Critical success factors for integration of CAD/CAM systems with ERP systems

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Keywords E-commerce, Knowledge management, CAD/CAM, Enterprise resource planning

Abstract Current advances in information technology and, in particular, computer-aided design/computer-aided manufacturing (CAD/CAM) and enterprise resources planning (ERP) systems, have led organisations to undertake significant investments in these systems. Next generation manufacturers require both systems to maintain or gain a competitive advantage, reduce risks and improve productivity and viability. In addition, recent attention to the implementation of CAD/CAM systems highlights their important role in automating complex design and next generation manufacturing processes. In the next millennium more manufacturers are likely to implement CAD/CAM and ERP systems and hence issues in the integration of CAD/CAM with ERP systems must become a major concern. Accordingly, this paper will: explore the problems of integration of CAD/CAM systems with ERP systems; study how the severity of these problems relates to CAD/CAM integration success; propose a set of critical success factors (CSF) for the integration of CAD/CAM with ERP systems; suggest hypotheses to study the relevance of these CSF for successful integration of CAD/CAM with ERP systems. In addition, the paper also demonstrates the importance of successful integration of CAD/CAM systems with other applications for next generation manufacturers. These findings suggest that integration of CAD/CAM systems with ERP systems is complex, involving many factors.

Introduction
In 1985 Porter and Millar reported that organisations realise that traditional approaches to achieving and maintaining competitive advantage are no longer sufficient. One of the most important elements in competitive advantage, they suggested, was information. Recently, Gustin et al. (1994) recognised that the link between information and competitive advantage is critical to achieving integration. They viewed information technology (IT) as resources to be used by the firm in gaining competitive advantage in the marketplace. In a similar vein, Garcia (1997) and Phillips (1997) suggest that organisations need to consider information and knowledge, more generally, as key business assets and that enterprises should expend considerable effort in capturing their collective knowledge. Accordingly, next generation manufacturers need to understand the issues related to the application of IT for gaining competitive advantage.

It is widely accepted that heightened attention to the employment of IT in key business functions is due in large part to the total quality management (TQM) and business process re-engineering (BPR) movements (Soliman, 1996).
Soliman and Youssef (1998) note that IT, in particular, enterprise resources planning (ERP) systems, is central to the success of the BPR method. ERP systems are systems that tie the organisation’s functional units and systems and databases together. The main objectives of this integration are of course sharing information, avoiding duplication of work, reducing wasted effort and eliminating non-value added activities (Duff, 1996; Mitskavich, 1996). According to Fawcett (1992), “integration of logistics into the design and management of global manufacturing networks is critical to the success of a global manufacturing strategy. Skilful management of logistics should be essential to time-based competition”. Soliman and Youssef (1998) identified these as areas where enterprise-wide information systems could significantly support the strategic objectives of modern organisations and, in particular, next generation manufacturers.

Soliman (1998) observed that the manufacturing of products is usually made up of a series of processes that contribute to the creation and the delivery of these products to customers. One of these processes which is central to any manufacturing operation is engineering design (ED). All down-stream production and procurement processes depend on the outcome of the ED process. An efficient design process is likely to enhance the performance of production and ultimately manufacturing processes. DE is just one of the many processes used in manufacturing and is therefore a critical part of the opportunity to delivery (OtO) chain. A typical OtO chain would also include sales, procurement, production, inspection and dispatch processes.

Figure 1 illustrates a typical manufacturing process in an OtO chain.

**Implementation of CAD/CAM systems**

Effective implementation of CAD/CAM systems offers manufacturers a number of benefits such as: cutting design costs, reducing cycle time, reducing matching time and improving information flow. For firms that have already implemented CAD/CAM systems the rise in their productivity will also coincide with a marked decrease in design and production costs, thus freeing valuable staff time so that they can concentrate on pro-actively managing customers’ demands and value added activities. There are two implementation scenarios to be considered:

1. **Full scale implementation.** In this scenario the focus during the implementation is on improving the business. This approach is suitable when:

   ![Figure 1.](image-url)
• improvements in business processes are required;
• customization of CAD/CAM processes are necessary;
• different alternative strategies need to be evaluated;
• high level of integration between CAD/CAM and ERP system is required; and
• there is multiple site implementation.

(2) **Short-cut implementation.** In this scenario the focus during the implementation is on technical migration with enhanced business improvements introduced at a later stage. This approach is suitable when:
• improvements in business processes are not required immediately;
• the organisation has a firm decision-making process;
• organisation operating procedures are driven from its strategic plans; and
• there is one single site implementation.

The success of a CAD/CAM implementation depends on how quickly the benefits can be reaped from the system. This necessitates rapid implementation, leading to shortened return on investment (ROI) periods (Clark and Soliman, 1997a, b).

Traditional approaches to implementation typically carry out a BPR exercise and define a “to be” model before the CAD/CAM system implementation. Although such a scenario has a theoretical appeal for management, in reality it usually leads to mismatches between the proposed model and the CAD/CAM functionality. The consequences of this can include extension of the implementation time frames, higher costs and loss of user confidence.

It is envisaged that next generation manufacturers would implement CAD/CAM systems in stages. The usual starting point is with the mission statement, from which one derives the implementation plan in line with the strategic plan of the next generation manufacturer. This is necessary to avoid mismatch and to ensure that the investment in CAD/CAM systems is aligned with the business direction of the organisation (Clark and Soliman, 1999). According to Soliman (1997), in the 1990s and beyond, IT and BPR will be used in conjunction with each other and will emerge as important tools to give next generation manufacturers a leading edge. By their very definition, most CAD/CAM systems reside in the servers of local area networks (LAN). Therefore they have their databases and produce output, usually in the form of drawings and bills of materials (BoM), for use by production and procurement departments. Hence, there is no shortage of data to use in achieving alignment.
CAD/CAM integration with ERP systems

Organisations using ERP systems have two significant choices, either of which they may follow:

1. Re-enter BoM and other relevant information into the ERP system for the purpose of performing material requirement planning (MRP) calculations and for ordering materials from suppliers;

2. Integrate the CAD/CAM system so that the information it generates is automatically passed on to the MRP, procurement and other modules in the ERP system, without a great deal of effort.

The integration between CAD/CAM systems and ERP systems cannot produce maximum results unless the data collection (interchange) is appropriate for the task. Traditional systems rely on a hierarchical, top-down model that conforms to the host hardware-processing environment, with extensive data interchange networks submitting transactions over a dedicated network. In these systems, transaction verification must be performed at the host level, leading to constant disruptions and delays for users. Therefore data interchange becomes a roadblock to effective CAD/ERP integration. With continual interruptions to the host process, the modern ERP system can be rendered ineffective. These problems and the inherent complexity of integration have led a movement of hardware-driven improvement in data interchange systems (DIS). The result is that modern DIS in next generation manufacturer will incorporate client/server architecture, extensive connectivity options, multi-platform computabilities and modular construction. These DIS must be deployed in accordance with the connectivity requirement of both the CAD/CAM and ERP systems. It should be remembered that the CAD/CAM connectivity requirement is normally for LAN connectivity while the ERP system requires wide area networks (WAN) connectivity. In general, this is because CAD/CAM systems run from LAN platforms while ERP systems run from WAN platforms.

Figure 2 illustrates the interface between ERP systems and CAD/CAM systems in next generation manufacturers. The interface is accomplished through DIS.

From the above discussion it should be evident that the implementation issues involved in integrating CAD/CAM systems with ERP systems pose unique problems, because of the following three decisive factors:

1. Databases. The same type of database architecture is required at all platforms.

2. Networks. The existing network capabilities must be such that it supports the large volume of data exchange between CAD/CAM and ERP system through DIS.

3. Maintenance. Consistency and validations of data could put additional burden on maintenance.
Critical success factors (CSF) for CAD/CAM integration

Rockart (1979) originated the CSF approach and has popularised it through helping executives identify their information needs. Rockart’s CSF approach was based on that of D. Ronald Daniel, apparently the person first to discuss the concept of “success factors” in the management literature (Rockart, 1979). Rockart defined CSF as the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organisation. They are the few key areas where “things must go right” for the business to “flourish”. He argued that managers need appropriate information on their management functions and that performance in each area should be measured continually. It follows that such information should be made available by organizations, as necessary, for enhanced managers’ performance (Soliman and Soar, 1997).

Davis (1979, 1980) criticised the use of the CSF approach because it relied on managers’ responses, which may be incorrect, incomplete, or insufficient and are constrained by human behaviour. According to Davis, these constraints are “bounded rationally, human ability to evaluate probabilities and to identify causality and the biasing effect of availability of data”. Thus, in his view, the CSF method will elicit the information that executives feel they need, not the information that executives actually do need. In other words, managers might unintentionally invent, overlook or fail to mention CSF. Davis (1980) recommended further research on the use of explicit models and implicit models to elicit information requirements. Several researchers have responded...
to Davis’ comments and suggested ways to minimise these weaknesses (Munro, 1983; Boynton and Zmud, 1984).

Munro and Wheeler (1980) presented a general approach for identifying CSF within the context of corporate planning. They analysed the process of determining information requirements for organisational control purposes by interviewing senior middle level managers in a training seminar. Those processes include: “understand business unit objectives; identify CSF and identify the performance measures and standards for each CSF; identify data required to measure performance; and identify decisions and information required implementing the plan”. From these processes, they concluded that the CSF method and the performance measures and standards for each CSF can help management information systems by providing required management information. They also indicated that identifying CSF within the context of organisation planning processes could overcome the potential difficulties noted by Davis.

In response to Davis’s comments, Munro (1983) compared the results obtained from Rockart’s CSF study (1982) and Martin’s CSF study (1982a,b), Munro also examined both authors’ articles in detail and compared the articles’ citations and descriptions, as well as their interviews with senior IT/IS managers. He commented that the results from these two studies were interrelated and quite similar. He also concluded that the results from CSF methods are reasonable and that the CSF approach is a reliable technique, while acknowledging that the CSF approach could not be completely free from the bias of an interviewer’s interests and perceptions, unless the interviewers were skilful (Munro 1983).

In their 1984 study, Boynton and Zmud concluded that the weaknesses identified by Davies that may occur when using the CSF method can be largely overcome through careful application of the technique. They conducted two case studies; one is a study of a financial services firm while the other was a study of a state university. From their experience, there are guidelines for effective application of CSF:

- CSF are an excellent tool for information resource planning. The CSF method seems particularly useful for organisations considering a more aggressive IT posture.
- The use of a prototype is recommended as a means of product development.
- The individual managing the CSF effort should have a through understanding of the organisation or should be literate in the organisation’s principal area of business.
- It is useful to identify and cultivate a senior-level manager to champion the project.

Their study suggests that organisations employing the CSF method appropriately have many strengths. The reliability of the CSF method can be
achieved when there is a structured design process using CAD/CAM systems and that in IT/IS planning, Davis’ criticisms can be overcome by interviewing managers across a diagonal slice of the organisation.

Benbasat (1984) suggested that the CSF approach could be considered in the same classification as information based on a management by objective approach. He indicated that the CSF approach could be a system analysis tool for eliciting executive’s information requirements at the management control level. CSF could be a means of supporting system planning and could grant successful competitive performance for the organisation. Since he did not explicitly criticise the CSF method, his support of the CSF approach is warranted. In addition, Soliman and Clark (1996) concluded that the system’s value is an important CSF for managing implementation of knowledge-based systems.

Zahedi (1987) suggested and developed reliability as the measure of information system success based on CSF. He attempted to provide a theoretical framework for measuring information system success based on CSF. His research used Rockart’s (1982) data to identify and build a hierarchical configuration of the observed CSF of the MIS. The study also used the data from Martin’s (1982a,b) studies to verify the construction of the IT/IS configuration derived from Rockart’s data. Zahedi’s verification indicated that the developed CSF configuration could be applied to other sample data with some minor modification. Based on the derived CSF configuration, Zahedi generated a reliability measure for information systems defined as “the probability that the system works successfully in achieving its objectives under a given set of environmental conditions.” Zahedi also presented numerical examples and demonstrated how reliability measures can be utilised in evaluating IS projects in cost/benefit analysis. Based on the strengths of the CSF research approach mentioned above and methods for dealing with critical comments, there appears to be some confidence and support for obtaining CSF for integration of CAD/CAM systems with ERP systems.

During the past decade, more extensive studies have attempted to overcome the weakness attributed to CSF and have broadened the concept to several different areas. These applications could utilise CSF for:

- strategic guidelines at board of directors’ level (Ferguson and Dickinson, 1982);
- information requirements and corporate planning (Munro and Wheeler, 1980; Boynton and Zmud, 1984);
- management decision process (Rockart and Crescenzi, 1984);
- crises communications (Dilenschneider and Hyde, 1985);
- IT/IS planning (Shank et al., 1985);
- information satisfaction in the small business environment (Dickinson et al., 1984; DeLone, 1988; Montazemi, 1988);
- financial services (Miller and Doyle, 1987); and
Drawing from these studies, we provide a research framework to identify CSF for the integration of CAD/CAM systems with ERP systems. The literature reviewed in this study is based on the idea that successfully managed integration of CAD/CAM systems with ERP systems depends on CAD/CAM management and the interactions among CAD/CAM resources (CAD/CAM staff, hardware and application software) and users, because “the success of the information system depends on the social structures and interactions that prevail during and after the development process” (Lyytinen, 1987).

We also review the literature related to IT/IS managers’ perceptions of implementation success. Several studies have examined the relationship between CSF of IS managers and CSF of IT/IS implementation success. They assert that if a section of a proposed system being considered is very important to the manager, this section usually performs better than others. Miller and Doyle (1987) also reported that all the identified performance measures were significantly related to the CSF of IT/IS managers. If this relationship holds true, the IT/IS managers’ perceptions of importance could indicate areas critical for information system performance.

**Statement of the problem**

Much has been written over the past 20 years on the success of IT implementation in organisations, but nothing has been published on the success of integration of CAD/CAM and ERP systems. It is important to investigate if there is any relationship between the use of CAD/CAM systems in manufacturing and the performance of manufacturers. Among the research questions that need to be answered, one must include the following:

- Can CAD/CAM systems be used as strategic tools to improve the competitive position of organisations?
- Have organisations taken advantage of this potential or have they squandered the opportunity?
- Are organisation users happy with the system installed?
- Is the installed system both safe to use and reliable?

To answer these questions, we propose to focus on two main performance indicators; namely:

1. Manufacturing costs.
2. Customer satisfaction in terms of quality and delivery time.

To date, there have not been any published surveys attempting to link the integration of CAD/CAM systems with the performance of organisations.
There are several questions to be answered about CAD/CAM integration with ERP systems in manufacturing organisations. In the research that we propose we will investigate if:

- manufacturing companies who integrated CAD/CAM with ERP systems have reduced their manufacturing costs;
- companies who integrated CAD/CAM with ERP systems are more likely to increase their customers’ satisfaction in terms of quality and delivery time;
- manufacturing companies who integrated CAD/CAM with ERP systems are likely to improve their strategic advantage in terms of manufacturing costs and customers satisfaction.

**Grounded theory investigation (GTI)**

GTI in management can be extremely valuable (Tantoush, 1998). A panel of management experts assisted in the construction of the CSF for CAD/CAM integration with ERP systems. Members of the panel comprised one chief engineer, one engineering director, two design engineers, one production manager, one quality control manager and one purchasing manager. The chief engineer takes the role of moderator of the group. An effective group moderator prepares a discussion guide to help ensure that the group covers all CSF of interest. It is the moderator’s job to make sure that everyone gets a chance to speak and to ask questions to clarify topics (CSF and CAD/CAM integration with ERP systems) that have been introduced into the discussion. The combined effort of the group is to achieve cost savings, time-savings, quality and efficiency. Using the grounded theory approach, the group could be expected to identify CSF for the successful integration of CAD/CAM with ERP systems.

**Research model**

The research model used in this study is based on the CSF study of Rockart (1982), modified according to the studies of Martin (1982a,b), DeLone (1988), Miller *et al.* (1987) and Bergeron *et al.* (1993).

Figure 3 shows a diagram summarising the proposed research model.

The variables in this model can be categorised into the following eight areas that might determine the success of the integration of CAD/CAM with ERP systems:

1. CAD/CAM users’ appreciation of integration;
2. communication between design office and other users;
3. design office services and support functions;
4. management commitment and support;
5. organisational effectiveness;
6. training of CAD/CAM staff on ERP system;
Due to the restricted application of CAD/CAM, a large sample may not be possible. However, this study will employ a survey for randomly selected engineers and engineering managers in CAD/CAM offices. Several empirical studies have found a positive relationship between IT success and managers' perceptions. The perceptions of engineers and engineering managers will be chosen because of their professional qualifications, interest and their knowledge concerning problems with the system.

**Significance of this research**

The results of this study may provide a contribution to both academic research and manufacturing management for CSF studies as well as for the integration of CAD/CAM with ERP systems. Identifying CSF could help focus future research on questions that have a significant impact on decisions in regard to the integration of CAD/CAM with other systems. Findings may help extend the existing knowledge on CAD/CAM implementation research. Based on the expected findings, the risk or dark side of CAD/CAM integration, e.g. hidden conversion cost, data corruption caused by inconsistencies between ERP databases and the server database etc., may also be identified in further studies.

Managers could be expected to utilise the identified integration CSF to adopt more successful CAD/CAM implementation strategies in the future. The expected CSF could also be used by production managers, both as evaluation criteria for system planning and control and as a facilitator of communication between production departments and their users. With better utilisation and
better understanding concerning the integrated CAD/CAM, organisations might be better able to achieve cost savings, time saving, quality and efficiency in their new systems. Thus, the benefits of successful integration could improve the corporate utilisation of information systems resources and assist in achieving a competitive advantage for organisations (Symon and Clegg, 1991).

Measuring performance and effectiveness
To evaluate the success of CAD/CAM integration, one should measure systems performance and effectiveness. Hamilton and Chervany (1981a) report the need for performance measures for IT/IS. They claimed that “Evaluating system effectiveness in meaningful terms has been the most difficult aspect of the IT/IS implementation process.” In their study, Hamilton and Chervany (1981b) described and compared the effects of evaluator viewpoints on system effectiveness, in terms of resources-oriented perspectives (or efficiency) and influences-oriented perspectives (or effectiveness). Some of their evaluation items (for example, MIS personnel productivity, computer performance, service and users’ attitude) are identical to the components of CSF from Rockart (1982), Martin (1982a,b) and later CSF studies. Some of Hamilton and Chervany’s evaluation items (productivity, service, users’ attitude and computer performance) will be included in the research instrument. Zmud (1979) suggested that organisational factors, IT/IS usage, top management’s support, decisions performance, personal and interpersonal characteristics, users’ attitude, IT/IS staff characteristics and IT/IS policies influence the success of system implementation (Symon and Clegg, 1991). Zmud suggests also that research should examine system usage, user satisfaction and user performance for IT/IS success. All these factors will be included in the research instrument.

Ginzberg (1981) attempted to track and manipulate the controllable variables by developing tools for system designers and users. He suggested that two management approaches can increase the effectiveness of the system development process. One approach is to identify those variables that are both especially important to the success of system development and controllable by the user or the system designer. The other approach is to manage the development process of the system designer and user by utilising development tools and procedures. Ginzberg conducted a field study in a large US bank and concluded: “the degree of realism of user’s pre-implementation expectations was positively correlated with a range of project success measures, both attitudinal and behavioural”.

According to Rockart and Flannery’s (1983) definition of end-users, an IT/IS manager could serve as a system designer and user as well. Following Ginzberg’s suggestion, this study will also attempt to examine the IT/IS manager’s view of the importance of IT/IS implementation success. Thus, engineers, engineering managers and IT/IS managers, will be chosen as the research subject for this study (Tantoush, 1998).
Yaverbaum (1988) applied the “job diagnostic survey” to 84 end-users to investigate motivation and satisfaction in a computer environment. Yaverbaum’s results indicate that task factors, organisational factors (management support, management activity and training program) and user factors (cognitive differences, users characteristics: attitude, age, past training, education, job experience and user participation) affecting user satisfaction, are crucial to the success of information systems. Since her results support Zmud’s (1979) study, this study will also include organisational factors, task factors and user factors in the research instrument.

Methodology
Yin (1994) suggested that a case study approach is an appropriate choice of research method for this type of problem. This is particularly true when:

- the researcher has little control over the environment;
- the events under investigation are contemporary; and
- the context of the research is important.

The researchers do not have any control over the CAD/CAM and ERP environments that organisations adopt. In addition, since the CAD/CAM and ERP systems are, at present, widely used in industry, the topic of research is contemporary. Furthermore, there is no published research on this topic and the outcome is likely to affect the investment and productivity of these systems. Accordingly, a case study approach is suitable for this analysis.

Hypotheses for this study can be grouped according to the expected CSF of CAD/CAM integration with ERP Systems. The hypotheses presented below are numbered for identification on the basis of grounded theory approach.

Statement of hypotheses
The development of hypotheses based on the expected CSF of the methods and procedures used to assess the degree of success of CAD/CAM integration with ERP systems.

**CAD/CAM users’ appreciation of integration**
A study by Ives and Olson (1984) reviewed 22 IT/IS-related studies. Only eight studies claimed a positive relationship between user involvement and system success. Seven studies claimed a negative relationship, while the other seven studies claimed mixed results. Of the seven studies that investigated the relationship between user involvement and user’s attitude toward the system, only one study reported significant results with user involvement and user’s attitude. Other studies by Baroudi et al. (1986), Tait and Vessey (1988) and Barki and Hartwick (1994) point to a relationship between users’ involvement and the success of integration of CAD/CAM systems with ERP systems. Accordingly, this research proposes to examine the relationship of these two
variables (user involvement and users’ attitude) and the success of CAD/CAM integration with ERP systems.

\(H1\): User appreciation (user involvement and users’ attitude) is positively related to the success of CAD/CAM integration with ERP systems.

**Communication between design office and other users**
In the case of integration of CAD/CAM with an ERP system, the design office could improve communication and assist users in communication with the design office. Thus, users could be less anxious and their attitude toward implementation more favourable (Rainer et al., 1992). In the environment of CAD/CAM, communication with users is more crucial and complex than in the classical environment of computing. Therefore, this study stresses the importance of communication between users and the design office and hypothesises that there will be a positive relationship of CAD/CAM integration with ERP system success.

\(H2\): Communication between users and the design office is positively related to the success of CAD/CAM integration with an ERP system.

**Design office services and support functions**
The basic function of the design office is to manage design and CAD/CAM resources and to co-ordinate and facilitate CAD/CAM functioning for users. An effective design office provides drawings and Bills of materials (BoM) with a competent design staff supporting production. Services such as technical support, trouble shooting, consulting and training are critical design office functions. In their study, Magal and Carr (1988) found that IT/IS staff’s understanding of the users’ business and problems, plus standardised hardware and software, to be important factors for the quality of IT/IS support services. This study proposes a positive relationship between the success of CAD/CAM integration with an ERP system and the support services of the design office.

\(H3\): The design office supporting services is positively related to the success of CAD/CAM integration with an ERP system.

**Management commitment and support**
The success or failure of any business effort is often determined by the amount of top management support (Rockart, 1982; Ives and Olson, 1984). Engineering and production managers actively participate in the organisation’s planning process with senior managers and top managers help engineering and production management and line management to overcome the problem of understanding top management’s objectives, thus facilitating good communications among management levels. Engineering and production managers who participate in the planning process also tend to promote communication and a favourable relationship with top management. Thus, such managers will more likely perceive the changing business objectives and thus help engineering and production management to achieve the new business
objectives. Top management would thus acknowledge the importance of CAD/CAM integration and generate an appreciation of CAD/CAM management issues. Top management that is better able to understand the idea or the problems of CAD/CAM management during the process of CAD/CAM integration will have a better image of the CAD/CAM integration phenomenon.

Ginzberg (1981) suggested that engineering and production management propose a strategic plan of CAD/CAM integration with an ERP system to top and line management, including the reasons for the change, its importance to the organisation, the impacts likely to result from it and the procedure for evaluating it. Such criteria will be important in determining a user’s response to an IT/IS change from the strategic plan studied and proposed by the IT/IS manager. Thus, under these circumstances, top and line management would be more likely to commit to and support CAD/CAM objectives and offer cooperation for successful CAD/CAM integration with an ERP system. This study examines this positive relationship.

**H4:** Management commitment and support are positively related to the success of CAD/CAM integration with ERP systems.

**Organisational effectiveness**

Any management task should be designed to achieve the organisation’s objectives; similarly, CAD/CAM integration with ERP system should be designed to achieve an organisation’s objectives. If CAD/CAM integration improves an organisation’s effectiveness, then integration is more likely to be regarded as a success. During such major organisational changes, CAD/CAM support may ease the tedious maintenance of drawings, BoM and specifications, thus improving the quality of managers’ decision making and easing the management of change. This study examines the relationship between the success of CAD/CAM integration with an ERP system and organisational effectiveness:

**H5:** Organisational effectiveness is positively related to the success of CAD/CAM integration with an ERP system.

**Training of CAD/CAM staff on ERP systems**

Hylas *et al.* (1989) indicated that not all systems applications are appropriate for implementation. Selection of the wrong business functional area or the wrong application or lack of adequate training can result in system failure. Not only lack of IT/IS implementation experience can cause an IT/IS manager to choose an inappropriate application; incompetent IT/IS staff may have difficulty recording or developing software for IT/IS implementation, while a deficiency of software packages for IT/IS implementation can cause rigidity and difficulty for IT/IS implementation (Hoffman, 1992).

Lucas (1981) suggested that human factors affect the successful implementation of a new IT/IS more obviously than do organisational factors. In addition, when applications are moving from the mainframe to the desktop, compatibility should be maintained. To ensure software
compatibility, the design office should review syntax, ERP software features and semantics and external behaviour and provide training to its users. This study hypothesises a positive relationship between training CAD/CAM staff on ERP system and the success of CAD/CAM integration with an ERP system.

\textit{H6}: Training CAD/CAM staff on ERP systems is positively related to the success of CAD/CAM integration with ERP systems.

\textbf{Security of CAD/CAM interface}

Applications should be acquired to solve business problems, not make problems. Data are interchanged between CAD/CAM system and other applications such as an ERP system through the interface. Many older applications often employ unique, antiquated and somewhat incompatible software coupled with unsophisticated security protocols. One of the design office functions is to use CAD/CAM systems to design products and create confidential design documents such as BoM. Therefore, the security of files and data bases used by the CAD/CAM system become a major concern. Accordingly, the interface and system integrity will be an integral component of ERP implementation. The interface integrity component is needed to ensure an appropriate level of internal control into the CAD/CAM databases. The systems integrity component is required to focus on establishing an ERP-based robust environment in which the CAD/CAM-ERP interface operates. The development of the integrity environment needs to mitigate the organisational risks and ensure that the controls implemented in the system do not encumber the business. The interface between CAD/CAM and other applications needs to be designed specifically for cross-platform use. This study examines the positive relationship between the security of the CAD/CAM interface and CAD/CAM integration success.

\textit{H7}: The security of the CAD/CAM interface is positively related to the success of CAD/CAM integration with the ERP system.

\textbf{User friendliness of ERP systems}

If the ERP system chosen is a complicated system involving significant amounts of data manipulation, this could be inadequate for successful CAD/CAM integration. The reason for this inadequacy is that complicated ERP systems may cause difficulties for users and hence communication with the CAD/CAM system. The candidate application for IT/IS implementation should be simple, familiar and based on an application’s basic merits, not on its politics (Klein, 1991). Accordingly, organisations should carefully evaluate potential ERP systems for implementation. This study examines the positive relationship between the degree of ERP user friendliness and the success of CAD/CAM integration with the ERP system.

\textit{H8}: The degree of ERP user friendliness is positively related to the success of CAD/CAM integration with the ERP system.
Research subjects
In this study we used CAD/CAM users (engineers, engineering managers) from business organisations as subjects. The reason for selecting these subjects was that IT/IS system success measures have in past studies been significantly related to the perceived CSF of IT/IS managers. The studies from Miller and Doyle (1987) and from Raghunathan et al. (1989) both cited some other case studies and/or empirical studies that uphold this relationship. Miller and Doyle and Raghunathan et al., also have examined and supported this concept in their studies. Therefore, if an IT/IS or CAD/CAM manager administers the CAD/CAM function corresponding to his/her CSF, he/she can improve CAD/CAM performance and effectiveness. Thus, this research will attempt to extract CSF for CAD/CAM in next generation manufacturing organisations from a CAD/CAM users’ perspective.

Survey instrument
This research used a survey-based field study of ED and production managers to investigate and test the above eight hypotheses. Surveys and questionnaires were used to facilitate collection of the required data, lower sampling cost, speed-up the time frame and make the required sampling size. According to Churchill (1979), the research instrument must meet the requirements of accuracy and validity. Several procedures were adopted to ensure and verify these criteria. These procedures are as follows:

1) Non-response bias. Non-response bias was not found in the sample tested. The non-response bias was calculated and tested by comparing the survey results obtained from the respondents to the entire sample because of its availability at the designing stage of the questionnaire.

2) Reliability. The instrument was found to be reliable because the Cronbach’s coefficient alpha (α) for the instrument was found to be above 0.6 (Churchill, 1979; Nunnally, 1978). Accordingly, the reliability (stability and consistency of the measuring instrument) is assured.

3) Content validity. Content validity examined the sampling adequacy of the instrument by:
   • a complete and extensive inspection of the literature for all possible items to be included in the measurement;
   • asking a group of academics, consultants and executives/managers to criticise the description and clarity of the questionnaire;
   • the questionnaire was tested with members of the focus group prior to the final survey. The modification of the questionnaire was then based on these experts’ opinions.

4) Construct validity. Construct validity tests were performed using a factor analysis to:
• assess construct validity, i.e. to determine the set of CSF by choosing a particular factor loading pattern, thus achieving content validity and construct validity;

• eliminate the unnecessary items from the instrument by checking the factor loading and utilising factor extraction and rotation options, unnecessary variables can be eliminated.

(5) Practicality. This criterion refers to economic factors, convenience of execution and interpretability of data and the results (Emory and Cooper, 1991). This study considered the trade-off among research variables, budget, ease of management and estimated which research instrument best accommodated the objectives of this research study.

Conclusions
A major problem with the integration of CAD/CAM with ERP systems is that little is known about factors that contribute to or detract from its success. Kalakota (1997) argues that not all systems are ideal candidates for implementation. Selection of the wrong system or the wrong business functional area can result not only in systems failure, but can also cause tension between departments and users’ departments (Cronin, 1996; Mougayar, 1997; Kalakota, 1997). Many analysts believe that it is difficult to estimate the hidden cost and the staff’s attitude toward implementation (Kalakota, 1997).

There are two situations when the organisation becomes concerned with the integration of CAD/CAM with ERP systems. These are:

(1) when an organisation acquires CAD/CAM after it has already a functioning ERP system; or

(2) when the organisation implements the ERP system after it has a fully operational CAD/CAM system.

In general, these two situations generate two different sets of success factors for the integration of CAD/CAM with the ERP system. Thus, identifying CSF for integration could help minimise risks associated with the integration and help promote the success of both CAD/CAM and ERP systems. Therefore, the identification of strategies for integration of CAD/CAM with the ERP system will be the main purpose of this study.

We propose that there is a significant direct relationship between the integration of CAD/CAM with the ERP system and a number of CSF. Several benefits and contributions are expected from establishing these CSF such as:

• Providing a checklist for integration of CAD/CAM with the ERP system. That is, from the findings, managers can attend to what seems to be the most important activities and select an approach more likely to achieve success in integration of CAD/CAM with the ERP system.

• Providing a guideline for CAD/CAM and ERP resource management. Managers may be able to use the CSF findings of this research for better
CAD/CAM and ERP resources management, such as investment in hardware, software and human resources.

- Identifying information needs. The CSF may be useful for managers to identify their information needs for CAD/CAM and ERP systems and hence understand more about the required support services that users need suggested by Rockart (1979, 1982).

- Evaluating the performance of the design office. The CSF may be useful as criteria for users, executives and managers to evaluate the performance of the design office.

- Furnishing a foundation for communication. The CSF can provide a foundation for communication between the users of CAD/CAM and ERP systems.

- Strengthening organisational goals. CSF can help the whole organisation understand the most important criteria and enhance its competitive stance.

- Providing a base for the future research. Further research can expand on the findings from this study. For example, the eight hypotheses developed here should be tested and the results should be made available to researchers and practitioners in the field of manufacturing management.

Many organisations have integrated their CAD/CAM with ERP systems without theoretical or academic rationalisation. Not all implementation efforts have been successful. So, this research aims to identify CSF for CAD/CAM integration with ERP systems. The research model is based on the classic CSF studies by Rockart (1982) and Martin (1982a, b), along with others identified in the newer literature.

As this research assesses the evolution of CAD/CAM integration with ERP, the results from this study will serve as a foundation for further research. Additional research may provide a better understanding and thereby improve and/or confirm the findings of this research.

**Recommendations**

A possible future study could conduct a limited number of case studies to compare, clarify and evaluate the possible response bias from this study. There is no guarantee that the selected CSF are complete, and completeness is a judgemental limitation of this research.

The possible future study of fail/success or risk/return factors may be of assistance to management of organisations with CAD/CAM and ERP systems. Other studies could compare the success of CAD/CAM and ERP integration by type of organisations, annual sales, number of employees and years of using the two systems. In other words, different types of organisations, different sizes of organisations and different experiences in CAD/CAM and ERP operation may relevant to compare the success of CAD/CAM and ERP integration.
Critical success factors for integration

References


Critical success factors for integration


