CAD/CAM SELECTION FOR SMALL MANUFACTURING COMPANIES

By

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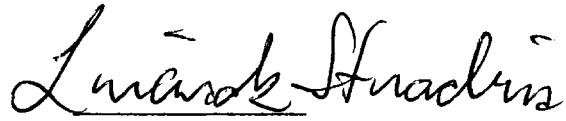

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Abstract

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In today's fast paced world, CAD/CAM systems have become an essential element in manufacturing companies throughout the world. Technology and communication are changing rapidly, driving business methods for organizations and requiring capitalization in order to maintain competitiveness. Knowledge prior to investing into a system is crucial in order to maximize the benefits received from changing CAD/CAM systems.

The purpose of this study is to create a methodology to aid small manufacturing companies in selecting a CAD/CAM system. The objectives are to collect data on CAD/CAM systems that are available in the market today, identify important criteria in system selection, and identify company evaluation parameters.

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Chapter 1

Introduction

In today's global market, manufacturers must rely on new technologies to capitalize on current market trends. Many companies have turned to Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) systems to help develop and produce complex parts quickly. As these systems have advanced in recent years, manufacturers struggle to maintain communications with suppliers and exploit current advancements in software. This research is directed towards analyzing and evaluating current criteria for selecting a CAD/CAM system for use by small manufacturing companies. Company and software evaluation will be considered to help in the selection of such a system.

Background of the Problem:

CAD/CAM systems have a history in assisting companies in design and high-speed manufacturing. Since the nineteen eighties, manufacturing has become dependent on these aids to perform critical tasks. Complex parts can be designed quicker with software that enables the user to visually see the part and its dimensions using CAD. These software programs can provide the compatibility to

assemble parts together, checking for fit while also providing the capability to edit the part at any time. This allows complex designs to be made quicker, and more accurately. CAM packages allow these complex parts to be brought to life by calculating tool paths and writing the code to manufacture the part on a Computer Numerical Controlled (CNC) machine such as a mill, lathe or EDM machine. Human error is reduced and higher accuracy can be attained when manufacturing parts that would be difficult to produce manually. Globally and locally there are companies using obsolete packages to design and manufacture products. Technology is changing very rapidly and most companies cannot keep up with the changes. The need to know what CAD/CAM packages are available and how to select one will help companies build for the future.

Statement of Problem:

The purpose of this study is to create a methodology that can be used to aid small manufacturing companies in selecting a CAD/CAM system.

Objectives of the Study:

Collect data on CAD/CAM systems that are available in the market today.

Identify important criteria in CAD/CAM system selection.

Identify company and CAD/CAM system evaluation parameters to aid in selection.

Increase the researchers knowledge of CAD/CAM systems and their implementation.

Purpose:

The purpose of this study is to help small manufacturing companies in selecting a CAD/CAM system by seeking out and grouping new technologies, and evaluating system and company selection criteria. Many times companies do not have the time or the capabilities to perform in-depth research in seeking out new tools to aid their design or manufacturing processes. The problem is compounded by the fact that these new technologies have been evolving at an accelerated rate. Systems evolve frequently with new features making it difficult for users to know what advancements are available. Companies also need to know what criterion is important in selecting a CAD/CAM system. This involves evaluating a company's needs in order to facilitate proper selection. A purchased system also must meet certain requirements in order to minimize risk and maximize efficiency. The significance of accumulating this criteria together will enable

companies to efficiently select a system that meets their needs, while also capitalizing on a CAD/CAM system's utilities and features.

Limitations:

This study evaluates CAD/CAM systems based on product literature. Actual performance of systems by demonstration is beyond the scope of this study. Chosen criteria are based on the researchers personal views and surveyed information from selected users of small manufacturing companies in northwestern Wisconsin.

Some associated CAD/CAM technologies will not be discussed within this study. Two-dimension drafting tools are not included in this evaluation due to the wide acceptance of three-dimensional and solid modeling technologies. Due to the main focus on CAD/CAM system selection, evaluation of Web interaction tools and Project Data Management systems is beyond the scope of this study.

Definitions:

Assembly Drawing A drawing that can be created to represent a major subdivision of the product, or the complete product.

Attribute A non-graphic characteristic of a part, component, or entity under design on a CAD system.

Benchmark The program(s) used to test, compare, and evaluate in real time the performance of various CAD/CAM systems prior to the selection and purchase.

Bills of Material (BOM) A list of all the subassemblies, parts, materials, and quantities required to manufacture one assembled product or part, or build a plant. A BOM can be generated automatically on some CAD/CAM systems.

CAD Computer Aided Design A process that uses a computer system to assist in the creation, modification, storage, and display of a design.

CAM Computer Aided Manufacturing The use of a computer and digital technology to generate manufacturing-oriented data. Data drawn from a CAD/CAM database can assist in controlling a manufacturing process, including numerically controlled machines, computer assisted parts programming, computer assisted process planning, robotics, and programming logic controllers.

Compatibility The ability of a particular hardware module or software program, code, or language to be used in a CAD/CAM system without prior modification or special interfaces.

Computer Numerical Control (CNC) A technique in which a machine tool control uses a mini computer to store NC instructions generated earlier by CAD/CAM for controlling the machine.

Configuration A particular combination of a computer, software, and hardware modules, and peripherals at a single installation and interconnected in such a way as to support certain applications.

Cutter Compensation A method by which the programmed tool path is altered to allow for the differences between actual and programmed cutter diameters.

Dedicated Designed or intended for a single function or use.

Electrical Discharge Machining (EDM) A method of conductive material removal through an electrical discharge by a formed electrode immersed in a dielectric fluid.

Finite-Element Analysis (FEA) A method used in CAD for determining the structural, thermal, and electrical integrity of mechanical parts or physical construction under design by numerical simulation of the part and its lading conditions.

G-Code Preparatory function code that establishes operating modes on CNC controlled equipment.

Initial Graphics Exchange Specification (IGES) An interface product that enables users to exchange CAD/CAM model data in a heterogeneous environment independent of hardware and software systems, which was developed to aid in communicating between early CAD systems.

Modeling, Solid A type of 3-D modeling in which the solid characteristics of an object under design are built into the database, so that complex internal structures and shapes can be realistically represented.

Numerical Control (NC) A technique of operation used with machine tools or similar equipment in which motion is developed in response to numerically coded commands.

Optimization, Design A process that uses a computer to determine the best design to meet certain criteria. Algorithms may be applied to rapidly evaluate many possible design alternatives in a comparatively short time.

Simulation A CAD/CAM program that simulates the effect of structural, thermal, or kinematic conditions on the part under design.

STandard for the Exchange of Product (STEP) An interface product that enables users to exchange CAD/CAM model data in a heterogeneous environment

independent of hardware and software systems, which was developed to aid in communicating between contemporary solid modeling and CAD systems.

Stereolithography File (STL) A computer-aided prototyping file format used in creating stereolithography models and also an interface product that enables users to exchange CAD/CAM model data in a heterogeneous environment independent of hardware and software systems.

Tutorial Prepared documentation displayed to provide information and guidance.

Virtual Reality Modeling Language (VRML) A language for describing multi-participant interactive simulations in three dimensions and virtual worlds networked via the global Internet and hyper linked with the World Wide Web.

Workstation The work area and equipment used for CAD/CAM operations. It is where the designer interacts or communicates with the computer.

Chapter 2

Literature Review

Introduction

Today CAD/CAM is within easy reach of just about all manufacturers, and this technology has become the standard way of operating, rather than the exception. (CAD/CAM traps and pitfalls, 1995) Companies need to utilize the benefits of CAD/CAM in order to compete in today's market successfully. CAD/CAM packages can reduce time in design and manufacturing, improve communications, improve design quality, reduce errors, and help create a database of standard documentation. In 1999 a projected 5.3 billion dollars will have been spent on CAD/CAM systems. (Donelan, 1999) The availability of engineering software designed specifically for desktop computers has increased the accessibility of CAD/CAM. (Puttre, 1994) Companies need to choose the best system to fully address their needs. This chapter will cover points associated with CAD/CAM selection.

History

CAM was first invented in 1954, when MIT developed a programming language to replace G-code. CAM software soon evolved from computer language, to conversational, to graphic interactive, and then to the PC platform. (Computers in Manufacturing, 1999) CAD began its commercial life in the 1970's as two-dimensional drafting software. As computer technology evolved, CAD grew in its advancements and its number of users. Today many programs have combined these two technologies to form broad-based programs with exceptional capabilities. CAD/CAM software has grown increasingly popular in the 1990's, becoming a staple for modern businesses.

Benefits of using CAD/CAM

Computer Aided Design is a joining of human and machine, working together to optimize design and manufacture of products. (Mantyla, 1995) Computers allow designers to graphically test ideas in real time without having to create real prototypes. This reduces engineering costs for an Original Equipment Manufacturer, and also results in products getting to market faster. (Partnerships, acquisitions highlight hot CAD/CAM market, 1999) Non technical team members from management to marketing can work side by side with engineers to view,

discuss, change, and document a design in progress before they build a prototype. This is an effective attribute of innovative designing that aids in identifying design flaws and reinforces group "brain storming". (Computers in Manufacturing, 1999) CAD/CAM systems permit for a more thorough engineering analysis and a larger number of design alternatives to be investigated, (Mohammed, 1990) saving time through minimization of mistakes early in the design process. Most systems automatically create a Bill of Materials to save time and improve communication. Locating drawings in a known place on a network results in better documentation and improved communication between departments and vendors. The result is fewer misinterpretations and a better product flow. The benefit of using CAD/CAM analytical tools is that they permit design improvements that would have been too expensive to implement in the past. (Computers in Manufacturing, 1999) New integrated software tools that are commercially available have been developed which allow design engineers to perform finite element analysis directly, during the early stages of design, thereby ensuring that the best design intent is achieved. (McGuffie, 2000) This in turn reduces final prototype numbers, lowers design costs, and decreases time to market. Programs can also use part optimization to reduce mass and maximize part efficiencies. Both of these features allow for quicker revisions and shorter

cycle times to create the part at maximum efficiency. Recent advancements in CAD/CAM systems allow for quicker design cycles today than even a few years ago. Today's systems are much more user friendly and can utilize current trends in Windows® computing. Some packages allow for the integration into a company wide program to create maximum effectiveness throughout the company by incorporating different facets of production.

Solid Modeling

Solid computer models are the most sophisticated forms of geometric modeling. (CAD/CAM traps and pitfalls, 1995) Modeling applications use three-dimensional entities and define relationships between these entities. (Wilson, 1997) These relationships are created through boundary representation. Boundary representation stores all geometric information along with relationships between faces, edges, and vertices. Every piece of the part is parameterized so that control points defining each surface have a driving dimensional value. (Basics of design engineering: CAD/CAM, 1997) This allows the part to be represented more completely but creates a larger file of topological data. Parts can also be parametrically driven, allowing for geometric information to automatically adjust to changes in parameters. Volume and mass calculations are easily made in most

programs, aiding in part optimization. Control points on solid modelers are interwoven within the entire model, sometimes making it time consuming to correct a detail that is defined incorrectly. (Dehl, 1998)

Solid modeling software mostly utilizes two kernels, ACIS and Parasolids. They are the core of a modeler, providing the complex mathematical algorithms needed to create a given solid. Most vendors employ one of the two in their programs allowing for differences and discrepancies between packages. They are utilized as graphics engines allowing for communication between CAD and CAM systems by creating file formats with accurate model description.

Surface Modeling

Surface modeling offers different advantages to part creation as compared to solid modeling. Surface modeling software tends to be easier to use, providing straightforward ways of manipulating curves and surface shapes. Wire frame models contain information about the lines and vertices, which make up the edges of a part. (Basics of design engineering: CAD/CAM, 1997) They require less memory to store than solid models and are often considered the simplest of modeling types. Many times surface modeling is used to correspond with solid

modelers by creating a surface and incorporating that surface into a solid. This is possible only when minimal conflicts arise with compatibility.

CAM Software

CAM software is the link between a computer model and a finished part. CAM software takes a model or a surface and converts it into NC code to allow CNC machining equipment to produce the part. The most flexible method converts the part into polyhedrons consisting of numerous triangles. The user defines the accuracy required, and the CAM system determines how many facets or triangles will be generated on the basis of the accuracy needed. (Dehl, 1998) NC software is frequently grouped according to the number of machining axes the package can control. (Basics of design engineering: CAD/CAM, 1997) Most programs create optimized tool paths to produce the shortest number of program steps, thus shortening machining time. CAM software must have the capabilities to communicate with different model files in order to decrease the chance of possible misinterpretation. Recently some assembly and solid modelers partnered with NC software companies to produce integrated solid machining (Dehl, 1998), reducing the risk of possible mistakes.

System Criteria

There are several criteria that need to be addressed when purchasing a CAD/CAM system for small manufacturing firms. The study will define small manufacturing companies as companies with less than fifty employees or less than fifty million dollars in gross sales. By defining system requirements, users can optimize on current trends and better determine a company's needs.

Ease of Use

Ease of use is a major factor when considering a new CAD/CAM system. If a system is difficult to operate, the end user will not perform up to their optimum potential, limiting end results and possible job satisfaction. One way that software companies are aiding use issues is to mimic the successful Microsoft Windows® architecture. This enables data to be shared with other applications at runtime, without the need for intermediate file translation. (Wilson, 1997) This also eliminates possible high-level data loss while linking it to other heterogeneous systems in a 'live' fashion. Geometric relationships are maintained throughout an application resulting in seamless integration. This architecture supports embedding, display, and in place activation, as well as access and control of model geometry and topology through the native design. (Wilson, 1997)

Another consideration is program help. Many systems today provide help indexes, online help, tutorials, and extended data information. Often times an Internet browser is used to view help information that can be displayed in several file formats. In the event that CAD product information is needed, the end user must be able to gather this information instantly and efficiently. By maximizing help opportunities, operators become more efficient and are better equipped to handle future problems.

The user interface should be straightforward, with minimal hidden menus so users can quickly perform tasks. Repeatability and productivity can increase dramatically when functions are readily available with minimum searching.

Added Features

CAD/CAM systems today must be able to utilize features that can be plugged-in or added on at a later date. Systems that can be upgraded are better suited for smaller manufacturers, due to the lower initial cost with the opportunity to expand in the future.

One feature that is often standard with many software packages is tool path optimization. This feature maximizes cutter wear to prolong life by adjusting feed rates. (Computers in Manufacturing, 1999) The program analyzes the rate of material removal and assigns the best possible feed rate. Tool path generation

should be created with optimal efficiency and minimal interaction. The CAM system should be able to output an optimized tool path that has been curve-fit within a specified tolerance. This reduces the machining file size substantially, improves surface finish, and allows for higher feed rates. CAM systems should support standard, bullnosed, and ballnosed end mills, with full gouge avoidance on each. (Dehl, 1998) A system that allows users to graphically cut and paste operations into an operations manager should also be utilized. This allows for easier planning, organizing and reordering of cutting routines. This will also allow the user to specify various cutting methods for any portion of the model. An undesirable function is scallop height control, which calculates the smallest step over requirement on a surface, and then applies that step over to the entire surface.

Another CAD/CAM feature that should be considered is the ability to simulate sheet metal forming. Many programs today are capable of modeling sheet metal forms, allowing users to accurately, quickly, and easily design sheet metal parts with the proper bend allowances.

Numerous programs are including part optimization as either a standard feature, or a feature that can possibly be added on at a later date. Part optimization analyzes a solid model and improves its strength and minimizes mass by

modifying the original design. The program looks at critical areas and modifies accordingly. This feature is very useful due to the fact that it helps create an optimum part, improving durability and strength while maintaining a minimum weight penalty.

Finite Element Analysis can also be used to analyze a part, but often simply provides insight into the location of high stress points. The designer can use this information to determine where the potential for failure exists. Users can generally view color-coded maps of stress concentrations, but with additional information about plastic strain or surface elongation analysis. (Basics of design engineering: CAD/CAM, 1997) Newer FEA codes have been developed to handle nonlinear deformations, those where assumptions of linearity do not hold true. (Basics of design engineering: CAD/CAM, 1997) Many of these packages include stamping, welding, casting, and molding simulations, which take much of the guesswork out of these manufacturing processes. (Computers in Manufacturing, 1999) According to the staff at Machine Design, FEA analysis identifies 70% to 80% of the problems likely to arise in manufacturing. (Computers in Manufacturing, 1999) It allows for quick revision and helps minimize the risk of future problems.

Many CAD/CAM companies offer libraries consisting of standard parts, features, tools, mold bases, connectors, pipe fittings, symbols, and human body dimensions on the World Wide Web, allowing users to employ these models in the design process. By providing access to these models, designers are able to incorporate them into assemblies faster and more accurately. This up front conceptual work can make the engineer 25% more productive. (Computers in Manufacturing, 1999) Many models of commercially available parts are also available to everyone via the World Wide Web.

Compatibility

A pressing issue that is currently being addressed throughout the software community is cross platform communication. Communication is critical in the fast transaction of knowledge required in today's market. Translation of file formats is critical within an organization and with vendors. In years past, a programmer was required to translate a wireframe design into a CAM system. The surfaced or solid data would either not translate or only partially translate, creating the need to fix portions of the model to produce the correct part. (Pollet, 1999) Today, many vendors utilize a comprehensive manufacturing system allowing for seamless conversion from computer model to generating an NC program. The set of data points used to machine the model comes from the same

computer model. (Dehl, 1998) The term "open system" is used to describe the ease by which data can be created by one system and readily used by, or imported into, other systems. This capability will minimize and hopefully eliminate the need to enter the same data several times into different products. (Pollet, 1999) In today's computer age, file transfer is generally used for communicating rather than the exchanging of paper drawings, making electronic transfer the norm. (Janowski, 1999) The advantages associated with electronic file transfer include eliminating time-consuming paper documentation, accelerating product release to market (Dehl, 1998), minimizing misunderstandings, cutting travel time and expenses, creating timely feedback of people involved (Computers in Manufacturing, 1999), and allowing for a more complete set of data to manufacture the product. Many file translators have been written independently by CAD or CAM software companies (Janowski, 1999), so a conversion standard has been difficult to implement. There are two basic types of file translators, neutral and direct. Neutral translators convert proprietary data to a general industry standard, such as the common file formats developed by using IGES, STEP, STL, BMP, TIFF, JPEG, and ASCII . This promotes the term "flavoring," which allows translators to put their own specific translations on the data. Direct translators interpret data into a CAD software's proprietary format, such as

AutoCAD and CADKEY DXF and DWG, Pro-Engineer and Solidworks PRT, Parasolid X_T, and I-DEAS MF1 and MF2. (Janowski, 1999)

Another rapid form of file transfer occurs by use of the World Wide Web. Studies have found that most engineers only spend 20% of their time designing products. Nearly twice that time is spent looking for and verifying data regarding design revision. (Small, 1998) Web communication offers the fastest feedback channel and allows for quick interaction. In some instances, the Web allows for face time or real time interaction. This allows people to see and interact with their business partners by pointing to some feature on a drawing or model, receiving instant feedback that prompts further discussion, while eliminating costly and timely business trips. (Computers in Manufacturing, 1999) Some programs allow users to revise models in real time on the Web allowing for design review and revision to occur concurrently. (Computers in Manufacturing, 1999) This also allows different users to work simultaneously on the same design. (Basics of design engineering: CAD/CAM, 1997)

Benchmarking

One aid that can be used in the selection of a CAD/CAM system is benchmarking. Benchmarking provides a point of reference from which performance measurements can be made. This insures that the benchmarked

companies possess the necessary hardware/software required to perform the task, and that it can be done more productively. (Coticchia, Crawford, Preston, 1993) Standard Performance Evaluation Corporation, SPEC, has written benchmark tests that make use of various sizes of CAD/CAM solid models. These tests are timed based on common user interaction with the models (Graphics benchmark debut, 1998), and provide indicators on intensively used hardware components. When testing any CAD/CAM system, performance evaluations must be made based on the most complex part likely to be created. (Dehl, 1998) This provides proper feedback on the evaluation, reducing the risk of choosing an improper system for a customer's specific needs.

Efficiency and Effectiveness

To most managers, efficiency and effectiveness play a major role in the selection of a CAD/CAM system. Design errors found late in the production cycle generate unwanted costs through time and rework, minimizing both efficiency and effectiveness. (Computers in Manufacturing, 1999) This usually leads to decreased moral, increased costs, and customer dissatisfaction. By being able to work efficiently, wasted time and effort is reduced, increasing profits and employee gratification. An important feature available with most CAD/CAM packages is the ability to customize libraries, part families, custom menus, and

programs that store rules for design of certain components. (CAD/CAM traps and pitfalls, 1995) In many instances this reduces the time to perform a task, with the potential of saving substantial amounts of money in the long term. Without customization, users may miss opportunities to make an application more productive and truly optimized for their business. (CAD/CAM traps and pitfalls, 1995)

The solution is to have a competitive design process that utilizes effective management of component data, efficient reuse of design information, immediate access to new component information, and automated transfer of this information within desktop tools. (Small, 1998)

Price

Price is one element that cannot be overlooked. To many manufacturers, price is one of the most important factors when buying a system; unfortunately it is often misused and misunderstood. According to Kenneth Kornbluh of Sci-Tech International, "There is no relationship between price and value." Many lower priced systems have almost as much functionality, and are easier to use. (Engineering productivity kit: CAD/CAM/CAE, 1999) Often times consumers will purchase a higher priced system thinking they will receive a higher return on

investment. This correlation may not be the case and a self-assessment of needs should be performed before basing a purchase on price alone.

Vendor Demonstrations

Vender demonstrations allow customers to try software before purchasing. This allows customers to evaluate programs using personal criteria and data specifications. Often, purchasers can usually download free program demonstrations from a vendor's Web site or request a trial version on Compact Disc. This can provide the user a preview of the program and also address compatibility issues that may occur with the users existing software and hardware. (Engineering productivity kit: CAD/CAM/CAE, 1999) Tight integration with other tools, sharing and accessing data and files, accurate data transfer, and the distribution of viewing files are all items that need evaluation.

Program Support and Service

Program support and services contribute a significant role in CAD/CAM selection. With technology changing rapidly, users are forced to rely on vendors and software producers for support through a transition. By evaluating a provider, the user will gain insight into how their service performs and what support avenues are available. While most programs use help libraries and indexes stored locally, some offer this support through the Internet, creating inconveniences if

the connection is broken. User groups of industry professionals often meet to discuss experiences and specific topics associated with particular CAD/CAM packages. Also look for help from suppliers, vendors, and even fellow employees to answer questions on pressing issues.

Company Needs

The first step in justifying a CAD/CAM system for a company is to identify what the company truly needs. According to John McEleney of Solidworks, there are three fundamental questions to ask, what are you trying to accomplish, why are you trying to accomplish it, and the time frame you want to accomplish it in. (Engineering productivity kit: CAD/CAM/CAE, 1999) By defining these questions, companies can calculate essential needs. Other questions may include how often would you use it, future company growth expectations, and who the potential users may be. Standards, personnel, and procedures may need to be redefined with a system selection, so identification becomes critical.

Upon answering these fundamental questions, a company must analyze the system life cycle. The system life cycle continues to grow shorter due to new technological advances occurring rapidly. In many cases, time becomes the number one constraint. How long a system may be used and how quickly it can be

utilized are a few important questions that must be asked and the answers of which can have a profound impact on selection.

A committee should select the system in order to provide interdepartmental feedback that will help support the final decision. Representatives from every department should have input in order to fully define needs, and also to maximize all possible benefits. The possibility of utilizing future Project Data Management systems in company wide applications of storage and distribution, resulting in efficient data refinement that is automatic and secure, should be considered.

Justification may be attained through cost analysis of current and future practices. The prospective company may need to gather specific information on number of users, regular hours used, current overtime or outsourcing in design and drafting, percent of time spent generating and updating drawings or models (Amirouche, 1993), and cost benefits attributed to this data.

Total Cost of Ownership

The total cost of owning a system is based on multiple factors that should be investigated before purchasing a system. The base cost is the software and add on purchases. It then becomes critical that computer hardware is compatible with the purchased system. The latest software has grown larger and larger in memory

space and CPU speed requirements. Often new hardware must be purchased in order to utilize purchased software.

Maintenance issues become important if the purchased system requires a substantial amount of upkeep. Software expansion and possible upgrades should be investigated prior to the initial purchase. Some CAD companies try to maintain their income through a steady stream of upgrades to their installed base customers. (CAD/CAM traps and pitfalls, 1995) Upgrades can have advantages but sometimes they may not include substantial advances, they have a possibility of containing new bugs, and customized programs may not work with newer versions. Waiting for other program users to put an upgrade into production reduces the chance for future problems.

Training cost can play a significant role in the total cost of a system. Mike Paludan of Solid Edge says the purchaser must include the time employees are away from their job, training expenses through outside professionals or internal training, and the time it takes for the user to be productive. (Engineering productivity kit: CAD/CAM/CAE, 1999) Training may be required for upgrades, initial purchase, and to train new employees.

Future

It is difficult to predict the future of CAD/CAM systems in that no one can predict where future technologies may lead. Computers will continue to get faster, smaller, and less expensive, increasing everyone's accessibility and allowing for more advanced CAD/CAM capabilities. (Computers in Manufacturing, 1999) The era of proprietary software for CNC equipment is fading. (Partnerships, acquisitions highlight hot CAD/CAM market, 1999) The International Standards Organization is working to implement a standard for transferring electronic data to eliminate miscommunication. (Janowski, 1999) Compatibility is and will continue to be a main issue in the future, leading to more universal applications that will directly affect companies by improving overall functionality.

Chapter 3

Methodology

This chapter will introduce the methods and procedures used to determine the functional requirements when selecting a CAD/CAM system. A survey was given to industry professionals to aid in determining what criteria are being used in CAD/CAM selection. To help evaluate available system features, a variety of different software packages that are currently available will be discussed.

Research Design

All subjects were chosen through a simplified selection process to assure representation of all groups in the sample. Subjects were selected from the Wisconsin Manufacturers Directory and divided into a geographic group located in the northwestern Wisconsin area. The criteria used for sample selection included number of employees and net sales. Users of CAD/CAM systems in manufacturing companies with fifty or less employees and/or net sales below fifty million dollars were selected. This resulted in the selection of one hundred forty eight companies for the survey.

Data Collection

The survey was mailed on March 7, 2000 to each selected subject within five Wisconsin counties. These counties include: Eau Claire, Chippewa, Dunn, Pierce, and Polk. Surveys were coded to indicate which companies responded within the representative sample. One hundred percent of the sample was surveyed due to a total population of only one hundred forty eight companies. Results were to be mailed back by March 24, 2000, using a self-addressed envelope included with the mailing.

Instrumentation

The developed survey (refer to Appendix A) posed questions related to CAD/CAM system requirements, selection, and pertinent company information. The survey was preceded by an introduction to the research being performed and a brief explanation of the survey instrument. Contact information was included with the survey materials should the recipients have had any questions about the survey.

System Evaluation

There are many programs available throughout the software industry that deal with Computer Aided Design and Computer Aided Manufacturing. Five common CAD systems and two common CAM systems will be discussed based on several features identified by the researcher. They are as follows:

- 3D modeling capabilities
- Surface modeling capabilities
- Drafting utilities
- System features
- Rendering options
- Translators
- The support and services offered
- Add-ons available
- Operating system used
- File management options
- Libraries available
- Software partners
- Internet/Intranet capabilities

- System hardware requirements

Due to the twenty-four different systems listed by surveyed respondents, this study will only discuss seven of the most common systems found in industry. The systems that will be discussed in this study are as follows:

- CADKEY 99 produced by the CADKEY Corporation.
- Mechanical Desktop produced by Autodesk Inc.
- Solidworks produced by Solidworks Corporation.
- Pro-Engineer produced by Parametric Technology Corporation (PTC).
- I-DEAS produced by Structural Dynamics Research Corporation (SDRC).
- Mastercam produced by CNC Software Inc.
- SURFCAM produced by Surfware Inc.

Key features available with the products from these CAD/CAM companies will be discussed in the following sections, providing insight into these systems.

CADKEY® 99

CADKEY 99 is a multi-functional CAD environment in that it supports two-dimensional drafting, wireframe modeling, and the generation of three-dimensional solid models. It is capable of expanding two-dimensional profiles into solid models, volume verification, interference checking between assemblies,

and redefinition of a given model. Users can generate "machinable" surface models that can be used with CAM applications. CADKEY 99 can also generate two-dimensional drawing layouts from solid models to reduce drafting tasks. Photo realistic rendering is provided to allow users to apply textures, light sources, ray tracing or perspective views to models.

CADKEY provides interoperability tools to repair imported model geometry, allowing for easier data translation between different systems. Several file translators, such as STEP, IGES, DXF, DWG, SAT, Parasolid X_T, and STL, are offered at no additional cost. CADKEY has many alliances with other software companies to provide integration from standard CADKEY files into another system. A list of these solution partners can be viewed at www.cadkey.com/solprt/index.htm.

TRUE TEXT and POWER-PAK are two add on utilities offered by CADKEY. When used together, they create solid or wireframe text along a curved path, or convert splines to smooth arc contours.

CADKEY Corporation offers free technical support by fax or Email, through online technical notes, a discussion area, and tips allowing users to access topics and information anytime. CADKEY operates on Windows® NT or Windows® 95/98 operating systems. It requires at minimum a 150 MHz

processor, CD-ROM drive, 64 MB of RAM, 200 MB of hard drive space for file swapping, 4 MB RAM OpenGL video card, and 90 MB of hard drive space for installation. (Web site, www.cadkey.com)

Mechanical Desktop Release 4

Mechanical Desktop unites parametric three-dimensional modeling with two-dimensional drafting capabilities resulting in one user design interface. Team members can work concurrently using a streamlined catalog interface with simple drag and drop procedures. The user can also access and edit multiple files in one session, allowing for geometry to be copied between drawings.

Autodesk provides online courses and tutorials, training centers and manuals to help answer user questions pertaining to technical problems.

Add-on features included with Mechanical Desktop are: resistance capabilities to objects under static load; a generator that creates springs, shaft, belts and chains; the ability to perform calculations on two and three-dimensional parts. Autodesk also offers an optional library called Power Pack, which adds over 1.2 million two and three-dimensional pre-drawn parts, holes, features, and standards.

The standard Mechanical Desktop system will exchange data in BMP, EPS, DWF, DWG, DXF, IDF, IGES, VDA-FS, VRML, SAT, STL, WMF, and 3DS file formats. An AutoCAD Data Exchange CD can be purchased separately to ensure complete data translation across many diverse CAD systems.

Mechanical Desktop will generate detailed views of the solid model for associative drafting, and allows for changes performed in either environment to update the other instantaneously. Users can purchase 3D Studio MAX release 3 or 3D Studio VIZ release 3, which produces photo realistic renderings, animations, and presentations.

Autodesk has a growing alliance of leading mechanical applications developers, providing seamless data integration. A list of these solution partners can be viewed at http://www.autodesk.com/develop/mai/index.htm.

Mechanical Desktop will run on Windows® NT, 95, or 98 environments. At a minimum, Mechanical Desktop requires a 300 MHz processor, 680 MB of hard disk space, a graphic card and OpenGL video card with 4 MB of video Ram, and 256 MB of RAM for large assemblies. (Web site, www.autodesk.com)

Solidworks® 2000

Solidworks is a Windows-native three-dimensional design software system. It can be used to create solid models as well as provide surfacing capabilities. Several new features include increased ease of use and a simple, comprehensive part migration from a two-dimensional to a three-dimensional design environment. The unique drag and drop capabilities can be used to quickly create different designs based on features developed for existing designs. Solidworks is provided with sheet metal design capabilities that let the user model in three-dimensions or with correct three-dimensional geometry when modeling in two-dimensions. It has a built in drafting component called RapidDraft, which allows users to work on drawings and assemblies separately, and then requires synchronization of the changes. Drafting utilities can generate detailed views of the solid model. Solidworks also offers eDrawings, an email enabled communications tool designed to ease the sharing and interpretation of two-dimensional mechanical drawings.

Solidworks is capable of working with DXF, DWG, SAT, STL, VDAFS, VRML, IGES, STEP, and Parasolid native file formats. Xchangeworks is also offered by Solidworks as a free data translation plug-in for use in AutoCAD and Mechanical Desktop, providing the capability to import data from most other

mechanical CAD products available on the market. Solidworks has many software partners, and they can be viewed at www.solidworks.com/swdocs/SolutionPartner/html/partnerquery.cfm.

Solidworks Explorer is a free file management tool included with the program, which is similar to Windows® Explorer. It is designed to automate typical operations that users are accustomed to using when managing files, such as copying, renaming, and regulating properties. It also allows users to view file discrepancies that occur for drawings, parts, and assemblies using a tree structure.

An annual subscription entitles users to upgrades, hotline support, technical tips, and a model library via the Solidworks Web site.

Photoworks provides users with rendering capabilities that are integrated with Solidworks. Users can also use the Solidworks Animator to create animations to better communicate design concepts.

Solidworks operates on Windows® NT, 95, 98, and 2000 operating systems. It requires at minimum a Pentium® class processor, 64 MB of RAM, a graphics card with OpenGL, a CD-ROM drive. Microsoft® Office 97 or 2000 is also recommended. (Web site, www.solidworks.com)

Pro-Engineer 2000i²

Pro-Engineer 2000i² is a parametric feature based modeler. It has been a dominant choice in the mid to high-end price range by manufacturing companies for its solid modeling capabilities in the past. New features include drag and drop capabilities, enhanced sketching operations and intelligent features. One standard feature included is an Associative Drawing Table, which provides detailed reports that associatively update with any changes made to the design, and that sort and filter information within a drawing to communicate design details such as BOM's. Pro-Engineer parts, assemblies, and process plans can also be exported to complete Web pages using standard HTML, VRML, CGM, JPEG formats and Java applets, for viewing on the Internet or intranet using a standard Web browser. The core foundation also comes with a programmable interface, sheet metal design tools, weld modeling, behavioral modeling, and surface modeling.

A major advantage of Pro-Engineer has been the capability of importing and exporting a wide variety of file formats. Pro-Engineer has direct file translators for CADDS 5, CATIA, PDGS, CADAM, MEDUSA, and AutoCAD DXF/DWG. It also has standard translators that can be used for IGES, STEP, SET, VDA, ECAD, CGM, COSMOS/M, PATRAN/SUPERTAB, SLA, JPEG, TIFF, RENDER, STL, VRML, INVENTOR, and XPATCH file formats.

Full detail documentation and two-dimensional drafting are included in the Pro-Engineer foundation. This allows users to create custom formats, all types of views, programmable drawing, and standard detail /drafting capabilities. Photo realistic images can also be generated to evaluate design aesthetics, evaluate surface quality, or create a communication media for sales and marketing.

Pro-Engineer provides access to expandable libraries of standard parts, features, tools, mold bases, connectors, pipefittings, symbols, and human body dimensions. This allows users to easily insert items into a design or assembly, or add components to the library to be accessed by others.

Some add-on features available for Pro-Engineer 2000 include:

- ModelCHECK, which helps quickly locate and reuse existing designs.
- NC programming and simulation tool set.
- A Tool Design Mold catalog, which allows users to define, select and place standard mold items such as ejector or core pins.
- Routing Systems Option to design, route, document, and produce harness and piping systems.
- Plastics Advisor Option, to simulate mold filling for injection molded plastic parts.

- Mechanism Design Extension, which allows users to assemble parts using pre-defined connections such as a pin or ball joint.
- Design Animation, a tool to convey information about a product or process through animation sequences.
- Application Programming Toolkit, which allows users to create applications that run parallel to Pro-Engineer to integrate product information, such as with the users MRP/ERP systems.
- CADAM Migration to maintain, modify, and revise mainframe CADAM drawings.

Parametric Technology Corporation offers technical support via the telephone or Internet twenty-four hours a day, seven days a week. Their Internet site also has over fourteen thousand technical documents that users can reference for information. PTC has many software partners, and a list can be viewed at http://www.ptc.com/for/partners.htm.

Minimum system requirements necessary to run Pro-Engineer 2000 include: Pentium® type processor, Microsoft® Windows NT/95/98/2000, 64MB of main memory, 400 MB of disk space, 128 MB of swap space, S3 compatible graphics, CD-ROM, and VFAT for Windows 95/98, HPFS, NTFS for Windows NT. (Web site, www.ptc.com)

I-DEAS 8

I-DEAS 8 is a system that offers CAD/CAM/CAE to customers in the mid to high-end price range. New features include dynamic drag and drop interaction and dynamic assembly manipulation. I-DEAS supports free form surface modeling, feature based solid, surface, and hybrid models, and assembly management. The user can create, simulate, optimize, document, build, and test products all within a single electronic environment. I-DEAS Master Drafting provides two-dimensional drawings converted from solid models. Master Drafting can also replace two-dimensional drawings with a three-dimensional digital prototype that encapsulates all necessary information required to manufacture the product.

A popular feature offered with this software is file management. Parts must be checked in or checked out of libraries to help control drawing changes, viewing, and security. Parts files have the capability to maintain intelligent associations so other users can also access and utilize information. Communication is also enhanced through supporting concurrent or team engineering. It provides the ability to document and communicate all manufacturing information in three-dimensions so it can be shared by team members within a project environment. I-DEAS distributes finite element

information for viewing by the entire engineering organization through its library storage.

Web training of I-DEAS is based on a wide range of topics through overviews, detailed descriptions, tutorials, and a library of parts and assemblies. I-DEAS offers over 100 online tutorials and a full help library. Technical support is also provided by means of telephone and email.

Many forms of file translation are offered with this software. Files can be directly translated with companies such as MSC, CSA, UAI, COSMIC NASTRAN, CADAM CADDS, CATIA, ABAQUS, and ANSYS, creating more integration capability while reducing translation errors. Standard file translations of PCB, ASCII, CMX, ATS, DWG, IGES, SET, STEP, OLE/DM, STL, JAMA I.S., VRML are also available with the standard software.

I-DEAS offers several add on features, which include the following:

- Imageware Surfacer V10, for reverse engineering, surface design, and evaluation.
- VGX Core/Cavity, which creates mold or die halves for injection molding, casting, or forging.
- Generative Machining, which creates NC machining programs.
- Metaphase Series 2, a data management system that utilizes I-DEAS.

- Master Surfacing, which allows design and modification of complex sculptured surface parts.
- I-DEAS View and Markup, which is a module for viewing and commenting on drawings and designs.
- Drafting Symbols Catalog, which contains over 20000 symbols to meet ANSI, JIS, and ISO standards.
- Open I-DEAS, a highly flexible open architecture toolkit used for customizing, automating, or integrating custom or third party applications and data translators.

Minimum system requirements needed to run SDRC I-DEAS include: Pentium® type processor, Microsoft® Windows NT 4.0, 2 GB hard disk, 128 MB of swap space, and CD-ROM. Compatible graphics cards, minimum graphic memory requirements and software are listed at www.sdrc.com/ideas/hardware/7-wnt/index.shtml. (Web site, www.sdrc.com)

Mastercam

Mastercam is a Windows based CAD/CAM software system used for simulating two through five-axis milling, turning, and 2 or 4 axis wire EDM. The package also includes three dimensional design, drafting, and surface modeling

modules. Lathe, wire, and three levels of milling modules are offered. Full drafting, dimensioning, and rendering are included with this modeling suite. Dimension generation that utilizes drag and place drafting notes can be created and attribute changes automatically updated from model changes.

Built in file translators include IGES, SAT, DXF, CADL, VDA, ASCII, STL, and ASCII text. An optional DWG converter and a new translator to read STEP data into version 7.2C are available at an additional cost.

Mastercam offers several forms of technical support, which includes a bulletin board system, support from Mastercam dealers, and technical support by telephone Monday through Friday eight a.m. to six p.m., eastern standard time.

Mastercam has many software partners, and a list can be viewed at http://www.mastercam.com.

Minimum system requirements to operate Mastercam software are the following: Pentium®-based PC, Windows® NT 4.0 (or higher), 95 or 98, and a minimum of 64 MB RAM.

SURFCAM

Surfware Inc. is a CAD/CAM software company that specializes in manufacturing applications. They offer several different product lines that

include: SURFCAM Design Products, SURFCAM Solids, SURFCAM Solids PhotoEffects, SURFCAM Verify PLUS 3,4, and 5 Axis, and SURFCAM Manufacturing Products. An optional SAT translator that converts ACIS SAT files into SURFCAM DSN files is also available.

SURFCAM Design is a wireframe-modeling version of SURFCAM with a true three-dimensional database used for part design, dimensioning, and editing. This includes DXF, CADL, and a write only IGES translator.

SURFCAM Solids is a modeling package that utilizes Solidworks98Plus. Parts that are generated through Solidworks98Plus can be directly translated into SURFCAM machining file format. Users receive all the standard features available with Solidworks software.

SURFCAM offers machining modules separately, to let users select the best fit within their price range. These modules include SURFCAM Lathe, and two through five Axis and Axis Plus SURFCAM Milling. All of these modules include SURFCAM Design and toolpath verification. SURFCAM 2 Axis includes two-axis wire EDM and 2 Axis Plus includes four-axis wire EDM.

SURFCAM 99 is a complete machining software package, which includes features from the previous modules. It has translators for CADKEY, AutoCAD,

DXF, ASCII, CATIA, IGES, NCAL, Parasolid (X_T), Solid Edge, Solidworks, SAT, SPAC, STL, and VDA.

SURFCAM Solid PhotoEffects creates realistic images from solid models. The user can specify part properties including lighting color, texture, reflectance, and transparency. A library consisting of pre-defined materials, which includes metals, plastics, and woods to name a few, is provided as a standard feature with this module.

SURFCAM Verify provides users the ability to read APT-CL files and G-Code output. Simulations can be performed while providing a display of fixtures, multiple graphic views, dynamic rotation, and record and playback features.

SURFCAM offers support through a secure Internet site and by telephone, and training is offered throughout the year. SURFCAM has many software partners, and a list can be viewed at http://www.surfware.com/m-search.htm.

Minimum system requirements necessary to run SURFCAM include: Pentium® type processor, Microsoft® Windows NT/95/98/2000, 32MB of main memory, 1.2 GB hard drive, 64 Bit Video Card with 2MB of memory, 6X CD-ROM, and VFAT for Windows 95/98, HPFS, NTFS for Windows NT. (Web site, www.surfware.com)

Chapter 4

Results

This chapter will provide a detailed overview of the survey instrument results sent to industry professionals March 7, 2000. By collecting information on current industry practices from a variety of manufacturers throughout northwestern Wisconsin, these results can be used to identify functional requirements that need to be addressed when selecting a CAD/CAM system for small manufacturing companies.

Of the one hundred forty-eight companies surveyed, forty-seven responded, resulting in a return rate of thirty-two percent. Twenty-eight of these companies, sixty percent, were currently using a CAD or CAM system. Forty percent, eighteen companies, were not using a CAD/CAM system. With the advantages of CAD/CAM system, it is surprising that forty percent of the surveyed companies are not using some form of CAD/CAM.

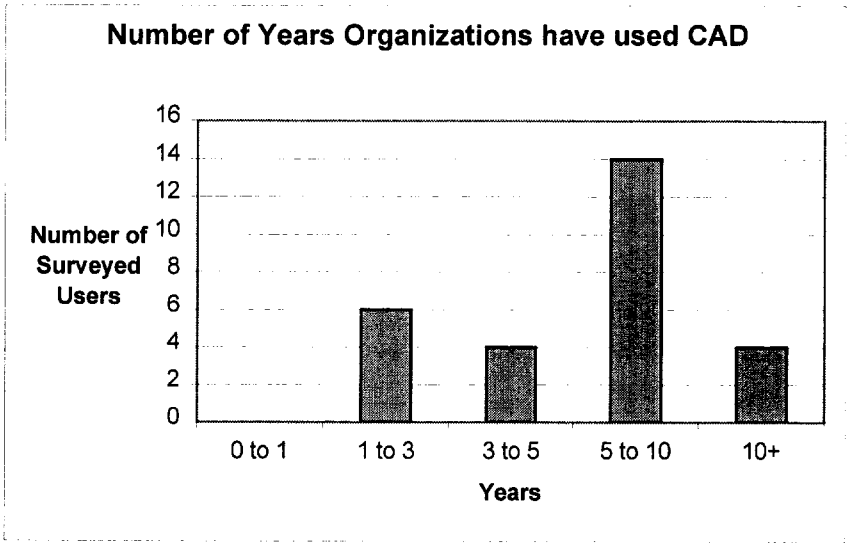

Figure 1 Years Organizations Used CAD

Seventeen different CAD systems were being used within the twenty-eight companies that responded to using a CAD or CAM system. Eight of the companies were using multiple systems. Using the following scale, 0 to 1, 1 to 3, 3 to 5, 5 to 10, and 10+, surveyed users were asked how many years their organization had been using CAD (refer to Figure 1). These companies had been using their CAD system for an average of five to ten years.

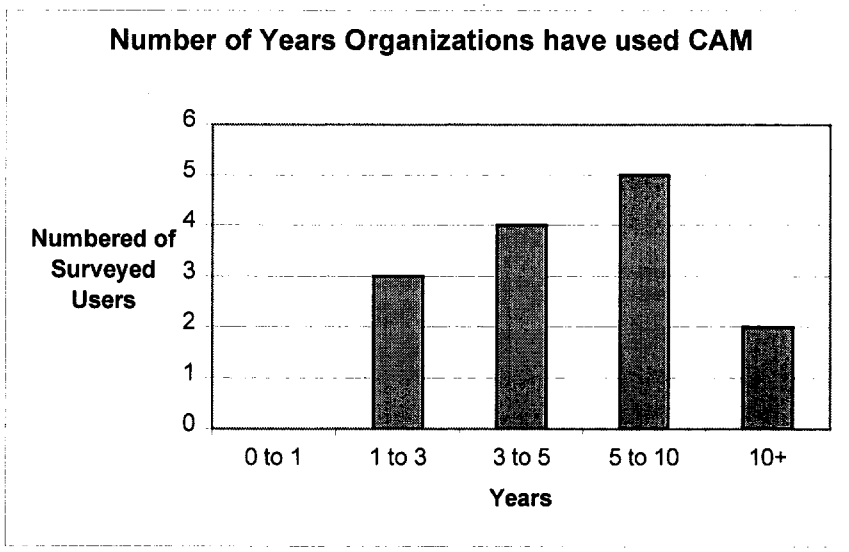

Figure 2 Years Organizations Used CAM

Seven different CAM systems were being used within the fourteen companies that responded to using CAM. Six of the companies were using a CAM package associated with their CAD system. Using the following scale, 0 to 1, 1 to 3, 3 to 5, 5 to 10, and 10+, surveyed users were asked how many years their organization had been using CAM (refer to Figure 2). These companies had been using their CAM system for an average of five years. With many companies using systems older than five years, many benefits available with new technologies were not being capitalized on.

	Mean	Std Dev
Capabilities	1.43	0.51
Efficiency	1.92	0.83
Functionality	2.17	1.23
Price	2.52	0.60
Support	2.54	0.83
Import/Export	2.56	1.16
Communications	2.67	1.13
Operating system	2.92	1.04
Viewing	2.92	1.00
Analysis	3.16	1.07
Expandability	3.25	0.86
Kernel	3.82	0.88

Table 1 Important Selection Criteria

Users ranked the criteria shown in Table 1 by importance, 1 being most important, 2 being important, 3 being fairly important, 4 being least important, and 5 being not important. The results shown in Table 1 rank the system's capabilities and efficiency of use as most important to important criteria used in selecting a CAD/CAM system. Functionality, price, support, import/export capabilities, and communication were rated as important to fairly important criteria used in selecting a CAD/CAM system.

Other criteria that surveyed users suggested were an important aid in CAD/CAM selection were the compatibility with customers, a system that was consistent with other corporate facilities, and a properly trained use base.

One hundred percent of the companies surveyed that had a CAD/CAM system, selected the software without the aid of a consultant. By not using a consultant, companies must rely on research and self-evaluation to effectively select a system. This burden is compounded by the results that indicate seventy-five percent of the companies state that a CAD/CAM system is critical to the operation of their company. Small manufacturing companies rely heavily on this technology to perform core functions of design and manufacturing, making selection errors detrimental and expensive to the facilities operations.

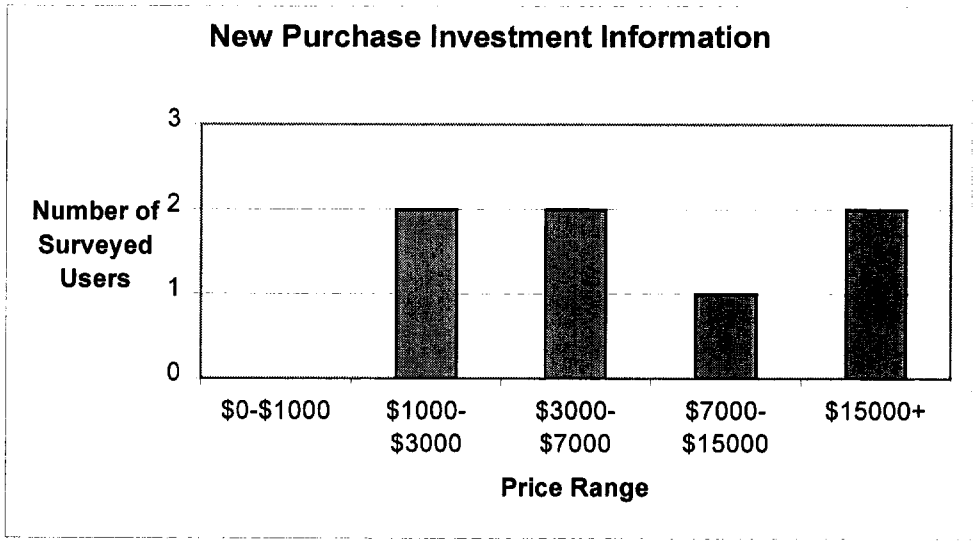

Figure 3 New Purchase Investment Information

Eighty-nine percent of the users surveyed indicated they were not interested in a new CAD/CAM system. Of the eleven percent that were, most had

researched available systems themselves. Using the following scale, $0 to $1000, $1000 to $3000, $3000 to $7000, $7000 to $15,000, and $15,000+, surveyed users were asked how much their organization might be willing to invest in the purchase of a new system (refer to Figure 3). These companies indicated they would be willing to spend an average of $7000 for a system.

	Mean	Std Dev
2D&3D/CFD	2.95	1.46
Project Data Management	3.18	1.47
Structural/Static	3.38	1.63
Tool Management	3.73	1.42
Fatigue/Fractures	4.00	1.38
Stress/Thermal	4.10	1.37
Stiffness/Buckling	4.10	1.18
Deflection	4.14	1.31
Dynamic/Vibration	4.24	1.18
Modal/Acoustics	4.52	0.93
Compressible/Incompressible Flows	4.52	0.98
Electromagnetic	4.52	0.98

Table 2 Important Add-on Utilities

Users ranked the add-on features shown in Table 2 by importance, 1 being most important, 2 being important, 3 being fairly important, 4 being least important, and 5 being not important. The results, shown in Table 2, indicate the most important add-on features end users desire when selecting a system. In general, surveyed users indicated little interest in add-on features, which may be

due to being unfamiliar with recent advancements in these areas. Flow analysis, corrugated industry specific features, tool paths, and post processors were other important add-on features suggested for evaluation.

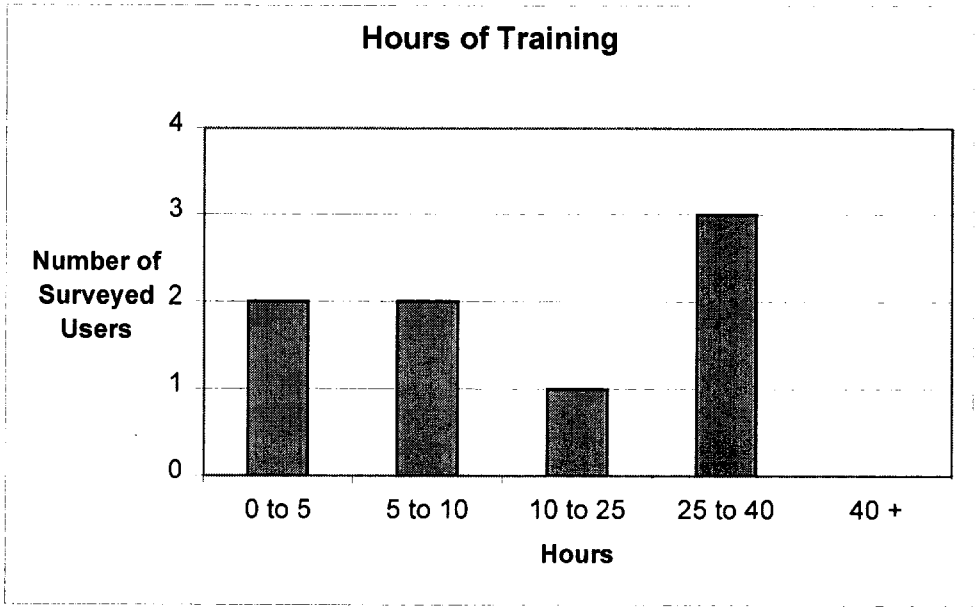

Figure 4 Hours of Training

Sixty-eight percent of the users surveyed indicated they did not receive training on the system they were using. Using the following scale, 0 to 5, 5 to 10, 10 to 25, 25 to 40, and 40+, surveyed users who did receive training were asked how many hours of training a year they were given (refer to Figure 4). An employee received an average of ten hours of training a year.

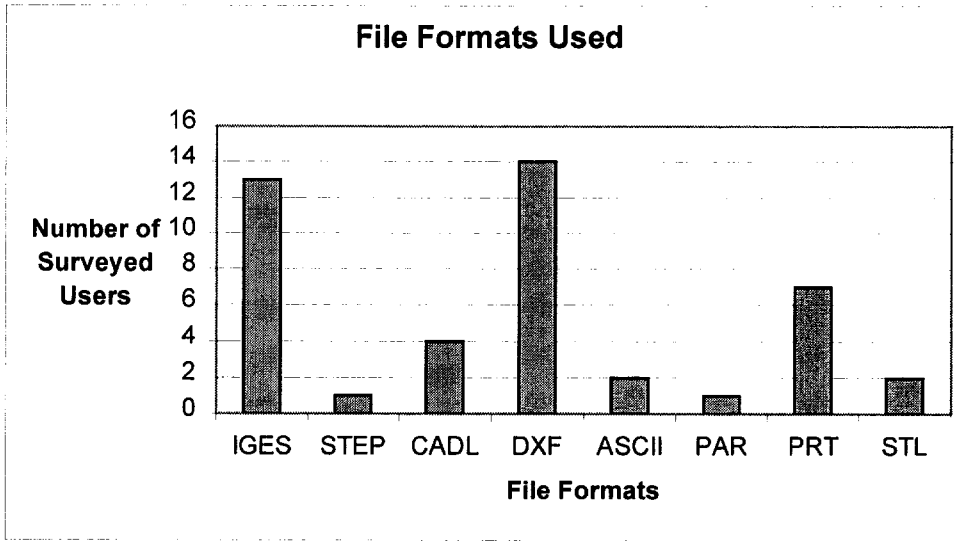

Figure 5 File Formats Used

Sixty-four percent of the companies surveyed translate files. Seventy-eight percent of these companies have experienced errors in file translation, while fifty percent have experienced errors in transferring files electronically. Figure 6 indicates popular file formats currently being used by respondents. The most common file formats used were DXF, IGES, and PRT.

Ninety-three percent of companies surveyed had Internet access, while eighty-nine percent used electronic mail. Using the following scale, 1 to 5, 5 to 10, 10 to 20, 20 to 50, and 50+, surveyed users were asked how many employees worked at their facility (refer to Figure 6). Surveyed companies had an average of 10 to 20 employees working at their facility, with a standard deviation of 1.47.

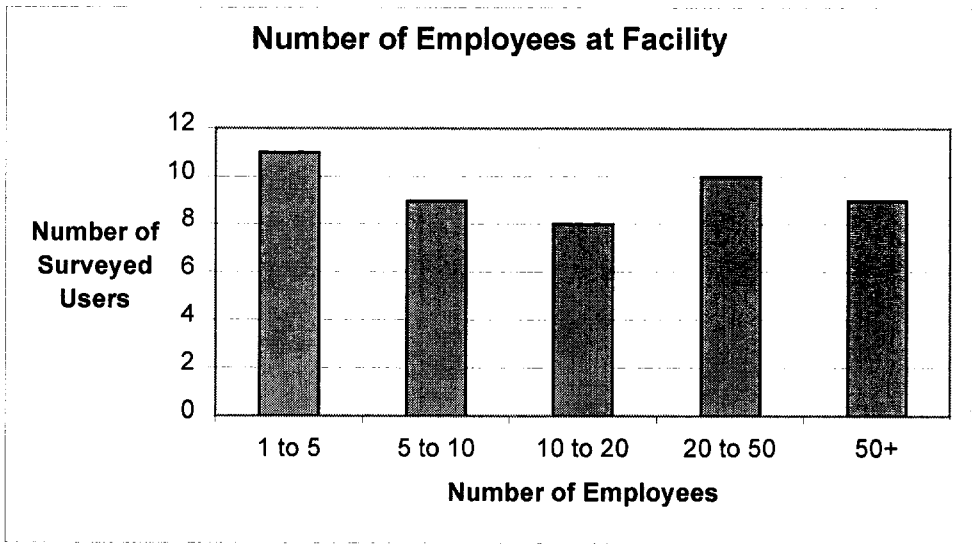

Figure 6 Number of Employees at Facility

Surveyed companies had an average of $1 to $5 million dollars in approximate gross sales (refer to Table 3). Fifty-one percent were original equipment manufacturers while forty-five percent were suppliers.

Gross Sales	% of Population
0-$50K	2
$50-$100K	7
$100-$500K	16
$500k-$1million	14
$1-$5million	37
$5-$20million	19
$20-$50 million	0
$50million+	5

Table 3 Population Gross Sales

Chapter 5

Conclusions

There are many important factors that need to be addressed when seeking the best CAD/CAM system solution for a manufacturing company. Although benchmarking should be performed, a thorough analysis of a company's needs must be completed to match requirements with available hardware and software, which can minimize the risk associated with CAD/CAM system selection.

Today's systems can perform many different operations, maximizing the benefits associated with CAD/CAM systems. A variety of add-on features, such as Finite Element Analysis, part optimization, sheet metal and welding modules, and libraries of standard parts, features, and symbols, allow users to create accurate parts quicker and more efficiently then ever. These benefits can equate to monetary rewards that can be capitalized on by manufacturing companies throughout the world.

A description of several CAD/CAM systems describes current software and features available. Recent advancements take advantage of current hardware capabilities to provide a variety of options unavailable just a few years earlier. A push from two-dimensional drafting to three-dimensional solid modeling has

resulted in accuracy and communication advancements. Through software development, improvements to design, testing, and generation of complex parts will continue to evolve.

The survey given to small manufacturing companies in northwestern Wisconsin communicated current criteria trends in CAD/CAM selection. Survey results confirmed that important selection factors include system capabilities, efficiency, functionality, price, support, and communication. Most showed little interest in add-on utilities for their system, possibly due to the fact that they are unaware of current utilities available.

Many surveyed users were utilizing older systems and were not interested in new CAD/CAM software. Seventy-five percent of surveyed users said their CAD/CAM system was critical to their company and all respondents had selected their current system themselves. This indicates how critical CAD/CAM selection information can be and the impact selection can have on a company.

The most alarming response indicated sixty-eight percent of surveyed users did not provide training on their system. This leads to the conclusion that dedicated users are forced to train themselves, removing productive time from other tasks.

Communication continues to be a major issue when selecting a CAD/CAM system within the manufacturing community. The ability to convey information is critical in every aspect of manufacturing. Sixty-four percent of the surveyed companies translate files, implying the importance of communication. The ability to read file formats between different systems is, and will continue to be, an issue for many years to come.

Recommendations for Future Studies

- Survey results indicated most respondents used older systems and few were looking for new systems. Future studies may want to inquire about satisfaction with current systems and why users were not looking to purchase a new system.
- Survey results indicated a poor response to add-on features by end users. Surveyed users should be asked what add-on features came with their system and which features have been purchased in the past to identify important add-on features.
- Future studies based on training and the effects of trained individuals in a CAD/CAM environment could better indicate why training was not important to surveyed users.

- Future studies about communication between different software systems may clarify what problems and solutions users experience when performing file format translations.

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Appendix A

Survey Cover Letter

SURVEY

TIM MERCER

UNIVERSITY OF WISCONSIN - STOUT

Purpose: The purpose of this study is to create a methodology to aid small manufacturing companies in selecting a CAD/CAM system. Your participation in answering questions in this survey will help identify information on important criteria for a CAD/CAM system selection. The responses will be kept confidential and used solely for the purpose of this study. Please return the survey form in the self addressed, stamped envelope by March 24, 2000. Thank you in advance for completing the survey.

Consent: I understand that by returning the/this questionnaire, I am giving my informed consent as a participating volunteer in this study. I understand the basic nature of the study and agree that any potential risks are exceedingly small. I also understand the potential benefits that might be realized from the successful completion of this study. I am aware that the information is being sought in a specific manner so that no identifiers are needed and so that confidentiality is guaranteed. I realize that I have the right to refuse to participate and that my right to withdraw from participation at any time during the study will be respected with no coercion or prejudice.

Note: Questions or concerns about participation in the research study or subsequent complaints should be addressed first to:
Tim Mercer
701 N. Broadway #5
Menomonie, WI 54751
Phone (715) 235-4817
mercert@post.uwstout.edu

and second to:

Dr. Ted Knous, Chair,
UW Stout Institutional Review Board for the Protection of Human Subjects in Research
11HH, UW Stout
Menomonie, WI 54751
Phone (715) 232-1126

CAD/CAM Survey

1.Does your organization currently use a CAD and/or CAM system? If no, skip to question 20.

___Yes ___No

2. Which CAD system/s is your organization currently using?

___None (if none skip to question 4)

___Applicon Bravo	___Design Pacifica	___MCS
___Ashlar Vellum	___EDS Unigraphics	___MICROCADAM
___AutoDesk	___EMT Software	___MSC
___Bentley	___IBM Catia	___PTC Pro-Engineer
___CADKEY	___ICEM Technologies	___SDRC Idea
___CoCreate	___IMSI TurboCAD	___Solid Edge
___Computervision CADDS 5	___Matra Datavision	___Solid Works
___VDS IronCAD		

___Other_____.

3. How many years has your organization been using the CAD system/s?

___0-1 ___1-3 ___3-5 ___5-10 ___10+

4. Which CAM system/s is your organization currently using?

___None (if none skip to question 6)

___CAMCORE Solid	___Maple-3AX	___PEPS Solid Cut
___Mastercam	___Esprit 99	___FeatureCAM
___GibbsCAM '99	___FF/CAM	___VisualMill
___TopCam	___EdgeCAM	___Factory Mill
___SurfCAM	___CAMWorks	___Visi-CAM

___A CAM package associated with your CAD package

___Other_____.

5. How many years has your organization been using the CAM system/s?

___0-1 ___1-3 ___3-5 ___5-10 ___10+

6. By importance, 1-5 and one being most important, which criteria did you or your organization use to select the system/s?

	Most Important	Important	Fairly Important	Least Important	Not Important
	1	2	3	4	5
Price					
Expandability					
Communications					
Efficiency					
Capabilities					
Import/Export					
Functionality					
Analysis					
Operating system					
Support					
Viewing					
Kernel					
Other					

Other_____.

7. Did you or your organization hire a consultant to help aid in system selection?

___Yes ___No

8. Is the CAD/CAM system critical to the operation of the company?

___Yes ___No

9. Are you or your organization interested in a new CAD/CAM system? If no, skip to question 12?

___Yes ___No

10. Have you or someone from your organization researched CAD/CAM systems?

___Yes ___No

11. How much are you or your organization willing to invest in the purchase of a new system?

___$0-$1000 ___$1000-$3000 ___$3000-$7000 ___$7000-$15000 ___$15000+

12. By importance, 1-5 and one being most important, which add on features are the most important to you?

	Most Important		Fairly Important	Least Important	Not Important
	1	2	3	4	5
Stress/Thermal					
Structural/Static					
Dynamic/Vibration					
Fatigue/Fractures					
2D&3D/CFD					
Stiffness/Buckling					
Modal/Acoustics					
Deflection					
Compressible/Incompressible Flows					
Electromagnetic					
Project Data Management					
Tool Management					
Other					

Other_____.

13. Does your company provide training on the system you are using, if no skip to question 16?

___Yes ___No

14. How many hours of training does an employee of the company receive a year?

___0-5 ___5-10 ___10-25 ___25-40 ___40+

15. Is your training conducted through your own company employees?

___Yes ___No

16. Does your company translate CAD/CAM files, if no skip to question 19?

___Yes ___No

17. What file formats do you or others use to translate files?

___Proprietary ___PAR
___IGES ___PRT
___STEP ___SAT
___CADL ___SUP
___DFX ___STL
___ASCII ___X_T
___NCAL ___MODEL
___Other _____.

18. Have you experienced errors in translating files?

___Yes ___No

19. Have you experienced errors in transferring files electronically?

___Yes ___No

20. Do you have Internet access?

___Yes ___No

21. Do you have Electronic Mail?

___Yes ___No

22. How many employees are currently working at your facility?

___1-5 ___5-10 ___10-20 ___20-50 ___50+

23. What are your company's approximate gross sales?

0-$50K	____	$1-$5million	____
$50-$100K	____	$5-$20million	____
$100-$500K	____	$20-$50 million	____
$500k-$1million	____	$50million+	____

24. Are you a supplier or Original Equipment Manufacturer (OEM)?

___OEM ___Supplier

25. How many years have you worked for this company?

___0-1 ___1-5 ___5-10 ___10-20 ___20+

26. What is the highest post secondary education level you have received?

___None ___Associate ___Bachelor ___Master ___Doctorate

27. What is the position you currently hold in this organization?

_____