# MODELLING AND ANALYSIS OF THE KEY ENABLERS FOR CAD/CAM/CAE IMPLEMENTATION USING INTERPRETIVE STRUCTURAL MODELLING AND MICMAC ANALYSIS

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## ABSTRACT

Today CAD systems are an integral part of the innovations to existing products and development of new products. They help to improve and speed up the development process with reducing costs. In order to implement CAD/CAM system, there are some key enablers of CAD/CAM/CAE are identified through expert opinion from academic and literature review. To study the role of these key enablers in CAD/CAM/CAE and to analysis these enablers with the help of interpretive structural modeling (ISM) approach and MICMAC analysis is used to find interrelation between these enablers. CAD/CAM/CAE integration offers designers, analysts, and manufacturers the opportunity to share data throughout the product development process.

Keyword; CAD/CAM/CAE, Interpretive structural modeling , CAD/CAM/CAE enablers

## 1.INTRODUCTION

Computer-aided design (CAD) is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design (Narayan and Lalit 2008) and its software is used to increase the productivity of the designer, increase the quality of design, improve communications through documentation and to create a database for manufacturing (Narayan and Lalit 2008). CAD is also used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern omnipresence and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry and computer graphics (Pottmann et al.2007).

Computer-aided manufacturing (CAM) is the use of software to control machine tools and related ones in the manufacturing of work pieces. This is not the only definition for CAM, but it is the most common; CAM also use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage. Its initial purpose is to create a faster production process and components and tooling with more accurate dimensions and material consistency, which in some cases, uses only required amount of raw material, while simultaneously reducing energy consumption. CAM is a subsequent computer-aided process after computer-aided design (CAD) and sometimes computer-aided engineering (CAE), as the model generated in CAD than verified in CAE can be input into CAM software, which then controls the machine tool.

Computer-aided engineering (CAE) is the large usage of computer software to aid in engineering analysis tasks. It includes finite element analysis (FEA), computational fluid dynamics (CFD), durability and optimization. CAE systems can give support to businesses. This is achieved by the use of architectures and their ability to place information views on the business process. Reference architecture is the basis from which information model, especially product and manufacturing models (Mark and peter 2007). CAE tools are very widely used in the automotive industry. In fact, their use has enabled the automakers to reduce product development cost and time while increasing the safety, comfort, and durability of the vehicles they produce. CAE dependability is based upon all proper assumptions as inputs and must identify critical inputs (BJ). Even though there have been many advances in CAE, and it is widely used in the engineering field, physical testing is must. It is used for verification and model updating, to define loads and boundary conditions and for final prototype sign-off. Today's industries cannot survive worldwide competition unless they introduce new products with better quality, at lower cost and with shorter lead time (Auweraer 2012).

### 1.1 IMPLEMENTATION OF CAD/CAM SYSTEMS

Effective implementation of CAD/CAM/CAE 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/CAE 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 which may be considered (Soliman et al.2001).

Full scale implementation- In this scenario the focus during the implementation is on improving the business (Soliman et al.2001).

Short-cut implementation- In this scenario the focus during the implementation is on technical migration with enhanced business improvements introduced at a later stage (Soliman et al.2001).

## 2.LITERATURE REVIEW

The Literature has been reviewed and related literature has been presented as under:-

**Sharma et al. (2014)** defines smart CAD/CAM technologies for superior product modeling in the intelligence of designing complete product variants become more and more pertinent in future. Many design techniques to help interdisciplinary design actions in different engineering domains in addition to consequent processes have to be developed. A necessary job to achieve this aim is to permanently investigate the present state of the art, emerging trends, new approaches, in addition to industrial problems and requirements about the entire CAD/CAM area. With the aim of direct future research and development activities as close as possible to the continuously rising requirements of a worldwide market we carried out a wide-ranging national study in cooperation with one of the Germans leading CAD/CAM magazines.

**Riesenfelda et al. (2014)** presented a critical analysis of the effectiveness of the current field of CAD, and discuss some of the forces that have taken it so far off course from its strikingly foresighted origins. Armed with the ensuing understanding of the operational forces that have taken CAD adrift, we conclude that the disparity between CAD's mired state-of-the-art condition relative to more appropriate, inspired and achievable goals for CAD calls for more drastic measures. It is asserted that, well beyond the evolutionary progression of incremental steps characteristic of next version system releases, the field is overdue for developing a class of genuine design centric, CAD systems architectures effecting the original CAD vision through the powerful instruments of contemporary computing tools and technologies.

**Kirkwood and Sherwood (2017)** conclude that CAD/CAM/CAE integration offers designers, analysts, and manufacturers the opportunity to share data throughout the product development process. Such integration reduces product development cost and supports the development of better products. Finite-element (FE) meshing applications integrated with solid model data from CAD systems represent a major subset of CAD/CAM/CAE integration. Many practitioners find that sustained integration with the CAD geometry is often not economical because of mixed CAD formats and the need to simplify geometry before modeling. This article assesses those circumstances and the cost/benefit trade-offs that lead to the not-economical conclusion.

**Lee (2004)** stated that spite of the widespread use of CAD systems for design and CAE systems for analysis, the two processes are not well integrated because CAD and CAE models inherently use different types of geometric models and there currently exists no generic, unified model that allows both design and analysis information to be specified and shared. In this paper, a new approach called the CAD/CAE- integrated approach is proposed and implemented by a feature-based non-manifold modeling system. The system creates and manipulates a single master model containing different types of all of the geometric models required for CAD and CAE. Both a solid model (for CAD) and a non-manifold model (for CAE) are immediately extracted from the master model through a selection process. If a design change is required, the master model is modified by the feature modeling capabilities of the system. As a result, thedesign and analysis models are modified simultaneously and maintained consistently. This system also supports feature-based multi-resolution and multi-abstraction modeling capabilities providing the CAD model at different levels of detail and the CAE model at various levels of abstraction.

**Mares and Senderska (2012)** define CAD systems are now an integral part of the development of new products and innovations to existing products. They help to speed up and improve the development process while reducing costs. Looking at the current market with CAD systems, he find that there are numerous available CAD systems, which differ in price, functionality, support, and so on. Therefore, the question arises in choosing which of a number of CAD systems to choose for the job. The article deals with the selection of CAD systems, focusing on the criteria that influence the selection of CAD system.

**Tolouei-Rad (2006)** concludes that the integrated CAD/CAM system for milling operations has been developed which helps designers to solve machining problems at the design stage. A methodology has been employed which provides all necessary information for machining products automatically. Use of these system results in reduced machining lead times and cost through designing machinable components; using available cutting tools; improving machining efficiency. The system is menu driven with a user friendly interface. Different components for developing such a system have been identified and various problems that arose in the development of this system have been dealt with The system developed leads to an adequate basis for fully integration of CAD and CAM technologies in one system. It allows simultaneous generation of all information required to satisfy machining requirements of the design such as its machine ability and availability of the required tooling resources.

**Li et al. (2017)** state that teaching of the traditional mold courses focus on the illustration of theoretical knowledge. Therefore, associating the design, evaluation, and manufacture links as a whole is difficult. Students cannot shape system knowledge, thereby making the study difficult. In addition, traditional teaching cannot meet the current enterprise needs of talents who have mold CAD/CAE/CAM technology. This study presents a teaching method that applies CAD/CAE/CAM technology to mold teaching. First, the positive effects of these technologies on the mold design and manufacturing process are introduced. Thereafter, lamp cover is used as an example to establish a series of computer-aided teaching development processes using existing software for mold design, mold flow analysis, and machining simulation. Lastly, survey results demonstrate that the effects of the proposed teaching method are better than the traditional method. Moreover, students and enterprises are substantially recognized in this teaching method.

**Satyanarayana and Prakash (2016)** define the development of CAD and CAM technology has significantly increased efficiency in each individual area. The independent development, however, greatly restrained the improvement of overall efficiency from design to manufacturing. Current integrated CAD/CAM systems can share the same geometry model of a product in a neutral or proprietary format. The user needs to manually create the machining operations and define geometry, cutting tool, and various parameters for each operation. Features play an important role in the recent research on CAD/CAM integration. This research work has focused on the integration of CAD/ CAM system by using EDGE CAM Software. The EDGE CAM software allows usage of machining features and automates the process of tool path preparation. In this work the chess coin is manufactured by using MTab XL Turning machine, for this the EDGE CAM software is integrated for the manufacturing of the chess coin.

**Tan et al. (2013)** presents a methodology for implementing the feature recognition system for achieving the Computer Aided Design/ Computer Aided Manufacturing (CAD/CAM) integration goals. The Feature based modeling is being used to model the solid models. The features being considered in this paper is hole form feature. The input of the feature recognition system is the Standard for the Exchange of Product Model Data (STEP) files. The set of feature recognition rules is generated by using ruled based technique.

**Soliman et al. (2001)** conclude 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.

## 3.IDENTIFICATION KEY ENABLERS OF CAD/CAM/CAE

On the basis of literature review and expert opinion from academia enablers are identified that play crucial role for implementation of CAD/CAM/CAE system in manufacturing industries as depicted in Table 1.

**Table 1:**CAD/CAM/CAE enablers and their references

| S.No. | CAD/CAM/CAE enablers | References |
|---|---|---|

| | | |
|---|---|---|
| 1 | Top management commitment and support | Rockart (1982), Ives and Olson (1984),Nagar and Raj (2012) |
| 2 | Effective long term planning | Huang and Sakurai (1990), Noble (1990),Nagar et.al (2012) |
| 3 | Communication between design office and other users | Rainer *et al*. (1992) |
| 4 | Design office service and support function | Magal and Carr (1988) |
| 5 | Availability of resources | Nagar and Raj (2012) |
| 6 | Team spirit and motivation | Narain et al.(2004), Nagar et.al (2012) |
| 7 | Organizational effectiveness | Soliman et al. (2001) |
| 8 | Training of CAD/CAM staff | Hylas *et al*. (1989), Hoffman (1992), Lucas (1981) |
| 9 | Security of CAD/CAM interface | Soliman et al. (2001) |
| 10 | User interface | Klein (1991) |
| 11 | Work culture of organization | Needle (2004) |
| 12 | Application knowledge | Giard et al. (2015), Maier (2007) |

The different type of enablers of CAD/CAM/CAE on the basis of literature review and expert opinion from academic are explained below:-

### 3.1 Top Management Commitment and support

The success or failure of any business effort is findout by the amount of top management support (Rockart, 1982; Ives and Olson, 1984). Engineering and production managers properly participate in the organizations planning process with senior managers and top managers help engineering and production management and line management to shortout the problem of understanding top management's objectives, thus facilitating good communications among management levels. Managers who participate in the planning process also tend to promote communication and a best 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/CAE integration and generate an appreciation of CAD/CAM /CAE management issues. Top management that is better able to understand the idea or the problems of CAD/CAM/CAE management during the process of CAD/CAM/CAE integration will have a better image of the CAD/CAM/CAE integration phenomenon. Ginzberg (1981) suggested that engineering and production management. Thus, under these circumstances, top and line management would be more likely to commit and support CAD/CAM/CAE objectives and offer cooperation for successful CAD/CAM/CAE integration. This study examines this positive relationship. Management commitment and support are positively related to the success of CAD/CAM/CAE integration.

### 3.2 Effective Long Term Planning

Exercise aimed at formulating a long-term plan in CAD/CAM/CAE implementation in current manufacturing, to meet future needs estimated usually by extrapolation of present needs of CAD/CAM/CAE in manufacturing. It begins with the current status and charts out a path to the projected status, and generally includes short-term (operational or tactical plans) for achieving interim goals (Huang and Sakurai 1990, Noble 1990).

### 3.3 Communication between design office and other users

In the case of integration of CAD/CAM/CAE, 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/CAE, communication with users is more complex than in the classical environment of computing. Therefore, this study stresses the importance of communication between users and the design office and that there will be a positive relationship of CAD/CAM/CAE integration. Communication between users and the design office is positively related to the success of CAD/CAM/CAE integration.

### 3.4 Design office services and support functions

The basic function of the design office is to manage design of CAD/CAM/CAE resources and to co- ordinate and facilitate CAD/CAM/CAE 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 standardized 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/CAE integration and the support services of the design office. The design office supporting services is positively related to the success of CAD/CAM/CAE implementation.

**3.5 Availability of Resources**

Availability means capable of being used or the extent to which resources are available to meet the project's needs. As it relates to project management, it typical refers to resources or funding. The level of availability of a resource may vary over time in implementation of CAD/CAM/CAE.(Nagar and Raj 2012)

**3.6 Team Spirit:-**

Team spirit is the feeling of pride and loyalty that exists among the members of a team and that makes them want their team to do well or to be the best in current manufacturing (Narain et al.2004).

**3.7 Organization effectiveness**

CAD/CAM/CAE integration should be designed to achieve an organization's objectives. If CAD/CAM/CAE integration improves an organization's effectiveness, then integration is more likely to be regarded as a success. During such major organizational changes, CAD/CAM/CAE support may ease the tedious maintenance of drawings, BOM and specifications, thus improving the quality of managers' decision making and easily the management of change. This study examines the relationship between the success of CAD/CAM integration with organisational effectiveness. Organisational effectiveness is positively related to the success of CAD/CAM/CAE integration( Soliman et al. 2001).

**3.8 Training of CAD/CAM staff**

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 organizational 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, software features and external behaviour and provide training to its users. Training CAD/CAM/CAE staff is positively related to the success of CAD/CAM/CAE integration.

### 3.9 Security of CAD/CAM interface

Applications should be solve business problems, not create problems. Data are interchanged between CAD/CAM/CAE system and other applications. 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/CAE 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. In which the CAD/CAM 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/ CAE interface and CAD/CAM/CAE integration success (Soliman et al. 2001).

### 3.10 User interface

If chosen a complicated system involving significant amounts of data manipulation, this could be inadequate for successful CAD/CAM integration. 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, organizations in which to define the use of CAD/CAM/CAE application and software for implementation. This study examines the positive relationship between the user friendliness and the success of CAD/CAM.

### 3.11 Work culture of organization

In which to see the behaviours that "contribute to the unique social and psychological environment of an organization". According to Needle (2004), organizational work culture represents the collective values, beliefs and principles of organizational members and is a product of factors such as market, product, technology, strategy, type of employees, management style, and national culture; culture includes the organization's vision, employees dedication and environment of shop floor in industries.

### 3.12 Application knowledge

Knowledge management is the process of creating, sharing, using and managing the knowledge and information of an application of the CAD/CAM/CAE in the organisation. It refers to a multidisciplinary approach to achieving organizational objectives by making the best use of application Knowledge efforts focus on organizational objectives such as improved performance, competitive advantage, innovation, the sharing of lessons learned, integration and continuous improvement of the organisation. These efforts overlap with organisational learning and may be distinguished from that by a greater focus on the application knowledge as a strategic asset and on encouraging the distributing of knowledge (Giard et al. 2015, Maier 2007).

## 4.ISM METHODOLOGY

Interpretive structural modeling (ISM) is such a methodology which is used to analyse the key enablers of CAD/CAM/CAE. This is a powerful and wildly used decision making methodology in literature for such type of analysis. MICMAC analysis Matrice d'Impacts croises-multipication applique´ an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The MICMAC principle is based on multiplication properties of matrices.The purpose of MICMAC analysis is to evaluate the drive power and dependence power of the enablers. This is done to identify the key enablers that drive the system in various categories.

### 4.1 OVERVIEW OF ISM

Interpretive structural modeling (ISM) is an interactive learning process. ISM approach is used to identifying and summarizing the relation among the specific variables and which define problems and issues. In ISM technique, a set of different directly and indirectly related elements/variable are structured into a comprehensive systematic model. Warfield first proposes ISM in 1973. Warfield, J.N (1974) has developed a powerful methodology for structuring complex issues. Various steps of ISM methodology are as follows:

Step 1: Different enablers or factors, which are related to define problems, are identified and enlisted by a survey or group problem solving technique.

Step 2: A structural self-interaction matrix (SSIM) is developed for enablers. This matrix indicates the pair-wise relationship among enablers of the system. This matrix is checked for transitivity.
Step 3: A reach ability matrix (RM) is developed from the SSIM.
Step 4: The RM is partitioned into different levels.
Step 5: The RM is converted into its conical form, the zero (0) elements in the upper diagonal half of the matrix and most unitary (1) elements in the lower half.
Step 6: Based upon the above, a directed graph (digraph) is drawn and transitivity links are removed.
Step 7: Digraph is converted into an ISM model by replacing nodes of the elements with statements.
Step 8: Finally, the ISM model is checked for conceptual inconsistency and necessary modifications are incorporated.

### 4.2 ISM MODELLING FOR ANALYSING THE KEY ENABLERS OFCAD/CAM/CAE

**Step1: Establishing the contextual relationship between the enablers**

After identifying and enlisting the 12 enablers with the help of literature review and expert opinion, the next step is to analyse these enablers. This means that one enabler reaches to another selected enabler. Based on this principle, a contextual relationship is developed.

**Step 2: Development of structural self-interaction matrix (SSIM)**

Based on the contextual relationship between enablers, the SSIM has been developed. The following four symbols have been used to denote the direction of the relationship between two enablers (i and j):

V is used for the forward relation from enabler i to enabler j.

A is used for the backward relation from enabler j to enabler i.

X is used for both direction relation if enablers i and j reach to each other.

O is used for no relation between two enablers i and j.

**Table 2:** Structural self-interaction matrix

| Enablers | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | O | V | O | V | V | V | V | V | V | V | V |
| 2 | A | V | O | A | A | O | V | V | O | A | |
| 3 | A | V | V | O | O | V | X | O | A | | |
| 4 | A | O | V | V | O | V | O | A | | | |
| 5 | A | O | O | V | V | V | O | | | | |
| 6 | O | A | O | O | O | X | | | | | |
| 7 | A | A | A | O | A | | | | | | |
| 8 | V | V | V | V | | | | | | | |
| 9 | A | O | O | | | | | | | | |
| 10 | A | O | | | | | | | | | |
| 11 | O | | | | | | | | | | |

**Step 3: Reachability Matrix**

Now convert the SSIM into binary elements i.e. 0 and 1, named as Initial Reachability Matrix. This Matrix is obtain by assigning 0 and 1 in place of V, A, X and O

- If the (i, j) entry in the SSIM is V then substitute in the (i, j) entry in the reachability matrix as 1 and (j, i) entry as 0.
- If the (i, j) entry in the SSIM is A then substitute in the (i, j) entry in the reachability matrix as 0 and (j, i) entry as 1.
- If the (i, j) entry in the SSIM is X then substitute in the (i, j) entry in the reachability matrix as 1 and (j, i) entry as 1.
- If the (i, j) entry in the SSIM is O then substitute in the (i, j) entry in the reachability matrix as 0 and (j, i) entry as 0.

**Table 3:** Initial Reachability Matrix

| Enablers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 2 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 3 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 4 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| 5 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 6 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 12 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |

Table 3 is known as initial reachability matrix which is obtain by the SSIM, Now final reachability matrix is obtain by incorporating transitivity. Transitivity is a relation between three elements such that if relationship holds between the first and second element – second and third element, then relationship must necessarily holds between the first and third elements. Now Table 3 is obtained by incorporating transitivity denoted by 1*

**Table 4:** Final Reachability Matrix

| Enablers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1 | 1* |
| 2 | 0 | 1 | 1* | 1* | 1 | 1 | 1* | 1* | 1* | 0 | 1 | 0 |
| 3 | 0 | 1 | 1 | 0 | 1* | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 4 | 0 | 1* | 1 | 1 | 0 | 1* | 1 | 0 | 1 | 1 | 1* | 0 |
| 5 | 0 | 1* | 1* | 1 | 1 | 1* | 1 | 1 | 1 | 1* | 1* | 1* |
| 6 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1* | 1* | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 1 | 1* | 1* | 1* | 1* | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | 0 | 1 | 0 | 0 | 1* | 1* | 0 | 0 | 1 | 0 | 1* | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 1* | 1 | 0 | 0 | 1 | 0 | 0 |
| 11 | 0 | 0 | 1* | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 12 | 0 | 1 | 1 | 1 | 1 | 1* | 1 | 1* | 1 | 1 | 1* | 1 |

**Step-4 Partitioning the reachability matrix**

Now from this RM, Reachability Set (RS) and Antecedent Set (AS) are achieved. After finding RS and AS than the intersection set (IS) of all these setsis derived for the measures. These measures for which AS and IS have same value is placed at the top level of ISM hierarchy. Once the top level measure is identified, it is extracted from consideration and other top level measures of the remaining sub-graph are found. This procedure is continued till all levels of the structure are identified. These identified levels help in the development of digraph and the final model. Top level measure is positioned at the top of digraph and so on. From Table 4 requirement uncertainties and validation of product is found at the top level I, these are positioned at the top of hierarchy.

**Table 5: Iteration 1**

| Enablers | RS | AS | IS | Level |
|---|---|---|---|---|
| 1 | 1,2,3,4,5,6,7,8,9,10,11,12 | 1 | 1 | |
| 2 | 2,3,4,5,6,7,8,9,11 | 1,2,3,4,5,8,9,12 | 2,3,4,5,8,9 | |
| 3 | 2,3,5,6,7,10,11 | 1,2,3,4,5,6,7,8,11,12 | 2,3,4,5,6,11 | |
| 4 | 2,3,4,6,7,9,10,11 | 1,2,4,5,8,12 | 2,4 | |
| 5 | 2,3,4,5,6,7,8,9,10,11,12 | 1,2,3,5,8,9,12 | 2,3,5,8,9,12 | |
| 6 | 3,6,7,10,11 | 1,2,3,4,5,6,7,8,9,10,11,12 | 3,6,7,10,11 | I |
| 7 | 6,7 | 1,2,3,4,5,6,7,8,10,11,12 | 6,7 | I |
| 8 | 2,3,4,5,6,7,8,9,10,11,12 | 1,2,5,8,12 | 2,5,8,12 | |
| 9 | 2,5,6,9,11 | 1,2,4,5,8,9,12 | 2,5,9 | |
| 10 | 6,7,10 | 1,3,4,5,6,8,10,12 | 6,10 | |
| 11 | 3,6,7,11 | 1,2,3,4,5,6,8,9,11,12 | 3,6,11 | |
| 12 | 2,3,4,5,6,7,8,9,10,11,12 | 1,5,8,12 | 5,8,12 | |

**Table 6: Iteration 2**

| Enablers | RS | AS | IS | Level |
|---|---|---|---|---|
| 1 | 1,2,4,5,8,9,12 | 1 | 1 | |
| 2 | 2,4,5,8,9 | 1,2,4,5,8,9,12 | 2,4,5,8,9 | II |
| 4 | 2,4,9 | 1,2,4,5,8,12 | 2,4 | |
| 5 | 2,4,5,8,9,12 | 1,2,4,5,8,9,12 | 2,5,8,9,12 | |
| 8 | 2,4,5,8,9,12 | 1,2,5,8,12 | 2,5,8,12 | |
| 9 | 2,5,9 | 1,2,4,5,8,9,12 | 2,5,9 | II |
| 12 | 2,4,5,8,9,12 | 1,5,8,12 | 5,8,12 | |

**Table 7: Iteration 3**

| Factor | RS | AS | IS | Level |
|---|---|---|---|---|
| 1 | 1,12 | 1 | 1 | |
| 12 | 12 | 1,12 | 12 | III |

**Table 8: Iteration 4**

| Factor | RS | AS | IS | Level |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | IV |

**Step 5: Development of Conical Matrix**

Conical matrix is developed by final Reachability Matrix measure at same level across rows and columns. Table 4 shows the dependence power and the drive power of enablers are calculated in the same level across the rows and columns of the final reachability matrix. The drive power of a enablers are derived by summing up the number of ones in the rows and its dependence power by summing up the number of ones in the columns. Next, drive power and dependence power ranks are calculated by giving highest ranks to the factors that have the maximum number of ones in the rows and columns,

**Table 8: Conical Matrix**

| Enablers | 7 | 10 | 11 | 6 | 3 | 9 | 2 | 4 | 5 | 8 | 12 | 1 | Drive power |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 10 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 11 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 6 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 3 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 7 |
| 9 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 5 |
| 2 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 9 |
| 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 8 |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 11 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 11 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 11 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 12 |
| Dependence Power | 11 | 8 | 10 | 12 | 9 | 7 | 8 | 6 | 7 | 5 | 4 | 1 | |

**Step 6: Development of digraph**

Based on the conical matrix, an initial digraph including transitivity links is obtained. This is generated by nodes and links of edges.After removing the indirect links , in this development the top level enabler is at the top of the digraph and second level enabler is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph.

**Step 7: Development of ISM model**

Next, the digraph is converted into an ISM model by replacing nodes of the elements with statements.

**Step 8: Check for conceptual inconsistency**

Conceptual inconsistency is checked by identifying and removing the intransitivity in the model.

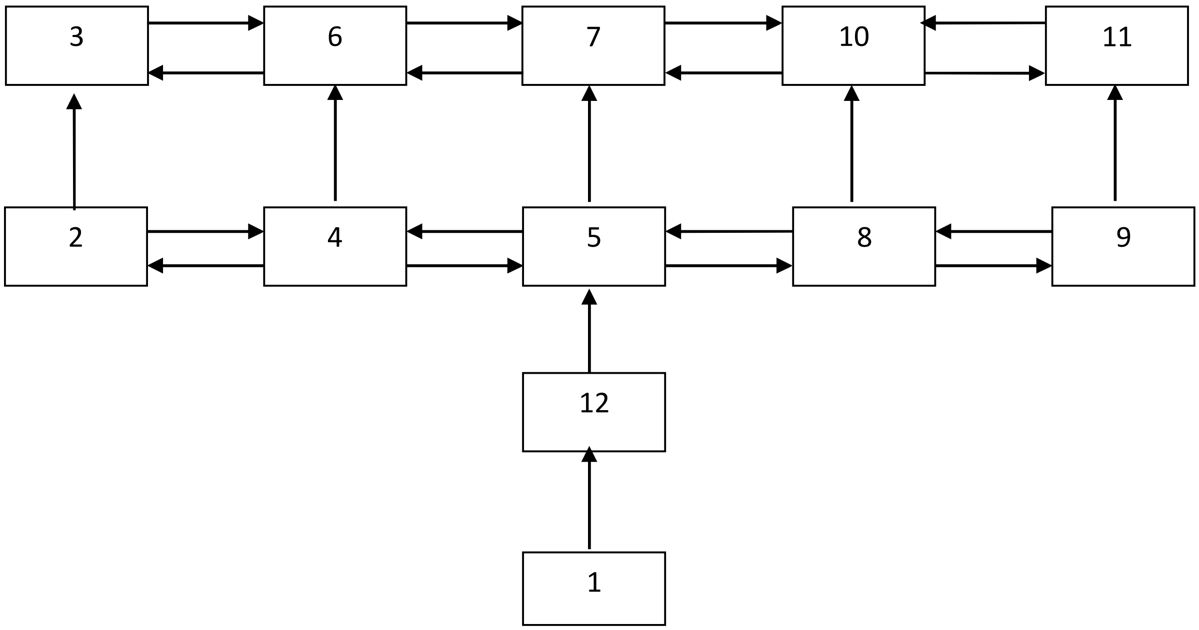


**Figure 1. Digraph showing the level of CAD/CAM/CAE enablers**

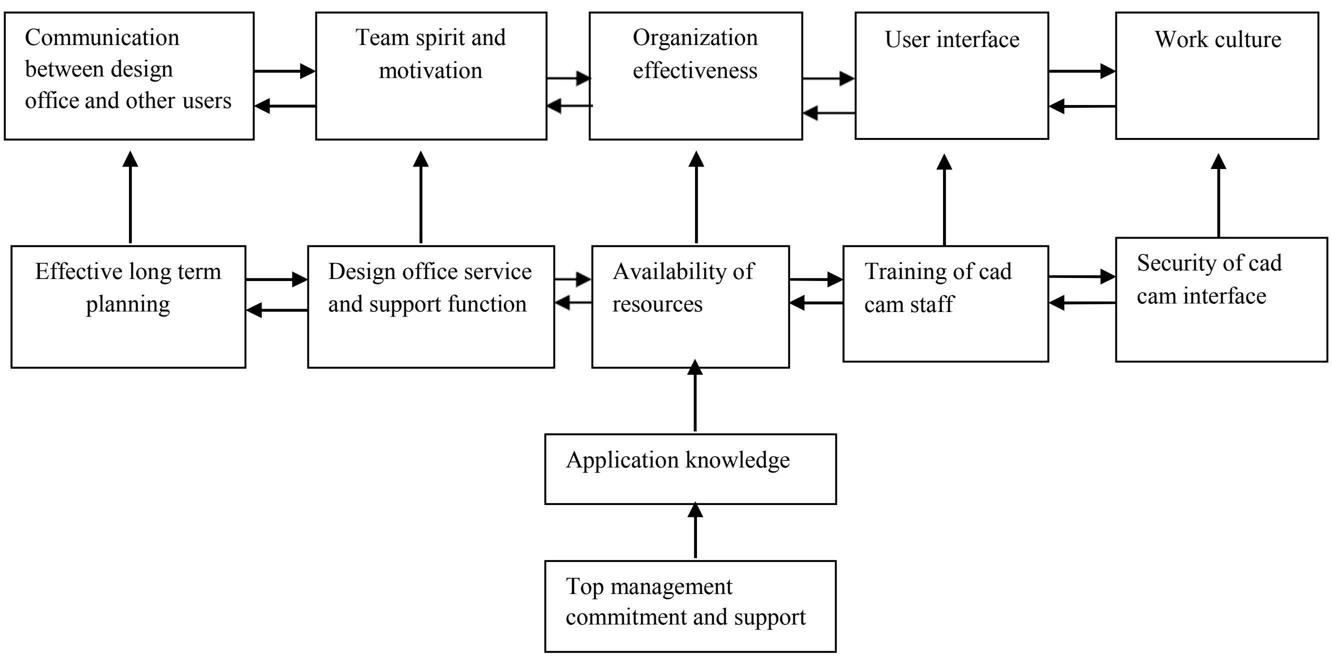


**Figure 2. ISM model showing the level of CAD/CAM/CAE enablers**

### 4.3 MICMAC ANALYSIS

MICMAC known as 'Cross-Impact Matrix Multiplication Applied to Classification' . It was developed by Duperrin and Godet in 1970 . MICMAC is applied in various fields. MICMAC was adopted in modelling the enablers in the implementation of Advanced Manufacturing System (Nagar and Raj, 2012). ISM and MICMAC was applied for analyzing the competitiveness of uncertainty and risk measures in supply chain (Mahesh C and Tilak R, 2015). MICMAC analysis is used to analyse the dependent power and driving power of enablers. The MICMAC principle is based on multiplication properties of matrices (Raj.et.al 2007).The purpose of MICMAC analysis is to analyse the drive power and dependence power of enablers. This is done to identify the key enablers that drive the system in various categories. Therefore, all variables are divided in to four clusters i.e Autonomous cluster, dependent cluster, linkage cluster and driven cluster.

**Cluster I**: Autonomous variables —These enablers have weak drive power and weak dependence power. In this cluster there is no enablers in this case.

**Cluster II**: Dependence variables — These enablers have weak drive power but strong dependence power. In this cluster we have five enablers in this category.

**Cluster III**: Linkage variables – These enablers have strong drive power as well as strong dependence power. In this cluster we have three enablers in this category

**Cluster IV**: Driving variables – These enablers have strong drive power but weak dependence power. In this cluster we have four enablers in this category.

**Table 9: cluster of measures**

Driving Power

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 1 | | | | | | | | | | | |
| 11 | | | | 12 | 8 | | 5 | | | | | |
| 10 | | | IV | | | | | | | III | | |
| 9 | | | | | | | | 2 | | | | |
| 8 | | | | | | 4 | | | | | | |
| 7 | | | | | | | | | 3 | | | |
| 6 | | | | | | | | | | | | |
| 5 | | | | | | | 9 | | | | | 6 |
| 4 | | | | | | | | | | 11 | | |
| 3 | | | I | | | | | 10 | | II | | |
| 2 | | | | | | | | | | | 7 | |
| 1 | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

Dependence Power →

## 5.RESULTS AND DISCUSSION

The main objective of this paper is to identify and analyse the key enablers of CAD/CAM/CAE and suggest suitable enablers to implement the current manufacturing system. Twelve CAD/CAM/CAE enablers has been identified form through expert opinions from academic and literature reviews. In this paper, an ISM model based on contextual relationships has been developed to analyse the inter-relation among CAD/CAM/CAE enablers. The manufacturing managers can get an insight of these enablers and understand their relative importance and inter dependencies. ISM is an interactive learning process. This approach is used to identifying and summarizing the relation among the specific variables and which define the problems and issues. In ISM technique, a set of different directly and indirectly related elements/variable are structured into a comprehensive systematic model. Warfield first proposes ISM in 1973. Warfield, J.N (1974) has developed a powerful methodology for structuring complex issues. The MICMAC analysis finds that there are zero variables in the autonomous cluster i.e. weak drive power and weak dependence power. So they do not much influence on the system. In the dependent cluster there are five variables i.e. team spirit and motivation, organization effectiveness, security of CAD/CAM interface and work culture in this cluster there is strong dependent and weak driving power. In the third cluster i.e. linkage cluster there are three variable i.e. availability of resources, effective long term planning, communication between design office and other users in this cluster. In this, there is strong dependent and strong driving power. The last cluster is the driving cluster, there are four variables in this cluster i.e. design office service and support function, training of CAD/CAM staff, application knowledge and top management commitment. In this cluster, there is weak dependence and strong driving power. They are treated as key enablers for successful implementation of CAD/CAM/CAE in an organization.

## 6.CONCLUDING REMARKS

In the past fifteen years, the modern technologies have been increasingly used in order to increase product quality and productivity of the manufacturing process. Implementation of advanced technologies, especially the application of computers and commercial (for market) is being developed. The process of implementation must be planned, because the direction of the company development depends on the selection of systems for product development. Practical advantages of the implementation of the CAD/CAM/CAE systems must be explored. In this research, an attempt has been made to identify various enablers, which facilitate the effective implementation of CAD/CAM/CAE. Sometimes manufacturing companies take quick decisions regarding the adaptation of new technologies just by following the production manuals. It is essential that the interested companies must do the introspection before implementing the CAD/CAM system. They must find out how many enablers for the implementation of CAD/CAM system are available to them. The results of this study show that all the considered enablers are very important for implementation of CAD/CAM system. There are a number of enablers affecting the implementation of CAD/CAM system in a more effective way. In this research, an analysis of CAD/CAM/CAE enablers in terms of their driving and dependence power has been carried out. Those enablers having higher driving power need to be taken care of on a priority basis. The enablers with high driving power are of strategic orientation and importance. On the other hand, dependent enablers are of operation and performance orientation. Hence, superior performance of CAD/CAM system can be achieved by continuously focusing on the driving enablers.

## 7.REFERENCES

1. "Introduction to Knowledge Management". www.unc.edu. University of North rolina at Chapel Hill. Archived from the original on March 19, 2007. Retrieved 11 September 2014.
2. Agarwal, V., & Naik, N. Y. (2004). Risks and portfolio decisions involving hedge funds. The Review of Financial Studies, 17(1), 63-98.
3. Boothroyd, Geoffrey; Knight, Winston Anthony (2006). Fundamentals of machining and machine tools (3rd ed.). CRC Press. p. 401. ISBN 978-1-57444-659-3
4. Chand, M., Raj, T., & Shankar, R. (2015). Weighted-ISM technique for analysing the competitiveness of uncertainty and risk measures in supply chain. International Journal of Logistics Systems and Management, 21(2), 181-198.
5. Duggal, Vijay (2000). Cadd Primer: A General Guide to Computer Aided Design and Drafting-Cadd, CAD. Mailmax Pub. ISBN 978-0962916595
6. Duperrin, J. C., & Godet, M. (1973). Méthode de hiérarchisation des éléments d'un système: essai de prospective du système de l'énergie nucléaire dans son contexte sociétal. CEA
7. Gilhousen, K. S., Jacobs, I. M., Padovani, R., Viterbi, A. J., Weaver, L. A., & Wheatley, C. E. (1991). On the capacity of a cellular CDMA system. IEEE transactions on vehicular technology, 40(2), 303-312.
8. Ginzberg, M. J. (1981). Early diagnosis of MIS implementation failure: promising results and unanswered questions. Management science, 27(4), 459-478.
9. Girard, John P.; Girard, JoAnn L. (2015). "Defining knowledge management: Toward an applied compendium" (PDF). Online Journal of Applied Knowledge Management. 3(1): 14.
10. Gupta, Jatinder; Sharma, Sushil (2004). Creating Knowledge Based Organizations. Boston: Idea Group Publishing. ISBN 1-59140-163-1

11. Harrison, A. W., & Rainer Jr, R. K. (1992). The influence of individual differences on skill in end- user computing. Journal of Management Information Systems, 9(1), 93-111.

12. Huang, P. Y., & Sakurai, M. (1990). Factor automation: the Japanese experience. IEEE Transactions on Engineering Management, 37(2), 102-108.

13. Hylas, R. E., Gordon, B., & Dinetz, G. R. (1989). The upside of downsized systems. Best's Review, 90(8), 78-82.

14. Ives, B., & Olson, M. H. (1984). User involvement and MIS success: A review of research. Management science, 30(5), 586-603.

15. Kirkwood, R., & Sherwood, J. A. (2018). Sustained CAD/CAE integration: integrating with successive versions of step or IGES files. Engineering with Computers, 1-13

16. Klein, A. M. (1991). Sport and culture as contested terrain: Americanization in the Caribbean. Sociology of Sport Journal, 8(1), 79-85.

17. Lee, S. H. (2005). A CAD–CAE integration approach using feature-based multi-resolution and multi-abstraction modelling techniques. Computer-Aided Design, 37(9), 941-955.

18. Li, X., Ding, S., Wei, J., & Wang, Q. (2017). Research on Teaching Method of Mold Course Based on CAD/CAE/CAM Technology. International Journal of Emerging Technologies in Learning (iJET), 12(07), 136-145.

19. Magal, S. R., Carr, H. H., & Watson, H. J. (1988). Critical success factors for information center managers. MIS quarterly, 413-425.

20. Maier, R. (2007). Knowledge Management Systems: Information And Communication Technologies for Knowledge Management (3rd edition). Berlin: Springer.

21. Nagar, B., & Raj, T. (2012). An AHP-based approach for the selection of HFMS: an Indian perspective. International Journal of Operational Research, 13(3), 338-358.

22. Nagar, B., & Raj, T. (2012). Analysis of critical success factors for implementation of humanised flexible manufacturing system in industries. International Journal of Logistics Economics and Globalisation, 4(4), 309-329.

23. Nagar, B., & Raj, T. (2012). Risk mitigation in the implementation of AMTs: A guiding framework for future. International Journal of Industrial Engineering Computations, 3(3), 485-498.

24. Nagar, B., & Raj, T. (2013). An analytical case study of an advanced manufacturing system for evaluating the impact of human enablers in its performance. Journal of Advances in Management Research, 10(1), 85-99.

25. Narayan, K. Lalit (2008). Computer Aided Design and Manufacturing. New Delhi: Prentice Hall of India. p. 4. ISBN 812033342X.
26. Narayan, K.and Lalit (2008). Computer Aided Design and Manufacturing. New Delhi: Prentice Hall of India. p. 3. ISBN 812033342X.
27. Needle, David (2004). Business in Context: An Introduction to Business and Its Environment. ISBN 978-1861529923.
28. Pottmann, H.; Brell-Cokcan, S. and Wallner, J. (2007) "Discrete surfaces for architectural design" Archived 2009-08-12 at the Wayback Machine., pp. 213–234 in Curve and Surface Design, Patrick Chenin, Tom Lyche and Larry L. Schumaker (eds.), Nashboro Press, ISBN 978-0-9728482-7-5
29. Raj, T., Shankar, R., & Suhaib, M. (2007). A review of some issues and identification of some barriers in the implementation of FMS. International Journal of Flexible Manufacturing Systems, 19(1), 1-40.
30. Riesenfeld, R. F., Haimes, R., & Cohen, E. (2015). Initiating a CAD renaissance: Multidisciplinary analysis driven design: Framework for a new generation of advanced computational design, engineering and manufacturing environments. Computer Methods in Applied Mechanics and Engineering, 284, 1054- 1072.
31. Rockart, J. F., Ball, L., & Bullen, C. V. (1982). Future role of the information systems executive. MIS quarterly, 1-14.
32. Saracoglu, B. O. (2006). "Identification of Technology Performance Criteria for CAD/CAM/CAE/CIM/CAL in Shipbuilding Industry". doi:10.1109/PICMET.2006.296739 The Business Dictionary. Organizational culture.[1] Accessed June 22, 2015
33. Satyanarayana, B., & Prakash, K. J. (2016). Design and manufacturing of a chess coin through CAD/CAM integration. History, 2(7), 370-377.
34. Shahabadkar, P. (2012). Deployment of interpretive structural modelling methodology in supply chain management–an overview. International Journal of Industrial Engineering & Production Research, 23(3), 195-205.
35. Sharma, P., Pathak, K., & Sharma, B. K. (2014). Role of CAD/CAM in designing, developing and manufacturing of new products. International Journal of Research in Engineering and Technology eISSN, 2319-1163
36. Soliman, F., Clegg, S., & Tantoush, T. (2001). Critical success factors for integration of CAD/CAM systems with ERP systems. International Journal of Operations & Production Management, 21(5/6), 609- 629.
37. Tan, C. F., Kher, V. K., & Ismail, N. (2013). Design of a feature recognition system for CAD/CAM

integration. World Applied Sciences Journal, 21(8), 1162-1166.

38. Tolouei-Rad, M. (2006). An approach towards fully integration of CAD and CAM technologies. Journal of achievements in materials and manufacturing engineering, 18(1-2), 31-36.
39. Van der Auweraer, Herman; Anthonis, Jan; De Bruyne, Stijn; Leuridan, Jan (2012). "Virtual engineering at work: the challenges for designing mechatronic products". Engineering with computers. 29 (3): 389–408. doi:10.1007/s00366-012-0286-6.
40. Warfield, J. N. (1974). Developing subsystem matrices in structural modeling. IEEE Transactions on Systems, Man, and Cybernetics, (1), 74-80.