
MES:	Manufacturing Execution System
EDM:	Electric Discharge Manufacturing
SGML:	Standard Generalized Markup Language
HTML:	HyperText Markup Language
W3C:	World Wide Web Consortium
XSL:	XML Stylesheet Layout

DTD:	Document Type Definition
OSEB:	Object Serialization Early Binding
CEB:	Containment Early Binding
GUI:	Graphic User Interface
MIS:	Management Information System
WBQ:	Web-Based Quotation
AML:	Advanced Manufacturing Laboratory
MFs:	Member Functions
IIS:	Internet Information Service
DFD:	Data Flow Diagram
COM:	Component Object Model Technologies
API:	Application Programming Interface
ODBC:	Open DataBase Connectivity
DB:	Database
DOM:	Document Object Model
TCP/IP:	Transmission Control Protocol/Internet Protocol
ANFIS:	Adaptive Neural-Fuzzy training of Sugeno-type FIS
FIS:	Fuzzy Inference Systems
EPPMR:	Enterprise Products & Process Models Repository
VASS:	Value Analysis Support System
PCMSS:	Product Cost Modeling Support System
PPSS:	Product Pricing Support System
CMT:	Cut-Make-Trim
STIX:	STEP Index
ASP:	Active Server Pages
MATLAB:	Mathworks product (www. Matworks.com)
CIMPLICITY:	GE Fanuc's CIMPLICITY, CIMPLICITY provides superior HMI and SCADA functionality and establishes a solid foundation for Collaborative Internet Manufacturing.
EXPRESS:	EXPRESS is a language directed towards the conceptual modeling of domains within the field of Product Data.
ISO TC184/SC4:	ISO TC184/SC4 develops International Industrial Data Standards
ST-XML:	ST-Developer (a product of STEP Tools Co.)

Chapter One: Introduction

1.1 Background

The manufacturing industry has faced many challenges in the past ten years. Such challenges include greater sophistication in manufacturing operations; improved global environment; enhancement of the discipline of manufacturing; and provision of opportunities for organizations of all sizes to respond to the globalization of manufacturing, facilitating the process of standardization [36]. Currently, internet-based computing and global competitiveness have revolutionized the way businesses and customers interact [15, 71]. Increasing global competition is challenging manufacturing industries to bring competitively priced, well-designed and well-manufactured products into the marketplace as quickly as possible. Manufacturing companies are responding to these changes and challenges in their industry by extending current internet trends to create virtual marketplaces where factories, suppliers and customers are part of the solution [65]. The vision of a completely integrated environment is not new; however, the technologies needed to accomplish these business-to-business and business-to customers' solutions are very complex [40].

To simplify this technology problem, innovation and integration must play an important role. When used collectively, feature based design, feature recognition and similar technologies evolving in Computer Aided Manufacturing (CAM) systems are within sight of a new version of streamlined manufacturing, called "Push-button CAM" [3, 64, 80]. The STandard for the Exchange of Product-Numerical Control (STEP NC, ISO 14649) is emerging to provide the required information for Numerical Control (NC) programming [18, 19]. eXtensible Markup Language (XML), a kind of web language, is used for transforming data via the Internet [46]. XML ensures that a Computerized Numerical Control (CNC) machine networked to the Internet will be able to find the information it needs from the product model database to machine a part [2].

STEP-NC (STEP application interpreted model for NC, *ISO 14649*) is one-step further than STEP in numerical control. The data needed for manufacturing a part consists of three significant parts, namely *work plan and executables*, *technology description*, and *geometry description*. STEP-NC is designed to standardise all these parts, and, importantly, all information is based on part features (which is defined by *ISO 10303 AP 224*) [82, 88]. The fundamental principle of the new Data Model is programming in terms of manufacturing features (hole, pocket...), instead of direct coding of sequences of axis motions and tool functions (which is defined by *ISO 6983*). The combination of manufacturing features and technological information is referred to as a "working step". Working steps represent the essential building blocks of the machining process. Each working step describes a single manufacturing operation using one tool and one strategy. An example of such a working step

would be the roughing of a pocket or the finishing operation of a region of a freeform surface [19].

STEP-NC allows a complete database of machining information to be built around the digital product model and ultimately makes it possible for this enhanced product model to serve as a machine tool input. And because the product model won't change, it will be available for machining "hard copies" whenever, wherever needed [19].

These new technological advancements have made Web-Based Manufacturing (WBM) a reality [71, 89]. Consequently, it has forced the Adaptive Quotation System (AQS) to be in place for WBM purposes. The ability to deal with a Request For a Quote (RFQ) electronically with an accompanying digital model is one of the basic functions of WBM. By taking advantage of these existing new technologies, cost estimation can be generated using a simple click of the mouse. RFQ can be fulfilled more expeditiously [93].

To achieve such an automatic quotation demands an integration of current technologies. The research problem consists of using CNC toolpath software, together with AI and data that has been generated in-house to take the Computer Aided Design (CAD) model and provide an estimated machining time automatically [52, 59, 96]. Generally, at present, human interaction is always necessary in the preparation of toolpaths using software because the choice of appropriate tooling, cutting speeds, cross-over and other features requires human operator experience.

A quotation is defined as the highest bid or lowest asking price available at any given time. Basically, a quote integrates cost calculation/estimation and profit markup. With regard to cost estimation, there are three main semi-automatic approaches, namely standards-based, engineering-based, and the intelligent simulation-based approach. Standards-based estimating programs use a table with standard times assigned to similar operations. Engineering-based are systems that rely on libraries of machine speeds and feeds for calculation. Intelligent simulation-based methods attempt to determine how long each operation will take as opposed to how long it should take, and as a consequence provide more accurate data for calculations [93].

For a standards-based estimation system, the accuracy is dependant on how much reliable data is input. The process knowledge has an important role in the intelligent simulation-based approach, and it adds a level of complexity that should be expected in an improved estimating system. The engineering-based approach relies more on experience because *speeds and feeds data differ for every material, every tool, and every machine type*, which make this approach relatively accurate and maintains certain flexibility. For this reason, the engineering-based approach is used by some dominant cost-estimation systems.

The approaches mentioned above are concerned more with direct cost of the product. To get an accurate figure for the pricing/quotation, an indirect cost/overhead allocation has to be established. After finishing the cost calculation, there is the problem of integrating it with a proper accounting costing system. As we know, there are two basic costing systems, namely, the job-order system and the process cost system. Through a proper costing system, the related indirect cost can be associated with the specific product.

To compose a quotation, many factors have to be considered. For example, competition, customer relations and the marketing influence have to be considered to determine a profit margin. That is, quotations comprise construction and non-construction factors. The construction factors include: demand, price limitation, and quality requirements. The non-construction factors include competitors' information, profit margin, engineering risk and other intangibles [98]. One of the tasks of an AQS is to eliminate those uncertainties, which originate from the non-construction factors, through continual data accumulation and self-learning progress in a WBM environment, and, this is generally considered mainly from profit margin expectation issues.

There exist many similar estimation systems, such as WeBid, eMachineShop, and Microestor etc. For quotations, there is a web-based framework called WeBid that endeavours to involve the supplier and customer together through a prototype web-based platform on the Internet/intranet using web technology. WeBid is a partnership broker for the two types of user [19, 44]. But this approach is not suitable for solving Web Based Manufacturing (WBM) problems, which requires in-time feedback and execution of the process as simply as possible. Mostly these systems are more focused either on cost estimation or the web, but are not manufacturing related. As this research is specially focused on WBM, it will target cost estimation/quotation that fully considers web-based requirements.

This research problem consists of using CAD/CAM/CNC software, together with Artificial Intelligent (AI) and data that has been generated in-house to take the CAD model and provide an estimated machining time automatically, and then a quote, via the web (ie. a web-based AQS). This is a very complex procedure.

The AQS is a suitable support tool for complex systems such as the WBM environment. It is a popular topic for research in this field. Through this research, it is expected that:

1. the outcomes would contribute to WBM problem investigation and architecture design
2. the agile ability of WBM is expected to make some improvement through the Decision Support System (DSS) implementation, which includes,
 - i. Flexibility. The ability to respond to product changeovers rapidly, and to mixed production of different products

- ii. Responsiveness. The ability to respond to customer "what-ifs" about the impact of various funding profiles and delivery schedule with improved accuracy (credibility) and timeliness
- iii. Customer relations. Improved relations through the increased participation of the customer in the quotation process, lower costs, better schedule performance, and greater responsiveness.

1.2 Thesis Scope and Problem Statement

1.2.1 Research Objective

The objective of this project is to design a manufacturing quotation system that can generate a quotation (and estimated delivery time) for part/parts to be manufactured using CNC equipment, after the potential customer has submitted a suitable CAD model via the Internet. The quotation will be generated automatically, and displayed by the system for on-line viewing. In addition, if the customer then wants to place the order, he should be able to do so via the same on-line system. The system should then log the order and the accompanying customer order number.

For the quotation process analysis, there are two fundamental processes, namely, cost estimation and profit margin expectation. Cost estimation cannot be achieved without thorough investigation of manufacturing related technologies, particularly CAD/CAM technologies which now has been combined in the STEP-NC technology, and is playing an important role in part manufacturing [37, 70]. Apart from the STEP-NC technology, another two main research fields associated with the project and are themselves related, namely, WBM and Decision Support Systems (DSS). The adaptive quotation system is one of the integrated /cross-fields of study. The relationship is shown in figure 1-1 below.

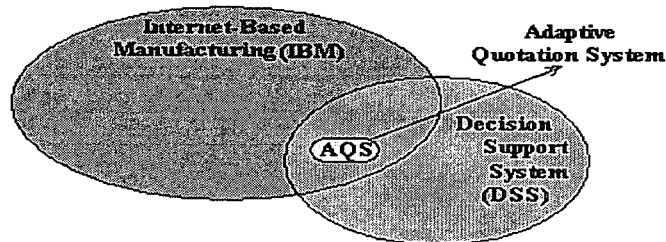


FIGURE 1-1: THE FIELD OF STUDY

Web-Based Manufacturing is the industries' response to technological changes. Adopting WBM successfully requires integration of everything from internal business systems to process level control systems. Issues associated with this endeavor require handling "networking" issues, "integration" issues and "managing" issues [40].

A Decision Support System is a computer program application that analyses data and presents it so that users can make decisions (or decision support) more easily. A DSS may include an expert system or artificial intelligence. Applications can be found in the many sectors like Health and Public Administration [38, 56]. DSS techniques will contribute to quotation processing adaptability.

Quotation problems become more complex when carried out via the Internet. In such an environment, adaptive/flexibility is equally as important as accuracy. To design a suitable AQS for WBM purposes, system integration that takes advantage of current developed technologies is necessary, thus providing a “cost-efficient” solution [57].

1.2.2 System Structuring

As mentioned before, the core of an AQS system is cost estimation and profit margin expectation, so the main parts of the AQS system are the cost estimation subsystem and profit margin expectation subsystem. The methodologies used are given in Table1-1 below.

Problems Investigation	Variables Identification: Search and find the variables that are related with production quotation.
	Data Collection: Find correct representation/valuation methods
Algorithm for Problem Representation	Data Classification: Analyze and sort data into related database.
	Input and Output Selection: Analyze the needed input and choose the desired output.
	Algorithm Design (Based on AI): Design a suitable AI/Neutral Network model and train it with input-output data.
Evaluation of Quotation System	Analyse the model’s validation: Add self-learning mechanism and analyse system’s validation
	Robust/Sensitivity Analysis.

TABLE1-1: AQS METHODOLOGIES

One sub-problem of this research is how the related input information is represented and interpreted. Currently, there are various kinds of CAD/CAM packages, which have caused confusion when interpreting the drawings information. With the recent CAx technologies advancement, STEP-NC seems to give a solution to this problem, and is designed to produce a standard for integrating CAD, CAM, and CNC.

Once the input information problems have been solved, the design/implementation of the AQS will be tackled, which includes,

- i. identifying the best architecture;
- ii. identifying the best type of training;
- iii. system testing and evaluation.

To process and translate digital part information into useable information, special programs need to be prepared. As *MATLAB* grants access to powerful *Toolboxes* for AI (Fuzzy Logic and Neural Network Toolbox), this package will be used as the main platform for the development.

In practice, the data collection problem can be the dominant problem if there is no suitable management information system in place. This issue is further discussed in the section dealing with data problems (Chapter 4).

Another sub-problem includes the Internet interface development, which will allow a user to load an appropriate CAD model for processing and display a system-generated quotation, as well as have capacity to accept an order, process it and allow on-line progress tracking. This is an integration related issue. The AI function acts as “glue” in this integration. A Neural Network (NN) mechanism investigation will be conducted, which includes learning mechanisms and result validation analysis.

The architecture design, for networking and database management, is another hurdle in this project. The basic function for the proposed AQS is quotation processing, based on the Web. The core of such quotation is automation. An automatic quotation function can offer customers a higher degree of satisfaction. The architecture design is important to achieve this, because it sets up a basic integrating platform. A three-tier architecture is proposed, with a Web browser acting as the ‘thin’ client, and a Web server acting as the application server. The three-tier architecture can also be extended to n-tiers, with additional tiers added to provide more flexibility and scalability [74]. The draft architecture is as follows:

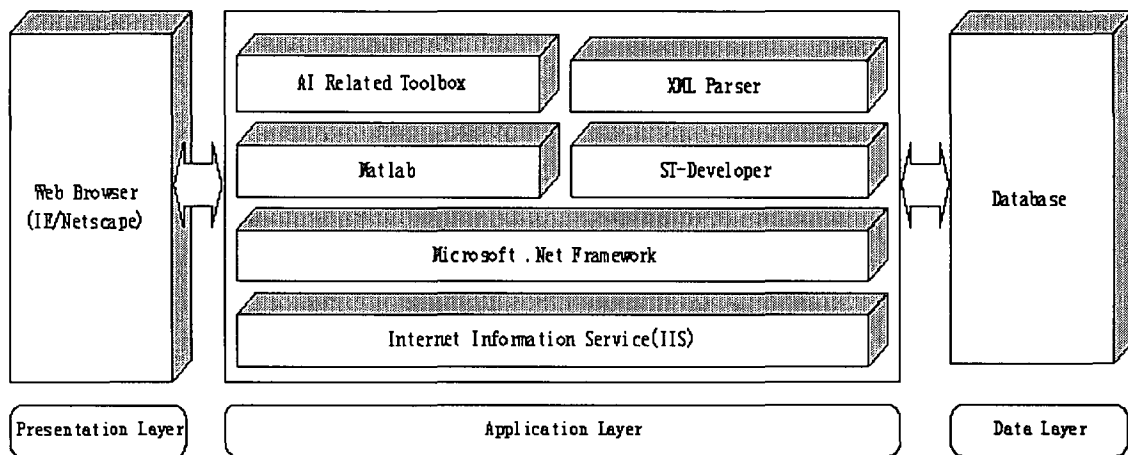


FIGURE 1-2: PROPOSED AQS ARCHITECTURE

Further, a dataset, which is used for training, validating and testing, will be prepared. The data will be prepared in two ways:

1. In the design stage, the data is generated by cost-estimation software, such as *emachineshop*, a micro-cost estimation system
2. For the final test, data needs to be collected from industry.

A comparison of the system-generated results with actual industry quota will be conducted. A thorough investigation and analysis of the dataset and system will also be carried out.

1.3 Thesis Organization

This thesis is based on an investigation-theory-implementation structure. In Chapter 2, firstly, a brief overview of research related topics is given. Feature recognition methodologies are addressed. A discussion about the cost estimation system and its application related to feature-based design is presented. Secondly, STEP and STEP-NC as an emerging technology is outlined, and also the development tools and automation in manufacturing fields are addressed.

As this is a cross-fields study, good background knowledge plays an important role for system construction. A brief outline of the related key knowledge/technologies will be presented, which includes discussion on cost estimation, STEP-NC, and profit makeup that is “funded” by artificial intelligence.

After that, a conceptual design and programming section follows (see Chapter 3). In this chapter, the detail-approach method is discussed and addressed, which covers all three technical issues. An overview of the proposed AQS system is presented at the end of this section. Based on this, the system programming is detailed, which includes the programming language, the architecture and structure, the database of the link module and the main functions of the program.

The evaluation of the designed system is described in Chapter 4, which is called *System Implementation*. Reference is made to the problem of implementation in the actual industrial environment in South Africa, and the final methodology to put the AQS concept into practice, viz. in a South African garment company. The problems which occur in a similar system (enterprise resource planning system/costing system) have provided some feedbacks for this project, which is reflected in some parts of the system design, such as costing system. By testing the design/system concept in real world implementation, this system becomes more flexible and practicable, and thus more valuable.

Finally, a conclusion is provided and future work relating to the link module is proposed. Additionally, the appendices contain a summary of the AQS system, the detail of system programming and its database structure. For evaluation purposes, a CD, which records the application of the AQS system and all it related documents, is included.

Chapter Two: Literature Review

One response to the continual push to become more competitive is the concept of Web-Based Manufacturing (WBM), in which the whole world becomes a factory, with the Internet acting as a global Direct Numerical Control (DNC) system [3]. Streamlined manufacturing, called "Push-button CAM", is within sight along with feature based designing and feature recognition development [2, 3]. STEP-NC (*ISO 14649*) is designed to cover manufacturing tasks (so-called "features"), and provide a data interface for NC programming [18, 19, 20]. This has made DNC a reality.

The eXtensible Markup Language (XML), a form of web language, has a great impact on WBM. XML provides a convenient means to link manufacturing strategy, tool-pathing, and tool selection information to geometry features and machining steps in the database. This is achieved by sorting data with the appropriate tags. Ultimately, XML ensures that a CNC machine networked to the Internet will be able to find the information it needs from the product model database to machine the part [3].

A sound understanding of the concept of cost estimation and the related trends in this research stream, as well as the associated knowledge and technologies is very important to implement the AQS concepts, and the design approaches. For example, STEP is used to provide a complete, consistent, and reusable manufacturing dataset to cover the entire product life-cycle, without losing data or additional expenditure for adaptation or conversion of data [19, 20]. This will change some of current manufacturing procedures and also create opportunity to improve manufacturing services, and cost-estimation will shift from estimation by experience to a more 'production information deduction' method.

In this chapter, a general background is presented. Firstly, an overall picture of research in this field is provided. Thereafter, an overview of the key knowledge/technologies for developing the AQS, namely, STEP/STEP-NC, cost estimation, and profit margin expectation will be addressed. Finally, a general review of cost estimation/quotation is provided, and an outline for the whole AQS, which includes the process flow and the interfacing, will be presented, which will serve as a summary for this chapter.

2.1 General Background

Major market trends and demographic realities are placing critical pressures on the existing manufacturing infrastructure [5, 30]. The Internet and related technologies offer significant new capabilities that will allow manufacturers to respond to these pressures. These capabilities are poised to create a new era of Internet based manufacturing, where manufacturing enterprises will not just communicate over the Internet, but exist over the Internet [14, 35]. Aligned with Internet technology, web-based manufacturing is coming to

the market place to enable the company to gain a competitive advantage for survival. There are at least two levels of understanding/concepts of web-based manufacturing. One is at a broad level, normally called Internet-Based Manufacturing (IBM) \ Virtual Manufacturing enterprises (VM). The other is at a low level, called Web-based Individual Workshop (WIW). This small complete unit does business via the Internet.

The concept of virtual manufacturing enterprises is made up of market entities that band together for the sake of a specific market opportunity without surrendering their legal identities [91]. Internet-based virtual manufacturing is about more than allowing manufacturing enterprises to talk to each other over the Internet. When manufacturing systems are connected to each other over the Internet to form a virtual enterprise, they need to form a cohesive unit, which is greater than its parts.

In the early stage of VM, the Virtual Manufacturing Technical Workshop, which was hosted by National Security Industrial Association on October 1994, provided a fundamental roadmap for VM. It analyses the related technology areas, and provides a technical roadmap for VM [91].

During the Dayton VM workshop, an architecture for VM was developed (see figure 2-1). It emphasized the need for government's support and regulation. For the VM architecture area, the government should support the development of a generic architecture which, if done properly, could facilitate manufacturing models and representation approaches. For the representation technical area, the government should play an important role as a catalyst, a neutral broker, and a potential clearinghouse for pre-competitive technologies and specifications. For the manufacturing characterization area, the government should develop standards for the generic models and the collection of shop floor data.

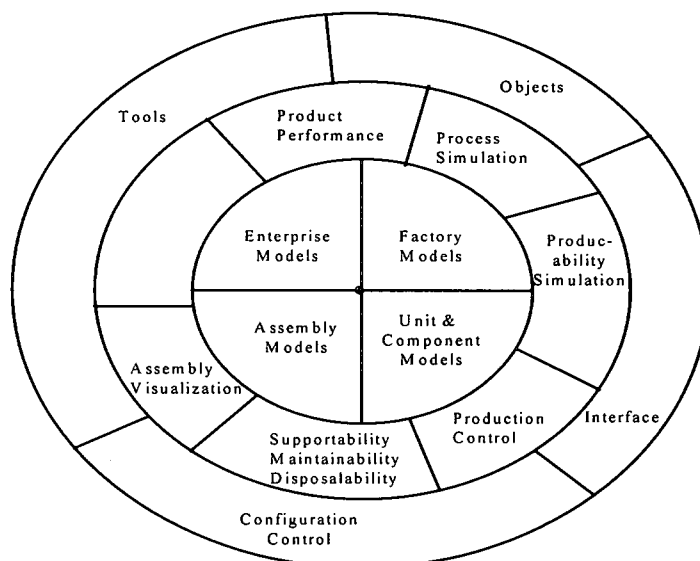


FIGURE 2-1: VM ARCHITECTURE

Most electronic commerce research is concerned with the non-trivial task of connecting corporations to each other. Common research issues include discovering trading partners, negotiating terms and conditions, establishing secure communications, agreeing on common product and process representations, and similar issues. Once the trading partners have settled the formation issues as a prerequisite to becoming trading partners, a corporation can then use Internet technologies as an effective resource while addressing the pressing manufacturing issues of distribution, agility and customization. These issues are discussed in more detail below [99].

Distribution. Manufacturing is inherently distributed, yet existing manufacturing information systems are artificially centralized on larger and larger server computers. Current trends are for manufacturing to become even more decentralized. The pressure is on manufacturers to manage this distributed manufacturing complex better and to provide better customer service and more cost effective utilization of the involved resources. The Internet provides a natural platform for managing the distributed manufacturing complex.

Agility. Business opportunities are rising and falling at a faster and faster rate. The manufacturing complex has to respond better to these changes and will continue to face significant pressure to reconfigure itself quickly when presented with unexpected changes [24]. Software agents implemented over local and wide area networks offer such essential agility features.

Customization. Consumers are demanding higher and higher levels of customized products. The long-term trend is towards mass customization, where every consumer is given the exact product they want [16]. This puts significant pressure on the existing mass production facilities to become substantially more flexible. Software agents can address this problem through the agile configuration of production resources over the Internet for each product produced.

Establishing relationships to form a virtual manufacturing enterprise is similar to establishing relationships to form any other virtual enterprise. However, the operation of the virtual manufacturing enterprise requires the manipulation of matter as well as information, and raises issues that do not appear in many other domains [99]. Normally, an agent technology will be used.

Mostly, the major agent species are composed of resource brokers, part brokers, and unit process brokers. Resource broker agents manage the capacity constrained resources of the system (e.g. people, machines, facilities). Part broker agents manage material handling and inventory. Unit process broker agents utilize their knowledge of how to combine resources and parts to make other parts. These three types of agents negotiate among themselves and with the customer to achieve the best possible price while taking into consideration uncertain factors like price, quality, delivery time and product features.

This architecture is distributed; the agents tie together resources, parts and process knowledge in a single location, in multiple locations, or in multiple corporations. This architecture is agile, as the agents agily configure themselves to each new order placed in the system. This architecture supports mass customization as any capability needed for a custom product can be dynamically added into the supply chain.

The emergence of globalization also contributes some aspects in VM research. An example is DHL's (DHL is the world's largest international air express network) global tracing system, The market already has some responses to this trend and there is some software and hardware available to meet the demands, such as GE Fanuc's CIMPLICITY Human Machine Interface (HMI) series and Omron's Open Network Controller (ONC). These technologies will enable VM researchers to obtain a broad and practicable view for developing VM and inherit some innovation ideas as well.

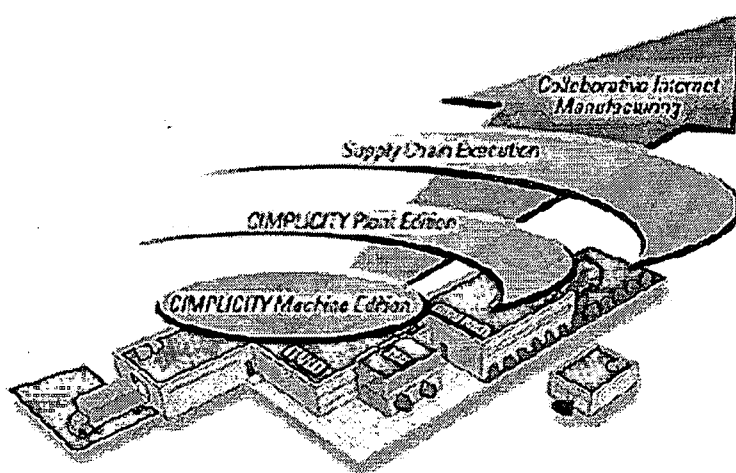


FIGURE 2-2: GE FANUC'S CIMPLICITY

The CIMPLICITY Plant Edition provides superior HMI and Supervisory Control And Data Acquisition (SCADA) functionality and establishes a solid foundation for Collaborative Internet Manufacturing. True client/server architecture and open-system design offer fast, easy integration with the ability to grow from a single computer node to a plant-wide monitoring and control system providing real-time information from the factory floor to all levels of the enterprise, and real-time access to the important indices to operate business. The interactive set of software business tools provides real-time collaboration between customers, manufacturers and suppliers [34].

It is expected that the manufacturing complex will move towards becoming a network of flexibly interconnected manufacturing capabilities. Thus, the Internet and related

technologies can substantially reduce the economies of scale and scope that have in the past consolidated manufacturing into large mega-corporations. The implications are significant:

- Manufacturing could return to being a cottage industry. An individual can plug his capabilities into the manufacturing network and participate just as well as an owner of multiple manufacturing capabilities.
- The manufacturing complex will be more dynamic and better utilized, resulting in better service, and lower costs.
- Because there will be a dynamic spot market for any type of manufacturing capability, outsourced manufacturing will increase. This outsourcing could increase to the point that today's manufacturers become merely Internet portal sites for the products in which they specialize. All real manufacturing would be dynamically outsourced over the Internet.
- Manufacturing planning, operation, and scheduling can be seamlessly integrated.
- Modular simulation technologies integrated with the actual systems operating the factory will allow better decision support. The addition of resources, potential disasters or unexpected growth will be better understood and planned for.
- Whole new factories can be created by merely plugging together a group of manufacturing resources having appropriate agent protocols.
- Machinery vendors can first provide an agent and its simulated machine for the manufacturer to test out the features of that machine in a realistic but simulated factory before purchase.

Under the direction of Dayton VM workshop's map, a great deal of work has been done in this field, such as manufacturability analysis [31, 73], CAD model translators, automatic tool selection and Web quota systems [42, 96]

After ten years of development, VM is not as vague as before, and is ready to be implemented. In the meantime, there also exists a lower level concept of Web-based Manufacturing, which treats WBM as an Internet/Web based Individual Workshop (WIW). WIW communicates with customers and conducts business via the Internet, while the delivery of finished goods may be via a third party company. It is a standalone unit in the Internet world, but is seldom regarded as a topic in the VM field.

From the market's view, a WIW should meet up such requirements/characteristics. The WIW should be very flexible. It should supply quality products to the customer on time. It should take advantage of the Web and AI technology to make the business process more open and fluent. WIW pushes some business activities to market to simplify the value chain. It demands high quality, productivity and reduced cost, but also the ability to react quickly, responsively and effectively to the market that is becoming more international, dynamic, demanding and customer-driven. To become agile, WIW has to distribute intelligence and

decision-making ability as close to the points of delivery, sale and even after-sale service as possible.

The simplest function of a WIW allows the customer to send (digital) production drawings to a WIW via the web, and then automatically generates the CNC program, reports to the customer, and based on the communication, gives a quotation and directs the production. To survive in such an environment, fast and flexible quotations are necessary. This is the field that this project targets.

From the global picture, it is obvious that Internet-based computing and global competitiveness have revolutionized the way businesses and customers interact. Manufacturing companies are responding to changes and challenges in their industry by extending current Internet trends to create virtual marketplaces where factories, suppliers, and customers are part of the solution. Aligned with Internet technology, web-based manufacturing is coming to the market place to enable a company to gain a competitive advantage for survival. The vision of a completely integrated environment is not new; however, the technologies needed to accomplish these business-to-business and business-to-customers solutions are very complex [40].

To simplify this complex technology, innovation and integration are playing an important role. These new technological advancements have made WBM (hereafter referred to as the lower level concept of VM) a reality. Consequently, there is pressure to have Adaptive Quotation Systems (AQS) in place for WBM purposes. The ability to deal with a Request For a Quotation (RFQ) electronically with an accompanying CAD model should be one of the basic functions of WBM. Taking advantage of current technologies, cost estimation can be generated using a simple click of the mouse and less guesswork; thus RFQ can be fulfilled more expeditiously [55].

For web-based quotations, there is a web-based framework called WeBid that tries to involve the supplier and customer together through a prototype web-based platform on the Internet/intranet using the web technology. WeBid is a partnership broker for the two types of user. But this approach is not suitable for solving the WBM problem, which requires in-time feedback and executes the process as simply as possible.

If Internet technology provides a platform for AQS to develop, then the technology of STEP-NC can make AQS happen, because it is oriented towards feature recognition development.

2.1.1 Features and Feature Based Modelling

It is difficult to give a definition of a 'feature'. Most researchers fail in their attempt to define the concept. They avoid being too specific, thus missing various kinds of features. Generally speaking, a feature is any perceived geometric or functional element or property of an object

useful in understanding the function, behavior or performance of that object [63]. There are different types of definitions.

Based on the general functions of the feature, a feature can be regarded as a unit that has a semantic meaning in design, process planning, manufacture, cost estimation or other engineering disciplines [94]. The designer can specify features in engineering terms such as holes, slots, or bosses, rather than in geometric terms such as circles or boxes. Features thus raise the level of abstraction at which the designer may work. Cost analysis for machining is especially suited to this approach, because geometrical features correspond in a direct fashion to the possible machining operations. Holes are related to drilling, slots are related to milling, etc. [10]. Features can store non-graphic information as well. They allow the user to "tag" relevant data in the CAD database. This information can later be used in activities such as NC machine code generation, finite-element analysis, kinematics analysis, process planning, tolerance analysis and cost estimation [83].

More abstract than Wierda, [94], the feature as defined by Bernard and Brissaud [8] is an element of a part based on a geometrical shape to which technological and topological attributes including quality attributes have been attached. Although these two definitions of features give the general engineering meaning of a feature, different CAD applications use different components of such general definitions and the definition of a feature still needs to be more specific in different applications.

According to Gibson et al. [29], the word "feature" is used at different times for three related but distinct concepts, such as in the feature description language EXPRESS (a language directed towards the conceptual modeling of domains within the field of Product Data):

- A feature class is a set of feature instances
- A feature description is the set of criteria whereby a candidate is tested for membership of a feature class, articulated in terms of the components of the candidate and their relationships.
- A feature instance is a structured collection of sub-feature instances, where those sub-features already satisfy criteria and relationships.

Such definitions can be used in feature recognition to find user-defined features within a database of objects of a user-defined structure. It is, however, still too general a definition to be used in practice.

Pedley and Ehrmann [69] classify features as application dependent. They applied these concepts to develop the Simultaneous Engineering System (SESAME), which provides feature-based design, process planning and NC part programming of components typically manufactured in machining centers. Such definitions only address complete geometric data for SESAME. They indicate that the feature is application dependent. Stevens [85] gives the different definitions based on different viewpoints, and it is clear that the feature has different meanings relating to the field in which the feature is applied.

The definition of a feature forms the base of feature-based design systems, which can be classified into two categories: feature recognition and feature-based modeling.

The intent of feature recognition is to extract information representing a higher conceptual layer than geometry from a set of geometrical information. These are sets of functional meaning within one of the phases involved in the production process [33, 58].

The intent of the feature-based modeling approach is to provide the designer with a set of functional primitives (design features) to be aggregated and modified to build up a complete representation of that design object. Feature-based modeling usually refers to the construction of geometry as a combination of form features. The basic entity in a feature model is a feature; defined as a representation of shape aspects of a product that can be mapped to a generic shape and that are functionally significant for some product life-cycle phase [63].

Boothroyd et al. [12] favored a design-with-features approach to determine the costs as the part geometry is built up in the CAD system. However, this may require the availability of a number of process-specific feature-based CAD modules so that the design of a part is achieved through the features, which relate directly to the manufacturing cost contributions for the specific process. On the one hand, the selection of the manufacturing methods is derived from explicit feature information, such as geometry, tolerance and material, and on the other hand, it is derived from workshop information, such as the available machines and tools.

Gupta and Nau [31] provided a method for analyzing a proposed product design to estimate the manufacturability aspects. By using features that correspond directly with machining operations, it can give the designers feedback on their manufacturing problems. This provides an opportunity to improve the manufacturability characteristics of the product by redesign.

Brett et al. [13] describe an industry example using feature-based design techniques to specify the relations between different types of holes in one part. By encapsulating access to the individual holes at the level of the radial feature, the designer can alter the number of holes and change the radius of the radial feature to prevent the designer from making inappropriate changes. It extends the capabilities for the user to model relationships between objects, but does not involve determining the feature.

Leibl et al. [51] developed a feature-based CAD information system. It contains a cost calculation module, a comparison module and a forecast module. According to the degree of detail in the drawings, it uses different modules to determine product cost. By coupling the cost information with the geometry, the designer can obtain cost information during the design process. However, a disadvantage is that the designer must have and use extra data sources that contain features that are manually defined by the user, instead of getting the information directly.

These examples give the main idea of feature-based modeling, and show its value for part cost estimation.

2.1.2 Feature Recognition

The success the solid modeling markets have seen with CAD products, apart from the steep price decline in the past few years, is obvious: even someone in accounting can look at the image and recognize the part. They do not need an engineering background to do this. Also, from that solid, it is possible to generate G-code, since you can recognize all of the features: the holes, flat surfaces, radii, and so forth. As a result, most CAM systems now either integrate with a solids package, or have their own, internal solids drawing capability.

Feature recognition now promises to take part design in a new direction. Solids packages enable feature recognition by other software [28, 60, 81]. Clusters of software packages that use solids will revolve around a technical database. This supports a consistent method of programming and manufacturing. In order to perform cost estimation, the designer first needs to obtain the manufacturing features, such as the machining area of a product and the volume of a part, from the CAD model. This procedure may involve using feature recognition technology, which is directly related to the development of the link module.

Feature recognition has been a popular research topic in recent years, and it can be divided into three main categories: Feature-class approaches, form feature approaches and graph-based approaches [27]. In the context of this thesis, feature recognition converts a general CAD model into an application-specific feature model. Feature recognition systems should be able to [78]:

- i. extract the design information of a part drawn from a CAD database
- ii. identify surfaces of the part
- iii. recognize reason about and/or interpret these surfaces in terms of part features.

2.1.2.1 Automatic Feature Recognition and Estimating

An estimator, knowing a part was designed in a solids program, will click on a pull down menu and choose "recognize features." When the software recognizes a "shaft adapter," and the estimator selects the machining center to run the part, the software will suggest a center drill, drill, face milling operation, contour end milling operation, and a burnishing operation. The set of work instructions will be based on the features identified. The estimator will be able to drag and drop and rearrange any tool or process, based upon his knowledge of the facility. The point here is that this is a technology tool which requires experience to understand what can be achieved.

An advanced feature-based CAM system has been implemented by Honeywell. The system was developed under the sponsorship of the Department of Energy and is called FB Mach. Honeywell has enhanced this system under contract to the Super Model project. It can read STEP CAD data (AP 203 or AP 214) and write STEP-NC data. STEP Tools has negotiated a license to market FB Mach as a system called ST-CAM. STEP interpreters for GibbsCAM and MasterCAM have recently been developed and were demonstrated in early 2003. Unigraphics, CATIA and Pro/Engineer CAD systems capable of understanding manufacturing features and interfaces to STEP-NC are expected to be included in future versions of these systems [2, 3].

In order to validate this interface, the European project STEP-NC has been launched. Implementation of the existing data interface for milling will be undertaken as well as extensive tests by end-users. For further exploitation of the results, an inter-regional collaboration with Europe, Switzerland and Korea with the scope of Intelligent Manufacturing Systems (IMS) also has been planned.

2.1.3 STEP and STEP-NC

STEP (STandard for the Exchange of Product model data, ISO 10303) is an international family of standards designed to enable the exchange of product data between heterogeneous computer systems used throughout the product life cycle [18]. The main point of the STEP is to provide a complete, consistent, and reusable manufacturing dataset to cover the entire product life-cycle, without losing data or additional expenditure for adaptation or conversion of data [19].

The parts of STEP that are implemented in software systems are called Application Protocols (APs). The first STEP AP became an ISO standard in 1994 and subsequently most major CAD vendors have implemented STEP data translation. It is estimated that more than one million CAD stations now contain STEP data translators [3].

A new AP within this family, ISO 10303-238 *Application interpreted model for computerized numerical controllers* (AP238) [14], henceforth referred to as "STEP-NC," defines a data exchange standard for computerized numerical control machining (milling, turning, and electric discharge machining). STEP-NC is being standardized within ISO TC 184/SC4 (ISO TC184/SC4 develops International Industrial Data Standards) as ISO 10303-238. STEP-NC will provide full product and process data interoperability between Computer-Aided Manufacturing systems and machine tool controllers. STEP-NC is being developed under the Model-Driven Intelligent Control of Manufacturing (MDICM) project, a three-year Advanced Technology Program (ATP) project awarded to STEP Tools, Inc. by the National Institute of Standards and Technology (NIST) [90].

Numerous prototypes and several commercial implementations of STEP-NC are currently being developed [21, 22]. Testing is an essential step toward ensuring conformance to a

specification and achieving interoperability between different implementations. Test methods and valid test cases that address specific operational scenarios are vital to speed the development and implementation process. A project within the Manufacturing Engineering Laboratory at ISO TC184/SC4 develops International Industrial Data Standards (NIST) and is focusing on testing the emerging STEP-NC specification.

The STEP data translation capabilities implemented in CAD systems today primarily support geometric models and configuration management as specified in ISO 10303-203 *Configuration-controlled 3D designs of mechanical parts and assemblies* (AP 203) [8] and ISO 10303-214 *Core data for automotive mechanical design processes* (AP 214) [6]. STEP-NC extends STEP into the manufacturing domain by adding data structures that support CAM and CNC requirements.

The STEP architecture facilitates sharing of common data structures between STEP APs. For instance, a CAD system may output STEP geometry, design features and product identification data in the AP 214 format. Manufacturing features may be defined in ISO 10303-224 *Mechanical product definition for process planning using machining features* (AP224) format [6]. A CAM system may then input that data and use it to develop the detailed process data needed to manufacture the part. The CAM system does not need to redefine the geometry and features because these data structures are shared between APs. The CAM system outputs geometry, features, process sequence, and tool requirement data in STEP-NC format. Because STEP-NC data is intended to be processed at run time, specific machine operations (e.g., cutter paths) are left to the machine controller. This offers some advantages over traditional methods:

- i. a STEP-NC file contains all the data required to produce a part, therefore, manufacturing operations may be adjusted to maximize production efficiency
- ii. STEP-NC allows for complete safety checking because safety areas for fixtures can be defined as part of the set-up
- iii. documentation may be easily generated by the CAM or CNC system to show the state of the part before and after each working step
- iv. STEP-NC is easy to generate; specific tool paths need not be defined in advance
- v. a STEP-NC file is not machine-specific; the STEP-NC file can be manufactured on any machine that meets the tooling requirements.

In the overall process, from start to part, STEP-NC provides the data interface between CAM systems and CNC machine tools. CAM systems output STEP-NC data while CNC systems read in STEP-NC data. At present, "data transfer" is accomplished using a physical file in ISO 10303-21 format; data sharing scenarios (i.e., a common database) may be used in the future [84]. Input and output activities must be tested separately.

CNC machining is a more automated process, although tool setting and machine setup (including part fixturing) are manual processes. Inputs are tooling specifications, setup specifications, and processing specifications (STEP-NC). The output of the CNC activity is the machined part.

To make STEP-NC becomes practicable in manufacturing, the concept of *feature*, and *feature recognition technologies* are playing an important role.

2.1.4 XML and STEP-XML

Over the last seven years, there has been an explosion of demand for access to enterprise databases over the Internet, to use them to support electronic business operations. These include transactions between systems within an enterprise ("enterprise integration"), between businesses in a supply chain ("B2B e-commerce") and directly to customers ("B2C e-commerce"). The initial reaction of most companies was to integrate these diverse operations by building or buying software such as "application servers" that employed protocols such as Distributed Component Object Model technologies (DCOM) or Common Object Request Broker Architecture (CORBA) to perform such integration. More recently, XML offers the option of performing the necessary integration by exchanging standardized data [7].

XML is the third generation of web technology. The Structured Query Language (SQL) standard defines a vendor-neutral way of finding and extracting data from a Relational DataBase Management System (RDBMS), so it is quite possible to write middleware applications that extract data from one database and put it in another. Nevertheless, these applications must be relatively complex and pay careful attention to the database schemas on each side in order to work properly. XML, on the other hand, is simply a standardized "meta-format" that can represent any kind of data, and for which precise schema definitions are optional.

Thus, XML has become widely used to integrate enterprises, supply chains, and Web applications because it is:

- i. **Standardized.** Many products from many vendors are available that implement something close to the World Wide Web Consortium Recommendation on XML
- ii. **Simple.** The technology is easy to learn and implement, with many tutorials and "how to" books available
- iii. **Self-describing.** Straightforward data exchange applications can be written without reference to detailed format descriptions or schemas.

STEP-XML is a product of STEP Tools Inc. STEP Tools Inc has played an important role in the STEP NC project. STEP Tools develops software solutions to leverage STEP and STEP-NC technology to enable global e-Manufacturing [72].

2.1.5 Cost Estimation Systems

During the past ten years, the value of computer aided estimating has grown as a manufacturing tool, as manufacturers and job shop owners realized the varied benefits this software brings. Published studies in trade magazines often discuss users' perceptions of direct benefits they've seen. Still, this is clear: among both prospective and existing users of estimating software, most do not understand how the software prepares an estimate, what makes a computer estimate accurate, or the different emphases played by the machine tool, the process, or the material in preparing the computer estimate [93].

Estimating software may range from products that simply replace a pencil and pad, to software called "standards-based," to systems that might go so far as to simulate the entire machining or fabricating process, because, unlike CAD/CAM software, there is no effort in the manufacturing industry to teach, or to learn, the underlying strategies that the different estimating software systems use to produce estimates [9].

MicCost Co has suggested a foundation for an industry-wide understanding of the computer-aided estimating process. In the quoting/estimating arena, today we find *quoting* programs and several classes of *estimating* software. Quoting programs quickly provide prices for quoting. Within the estimating classification, some software systems are standards-based, some are engineering-based, and some exhibit genuine intelligence. Today, some programs also are evolving from one form toward another, as even software developers begin to better understand the actual estimating process.

Pure quoting does not calculate time, while estimating bases its quote on calculated time. 'Standards-based' estimating programs use a table with standard times, which can be assigned to similar operations. Systems that rely on libraries of machine speeds and feeds are 'engineering-based.' Differentiating between the engineering-based and the "intelligent" packages is harder. Both systems come up with an answer for the portion(s) of the process that they compute [93].

Beside MicroEst, there are many other costing systems available, like emachineshop and featureCAM, to name a few [64, 87]. MicroEst's product is specific to process technology, and thus based on the manufacturing processes to give the product cost and its price. As for the concept of web-based quotations, only emachineshop has tried to play a role in the Web environment, but on the whole, it is too simple for the quotation process involved [55].

There is a product called Costimator OnLine® which offers the advantage of manufacturing job quoting and process planning with the flexibility of access via the Internet. It provides an

unparalleled combination of flexibility, manufacturing data access, speed, ease-of-use, estimating accuracy and affordability, all without having to maintain a PC or server-based system. The result is a cost estimating solution that provides customers with the tools they need to be able to provide RealCost™ management solutions for any manufacturing environments [39].

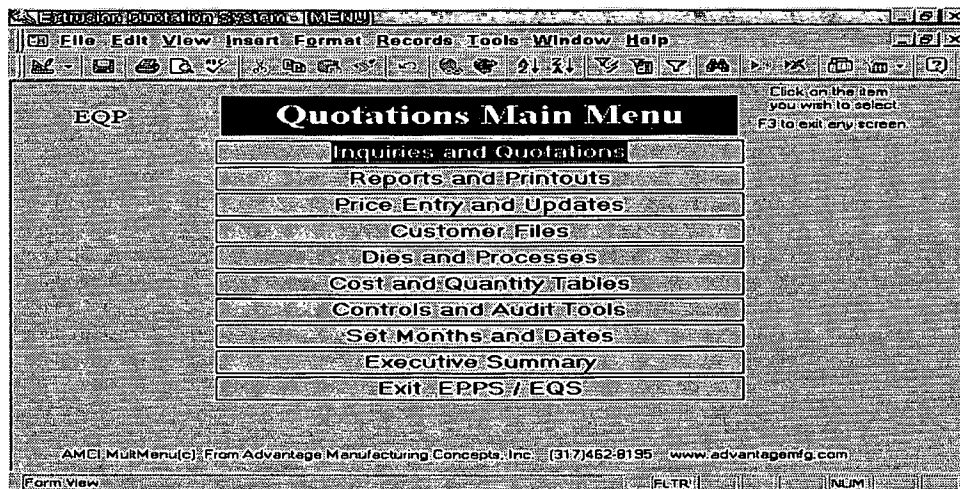


FIGURE 2-3: SOME MAIN FUNCTIONS OF COSTIMATOR ONLINE

This system requires a potential customer to supply hard copies drawings of the product, and in that regard is limited. The details required for a quotation on line are shown below:

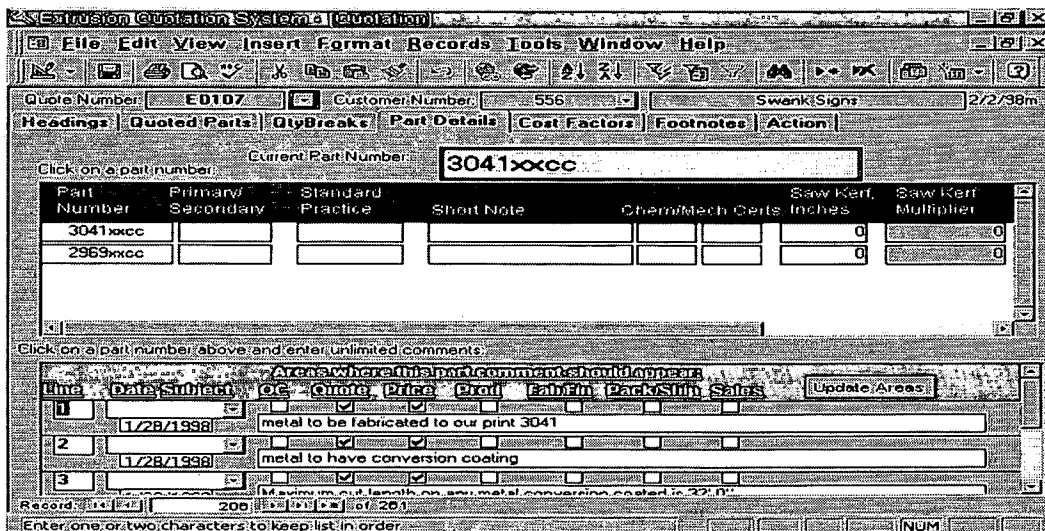


FIGURE 2-4: AN EXAMPLE OF THE INPUTS REQUIRED

For this project, it is believed that there should be integration between STEP and STEP NC, and AI technologies. The need for knowledge about cost estimation (cost management) is fundamental to the whole system.

2.1.6 Artificial Intelligence Applied to Quotation Systems

A group at the Dalian University of Technology (PR China) has reported on using neural network for manufacturing product quotation purposes. The method used to classify various influence factors into groups, and then to try to take advantage of the powerful mapping function of neural networks [98]. The results were very limited (see the following figure).

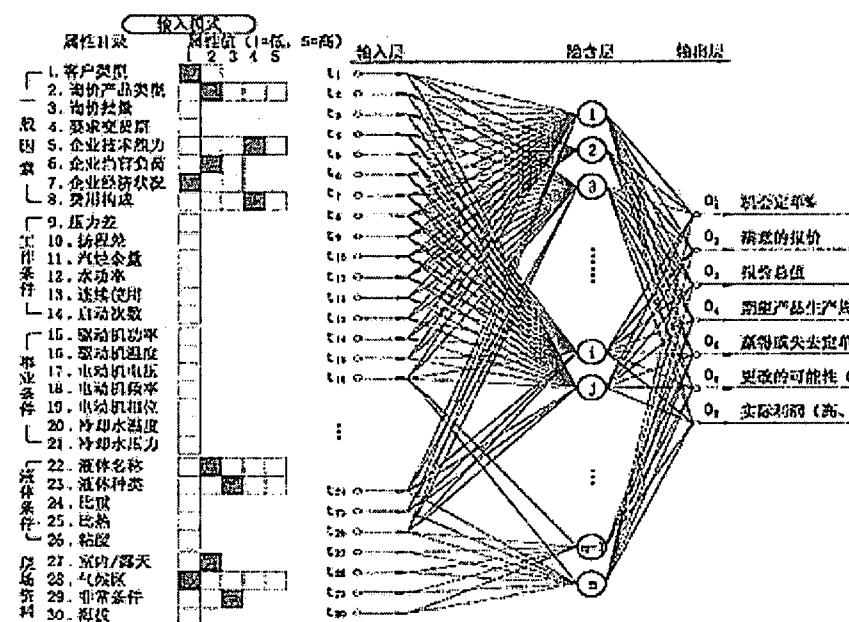


FIGURE 2-5: A REPORTED AI BASED COST QUOTATION SYSTEM [98]

From author point of view, this method is hard to implement and it is difficult to achieve the desired expectations. Firstly, it requires a lot of inputs, which make the system very complex. Secondly, without good pre-processing of the various data, it is difficult to expect that the system will self-tuning to achieve a satisfy result.

2.2 Related Technologies

In order to easily understand the design concept of this project, a detailed explanation of the related technologies will be given. The structure of the architecture is summarized in this section.

Considering current technological advancements, the related research work can be identified/classified as CAD, Process Technology, and Profit Expectation (mainly related to Artificial

Intelligence). CAD-feature recognition and the STEP-NC, Process Technology/STEP-XML, profit Expectation-Neural Network will be discussed/presented in detail in the paragraphs which follow.

2.2.1 Cost Estimation

Ideally, costs should be submitted/summed up from various sectors. Production estimates, labor costs and tool costs (if applicable); Purchasing estimates material and purchased-component costs; Engineering estimates engineering costs; and Accounting provides the overhead rates which should be applied. In practice this seldom works as planned in most companies [17].

Generally, the cost estimating function does not produce exact cost data, but rather supplies cost figures having a high probability of falling within an acceptable range. An estimated cost differs from the actual cost of an item in that all the factors affecting the cost cannot be fully evaluated. The most important factors are given primary attention, but many factors of lesser important must be left to influence the results in a random manner. Some factors cannot be predicted with certainty at all, such as delays caused by defective materials and machine breakdowns.

Cost estimating is important for a company. The key to producing new products and growing customers is to provide products that are competitive in price, perceived to be of good quality and delivered on time. A carefully prepared estimate is essential in deciding whether to submit a quote or manufacture a product. In the overall planning process, the estimating phase is where product costs, tooling costs, and lead-time are predicted.

Most current cost models acknowledge that pricing of products is independent of cost estimating and is handled by a pricing committee. The pricing committee is made up of the general management in a company, and they have knowledge of competitive conditions and pricing.

The best estimating methods for a company are those that effectively meet the needs of its organization and customers. The methods differ widely among companies and are influenced by the complexity of the organization, sophistication of products, and variety of product mix [25].

The challenge for most costing systems is how the burden rates are applied. Burden consists of both fixed and variable costs. Fixed burden includes all continuing costs regardless of the production volume for a given item, such as salaries, building rent or mortgage payments, and insurance. Variable burden costs, on the other hand, increase or decrease as the volume

of production rises or falls. Indirect material, indirect labor, electricity used to operate equipment, and certain tooling are classified as variable burden items.

The method of assigning factory burden to individual products differs widely among companies. Any quantifiable factor may be used to assign burden costs as long as there is a full and equitable burden distribution. The factors most frequently used are:

1. Direct labor cost
2. Direct material cost
3. Number of parts produced.

The major cause of inaccuracy of product cost estimates is misunderstandings regarding the features, performance requirements, and quality needs for the product. It is critical that this information be used to update the database summarizing relevant historical data. This database must be audited periodically for accuracy, and to guarantee the accuracy of this part of the estimate.

The knowledge base contains tables of relationships between, for example, the part configuration and the time required. The database is an accumulation of thousands of 'real' time elements drawn from actual observations of manufacturing operations. A key feature of this software is a knowledge base for including prior estimates in various levels of detail. The knowledge base is custom, in the data used must be from the company using the software. A classification system is used for ease of retrieval.

An estimate is an independent, realistic prediction of what it will cost to make a given product. The estimate must be independently arrived at. This means that it must be unbiased, free from whim, and unaffected by emotion or preconceived preferences. The estimate must be realistic. It must reflect the estimator's considered judgment of what can actually be expected.

There are ten Most Common Estimating Problems, namely; Inadequate Data (Inadequate Product data, Inadequate Labor-Cost Data), Mass Quoting (in some estimating situations, frequently because of inadequate time and staff, a great deal of mass quoting is done), Lack of Coordination Between Estimating and Production, Improper Overhead Charges, Careless Estimating, Optimistic Estimating, Poor Estimating Follow-up, Improper Pricing, Poor Estimator Selection and Training, and Management Inertia [50].

Estimating Follow-up can be done in three ways, depending on the business and product involved:

1. In a company making one-offs or big units in limited quantities the follow-up can be by unit number or job

2. Where production is by batch or lot, costs are incurred, collected, and recorded by production lot or batch
3. In practice it may not be feasible to collect and calculate the actual cost of individual units or the cost per average unit of a given lot or batch in high-volume like in the continuous chemical manufacturing sector (eg. oil refineries, soap plants, cement plants, etc). Here the follow-up record must be kept not by units but by cost accounts (labor, material, scrap). The estimation follow-up depends upon the factory's situation (product and cost-recording procedures).

Unfortunately Management Inertia is often the result of the failure of Estimating to communicate strongly and repeatedly:

1. The need for additional data.
2. The kind of accounting action needed for better estimating follow-up
3. Suitable time frames from marketing and the prospect of marketing
4. Other areas needing improvement.

There are factors that increase the difficulty and importance of estimating, such as wider product lines, more models within product lines, tighter engineering and quality specifications, increasing company diversification, changing capacity utilization, greater quality and price competition, increasing capital investment, more widely disseminated management techniques, and greater management sophistication, to name a few [95].

Proper cost analysis needs reasonably good data to analyze, which in turn requires well-defined and disciplined cost-charging practices and good cost reporting. Of course, the estimators and the cost analysts can never use past history blindly. They must be able to evaluate its accuracy, be familiar with how it was collected, and know what such data does and does not include and the surrounding operating conditions.

Thus, estimating should have a voice in how the costing and burden rates used in the estimate are developed and applied. Then senior management can hold Estimating responsible for the quality of the total cost predication. The need for proper overhead allocations via appropriate burden rates is so great that it deserves more attention than it seems to receive.

Like so many areas of management, overhead allocations and product costing is a challenging field of endeavour. In many cases, it is in the area of realistic overhead allocations that estimating and cost accounting have the greatest need for good analytical thinking, sound logic, and a realistic approach. The standard procedure for overhead allocations, such as Selling and Administrative costs monthly is to distribute them to the profit and loss statement between the total product cost, by using a percentage or percentage applied on top of the estimated manufacturing cost.

2.2.1.1 Multiple-regression Approach for Cost Estimation

According to Pareto's law, in any series of events to be controlled, a selected small fraction, in terms of numbers, will always account for a large fraction, in terms of effect (Vilfredo Pareto was an Italian economist and sociologist). This is used for choosing variables in a multiple regression approach.

Multiple regression is a statistical tool that determines (1) the degree of correlation between two or more independent variables and a dependent variable and (2) the mathematical relationship between those individual independent variables and the dependent variable [23].

In product-cost estimating, the dependent variable is product cost, which usually depends on such independent product variables as size, weight, and complexity by type of component parts, and so forth.

How accurate the estimate will be depends on the type of product and three interdependent product characteristics: Complexity of the product; Individuality or differences between orders for the product and Uniqueness of the product.

The disadvantage of multiple regression analysis is that it requires much calculation and is too time-consuming to make it a suitable technique for most estimators, but increases in computer availability and capacity makes the subject worth considering [50].

2.2.1.1.1 Some Cost Models

Cost models have been developed in order to facilitate a cost-guided design process and the optimal use of cost information for evaluation and comparison of design. Most of them can be considered comparative in the sense that they are based on data recorded in the past or built up by experience. Kroll [47] and Sheldon et al. [75, 76] classify them in two general approaches, namely the process based cost model and the feature based cost model, which are useful in engineering design.

Process-based Cost Model. This type of cost model is based on variables specifying follow-on activities such as manufacturing and assembly operations. The fabrication of a product can usually be decomposed into a sequence of processes. This kind of process structure or work breakdown can be used as the cost structure for estimating the product's total cost by recursively summing up costs associated with process elements. The emphasis on activities involved in producing a product is consistent with Activity-based Costing (ABC) method. The question then is how to estimate the costs of elementary processes. An example for this kind of cost model is the *Design for Assembly* (1994) software. The user has to define the assembly structure and the fabrication processes involved, when adding a part.

The time for MIG-welding a butt weld (mild steel) is, for example, estimated as follows:

$$Time \approx C_1 + C_2 * NoOfTacks + C_3 * Length_{weld_bead} * C_4 * (Thickness_{Material})^{C_5 * Length_{weld_bead}}$$

where C_1 to C_5 are constants. The user has to enter the relevant parameters, i.e. number of tacks, length of weld bead, and thickness of the material.

Nordhoff [67] and Ostwald [68] use a similar approach. However, instead of formulas they use table values.

Feature-based Cost Model. This type of cost model is used when looking at the features of a part. A breakdown into a sequence of distinct manufacturing operations is not done. Rather the total cost of manufacturing is calculated as the sum of the tooling, processing, and material cost. It is usually possible to identify a product parameter as the dominant cost driver, e.g., weight, volume, etc., although there may be many others. The cost is then a function of parameters relevant to design. In other words, cost distribution is carried out based on parametric breakdown of a design object. Such data is very useful for rapid cost estimation when only conceptual information is available [52].

Farkas and Jármai [25] give an example for this type of cost model. Their resulting two formulas are sufficient to estimate the time to weld simple, plated structures. The formulas are as follows.

$$Time_{preparation,assembly,jacking} \approx Difficulty_Factor * \sqrt{Mass_{assembly} * No_of_Parts}$$

$$Time_{welding,changing_electrode,chipping} \approx \sum_{Elements} C_1 * Weld_Size^{C_2} * Length_{weld_bead}$$

The difficulty factor depends on the structure (planar or spatial), and the kind of weld (V-weld, 60° or fillet weld, 90°, long or short welds, plate or profiles). C_1 and C_2 are constants for different welding technologies. The user has to enter the total mass of the assembly, the number of parts in the assembly, the cross-section and the length of the weld bead. With these two formulas, the designer has the possibility of mathematically minimizing the product cost by changing the available parameters.

2.2.1.2 Cost Estimation in Practice

With computer-aided estimating systems today, the user has a wide choice, capability wise. The first choice to be made is between accuracy and economy. Many of the 'economy' choices are made without concern for accuracy issues. For the 'accuracy' issues, however, there is no source where one can determine what those choices involve. The important fact to remember, when looking at computer aided estimating systems, is that each time you send a quote to a customer, one is betting the business on the accuracy.

Cost estimation is a very complex process. A simple example is drilling a half-inch hole, three inches deep. Will the software automatically generate a different cycle time for a CNC machine than it does for a turret lathe or a universal lathe? Moreover, will that be by machine vendor's model and type? Will it give a different time for a different model? When cycle time is for a specific model, the program times can be quite close. Finally, will the software arrive at a different time for the same metal whether or not it has been heat treated? And so on.

Even more difficult is the process of accounting for the length-to-diameter ratio on an end mill. The feed/speed books do not address this issue. For example, perhaps the plunging depths are based upon 1-½ X diameter. What if the depth designed is ½ X or 3 X the diameter into the stock? The feed rate will change. Is it necessary for the estimating program to have a provision to deal with that situation?

2.2.1.2.1 Classified Quoting and Estimating Categories

In summary, the industry neither has a standard definition for an estimate, nor universally understands what an "estimating" program could or should provide [93].

If judged by identifying the range of functions performed, there are two groups of software: (i) software which simply assists the shop owner to provide a price to the customer. If the estimator manually calculates or guesses the time it will take, it can be called a computer prepared quote, (ii) software which provides, in addition to that same quoting function, estimates of actual times the job will require in the shop. When the computer estimates the times, it can be called a computer-generated estimate. *Time* is the differentiator. Using time makes it rather simple to differentiate between quoting and estimating software.

Judged by the design strategy, estimating programs are based on one or more of the following categories:

1. Standards-based
2. Engineering-based
3. Intelligent simulation

'Standards-based' estimating programs use a table with standard times assigned to similar operations. Systems that rely on libraries of machine speeds and feeds are 'engineering-based.' Differentiating between the engineering-based and the "intelligent" packages is harder. Both systems come up with an answer for the portion(s) of the process that they compute.

Standards-based Estimation. Standards-based estimating software, while similar to quoting software, can take more time for initial setup after it is purchased. It may require the user either to enter the standards or to update those provided to reflect the shop's actual operations. Often this software already has the standards included; however, companies must realize that if they use someone else's standards they may only be accepting someone else's

guesses. In estimating, there really are no industry wide standards; there are only company standards. If a standards-based system was purchased, the company must have the ability to quickly and easily change the standard.

Standards-based knowledge offered the earliest computer-aided estimating assistance and programs based on this alone may provide the least accurate estimating method. The ongoing evolution is from the standards-based programs toward the engineering-based programs. Many vendors are revising their systems to become more engineering-based. While some still don't deliver a precise conclusion, they can be more accurate than the standards-based packages.

Engineering-based Estimating. The engineering-based estimating programs use the same formulae used when manual estimators need a precise cost. They are unchangeable, based on the laws of mechanics. Given a drill diameter and style, the depth of hole, the material, and the machine doing the drilling, there can be only one correct answer. The formula to derive that time never changes. Feed rates and surface footage-rates may change; once those rates are set, the mathematics is constant. The same is true of idle times. For different machines, the rates may differ, but the movements are the same.

While a standards-based system having a standard for every half-inch of hole depth gives ½ - inch accuracy, in an engineering-based system, setting up the core data covers any hole, at any depth, and is accurate in every situation. The engineering-based system may seem to demand more setup than a standards-based system, but for a standard-based system, it is impossible to set up enough standards to reach the same level of accuracy. There is a difference in the time needed to drill a one-inch hole and a hole 1.021 inch deep, and the engineering approach can be 100% correct; the standards-based approach can only be approximate.

Being engineering-based, however, doesn't guarantee perfection. Speeds and feeds data differ for every material, every tool, every machine type. If an engineering-based estimating program doesn't provide speeds and feeds data for every material, but rather has assigned them on the basis of material *groups*, then accuracy is sacrificed.

While any engineer can look up the feed rate for 12L14 steel, that data is irrelevant without knowing the machine type. The speeds and feeds data is only the starting point. If every material is given its own speed and feed and multiple classes, you can change 12L14 to represent your shop's experience, without affecting 12L50. That would not be possible in any engineering-based system that grouped speeds and feeds by material type.

The engineering-based computer-aided estimating system mimics the correct manual estimating method, using the same equations. The added benefit of computer aided estimating is its ability to take more into account, such as idle time movements or rapid travel rates, to retain the correct information, and to always use the correct data.

For engineering-based systems in practice, they may already include one or more sophisticated modules for hole making or milling (vs. individual computations for complex movements and operations). They employ simple formulae to compute the time required for a procedure — mill a pocket, or drill a hole. What they may lack in any formula is a concept of machine movement and operations. Typically, the software in this evolving class also omits consideration for many idle time elements or specific machine capabilities. For example, a 600 IPM machining center does not make 600 IPM for a one-inch move. In addition, while some systems include basic indexing times, they neglect the more precise indexing time components, such as acceleration/deceleration, spindle index, or rapid ramp-up.

Machining mathematics, by itself, is quite simple:

$$\begin{aligned}(\text{CUT LENGTH})/\text{FEED} &= \text{REVOLUTIONS} \\ \text{REVOLUTIONS}/\text{RPM} &= \text{TIME}\end{aligned}$$

The difficulty lies in knowing the time the operation takes on a particular machine — for example an engine lathe. Does the operator have to manually turn the crank to remove the drill and the chips? And then turn the crank back in to resume drilling? That process knowledge is more important than simple mathematical results, and it adds a level of complexity you should expect in the better estimating systems. This is the level of program depth that is beginning to be called ‘intelligent simulation’ estimation.

Intelligent Simulation. Having the capability to account for issues like rapid travel and complex idle times defines the difference between the engineering-based and the estimating systems that simulate the machines – this is Intelligent Simulation.

Compared to standards-based estimating, engineering-based is more comprehensive, and more accurate. An approach based upon intelligent simulation will improve upon the engineering-based results, but requires the same amount of data from the user, and the same effort for initial setup. It’s claim of improved accuracy is that it is a closer representation to the real world. In it’s estimate, it attempts to include everything significant that will happen, as opposed to what should happen. When it comes to estimating, it can give the time for how long the machining *will* take. For a standard-based estimation, the computer tells how long something should take, rather than the software *determining* how long it does take.

A thorough estimate provides allowances for clearances between tools and makes use of actual spindle speeds and feeds from the gear charts, when appropriate. It will also consider rapid travel rates based on distance and spindle speed ramp-up/ramp-down. Estimating software that intelligently simulates machine operations allows for all these issues, but to do so, it must be written for each specific machine. This is the key difference between engineering-based and intelligent simulation estimating software.

For an Intelligent Simulation system, the determinations that should be made are:

- How the software calculates cycle time
- How it calculates cycle time for specific types of machines (CNC mill, Bridgeport)
- How it calculates a cycle time for a specific model within a type (model A or B)

A genuinely intelligent system accounts for set up time, idle time, complete machine time for the correct type and model of machine, available power, minimum and maximum Revolutions Per Minute (RPM) and feed, fixed or variable RPMs and feed rates and special lever/gear/control settings or rules

Such software literally emulates the machine's movements, stepping through them one at a time. For example, to estimate a facing operation, the program doesn't resort to a single predefined equation; rather it simulates what will actually happen by calculating every revolution and recording the time.

To determine the correct, total time, for example, the estimating program literally models the operation for each process involved and the software loops through every turn the machine will make, making adjustments at every step to account for RPM, feed, minimums, maximums and so forth. To do constant surface footage correctly, the program computes a new RPM for every revolution and considers minimum and maximum RPM at each step. The program must know things like how long it takes to reach top speed, as well as what the top speed is for the type of tooling being used; how long to remain at top speed; and how long it will take to reach center. In other words, the Surface Feet per Minute (SFM) formula at exact center calculates an infinite RPM (which is not possible), and it steps down from there towards the outside diameter of the cut. The machine maximum RPM must be considered. The estimating loop goes through every movement, whether for lathe or pocket milling. Machine tool emulation is the basis of the estimate's accuracy, and it is based upon the combination of all pertinent parameters at every moment in the operation.

Similar, stand-alone software called "tool path optimization" software is considered fairly new today, when applied to NC output from CAD/CAM programs. However, this feature also should be the basis of any comprehensive computer-aided estimating program — and there it is referred to as machine tool emulation. That's what an intelligent, engineering-based estimating program does.

In the end, a choice must be made between accuracy and economy.

2.2.1.3 The Learning Curve in Estimating

Each manufacturer develops knowledge of its own specific learning curves. In practice, it must not blindly adopt another company's learning curves.

The basic learning-curve formula is

$$y = ax^b$$

where y = cost of unit x , a = cost of first unit, x = any given unit, b = slope constant of particular LC being used and Slope constant $b = \log LC / \log 2$.

Related to setting cost objectives with the learning curve is its use for controlling manufacturing costs and achieving cost improvements as more and more units are made.

Learning curves are highly individualistic, and each company must determine its own curve or set of curves by collecting and analyzing actual cost performances on individual products. The type of industry or operation has a major influence on the learning curve generated. Conversely, as observed earlier, the greater the hand-assembly content of the total work needed to make the product, the lower the learning-curve percentage normally encountered [95].

2.2.2 The Implementation of STEP and STEP NC

As mentioned previously, *ISO 10303, Standard Exchange for Product Data (STEP)* which covers product data, is being developed by a broad range of industries to provide extensive support for modeling, automated storage schema generation, life-cycle support, plus many more data management facilities. It is being developed by the ISO TC184/SC4 committee. For practitioners STEP is a collection APs, based on a common underlying methodology e.g. STEP physical file format, EXPRESS data definition language, shared definitions as common resources etc. For researchers and developers STEP is also an important source of modeling and implementation methodologies. Many institutions (involving various projects) have been involved in conducting research in this field (<http://cic.vtt.fi/links/euproj/index.html>).

Part programming for NC machine tools is normally done by using ISO 6983. This standard dates back to the time of punched cards and does not cover the demands of modern NC technology. Within several research projects, such as OPTIMAL and MATRAS, European industries and university institutes have developed a new STEP-compliant programming interface which is based on an object-oriented data model.

The main characteristic of the new interface presents higher levels of information. Whilst a part program according to ISO 6983 describes movements (G1, G2, G3) and switching

instructions (M3, M8), the new language covers manufacturing tasks (so-called "features"). Such a task could be, for example, roughing of a pocket. All operations necessary to produce the finished part from the raw piece can be described by a sequence of manufacturing tasks.

Since the data model describes tasks, the part program supplies a higher quality of information to the shop floor. Therefore, modifications at the shop floor can be saved and transferred back to the planning department which enables a better exchange of experience. Because of the difference in geometry of the raw piece and finished parts using the STEP syntax, a direct exchange of information between CAD/CAM and NC can be realized. Geometry data can be imported directly from CAD systems. Thus, only technology information has to be added in order to generate the part program.

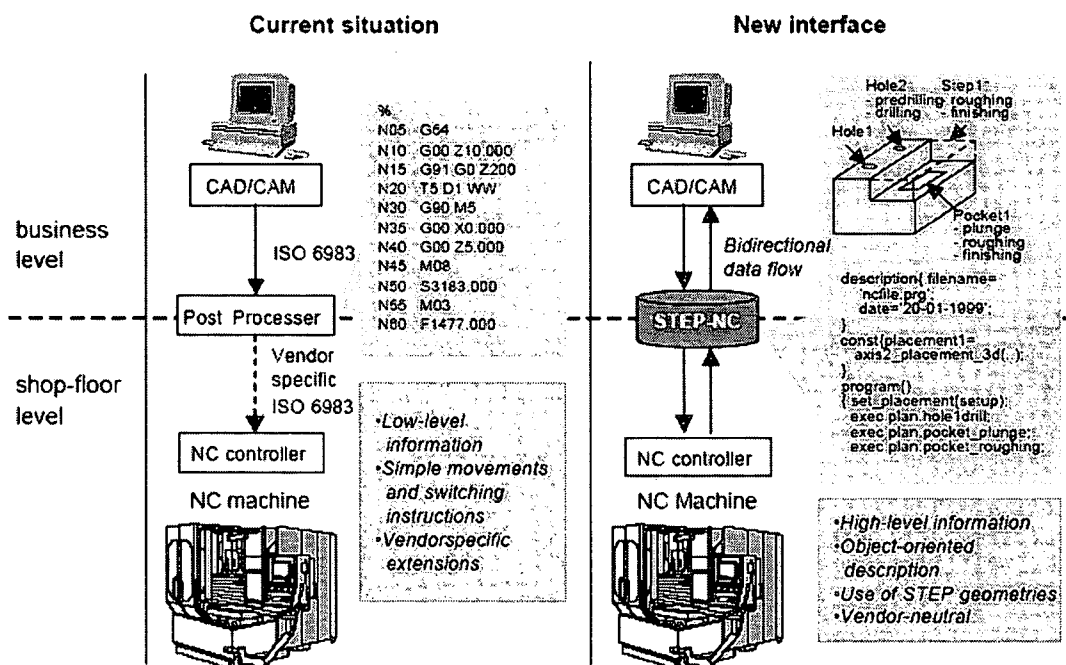


FIGURE 2-6: COMPARING TRADITIONAL AND STEP APPROACHES [20]

The new data exchange format has been implemented as a prototype for both 2½ D and 3D machining into controllers made by Siemens and Fidia as well as into the European open architecture OSACA NC controller and its performance has been proven in laboratorial environments. It is a cornerstone for a truly open manufacturing environment.

2.2.2.1 Standardization

Since 1996, the ISO TC184/SC1/WG7 works on a new STEP based CNC Data Model. ISO 14649 is therefore the forerunner of STEP-NC and will be extended with the results of the

STEP-NC project (see figure 2-7). The multiple advantages of the STEP-NC data interface can only be realized if the common base principles become a widely accepted international standard.

The new data model was introduced to an ISO Working Group and is currently under final deliberation for a Draft International Standard (DIS), called ISO 14649 by ISO TC184/SC1. The standard aims to replace the current used ISO 6983 with the new data model. For the first stage, the general work for milling, including structure and data model has been completed.

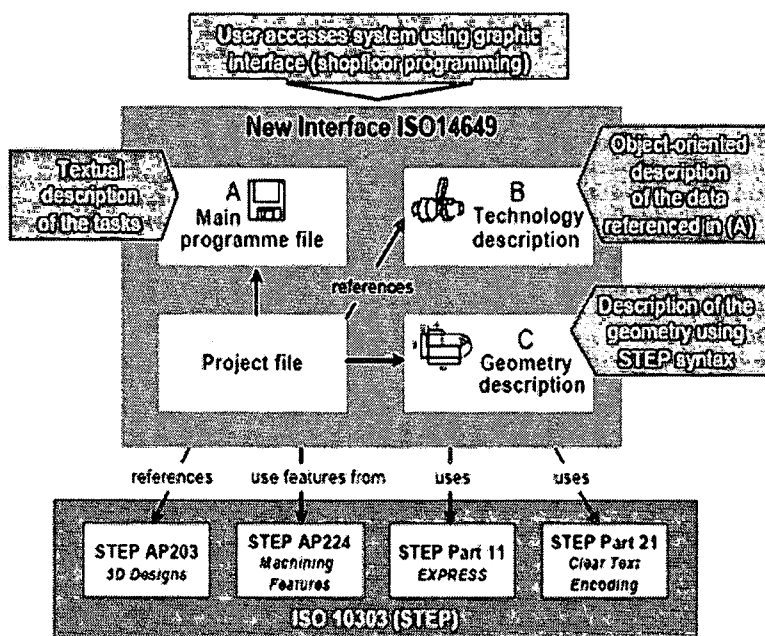


FIGURE 2-7: PHYSICAL STRUCTURE OF ISO 14649 [19]

The fundamental principle of the new Data Model is the programming in terms of manufacturing features (hole, pocket, ...), instead of direct coding of sequences of axis motions and tool functions. The combination of manufacturing features and technological information is referred to as a “working step”. Working steps represent the essential building blocks of the machining process. Each working step describes a single manufacturing operation using one tool and one strategy. An example of such a working step would be the *roughing of a pocket* or the *finishing operation of a region of a freeform surface*.

CAD systems and CAM systems have standardized their exchange of product data, especially the geometry description, with ISO 10303 data (ISO 10303 “STEP” parts 21 and 42/43). All geometrical data for workpieces, setups, and manufacturing features are described using this ISO 10303 data format. This format will be used directly by the CNC to avoid conversions between different data formats which may result in reduced accuracy. This means that, in

order to generate the part programme, the geometrical data has to be supplemented with technological information. This is the most striking feature of the STEP-NC data interface.

STEP-NC adopted a strategy for integration of geometrical and technological information in a structured part programme. The main structure includes two parts: Header and Data section.

A part program is described in a Physical File Format according to the ISO 10303 Part 21. The first section of the part program is the header section marked by the keyword "HEADER". In this header, some general information and comments concerning the part program are given. These are, for example, filename, author, date, organization, etc. The second and main section of the program file is the data section marked by the keyword "DATA". This section contains all information about manufacturing tasks and geometries.

The contents of the data section are divided into three significant parts: workplan and executables, technology description, and geometry description. A Project entity serves as an explicit reference for the starting point of the manufacturing tasks. The figure below shows the relationship among these significant parts of an ISO 14649 data set.

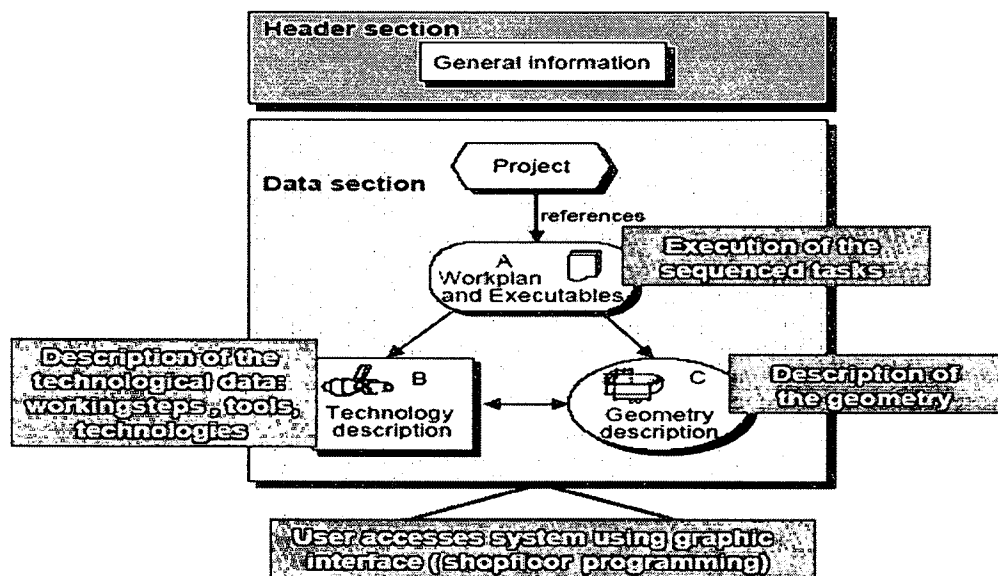


FIGURE 2-8: STEP_NC STRUCTURE [20]

The project entity serves as a starting point to execute the part program. Each part program based on this standard must include an instance of this entity in a "DATA" section of an IS10303 Part 21 file.

The work plan and executables part combines several executables in a linear order or depending on given conditions if conditional controls are used. There are three types of executables: working step, NC function, and program structure. In order to change the

sequence of operations, only this part of the program file has to be changed. The remaining definitions of geometry and technology are untouched. Besides working steps, other NC function statements may be included in the sequence of the part program.

The technology description part contains a detailed and complete definition of all working steps used in the work plan. The technological description includes tool data, machine functions, machining strategies and other process data. Included in this description is a definition of the work piece and all surfaces, regions and features of the finished part. The association between surfaces, regions or features and working steps is given, that is, which working steps belong to which surface, region or feature. A complete technology description includes but is not limited to cutting width and depth, spindle speed, feed, finishing allowance, and tool used. The description of the tools includes the tool dimensions, tool type, and other data used to identify the usage and conditions of the tool.

The technology description will be fairly large for many applications, and is intended to be manipulated by computers. If a human operator intends to manipulate such data, he will be guided through a graphic interface.

The geometric description part describes all geometrical data for the work pieces, the manufacturing features referred to in the working steps and the setups are described using the ISO 10303 data format.

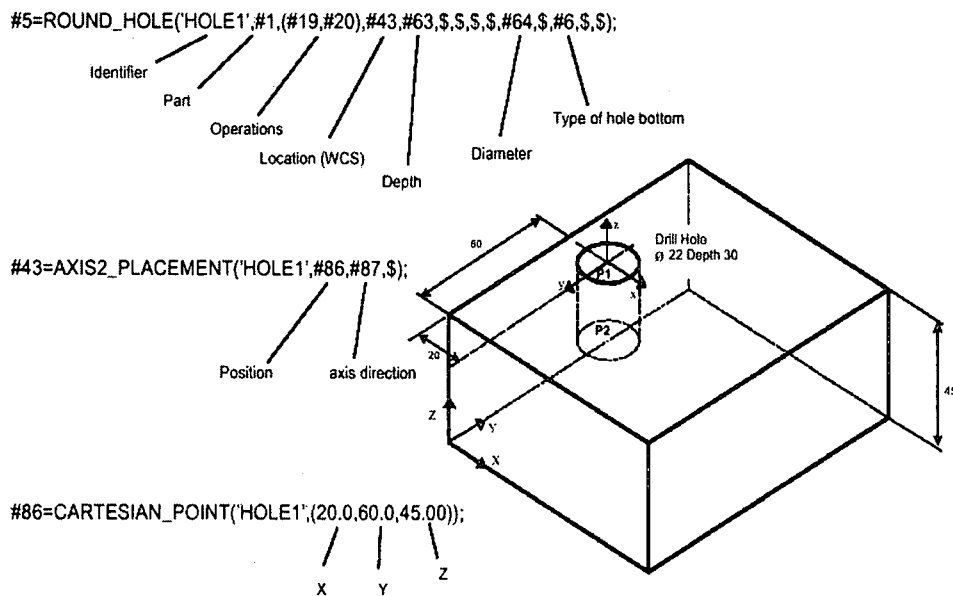


FIGURE 2-9: ISO 10303 DATA FORMAT [83]

An example is given in figure 2-10.

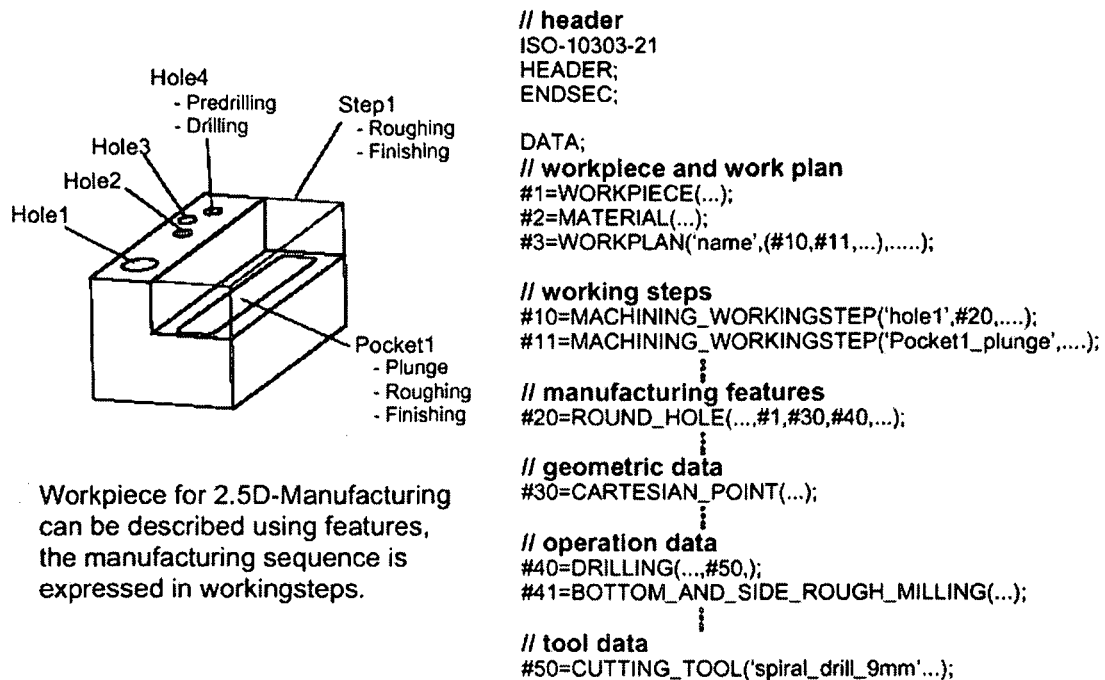


FIGURE 2-10: ILLUSTRATION OF ISO 14649 DATA FORMAT [65]

For this new STEP-NC data interface, new possibilities are offered. The main advantages of the new data interface are the following:

- i. the STEP-NC data interface is a neutral data description; CAM system independent, machine controller independent and machine tool independent. This significantly enhances exchangeability and flexibility. The affectation of created NC programs will be possible at the very last minute, allowing a quick adaptation to production constraints
- ii. it offers opportunity for straightforward information exchange using STEP. Since geometry of raw and finished parts is described using the STEP syntax, a direct exchange of information between CAD, CAM and NC can be realized. Only technology information has to be added in order to generate the part programme.
- iii. higher quality of information can be used on the shop floor. The information available on the controller will allow the operator to have a complete understanding of the program and powerful capabilities to make safe modifications. Graphical user interfaces will support the correct representation and manipulation of the information
- iv. bi-directional information flow can be done. The optimised machining description is transferred back to the planning department, where the executed machining data are used to update the planning, and where the comprehensive and consistent machining description of the part is stored.

For application of this new data interface, the figure below demonstrates the manufacturing cycle, from design to fabrication, and how ISO 14649 would be used within this cycle. The design phase results in CAD data (Geometry ISO 10303 AP203) and includes the definition of all the part features in ISO 10303 AP 224. The process-planning phase generates the resource requirements for part fabrication, using ISO 10303 AP213, and other results suitable for use in a Manufacturing Execution System (MES). Process planning also splits the AP224 manufacturing features into sets suitable for various processes, e.g., milling, turning, electric discharge manufacturing (EDM), and inspection (which also use AP 219). The AP 224 feature sets are used during the CAM phase, which generates ISO 14649 files that are executed by the controllers.

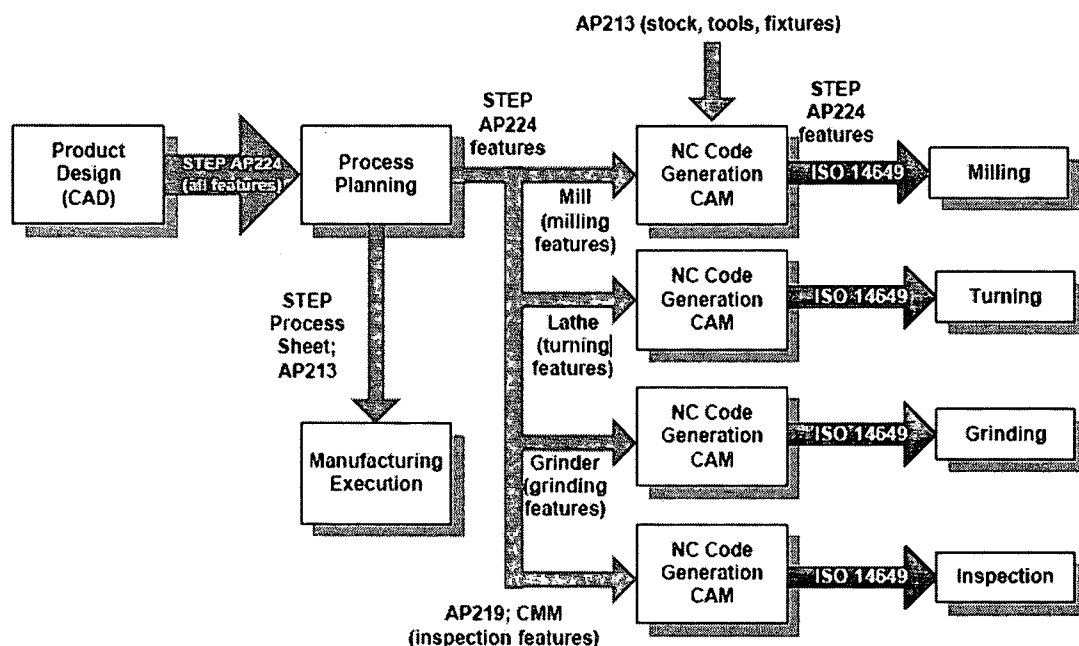


FIGURE 2-11: CNC BASED ON STEP-NC [19]

2.2.3 The Implementation of XML

As mentioned previously, XML is a simplified dialect of SGML. It combines the simplicity of HTML and the flexibility of SGML. A major promise of XML is easy distribution of structured documents and data exchange over the web.

XML is a standard, simple, self-describing way of encoding both text and data so that content can be processed with relatively little human intervention and exchanged across diverse hardware, operating systems, and applications.

In brief, XML offers a widely adopted standard way of representing text and data in a format that can be processed without much human or machine intelligence. Information formatted in

XML can be exchanged across platforms, languages, and applications, and can be used with a wide range of development tools and utilities.

XML is similar enough to HTML in its actual format (both are closely related to the SGML markup definition language that has been an ISO standard since 1986) so that those familiar with HTML can fairly easily pick up basic XML knowledge. But there are two fundamental differences:

- i. separation of form and content - HTML mostly consists of tags defining the appearance of text; in XML the tags generally define the structure and content of the data, with actual appearance specified by a specific application or an associated stylesheet
- ii. XML is extensible - tags can be defined by individuals or organizations for some specific application, whereas the HTML standard tag set is defined by the World Wide Web Consortium (W3C).

The reason XML is very important for this project is that XML is a universal data format for integrated electronic business solutions.

Relational database systems cannot meet all the demands of electronic business because they process data independently of its context. Traditional databases may be well suited for data that fits into rows and columns, but cannot adequately handle rich data such as audio, video, nested data structures or complex documents, which are characteristic of typical Web content. To deal with XML, traditional databases are typically retrofitted with external conversion layers that mimic XML storage by translating it between XML and some other data format. This conversion is error-prone and results in a great deal of overhead, particularly with increasing transaction rates and document complexity.

XML databases, on the other hand, store XML data natively in its structured, hierarchical form. Queries can be resolved much faster because there is no need to map the XML data tree structure to tables. This preserves the hierarchy of the data and increases performance.

Some of the key characteristics of XML are:

1. XML data is self-describing data

Unlike records in traditional data base systems, XML data does not require relational schemata, file description tables, external data type definitions, etc., because the data itself contains this information. In contrast to the widely used Web format HTML, which only ensures the correct presentation of the formatted data, XML also guarantees total usability of data. This is imperative for business applications whose tasks extend beyond the mere presentation of content.

2. It completely integrates all traditional databases and formats

XML documents can contain any imaginable data type - from classical data like text and

numbers, or multimedia objects such as sounds, to active formats like Java applets or ActiveX components.

3. It is easy to modify the data presentation - no reprogramming required

It is easy to change the look and feel of documents or even entire websites with a proper XML Stylesheet Layout (XSL) without manipulating the data itself.

4. Distributed data can be viewed

XML documents can consist of data from many different databases distributed over multiple servers. In other words, with XML the entire web is transformed into a single all-encompassing database.

5. It is an internationalised format

Internationalization is of utmost importance for electronic business applications. XML supports multilingual documents and the Unicode standard.

6. It is open and extensible

XML's one-of-a-kind open structure allows one to add other state-of-the-art elements when needed. This means that one can always adapt one's system to embrace industry-specific vocabulary.

7. It is a future-oriented technology

XML is the endorsed industry standard of the W3C and is supported by all leading software providers. Furthermore, XML is also the standard today in an increasing number of other industries, like health care.

The benefits of XML are obvious. Information coded in XML is easy to read and understand, and computers can process it easily. XML is a W3C standard, endorsed by software industry market leaders, and there is no fixed set of tags. New tags can be created, as they are needed. In traditional databases, data records require schemas set up by the database administrator. XML documents can be stored without such definitions, because they contain Meta data in the form of tags and attributes.

XML provides a basis for author identification and versioning at the element level. Any XML tag can possess an unlimited number of attributes such as author or version.

As mentioned, XML supports multilingual documents and Unicode. This is important for the internationalization of applications. It can map existing data structures like file systems or

relational databases to XML. XML supports multiple data formats and can cover all existing data structures and provides a 'one-server view' for distributed data. XML documents can consist of nested elements that are distributed over multiple remote servers. XML is currently the most sophisticated format for distributed data - the web can be seen as one huge XML database.

The most important feature for XML is that it contains machine-readable context information. Tags, attributes and element structure provide context information that can be used to interpret the meaning of content, opening up new possibilities for highly efficient search engines, intelligent data mining, and agents. This is a major advantage over HTML or plain text, where context information is difficult or impossible to evaluate. It can separate content from presentation. XML tags describe meaning not presentation. The motto of HTML is: "I know how it looks", whereas the motto of XML is: "I know what it means, and you tell me how it should look." The look and feel of an XML document can be controlled by XSL style sheets, allowing the look of a document (or of a complete web site) to be changed without touching the content of the document. Multiple views or presentations of the same content are easily rendered. It can embed multiple data types. XML documents can contain any possible data type - from multimedia data (image, sound, and video) to active components (Java applets, ActiveX).

XML has been rapidly adopted by industry. Software companies like IBM, Sun, Microsoft, Netscape, Data Channel, SAP and many others have already announced support for XML. Microsoft will use XML as the exchange format for its Office product line, while both Microsoft's and Netscape's web browsers support XML. SAP has announced support of XML through the SAP Business Connector with R/3. Software AG supports XML in its Natural product line and provides Tamino, a native XML database.

Thus XML is redefining modern database infrastructure by serving as the "glue" that binds diverse enterprise systems to each other and to the Internet.

To illustrate the XML concept, a simple XML example is given next:

```
<?xml version="1.0"?>
<!DOCTYPE PARENT [
<!ELEMENT PARENT (CHILD*)>
<!ELEMENT CHILD (MARK?,NAME+)>
<!ELEMENT MARK EMPTY>
<!ELEMENT NAME (LASTNAME+,FIRSTNAME+)*>
<!ELEMENT LASTNAME (#PCDATA)>
<!ELEMENT FIRSTNAME (#PCDATA)>
<!ATTLIST MARK
    NUMBER ID #REQUIRED
    LISTED CDATA #FIXED "yes"
    TYPE (natural|adopted) "natural">
<!ENTITY STATEMENT "This is well-formed XML">
]>
<PARENT>
&STATEMENT;
<CHILD>
<MARK NUMBER="1" LISTED="yes" TYPE="natural"/>
```

```
<NAME>
<LASTNAME>child</LASTNAME>
<FIRSTNAME>second</FIRSTNAME>
</NAME>
</CHILD>
</PARENT>
```

XML is divided into markup and content. Markup is information about content. Makeup describes any level of detail desired. Correct markup must follow certain rules.

First, markup containing content must have opening and closing tags. Opening tags start with < and close with >. Closing tags start with </ and close with >.

Second, markup must nest properly. Markup tags divide into parents and children. Parent markup encloses child markup. A child's opening and closing tags must be contained within its parent's opening and closing tags.

Third, if markup contains no content, it must begin with < and end with />

A Document Type Definition (DTD) is the primary distinction between well-formed and valid XML. Well-formed XML can give you a vague idea of an XML document's purpose but leaves room for doubt. A DTD eliminates this by providing a stringent standard to measure a document against.

A DTD declares each part of an XML document and its proper form exactly. DTD's are enclosed between an opening [and a closing]>. A DTD includes element, attributes, and entity.

In this XML example, <?xml version="1.0"?> declares the XML is version 1.0, so programs know how to use it like XML 1.0. The second line, <!DOCTYPE PARENT [, declares this section is a document type definition or DTD and its name(PARENT).

An element defines markup's name and form. <!ELEMENT PARENT (CHILD)*>, shows a DTD's most basic part, the element.

Another DTD fundamental is attribute. Attribute is a description given to an element to further define it. Attributes are declared in attribute lists. In this example, it is attached to (MARK).

```
<!ATTLIST MARK
  NUMBER ID #REQUIRED
  LISTED CDATA #FIXED "yes"
  TYPE (natural|adopted) "natural">
```

A third DTD part, is entity. The entity points to something that can be inserted at any point in the XML document. The line <!ENTITY STATEMENT "This is well-formed XML"> inserts This is well-formed XML whenever &STATEMENT; appears.

2.2.4 The Implementation of STEP-XML

ST-XML is an add-on for ST-Developer (a product of STEP Tools Co.) that provides a set of tools and libraries to read and write XML files. By storing STEP data in XML files, it is possible to develop an application to use standard XML processing tools to manipulate STEP data, streamlining application development and deployment.

With ST-XML, one can read and write STEP data in two XML bindings: the Object Serialization Early Binding (OSEB) and the Containment Early Binding (CEB). The OSEB is a Part 21-like encoding for the exchange of a complete model instance. The CEB lets a user define the XML format to be used for STEP data exchange and supports both complete model and partial model exchange. The CEB processor is implemented as a C++ class library that adds XML capabilities to ST-Developer. With this library, one can read and write STEP instances and control how data is converted between STEP and XML [86].

The ST-XML API enables one to have fine control over how the STEP data is converted to XML. There are two distinct operations involved in this process: conversion of STEP to XML, and conversion of XML to STEP.

Unlike a filter which converts an entire model between XML and STEP, the API in ST-XML allows you to export or update individual instances, and thus create simple, compact XML data sets. The API can be controlled from a C++ program or from the header of the XML data. Thus, the server side of a distributed STEP XML application can be implemented without any programming at all.

2.2.4.1 CEB Structure

The Containment Early Binding (CEB) for XML defines a binding for STEP instance data to XML elements. CEB is powerful enough to represent any STEP instance data; it is designed to transfer a portion of a STEP model, in a transaction, and then later reintegrate the updated XML into the original STEP model and update it. This process of extracting processing and updating the XML data is a CEB transaction, the subset of the data that is processed is the transaction data.

One can extract the transaction data from the STEP model in several ways. One can choose all of the instances of a particular entity; use an EXPRESS-X mapping to select the instances which will be converted; or use an application specific C++ code to select the instances which need to be extracted.

For example, set out below is a CEB data file for the following schema:

```
ENTITY Point;  
    x : REAL;  
    y : REAL;  
END_ENTITY;
```

```
ENTITY Circle;  
    radius : REAL;  
    center : Point;  
END_ENTITY;
```

The following instance data

```
#34=CIRCLE(3.14, #78);  
#78=POINT(1.3, 5.1);
```

which may look like the following in CEB form:

```
<data>  
    <circle id="34">  
        <radius>3.14</radius>  
        <center>  
            <x>1.3</x>  
            <y>5.1</y>  
        </center>  
    </circle>  
</data>
```

In this case, entity circle is written as a root type, and entity point is written as a contained type. The decision on what will be root types is made by the application that generates the CEB data. It is also possible for both circle and point to be declared as root entity types. In this case, the CEB output for the same instance data is the following:

XML:

```
<data>  
    <circle id="34">  
        <radius>3.24</radius>  
        <center href="#78"/>  
    </circle>  
  
    <point id="78">  
        <x>1.3</x>  
        <y>5.1</y>  
    </point>  
</data>
```

In this case, the value of the attribute center is specified by reference the id and href XML attributes, and the value of the attribute is given as a separate root object.

2.2.4.2 Control Language

There are a number of options that control the details of how the CEB file is created. These options include such issues as which entities are processed as root objects, and which, if any, informational attributes are included in the XML. These options are specified in an XML-based control file. By default, the CEB creator inserts the options into the header of the generated CEB XML data.

There are four principal verbs in the control language, namely,

- root Defines what types of entities are the root instances in the XML file.
- cast Makes an assertion about the data types allowed for an attribute value to simplify the XML.
- inverse Reverse the direction of a reference to make data traversal easier.
- replace Convert a STEP data instance into an XML data type.

The following is a sample options file:

```
<?xml version="1.0"?>
<ceb:header xmlns:ceb="urn:iso10303-28:ceb">
<options ids="true" ctype="true"/>
  <root subtypes="false"
    type="product_category_relationship"/>
  <root subtypes="false" type="cc_design_approval"/>
  <root subtypes="false" type="cc_design_certification"/>
<cast target="product_definition_shape"

path="property_definition_representation.definition" />
  <inverse name="context_elements"
    attribute="application_context_element.frame_of_reference" />
</ceb:header>
```

2.2.4.3 Root Objects

To serialize the STEP data into CEB form, STEP data needs to declare the set of root entities that CEB will be using. These types identify the EXPRESS entity definitions whose instances are represented as root elements in the XML data. The CEB specification only allows instances of entities declared as root objects to be serialized, so it needs to declare one or more root types in order to bootstrap the conversion.

In XML, there is exactly one root element for each document. In the CEB file, selections of entity types are represented as root objects which are flexible. Any time an attribute is written with a *controlling* type that is a root type, the attribute is written as a reference (that is, no value, but instead the XML includes an href attribute which refers to the value).

To select a root type, one uses the <root> option in the control file, which gives the following parameters:

type The entity type which is to be represented by a root element.
subtypes Optional parameter (default is true) which determines if this root declaration applies to subtypes of the identified type parameter, or only to the exact type.

In addition to the <root> element, there is a <no-root> element that can be used in a control file to override a root declaration on a subtype. For example,

```
<root type="representation_item" />  
<no-root type="geometric_representation_item" />
```

The above declarations are to force instances of representation_item, and all subtypes of representation_item except for geometric_representation_item to be root types.

Thus,

```
ENTITY Point;  
    x : REAL;  
    y : REAL;  
END_ENTITY;  
  
ENTITY Circle;  
    radius : REAL;  
    center : Point;  
END_ENTITY;
```

For all of the examples in this section, the following STEP data is used

```
#32=CIRCLE(2.4, #40);  
#40=POINT(3.1, 5.0);
```

Declare entity point and circle to be a root type with the following declaration:

```
<root type="point" />  
<root type="circle" />
```

With this declaration, any attribute that is declared as being of type point or circle or one of its subtypes is converted to a root type.

Using these root declarations, the corresponding CEB file output will include the following:

```
<circle id="32">  
    <radius>2.4</radius>  
    <center href="40" />
```

```

    </point_label>
    <point id="40">
        <x>3.1</x>
        <y>5.0</y>
    </point>

```

Because of the root declaration, the center attribute of the circle instance is not written as a contained value. Instead, it has an href attribute which points to the corresponding point instance, which is written elsewhere in the CEB file as a root object.

2.2.4.4 Object Substitution

When mapping STEP to XML data, it is sometimes desirable to map the instance data to something more easily processed using XML tools. There are several standards for mapping EXPRESS defined data structures into XML elements (including this one). However at times such transformations may be too low-level for the application being used and need to be translated to a higher-level semantics of information rather than merely reformatting the same data structures into an XML format.

A common situation where this feature may be needed is for the representation of dates. STEP defines its own common representation, but to represent these values in a more XML-friendly form such as the xsd:date type defined in the XML Schema, a specification will be needed.

STEP defines a date as follows:

```

ENTITY date
    SUPERTYPE OF (ONEOF (calendar_date));
    year_component : year_number;
END_ENTITY; -- date

ENTITY calendar_date
    SUBTYPE OF (date);
    day_component : day_in_month_number;
    month_component : month_in_year_number;
END_ENTITY; -- calendar_date

```

It can define a person and their birthday with the following entity:

```

ENTITY person;
    name : STRING;
    birthday : calendar_date;
END_ENTITY;

```

For writing out an instance of person, the following XML data can be used:

```

<data>
  <person id="56">
    <name>John Doe</name>
    <birthday>
      <year_component>1984</year_component>
      <day_component>15</day_component>
      <month_component>4</month_component>
    </birthday>
  </person>
</data>

```

If the EXPRESS date type is replaced with the XML date type, then the following output should result:

```

<data xmlns:xsi="">
  <person id="56">
    <name>John Doe</name>
    <birthday otype="xsi:date">1984-4-15</birthday>
  </person>
</data>

```

Here, the birthday element has an otype attribute which identifies the XML type with the data is being written as it is being processed.

The ST-XML library includes a number of common mappings between STEP representations and XML schema types. Besides this, when declaring the <replace> tag in the header, write and register mapping handlers that will convert a STEP entity instance to an arbitrary.

The <replace> tag can take the following attributes:

- type The EXPRESS type that is being mapped
- map A mapping function to perform the translation.

The following declaration uses the xsdate translator to convert all date instances to the XML Schema representation of date:

```

<replace type="date" map="xsdate" />

```

In addition to the above methods one can use a C++ API to define and register different types of mapping functions.

2.2.5 Artificial Intelligence

As AI is a powerful tool to handle uncertainty and complex problems, it would be helpful in this project to discuss various points/issues. The most significant part AI can help to solve is

the profit margin expectation problem, which is highly affected by the uncertainty of marketing. Here, two basic AI tools, Fuzzy Logic Control (FLC) and Neural Network (NN) are introduced.

2.2.5.1 Fuzzy Logic Control

Basic FLC consists of four principle components, namely

- i. the condition interface;
- ii. a knowledge base that consists of the fuzzy control rules and fuzzy set definitions database;
- iii. the fuzzy controller itself; and
- iv. an action interface.

The condition interface (also denoted as “justification interface”) is responsible for three main activities:

- i. measurement of input variables;
- ii. scaling the input values into a corresponding universe of discourse;
- iii. mapping the input variables into suitable linguistic value. This activity is referred as “fuzzification”

The Knowledge base contains the knowledge of the application domain and the control goals. It consists of a set of control rules and a set of definitions. These definitions represent the descriptions of the fuzzy sets that correspond to the various input parameters.

The Fuzzy Logic Controller is the unit that combines all the elements of the system into a decision-making unit that operates in real time, at timely intervals, or based on interrupt signals.

The action interface is the unit responsible for the communication of the decision made by the FLC back into the controlled system. This unit translates the decision variable into a corresponding universe of discourse and converts the fuzzy values into a crisp control action or decision (this activity is termed “defuzzification”) [49].

The operation of the FLC consists of four steps. In the first one, the input variables are measured. Next, these variables are converted into fuzzy linguistic terms such a “Long”, “Very Short”. These linguistic terms are then used to evaluate the fuzzy control rules. The result of this evaluation is itself a fuzzy control decision. This fuzzy control decision is then converted into a crisp control action, which is executed.

2.2.5.2 Neural Networks

The main component of a neural network is the processing element. A neuron is an information-processing unit that is fundamental to the operation of a neural network. There are three basic elements of the neuronal model:

1. A set of synapses or connecting links, each of which is characterized by a weight or strength of its own;
2. An adder for summing the input signals, weighted by the respective synapses of the neuron; the operations described here constitute a linear combiner;
3. An activation function for limiting the amplitude of the output of a neuron.

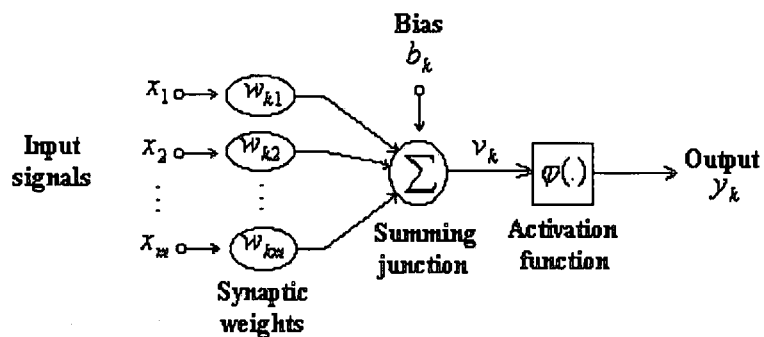


FIGURE 2-12: NEURON STRUCTURE

In mathematical terms, it can describe a neuron k by writing the following of equations:

$$u_k = \sum_{j=1}^m w_{kj} x_j$$

and

$$y_k = \varphi(u_k + b_k)$$

where x_1, x_2, \dots, x_m are the input signals; $w_{k1}, w_{k2}, \dots, w_{km}$ are the synaptic weights for neuron k ; u_k is the linear combined output due to the input signals; b_k is the bias; $\varphi(\cdot)$ is the activation function; and y_k is the output signal of the neuron [32].

2.2.5.2.1 Backpropagation Algorithms

The multiplayer perceptron, trained by the backpropagation algorithm, is currently the most widely used neural network, as the single-layer network has a disadvantage in that it can only solve linearly separable classification problems.

A three-layer perceptron is where, for example, the output of the first network is the input to the second network, and the output of the second network is the input to the third network. Each layer may have a different number of neurons, and even a different transfer function.

The backpropagation algorithm for multiplayer network is a generalization of the LMS algorithm, and it uses a mean square error as its performance index. For the multiplayer network the error is not an explicit function of the weights in the hidden layers, therefore its derivatives are not computed so easily. Taking advantage of the power of the chain rule, this problem can be solved [61].

Thus, in summary, with the backpropagation algorithm, the first step is to propagate the input forward through the network, and the next step is to propagate the sensitivities backward through the network. Finally, the weights and bias are updated using the approximate steepest descent rule.

Chapter Three: System Design and Programming

Pricing is generally based essentially on costs with an appropriate margin added [55]. Thus, basic costing plays an important role when making a quotation. As mentioned previously, with regard to cost estimation, there are three main approaches, namely standards-based, engineering-based, and intelligent simulation-based. *Standards-based estimating* programs use a table with standard times assigned to similar operations. *Engineering-based systems* rely on libraries of machine speeds and feeds for calculations. *Intelligent simulation-based* attempts to determine how long each operation will take as opposed to how long it should take, and as a consequence provides more accurate data for calculations [93].

For a quota/pricing system, one must be concerned with the fact that most of the information available is imprecise and uncertain. Intelligent pricing needs to focus on the overall strategy of the manufacturer, information and knowledge about the competition, needs of the customer and the manufacturer's own strengths and weaknesses.

Quotation problems become more serious when quotations are done via the Internet. In such an environment, adaptation and flexibility are equally as important as accuracy. To design a suitable AQS for WBM system integration, an engineering-based approach can provide a base, but it also requires knowledge of current technologies to provide a cost-efficient solution.

In this section, a conceptual approach to design a system for adaptive quotation that addresses the problems mentioned above will be presented. First, a similar estimation/quotation system, called WebBid systems is analyzed. After that, a detailed system design procedure of the AQS is outlined, which covers cut-time estimation, based on job-order costing or process based costing; and is followed by profit margin expectation. Web integration technology and system integrations are also discussed.

The detail system construction, viz., system software programming, is also described. The section starts with database construction, oriented for inputting system-needed information, followed by processing technologies, and then outputting of generated data. A detailed introduction to Graphic User Interfaces (GUI) is also presented.

3.1 The Design Objectives

The objective of the project is to design a manufacturing quotation system that automatically generates a quotation and estimated delivery time for part/parts to be manufactured using CNC equipment, over the Internet, after the customer has submitted a suitable digital CAD model. The quotation should be generated as quickly as possible, and should either be output by the system for viewing by the customer, or e-mailed back to the customer.

Many publications discuss systems design and analysis. In general, a system must be kept as simple as possible. The main attribute of systems theory in the area of manufacturing systems design and analysis is simplicity [26, 45]. This is achieved by dividing the system as a whole into sub-systems, by:

- (i) clearly identifying the input, process and output elements of each sub-system;
- (ii) determining the appropriate controls for monitoring achievement against predetermined standards; and
- (iii) formulating and initiating the necessary corrective action.

This system is divided into several sub-systems. One main sub-objective is the input information. The research problem consists of using CAD/CAM software (specially STEP-NC) , together with AI and data that has been generated in-house to take the CAD model and provide an estimated machining time automatically. This is a very complex procedure. Generally, at present, human interaction is always necessary in the preparation of toolpaths using software because the choice of appropriate tooling, cutting speeds, cross-over and other features requires human operator experience. Thus, the objective of this research is to develop an AI software subsystem that makes use of the data that has been gathered over time in a manufacturing environment to provide an estimated processing time without such interaction.

To achieve this objective and build the AQS, the following must be done:

- i. identify the best architecture. The architecture will determine the frame for this system. Good structure will give more 'space' for design and will allow future development
- ii. identify the best type of AI training. Analyze the required inputs and choose the desired output; build the neural network model to realize this input-output function
- iii. test run and evaluate the system. Add the self-learning mechanism and validate the system.

The objectives also include developing the Internet interface that allows a user to download an appropriate CAD model for processing, develop the AI subsystem to generate the processing time, and then use this information to produce a quotation. Finally, the interface must have the ability to process an order (together with order number/credit card payment) and generate an official order confirmation.

3.2 The Quoting Process

In a normal estimation/quotation process, the estimator plays an important role. An estimator usually has experience in time-study work in the machine shop. During this period, he has had the opportunity to observe in detail the machine shop at work. He will understand the problems of the shop and know the limitations of its equipment and its personnel. He will

have become methods-conscious and will know that there are several ways to perform an operation, one of which is the best way [67].

Machine shop estimation differs quite significantly from time-study [67]. The estimator can picture the fabrication process in his mind and his only information usually is the engineering drawing and the required quantity. From there on he has to outline the steps necessary in the fabrication of the part: what operations are necessary? In what order are they to be performed? What machines available are best suited to perform the operations? What tooling in the way of fixtures and jigs will be available or ought to be available to facilitate the production of the part? Will the quantity of the shop order justify expensive and permanent tooling? What part and operator movements are involved? The estimator must answer all these questions before he can make a reliable estimate of the job.

After the estimator receives the engineering drawing and the required quantity, the first step for him is to break down the job into the operations necessary to fabricate the part. On a form known as a routing sheet, or a manufacturing outline sheet, he writes the operations in sequence. The next step is to break down the operations into their elements. The method outlined on the routing sheet represents the best manufacturing process within the limitations of the available equipment in the shop. In detail, it involves the process of setup and breakdown into operation elements.

Setup includes work to prepare the machine or process for the production of parts in the unit standard-operation time [68]. Starting with the machine or process in a neutral position, setup consists of elements such as time to sign in on the job, paperwork, obtaining tools, positioning unprocessed materials nearby, adjusting, and inspecting. It also includes return tooling, cleanup, and tear down of the machine or process to a neutral condition ready for the next job. Setup does not include the time to make parts or perform the repetitive cycle.

Setup time estimating is necessary for job shops and companies whose parts or products have small to moderate quantity production. As production quantity increases, the setup time may become negligible, although its absolute value remains unchanged. Some operations may not require setup. This is the case for flexible manufacturing systems or combined operations.

Theoretically, the set-up time for the same operation on a part is the same every time it reappears in the shop. In actual practice, it is seldom, if ever, the same. The job that was previously performed on the machine affects set-up time. Perhaps the same stock material could be used for cutting two parts that differ just in length. Then the time required to prepare the machine for the new job would be less than if the cutters used on the previous job had to be changed.

According to Nordhoff [67], the estimator assumes that the machine is clean. The operator must start from scratch, with nothing used on the previous job that can be utilized on the present job. Regardless of whether or not there is a possibility of equipment used on a

previous job being utilized on the present job, the estimator will assume that a complete set-up is necessary. An intelligent foreman or a wise planning group will try to arrange the flow of work to a machine that will require the minimum changes in the set-up in going from one job to another. The estimator, however, calculates the maximum time required for the set-up.

An *operation element* may be defined as the smallest component into which an operation is divided. It includes all the elements that are needed to complete one unit after the setup work is concluded. Operation elements are roughly divided into handling and machining elements [67].

The *handling elements* will be considered as comprising all physical movements by the operator that are necessary to prepare the part for the machining element and the disposing of the part after the machining element has been completed. They are those elements which contribute to the loading and unloading processes.

The *machining elements* are those which are performed by the machine. These elements start when the tool touches the work and end when the tool leaves the work.

Miscellaneous allowances take into account personal requirements, fatigue, tool life, checking, and others. They must be included in a job estimate. It is customary to calculate allowances as a percentage of the element times [67].

3.3 System Conceptual Design

A quotation is defined as the highest bid or lowest asking price available for a security at any given time. The quotation process can be used in the normal trading transaction between the (potential) customer and the supplier to enable an order to be placed.

The general part quotation process consists of eight steps, illustrated in figure 3-1.

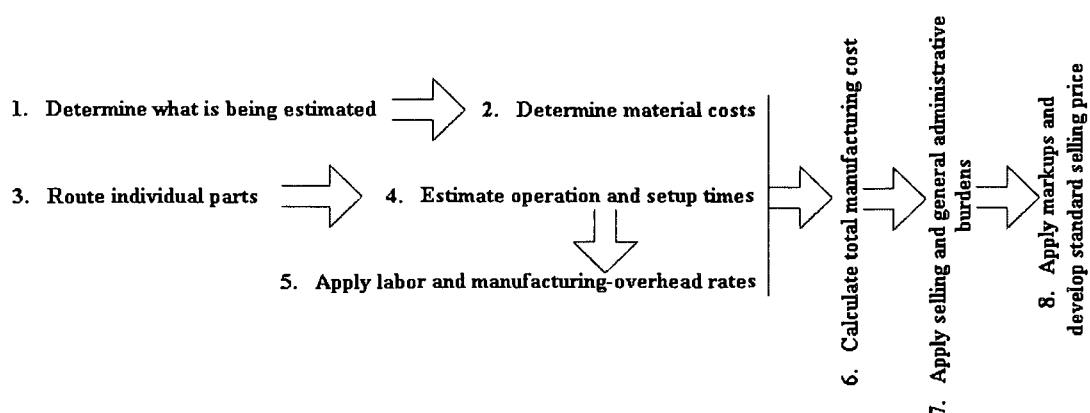


FIGURE 3-1: GENERAL QUOTATION PROCESS

When these processes are done via the Internet, step 1 corresponds to the process of the customer inputting information via the web. When the part data is processed via STEP-NC system, the information needed for step 3 and step 4 can be derived [54]. The information required in step 2, 5 and 7 can be derived from the Management Information System (MIS). The various departments should maintain up-to-date data in the MIS (*HR* of labor costs; *Purchasing* generate material and purchased-component costs, as well as tool costs; *Engineering* of engineering costs; and *Accounting* the overhead rates to be applied). Generally, step 8 is hard to keep away from human interference, which normally is determined by a management committee meeting.

With the advancement of information systems and technologies, various cost estimation methods are available for quotation purpose, but most of them are still not flexible for markup and burden calculations. The development and application of markups reflects tremendous differences between industries and between companies within a given industry. This has introduced a challenge for Web-Based Quotation (WBQ) system design. Using AI to streamline this process is one of the possible solutions.

3.3.1 The Proposed System

From a system point of view, in theory, an automatic quotation system needs to include the following (see figure 3-2) [77]:

- A module for value analysis that will enable the system to evaluate, from the perspective of the buyer, the value of each proposed integrated solution to his needs.
- A module for analysing the competitive environment to quantify the expected "value" to the buyer of different potential solutions proposed by competitors.
- A repository in which one can hold information about the different products and processes of the manufacturer and the ways in which they could be combined in order to provide integrated solutions to meet the client's needs. This repository would also hold the information and knowledge that the manufacturer is able to obtain about the competition via market intelligence picked up by his marketing/sales departments.
- A module for analysing the costs of any proposed solution by the manufacturer as well as analysis of costs of potential competitor pricing.
- A pricing module, which will have a set of decision rules or some optimisation algorithm to provide the most profitable price which provides the highest value to the client at sufficiently low cost to the manufacturer.

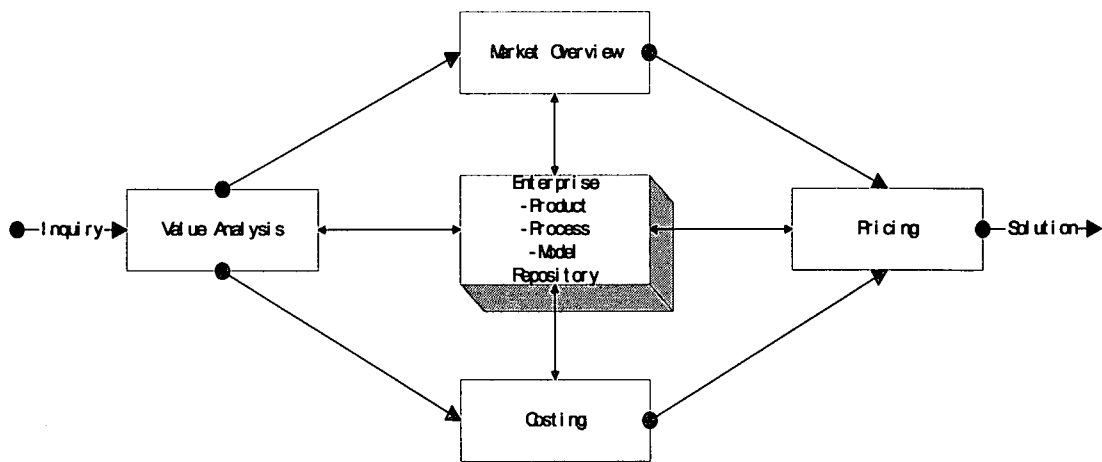


FIGURE 3-2: ARCHITECTURE OF A PRICING DECISION SUPPORT SYSTEM

For this project, just two fundamental modules will be implemented. The first is the 'cost' module, which derives its data from fixed information, and the other is the 'profit margin expectation/pricing' module, basing its data on uncertain factors. Most of the required information could be derived using STEP-NC and the MIS with current technology. The tangible information can be classified as construction factors, such as demand, price limitation, and quality requirements. The non-construction factors include competitor information, profit margin, and engineering risk etc [98]. If the profit margin can be used to make up the non-construction factors, the quotation process flow can be represented as illustrated in figure 3-3. This is the basis for the proposed AQS architecture.

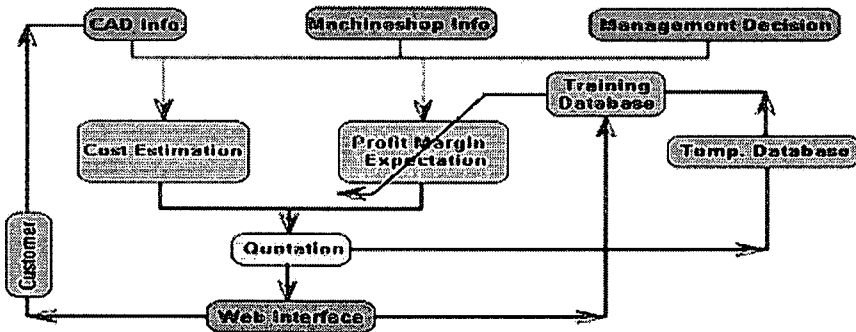


FIGURE 3-3: PROPOSED ADAPTIVE QUOTATION SYSTEM

Here, the information needed for cost estimation can be retrieved and calculated if the part is presented using the STEP-NC format. A Neural-Fuzzy system can be used for profit margin expectation and the related database upgrading based on the whole system's performance [57].

Basically, there are two main parts to a quotation, namely the production cost and the profit margin. The production cost can be determined by many methods. Production costs include direct cost and indirect costs. For example, production cost can be solved via an engineering-based cost estimation system. To handle the uncertain/imprecise factors, a routine called *Part Complexity* is proposed and used for profit margin assessment. When implemented, an integrated product quotation system can be devised, which is rationally accurate and has some flexible features. The calculation formula is: Product Quotation = Product Cost x Profit Margin

3.3.1.1 Production Cost

As mentioned previously, *cost* is the use of organizational resources and can be classified into fixed costs and variable costs. Fixed costs includes the opportunity costs of using the facilities, purchasing machines, employing senior managers, and using other resources that will not change by the rate of output. The cost that increases with the rate of output is named variable cost. Variable costs include the opportunity costs of using additional labor, materials, and other resources to make more units.

Estimating the cost of a cost object requires the identification and measurement of all the costs associated with it. Linking cost with cost objects is called tracing. The cost that is easily identified as belonging to a particular cost object is called direct cost. Other costs that cannot be easily traced to a particular cost object are called indirect costs. Indirect cost occurs because an organization performs an activity or process that is related to multiple cost objects, which make indirect cost difficult to trace. A cost driver is the cause of the cost of an activity. Cost drivers are ideal tracers of indirect costs when the usage of the cost driver is proportional to the indirect cost.

Product cost should include both direct and indirect cost. The tracing of indirect product cost, also called overhead cost or common cost, is more difficult. Overhead is often peripherally related to a product or service only. To estimate the indirect cost of products, the management accountant must have a good understanding of the operations of the organization. A cost driver causes, or “drives”, the indirect cost of an activity. Ideally, cost driver usage is proportional to the indirect opportunity cost of the activity.

When analyzing the manufacturing process, cut time can be treated as the cost driver for manufacturing cost, both direct and indirect costs. Based on cut time estimation, direct labor, and machinery cost can be calculated by multiplying with a proper rate. The product cost can be calculated by adding it with the direct material cost, set-ups, factory rental, and other factors.

The imminent STEP-NC format (ISO 14649) is designed to embrace most CAX and production information, and it can provide the information required for cut time calculation [54]. The procedure is shown in figure 3-4.

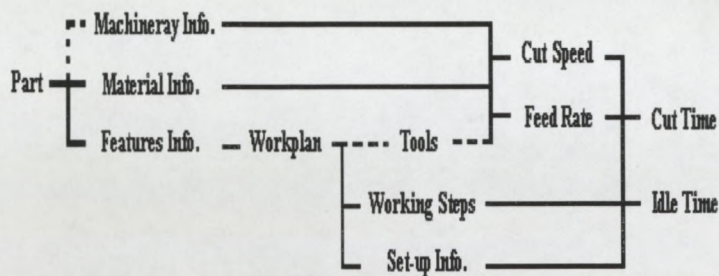


FIGURE 3-4: CUT TIME ESTIMATION

3.3.1.1.1 Cut-time Estimation Based on STEP-NC Data

Currently, machining cut-time data is generated by CAM simulation. The general procedure is highly human interactive, namely loading part drawings into CAM applications, making a machining plan, choosing the correct tool, choosing related machining strategies, dry-runs and displaying the operational report. The process is summarized in figure 3-5 below.

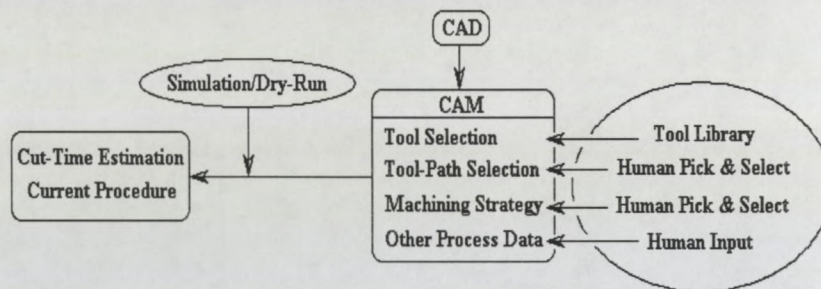


FIGURE 3-5: GENERAL PROCEDURE FOR CUT-TIME ESTIMATION USING CAM SIMULATION

This approach leaves many manufacturing decisions to the operator, thus ensuring that each operator will produce a unique result. Further more, all processes are done manually, that is, the operator selects tools, cutting strategies and is responsible for collision avoidance. This is time consuming. In most cases cut-time estimation is based on experience.

As mentioned, the international Standard for the Exchange of Product Model Data (STEP/ISO 10303) is a standard for the computer-interpretable representation of product information and for the exchange of product data. STEP provides a basis for communicating product information at all stages in the product life cycle [18]. The key word of data exchange in STEP is the *Data Model Sharing*. In fact, in STEP architecture, data models are developed either as Integrated Resources (IR) or as Application Protocols (AP).

STEP-NC (ISO 14649) is more advanced than STEP in numerical control. The data needed for manufacturing a product consists of three significant parts, namely *work plan and*

executables, technology description, and geometry description. STEP-NC is designed to standardize all those parts, and one most importantly, all information is based on part features (which is defined by *ISO 10303 AP 224*). The fundamental principle of the new Data Model is programming in terms of manufacturing features (hole, pocket...), instead of direct coding of sequences of axis motions and tool functions (which is defined by *ISO 6983*). The combination of manufacturing features and technological information is referred to as a “working step”. Working steps represent the essential building blocks of the machining process. Each working step describes a single manufacturing operation using one tool and one strategy. An example of such a working step would be the roughing of a pocket or the finishing operation of a region of a freeform surface [19]. As shown in the figure which follows, ISO 14649 encapsulates geometry, technology and process sequence.

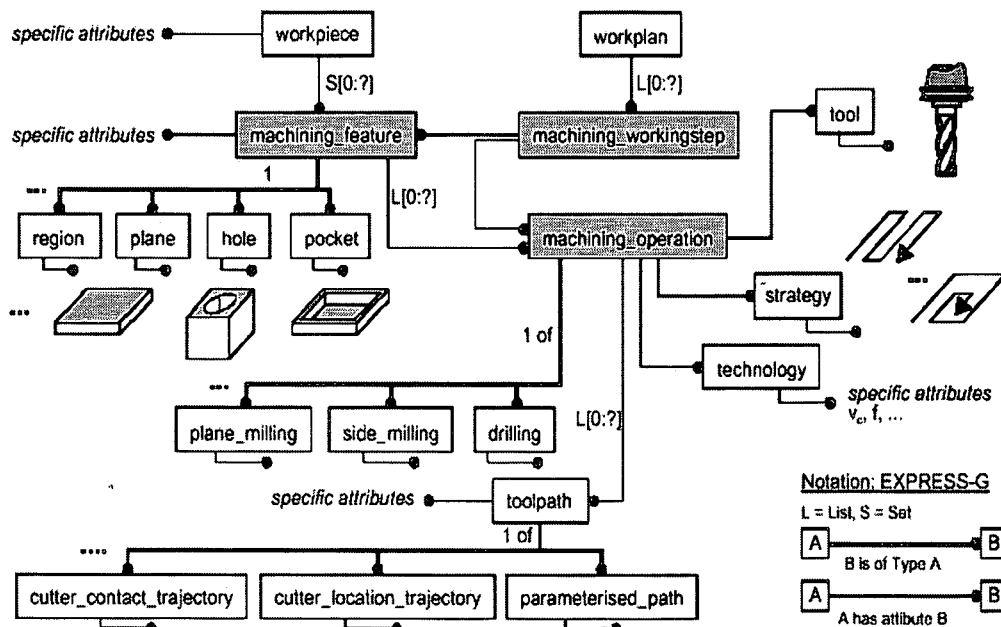


FIGURE 3-6: STEP-NC DATA MODEL SCHEMA [83]

A part program is described in a Physical File Format according to the *ISO 10303 Part 21*. As mentioned, the first section of the part program is the header section marked by the keyword “HEADER”. The second and main section of the program file is the data section marked by the keyword “DATA”. This section contains all information about manufacturing tasks and geometries. The content of the data section is divided into the three significant parts: *workplan and executables, technology description, and geometry description.*

The *technology description* part contains a detailed and complete definition of all working steps used in the work plan. Included in this description is a definition of the work piece and all surfaces, regions and features of the finished part, as well as the association between surfaces, regions, features and working step. A complete *technology description* includes tool

data, machine functions, machining strategies and other process data, including cutting width and depth, spindle speed, feed rate, finishing allowance, and tool selection [19].

If a CAD part file is converted into this format, it will include all the original data that relates to machining, thus it is easily to derive machining related information from this dataset. For example, cut-time estimation can be derived based on this data format, as shown in figure 3-7.

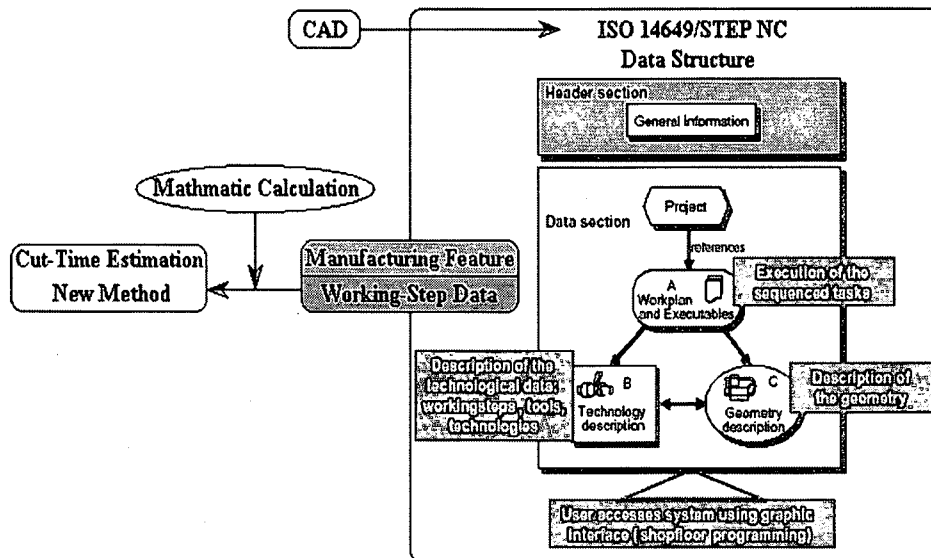


FIGURE 3-7: DIRECT USE OF STEP-NC DATA FOR CUT-TIME ESTIMATION

3.3.1.1.2 A Simple Example

A simple part, which has a pocket feature, is used to illustrate the process (this part file is available on line: <http://www.stepnc.com/strepo/frontend.htm>).

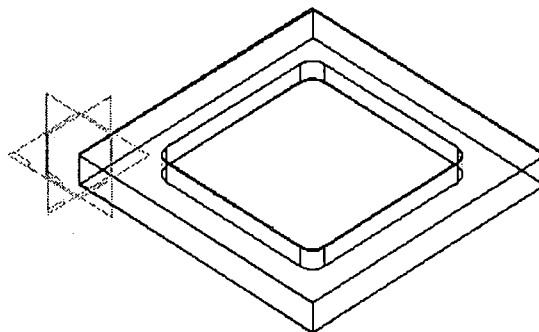


FIGURE 3-8: EXAMPLE PART

Parts of the STEP representation are given below:

```

ISO-10303-21;
HEADER;
/* Generated by software containing ST-Developer
 * from STEP Tools, Inc. (www.steptools.com)
 */
/* OPTION: using custom schema-name function */

FILE_DESCRIPTION(
/* description */ ('ACIS model converted to STEP'),
/* implementation_level */ '2;1');
FILE_NAME(
/* name */ 'pezzol_ap238',
...
FILE_SCHEMA (('INTEGRATED_CNC_SCHEMA'));
ENDSEC;

DATA;
#10=MACHINING_FUNCTIONS('', 'milling', '', '');
.....
#65=MACHINING_TOOL_BODY_REPRESENTATION('shell_mill', (#537, #538), #640);
.....
#80=ACTION_RESOURCE_TYPE('cutting tool');
#81=MACHINING_TOOL('TL SHELL MILL-1', '152.4000 mm FACEMILL', (#131), #77);
.....
#136=MACHINING_WORKINGSTEP('end_mill', 'End           Mill-1-Macro-1-Pocket-
01', '', '');
.....
#552=BLOCK_SHAPE_REPRESENTATION('base shape', (#1497, #494, #495, #496), #640);
.....
#1550=ADVANCED_BREP_SHAPE_REPRESENTATION('', (#1112, #1490), #640);
ENDSEC;
END-ISO-10303-21;

```

This dataset includes the information for machining the part, but the *part 21* syntax, although adequate for the task at hand, lacks extensibility, and perhaps the most limiting factor is that computers must use STEP supporting software. One of the remedies is using XML to translate those into a more readable format. As mentioned, XML will enable developers to implement file-based exchange and visualization of STEP data, but also potentially facilitate the use of STEP models in emerging areas, such as XML-based web services.

ISO 10303 part 28 specifies the way in which XML can be used to represent both EXPRESS schemas and corresponding data. This part determines means by which data governed by EXPRESS schemas could be represented as an XML document (Extensible Markup Language W3C Recommendation). In the example given above, the 'INTEGRATED_CNC_SCHEMA' is implemented.

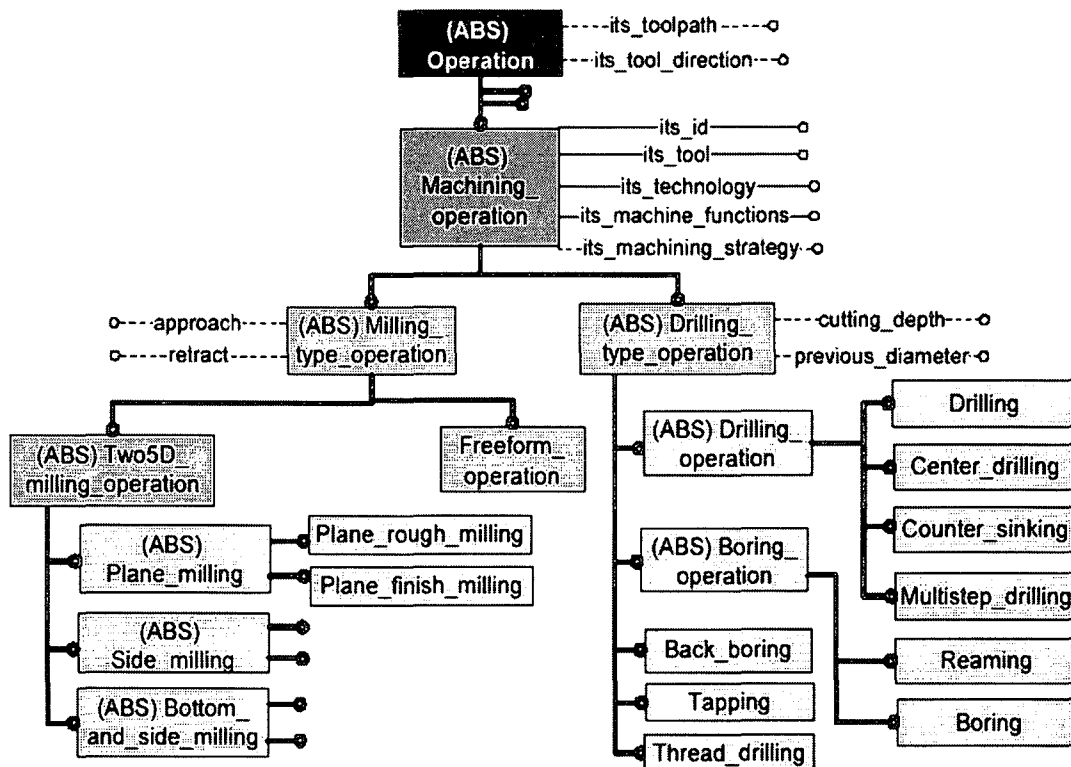


FIGURE 3-9: EXPRESS-G REPRESENTATION OF STEP-NC [83]

A tool called ST-XML, which was developed by STEP Tools Inc (<http://www.steptools.com/strepo/translate.cgi>), is used here to convert STEP *Part 21* data into XML data and objects. It uses CEB techniques, in which XML represents tag names corresponding directly to their counterparts in EXPRESS.

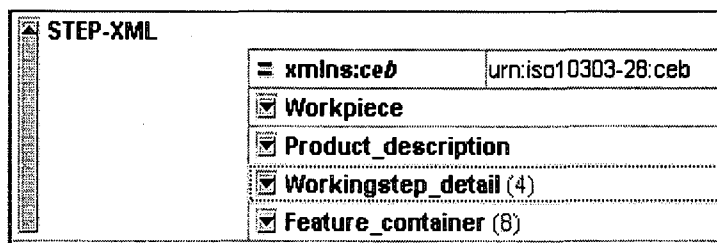


FIGURE 3-10: XML PART DATA REPRESENTATION

The part data is then ready for export. For cut-time estimation, for example, the data is exported to Microsoft Access, and the necessary information is acquired from the data tables, although the Internet can be used if a proper XML Stylesheet Layout (xsl) is assigned (see figure 3-11).

type	depth	name	corner_radius	profile_length	profile_width	tool
RECTANGULAR_CLOSED_PROFILE	25	NC Pocket-1	20	270	270.38.1000	mm ENDMILL

Address: D:\Li\Research\Project\CAM\STEP-NC\xmltest\STEPNC\Simple\test.xml			
bottom_condition	planar_radius	orthogonal_radius	feature_boundary
planar	0.000000		RECTANGULAR_CLOSED_PROFILE 270.000000270.00000020.000000

FIGURE 3-11: WEB REPRESENTATION

As an example, the rough machining time for the pocket feature is calculated. The machining strategy uses a Zigzag method and a simple cut-time estimation algorithm is shown below:

Cutting Steps: $M = \frac{h}{d}$, and round up

Fill in the Zip Line: $N = \frac{(b - 2r)}{2r * A}$, and round up

Cutting-Time: $T = \frac{N * (a - 2r) + (b - 2r)}{f} * M$

Related Data: Cutting Depth: h = 25 mm; Z-Steps: d = 5mm; Pocket Length: a = 270mm; Pocket Width: b = 270mm; Tool Radius: r = 18.05mm; Machining Cut-Feed: f = 1.2 PM; Cut Width: A = 38% (14.6); Speed: 900 RPM.

Comparative results are given in Table 3-1.

	General CAM Process	New Method	Comment
Human Time Involved	8.4 min	3.7 min	56% improvement
Estimated Cut-time	181.7 min	173.925 min	95.7% reliable

TABLE 3-1: COMPARISON OF RESULTS

When a human estimates the cutting time (using a CAM tool), about 8.4 minutes is spent doing so, and the calculated cutting time is about 181.7 minutes. When the person uses the method described, the estimation time is reduced by 56%, with a resulting cut time of about the same duration, even though tool change time and other procedures have been neglected.

3.3.1.2 Profit Margin Expectation

As proposed previously, a Neuro-Fuzzy system can be used for profit margin expectation, because it can combine the parallel computation and learning abilities of neural networks with human-like knowledge representation and explanation abilities of fuzzy systems. Neural networks are low-level computational structures that perform well when dealing with raw

data; fuzzy logic deals with reasoning on a higher level, using linguistic information acquired from domain experts. However, a fuzzy system lacks the ability to learn and cannot adjust to suit new environments. On the other hand, although neural networks can learn, they are opaque to the user. A Neuro-Fuzzy system has both advantages. The neural network becomes more transparent, while the fuzzy system is capable of learning [1].

3.3.1.2.1 Part Complexity

Since cost estimation has not taken into consideration any uncertainty factors and cannot handle imprecision data either, it cannot reflect the true opportunity cost. To overcome this problem, the *Part Complexity* (PC) concept plays an important role in generating a proper profit margin [55].

PC is a combined/joint concept, designed to reflect the uncertainty factors' influence in quoting, and to make the quotation reflect the opportunity cost. Information is the most comprehensive resource in system control and decision-making. In general, system I/O data and external and internal knowledge are the major forms of information. The selection of a limited number of data that contain rich information is a vitally important topic in system identification and adaptive control.

The proposed approach has been divided PC into three parts, namely, main external factors that are derived from the environment, main internal factors, that is, mainly derived from the part itself, and combined factors that are try to balance/reflect the other omitted factors' influence. In each part, a dominant/driven (according to experience) factor(s) is considered.

Competition Factors (for the main External Factors). From the workshop technicians' point of view, the "working load" in the workshop is the main item of external influence. To be more specific, two variables, the order quantity and the date of delivery, are taken into consideration. The plot chart below shows a general relationship between the quotation and the delivery date (which are generated by a commercial software).

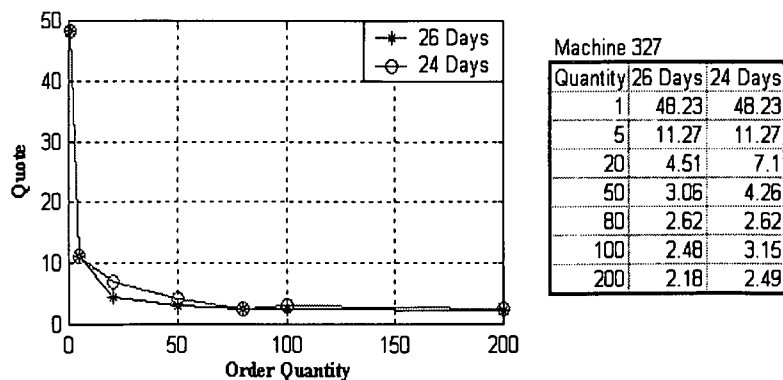


FIGURE 3-12: COMPETITION FACTOR ESTIMATION

Different functions are associated with different workshop situations, because the actual workshop situation/facilities are different. By anglicizing the data that is generated from the software, a formula like the following is used:

$$f(n) = a * \text{arc cot} \left(\frac{b * \sqrt{n}}{c} \right)$$

where a is the basic cost influence factor and b and c are the delivery date influence factors.

Geometry Factors (for the main Internal Factors). A geometry factor value needs to take into consideration the specific workshop facilities and experience situation as well. A geometry factor value is different for different workshops. To make it more general, the geometry factor in this project takes account of two common factors, namely part size and part feature, for analysis.

1. Part Volume Size.

For certain workshop facilities, very small or very large parts are difficult to manufacture. This is approximately quantified using fuzzy logic in the figure below.

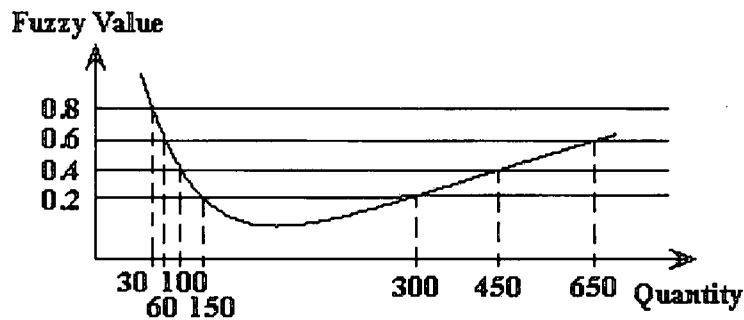


FIGURE 3-13: PART LENGTH SIZE INFLUENCE

Accordingly, there are different fuzzy values for part Length (f_L), Width (f_W), and Height (f_H), and these factors can inter-influence each other. The 'bigger' the values are, the more difficult to manufacture.

As an example, take a workshop that has the following machine limitations: 800mm x 500mm x 500mm, and power 15 HP.

The final part volume/size influence is calculated using the following equation:

$$PS = \sqrt{f_L * f_W * f_H}$$

For this example, for a part size of 300x150x40;

$$PS = \sqrt{0.2 * 0.25 * 0.3} = 0.3873$$

2. Feature Type.

For the feature type fuzzy value, different workshop facilities should be judged differently. For example, consider a Pocket feature and Hole feature. The feature factor chooses five popular types for each feature, and ranks them into five fuzzy ranks. This means the value of each fuzzy group overlaps somewhat with its neighboring groups. One possible setting is shown in Table 3-2.

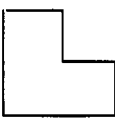
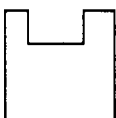
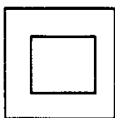
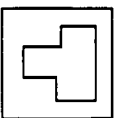

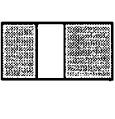
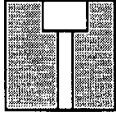
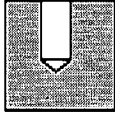

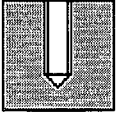
	Very Simple	Simple	Medium	Complex	Very Complex
Feature	0.01-0.3	0.2-0.42	0.3-0.6	0.4-0.7	0.68-0.98
Pocket Milling					
Hole Milling					

TABLE 3-2: FUZZY VALUES FOR TWO FEATURE TYPES

For this project, only two issues are considered for internal factor influence assessment.

Engineering Factor. This factor is used when the internal and external factors cannot account for complexity, like the following:

1. Material. This is a very important factor as materials influence the cost of manufacturing directly. Typical values for six common materials are listed in table 3-3, based on operators' experience.

Plastic-Nylon	Al	Milo Steel	Tool Steel	Stainless Steel	Exotic Ti
1	3	4	5-7	8	10

TABLE 3-3: MATERIAL FUZZY VALUES

2. Tolerance. This also is a very important factor, but considering that tolerance is very complex in nature, it will not be dealt with directly but included in the engineering factor.

The engineering factor can also include influences like working step details, shipping etc, and used to incorporate the less important/other internal and external factors.

The purpose of a structured design is to better balance the various factors, and make it easier for the user to adjust them. By dividing the factors into groups and commencing with the main factors, it is expected that control and adjustment will be easier.

Data Issues. If the above-mentioned is adopted for the project, all the fundamental input information is available. That is, the order quantity and required delivery date can be input by the customer, and the part material, part size, part feature type, machining step-information, and tolerance can be derived from the part STEP-NC data. Using the method, the *part complexity* can be generated from an AI system.

For an AI system, adequate data for training, testing and validation is needed. As this system is still in the development stage, the data used is generated via cost-estimation software (the data generated is for method validation testing only, because it is possible that this software design schema is quite different to an actual workshop quotation process).

All the data has to be pre-processed and post-processed, to make it more suitable for fuzzy system interpretation.

3.3.1.2.2 Fuzzy System Model

In a conventional fuzzy approach, there needs to be linguistic input and output data to set up the fuzzy membership functions (associate the value with Very Small, Small, Medium, Large, Very Large groups, for example). The model designer uses prior knowledge to fix the membership functions and the consequent models. Neuro fuzzy systems are a powerful trade-off in terms of readability and efficiency between a human-like representation of the model and a fast learning method [48].

For this project, a first order Takagi Sugeno fuzzy model (also known as the TS fuzzy model) was used, which a systematic approach to generating fuzzy rules from a given input-output dataset [11]. A TS fuzzy inference system is a set of if-then rules of the form:

$$\begin{aligned} {}_1 \mathcal{R} &: \text{if } x \text{ is } A_1 \text{ and } y \text{ is } B_1 \text{ then } z = p_1x + q_1y + r_1 \\ {}_2 \mathcal{R} &: \text{if } x \text{ is } A_2 \text{ and } y \text{ is } B_2 \text{ then } z = p_2x + q_2y + r_2 \end{aligned}$$

where A and B are fuzzy sets in the antecedent, while p, q, and r are all constants.

These constants will be set via Neuro Network learning. The Takagi Sugeno Neuro-Fuzzy architecture is shown in Figure 3-14 follows:

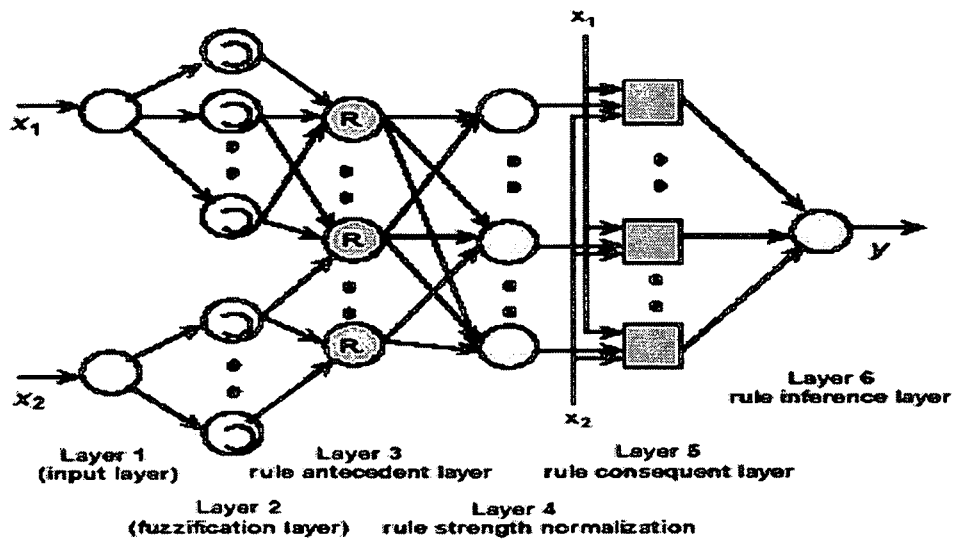


FIGURE 3-14: TAKAGI SUGENO NEURO FUZZY SYSTEM

The detailed functioning of each layer is as follows [1]:

Layer 1 (input layer). No computation is done in this layer. Each node in this layer, which corresponds to one input variable, only transmits input values to the next layer directly. The link weight in layer 1 is unity.

Layer 2 (fuzzification layer). Each node in this layer corresponds to one linguistic label to one of the input variables in layer 1. In other words, the output link represents the membership value, which specifies the degree to which an input value belongs to a fuzzy set, and is calculated in layer 2. A clustering algorithm will decide the initial number and type of membership functions to be allocated to each of the input variables. The final shapes of the Member Functions (MFs) will be fine tuned during network training.

Layer 3 (rule antecedent layer). A node in this layer represents the antecedent part of a rule. Normally a T-norm operator is used in this node. The output of a layer 3 node represents the firing strength of the corresponding fuzzy rule.

Layer 4 (rule strength normalization). Every node in this layer calculates the ratio of the i -th rule's firing strength to the sum of all rules firing strength, according to the following;

$$\overline{w}_i = \frac{w_i}{w_1 + w_2}, i = 1, 2, \dots$$

Layer 5 (rule consequent layer). Every node i in this layer has a node function;

$$\overline{w}_i f_i = \overline{w}_i (p_i x_1 + q_i x_2 + r_i)$$

Layer 6 (rule inference layer). The single node in this layer computes the overall output as the summation of all incoming signals;

$$\text{Overall output} = \sum_i \bar{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}$$

After training, knowledge is stored as synaptic weights between neurons, and the system output can be interpreted by a set of IF-THEN rules.

3.3.1.2.3 Model Training and Testing

In the initial design stage of the project, a total of fifty software-generated datasets were collected. Thirty-seven datasets were chosen for training, and the parts ranged from *Very Simple* to *Very Complex*. The remaining thirteen sets were used for (accuracy) checking purposes. By using the aforementioned Neural-Fuzzy system, respectable profit margin training for different products/situations was obtained, as shown in figure 3-15.

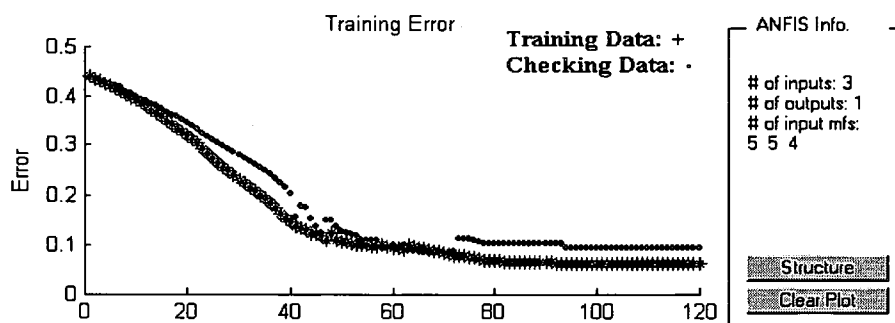


FIGURE 3-15: TRAINING PERFORMANCE

It can be seen that at epoch 72, the checking error suddenly increased. This indicates over fitting, and thus the system was limited to 72 epochs, and the training error was then 0.077644.

When system checking was carried out (see figure 3-16), the average error was 0.10954.

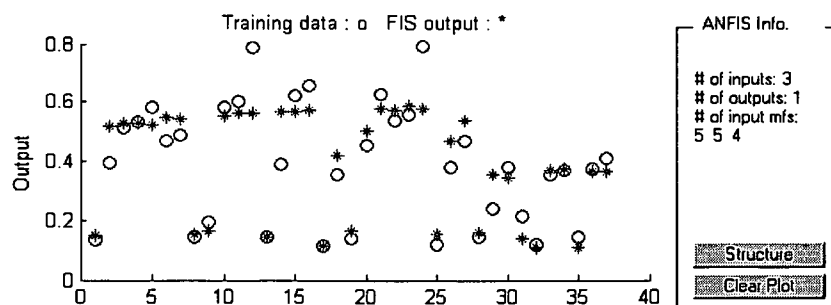


FIGURE 3-16: TRAINING ACCURACY

After training, the model could be used for quotation generation. For example, with a product RFQ with a quantity of 80 and a 26 days delivery period, and assuming the quantity is sufficient and delivery period is long enough, the generated quote price is treated as the production cost, which is \$27.83. The original software generated quotation is \$54.32. If the training data is pre-processed to range between 0 and 1, the output data can be pre-processed as following;

$$\text{Training Output } 3 = 1/(54.32/27.8) = 0.5123).$$

Using our system, the output is 0.5208, which means the quote price is \$53.44 (viz. *System Quotation* $3 = (1/0.5208)*27.83 = \$53.44$).

It can be seen that even when the software design schema is not known, this system can generate a comparable quotation for certain parts. This indicates that the factors that have been chosen as inputs include profit margin data, but further analysis of these inputs is needed. The testing has shown that the quality of a training data set has a great influence on the quality of system output. If the seven large error sets are removed, the general system output quality is improved, as indicated in table 3-4 below.

Error tolerance: 0.05	Epoch	Average Check Data Error
37 sets	210	0.085465
30 sets	186	0.089002

TABLE 3-4: TRAINING DATA INFLUENCE ON SYSTEM

Further testing showed that the system functions were inefficient at adapting to new datasets, which demonstrated that insufficient training had been carried out. In reality, it is impossible to exhaust all possible training scenarios; what was necessary was to improve the system with *dissimilar* datasets. This can be achieved by enhancing the system with an adaptation/self-learning capacity. In addition, finding ways to improve the accuracy of *Feature type* and *Engineering factors* will also greatly enhance the system.

3.3.1.3 System Adaptation Design

Generally speaking, an adaptive system, for example, a learning system, is capable of working from a very low level of prior information, or so-called 'incomplete information', that is, with very little knowledge of system environment and disturbance. From the system control point of view, a controller or system model in an adaptive system can automatically upgrade structure and/or parameters to match the changes of dynamics and inputs of the controlled plant with on-line or historical information. As a result of system adaptation, satisfactory or desired reference control behavior may be provided. Adaptive systems can be

divided into two categories based on adaptive action, namely 'environment knowledge driven' and 'control performance driven' systems.

An AI integrated rapid quotation system will generally require for an online adaptation, self-learning capability. For example, when a catalogue of product cannot compete with production order in price, the system should have the ability to adapt for this scenario. The system should be 'intelligent' enough to put the quote price down automatically. As quotation is a one-way process, this is not exactly an accurate/proper quote price for a product. The general AI system's self-adaptation algorithm, which is learning from 'error', is hard to apply in such a situation. So, an alternate method is using the batch-training method, which is triggered by a certain algorithm or by management decision.

If a batch training method is used for the Neuro-Fuzzy system upgrading, there is the question of training database construction. The system should have adaptations that can respond to system's performance or management decisions.

The variances between actual profit and the expected profit margin provide management with a tool to evaluate the effectiveness of manufacturing departments. On the other hand, variances below expected profit might reflect an uncontrollable cost increase. In this case, variances serve as an effective reporting system. By readily identifying costs/expected profit margin that is out of line, management can take appropriate action, thus providing a direction to make use of the AI system to reflect such changes.

In a WBM environment, the 'accepted'/processed quote may be reasonable or likeable and favored by RFQ side. On the manufacturing side, whether the system needs to be re-established or not is determined by the profit performance. The following two 'lost' situations are considered in the decision-making.

The loss that occurs through a lost order. One reason for loss of order is because the quote price is too high. If that prediction yields a price that will not be competitive, the company must (1) redesign the product, (2) improve manufacturing costs, (3) use a competitive price and accept a lower profit margin, or (4) do all three.

The loss that occurs through a low quotation price, which is shown by pass order statistic. Basically, the management requires the system-generated quotation outcome can satisfy the profit expectation. This could interfere with strategy decision issues. In such a situation, the system should have the competence for human adjustment.

To make the system adaptable, a feedback loop to update the training datasets should be constructed. The special adjustment mechanism designed for such system's updating need s to be combined with prior human knowledge. For example, one reason for loss of order is because the price cannot compete with other manufacturers' prices, and gives a hint for improvement. Somehow the 'rejected' quote should be reduced in price, which means that

products that have similar properties will need to have profit margins adjusted downwards. This is a kind of 'error', and provides a clue for adjustment.

3.3.1.3.1 Self-learning Training and Testing

One problem with model validation for models constructed using adaptive techniques is selecting a data set that is both representative of the data the trained model is intended to emulate, yet sufficiently distinct from the training data set so as not to render the validation process trivial. Unfortunately, there are still not many datasets available at this stage. However, the updating method can be verified using those datasets available. Hopefully when a large amount of data is collected in the final stage, the data will contain all the necessary representative features, so the process of selecting a data set for checking or testing purposes is made easier [56].

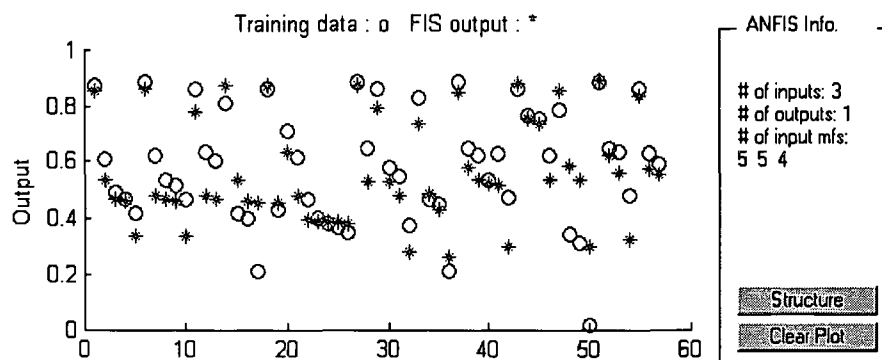


FIGURE 3-17: A NORMAL TRAINING RESULT

Some values used to test the system's adaptation ability are listed in the table below.

Epochs: 220 (57 inputs)/Average Error	3 inputs	2 inputs
Normal Process	0.10049	0.086553
Revert Output Processing	0.090684	0.10137
Upgrading Method 1 (cut 7 data)	0.063087	0.062659
Upgrading Method 2 (10% profit off for 3 set)	0.1005	0.086674

TABLE 3-5: COMPARISON OF UPGRADING METHODS

In table 3-5, it can be seen that if the large error training sets are ignored, the Neuro-Fuzzy system's performance can be significantly improved. The test result shows that the training dataset's quality has a significant influence on the system's performance, and also implies that the more qualified the input factors, the more accurate the results, because the NN mapping will be more efficient. The proposed upgrading methodology (updating training

database, followed by batch training) also shows some improvements. How to construct an algorithm to use for database upgrading is still a challenge, nonetheless. It is also demonstrated that the system can react to the management decisions (Upgrading Method 2), but the result is not as good as expected; that is, only one out of three dataset's profit margin is reduced. Thus, further tests have to be conducted with more qualified training data sets.

A database summarizing relevant historical data is critical. This database must be audited periodically for accuracy, and to guarantee the accuracy of this part of the estimate. One way to improve the system is to try to build up an 'ideal quotation database' which can be used for training, and which should combine human/management decisions. This database is constructed with those 'good' quotations, and those quotations with characteristics like long and stable contracts; a good relationship between manufacturer and buyer; favoured by the management/financial department, and so on.

The cost estimating function does not produce exact cost data but rather supplies cost figures having a high probability of falling within an acceptable range. Most of the estimates show relatively small deviations, which is a general characteristic of good estimating practice. The average estimates over a period of time must be reasonably close to the average manufacturing cost. The major cause of inaccuracy of product cost estimates is misunderstandings regarding the features, performance requirements, and quality needs for the product. It is critical that this information be used to update the database summarizing relevant historical data.

3.3.1.4 System Architecture

Integrating the above-mentioned subsystems allowed a demonstration version of the proposed quotation system to be constructed. A three-layer architecture was proposed here, with a web browser acting as the 'thin' client and a web server acting as the application server. The draft architecture is shown in the figure below:

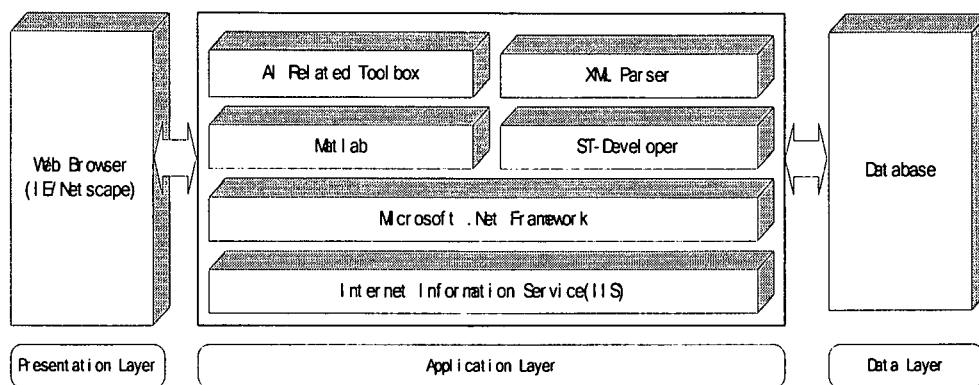


FIGURE 3-18: ARCHITECTURE OF DEMONSTRATION AQS

The detailed functions of these three layers are [57]:

Presentation Layer: This layer acts as a client-server interfacing platform. It does functions like receiving user events, controlling the user interface, and presenting the system generated quote. At this layer, the user only needs to use the web browser to access the web server without installing any corresponding software on the local computer.

Application Layer: This is a very important layer as all the application logic is implemented in this layer. There are several key parts in this layer, namely IIS & .Net framework (they are the foundation of the web server), Matlab & AI related toolboxes (they provide tools for AI based implementation), ST-Developer (updating STEP data into STEP-NC data in a XML format), and XML Parser (parsing XML data and transferring them into relation database).

Data Layer: This layer is responsible for data storage. The widespread relational database systems can be adopted. Here, existing legacy system databases are used.

The main advantage of this architecture is that it separates the user-interface-control clearly and presents data for application-logic. By doing so, the whole system can be upgraded easily. The corresponding quotation Data Flow Diagram (DFD) is shown in figure 3-19.

When a new product quotation needs to be generated, the part's CAD file (in STEP format) should be inputted into the system. It will be translated into a STEP-NC file (in XML form). Subsequently the XML Parser will parse the XML file and translate data in the relational database. After that, two sub processes are used to deal with the data.

Cost Calculation: The engineering based approach was used to obtain product cost; which means that some accounting data (such as material price) from MIS was required.

Profit Margin Expectation: The AI approach was used to generate a proper profit margin for the new product; which means that some marketing and technology data (such as a quotation history) is required from MIS. After obtaining the Product Cost and related Profit Margin, the quotation can be easily derived.

To make the system more adaptive, a loop for database updating should be conducted. If an ideal quotation is identified, the system will record the quotation result and related information, and it will be used for further AI training.

3.3.2 Costing Follow Up

Organizations are dependent on their management accounting systems to provide information in a dynamic environment. The whole management accounting system is very important for this project, but only the cost analysis will be addressed, as it is important for estimation follow up.

Cost analysis is the process of obtaining *cost breakdowns, verifying cost data, evaluating specific cost elements, and examining data to determine the allow-ability of the costs including the budget.* The objective of a cost analysis is to *determine that proposed costs are reasonable and locatable and are consistently treated in accordance with generally accepted accounting principles.*

Cost is the use of organizational resources. The tracing of indirect product costs, also called overhead cost or common cost, is more difficult. To trace Indirect Product Costs, at least one Cost Driver is needed. A cost driver causes, or "drives", the indirect cost of an activity. To choose the cost driver it should be recognized whether the activity causes unit-level, batch-level, product-level, or facility-level cost. Ideally, cost driver usage is proportional to the indirect opportunity cost of the activity. Unit-level indirect cost should have cost drivers that vary with the number of units, and batch-level indirect cost that vary with the number of batches, and so on.

Cost allocation is the process of assigning indirect cost-to-cost objects. The subjective nature of indirect cost allocations makes the process one of the most controversial in accounting. An allocation base is a characteristic of the cost object that is used to allocate cost. Cost drivers are a type of allocation base that reflect the cause of the indirect cost being allocated. Cost drivers are important for estimating the cost of a product or other cost object. In summary, the cost allocation procedure allows for the flow of cost from a cost pool to cost objects. Cost objects are identified, cost is accumulated in cost pools, allocation bases are chosen, and application rates are calculated, as well as indirect cost is allocated (a more complicated way to allocate overhead cost is to use multiple allocation bases).

Actually, the costing in practice is similar to an auditing process. It requires strong logic ability and accurate data collection is very important. If a quality costing is followed, the quotation/ cost estimation quality improving can be checked/expected.

3.3.3 Section Summary

Recent developments in automatic feature recognition and feature-based design are making a great impact on WBM. Forming standards such as STEP and STEP-NC have accelerated the WBM development process. STEP and STEP-NC, together with the XML language, are used for data transformation via the Internet and have revealed the potential for WBM development. To organize all the related technologies for a web AQS, integration that needs to cope with "networking" issues, "integration" issues and "managing" issues is required.

In this section, a model for an adaptive quotation system was described. It contains two main parts; one is cost estimation/cut time calculation, and one is profit expectation. STEP-NC allows a complete database of machining information to be built around the digital product model. By using this format, much manufacturing related information could be derived with more accuracy and faster response time. By using this method, cut-time estimation is far

more accurate and reliable than estimated by experience, and it is quicker than simulation via a CAM package. A Neural Fuzzy System is used to generate the *Profit Margin* for quotation calculation. By clearly structuring quotation related factors, especially uncertainty factors (grouping into three groups, namely *Internal*, *External* and *Other Combined* factors) makes further upgrading easier. More importantly, this structuring has made room for implementation of a self-learning function for this system, by monitoring the dominant factor changes. This system is also different to normal quotation systems in terms of profit margins, allowing flexible profit margins (normally a fixed percentage - 20%, for example - in most quotation packages).

The whole quotation generation can be depicted in figure 3-19 below.

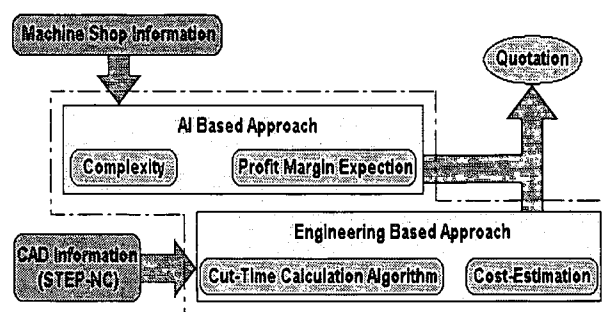


FIGURE 3-19: PROPOSED DEMO QUOTATION SYSTEM

By using this method, the server can deal with all the processes automatically, and the quotation results can be fed back to the client directly via the Internet. To realize AQS for WBM, data generation and mining, network architecture design and Internet data transformation issues will need further investigation.

3.4 System Integration

As was demonstrated in the system conceptual design, a quotation can be generated automatically via the Internet, and it can be expected that the generated result can achieve some form of the estimation's requirement [56]. The advantage of the proposed system is that it is combined with the neural network's self-learning function. With the backup of a costing system and MIS, the output of the system can be tuned to achieve even better results than the usual approach.

As has been presented, this system is made up of three parts: cost calculation, profit margin expectation, and system integration. In this section, details of the system construction and each parts' real role is presented, including a brief description of the hardware requirements and operating system, software used, programming outline, and user interface design. The database and advisory system for this system are also elaborated upon.

The different methods are compared and limitations and memory problems are discussed in order to achieve better understanding. The advantages and disadvantages of the analysis are detailed in the summary, and can provide some guidance for further development.

3.4.1 System Structuring

From a system design point of view, the system can be summarized as three technical components; one is cost calculation, one is profit margin expectation, and the other is system integration. For cost calculation, the CAD information transformation was the first technical problem encountered; for profit margin expectation, the NN architecture and training are the tasks that need investigation; system integration stand-alone always is the challenging part in system construction. To summarize what was achieved in the conceptual design section, the corresponding quotation Data Flow Diagram (DFD) is shown in figure 3-20 below.

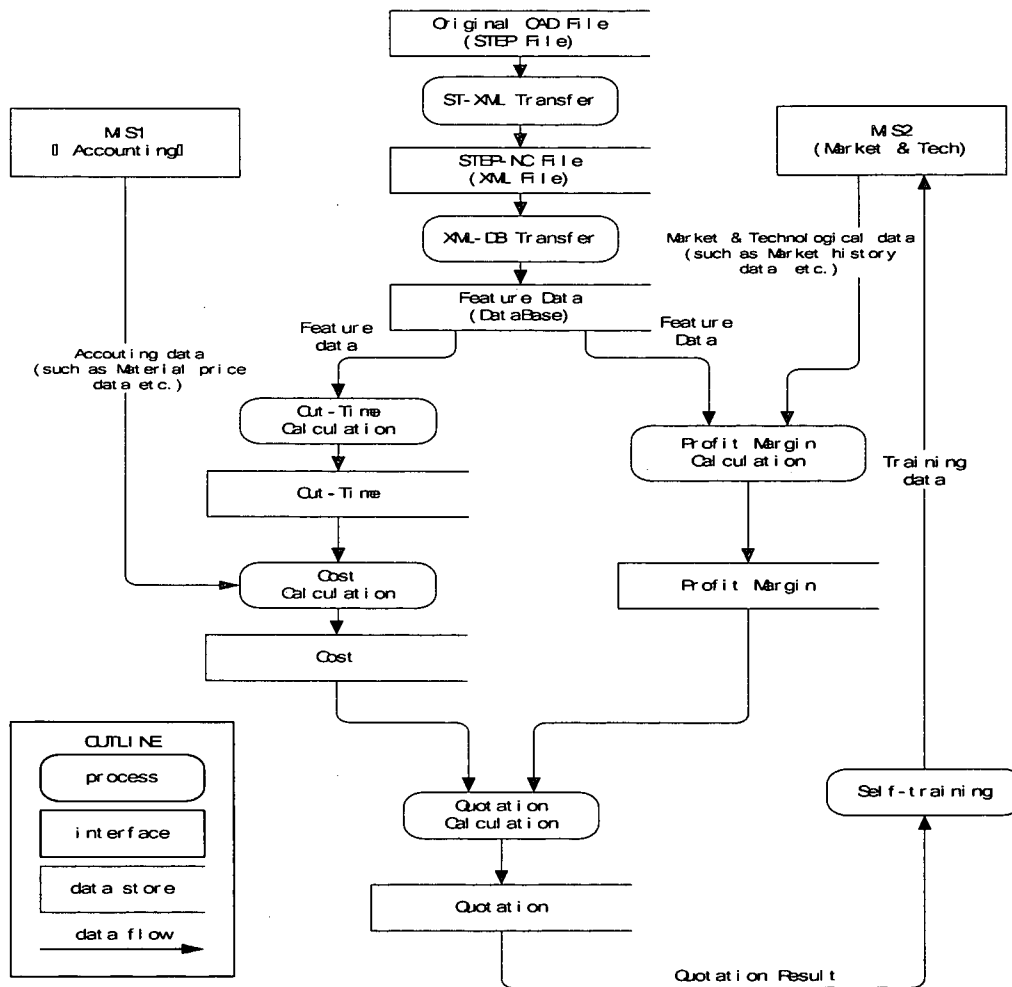


FIGURE 3-20: DFD FOR THE AQS

The system process/data flow has its origin in the product CAD model input; the client designs the product using CAD software (e.g. AutoCAD, Solid Edge, etc.). The input process requires the client to use CAD software to generate a part CAD file in some popular format, such as the dwg format, and then to use the CAD application to translate the file into a STEP standard format [79] - most CAD software providers have already integrated this function into their CAD applications.

To make the CAD information transferable via the Internet, transformation of the STEP file into XML format is necessary. Here a ST-XML tool is used for this purpose. After the system converts the STEP file into the XML format, a further conversion, to the STEP-NC format, is carried out. At that point, the STEP-NC format will contain all the required product information for manufacturing. This can be used as a basis to generate the quote.

The process then is separated into two flows. One is the cost estimation (considering the main cost factors: 1.cut-time (machinery cost), 2.labor hours, 3.material cost); the other is the profit margin expectation (marketing history data, price & success, competition etc.). The system uses the method described in the conceptual design section.

One essential point in practice is the quotation follows up, which can be viewed as a self-training cycle in the process flow chart. The quotation needs a costing system as a follow up, so it can provide the required information for correction, and also tune the preferred data to the system to achieve a better self-tuning result.

3.4.1.1 Process Detail

At first, when a new product quotation needs to be generated, the product's CAD file (in STEP format) should be uploaded into the system. It will be converted into a STEP-NC file (in XML form). Subsequently the XML Parser will parse the XML file and translate the data in a relational database. After that the following two subsystems are used to process the data:

Process one: Cost Calculation

An engineering based approach is used to determine product cost. Some accounting data (such as material price, etc.) from MIS is needed.

Process Two: Profit Margin Expectation

An AI based approach is used to generate a proper profit margin for a new product which has been integrated into the system. It also needs some marketing and technology data (such as quotation history) from MIS.

After obtaining the product cost and related profit margin, the quotation can be easily derived with the formula:

Product Quotation = Product Cost x Profit Margin

For system adaptation purposes, a feedback loop is implemented to update and enhance the training database. That is, if an ideal quotation is identified, the system will record this quotation result and store the related information in the training database, and it will be used for the next AI quotation training.

System Architecture

To integrate these two process flows and combine the related technologies, a three-layer architecture is proposed here, with a Web browser acting as the 'thin' client and a Web server acting as an application server. As stated previously, the detailed functions of these three layers are:

Presentation Layer. Acts as a client-server interfacing platform. It does functions like receiving user events, controlling the user interface, and presenting the system generated quote etc.

Application Layer. There are several key parts in this layer, namely the IIS & the .Net framework (the foundation of the web server), Matlab & AI related toolbox (provides tools for AI based approach implementation.), ST-Developer (transferring STEP data into STEP-NC data in an XML format), and XML Parser (parsing XML data and transferring it into a relation database. In this demo, XMLSpy is used as the parser).

Data Layer: This layer is responsible for data storage. Common relational database systems can be adopted. Here, existing legacy systems databases are suitable.

The System Architecture (Network Topology) is illustrated in figure 3-21 below.

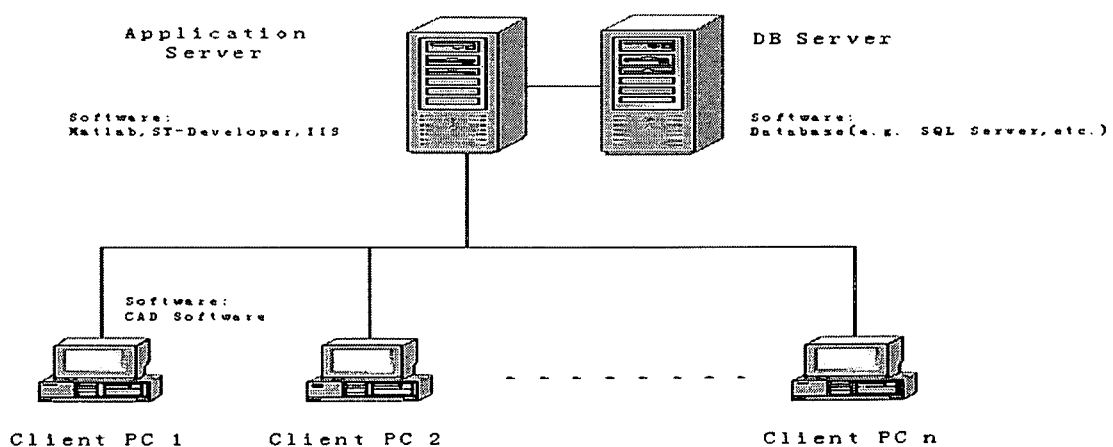


FIGURE 3-21: SYSTEM ARCHITECTURE (NETWORK TOPOLOGY)

The main advantage of this architecture is that it separates the user-interface-control clearly and it presents the required data for the application logically. By doing so, the whole system can be maintained and upgraded easily.

3.4.2 Software Implemented

After considering the software available on the market and the design requirements, several software integration plans are listed as below.

Plan1: Matlab(CGI+mFiles) + ASP + IIS + ...

Plan2: Matlab(COM) + MS.Net + IIS + ...

This plan is suitable for lab and research purposes, because these two plans take advantage of Microsoft products.

Plan3: Matlab(CGI+mFiles) + Java(Plug-in) + IIS/JavaWebServer + ...

Plan4: Matlab(CGI+mFiles) + MS.Net + IIS + ...

Those two plans are more likely for business use. More effort is required for development.

As this is a prototype system, Plan 2 was chosen. The software implemented is listed in the table below.

Software	Description	Remarks
.Net	.NET Framework Redistributable 1.1	For Server use
IIS 5.0	Windows 2000/XP component	
Matlab	Matlab 12.0/13.0	
Access	MS Office (Access, Excel, etc.)	
ST-XML	ST-XML (need 2.0 or higher version)	

(.Net from <http://msdn.microsoft.com/netframework/technologyinfo/howto/get/default.aspx>)

TABLE 3-5: SOFTWARE IMPLEMENTED

- Matlab

One of the key features of the system is that it is built on the Matlab platform. As a result, users have direct access to the wide range of Matlab - based tools for generating, analyzing, and optimizing systems implemented in Matlab. These tools include Matlab application toolboxes and specialized collections of M-files for working on particular classes of problems. Toolboxes are more than just collections of useful functions; they represent the efforts of some of the world's top researchers in fields such as control, signal processing and system identification. Matlab application toolboxes, therefore, allows one to stand on the shoulders of world-class scientists [62].

In this project, most programming is done within Matlab's compile environment, as it is designed for easy integration with other popular software/programming languages. The advantage is that it uses the best aspect of the Neural Network toolbox and the Fuzzy Logic Toolbox.

- .NET

This is an integrated component of Microsoft Windows 2000/XP software.

- Internet Information Services

Internet Information Services (IIS) is a free component of Windows 2000. To run IIS, one must have Windows NT 4.0 or later.

Active Server Pages (ASP) is a Microsoft technology. An ASP file is just the same as an HTML file, which can contain text, HTML, XML, and scripts (scripts in an ASP file are executed on the server). The main difference between ASP and HTML is that when a browser requests an HTML file, the server returns the file; but when a browser requests an ASP file, IIS passes the request to the ASP engine. The ASP engine reads the ASP file, line by line, and executes the scripts in the file. Finally, the ASP file is returned to the browser as plain HTML. The advantages of ASP technologies are:

- i. Dynamically edit, change or add any content of a web page
- ii. Respond to user queries or data submitted from HTML forms
- iii. Access any data or databases and return the results to a browser
- iv. Customize a Web page to make it more useful for individual users
- v. The advantages of using ASP instead of CGI and Perl, are those of simplicity and speed
- vi. Provides security since your ASP code can not be viewed from the browser
- vii. Since ASP files are returned as plain HTML, they can be viewed in any browser
- viii. Clever ASP programming can minimize the network traffic.

- Access

Access is a relational database that is distributed with Microsoft Office. The biggest advantage of Access is its convenience. It was used to construct the related database for this system at an infant stage. After the prototype edition is finished, a more powerful platform for database construction should be considered, as Access as a whole has some limitations. In particular, it is not suitable for large data transformations.

It is possible to upgrade the Access database into another Structured Query Language (SQL) - based relational database if it is needed. The advantages of an SQL-based relational database are easy database design, easy data management and easy data access using SQL [b24]. The application programmer is only concerned with the logical view of the database. The details

of physical storage, the access paths and data structures are handled by the relational database management system. A relational database exhibits both data independence and structural independence.

- ST-XML

ST-XML is an add-on for ST-Developer that provides a set of tools and libraries to read and write XML files. By storing STEP data in XML files, it is possible to develop an application to use standard Document Object Model (DOM) and SAX XML processing tools to manipulate STEP data, streamlining application development and deployment.

With ST-XML, one can read and write STEP data in two XML bindings: the Object Serialization Early Binding (OSEB) and the Containment Early Binding (CEB). The OSEB is a Part 21-like encoding for the exchange of a complete model instance. The CEB allows a user to define the XML format to be used for STEP data exchange and supports both complete model and partial model exchange. The CEB processor is implemented as a C++ class library which adds XML capabilities to the ST-Developer. With this library, one can read and write STEP instances and control how data is converted from STEP to XML (and vice versa if necessary).

Unlike a filer which converts an entire model between XML and STEP, the API in ST-XML allows you to export or update individual instances, and thus create simple, compact XML data sets. The Application Programming Interface (API) can be controlled from a C++ program or from the header of the XML data. Thus, the server side of a distributed STEP XML application can be implemented without any programming at all.

3.4.3 Database Construction

The supporting database is one of the core parts of the system. Ideally, all information, entered by the user while doing an analysis as well as default values, e.g. material properties and the results of the quotation, must be stored in a database. This will help to speed up the revision process.

In practice, involving the various data sources which start from the initial point, is hard to achieve (this means that many fundamental systems should be in place to collect the first line data). Therefore, most of the database constructed here is a 'buffer database', which means that it is a collection of information that can link to this system directly. As for the source of the information, it may require other systems' support, for example, MIS.

A part/product related database must be provided. The stock size, material properties and order quantity information must be stored in this database.

The machine and workstation information must be stored in a database. All the information about the machines that will be required to machine a part must be stored for the purposes of costing. For this project, the databases created and used are listed in table 3-6.

*.mdb File Name	Description
Database_Test.mdb	System default study database
New_Product.mdb	New product basic information
ProductInfo.mdb	Store transferred XML info
WorkshopInfo.mdb	Used to collect quotation related info from MIS
CustomerInput.mdb	Web database with which to contain web inputs
Null.mdb	Null database
Null_New_Product.mdb	Null New_Product.mdb

TABLE 3-6: LIST OF MDB FILES

There are various sources, and they have been classified into different System ODBC databases, so as to keep their own characteristics of data type and thus make it easy to tune. The relationships/linkage of these databases is illustrated in the figure below.

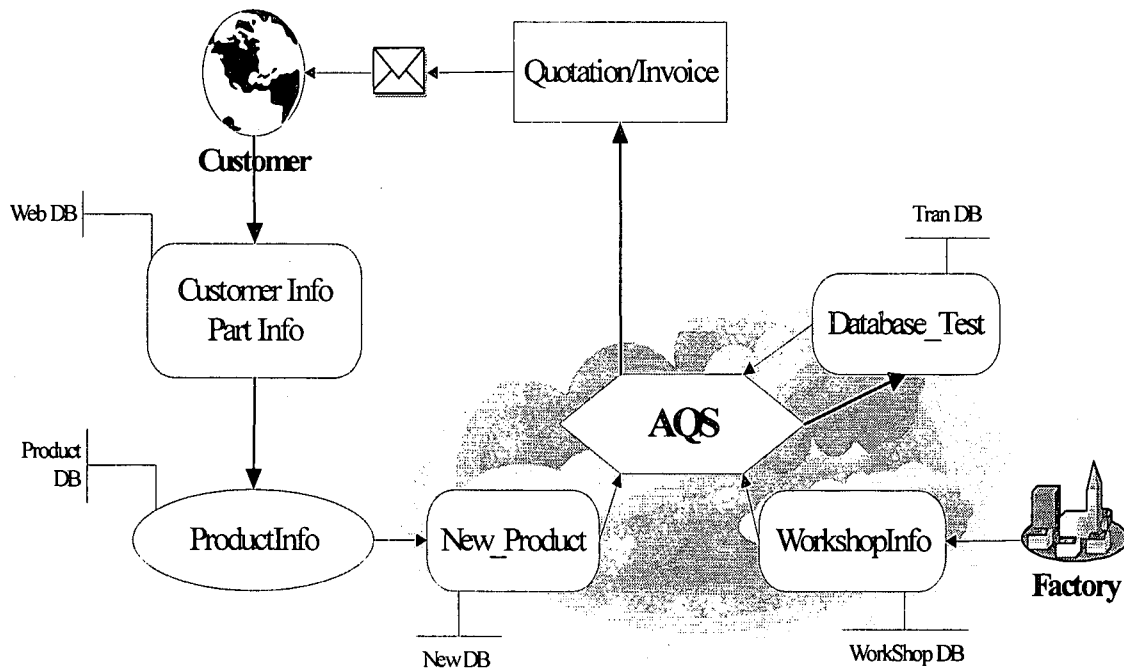


FIGURE 3-22: SYSTEM DATABASES RELATIONSHIP

To make the databases available when called by other applications, each has to be assigned a configured Open Database Connectivity (ODBC), whereby a name is given to identify different data sources. The ODBC name of each database is listed in table 3-7.

ODBC Name	Statement
TranDB	Database_Test.mdb
ProductDB	ProductInfo.mdb
WorkShopDB	WorkshopInfo.mdb
WebDB	CustomerInput.mdb
NewDB	New_Product.mdb

TABLE 3-7: LIST OF ODBC NAMES

For the prototype, the techniques implemented are kept as simple as possible. Down the line, some of the databases can be combined to achieve better integration and make management convenient.

3.4.4 System Programming

The programming stream can be best understood by examining the system architecture and the main process flow, depicted in figure 3-20.

Briefly, Matlab acts as a platform for the system's programming/construction in this prototype version. Microsoft's Access database is used as a buffer zone for data storage and exchange, that is, any related information (including indistinct information) is transferred and interpreted into a specifically located Access database. Through the Matlab interfacing program, the required data is retrieved, processed, and feedback is given in terms of the results. The details are given below.

3.4.4.1 Key Technologies

3.4.4.1.1 Method Used to Translate STEP Data into XML Format

There are three ways to translate STEP data into the XML format:

1. Catching the Window handle;
2. Using a Command line;
3. Using Plug-in Programming.

After comparing most of the available application software, the command line method is the best. At this stage, a simple function should be chosen to fulfill the requirements. An ST-XML command is used to translate the STEP data into the XML format.

For example, using the following would do the job:

```
ceb -write foo.stp -o foo.xml
```

where *ceb* is a ST-XML supported command, *foo.stp* is the input CAD file, and *foo.xml* is the output XML format file.

3.4.4.1.2 XML File Handling

As shown previously, by using an XML application (XMLspy in this case), xml formatted data can be transferred into an Access database. Using the DOM interface provided by the XML application, the transfer function can be integrated with another application seamlessly (COM based API, C, C++, VB, Delphi and from scripting languages like VBScript and JavaScript). Here, the Matlab platform is used. (XMLSPY: xml->db export (Java))

MatlabCOM Builder enables one to integrate compiled Matlab models into Visual Basic, C++, or any other language that supports COM (COM is an acronym for Component Object Model, Microsoft's binary standard for object interoperability). COM is the widely accepted standard for integration of external functionality in Microsoft Office applications, such as Excel). Each Matlab COM Builder component is built as a stand-alone COM object. Each Matlab function included in a given component appears as a method of the created COM class. The resulting call syntax from Visual Basic, for example, is systematically mapped to the syntax of the original Matlab function. This mapping provides an intuitive bridge from Matlab, where the functions are created, to Visual Basic, where the functions are ultimately called. Matlab COM Builder provides robust data conversion and an array of formatting to preserve the flexibility of Matlab when calling from Visual Basic. In addition to this, the errors originated from Matlab functions can be manifested as Visual Basic exceptions automatically. The information returned with the error always makes reference to the original Matlab code, making debugging easy.

3.4.4.1.3 Matlab B/S Structure

The Matlab Web Server enables a user to create Matlab applications that use the capabilities of the web to send data to Matlab for computation and to display the results in a web browser. The Matlab Web Server depends upon Transmission Control Protocol/Internet Protocol (TCP/IP) networking for transmission of data between the client system and Matlab. The required networking software and hardware must be installed on the system prior to using the Matlab Web Server. In the simplest configuration, a web browser runs on the client workstation, while Matlab, the Matlab Web Server (Matlabserver), and the web server daemon (httpd) run on another machine.

The Matlab Web Server consists of a set of programs that enable Matlab programmers to create Matlab applications and access them on the web. They are:

1. `Matlabserver`. Manages the communication between the web application and Matlab. `Matlabserver` is a multithreaded TCP/IP server. It runs the Matlab program (M-file) specified in a hidden field named `mlmfile` contained in the HTML document. `Matlabserver` invokes `matweb.m`, which in turn runs the M-file. `Matlabserver` can be configured to listen on any legal TCP/IP port by editing the `Matlabserver.conf` file in Windows NT or running `webconf` on Solaris/Linux.
2. `matweb`. A TCP/IP client of `Matlabserver`. This program uses the Common Gateway Interface (CGI) to extract data from HTML documents and transfer it to `Matlabserver`.
3. `matweb.m`. This calls up the M-file that you want the Web application to run.

Two configuration files are used in conjunction with the Matlab Web Server programs:

1. `matweb.conf`: A configuration file that is needed by `matweb` for connecting to `Matlabserver`. Applications must be listed in `matweb.conf` and only one `matweb.conf` will work in B/S structure. Thus,

```
<Root>\webserver\matweb.conf  
eg: D:\MATLAB6p5\webserver\matweb.conf
```

The standard format is:

```
[mfile_template]  
mlserver=localhost  
mldir=D:/MATLAB6p5/work/MyMatWeb/Test
```

2. `hosts.conf`. This is an optional file which provides additional security. If `hosts.conf` is present, only listed machines can connect to the Matlab Web Server. Machines are listed by name in a single column, e.g., `parrot.mathworks.com`, `bluebird.mathworks.com`. Machines must be listed by name, not by an IP number. The operating system then converts the name into a valid IP address.

The Matlab B/S structure is illustrated in the figure follows.

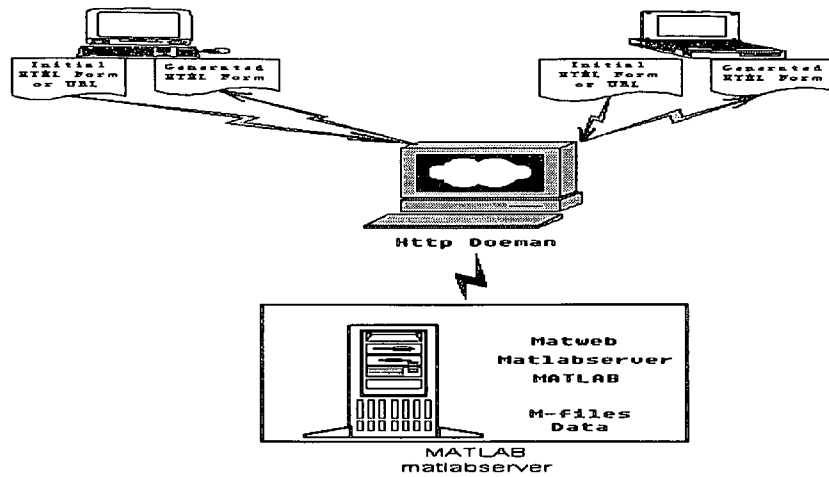


FIGURE 3-23: MATLAB B/S STRUCTURE

To correctly set up the Matlab server's working environment, the following procedure should be followed.

1. Software Install sequence:
IIS ->.Net Framework -> Matlab -> Set IIS Path -> Matlab Server config
2. Register ASP.NET to Internet Information Service (IIS)
C:\WINDOWS\Microsoft.NET\Framework\v1.0.3705\aspnet_regiis.exe -I
3. It is very helpful to use Matlab webdemo to test whether the web configuration setting is correct or not. The path is D:\MATLAB6p5\toolbox\webserver\wsdemos.

IIS Path	OS Path
\AQS\	D:\AQS\ (Set default page: Login.asp)
\cgi-bin\	D:\MATLAB6p5\webserver\bin\win32
\icons\	D:\MATLAB6p5\toolbox\webserver\wsdemos
\wsdemos\	D:\MATLAB6p5\toolbox\webserver\wsdemos

TABLE 3-8: REQUIRED IIS PATH SETTINGS

Object	URL Address	URL Address(Example)
AQS	<a href="http://<PC Name>/AQS/">http://<PC Name>/AQS/	http://Qingxue-Li/AQS/
Matlab Web Server demo	<a href="http://<PC name>/wsdemos/index.html">http://<PC name>/wsdemos/index.html	http://Qingxue-Li/wsdemos/index.html

TABLE 3-9: LIST OF SYSTEM URLS

3.4.4.2 Neural Network Training

In Matlab version 13, there is a function called Adaptive Neural-Fuzzy training of Sugeno-type FIS (ANFIS), which uses a hybrid-learning algorithm to identify the membership function parameters of single-output, Sugeno type Fuzzy Inference Systems (FIS). A combination of *least squares* and *backpropagation* gradient descent methods are used for training FIS membership function parameters to model a given set of input/output data. This function is the same as, and originated from, the Fuzzy-Neural system that was proposed in the design stage.

Here, a training data set, called TranData is used for system network training. GENFIS1 is the function which is used to generate an initial FIS matrix from training data. Thus,

```
fismat = genfis1(TranData, [5 5 4]);
```

Thereafter, an ANFIS function is used to generate a FIS matrix which is used as a margin expectation FIS matrix, viz.

```
[trn_fismat, trn_error] = anfis(TranData, fismat,[],[]);
```

```
save systemfismat trn_fismat;
```

Neural fuzzy system training is integrated with the whole system through function calls, which is shown in the Margin.m program. First, the new product data is taken in, and then the generated FIS matrix is used to calculate the expected profit margin for the specific quotation part.

The data used for training is stored in a database called TranData (as mentioned previously), which will be updated constantly to reflect the management decisions. Thus, self-adjusting is achieved.

3.4.4.3 System Follow Up

To make the system work in practice, a simple costing system needs to be constructed. It serves two functions. Firstly, it serves as a direct cost accumulation system, thus it can provide accurate direct cost for the product to be quoted on. It is also used for indirect cost accumulation and can thus provide a proper overhead allocation rate for the product. The second function is to take over some of the MIS's function. Based on this, profit or loss can be calculated, and thus feedback or guidance can be provided for a profit margin expectation. The more accurate the cost calculation, the more reliable the associate quota will be.

In this project, the costing system has not been addressed in detail but it is simply divided into two basic buffer databases, which are WorkshopInfo.mdb and Material.mdb. It is assumed that the required information has to be processed and queried in the database and must meet the requirements.

3.4.4.4 System Matlab M files

For this prototype, Matlab acts as a basic integration platform for system construction, and this is achieved by a set of Matlab programs, which are listed in the table below.

*.m File Name	Description
GraspInput.m	Retrieve customer Web input information
TransST2XML.m	Translate ST file to XML file
TransXML2DB.m	Translate XML file to DB
QuotationCount.m (main)	Quotation calculation
QuotationCountTest.m	Total Quotation function Test
QuotationStore.m	Update quotation statue if confirmed
Quotation.m(main1)	The main program to calculate the quotation
CompetFactor.m	Updating Information for NewDB CF input
GeomFactor.m	Updating Information for NewDB
EngFactor.m	Updating Information for NewDB
Margin.m	Use the SystemFismat to derive proper margin
Cost.m	Calculated the actual cost of the product
SystemFismat.m (main2)	Another main program to derive SystemFismat
Trainingdbimport.m	Import the training data into Matlab
newproductinput.m	Import the New product info into Matlab

TABLE 3-10: SYSTEM M FILES

In the prototype, Access is used as a buffer database. This means that any information in any other format is transferred into a specifically named Access database. A STEP_NC XML file is retrieved and the related feature information is stored in New_Product.mdb. This information is then queried from a CAD XML file, which has been put in the database via the TransXML2DB.m program. Another category of information is company related information. This is stored in WorkshopInfo.mdb and Material.mdb, as mentioned previously.

The fundamental information needed for profit margin expectation is retrieved and stored via the CompetFactor.m, GeomFactor.m, EngFactor.m programs. These programs are used for updating information for NewDB CF input, updating information for NewDB GF input, and updating information for NewDB EF input.

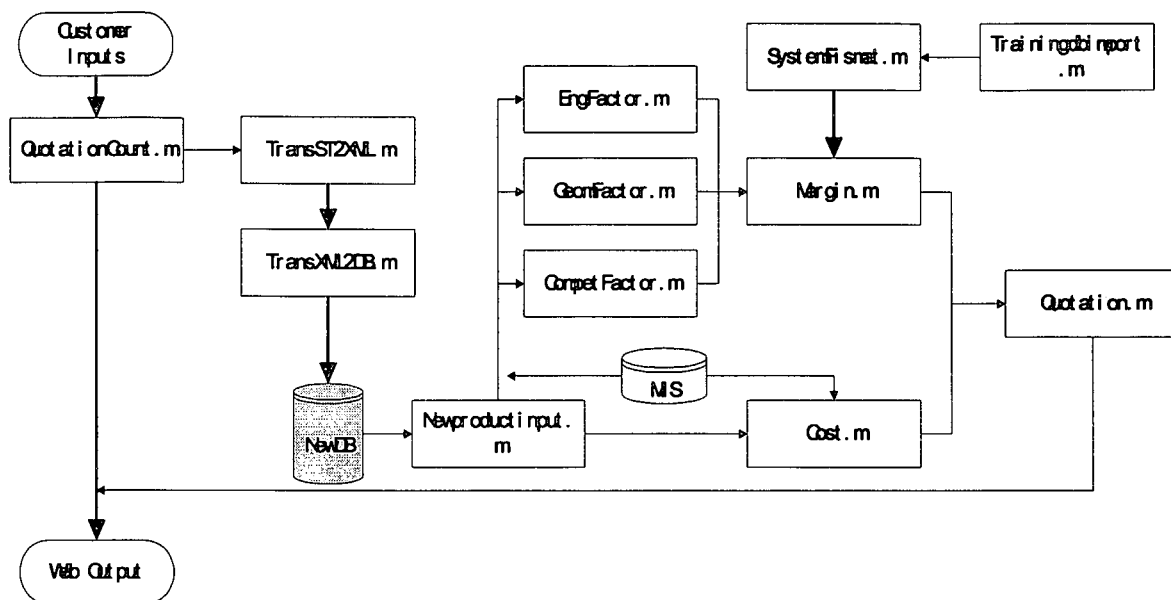


FIGURE 3-24: SYSTEM M FILES RELATIONSHIPS

When all the required information is ready, two main programs, Cost.m and Margin.m are triggered. These two functions are combined in the Quotation.m program. Thereafter, by simple calculation, the product quotation is generated. The following table shows a list of Mat files which are used to save the datasets/parameters generated by the individual programs, and to reload the datasets/parameters when needed.

*.mat File Name	Description
ProductCost.mat	From Cost.m
Margin.mat	From Margin.m
systemfismat.mat	From SystemFismat.m

TABLE 3-11: LIST OF MAT FILES

3.4.5 User Interface Design

Since this project is aimed at web-based manufacturing, the user interface design focuses on the web interface design. Creating an attractive and useful interface was deemed very important. A significant way in which the AQS was made user-friendly was through the use of forms. The design flow chart is shown below.

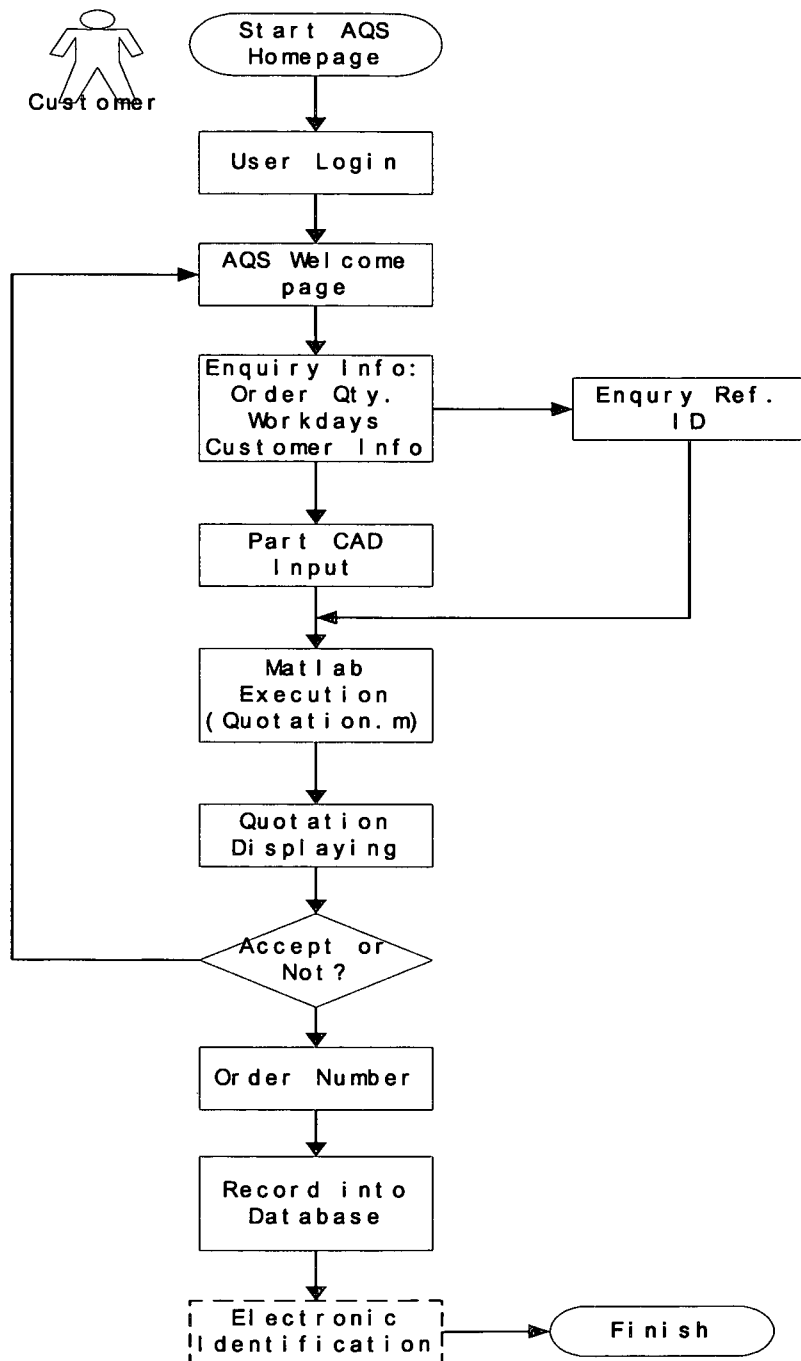


FIGURE 3-25: SYSTEM WEB DATA FLOW CHART

The software framework is based on ASP technology. It starts with a login page, which limits abuse of the website (by default, in this prototype version, the user name and password is fixed). The login page is shown in the following figure.

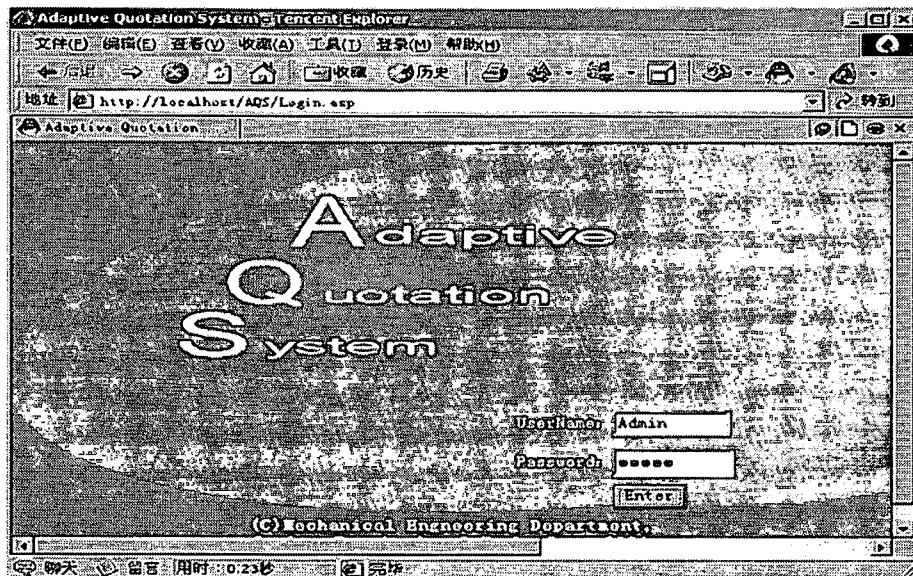


FIGURE 3-26: AQS LOGIN PAGE

After a user logs in, a greeting page follows, which has a list of control buttons on the left. There is also a bullet board which is in the lower section of welcome page, used to a few important milestones of the project development.

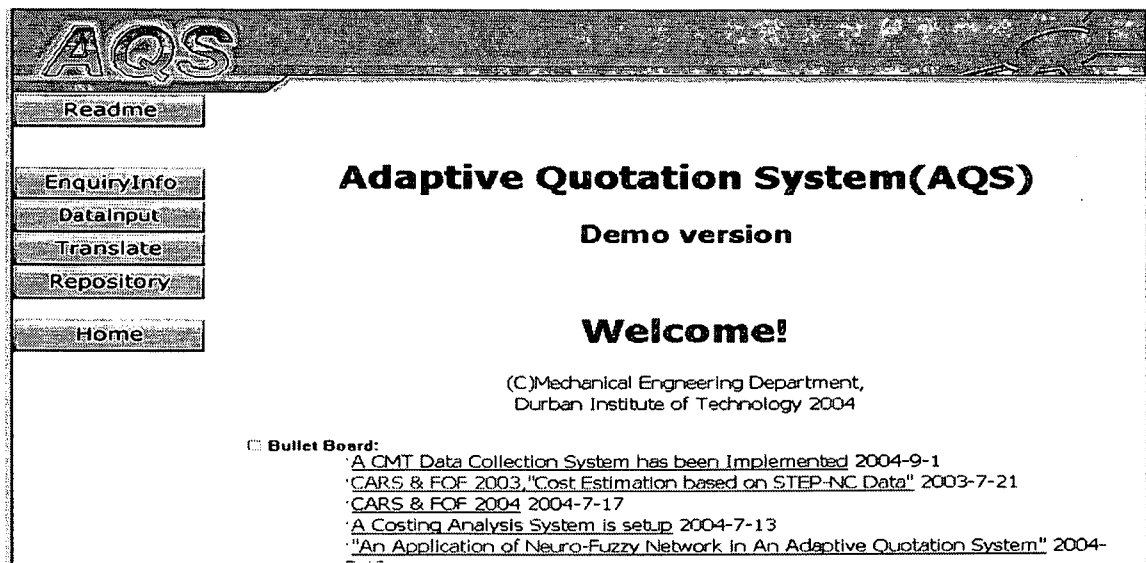


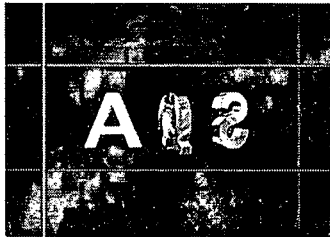
FIGURE 3-27: AQS WELCOME PAGE

If a user clicks on the ReadMe button, an introduction to the AQS project is briefly presented.

Readme
EnquiryInfo
DataInput
Translate
Repository
Home

Adaptive Quotation System(AQS)

Demo version



With recent advancements in technology, the dream for "push-button manufacturing" can become a reality. This is incorporated within the concept of Web-Based Manufacturing (WBM). However, technologies needed to accomplish these customer-to manufacturer solutions are very complex. The Adaptive Quotation System(AQS) is one of the tools that will attempt to simplify this problem

and is designed to streamline the WBM quotation process.

An integral approach for a Web based quotation system is proposed and some related key technologies are investigated. The essential functions and systems are also discussed. By structuring the related information, this objective of this Website is to provide some guidelines for AQS development.

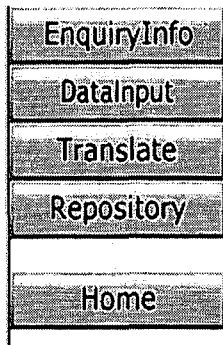
FIGURE 3-28: AQS README PAGE

As mentioned previously, order information should be input first. This includes the order quantity, required delivery time (termed here *working days*), and contact details.

AQS	
Readme	Basic Order Information
EnquiryInfo	Your Name: <input type="text" value="DIT2"/> *
DataInput	Company Name: <input type="text" value="DIT"/> *
Translate	Contact Number : <input type="text" value="0312042116"/>
Repository	Enq Ref No: <input type="text" value="2004003"/> * Used to help to identify this order
Home	Password: <input type="password"/> * Used for modifying! At least 4 Char/Num
	PW Confirm: <input type="password"/> * Please enter your password again
	Retrive Question: <input type="text" value="2004003"/> * To retrieve your password
	Related Answer : <input type="text" value="2004003"/> *
	Order Quantity: <input type="text" value="1000"/> *
	Working Days : <input type="text" value="26"/> *
	Requirements : <input type="text" value="Polish"/>
	E-mail : <input type="text" value="liqingxue@yahoo.com"/> * Used for ordering
	<input type="button" value="OK"/> (Please enter all info which marked with *)

FIGURE 3-29: AQS ENQUIRY INFORMATION PAGE

Once the order information has been entered, a user can confirm the inputs by clicking the OK button. All the data is stored in the server database (CustomerInput/WebDB).



Basic Quotating Info Input success! The CAD file uploading needs to be followed!
Your enquiry reference No. is: 2004003

Please click the DataInput button on the left to continue!

FIGURE 3-30: AQS ENQUIRY CONFIRM PAGE

Clicking on the DataInput button brings up the data input page, which is supported by CadInput.aspx (main1) and is used for the CAD file (in .xml format) uploading.

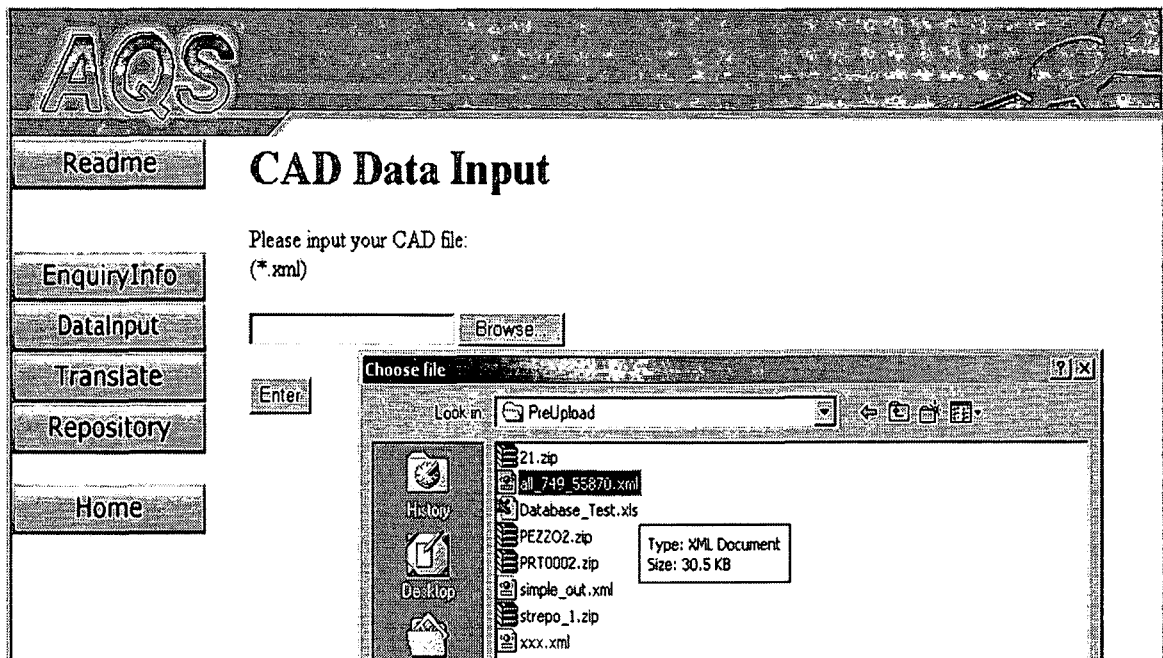
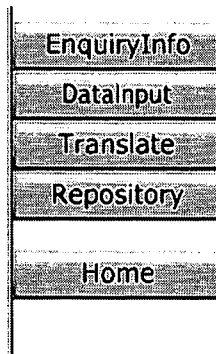


FIGURE 3-31: CAD DATA INPUT PAGE

After uploading the CAD file, the system automatically enters the QuotationCount page. The quotation-counting page is used for processing-delay purposes. By showing this, the user knows the processing is being carried out in the background, and there is nothing wrong with the CAD data file.



Quotation Being Generated...



FIGURE 3-32: AQS QUOTATION COUNT PAGE

If problems are encountered, the error will automatically be presented on the web page which is generated by the Matlab application. An example of an error display is shown below.

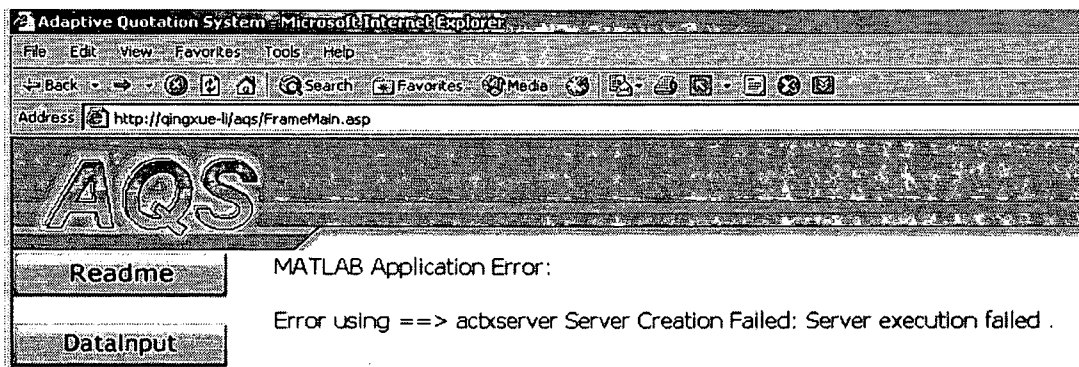
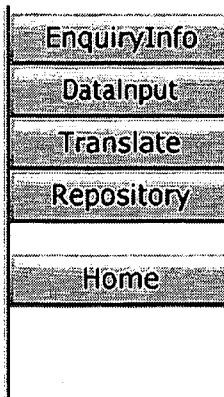


FIGURE 3-33: EXAMPLE OF AQS ERROR DISPLAY

Once the processing is complete and quotation result will be presented, as follows:



Your unit price should be: R483.225.



FIGURE 3-34: RESULT DISPLAY

If the potential customer is satisfied with the quotation, he or she can view the formal quotation by clicking on the Continue button, which calls the Quotation page, used to generate a formal quotation. He or she can also reject the generated quotation by clicking on the Reject button if he/she is not satisfied or wants to check again. Reject action will return the user to the DataInput page.

(AQS Demo Version)
 (C)Mechanical Engineering Department,
 Durban Institute of Technology 2004

Quotation

Invoice To: DIT2
 XXX Manufacturing
 Durban, 4000
 South Africa

Invoice Reference Number: 2004003
 December 17, 2003

Generated Quotation Result(Please check related information)

Ref ID	Working Days	Unit Price	Quantity	Total Price
2004003	26	483.225	1000	483225
All in total, Amount is:				483225

FIGURE 3-35: AQS QUOTATION PAGE

If the user is satisfied with the quotation, the contact details are again displayed for double-checking purposes. A user can then even input an order number, and if this is done, the system will schedule the job with the shopfloor.

Individual Web-Based Workshop
(AQS Demo Version)
 (C)Mechanical Engineering Department,
 Durban Institute of Technology 2004

Quotation

Please Confirm your Order information!

Your Order Number is: *Must Input

FIGURE 3-36: ORDER CONFIRMATION PAGE

By clicking on the Next button, the order number and related information will be stored in a separated database where all confirmed orders are recorded.

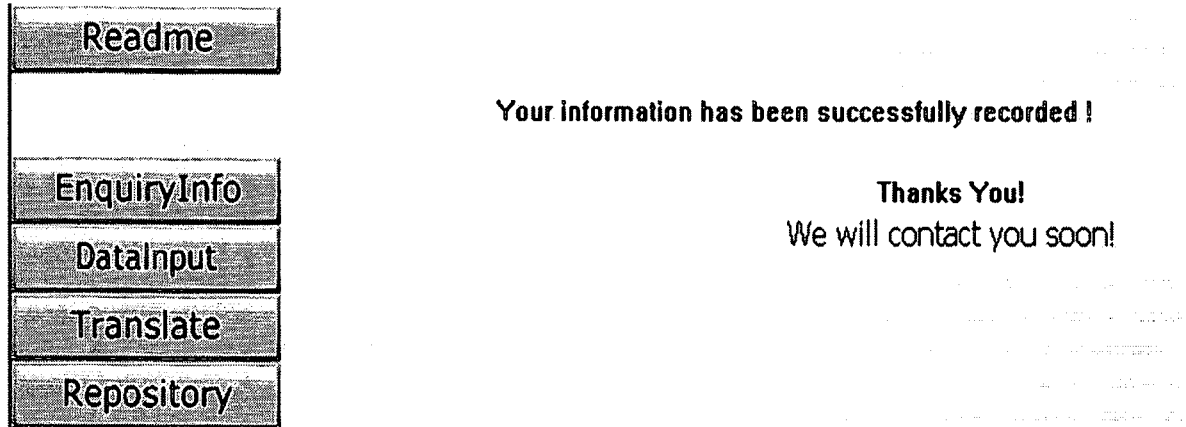


FIGURE 3-37: AQS DATA RECORD PAGE

Because this is a prototype version (and meant for research purposes), the Profit margin self learning page is separated here. This function can be used for off-line system upgrading purposes.

As demonstrated, the web user interface is complete and functional. The related main ASP files used in the web design and a brief explanation of each file are listed in table 3-12.

*.asp File Name	Statement
Login.asp	The default page of AQS
Welcome.asp	Bullet Board that provides some developing info
Readme.asp	General introduction of AQS system
OrderInfo.asp (main1)	Customer order info input
CadInput.aspx (main2)	CAD file input & upload
QuotationCount.asp	Count page (call QuotationCount.m)
QuotationConfirm.asp	Retrieve and present the generated quotation
StudyInput.aspx (main3)	Study file input
SystemFismatCount.asp	
SystemFismat.asp	
Repository.asp (main4)	Information and Data source

TABLE 3-12: LIST OF ASP/ASPX FILES

3.4.6 Section Summary

1. System Installation

The operating system recommended is Windows 2000 professional edition. The program also works in the Windows XP enterprise edition, but not the Windows XP home edition, as it does not fully support some of the key applications needed for this system.

Address	Statement
\	Root of AQS, asp/aspx files (e.g. D:\AQS)
\Image	Pictures
\DB	Database files
\PreUpload	Prepared files for upload
\Upload	Upload file(s)
\MFiles	Matlab m/mat files
\Test	Test files
\Other	Other not important files

TABLE 3-13: DETAILS OF INSTALLATION DIRECTORY

Using this prototype version of the AQS, a part quotation can be automatically generated and displayed in the client's web browser in less than a few minutes.

2. Future System Design

This system still too simple to be implemented industrially, but the concept developed can be integrated into a real industrial environment (see appendix).

Considering what has been achieved and considering what industry needs, a complex quotation "intelligent deductive system" is the next version that needs to be developed. In such a system, the AQS can act as an initial quotation generator, the results of which need to be output to an analysis sub-system, which includes an important function for profit or loss analysis and marketing analysis. Thereafter, it would pass a modified instruction back to the AQS, which would generate an update.

Chapter Four: System Implementation

Before implementation issues are considered, new advancements in STEP-NC are outlined. These influence the implementation procedure.

In the following section, a simple design for a costing system is presented, and the relationship and link with the AQS is addressed. The real time operation of the AQS is emphasised, which includes real time data analysis as well as the advantages and shortcomings. A summary of real-time execution experience is also stated for further development guidance.

As mentioned in former sections, there are three technical problems with this system; namely, cost estimation, profit expectation, and system integration. In this section, it will be shown that the advancement of STEP-NC technology can make the cost estimation much easier than before.

4.1 The South African Industry and its Limitations

With regards the implementation issues, the problem is rooted in the absence of industrial support (at this stage). As this is a conceptual and opportunity investigation, to put it into practice is very challenging if the marketing, risk analysis and investment policies are not in place. Allied with the first problem is the second – access to industrial data.

An AQS that embraces STEP-NC is a new concept and a new application of STEP-NC.

In order to validate this technology, the European STEP-NC project was launched. The project started on 01 January 1999. In total, 20 industrial and academic partners with experience in the fields of CAD/CAM, control, and machine tools in Europe joined this project. The results of tests and a collection of user demands will then form the basis for the development of a new data interface for turning, grinding, EDM, rapid prototyping, wood and glass cutting. For further benefit, an inter-regional collaboration with Europe, Switzerland and Korea, with the focus on Intelligent Manufacturing Systems (IMS) has also been initiated [18].

The European STEP-NC project participants are:

Organization	Country	Activity
DAIMLER-CHRYSLER AG	Germany	Manufacturing equipment user
VOLVO	Sweden	Manufacturing equipment user
Franci	Italy	Manufacturing equipment user
Derendinger & Cie SA	Switzerland	Manufacturing equipment user

Wyss SA	Switzerland	Manufacturing equipment user
DASSAULT Systemes	France	CAD/CAM supplier
OPEN MIND	Germany	CAD/CAM supplier
CADCAMation KMR S.A.	Switzerland	CAD/CAM supplier
PROGETTI S.R.L.	Italy	Consultant
AMT Consulting	Switzerland	Consultant
SIEMENS AG	Italy	Control manufacturer
OSAI	Italy	Control manufacturer
AGIE	Switzerland	Machine Tool builder
CMS SpA	Italy	Machine Tool builder
Starrag	Switzerland	Machine Tool builder
EPFL	Switzerland	Research/education
WZL-RWTH AACHEN	Germany	Research/education
University of Stuttgart-ISW	Germany	Research/education
EIG-tech	Switzerland	Research/education
CECIMO	Belgium	Association

TABLE 4-1: LIST OF PARTICIPANTS OF MATRAS PROJECT

In the USA, a similar project called Supermodel was started. The leader of the project is Prof. Hartwig, owner of the company Steptools, which chose a slightly different direction for STEP-NC. It mapped the new standard in an “application integrated model” and did the implementations on toolware. Compared with the European project, this project used a solution based on information technology whilst the European one is more technology-oriented [41, 72].

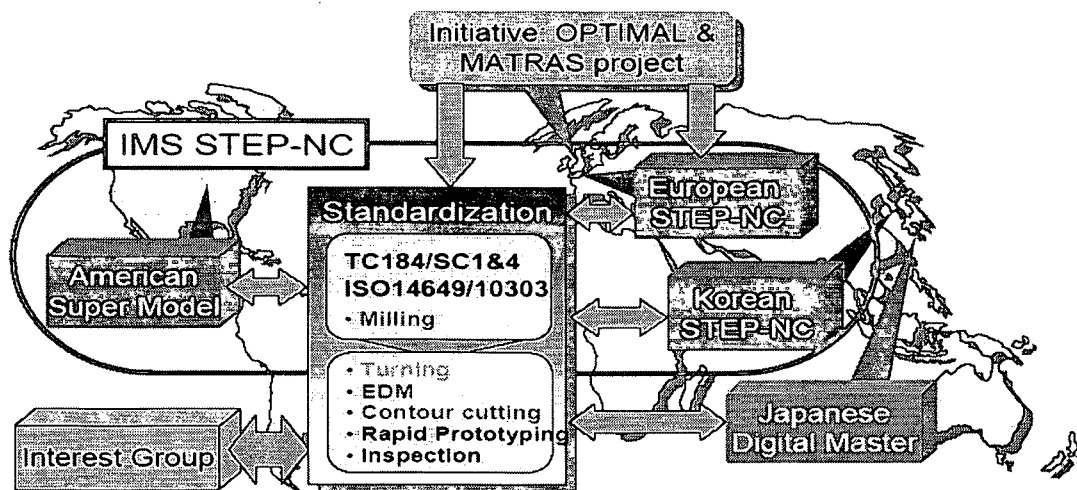


FIGURE 4-1: STEP-NC RELATED PROJECTS

Due to various reasons, South Africa has not had much involvement with this new standard's origins or implementation. There are few industries and institutions that know of, and are involved in these kinds of projects. As a result, the implementation/testing environment in SA is limited.

4.2 General Factory Implementation Problems

The system construction described above is constructed for laboratory (research) purposes. When such a system is to be implemented within a company, it is envisaged that there may be some major problems:

1. Data collection and preparation. To retrieve data from a real industry environment is usually a problem, because in real time one simple type of data is generally combined with many others. Also, even in a well-managed factory, the MIS cannot generally be fully integrated, thus causing difficulty with data vital to the AQS.
2. The accuracy of data could not be trusted.
3. The difference in methods, when dealing with the problem theoretically and practically. Theoretically, the quotation consists of cost and profit margins, but in real time, the factors that influence the quotation are far more complex than what was imagined and anticipated (by the student initially). This influences the results dramatically. For example, with cost analysis done manually, at least 50% of the effort is spent on communication and data preparation. Only 20% effort is spent on the costing processing.
4. Support of management. Without management's support, even a perfect MIS cannot function well. This would impact on the AQS.

4.3 The Method Used for Testing

For this project, an attempt was made to look for a suitable company for testing. But, as stated in the limitations, the factories which are involved in implementation are few in South Africa, due to the risks involved. Finally, one large-scale South African garment-manufacturing factory agreed to cooperate with testing some concepts developed in this project. The focus then switched to dealing with uncertainties in real industrial cases.

The issue at this point was what product made at the garment factory could be used to test the AQS. Even for this company, the MIS could not provide valuable data for analysis. One reason is the absence of checkpoints, and another is accuracy of the data/information. A further major (and unusual) factor is the exchange rate between USD and SAR, which is not considered by the AQS.

To test the AQS practically, a scaled-down problem, Cut-Make-Trim (CMT) estimation, was investigated. In this factory, there is a problem in CMT cost estimation; thus the total direct cost of one garment is not certain, and this has an influence on total cost estimation. Actually, this problem is so serious that it has led to quotation prices being much lower than acceptable. CMT cost estimation contains several factors which are similar to the AQS's Complexity factor, namely factory busy or not, garment's features/difficulty scale, and material used (fabric). Thus, the result of this test could definitely give an idea of the issues involved in implementing the AQS in industry.

Even with this scaled-down problem, the system for data collection had to be redesigned. A development tool called Power Builder and the EAS database was used to formulate a feasible system. It contains three main parts; basic order info, CMT daily updating, and CMT summary pages. The software system and test results will be addressed in a later section.

4.3.1 Advancement in STEP-NC

As STEP-NC is presently a very popular research field in manufacturing, there were many new advancements in STEP-NC AP and its application during this project's final stages. All of the recent demonstrations have shown that STEP-NC is a powerful tool in automatic manufacturing, which can be trusted and relied upon. In South Africa, there are still not many favourable opinions, but one can still rely on what is reported and assume that feature-related automatic manufacturing is not a problem, and thus STEP-NC can provide reliable figures for cut-time estimation. Based on this, the direct cost can be derived.

4.3.1.1 Updates

In September 2003, the fifth issue of the STEP_NC newsletter gave information on the development of the data model and the prototype process chain for turning applications [18]. They also show harmonization with ISO/TC184/ SC4 for feature description and material model, and ongoing harmonization with the new ISO/ TC29 (ISO 13399) for cutting tools reported recently. A report on milling was also finalised at the end of 2001 (ESPRIT project EP29708), but under the IMS project, there are still many new applications, and thus the work is ongoing.

For example, at the STEP-NC workshop (in Aachen in February 2003) a Global Milling Process for Prototype Validation was presented, which integrated most of the new applications based on STEP-NC, and presented a holistic picture for automatic manufacturing [41].

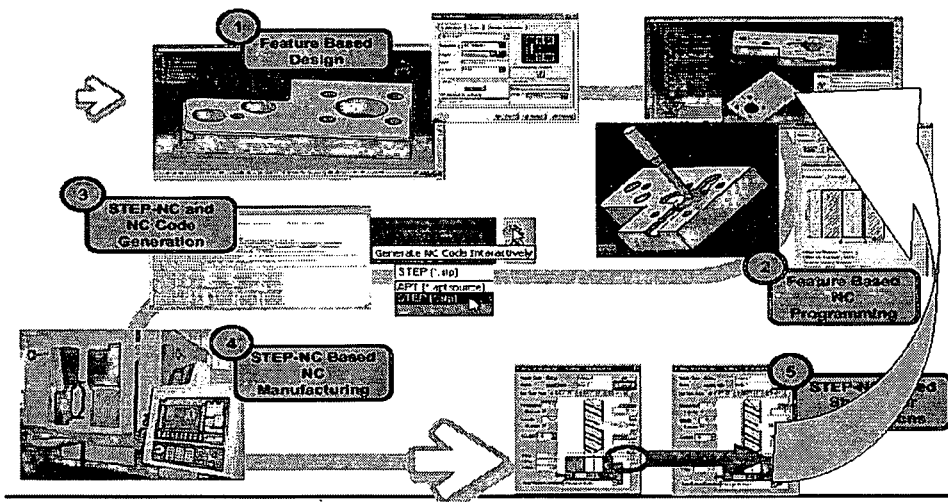


FIGURE 4-2: STEP-NC LINKING ALL MANUFACTURING PROCESSES

Pure geometry is interpreted by feature recognition, because it uses parameterized, scalable description for classified shapes, and elements and operations are classified appropriately. Thus, machining operations are defined based on features, and feature based NC programming can be done and the NC code can be generated. Because modern NC cycles are often based on features, and STEP-NC associates machining tasks logically, STEP-NC based NC manufacturing can also be achieved.

In addition, the STEP-NC server concept has been developed. It uses a closed loop between the planning department and the shop floor for the integration of the know-how of the machine operator.

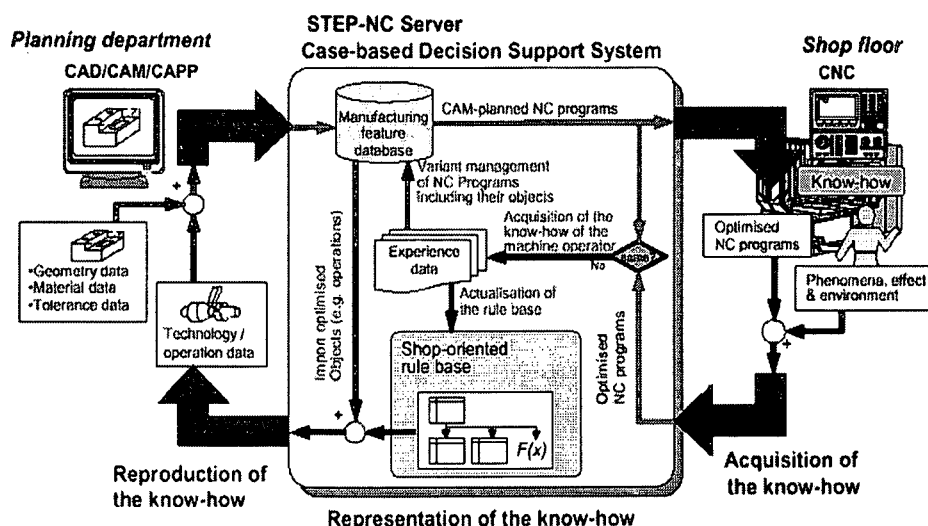


FIGURE 4-3: PRINCIPAL DESIGN OF A STEP-NC SERVER

It also uses of a kind of case-based reasoning, and clusters the various conditions according to the effect of the modification (see figure 4-4).

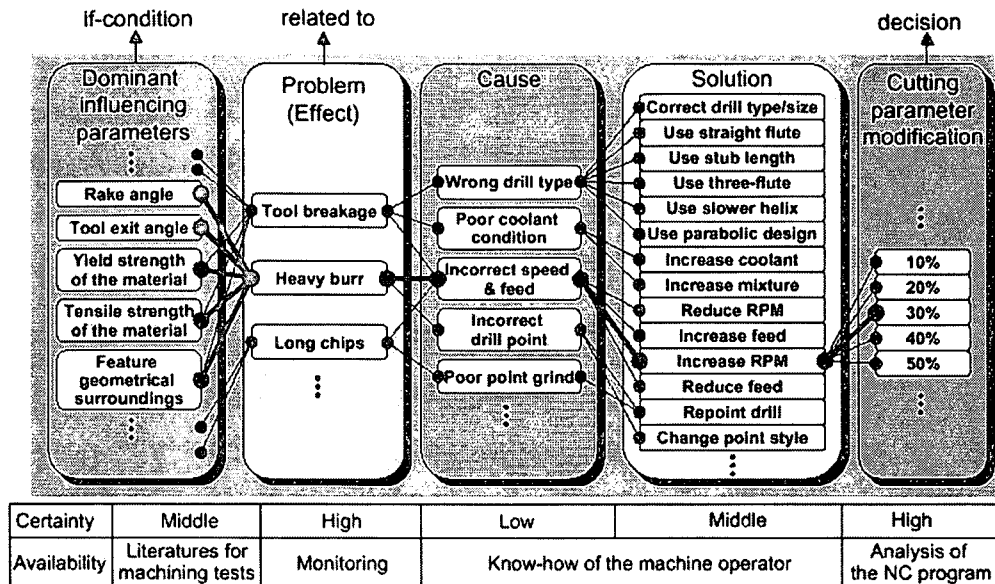


FIGURE 4-4: AN EXAMPLE OF KNOWLEDGE ACQUISITION

The application and development of STEP-NC has made fully automatic manufacturing a reality. In the following section, an integrated product of STEP-NC, which was developed by STEP TOOLS, INC., is introduced.

4.3.1.2 Updates in STEP-Tools (STEP, Inc.)

An advanced feature-based CAM system has been implemented by Honeywell. The system was developed under the sponsorship of the Department of Energy and is called FB Mach. Honeywell has enhanced this system under contract to the Super Model project. It can read STEP CAD data (AP 203 or AP 214) and write STEP-NC data. STEP Tools has negotiated a license to market FB Mach as a system called ST-CAM. STEP interpreters for GibbsCAM and Master CAM have been developed and were demonstrated in 2003. Unigraphics, CATIA and Pro/Engineer CAD systems are all capable of understanding manufacturing features, and interfaces to STEP-NC are expected to be included in future versions of these CAD systems [72].

The main product families of STEP-Tools are ST-Plan, ST-Machine, STIX - STEP Index and ST-NC Developer. ST-Plan creates machine independent CNC control files, which include Tolerance definition, Feature recognition, Process sequence definition, and Tool requirement definition. ST-Machine generates tool path data. It can optimize compiler code for STEP-NC, Machine independent data converted to machine specific tool paths, CAM system plug-in,

and Use On or Off the CNC machine. STIX - STEP Index provides a direct interface to the AP-238 data. It is used to read and build in-memory indices and back pointers in the AP-238 data for speed of processing, simplify use of AP-238 data by providing the API to common access paths and calculations, and wrapping with COM interface for lightweight applications. ST-NC Developer is used to write manufacturing applications and translators. It can make or use the Machine independent CNC control data, ST-Plan desktop translator with feature recognition to make data, STIX Programming API with links to ACIS and Parasolid, and Viewers, checkers and ST-Machine harness [72].

ST-NC Developer can be viewed as a system platform, and all the applications are based on this base for integration.

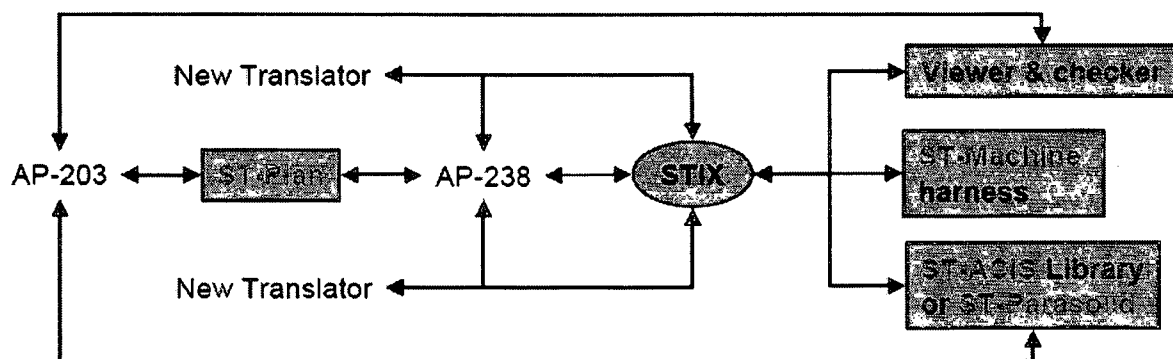


FIGURE 4-5: STEP TOOLS PRODUCTS

4.3.2 Stipulation/Reservation for System Training

As was mentioned previously, an SA based garment factory agreed to cooperate and provide data for analysis. CMT estimation will be investigated and analyzed here. It was hoped that this problem analysis would provide some guidance for this project's profit margin expectation design and construction.

The garment cost is composed of three main factors, namely fabric cost, trim cost, and CMT cost. These factors are exceptions because they have almost the same weighting, theoretically. In reality, the CMT cost varies greatly due to different styles and the factory's current order, and this has been the cause of cost uncertainty. Currently, the factory has no choice but to disregard the CMT cost inaccuracy in the cost estimation. With analysis, it was found that the CMT cost can vary from R0.89 to R6.00 in the actual manufacturing. In mass production, the CMT cost inaccuracy influenced the profit greatly.

The CMT (cost) estimation problem has some similar characteristics with profit margin expectation. For CMT estimation, access to management information is required, via the MIS, along with the CMT costs associated with the complexity of individual garment styles.

4.3.2.1 A Data Collection System

To analyse the CMT problem, a CMT data collection system was constructed, built on an Adaptive SQL Anywhere database. Firstly, this system is used as a daily data recording system, which is used to generate the actual CMT cost for each style. Second, it records some management guidelines for production, such as how the production lines are arranged, and the daily target for each line. This system provides some basic information for CMT estimation (a detailed explanation of this system can be found in the document *CMT Data Collection System* in the appendix).

The CMT system can only collect some lower level, first hand information. To be able to start CMT estimation, some other influencing factors also need to be taken into account. Processed information which comes from Sales and Planning, called delivery sequence, will be considered as it has an influence on CMT estimation (from this data source, order on hand and the required production outputs is provided).

The CMT estimation process flow is shown below.

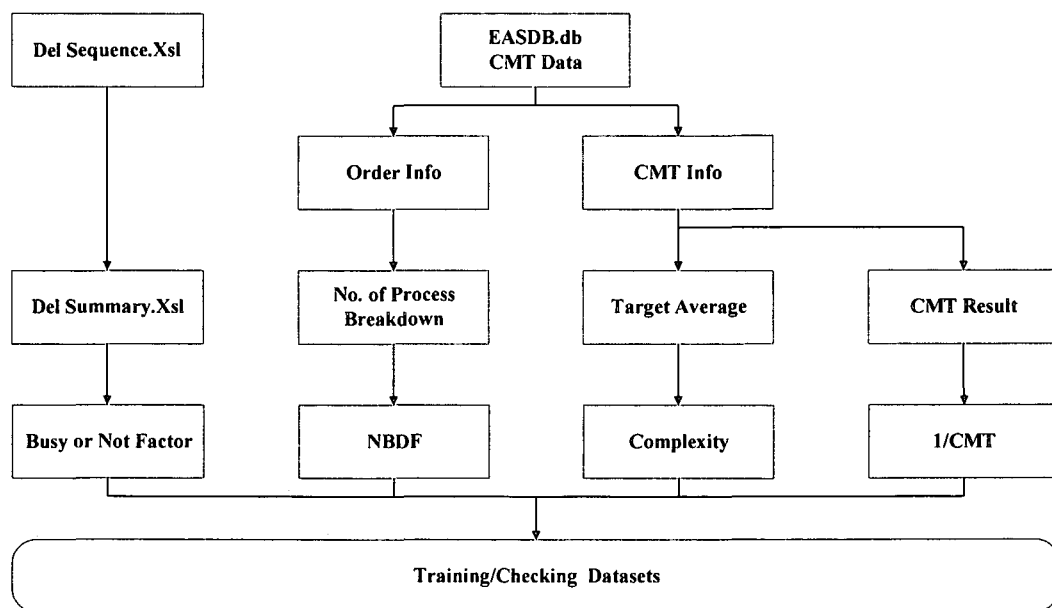


FIGURE 4-6: CMT ESTIMATION PROCESS FLOW

A detailed explanation of data process procedures is presented in the document in the appendix. An example of a processed dataset is given in the following table.

ExpID	NPBD	Trag Avg	CMT	EXP BON	NBDF	Complexity	1/cmt
295	10	1645.7115	R 2.68	0.6421	0.6667	0.8229	0.3735
277	9	1583.2653	R 2.12	0.5775	0.6000	0.7916	0.4727
268	9	1800.0000	R 4.34	0.6825	0.6000	0.9000	0.2302
281	12	700.0000	R 3.58	0.7002	0.8000	0.3500	0.2792
295A	10	1607.6923	R 2.68	0.6421	0.6667	0.8038	0.3730
262	11	1539.0000	R 2.02	0.7162	0.7333	0.7695	0.4947
190C	8	2000.0000	R 4.60	0.6887	0.5333	1.0000	0.2173
271	9	1800.0000	R 3.19	0.6947	0.6000	0.9000	0.3138
277B	11	1584.6111	R 2.09	0.5775	0.7333	0.7923	0.4795
264	9	1754.0526	R 5.83	0.6819	0.6000	0.8770	0.1716
260A	10	1472.8571	R 1.99	0.7228	0.6667	0.7364	0.5019
243C	12	1428.6364	R 1.72	0.6333	0.8000	0.7143	0.5819
269	9	1800.0000	R 4.49	0.7002	0.6000	0.9000	0.2229
261	10	1605.0000	R 2.54	0.7057	0.6667	0.8025	0.3940
272	9	1790.0000	R 6.15	0.6827	0.6000	0.8950	0.1626
266	9	1744.4444	R 2.74	0.6805	0.6000	0.8722	0.3646
267	12	1076.7778	R 2.03	0.6823	0.8000	0.5384	0.4937
265	9	1628.5714	R 3.49	0.6833	0.6000	0.8143	0.2863
270	9	1581.6667	R 4.21	0.6833	0.6000	0.7908	0.2377
243B	10	1424.6970	R 2.30	0.6333	0.6667	0.7123	0.4340

TABLE 4-2: EXAMPLE OF PROCESSED DATASET (FACTORY XXX1)

4.3.2.2 Analysis of Variables

The design of this CMT data collection system is based on management experience and some investigations. How those factors influence the CMT cost is a very complex process. From a practical point of view, these datasets can serve as a starting point to CMT estimation. It was hoped that this initial start could meet some estimation requirements of prediction.

4.3.2.2.1 Variables Co-relationship Analysis

The correlation between two random variables x and y is a measure of the degree of linear association between them. The population correlation coefficient is denoted by ρ . The coefficient ρ can take on any value from -1, through 0, to 1. When $\rho = -1$, there is a perfect negative linear relationship between x and y . When x or y increases, the other variable decreases; and when one decreases, the other one must increase [43].

The data collected for the CMT cost estimation was divided into three categories, namely, Factory Busy or Not (EXP BON), Number of Process Breakdowns (NBDF), and Garment Style Complexity. Based on the data collected (see example in table 4-1), a correlation analysis of the three input variables, namely, EXP BON, NBDF and Complexity, was done. The result is given in table 4-3.

	EXP BON	NBDF	Complexity
EXP BON	1		
NBDF	-0.1172699	1	
Complexity	-0.00765793	-0.8208222	1

TABLE 4-3: CORRELATION ANALYSIS RESULT

A strong correlation between NBDF and Complexity was identified. The greater the NBDF, the more difficult it is to make the garment, viz. Complexity is greater (for more details, see the appendix). To simplify CMT training, only two factors will be taken into consideration. This is to demonstrate a procedure to identify the influencing factors for system training, and can be applied when there is a need for manufacturing data analysis.

4.3.2.2.2 Comparison of Two CMT Populations

CMT data has been collected from two factories, namely XXX1 and XXX3. Even with a shared sales /merchandising department, and similar product planning departments, the CMT data has shown some differences. A further descriptive statistical analysis was conducted on the CMT data and the result is shown in the table below.

	XXX 3 (11-2)	XXX 3 (12-6)	XXX 1
Mean	2.400773137	2.315981	2.914095
Standard Error	0.12928599	0.092092	0.181431864
Median	2.19194172	2.143767	2.4287
Mode	#N/A	#N/A	#N/A
Standard Deviation	0.684117153	0.657668	1.147475858
Sample Variance	0.468016279	0.432527	1.316700846
Kurtosis	3.419736133	2.256863	-0.317999771
Skewness	1.848447735	1.325809	0.813789244
Range	2.81114827	3.331597	4.6044
Minimum	1.701778272	1.223641	1.2236
Maximum	4.512926542	4.555238	5.828
Sum	67.22164783	118.115	116.5638
Count	28	51	40
Confidence Level (95.0%)	0.265272761	0.184972	0.366980222

TABLE 4-4: DESCRIPTIVE STATISTICAL ANALYSIS OF TWO POPULATIONS

According to the Central Limit Theorem, if the sample is sufficiently large, regardless of the shape of the population distribution, *the sampling distribution is normal* [4]. With a 95% confidence level, tern1's CMT will be in the range of [1.658, 2.974], and XXX3's CMT is ranged from [1.716, 3.084]. When conducting a *t*-test for the populations, the result is shown in the following table.

t-Test: Paired Two Sample for Means	XXX 1	XXX 3
Mean	2.844517778	2.375386159
Variance	1.212656925	0.453608615
Observations	45	45
Pearson Correlation	0.032107642	
Hypothesized Mean Difference	0	
df	44	
t Stat	2.473579922	
P(T<=t) one-tail	0.008653904	
t Critical one-tail	1.680230071	
P(T<=t) two-tail	0.017307808	
t Critical two-tail	2.0153675	

TABLE 4-5: *t*-TEST FOR TWO POPULATIONS

Since the *t* statistic exceeds the critical *t* for the one-tail test, the null hypothesis that the average CMT cost is the same is rejected, and the result shows Tern1's CMT cost is higher than Tern3's CMT cost. It was thus suggested that these two datasets can not be mixed for CMT cost training. Thus, the prediction of CMT cost should be done individually for each factory when the garment style is confirmed and assigned to be manufactured by the specific factory.

4.3.2.3 System Training

To conduct CMT estimation, only one factory's CMT data can be used. A total of 42 datasets were collected from XXX3, and used for system training. Two input, five hidden node NN architecture was adopted. Doing so ensures there was enough datasets for training, testing and checking. (Some of the collected datasets are given in the appendix named CMT Data Collection System).

Using the same training techniques described in the system design section, a system fismat was generated. Training the XXX3 CMT data produced the following result:

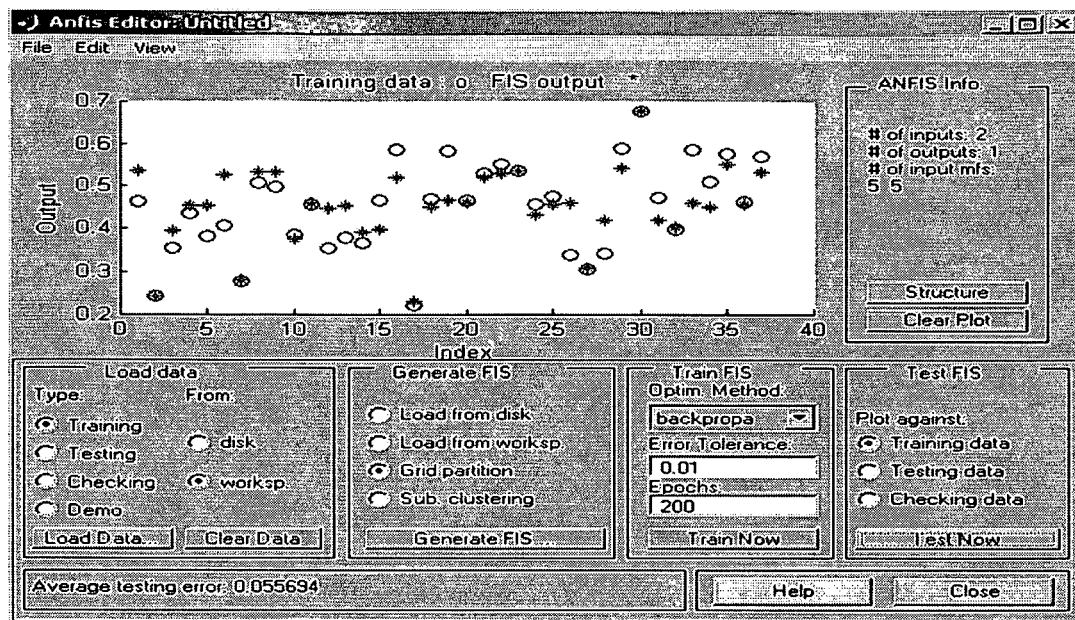


FIGURE 4-7: XXX3 CMT DATA TRAINING RESULT

The surface plot of the decision rules is shown in figure 4-8.

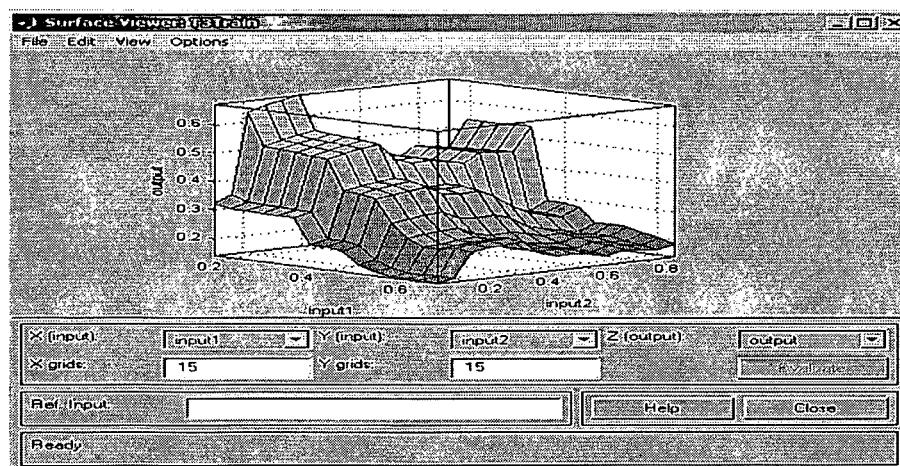


FIGURE 4-8: SURFACE PLOT OF TRAINING RULES

The training result was adequate, because it understandable, viz. as the Complexity increases, the CMT cost is higher, and as the factory's busy or not factor increases, the CMT cost also increases (note that output is 1/CMT). Some unusual issues were also identified. For example, where the input2/BON is close to 0 and 1, the surface plot shows strange

reflections. This is caused by the insufficient training data. When enough training data is accumulated, this problem is expected to be resolved.

Further modification of the training datasets has showed some improvement in training, but not changed it significantly. For example, some large variance datasets were identified in the first training. If those datasets had been treated as abnormal and were removed, the training achieved a more efficient result, and the average testing error dropped from 0.056 to 0.04 (with 200 epochs).

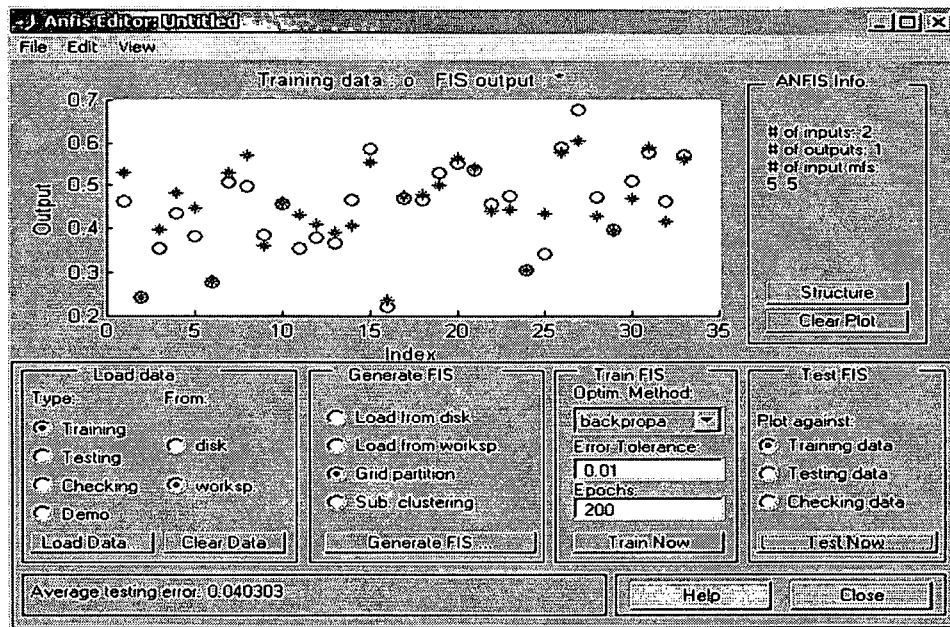


FIGURE 4-9: PLOT OF TRAINING DATA

The Fismat summary information is shown in the table below.

ANFIS info	
Number of nodes:	75
Number of linear parameters:	75
Number of nonlinear parameters:	30
Total number of parameters:	105
Number of training data pairs:	37
Number of fuzzy rules:	25

TABLE 4-6: ANFIS INFO

Testing against the checking data also showed some improvement; the average testing error dropped from 0.062 to 0.053.

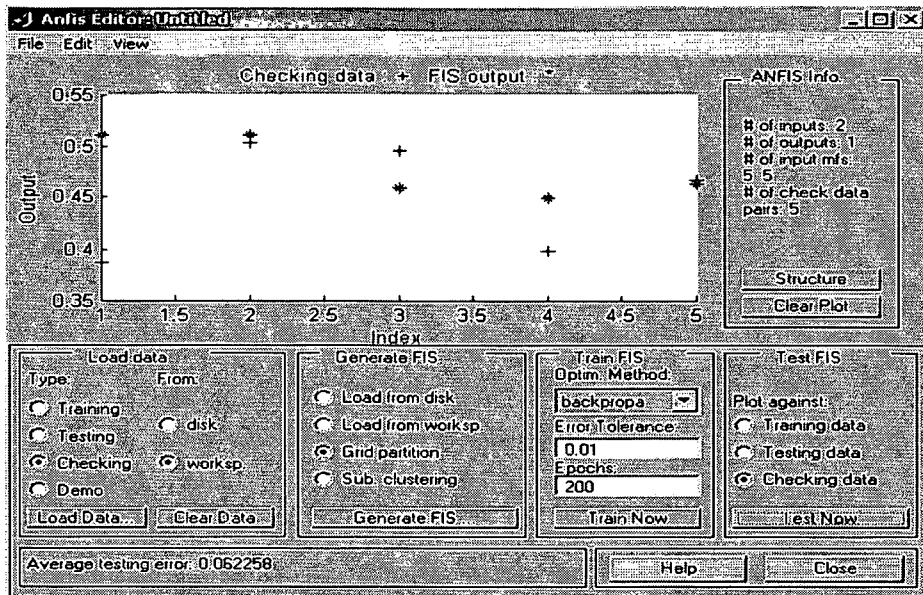


FIGURE 4-10: PLOT OF CHECKING DATA

This result may give some direction, viz, the improvement can only be based on better prepared training datasets; it may consider the adjustment for the training fismat based on the rule surface view (combined with the management judgments, and general knowledge).

Using a similar procedure for Tern1 training, the average testing error was 0.04 with 150 epochs. The surface plot of the training rules revealed some interesting findings.

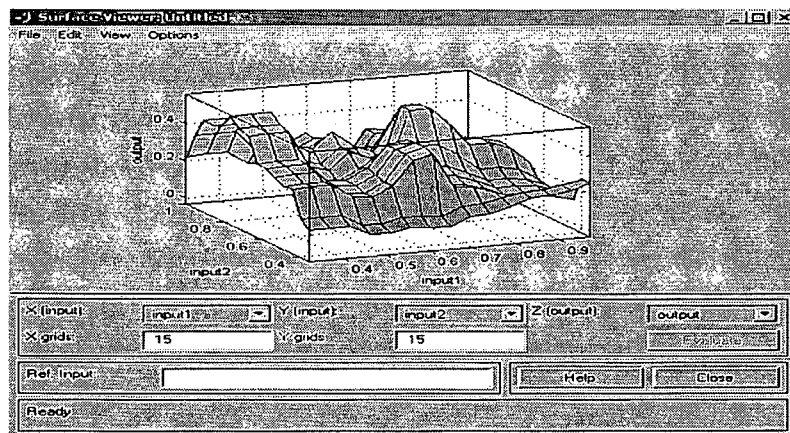


FIGURE 4-11: XXX1 TRAINING RULES SURFACE PLOT

In the figure above, input 1 is the factory busy or not factor and input 2 is the garment Complexity factor. The fuzzy surface plot indicated that the CMT should be *low* when the factory is busy and high when the Complexity is the high. This result is astonishing; the factory spends more when the factory is not busy, and implies that the factory needs better

management when the factory production is not at capacity. The rule surface is not as smooth as XXX3's, and this is a result of insufficient training datasets.

4.3.2.4 Hypothesis Testing

After considering the influence of repeated styles, the testing data was composed of 50% history data and 50% new data (randomly chosen).

EXP	Complexity	BON	1/CMT	A CMT	Output	E CMT	Variance
218	0.34308	0.34695	0.38697	2.5842	0.5106	1.9585	0.2421
224	0.30191	0.22827	0.50315	1.9875	0.5106	1.9585	0.0146
243	0.329	0.57581	0.49611	2.0157	0.4591	2.1782	-0.0806
253	0.262	0.69175	0.39791	2.5131	0.4495	2.2247	0.1148
296	0.26071	0.74628	0.46633	2.1444	0.4636	2.1570	-0.0059
187	0.29	0.47374	0.38354	2.6073	0.4531	2.2070	0.1535
227	0.22058	0.29422	0.49808	2.0077	0.5335	1.8744	0.0664
248	0.27778	0.57286	0.46691	2.1417	0.4609	2.1697	-0.0130
249	0.30806	0.27958	0.52854	1.8920	0.5192	1.9260	-0.0180
294	0.23197	0.4	0.57584	1.7366	0.5509	1.8152	-0.0453

TABLE 4-7: TESTING DATASETS AND GENERATED RESULTS

The system output variance analysis is given in the next table.

Variance Analysis	
Mean	0.042859827
Standard Error	0.031744479
Median	0.00435099
Standard Deviation	0.100384858
Sample Variance	0.01007712
Range	0.322741155
Confidence Level (95.0%)	0.071811056

TABLE 4-8: VARIANCE ANALYSIS

From the table it can be seen that the system-generated result is located in the range [-0.057, 0.1433] within a 95% confidence level. The result is within the required range of -30% to 30% [50]. Considering that there were insufficient training datasets, this was a very good result.

4.4 Section Summary

One of the main limiting factors of the AQS at this point was the profit margin calculation. Since the student had difficulty in determining what was reasonable, by using the CMT estimation problem, it was hoped to learn something applicable to the problem at hand. Once the CMT problem had been tackled, it was found that there are many similarities and that the exercise was a worthwhile one.

The variable analysis and the training method/procedure used for CMT estimation can be applied to profit margin expectation for the AQS. As for most Neutral Fuzzy training, sufficient and qualified training datasets are vital to generate the desired outputs.

To summarise, using the NF network for uncertainty estimation is appropriate. The challenge for further development is how to filter the odd datasets to make the system robust.

Chapter Five: Conclusion

Increased global competition is challenging manufacturing industries to bring competitively priced, well-designed and well-manufactured products into the marketplace as quickly as possible. Manufacturing companies are responding to these challenges in their industry by extending current internet trends to create virtual marketplaces where factories, suppliers, and customers are part of the solution. Because of pressing demands to reduce lead-time, providing a suitable manufacturing price for a product has become an important step.

The AQS is software that was developed by the student at the Department of Mechanical Engineering at the Durban Institute of Technology, South Africa. This system provides an approach to provide an autonomous quotation for a product via the web. The customer uploads a CAD file via a web browser, the quotation is generated automatically, and is presented to the customer (almost) instantly via the same internet interface window. In addition, the customer can have the quote emailed to make it official, and the system also has the capability of allowing the customer to input an order number, allowing the job to be queued within the shopfloor.

Based on the literature reviews, a systematic design method was developed for the AQS. To develop such a system, three technical problems, namely cost calculation, profit margin expectation, and system integration needed to be solved. Machining time is the basic for the cost calculation. To generate machining time automatically, this project has adopted the latest advancement in CAx, which is the STEP-NC (ISO 14649) standard. By using this format, the related product CAD information can be queried out, and then the related machining time can be calculated. This research also has targeted the quotation generation, which is oriented around the profit margin expectation. By adopting the concept of 'part complexity', the system has the ability to handle uncertainty factors that are related to pricing. This is achieved via Artificial Intelligence, which is characteristic of self-learning functions.

This project also investigated various issues related to integration. The method proposed has been partially tested in industry. The related system implementation has proved that the method used is practicable, and can be embedded with WBM completely. An AQS will be useful in responding quickly to change demands and opportunities in the marketplace.

5.1 Research Contributions

The AQS is a new concept in manufacturing and it is also a system response to global competition and new technology trends. This has brought new ideas for WBM design, both in practice and research.

Compared with existing Cost Estimation systems, two distinguish characteristics are identified. Firstly, the whole quotation is processed via the Internet, which can be treated as a part of a WBM system. Secondly, the quotation generation is a fully automatic, autonomous and adaptive process, due to the imbedded AI building blocks. The concept of part complexity is developed and handled via a Fuzzy-Neural system.

Contributions:

1. A new approach for a web-based quotation system is discussed. The related programming has been finished. This system offers an integrated platform to assimilate many new technologies.
2. The advancement in ISO 14649 has been traced, and applied in development of the system. Various methods to explore this technology, particularly in retrieving manufacturing and cost related information from CAD inputs, have been tried and tested.
3. An investigation of uncertainty decision-making, particularly with respect to that associated with quoting, has been undertaken. The details of information process steps, data analysis and training procedures have been presented.
4. System integration, especially for the web-based environment, has been investigated. Based on Matlab server, a seamless integration of DB maintenance, programming and web interface has been achieved.

Many problems and obstacles during the system design and implementation were encountered. What has been developed during this project should provide a guideline for further development and practical applications.

Chapter Six: Further Research

Although much has been achieved in this project, there are still many issues requiring further investigation, both in system design and system implementation.

6.1 Recommendations

As stated in the system design, this system relies heavily on STEP-NC. Unfortunately, there was no opportunity for further investigation of this recently developed technology.

A Neutral-Fuzzy system is used to handle uncertainty issues. This field is a very interesting and challenging area for further studying. Better network architecture, new training methods, and data filtering technologies will make contributions to this system.

Web integration also needs further study. For example, network security and better and more efficient data exchange are some issues for further research.

The quotation follow-up is needs further investigation. The best estimating methods for a company are those that effectively satisfy the needs of its organization and customers. The methods differ widely among companies and are influenced by complexity of the organization, sophistication of products, and variety of product mix. Analysis of below or above desired pricing also needs to be done, to provide feedback data for further system training. It is obvious that even through a higher quotation may result in greater profit than anticipated, this is undesirable because it:

1. Leads to overbidding and causes rejection of proposals that could be profitable
2. Causes loss of customer good will if quotations are consistently high
3. Leads to waste in design and fabrication when they become the initial standards of performance.

For the implementation of the AQS, vertical and horizontal integration should also be considered. An inefficient management information system will disadvantage the system implementation process, an issue which was identified when implementing the CMT system in the garment factory. In order to obtain useful and meaningful information, an analysis of factory process flow and its management characters needs to be conducted. Sometimes, a specific design and system change/modification is needed, as the needs and wants of real industry should always be placed first, otherwise the information required is hard to obtain.

6.2 Probable Tasks in Next Version

There are a few issues which need to be considered in the next version of the AQS. In a demonstration (or prototype) Version 2, the probable tasks include:

1. Improvement in AI architecture, a better data structuring
2. A more suitable AI self tuning method (e.g. self study)
3. AQS Reports querying, which are based on a new DB updating method
4. Further exploration of the ST-XML function
5. Help messaging and Error/Warning handling instructions should be complete
6. Some other mini aspects: e.g. Path fixing without loss of the flexibility.

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Appendix

A1. Report for Costing System

Background

Integrated supply chain management and Enterprise Resource Planning (ERP) have become buzzwords in boardrooms and offices all around the world as companies fight to gain a significant edge over their competitors. More than ever companies need to simplify the business process, modify and streamline the business cycle so as to be cost efficient.

ERP emphasizes on evaluating the performance, management and achievement of a company on an enterprise-wide basis, rather than considering each business function piecemeal. It is designed to incorporate and address the needs of all major business functions carried out by enterprises extensively on a consistent and integrated basis, providing it is vital for our company with the intelligence to be competitive.

ERP is able to provide an advanced tool for enterprises to achieve a state of art of management. Cost analysis is one of fields that can be benefited from this system via a more accurate and abounding data source.

Fundamentally, ERP can provide entire information for management use. But what is designed for cost estimation and analysis function is limited. For example, the calculated cost is based on the material consumed; it doesn't include the administration/overhead cost. Each enterprise keeps its own specific ways for production, thus the approach for cost should be different. It needs a deep analysis of our current approach, and designs one that is more suitable for the enterprise, which is based on the information provided by ERP.

The Purpose and Target of Cost Management

Management accounting approaches are chosen to help an organization achieve its goals by way of better decision-making and management of organisation members. Organizations are dependent on their management accounting systems to provide information in a dynamic environment.

Management Accounting involves the use of accounting information by managers to help achieve the organization's goals. Basically, management accounting provides information for two general functions, namely making planning-decisions and control. Planning-decisions is for products & services (mix and pricing decisions), activities & processes, subunits of the organization and customers and suppliers which can be improved with additional information; Controlling is for stimulate members of the organization to work toward the goals of the organization. Preferred characteristics of management accounting include accurate measures of multiple inputs of the organization, timeliness, identification of responsibilities, and the capacity to be promising.

The Purpose and Target of Cost Analysis

Cost analysis is the process of obtaining *cost breakdowns, verifying cost data, evaluating specific cost elements, and examining data to determine the allow-ability of the costs including the budget*. The objective of a cost analysis is *to determine that proposed costs are reasonable and allocable and are consistently treated*

in accordance with generally accepted accounting principles.

Theory of Cost Analysis

Cost is the use of organizational resources. Generally speaking costs can be classified into fixed cost and variable cost. Fixed cost includes the opportunity cost of using the facilities, purchasing machines, employing senior managers, and using other resources that won't change by the rate of output. The cost that increases with the rate of output is named variable cost. Variable cost includes the opportunity cost of using additional labours, materials, and other resources to make more units.

There is another definition, historical cost, which is used very often in practice. The historical cost of a resource reflects the cost at the time of acquiring the resource. At the time of acquisition of a resource, the historical cost is usually a closest approximation of the opportunity cost.

Estimating the cost of a cost object requires the identification and measurement of all the cost associated with the cost objects. Linking cost with cost objects is called tracing. That cost that is easily identified as belonging to a particular cost object is called direct cost. Other cost that can't be easily traced to a particular cost object is called indirect cost. Indirect cost occurs because an organization performs an activity or process that is related to multiple cost objects, which make indirect cost difficult to trace. A cost driver is the cause of the cost of an activity. Cost drivers are ideal tracers of indirect costs when the usage of the cost driver is proportional to the indirect cost.

Product cost should include both direct and indirect cost. The tracing of indirect product costs, also called overhead cost or common cost, is more difficult. Overhead is often peripherally related to a product or service only. To estimate the indirect cost of products, the management accountant must have a good understanding of the operations of the organization.

To trace Indirect Product Costs, at least one Cost Driver is needed. The general procedure is showing as follows: Identify and estimate all of the indirect product cost.

Identify a cost driver to apply indirect costs and estimate the usage of the cost driver for all products and services. As soon as the total indirect product cost is estimated, a cost driver must be chosen. The cost driver should reflect the cause of the indirect cost. This cost driver could be related to the process of making the product or providing the service. The cost driver should be easily measured once chosen, the amount of the cost drivers used by each product or service must be estimated.

Calculate the application rating by dividing estimated indirect opportunity costs by the estimated usage of the cost driver for all products and services.

Apply indirect cost to the various products and services based on the expected usage of the cost driver for each product and service.

Without an accurate tracing of indirect cost to products, organizations are likely to make poor product mix and pricing decisions.

There is another approach for costing, which is called Activity-based costing (ABC). ABC is a procedure that attempts to provide more accurate product cost. Once the activities are identified, the indirect cost associated with each activity is estimated. While identifying the activities and estimating the cost, a cost driver is chosen for each activity. A cost driver causes, or "drives", the indirect cost of an activity. To choose the cost driver it should recognize whether the activity causes unit-level, batch-level, product-level, or facility-level cost. Ideally, cost driver usage is proportional to the indirect opportunity cost of the activity. Unit-level indirect cost should have cost drivers that vary with the number of units, and batch-level indirect cost the number of batches, and so on.

Cost Allocations

Cost allocation is the process of assigning indirect cost to cost objects. Cost objects include products, activities, subunits of the organization, customers, suppliers, and time periods. The subjective nature of indirect cost allocations makes the process one of the most controversial in accounting. Each cost allocation has planning, controlling, and external reporting implications, and an organization must often make trade-offs in choosing a cost allocation approach.

Given the contentious nature of the allocation of indirect cost, there must be some benefits to allocating indirect cost. These benefits fall into two main categories: (1) planning purposes, and (2) control purposes. The details are listed as follows:

Cost Allocation for Planning Purpose

The allocation of indirect cost can provide managers with information that allows them to make better decisions. The allocation of indirect cost also serves as a communication mechanism to inform managers how their actions are affecting cost in the rest of the organization.

Cost Allocation for Control Reasons

The allocation of cost in some organizations coincides with the allocation of resources. An organization may choose to allocate uncontrollable indirect cost through methods that can be affected by managers. By doing so, the organization can motivate managers to achieve certain goals of the organization.

Practically, an organization should continually evaluate its cost allocation methods. If the cost of an indirect resource is allocated at a rate different than the opportunity cost of using that indirect resource, managers will have an incentive to use too much or too little of that indirect resources.

Basic Steps of Cost Allocation

An allocation base is a characteristic of the cost object that is used to allocate cost. Cost drivers are a type of allocation base that reflects the cause of the indirect cost being allocated. Cost drivers are important for estimating the cost of a product or other cost object. Allocation bases, however, may be chosen for other reasons than estimating cost, such as controlling. There are five steps for cost allocation:

Defining the cost objects

The organization must decide what departments, products, customers, suppliers, or processes should receive the indirect cost. The cost object can be a subunit of the organization, such as a cost or profit centre.

Accumulating indirect cost in cost pools

The indirect cost being allocated is caused by the common use of a resource such as a machine, building, administrative service, or a production or service department. Cost associated with these resources is accumulated in a cost pools. The size of the cost pool depends on how resources are aggregated. Indirect cost associated with a resource includes all the cost that can be traced to the resource. In addition, a cost pool may contain cost that is only indirectly associated with the resource. Multistage cost allocation occurs when cost is allocated through a series of cost pools.

Choosing an allocation base

An allocation base is a measurement of a characteristic used to distribute indirect cost of a cost pool to cost objects. The choice of the allocation base depends on the goals of the organization. Because cost allocations are used internally for two primary purposes (making planning decisions and control), there is no single choice of an allocation base that is always right or always wrong. In general, the cost allocation bases chosen are those that have the greatest association with the cost being allocated.

Estimating an application rate,

Once the allocation base for a cost pool is chosen, an application rate is calculated. The application rate is

normally determined at the beginning of the year prior to the actual incurrence of the indirect cost.

Allocating indirect cost based on use of the allocation base.

Cost allocation for planning decisions should be performed to obtain estimation of the opportunity cost of using the common resource.

In summary, the cost allocation procedure allows for the flow of cost from a cost pool to cost objects. Cost objects are identified, cost is accumulated in cost pools, allocation bases are chosen, application rates are calculated, as well as indirect cost is allocated.

Traditional Absorption Cost Systems

Absorption costing is the process of allocating variable and fixed overhead cost to products, which are the cost objects. Absorption cost systems is widely used in financial reports for determining cost of goods manufactured. There are two basic types of absorption systems: job order system and process cost system. Job order costing is used in departments that produce output in distinct jobs (job order production) or batches (batch manufacturing). The central problem addressed in cost system is how to allocate indirect costs to products, jobs, or services.

The several important features of job order costing are:

All direct cost of manufacturing the job is traced directly to the job.

Each job is charged for some manufacturing overhead

At least one allocation base such as machine hours is used to distribute overhead cost to jobs.

The application rate for overhead (here, the rate per machine hour) is set at the beginning of the year, before the first job is started. This overhead rate is based on an estimate of what factory overhead cost and machine hours will be for the year.

Reported product cost is average, neither variable nor marginal, costs. Each job is assigned a portion of the overhead.

Overhead accounts are also recorded in other accounts (such as insurance, property taxes, depreciation, accounting, purchasing, security, general factory management, and utilities) before being allocated to job-order cost sheets through the use of allocation base.

Allocating Overhead to Jobs

The cost objects are jobs, which include individual products or batches of products. The accumulation of indirect cost includes cost that is both fixed and variable with respect to the allocation base. The allocation base is some input into the production process such as direct labour hours, machine hours, or material costs. The allocation base is chosen for making planning decisions and for control reasons. The application rate is predetermined based on budgeted overhead cost and predicated use of the allocation base. The predetermined application rate allows for the allocation of overhead cost to jobs throughout the period based on usage of the allocation base.

The application rate is a ratio of predicted overhead cost to predicted usage of the allocation bases. In reality, however, the estimated application rate is unlikely to equal the actual application rate. Therefore, the applied overhead will not equal the actual overhead. If allocated overhead cost is greater than actual overhead cost, the difference is called over absorbed overhead. If allocated cost is less than the actual overhead cost, the difference is called under absorbed overhead.

Multiple Allocation Bases

A more complicated way to allocate overhead cost is to use multiple allocation bases. In this case, there are multiple overhead cost pools, each having its own allocation base and application rate. The advantages of using

multiple cost pools and allocation bases include improved planning and control. Improved planning occurs because multiple allocation bases are more likely to capture the different ways overhead resources are being used by the cost objects. Each allocation base should be proportional to the opportunity cost of using the overhead cost pool.

With multiple allocation bases, managers would have to make trade-offs in using overhead resources. With multiple goals, an organization can use multiple allocation bases more effectively on the way to achieving those goals.

Current XXX Cost Analysis Investigation

Basically, current cost analysis function in XXX is mainly a material cost accumulation system. It is oriented with the material consumed, such as Fabric cost and Trims cost. It deals with the manufacturing cost very simply, which is an estimation value for CMT. An example of cost calculation is as follows:

	ESTIMATED					RECEIVED			ACTUAL		
	QUANT / UNIT	UNIT COST	QUANT / ORD	RAND / UNIT	RAND / ORDER	QUANT ORD	QUANT REC	TRS TO STOCK	QUANT USED	ACTUAL COST	AVGE / UNIT
FABRIC 1	0.28	13.84	72800	3.88	1,007,552.00	80663	695,56.90	2,205.50	67351	874,894.69	12.99
FABRIC 2	0.03	9.80	13000	0.50	128,700.00	13323	14058.80	6,398.10	7660.7	102,117.13	13.33
FABRIC 3											
THREAD	1	0.2	260000	0.2	52,000.00				10401	101,238.53	9.73
LABELS	1	0.3	260000	0.3	78,000.00				263379	2,889.40	0.01
WASH CARE											
POLYBAGS	1	0.1	260000	0.1	26,000.00				94761	66,424.53	0.70
CARTONS	1	0.2	260000	0.2	52,000.00				7660	21,311.02	2.78
SELLOTAPE	1	0.1	260000	0.1	26,000.00				648	992.16	1.33
PRICE STICKERS	1	0.1	260000	0.1	26,000.00				263224	21,037.93	0.08
SHOULDER TAPE	1	0.1	260000	0.1	26,000.00				87454	12,899.47	0.15
TAG PINS	1	0.1	260000	0.1	26,000.00				258257	736.69	0.00
SIZE STICKER	1	0.14	260000	0.14	36,400.00				251440	35,201.60	0.14
P-PACK STICKER									34606	1,462.83	0.06
TRANSPORT	1	0.2	260000	0.2	52,000.00				250783	13,872.36	0.06
CMT COST	1	3.5	260000	3.5	910,000.00				260073	910,262.30	3.50
TOTAL				9.41	2,446,652.00					2,165,380.81	
COST PER GARMENT					9.69						8.33

TABLE A-1: AN EXAMPLE OF CURRENT COSTING

It has not included the direct service cost such as Sampling cost and Order Tracing cost. Further more, it has not considered the indirect cost such as Administration cost, Facility Deprecation, Factory Rent and so on. And what is the most serious problem is that the structure for costing is not in place due to various reasons. The figure below somehow is the resources that it currently used for cost estimation.

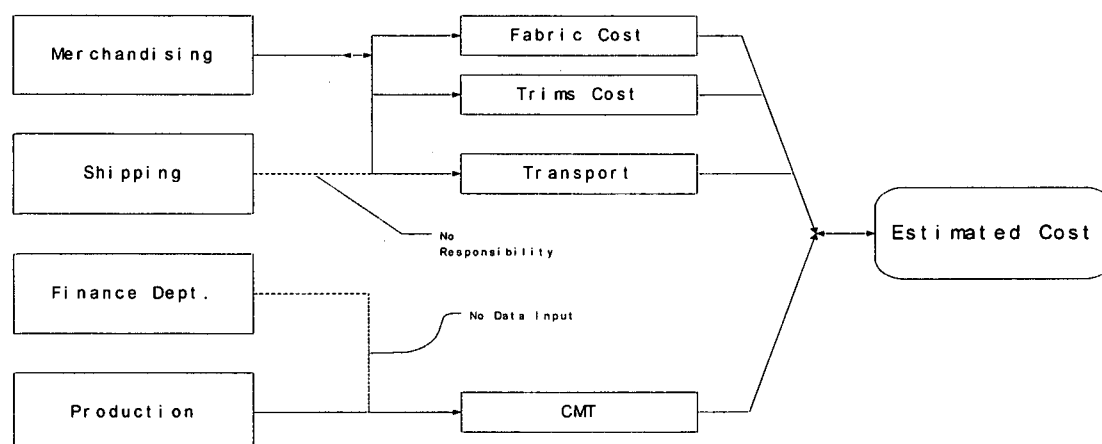


Figure A-1: Current Costing System

From the figure above we can see that current estimation is a one-way process, and no any feedback to enhance the costing knowledge, for example, it is the merchandising put the transport cost, but there is no feedback for real transport cost to merchandising again, and which is very important for cost control. Secondly, the responsibility is not right, as “The controllability principle based on responsibility accounting suggests that managers should be responsible only for cost they can control”. The merchandising department cannot be responsible for all the cost data’s accuracy. A good cost control system requires the various departments to take their own responsibilities.

Suggested Solution for Cost Analysis

According to our current situation, a job-order system should be used for our need. The cost is calculated based on one specific order, EXP 417, for example, and the cost estimation are based on every single proceeding that is related with this order. The cost analysis is based on job-order also. It supposes to provide feedback information for further decision-making, and production control. From a system point of view, a cost analysis and management system for control purpose can be illustrated as follows:

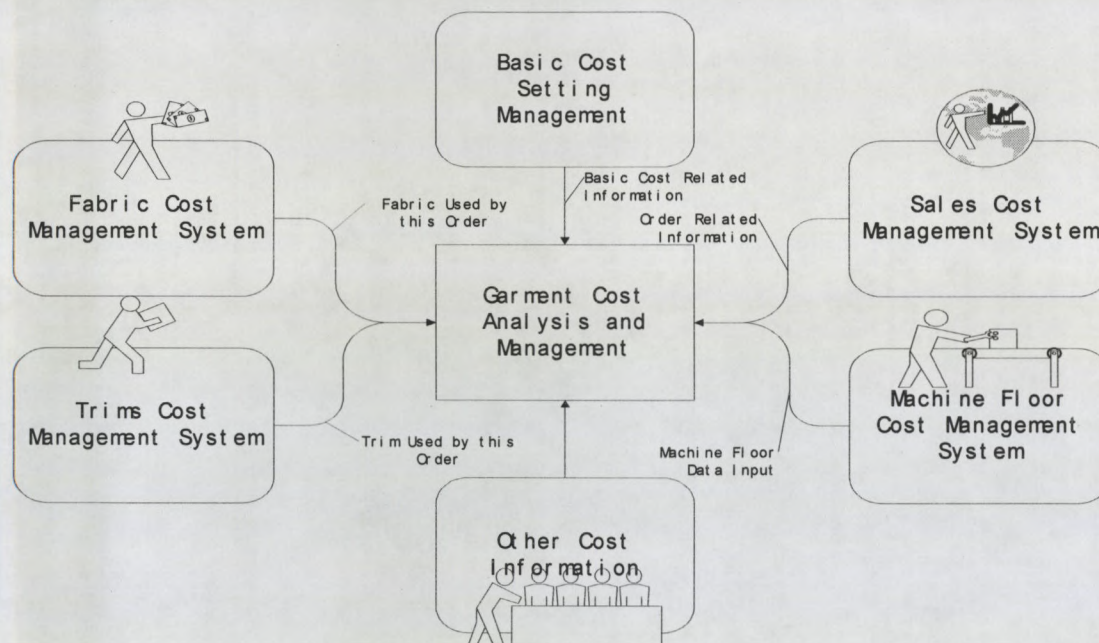


Figure A-2: A Proposed Costing System

For control purpose, cost should be oriented with the production process flow, thus it can base on the calculated cost to provide feedback for costing control that related with the various processes. In details, a possible costing stream can be illustrated as the following figure,

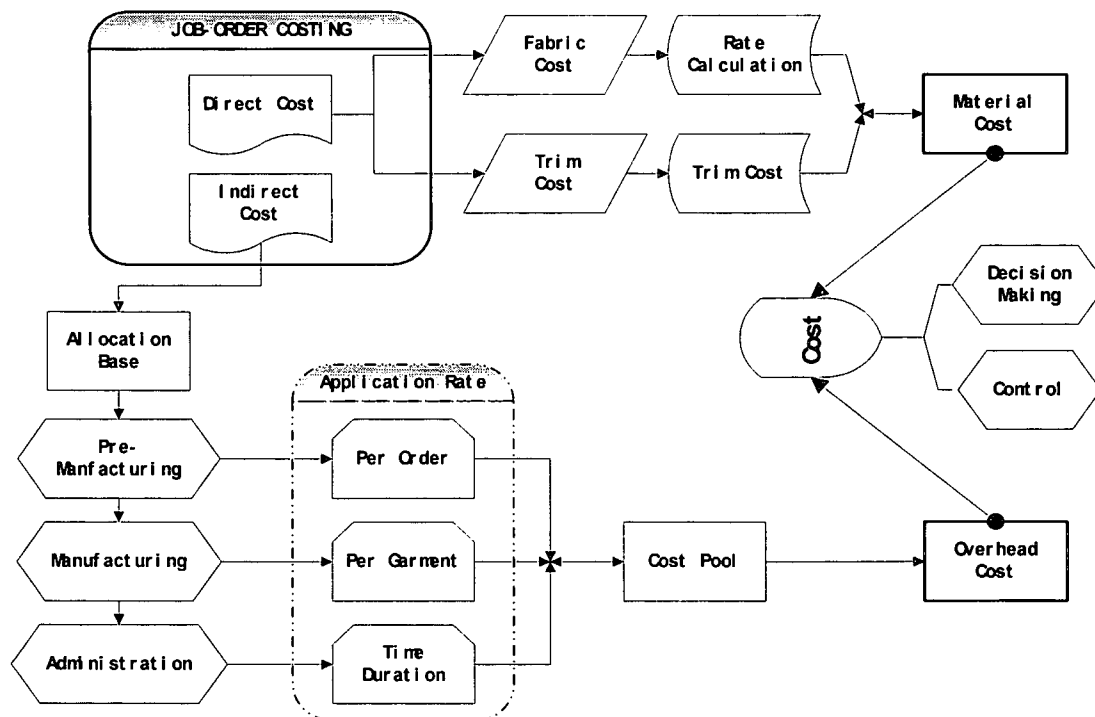


Figure A-3: The Cost Flow of New Approach

For material cost calculation, it is easy to be achieved. The problem is for the Direct Labour Cost calculation. According to current management system, it is very hard to accumulate such data to figure out how much direct labour cost is associated with each garments. Here we will treat labour cost as a factory level 'overhead', which can be allocated to each garment via factory cost pool. When we get the possibility to calculate direct labour cost individually, we can put it back to direct cost calculation.

For Overhead cost calculation, it needs careful analysis to choose the right allocation base, and it requires accurate data that from machine floor to financial department. The new approach has structured the cost allocation into three levels, namely order level base, factory level base, and enterprise level base. What is the biggest difference with the former approach is that now the cost allocation base is clear structured, and this makes further criticising and updating becomes possible. (The former approach only include a CMT cost, which is very vague and has no way to criticising it but estimating by experience)

With the ERP implementation, it can provide basic machining related information. Together with the information from financial department, the application rates that are shown in the above figure can be derived. The calculation formulas are:

Pre-Manufacturing Order Costing Rate:

$$\frac{\text{Merchandising/Planning/Purchasing Cost for 3 Months (Salary \& Spends)}}{\text{Processed Order in 3 Months}}$$

Manufacturing Costing Rate

$$\frac{\text{One Month Cost Accumulation for Machine Floor (Rent, Depreciation, Labour Cost etc.)}}{\text{Finished Garment for this Month}}$$

Administration Costing Rate

Accumulated Administration Cost for this Finance Year / Total Finished Garment for this Year

The data sources for allocation rate calculation are from Finance Department (data from Budgeted Income Statement is used for illustration example later), and information from Merchandising and Machine floor. The formulas used above are very simple. With more data accumulated, a better-cost allocation method can be implemented.

As an accurate cost is placed well, it can be used for various purposes. A brief illustration is shown as follows.

For decision-making

With a suitable costing system in place, it can help to develop a more accurate cost-estimation for further order dealing, help to decide a more competitive price, for example.

With a more accurate costing system, we can detect which process is money consuming process, thus can help us to make outsourcing decision or for new facility purchasing decisions.

With an accurate cost in hand, a profit-loss analysis can be done, and it can help the management to make important decisions, expanding decisions, for example.

For control purpose

For cost control, the benefit is obviously. First, a more reliable Budget can be developed, which is the main tool for cost control. A good costing system can set up a more applicable standard cost for various departments.

Secondly, it also has impact for machine floor controlling. For example, it can help to detect some over-spend places, and to make further control actions.

Summary

From management administration point of view, it is strongly recommended that a detailed cost estimation should be placed. With the ERP system implementation, it provides a chance to upgrade current cost analysis and management system to a new level. With the analysis for AnCheng ERP system, it can provide the basic data for cost analysis. But as this system is not specializing in cost management, the processing functions are limited.

Company with new ERP system's implementation, some special costing function modules can be designed and be employed into ERP system. Along with the Information System optimization, we can design a more specific cost management system that needs a streamline integrating with the financial system, but it had to wait until the most management functions are working to provide a fundamental for further achievement.

Appendix

An Example for Cost Calculation

--- EXP 413, *Old Navy, Baby Boys s/s Ringer Top*
 QUANTITY ORDERED, 260000

a) Material Cost Calculation

	QUANT / UNIT	UNIT COST	QUANT / ORD	RAND / UNIT	RAND / ORDER
FABRIC 1	0.28	13.84	72800	3.88	1,007,552.00
FABRIC 2	0.05	9.90	13000	0.50	128,700.00
FABRIC 3			0	0	-
THREAD	1	0.2	260000	0.2	52,000.00
LABELS	1	0.3	260000	0.3	78,000.00
WASH CARE			0	0	-
POLYBAGS	1	0.1	260000	0.1	26,000.00
CARTONS	1	0.2	260000	0.2	52,000.00
SELLOTAPE	1	0.1	260000	0.1	26,000.00
PRICE STICKERS	1	0.1	260000	0.1	26,000.00
SHOULDER TAPE	1	0.1	260000	0.1	26,000.00
TAG PINS	1	0.1	260000	0.1	26,000.00
SIZE STICKER	1	0.14	260000	0.14	36,400.00
P-PACK STICKER			0	0	-
TOTAL				5.71	1,484,652.00
Material COST PER GARMENT		(x 3%)		0.28	5.88

TRANSPORT	1	0.2	260000	0.2	52,000.00
CMT COST	1	3.5	260000	3.5	910,000.00

b) Overhead Allocation

❖ Pre-Manufacturing Order Costing Rate

Merchandising/Planning/Purchasing Cost for 3 Months (Salary & Spends)
Processed Order in 3 Months

Pre-Manufacturing Order Costing Rate=(54000+42000)/22=4364

❖ Manufacturing Costing Rate

One Month Cost Accumulation for Machine Floor (Rent, Depreciation, Labour Cost etc.)
Finished Garment for this Month

			<u>Mar-04</u>
Cleaning	1512		
Medical AID	26000		
UIF	32885		Graments @ US\$2.5
Provident Fund	131541		Convert @ R6.50
Dep. Machinery	200000		
Inspection Costs	75000		
Vehicle Exp.	100000		
Pest Control	600		
Printing	74000		
Protective Clothing	1000		
Refuse Removal	5000		
Rent	110000		
R&M Equipment	76000	1031641/16.25	EQ 63485.6
Security	14000		Budgeted Garment Processed:
Spares Maint.	15768		Actual 1497000
Staff Training	131541		
Workmens Comp	13200	SUM	1008047
Workers Wages	4500000	4034155	Manufacturing Costing Rate:
			EQ 3.6793901
Total	5508047		

❖ Administration Costing Rate

Accumulated Administration Cost for One Month / Total Finished Garment in this Month

Accumulated Administration Cost for One Month: $1160509 - 1008047 + 380000 = 532462$

Total Finished Garment in this Month: 1497000

Administration Costing Rate = $532462 / 1497000 = 0.36$

c) Cost Calculation

EXP 413, *Old Navy, Baby Boys s/s Ringer Top*

Quantity 260000

Material Cost	Fabric Cost	4.28/p	4.28
	Trim Cost	1.43/p	1.43
Overhead Cost	Pre-Manufacturing	4364/o	0.017
	Manufacturing	3.68/p	3.68
	Administration	0.36/p	0.36
COST PER GARMENT			9.767

The old approach calculated cost is 9.69. Using the new approach, cost per garment is 9.767. There is 0.79% variance, which is R20020 in total for this order. It is big enough to pay more attention for this because we get average 33 orders every month.

The difference is more in how the data is used for calculation. The new approach has clear flow for how data is generated without guessing, thus make further cost controlling becomes possible and achievable. With a more reliable cost estimation and analysis in hand, we can propose costs that are reasonable and allocable in the future.

We can see that the garment cost is composed with three main parts, namely: Fabric Cost, Trims Cost, and CMT. Fabric cost, Trim and CMT are an exception because they get almost the same weight in garment cost. In the real situation, the CMT cost varies greatly due to different style and the factory's order currently at hand and this has been the cause for cost uncertainty.

Cost analysis

Due to this it is impossible to audit the system for CMT calculations and the *Cost & Analysis* had no choice but to ignore the CMT's inaccuracy.

CUSTOMER: Old Navy		FLEECE PANT WITH ERB									
Date	2/14/16/18	JOB #	EXP 100								
QUANTITY ORDERED	BASED	Est:									
QUANTITY MADE		Yield:	1.32								
MB: Costed Rate	0.078 0.75	Fabric Util:	64								
Cost Items	ESTIMATED			ACTUAL			STOCKED			VARIANCE	
	QUANT	ESTD	ESTD	QUANT	ACTUAL	ESTD	QUANT	ESTD	STOCKED	QUANT	E.
FABRIC 1	27247	4.38	118461.66	0	0.00	-	0	0.00	0.00	27247	118461.66
FABRIC 2	0	0.00	-	0	0.00	-	0	0.00	0.00	0	0.00
FABRIC 1	4825	0.95	4582.75	0	0.00	-	0	0.00	0.00	4825	4582.75
Fabric Rec											
THREAD		0.20	12,870.00	3361	21,023.47	0.25	3361	1.851	-1,480.00		-3203.47
LABELS	176470	0.30	52,941.00	0	17,035.40	0.22	0	158070	*****		8909.00
WASH CARD											
POLYUREA	14400	0.15	2,160.00	13600	2,305.51	0.03	*****	0	-13,600.00		11698.99
CARTONS		0.50	44,875.00		15,750.00	0.10	*****	0	0.00		28025.01
BILL OF M			#VALUE!		220.00	0.01	0	0	0.00	0	
ELASTIC											
PRICE TICKET		0.10	8,935.00	26280	6,902.40	0.08	*****	86280	-4,760.00		
HANG TAGS	2010			4250	452.85	0.01	4250	0		2260	-452.85
PLED											
SHOULDER TAP		0.10	8,935.00		13,235.70	0.15	0	0		0	-4300.70
TAC RING		0.01	893.50	1E+05	0.00						
FACE											
CRAP CORDS											
RIB STICKER	89350	0.30	26,805.00	28500	10,340.70	0.12	*****	0	-88,500.00	250	7620.50
PRE-PACK STICKER		0.10	8,935.00	7390	756.50	0.01	0	15130			8178.50
STONES-TRANSFER											
PRINTING OUT	89350		#VALUE!	28535	94,970.44	1.15	*****	28535		315.00	#VALUE!
EMBROIDERY		1.00									
COLLARS											
TRANSPORT	89350	0.20	17,870.00		48,986.52	0.59				89350	#VALUE!
OTHER		0.50									
CMT COST	89350	2.50	223,375.00	38258	230,595.00	2.50				1112	#VALUE!
TOTAL		11.68	#VALUE!		~5,871.57						#VALUE!
COST PER GARMENT	0.82		12.50				5.48				#VAL. UN?
MARK-UP	7.0%						7.0%				
SELLING PRICE			R 12.25		R 2.75				R 7.00		
Profit Based on Estimated Cost/Manufacturing:					561.39%		Fabric Actual Rating:				0.000
Sub Cost Pa Pda		QTY	Actual Cost	1. Fabric		2. Trim		3. CMT			
R. T. ...		89350	4,364.00	-		2.80		2.50			
			481,014.91	-		1.3%		2.6%			

After further analysis, it is found that the CMT can vary from R0.89 up to R6.00 in the real manufacturing situation. As to mass production, the CMT inaccuracy greatly influenced the profit.

2. Analysis of CMT Influence Factors

The summary of all data inputs for this month shows us some problems and solutions too.

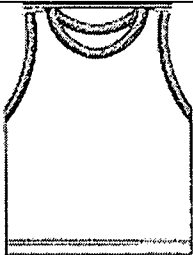
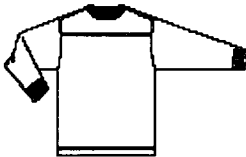
Style Complexity


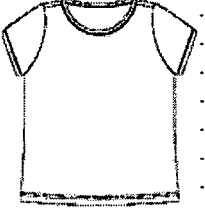
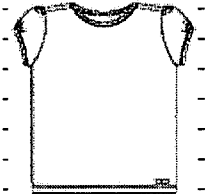
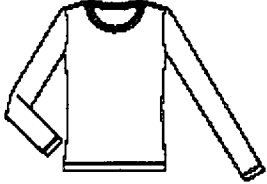
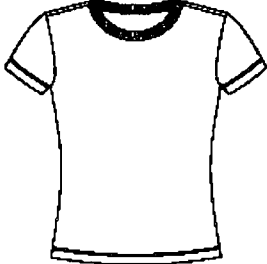
Firstly, we did get a problem to evaluate the Order Complexity factors, but it did get some link/relationship with the pre-set Target, which is reflecting the Supervisors evaluation for this style. We needed to complete the record for No of Breakdowns, which also reflected style complexity somehow.

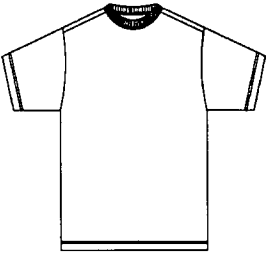
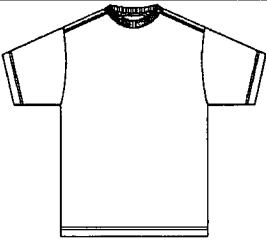
Now what we should do is to try to combine these two factors together to give an evaluation for style complexity.

Example: Out put 1200 (rank 0.65), and No of Break down is 10 (rank 0.35). As the maximum output since achieved is 2000, and maximum Breakdown is 16 processes, so the calculation can be,

$$((2000-1200)/2000)*0.65 + ((16-10)/16)*0.35 = 0.39$$

Exp No.	Description	Drawing	Rating
284	BABY BOYS ARCH LOGO TANK		7P
	12600 100% CTN SINGLE JERSEY 220 G/M2 A/W		1
181	BOYS COLOR BLOCKED SPORT BALL		14P
	191800 PCS 100% COTTON S/JERSEY 220 G/M2 AFTER WASH		8
223	baby boys fleece pants with print		14P

	563700 80%ctn 20% poly-colors / 75%ctn 25%poly-h.grey		8
248	BABY BOYS L/S BASKETBALL TEE 17592 100% CTN SINGLER JERSEY 220G/M2 A/W		8P
			2
249			9P
			1
250	BABY GIRLS LOVE SS TEE 16500 100%COTTON 1X1RIB 240GM/M2 A/W		11P
			6
207	LADIES L/S HOL GRAPHIC TEE 6500 85% CTN 15%POLYESTER 1 X 1 RIB 265 G/M2 AW		9P
			1
232	LADIES S/SL FOOD TEE 17000 PCS 100%ctn s/j 150 gm2 a/wash		9P
			3

137	MENS S/SL BASIC TEE 19670 PCS 100%Ctn , 55%CTN45%POLY S/J 185 GM/M2		8P
			1
196	MENS S/SL TATOO FLAME TEE 1800 PCS 100% COTTON S/JERSEY 220 G/M2 AFTER WASH		8P
			1

Fabric Ranking

The amount of fabric used should be prepared, and it needs the comment and rating from cutting room, and sewing room as well. The margin expectation has also a close relationship with what fabric used, as this is associated with the quality factors.

Actually, we also can take the full advantage of Neural Fuzzy network's powerful mapping ability. What we need to do is trying to identify different fabric; associate those with specific identify number. Then let the neural network map the difficulties to specific fabrics by themselves. This is exactly what we have done, but the difference we tried to make the figure associated with Fabric meaningful and interpretable by the reader. So, we need not crucify too much for the rating's accuracy, as long as it is a fixed value for specific fabric.

Busy or not

There are two sources which we may use for this factor's rating. One is from this order itself and the order quantity. The other should come from factory statistics, which can be reflected in the monthly, weekly shipment register.

Again, the less the order quantity, the more difficult for us to plan lines and the more total quantity are manufactured, the busier we are. We can expect that the largest order quantity to be 200,000. We get 25 lines in Tern3, and 18 lines in Tern 1, each line output gives 1400 in average, which will gives us the maximum outputs (60200/Day, 500,000/week) for each factory.

Example: EXP181, Order Qty is 191800 (0.3). It starts from the beginning of Sept, so it should use the weekly rating average for the final rating (0.7).

A summary of weekly sales is,

09/15	189	8998	0.23827
119135	190	20561	
	223	10400	
	223	8944	
	223	14170	
	223	840	
	223	16208	
	227	13520	
	227	20432	
	227	2000	
09/22	181	1000	0.671658
335829	181	6693	

Since this is a shipment register, whatever Busy or not rate is shown, it should be applied for the previous week, meaning from the 8th-15th.

The procedure for Delivery Sequence data processing:

- Summarize all monthly delivery schedules together, transfer them into Access and delete duplicated rows.
- In Access, sort the data by date, and export to Excel sheet again.
- Link the Access dataset to Crystal, and group it weekly.
- Summarize the weekly total quantity and record the summarized info into excel then process the general BON rating by 4, 3, 2, 1 ratio. (Remember, to put one week in advance)
- After that, apply this rating to each manufacturing period. Then copy to every PO. Then do process 1, which uses each of the PO's quantity multiply by according rating.
- Import this to Access again, and then sort the data by EXP order. Export to excel again.
- Do process 2 to obtain average the EXP order's rating. That is, sum all the related ratings and multiply by quantity, then divide by total quantity.
- Do the related final sorting.

Available data source for forecasting

- Orders at hand and the delivery sequence plan can be used for busy or not ratings.

- b. From order information, we can get the fabric info, style info, and order qty info.
- c. The list of fabric can be used directly.

The final data processing procedure list as follows

- a. Use EAS interactive SQL export EASDB into excel sheet. (cmtinfo, product)
- b. Import these two excel sheets into Access, and check the NTworkers correct or not, and do general checking. Please remember to change the number setting for specific columns.
- c. Link these two tables, and then do Query.
- d. Open a blank Crystal sheet and link the database connection to the queried view.
- e. Do grouping by cmt-id, and summarize the related column information. Do remember to adjust the group field's column width.
- f. Export the report to EXCEL sheet.
- g. Perform final modifications and do the related processing.
- h. This info can be used to generate the actual CMT cost. That is
 - 1) Based on average target to generate the complexity figure
 - 2) According to the fabric description, recording the fabric ratio manually.
- i. After that, link this processed table with generated factory Busy or Not table.
- j. Final output the dataset which can be used directly for Neural Fuzzy training and testing.

The final dataset used for training includes

- a) Order Quantity,
- b) Busy or not
- c) Target average
- d) Fabric type

Please remember all the dataset should be pre-treated before used for training.

3. The proposed CMT system.

Labor Cost per Garment= Total Wages Spent/Total Garment Made

Total Wage Spent= (Total Working Days/5) X Average of Wages

These are the direct factors to calculate the CMT, but the factors that can be used for expectation it is hard to detect. The details of the influence factors analysis refer to point 2 above.

An example: CMT for EXP145

In this first stage of CMT calculation, it only focused on the machine floor's Labour Cost (Factory CMT). Based on the summary from the factory CMT report, CMT for one style (EXP145) can be worked out.

For one style, random choose one to few week(s) as the calculation data source. The formula is stated as following,

$$\begin{aligned} \text{FCMT} &= \text{Total Money Paid for the Workers} / \text{Total Garment Made} \\ &= (\text{Total Workers Summarized in Daily} \times \text{R241} / 5) / \text{Total Garment Made} \end{aligned}$$

Here choose EXP 145 CMT report from 7th of July to 13th of July (One week) as the calculation data source. The summary information is as the table followed,

Duration	Working Days	Output in Total	Average Wages Per Week
7 th – 13 th	2283 days	56707pcs	R241

The Total Money Paid for Workers:
 $(2283 / 5) \times 241 = 456.6 \times 241 = 110040.6$

$$\text{FCMT} = 110040.6 / 56707 = \text{R } 1.94$$

If we take the administration, cutting room and despatching department into account, CMT can be adjusted to:

NB: 15% as administration fee.
Cutting and Despatching takes 10%

$$\begin{aligned} \text{CMT} &= \text{FCMT} \times (1 + 15\% + 10\%) \\ &= 1.94 \times 1.25 \\ &= \text{R}2.5 \end{aligned}$$

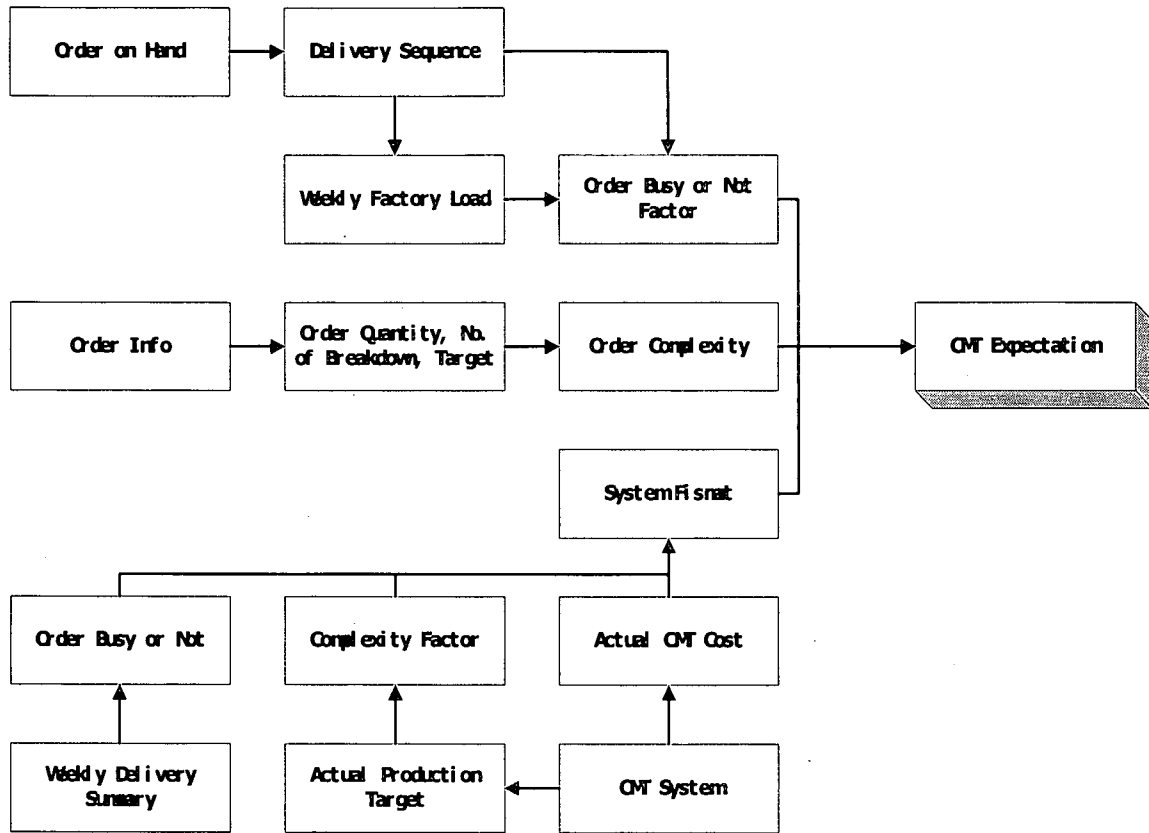
Developing Software and Database Used

The Sybase's product, Power Builder was used for system design, as it gets such a powerful tool called *Datawindow*, which is especially useful for data collection.

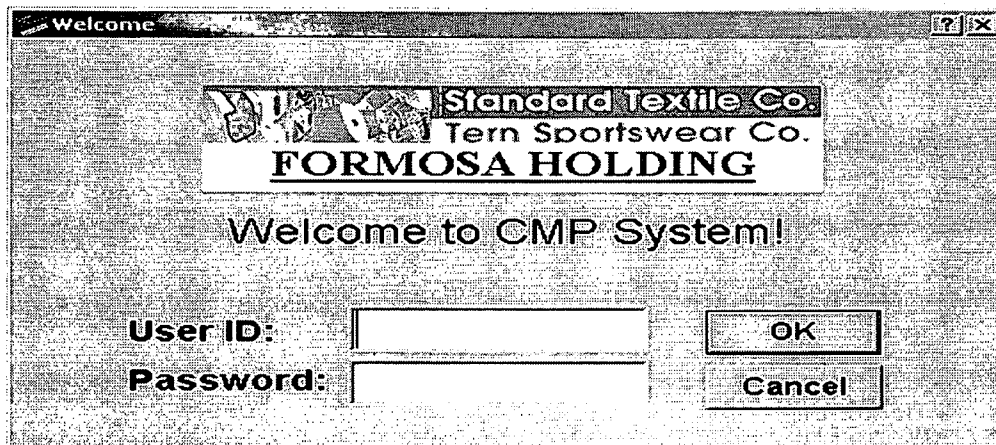
The integrated database with Sybase product, called SQL Anywhere was use for database construction.

CMT system constructed

The proposed CMT system's data flow is illustrated as follows,

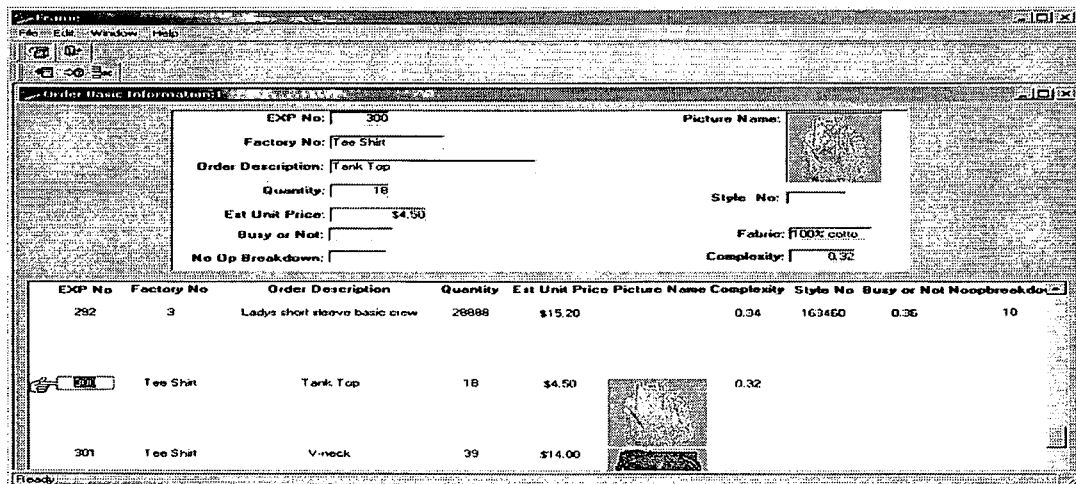


CMT system tutoring

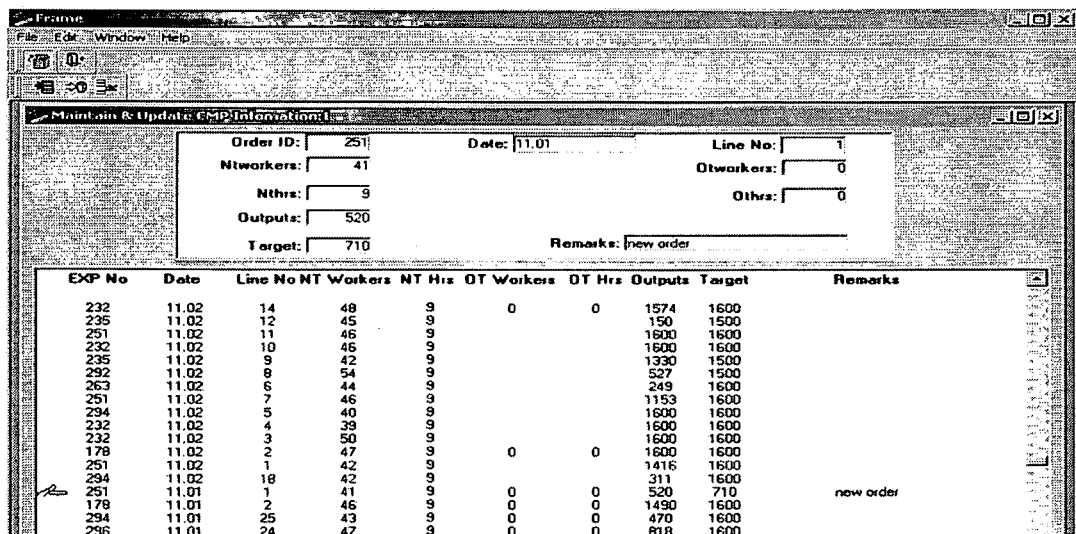


This is the system Login page. The user has to use a User Id and a correct password to login into the system, thus to prevent unauthorized people from accessing the system and change data.

After the user logs-in, the main system window is presented. Click on the **File** menu, and three sub-functions, namely, **Order basic information** page, **CMP daily update** page, and **Order CMP summary** information will be displayed.



This page is served as the order basic information collection, as this CMP system also has an act for factory management purpose. The basic information can also provide useful information that influences the actual CMP cost.



This is the daily CMP information input page. The input boxes are at the top of the Datawindow, and data input can be easily performed by using the *Tab key* from the keyboard. The bottom Datawindow is used to display all the data that was entered into the system and the display sequence is sorted in date ascending order. Using this method enables the operator to efficiently identify any data mistakes and daily production information for factory manager also.

The screenshot shows a window titled "Summary Information:1" with a menu bar (File, Edit, Window, Help) and a toolbar. The main area contains input fields for various parameters:

- Enter EXP No Here:
- EXP No: Fabric:
- Factory No: Complexity:
- Order Description: Style No:
- Quantity: Busy or Not:

Below the input fields is a table with the following data:

EXP No	Date	Line No	NT Workers	NT Hrs	OT Workers	OT Hrs	Outputs	Target	Remarks
223	09-06	15	48	9			1500	1500	operation 9
223	9-6	21	50	9			1098	1500	0
223	9-6	11	47	9			1027	1500	
223	9-6	7	49	9			1444	1500	
223	9-6	22	46	9			1370	1500	
223	9-6	24	49	9			1301	1500	
223	9-6	9	49	9			1500	1500	
223	9-6	10	47	9	0	0	1400	1500	
223	9-7	7	49	9			1500	1500	
223	9-7	9	46	9			1107	1500	
223	9-7	10	47	9	0	0	1500	1500	
223	9-8	7	46	9			1500	1500	
223	9-8	9	46	9			1109	1500	
223	9-8	10	47	9			1500	1500	

For quick reference and management information purposes, an Order CMP summary page is designed. It is characterized with a **Search** function and **Excel** function that can export looked up information, into an Excel sheet.

The screenshot shows the same "Summary Information:2" window as above, but with a "Save Files" dialog box open over it. The dialog box is titled "Save Files" and shows the "EXCEL" folder selected. The file list contains several .xls files, with "223.xls" selected. The "File name" field contains "223.xls" and the "Save as type" is set to "Excel Files (*.xls)".

The background table from the previous screenshot is partially visible behind the dialog box.

Up to now, this system has provided a data collection tool for the operators, and the collected data is stored in the database that can be used for further analysis. For example, a CMP cost can be easily calculated based on the exported Excel sheet.

G42		=SUM(D\$2:D37)+SUM(F\$2:F37)*1.5							
	A	B	C	D	E	F	G	H	I
22	223	9.8	9	47	9			1500	1500
23	223	9.8	10	47	9			1500	1500
24	223	9.8	11	49	9			1034	1500
25	223	9.8	15	49	9			1287	1500
26	223	9.8	21	47	9			1231	1500
27	223	9.8	22	44	9			1500	1500
28	223	9.8	24	47	9			1500	1500
29	223	9.9	7	46	9			1333	1500
30	223	9.9	9	47	9			1500	1500
31	223	9.9	10	47	9			1500	1500
32	223	9.9	11	49	9			1034	1500
33	223	9.9	15	49	9			1269	1500
34	223	9.9	21	47	9			1231	1500
35	223	9.9	23	51	9			793	1500
36	223	9.9	24	47	9			1500	1500
37									
38									
39							Total	47016	
40									
41									
42						No. of Workers	1662		
43						Wages in Total	332.4	80108.4	
44						CMP Cost		1.70385	

4. An example of CMT calculation

EXP NO.	QUANTITY	VESSEL DATE	BONZ
279	8100	20-Dec-04	0.0979
242	48000	03-Oct-04	0.2023
181B	31600	29-Sep-04	0.2171
224	87957	06-Oct-04	0.2283
237	128620	02-Oct-04	0.2322
238	33600	13-Oct-04	0.2326
239	18200	13-Oct-04	0.2332
281	3500	11-Oct-04	0.2332
179A	13800	08-Sep-04	0.2567
219	5300	29-Sep-04	0.2657

250	16500	24-Nov-04	0.2676
249	45300	07-Dec-04	0.2796
217B	12000	29-Sep-04	0.2801
215	10400	10-Sep-04	0.2879
227	56086	22-Sep-04	0.2942
180B	24000	06-Sep-04	0.2945
184	2400	10-Sep-04	0.2945
183	1800	10-Sep-04	0.2945
298	65528	01-Dec-04	0.3196
283	24200	24-Nov-04	0.3274
223	451000	20-Oct-04	0.3396

By giving each week a Busy or Not rating (based on the weekly delivery quantity), a summary of order Busy or Not factor is list as table above.

F2						=	=((B2/5)*241)/D2
A	B	C	D	E	F		
Order ID	NTworkers	OTworkers	Outputs	Remarks	CMT Cost		
178	318	0	6983	normal	2.19		
179	455		5305		4.13		
181	1592		27236		2.82		
185	377		9049		2.01		
187	96		2760		1.68		
196	64		2521		1.22		
199	45		1200		1.81		
217	659		12954		2.45		
218	621		11583		2.58		
219	413		5524		3.60		
223	7158		188054		1.83		
224	1625		39409		1.99		
227	2118		50848		2.01		
230	137		2553		2.59		
237	2690		44984		2.88		
238	771		17335		2.14		
239	376		10204		1.78		
242	5013		53541		4.51		
255	48		731		3.16		
257	933		17899		2.51		
292	194		3464		2.70		

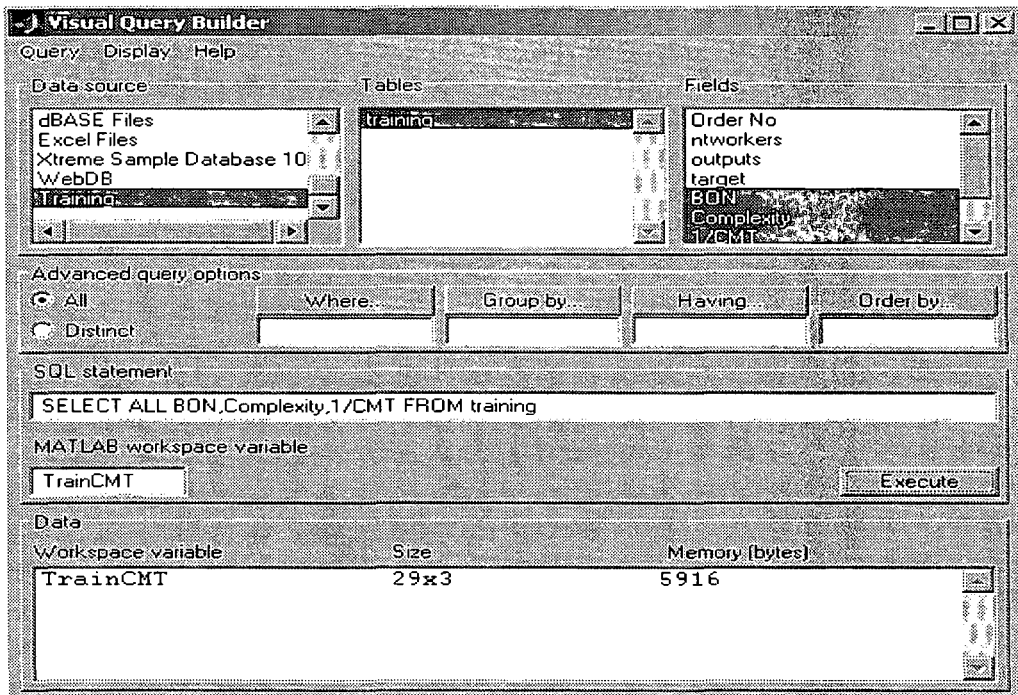
Based on what the information provided by the CMT system, each order's CMT cost can be easily calculated, which is shown in the figure above.

Training

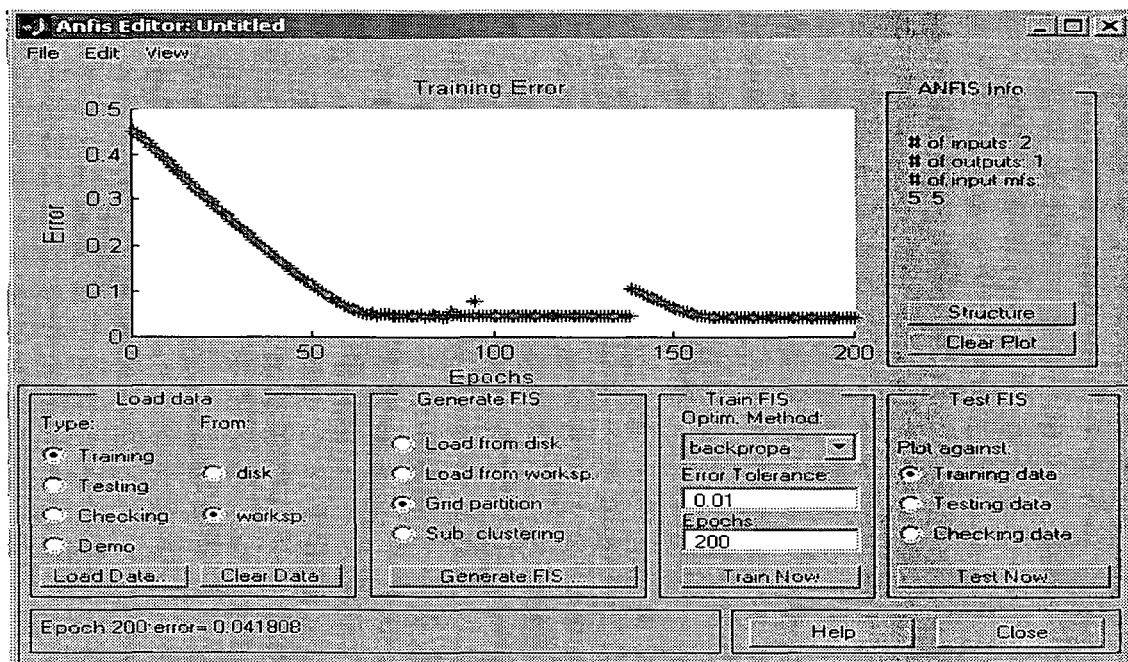
After the Management Information processing, a training dataset can be obtained, which is shown as the table below.

Order No	ntworkers	outputs	target	BON	Complexity	1/CMT	CMT
178	318.00	6,983.00	1,340.00	0.3582	0.3300	0.45558	2.194988
179	455.00	5,305.00	729.00	0.2567	0.6355	0.2419	4.134025
181	1,592.00	27,236.00	1,197.27	0.2171	0.4014	0.35494	2.817389
185	519.00	13,646.00	1,547.27	0.4691	0.2264	0.5455	1.833197
187	283.00	5,819.00	1,393.33	0.4737	0.3033	0.42659	2.344148
217	659.00	12,954.00	1,480.00	0.2801	0.2600	0.40782	2.452046
218	621.00	11,583.00	1,313.85	0.3469	0.3431	0.38697	2.584149
219	413.00	5,524.00	1,041.25	0.2657	0.4794	0.2775	3.603657
223	8,475.00	209,673.00	1,418.41	0.3396	0.2908	0.51328	1.948248
224	1,625.00	39,409.00	1,396.18	0.2283	0.3019	0.50315	1.98749
227	2,118.00	50,848.00	1,558.84	0.2942	0.2206	0.49808	2.007701
230	137.00	2,553.00	1,233.33	0.4904	0.3833	0.38662	2.586526
234	373.00	6,359.00	1,493.75	0.6918	0.2531	0.3537	2.827268
237	3,630.00	64,414.00	1,152.56	0.2322	0.4237	0.36815	2.716273
238	771.00	17,335.00	1,205.00	0.2326	0.3975	0.46647	2.143767
239	335.00	9,454.00	1,535.71	0.2332	0.2321	0.5855	1.707954
242	5,013.00	53,541.00	849.37	0.2023	0.5753	0.22159	4.512927
243	1,326.00	31,659.00	1,368.33	0.5758	0.3158	0.49534	2.0188
244	1,006.00	21,118.00	1,563.35	0.8316	0.2183	0.43552	2.296108
245	1,364.00	38,633.00	1,384.29	0.7184	0.3079	0.58762	1.701778
248	822.00	18,499.00	1,444.44	0.5729	0.2778	0.46691	2.141759
253	84.00	1,610.00	1,600.00	0.6918	0.2000	0.39765	2.514783
255	2,026.00	44,613.00	1,533.72	0.6605	0.2331	0.45685	2.188896
257	5,159.00	118,152.00	1,400.95	0.5369	0.2995	0.47515	2.104609
291	540.00	15,281.00	1,582.50	0.5134	0.2088	0.5871	1.703292
292	1,184.00	29,836.00	1,352.80	0.4546	0.3236	0.52281	1.91275
296	1,519.00	33,317.00	1,542.42	0.7463	0.2288	0.45505	2.197551
297	1,061.00	25,074.00	1,488.80	0.6979	0.2556	0.4903	2.039571

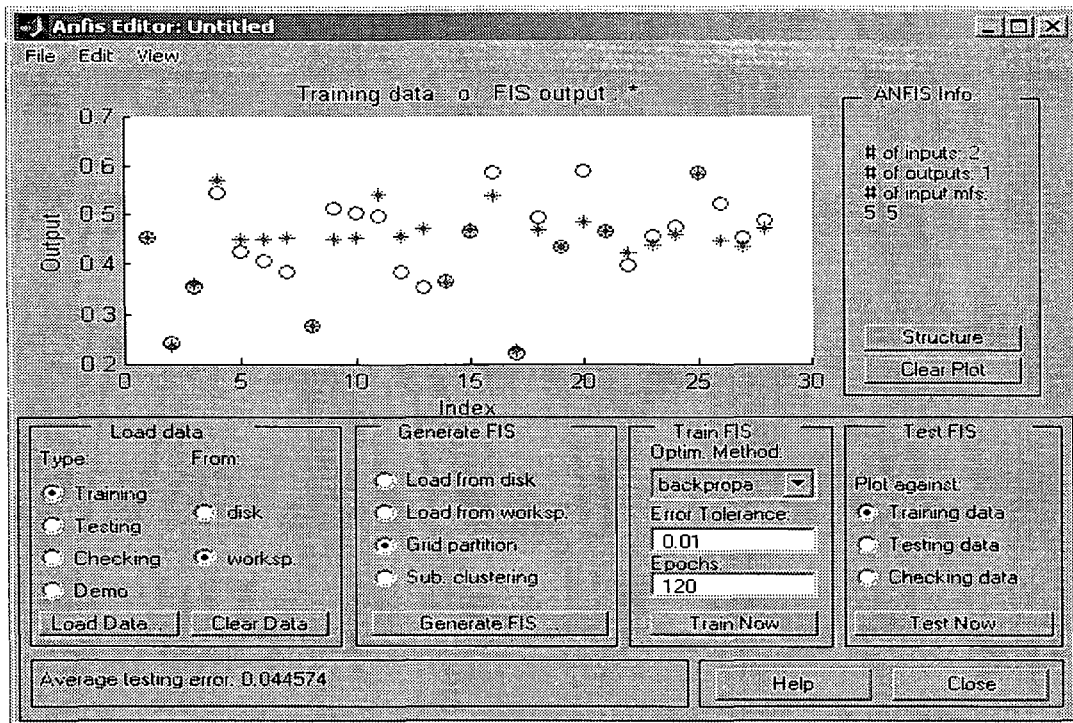
The training process is quite simpler by take advantage of ANFIS functions (by using Visual Query Builder tool, the dataset above can be easily retrieved into Matlab workspace, which is ready for any further processing).



A training result can be plotted as the figure follows,



From the training error plot, a final training with 120 epochs will be used (with a training error of 0.044593). A plot of training data against with FIS out put is shown as follows,



From above plot, several stranger dataset can be identified, which are marked with colour in training dataset in the beginning of this section.

A3. Main Programs

A3.1 Matlab M Files

A3.1.1 New Product Data Input

```
%function dbimport()
%DBIMPORTDEMO Imports data into MATLAB from a database.

% Set maximum time allowed for establishing a connection.

timeoutA=logintimeout(5);

% Connect to a database.

connA=database('NewDB','');

% Check the database status.

ping(connA);

% Open cursor and execute SQL statement.

cursorA=exec(connA,'select * from NewProduct1');

% Fetch the first 57 rows of data.

cursorA=fetch(cursorA,1);

% Display the data.

ImportData=cursorA.Data;

% Close the cursor and the connection.

close(cursorA);
close(connA);

%for i = 2:n
%for i = 2:5
tmpN(:, 1) = ImportData(:,2);
tmpN(:, 2) = ImportData(:,3);
```

```
tmpN(:, 3) = ImportData(:,4);
```

```
%end
```

```
NewData=cell2MAT(tmpN);
```

A3.1.2 Cost Estimation

```
% Cut Time Estimation (here take Pocket Milling as an example.
```

```
h=25;
```

```
d=5;
```

```
a=270;
```

```
b=270;
```

```
r=18.05;
```

```
f=1.2;
```

```
A=0.38;
```

```
% Calculation
```

```
M=h/d;
```

```
N=(b-2*r)/(2*r*A);
```

```
T=(N*(a-2*r)+(b-2*r))*M/(1000*f);
```

```
%Loading Management Information
```

```
LabourRate=2;
```

```
MachineryRate=4;
```

```
Overhead=50; ... ..
```

```
ProductCost=(LabourRate+MachineryRate)*T+Overhead;
```

```
save NewCost ProductCost;
```

A3.1.3 System Profit Margin Training

```
%% Adaptive Quotation System Testing
```

```
% quotation prediction using ANFIS.
```

```
%
```

```
% Copyright DIT.
```

```
% $Revision: 0.5 $
```

```
%%
```

```
function SystemFismat
```

```

% prepare training data
Trainingdbimport;

fismat = genfis1(TranData, [5 5 4]);

[trn_fismat,trn_error] = anfis(TranData, fismat,[],[]);

save systemfismat trn_fismat;

clc

```

A3.1.4 Profit Margin Expectation

```

% Put New product information into Matlab Workspace
newproductinput;

% load training results
load systemfismat;

input = [NewData];
anfis_output = evalfis(input, trn_fismat);

ProfitMargin=1/anfis_output;

save NewMargin ProfitMargin;

```

A3.1.5 Quotation

```

function structResult = Quotation()
% Quotation Programming

% Processing AI inputs

% Competetion Factor
CompetFactor;

%%%%%%%%%%%%PENDING%%%%%%%%%%%%
% Geometry Factor
%GeomFactor;

% Engineering Factor
%EngFactor;

```

```
Cost;

Margin;

% Loading Cost and Profit margin
load NewCost;

load NewMargin;

structResult.ProductCost = ProductCost;

structResult.Margin = ProfitMargin;

structResult.Quotation = ProductCost*ProfitMargin;
```

A3.2 Web Integration

A3.2.1 Database Connection

```
<%@LANGUAGE="VBSCRIPT" CODEPAGE="936"%>
<%option explicit
response.Buffer=true

dim conn
set conn= Server.CreateObject("adodb.connection")
conn.open "provider=microsoft.jet.oledb.4.0;data
source=" & server.MapPath("DB/CustomerInput.mdb")

dim rs
set rs= Server.CreateObject("adodb.recordset")

sub closers
rs.close
set rs=nothing
end sub

sub closeconn
conn.close
set conn=nothing
end sub

sub alert(msg)
```

```
response.write "<script language='javascript'>alert("""对不起, "&msg&""");history.go(-1);</script>"
response.end
end sub
```

```
sub suc
response.write "<script language='javascript'>alert("""操作成功!""");location.href=""&comeurl&""";</script>"
end sub
```

```
dim comeurl,temp
comeurl=Request.ServerVariables("HTTP_REFERER")
if comeurl="" then
comeurl="login.asp"
else
temp=split(comeurl,"/")
comeurl=(temp(ubound(temp)))
if instr(lcase(comeurl),"orderinfo.asp")>0 or comeurl="" then
comeurl="login.asp"
end if
end if
```

```
'take the characters
Function StrLenB( strString )
dim intLoop,intReturn
if isNull(strString) then
StrLenB = 0
exit Function
end if
intReturn = len(strString)
for intLoop = 1 to len(strString)
if ( asc( mid( strString, intLoop, 1 ) ) < 0 ) then intReturn = intReturn + 1
next
StrLenB = intReturn
End Function
```

```
Function strLeftB( strString ,intLen)
dim intLenB,intLoop
if StrLenB(strString) < intLen then
strLeftB = strString
exit Function
end if
```

```

for intLoop = 1 to Len(strString)
if ( asc( mid( strString, intLoop, 1 ) ) < 0 ) then
intLenB = intLenB + 2
else
intLenB = intLenB + 1
end if
if intLenB > intLen then
intLoop = intLoop - 1
exit for
elseif intLenB = intLen then
exit for
end if
next
strLeftB = left(strString,intLoop)
End Function

```

```

Function IsLetter( chr )
dim blnReturn
blnReturn = false
if ( ( chr >= asc("a") and chr <= asc("z") ) or ( chr >= asc("A") and chr <= asc("Z") ) or ( chr
>= asc("0") and chr <= asc("9") ) ) then
blnReturn = true
end if
IsLetter = blnReturn
End Function

```

```

Function AlignString( string, byVal size )
dim r,nLen,n,i,a,s_i
r = string
nLen = StrLenB( string )
' if string's width less then size ,return this string .
if ( nLen > size ) then
size = size - 2
n = 0
i = 1
' cut to index
do while ( i )
a = asc( mid( string, i, 1 ) )
if ( a < 0 ) then
if ( n + 1 = size ) then
i = i - 1
exit do
end if

```

```

n = n + 1
end if
n = n + 1
if ( n = size ) then exit do

i = i + 1
loop
'fxDebug( i )
s_i = i
a = asc( mid( string, i+1, 1 ) )
if ( IsLetter(a) ) then
do while ( 1 )
a = asc( mid( string, i, 1 ) )
if ( not IsLetter(a) ) then exit do
i = i - 1
if ( i = 0 ) then
i = s_i
exit do
end if
loop
end if

```

```

r = mid( string, 1, i ) & ""
end if
AlignString = r
End Function

```

```

function cutstr(str,bytes)
str=alignstring(trim(str),bytes)
cutstr=str
end function

```

```

'Msg function
function subject(msg)
On Error Resume Next
subject = False
Err = 0
Dim tobject
Set tobject = Server.CreateObject(msg)
If 0 = Err Then subject = True
Set tobject = Nothing
end function%>

```

A3.2.2 EnquiryInfo

```
<!--#include file="conn.asp"-->
<!--#include file="inc/char.asp"-->
<HTML><HEAD>
<TITLE>Adaptive Quotation System</TITLE>

</HEAD>
<BODY leftMargin=0 background=Images/back.gif topMargin=0>
<%dim act
act=Trim(Request("act"))
if act="agree" then
agree
elseif act="disagree" then
disagree
else
reg
end if

sub reg%>
<table width="553" border="0" align="center" cellpadding="0" cellspacing="0">
<tr>
<td colspan="2" class="b" style="font-weight: bold" height="14">Agreement:</td>
<td width="43"></td>
<td width="10"></td>
</tr>
<tr>
<td width="8" height="75"></td>
<td valign="top" colspan="2">
<p><br>
1. Copyright at Mechanical Engineering, Durban Insitute of Technology,
South Africa</p>
<p>2. No contents of this Web can be used for commercial purpose.<br>
</p>
</td>
</tr>
<tr>
<td colspan="3" valign="top" height="18" align="center"><a
href="OrderInfo.asp?act=agree"></a>
<a href="OrderInfo.asp?act=disagree"></a></td>
```

```

        <td></td>
    </tr>
    <tr>
        <td height="1"></td>
        <td width="492"></td>
        <td></td>
        <td></td>
    </tr>
</table>
<%end sub

```

```
sub agree%
```

```
<table width="555" border="0" align="center" cellpadding="0" cellspacing="0">
```

```
<tr>
```

```
<td colspan="3" class="b" style="font-weight: bold" height="14">Basic Order  
Information</td>
```

```
<td width="44"></td>
```

```
<td width="11"></td>
```

```
</tr>
```

```
<form name="reg" action="savereg.asp?act=reg" method="post"
```

```
onSubmit="javascript:return chk();">
```

```
<tr>
```

```
<td rowspan="13" class="r_split" width="3"></td>
```

```
<td valign="top" height="42" colspan="3"><br>
```

```
Your Name:
```

```
<input name="truename" type="text" class="text_input1" id="truename">
```

```
* </td>
```

```
<td></td>
```

```
</tr>
```

```
<tr>
```

```
<td height="28" valign="top" colspan="3">Company Name:
```

```
<input name="companyname" type="text" class="text_input1" id="companyname">
```

```
* </td>
```

```
<td></td>
```

```
</tr>
```

```
<tr>
```

```
<td height="28" valign="top" colspan="3">Contact Number :
```

```
<input name="tel" type="text" class="text_input1" id="tel"
```

```
onKeyUp="value=value.replace(/[\^d]/g,")
```

```
"onbeforepaste="clipboardData.setData('text',clipboardData.getData('text').replace(/[\^d]/g,")
```



```
</td>
```

```
<td></td>
```

```

</tr>
<tr>
  <td height="28" valign="top" colspan="3">Enq Ref No:
    <input name="username" type="text" class="text_input" id="username">
    <span class="price">*</span> <span class="brief">Used to help to identify
    this order</span> </td>
  <td></td>
</tr>
<tr>
  <td height="28" valign="top" colspan="3">Password:
    <input name="password1" type="password" class="text_input" id="password1">
    <span class="price">*</span> <span class="brief">Used for modifying! At
    least 4 Char/Num</span></td>
  <td></td>
</tr>
<tr>
  <td height="28" valign="top" colspan="3">PW Confirm:
    <input name="password2" type="password" class="text_input" id="password2">
    <span class="price">*</span> <span class="brief">Please enter your password
    again </span></td>
  <td></td>
</tr>
<tr>
  <td height="28" width="484">Retrive Question:
    <input name="question" type="text" class="text_input">
    <span class="price">*</span> <span class="brief">To retrive your password
    </span></td>
  <td rowspan="7" width="13"></td>
  <td></td>
  <td></td>
</tr>
<tr>
  <td height="14">Related Answer :
    <input name="answer" type="text" class="text_input">
    <span class="price">*</span> </td>
  <td></td>
  <td></td>
</tr>
<tr>
  <td height="28">&nbsp;</td>
  <td></td>
  <td></td>
</tr>

```

```

<tr>
  <td height="28">Order Quantity:
    <input name="quantity" type="text" class="text_input" id="quantity"
onKeyUp="value=value.replace(/^[^d]/g,") "
maxLength="12"onbeforepaste="clipboardData.setData('text',clipboardData.getData('text').re
place(/^[^d]/g,")"&>
    *</td>
  <td></td>
  <td></td>
</tr>
<tr>
  <td height="28">Working Days :
    <input name="days" type="text" class="text_input1" id="days">
    <span class="brief">*</span></td>
  <td></td>
  <td></td>
</tr>
<tr>
  <td height="28">Requirements :
    <input name="requirements" type="text" class="text_input" id="requirements">
  </td>
  <td></td>
  <td></td>
</tr>
<tr>
  <td height="28">E-mail :
    <input name="email" type="text" class="text_input" id="email">
    <span class="price">*</span> <span class="brief">Used for ordering</span>
  </td>
  <td></td>
  <td></td>
</tr>
<tr>
  <td height="28"></td>
  <td></td>
  <td></td>
  <td></td>
  <td></td>
</tr>
<tr>
  <td height="14">&nbsp;</td>
  <td></td>
  <td></td>

```

```

        <td></td>
        <td></td>
    </tr>
    <tr>
        <td height="20" colspan="4" valign="top" align="center">
            <input name="imageField" type="image" src="images/reg2.gif" width="38"
height="18" border="0" align="absmiddle">
            [Please enter all info which marked with *]</td>
        <td></td>
    </tr>
</form>
</table>
<script language="javascript">
function chk()
{
if (document.reg.username.value=="")
{alert("Please enter your order ID");return false;}
if (document.reg.companyname.value=="")
{alert("Please enter your company name");return false;}
if (strlen(document.reg.username.value)>16)
{alert("It is limited by 16 bytes");return false;}
if ((document.reg.password1.value=="")||(document.reg.password2.value==""))
{alert("Please enter your password");return false;}
if (document.reg.password1.value!=document.reg.password2.value)
{alert("Not match! Try again!");return false;}
if ((strlen(document.reg.password1.value)>20)||(strlen(document.reg.password1.value)<4))
{alert("Must between 4-20 characters");return false;}
if ((strlen(document.reg.password2.value)>20)||(strlen(document.reg.password2.value)<4))
{alert("Must between 4-20 characters");return false;}
if (document.reg.question.value=="")
{alert("Your retrieve question, please!");return false;}
if (strlen(document.reg.question.value)>40)
{alert("Limited by 40 characters");return false;}
if (document.reg.answer.value=="")
{alert("Answer?!");return false;}
if (strlen(document.reg.answer.value)>40)
{alert("Limited by 40 characters");return false;}
if (notmail(document.reg.email.value))
{alert("It is not a e-mail format!");return false;}

if (document.reg.quantity.value=="")
{alert("Please enter order quantity");return false;}
if (document.reg.days.value=="")

```

```

{alert("Please enter the demanded working days");return false;}
if (document.reg.truename.value=="")
{alert("Please enter the name that the finished parts to be delivered to!");return false;}

return true;
}
</script>
<%char
end sub

sub disagree
alert "If you want to use this facility, you must agree with the Agreement!"
end sub%>
</BODY>

```

A3.2.3 CADInput

```

<%@ Import Namespace="System.IO" %>
<%@ page Language="C#" debug="true" %>
<html>
<head>
<title>Adaptive Quotation System</title>
<script language="C#" runat="server">
//This method is called when the "upload" button id pressed
public void UploadFile(object sender , EventArgs E)
{
    if(myFile.PostedFile.FileName.Trim()=="")
        Response.Redirect("SystemMessage.asp?MsgNo=ERROR001" );

    if(myFile.PostedFile.FileName!="")
    {
        string nam = myFile.PostedFile.FileName ;
        int i= nam.LastIndexOf(".");
        string newext =nam.Substring(i);
        DateTime now = DateTime.Now;
        string newname=now.DayOfYear.ToString()+myFile.PostedFile.ContentLength.ToString();
        myFile.PostedFile.SaveAs(Server.MapPath("\\AQs\\Upload\\"+newname+newext));

        if (newext != ".xml")
            Response.Redirect("SystemMessage.asp?MsgNo=ERROR002" );
        else
            //Goto Quotation Count Page

```

```
        Response.Redirect("QuotationCount.asp?strFileName=" +
myFile.PostedFile.FileName );
    }
}
```

```
</script>
</head>
<body leftMargin=0 background=Images/back.gif topMargin=0>
```

```
<form id="uploderform" method="post" action="FileUpload.aspx" enctype="multipart/form-
data" runat="server" >
```

```
<h1>CAD Data Input</h1>
<p>Please input your CAD file:<br>
(*.xml)</p>
<p>
<input type="file" id="myFile" runat="server" NAME="myFile" size="20">
</p>
<p>
<input type="button" value="Enter" OnServerClick="UploadFile" runat="server"
ID="Button1" NAME="Button1">
</p>
</form>
<br>
<br>
<br>
<br>
<br>
<br>
</body>
</html>
```

A3.2.4 QuotationCount

```
% *****
% func name: QuotationCount
% description: Quotation Count through a CAD file(ST file)
% parameter: strFileName: CAD file name
% *****
```

```

function retstr = QuotationCount(instruct, outfile)

% ***** ini return value *****
retstr = char("");

% ***** change to work directory *****
cd(instruct.mldir);

% ***** Create local variable *****

outstruct.Temp = char('Hello,out!');

% *****
%          Quotation Count
% *****

% *****
% *** Step1: Translate ST file to XML file (ST-XML.exe)
% *****
system('xcopy D:\AQS\other\simple_out.xml D:\AQS\XML /y');

% *****
% *** Step2: Translate XML file to DB access (XML SPY)
% *****
system('xcopy D:\AQS\DB\Null_New_Product.mdb D:\AQS\DB\New_Product.mdb /y');
TransXML2DB(instruct.strFileName);
% TransXML2DB('all_749_55870.xml');
% Note: instruct.strFileName -> (e.g.D:\AQS\XML\simple_out.xml)

% *****
% *** Step3: Quotation Count
% *****

structQutationResult = Quotation;

outstruct.QuotationCost =      structQutationResult.ProductCost;
outstruct.QuotationProfitMagin = structQutationResult.Margin * 100;
outstruct.QuotationResult =    structQutationResult.Quotation;

```

```

ErrorFlag = false;
% ***** Set ErrorFlag *****
if ErrorFlag == false
    % templatefile = which('D:\AQS\QuotationCount2.asp');
    templatefile = which('QuotationCountTemp.htm');
else
    templatefile = which('QuotationCountMsg.asp');
end

% ***** Goto out page *****
if (nargin == 1) % nargin means number of input parameter(s).
    retstr = htmlrep(outstruct, templatefile);
elseif (nargin == 2)
    retstr = htmlrep(outstruct, templatefile, outfile);
end

```

A3.2.5 *QuotationConfirm*

```

<!--#include file="conn.asp"-->
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.0 Transitional//EN">
<HTML><HEAD>
<TITLE>Adaptive Quotation System</TITLE>

</HEAD>
<BODY leftMargin=0 background=Images/back.gif topMargin=0>
<h1 align="center"><b><font size="5">Individual Web-Based Workshop</font></b></h1>
<h2 align="center">(AQS Demo Version)</h2>
<p align="center">(C)Mechanical Engineering Department,<br>
Durban Institute of Technology 2004</p>
<h1 align="center">&nbsp;</h1>
<h1 align="center">Quotation</h1>
<h1 align="center">
    <%if request("act")="next" then
cnext
else
show
end if

sub show%>
</h1>

```

```

<table width="600" border="0" align="center">
<tr>
  <%rs.open "select * from OrderResult",conn,1,1
    %>
  <td width="50%">
    <div align="center"><b>Invoice To:</b></div>
  </td>
  <td width="50%">
    <div align="center"><b>Invoice Reference Number:</b></div>
  </td>
</tr>
<tr>
  <td height="23" align="left">
    <div align="center">
      <input name="username" type="hidden" id="username"
value="<%=rs("username")%>">
      <%= rs("username") %></div>
    </td>
  <td height="23" align="left">
    <div align="center">
      <input name="orderid" type="hidden" id="orderid" value="<%=rs("orderid")%>">
      <%= rs("orderid") %></div>
    </td>
</tr>
<tr>
  <td align="middle" width="50%">XXX Manufacturing</td>
  <td width="50%"> </td>
</tr>
<tr>
  <td align="middle" width="50%">Durban, 4000</td>
  <td width="50%"> </td>
</tr>
<tr>
  <td align="middle" width="50%">South Africa</td>
  <td align="middle" width="50%">
    <div align="center">
      <!-- #BeginDate format:Am1 -->December 17, 2003<!-- #EndDate -->
    </div>
  </td>
</tr>
<tr>
  <td width="50%"></td>
  <td width="50%"></td>

```

```

</tr>
</table>
<table width="500" border="0" align="center" cellpadding="0" cellspacing="0">
  <tr>
    <td valign="top" height="28" colspan="5">&nbsp;  </td>
  </tr>
  <tr>
    <td colspan="5" class="dot1" height="22" valign="top"><span style="font-weight:
bold">Generated
  Quotation Result(Please check related information)</span></td>
  </tr>
  <tr>
    <td width="108" height="24" valign="top" align="center" bgcolor="#F7F3F7"><b>Ref
  ID</b></td>
    <td valign="top" width="117" align="center" bgcolor="#F7F3F7"><b>Working
  Days</b></td>
    <td width="74" align="center" bgcolor="#F7F3F7"><b>Unit Price</b></td>
    <td width="82" align="center" bgcolor="#F7F3F7"><b>Quantity</b></td>
    <td align="center" bgcolor="#F7F3F7" width="118"><b>Total Price</b></td>
  </tr>
  <form action="?act=next" method="post">
    <%
if rs.eof and rs.bof then
response.write "<script>alert('\"Some information are missing!'\");self.close();</script>"
else
dim totalprice
totalprice=0
do while not rs.eof%>
  <tr>
    <td height="18" valign="top" align="right" class="price"><%= rs("orderid") %>
    <input name="orderid2" type="hidden" id="orderid" value="<%=rs("orderid")%>">
  </td>
    <td valign="top" align="right" class="price"><%= rs("workdays") %>
    <input name="workdays" type="hidden" id="workdays"
value="<%=rs("workdays")%>">
  </td>
    <td align="right" class="price"><%= rs("quotation") %>
    <input name="quotation" type="hidden" id="quotation"
value="<%=rs("quotation")%>">
  </td>

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        <td align="right" class="price"><%= rs("quantity") %>
        <input name="quantity" type="hidden" id="quantity" value="<%=rs("quantity")%>">
        </td>
        <td align="right" class="price"><%= rs("quantity")*rs("quotation") %></td>
        <td></td>
    </tr>
    <%totalprice=totalprice+rs("quantity")*rs("quotation")
rs.movenext
loop
end if
rs.close%>
    <tr bgcolor="#F7F3F7">
        <td height="23" colspan="3" align="center"><b>All in total, Amount is:</b>
        <input name="totalmoney" type="hidden" value="<%= totalprice %>">
        </td>
        <td align="right" class="price"><%= totalprice %></td>
        <td></td>
        <td></td>
    </tr>
    <tr align="center">
        <td height="40" colspan="5" valign="top"><a href="/Welcome.asp"></a>
        <input name="imageField3" type="image" src="Images/Confirm.gif" width="65"
height="18" border="0">
        </td>
        <td></td>
    </tr>
</form>
<tr>
    <td colspan="5" height="14" valign="top">&nbsp;   </td>
    <td></td>
</tr>
</table>
<%end sub

sub cnext%>
<table width="500" border="0" align="center" cellpadding="0" cellspacing="0">
<tr>
    <td colspan="3"><span style="font-weight: bold">Please Confirm your Order
    information! </span></td>
</tr>
<tr>
    <td colspan="3" class="dot1"></td>

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```

</tr>
<tr>
  <td colspan="3">&nbsp;</td>
</tr>
<form action="saveform.asp" name="form1" method="post" onSubmit="javascript:return
cform1();">
  <tr>

    <%rs.open "select * from [OrderResult] where orderid=2004003 ",conn,0,1%>
    <tr>
      <td width="169" height="25" align="right">&nbsp;</td>
      <td colspan="2">&nbsp;</td>
    </tr>
    <tr>
      <td height="25" align="right">&nbsp;</td>
      <td colspan="2">&nbsp;</td>
    </tr>
    <tr>
      <td height="25" align="right">Your Order Number is:</td>
      <td colspan="2">
        <input name="orderno" type="text" class="text_input" id="orderno"
value="<%=rs("orderno")%>" onKeyUp="value=value.replace(/[^\d]/g,)" "
maxlength="12"onbeforepaste="clipboardData.setData('text',clipboardData.getData('text').re
place(/[^\d]/g,))">
        <span class="price">*</span><span class="brief">Must Input</span></td>
      </tr>

    <tr>
      <td height="25" align="right">&nbsp;</td>
      <td>&nbsp;</td>
    </tr>
    <tr>
      <td height="25" align="right">&nbsp;</td>
      <td>&nbsp;</td>
    </tr>
    <%rs.close%>
    <tr align="right">
      <td colspan="3" align="right">&nbsp;</td>
      <input name="totalmoney" type="hidden" value="<%=request("totalmoney")%>">
    </td>
    </tr>
    <tr align="right">
      <td colspan="3">

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```
<input name="imageField4" type="image" src="images/next1.gif" width="45"
height="18" border="0">
</td>
</tr>
</form>
<tr>
<td colspan="3">&nbsp;</td>
</tr>
</table>
<script language="javascript">
function cform1()
{
if (document.form1.orderno.value=="")
{alert("The contact tel number is essential input. We will keep this as a confidential
information");return false;}
return true;
}
</script>
<%end sub%>

</BODY>
```