

Cranfield University

Patrick Ollerton

**An Investigation into Product Structure Management
using Product Data Management Systems**

School of Industrial and Manufacturing Science

MRes Thesis

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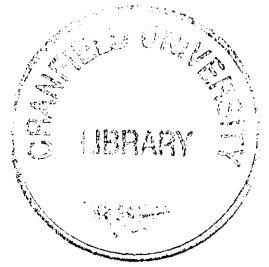
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**An Investigation into Product Structure Management using
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Supervisor: Dr. J. X. Gao

September 1998

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for the degree of Master of Research*

Abstract

With the increased use of Computer aided Design (CAD), Computer aided Manufacturing (CAM) and Computer aided Engineering (CAE), many engineering and manufacturing companies are experiencing problems with managing their product related data or information.

Product Data Management (PDM) systems are tools that catalogue and manage all types of product data / information. PDM systems also offer Product Structure / Bill of Material management functions that are used for defining and analysing product configurations.

In order to maximise the benefit of PDM systems, methods of creating generic Product Structure / BoM's need to be developed and evaluated. The possibility and effects of extending Product Structure / BoM access to departments other than design is investigated in the research. Combined with these factors is the need for transfer of data from PDM systems to manufacturing software such as Computer aided Process Planning (CAPP) and Manufacturing Resource Planning (MRP).

The research also contains an investigation into the potential effects of emerging technologies such as Enterprise Resource Planning (ERP), object - oriented database management systems (OODMS) and the internet.

Finally, the project includes two industrial case studies focusing on Matra BAE Dynamics Ltd and Rolls – Royce Aerospace and a market research survey.

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1 Introduction

Product Data Management (PDM) systems are the latest software tools that help engineering and manufacturing companies manage and control their product information and business processes. Most PDM systems offer Product Structure Management (PSM) or Bill of Material (BoM) management functions which control and record a product's assembly structure.

Because PDM systems are mainly used during design development they must co-exist with manufacturing software systems. These can include Computer aided Process Planning (CAPP) and Manufacturing Resource Planning (MRP) software.

In order to maximise the benefits of PDM software and reduce manufacturing time and costs, it is proposed that a generic product structure or BoM will be stored and managed within a PDM system and transferred to the relevant manufacturing systems.

The project is supported by Matra BAe Dynamics Ltd. and Rolls-Royce Plc. Aerospace Division, who are both investigating PDM systems for future implementations. Case studies focusing on both companies are included in the thesis giving recommendations covering PDM and Product structure / BoM usage. This section is directed towards the individual companies, but most of the analysis can be applied to more general industrial situations.

There are four main sections to the thesis; literature review, market research, industrial case studies and discussion and conclusions. The first section, literature review, discusses definitions, software functions and relevant current research. The next section discusses and analyses a market research survey conducted on engineering and manufacturing companies. The survey investigates industrial requirements and opinions relevant to the research area. The third section contains the industrial case studies and

focuses on technical and business analysis and recommendations. The final section includes discussion and conclusions to the research and also suggestions for further work.

2.0 Literature Review

2.1 Introduction

The use of CAD (computer aided design), CAM (computer aided manufacturing), CAE (computer aided engineering) and CIM (computer integrated manufacturing) has increased rapidly over the last decade, and this trend is set to continue throughout the engineering and manufacturing industry [1]. With the improved functionality and increased power of these modern systems, engineers are able to generate and modify large amounts of product / process data very quickly [1].

This situation creates serious problems concerning the storage, control and management of product related information / data. The rapid creation of information also brings difficulties in controlling the product development process, mainly because of lack of structured workflow and communication processes. Further complications occur when companies are required to respond to engineering change as a result of the need for product variants or revisions [2].

Overcoming these problems is essential if maximum benefits are to be gained from the software applications and effective concurrent engineering is to be employed to reduce product life - cycle times and costs [1].

2.1.1 History of Product Data Management

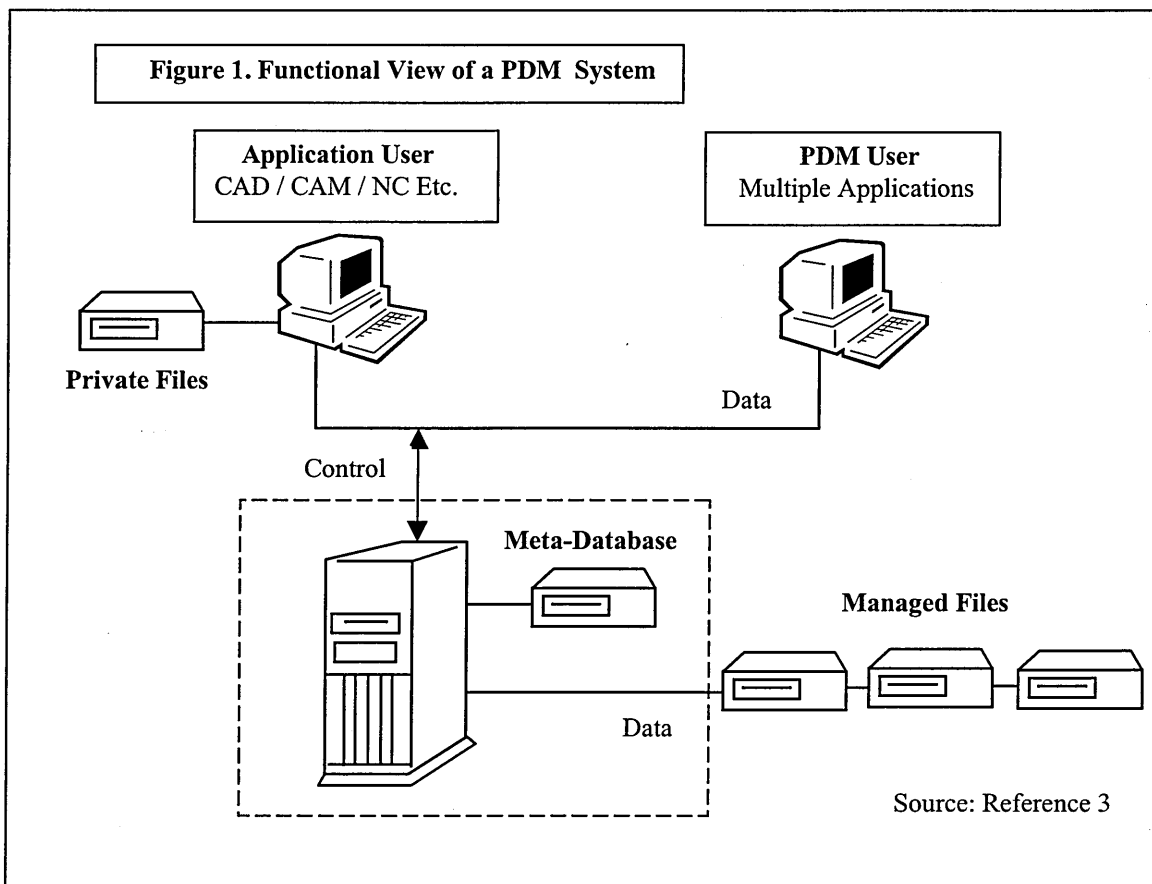
Product Data Management (PDM) systems were originally developed in – house to solve specific data management and workflow problems [1]. During the early 1980's, many large corporations that were experienced in applying computers to engineering problems attempted to develop their own systems. The level of success varied from

company to company, but software vendors realised the demand for such a system. By the late 1980's, the first generation of commercial PDM systems were available.

The scope of PDM systems has grown considerably over the last decade, moving from a engineering design focus to covering the entire product life – cycle. The latest generation of PDM system promote and support concurrent engineering philosophies and help to reduce life cycle time and costs, important issues in the highly competitive market of the 1990's.

2.2 Product Data Management

PDM systems are tools that provide a structure to manage and store all types of product related data / information [1]. This is achieved using a data 'vault' that stores a secure master copy of all required data and a network connecting the relevant personnel. A functional view of a PDM system is shown below in Figure 1.



The system keeps track of all the generated data and records all product revisions in a chronological order. System access privileges and data distribution rules are managed automatically according to user defined configurations, ensuring data security and effective workflow control. Workflow can be aided by creating specific 'packets' or 'folders' of data to provide a tailored working environment for individuals, workgroups,

departments or entire organisations [2]. Work histories are automatically generated within the system and can be viewed, with access approval, to review current work states, completed work details and workflow history information. Work histories provide comprehensive information covering data generation allowing analysis of productivity and design responsibility. Work histories are also valuable records for audit requirements and ISO 9000 compliance. Because PDM systems retrieve data from databases within the 'vault', cross-referenced searches / queries can be carried out on part attributes to give instant access to specific 'packets' or 'groups' of data [2]. PDM systems also offer Product Structure and Bill of Material management functions which allow the creation, edition and revision of hierarchical assembly structures. This allows efficient development and analysis of whole or part of component assembly configurations.

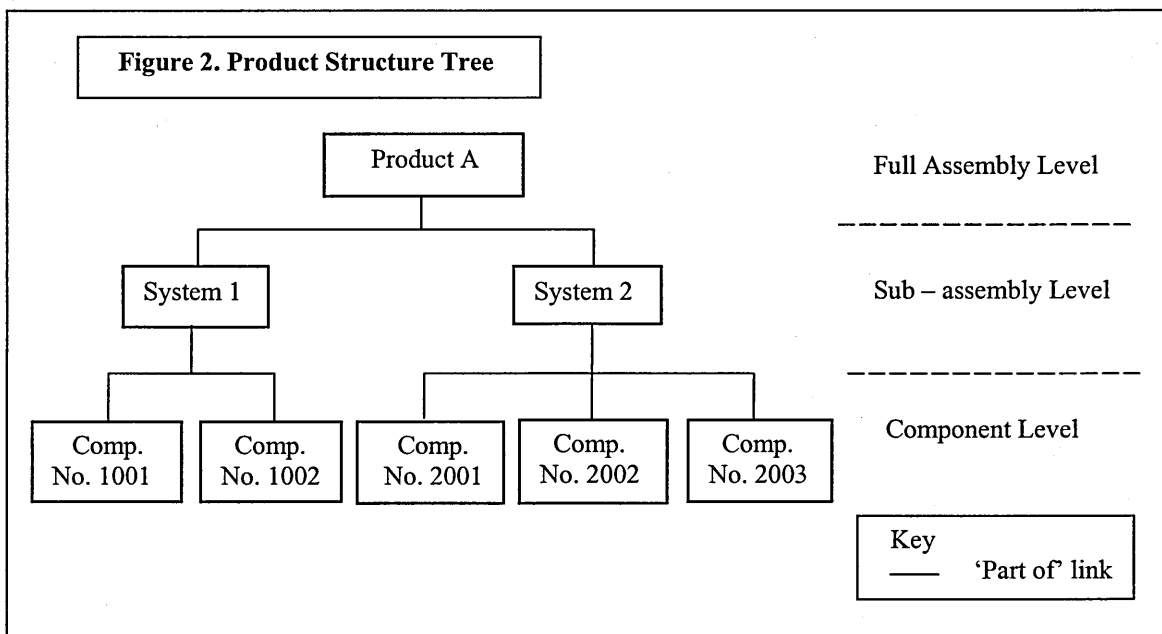
PDM software encourages concurrent engineering principles because of the ability to promptly distribute relevant data to the relevant personnel, and to increase communication between teams or individuals [1]. Effective concurrent engineering can bring many benefits such as reduced life-cycle time and cost and, ultimately, increased competitive advantage. Because PDM promotes parallel task completion and teamworking within an organisation, PDM systems are often seen as concurrent engineering 'enabling' tools [1].

Although PDM promises to solve many types of information management problems, implementing effective systems within organisations proves to be very difficult. Problems occur because companies fail to fully identify their information / data management requirements, and then struggle to translate these requirements into the chosen PDM system. Maintaining systems also requires constant review and management to ensure the PDM system evolves coherently with the business [1].

In order to maximise the benefits of a PDM system, businesses must analyse and improve their current workflow, product development and information management processes, and then translate these into the PDM system [1].

2.3 Product Structure Management

In order to control product specification requirements, a PDM system facilitates the use of user defined product structure configurations. This means building attribute sets for, and relationships between, the product's various components, parts, sub-assemblies and assemblies [1] within a PDM system. The structure is represented graphically using a hierarchical structure breakdown tree, as shown in an example below in Figure 2.



Product Structures have user defined links to associated product data such as CAD, CAM, analysis or text files, and Bills of Material. The Product Structure tree can be expanded or collapsed at any point allowing the user to focus on the appropriate assembly or sub – assembly.

A Bill of Material (BoM) is similar to a Product Structure but in addition it usually contains relevant manufacturing information [4]. This can include a list of a product's components, assembly structures, raw materials and also manufacturing

processes [5]. A product's Bill of Material is a vital piece of information for manufacturing process and production planning [4].

2.3.1 Product Structure Definition

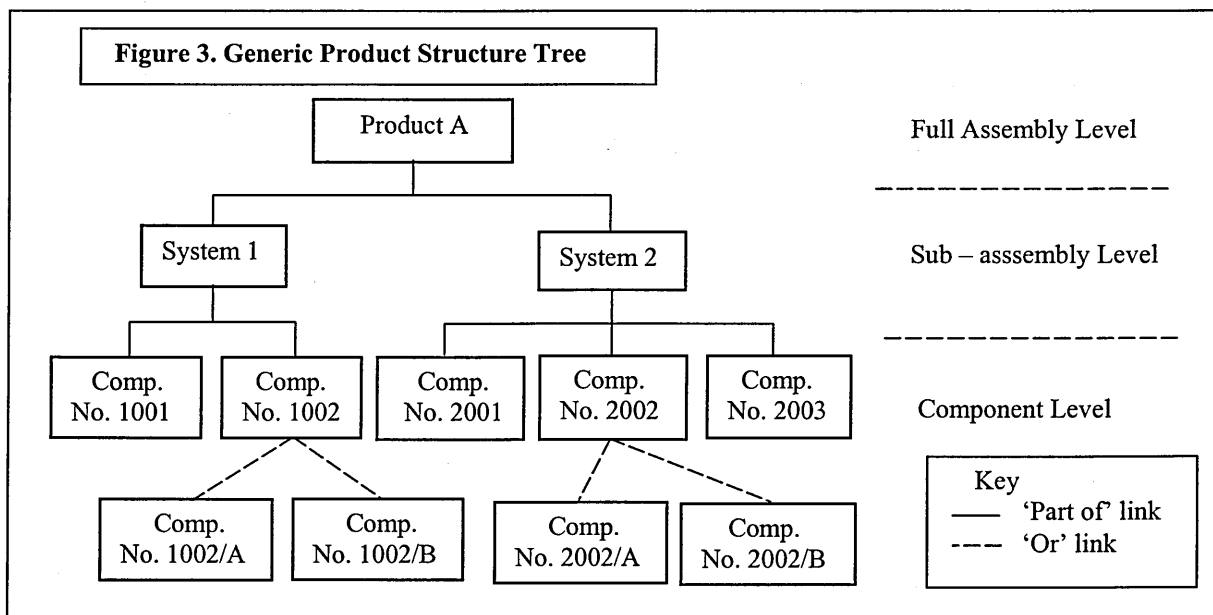
Effective Product Structure definition is a crucial requirement for successful PDM system implementation [6]. The process involves examining the assemblies, parts and components for order and physical relationships and representing the structure in an organised structure breakdown tree. To complete this task accurately, detailed information is required from product development covering the formulation of the product, which would usually be recorded in 2D CAD drawing and / or 3D CAD model forms, and Bills of Material [4].

Because many organisations out-source components and assemblies, the need to control the corresponding product data is very important. In order to build a complete and accurate product structure, externally created parts need to be included.

2.3.2 Generic Product Structures

To maximise market competitiveness, engineering and manufacturing companies need to be able to meet a variety of customer product requirements. This means responding to given specifications quickly, accurately and efficiently [5]. Product Structures need to reflect this situation by incorporating alternate, or variant components, assemblies and sub – assemblies within the structure tree.

Product variants can be stored within a generic Product Structure, and specific structures can be generated to meet customer product requirements. Managing the relationships between the data is a complicated task, but is essential for implementation and management of a generic structure. If a generic Product Structure can be created, it will ensure that accurate product configurations can be extracted for design, analysis, manufacture and assembly [2]. An example of a simple, generic Product Structure is shown below in Figure 3. The format for the diagram was proposed by F.J. O'Donnell *et al.*, where dashed lines are used to indicate alternative or variant components or sub – assemblies.



2.3.3 Generic Product Structure Definition

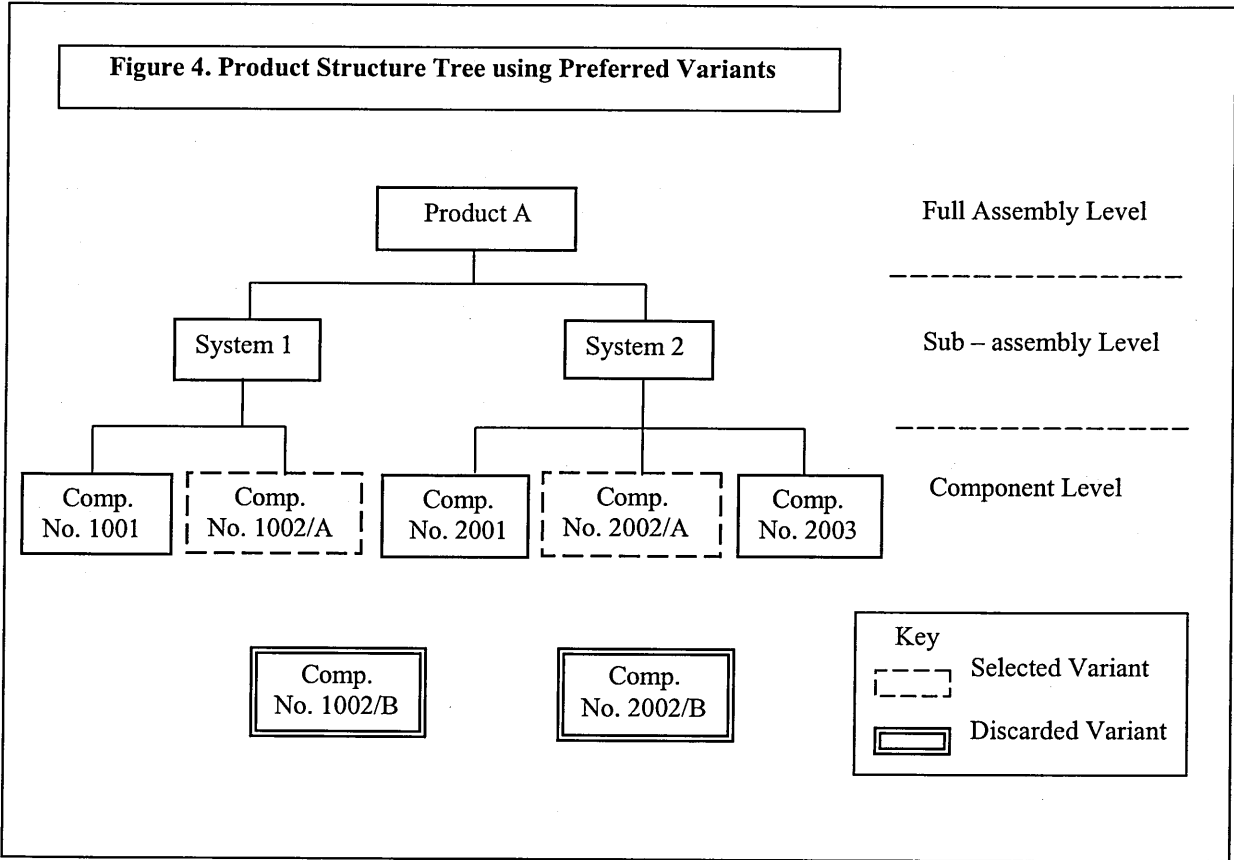
Defining a generic Product Structure can be a very complicated task, mainly because of the number of possible variations (including supplier variations) and the complexity of knock on effects created by variant parts [4]. Creating the generic structure requires detailed investigation and analysis of the part variations and where the parts are located in the structure [7]. Knock on effects such as dimensional or mechanical constraints can be accommodated by using text notes in the variant part model file, and again these factors need careful consideration to achieve successful generic structure configuration [7].

Most PDM systems allow the use of variant or alternate component definition, enabling the creation of generic Product Structures [2] [8]. Although this feature helps with providing comprehensive records within a company, manual configuration of the desired variants is still required [8]. This problem surfaces whenever an engineering change order is passed resulting in the need for increased automation of product configuration. More advanced PDM systems allow 'preferred' variants to be built into the Product Structure / BoM, allowing automatic configuration of the preferred variant [8]. The problem with this system is that when a variant Product Structure / BoM is called, the same variants are used regardless of the nature of the engineering change order. This is because the preferred variant is usually selected as the most widely used variant. If the automatically selected preferred variant is incorrect, more manual configuration of the Product Structure / BoM is required.

One method of organising the variant components is by using a 'by project' or 'by customer' classification system. This uses the concept of preferred variant components where specific, configured product structures can be automatically generated. To use this method, all preferred variant components must have as part of

their classification number a code that links them to one or more companies or projects. Then by using search and replace database commands the preferred variant can be automatically substituted into the Product Structure / BoM.

An example of preferred variants using the generic Product Structure in Figure 3 is shown below. The example uses ‘A class’ variants, which would be the designated preferred variants for customer A (or project A).



Although most PDM systems struggle to cope with engineering change orders, preferred variants can be used to enable the software to automatically select the correct alternate for the relevant project or customer [2]. This ensures that change orders are

backed up by delivering an accurate Product Structure / Bill of Material to the correct people.

Where a preferred component can not be defined or assigned to a customer or project, the Product Structure will remain generic in the relevant area. This ensures that the design or manufacturing engineer will check the product configuration required by the customer and select the correct variant manually.

This system offers greater flexibility than those previously mentioned but has yet to be incorporated into the major commercial PDM systems. The software industry response to this complicated configuration task has been to develop separate add – on applications that work with the PDM system controlling the product structure and change management functions [9].

Implementing engineering change orders can be very difficult within large organisations, but PDM systems give significant improvements over existing methods in terms of validity of information/data and change times. PDM systems also ensure that there is only one source of information that contains a comprehensive definition of all product configurations [10]. Combining PDM with specialised configuration management software will go a long way to solving Product Structure / BoM configuration problems [9] , but use of the systems together is still limited within industry.

As with most elements of a PDM system, product structure management requires careful consideration if the generated product structures are to be of any use to the organisation [5]. If product structures are accurately defined and managed, engineering and manufacturing companies can exploit the data to improve project management, workflow control, response to engineering change, productivity, design / manufacturing accuracy, and ultimately reduce time to market cycles, improve efficiency and improve

product quality [11]. Effective product structure management also goes a long way towards fulfilling the ‘correct design first time’ concurrent engineering principle [2].

2.4 Bill of Material (BoM) Views

In order to widen the benefit of Product Structure / BoM use it has been proposed that other departments should be given access to the information [2]. This would benefit several disciplines because of fast access to accurate product configurations and BoM data.

PDM systems usually give the Product Structure / BoM tree with an engineering design context [7]. This means showing the assembly hierarchy by giving the parent and child relationships. In order to present useful Product Structure / BoM data to other departments, careful consideration of their information requirements is needed. These findings can then be used to define a certain type of Product Structure / BoM which can only be accessed by certain departments. Many PDM systems allow the definition of several Product Structure / BoM views, which are then linked to personnel or workgroups in the relevant departments [11] [2].

2.4.1 Purchasing BoM View

The main concern of purchasing departments is to maintain stock levels by monitoring the inventory. This can also require planning by assessing future customer orders and adjusting the purchase orders to accommodate. By having access to comprehensive Product Structure / BoM data, benefits could be gained in terms of future planning, accuracy, time and costs. The sort of data required would not be an assembly structure tree, but rather a structured list of all components in each product configuration. This would give sufficient information to assist stock checks, but inventory levels are also needed to formulate order figures.

In order to include inventory details it may be possible to program a link between PDM and MRP systems [2]. This would provide up to date and accurate stock level

information allowing the purchasing department to make informed decisions concerning purchase volumes.

To develop a link between the two systems an applet may be used to interface between the MRP database and the PDM database [2][8]. This would require the skills of an experienced computer programmer.

2.4.2 Sales and Marketing BoM View

The sales and marketing department will require comprehensive information covering the various product configurations available. This will allow salesmen and marketers fast reference to accurate product specification data. Although access to the Product Structure / BoM would be advantageous it may not prove to be cost effective to supply all sales or marketing staff with PDM software. A possible solution would be to provide up to date configuration information in a more common data format such as a text document. This could be presented in the form of structured lists as opposed to assembly trees. An example of such a list is given below in Figure 5.

Product A			
Assembly 1		Assembly2	
Sub-assembly 1.1	Sub-assembly 1.2	Sub-assembly 2.1	Sub-assembly 2.2
Component 1.1.1	Component 1.2.1	Component 2.1.1	Component 2.2.1
Component 1.1.2	Component 1.2.2	Component 2.1.2	Component 2.2.2
Component 1.1.3			

It would be possible to produce such a list by accessing the PDM database and extracting the BoM meta-data using database commands [12]. The BoM data could then be exported or copied into a word processor and saved in a suitable network directory. Obviously this is not an automatic link and the information would require regular validation. The most effective way of achieving this would be to give one person in the marketing / sales department access to the PDM system to check product configurations.

2.4.3 Manufacturing BoM Views

Product Structures / BoM trees can be utilised in manufacturing departments by addressing the relevant issues such as assembly and manufacturing planning. For assembly purposes, the Product Structure tree would show the order in which components need to be assembled [7]. This will give precise assembly information that can be used for assembly scheduling. An example of an assembly Manufacturing BoM is shown below in Figure 6.

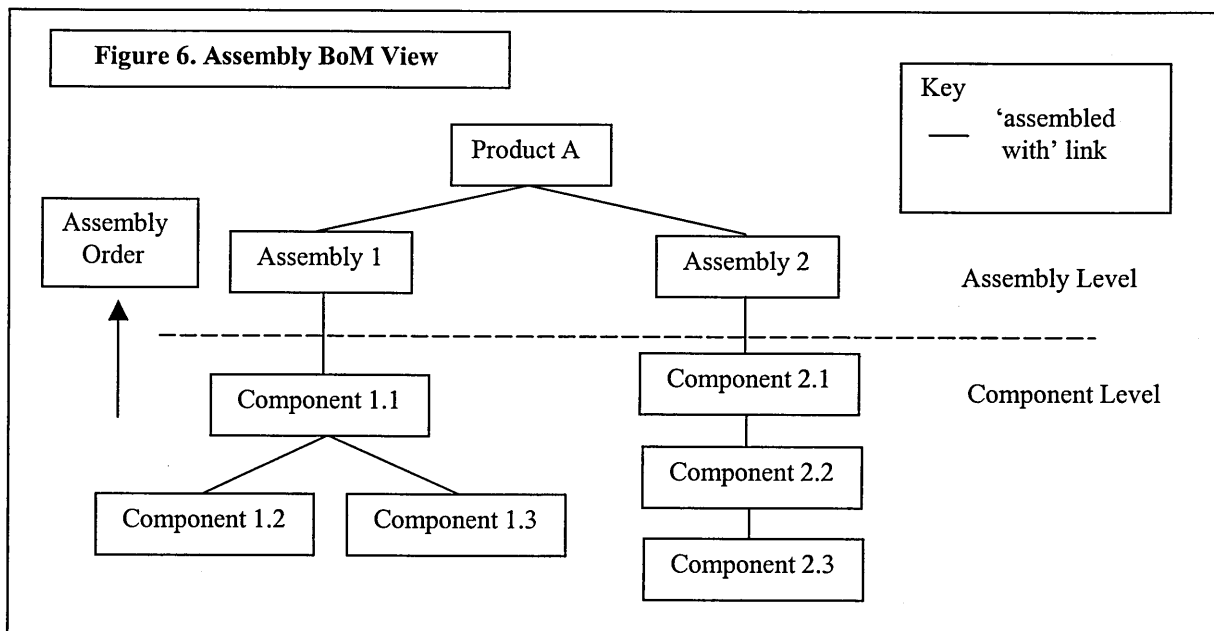
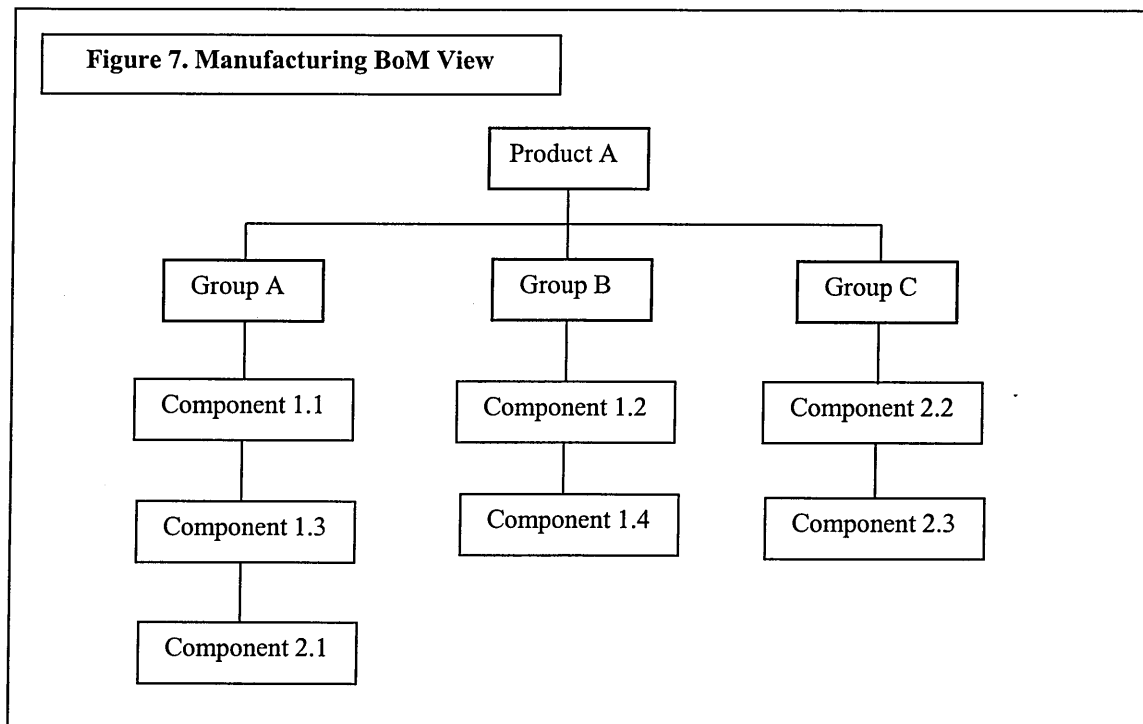


Figure 6 shows the assembly sequence of the components and sub-assemblies. It can be seen that Component 1.2 and 1.3 are assembled to Component 1.1 to form Assembly 1. For Assembly 2, Component 2.3 is assembled to Component 2.2 which is assembled to Component 2.1. It is also possible to include assembly methods and equipment by linking text files with the component in question.

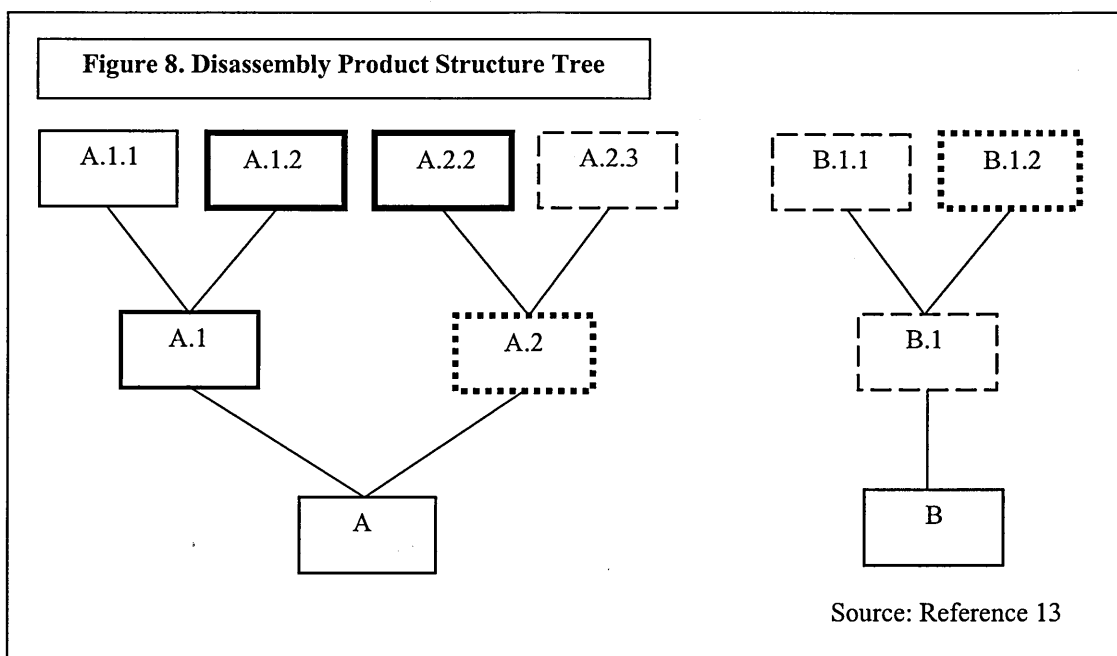
As well as being used for assembly purposes, Product Structure / BoM views can be used to group and relate manufacturing processes. All components to be manufactured are assigned to a group which represents a machine or a group of machines that can produce the part. The Product Structure / BoM shows each machine group and which components are to be manufactured on that machine or machines [7]. Using this structure will assist manufacturing scheduling and process planning. An example of a manufacturing BoM view is shown below in Figure 7.



2.4.4 Disassembly of Product Structures / BoM's

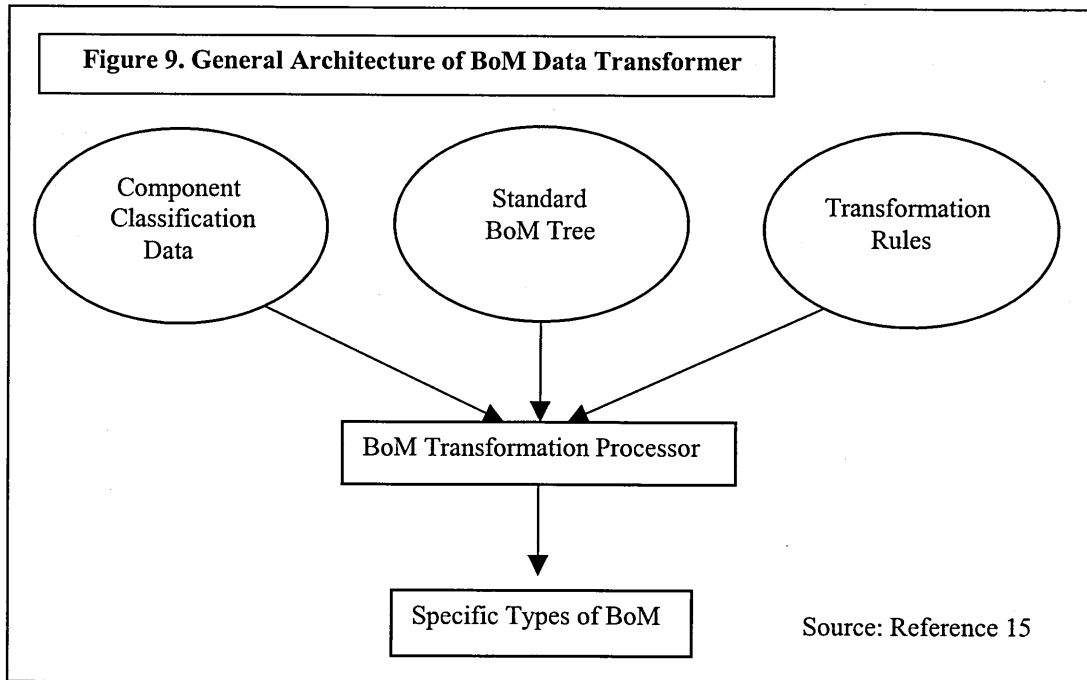
With growing environmental and economic pressures most industrialised nations are aiming to increase the amount of recycling or re-use of manufactured products [13]. A few countries have already passed legislation that compels companies to take back and disassemble their products for recycle or re-use [13]. With this trend certain to continue it is likely that it will have a major impact on the manufacturing industry within the next few years [13].

Because of these factors, manufacturing companies need to retain Product Structure / BoM information so it can be used during the recycling process. In order to organise the disassembly process, which will involve several products simultaneously, Taleb *et al.* [13] [14] proposes a method of grouping and relating common parts and materials. With effective scheduling this will allow many recalled products to be disassembled concurrently and efficiently. An example of the system is shown below where common components or materials share the same box style.



2.4.5 Product Structure / BoM Data Transformer

With the use of several different types of Product Structure / BoM views, time consuming manual configuration of structure trees is required. This is needed whenever the original Product Structure / BoM is altered, possibly as re-design, or when a new product is to be manufactured. To enable automatic generation of different Product Structure / BoM views from the standard engineering view, Küng *et al.* propose the use of a rule driven transformation processor. Figure 9 shows the general architecture of the system.



The system works by extending a commercially available relational database management software package by adding procedures that form a rule – driven transformation processor for BoM data [15]. This is achieved by defining a data structure for the standard BoM and several transformation specifications (rules). The transformation rules are grouped together to form a complete transformation to provide

different specific BoM view. The basic transformation procedures used in the system are:

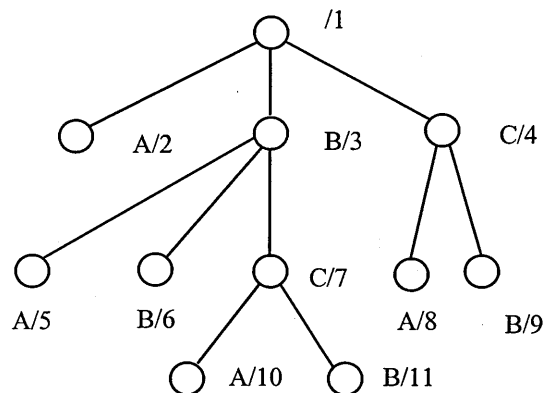
- ‘decompose’ - one level of a sub - tree has to be decomposed
- ‘decompose all’ - all levels of a sub - tree have to be decomposed
- ‘high’ - item has to be placed one level higher in tree
- ‘move’ - item has to be moved from one position in tree to another
- ‘delete’ - item has to be removed

These procedures cover all simple transformations that are likely to be needed for BoM tree manipulation. An example of BoM tree transformation is given below in Figures 10 - 15, also showing the BoM data structure and the transformation rule – base [15].

Figure 10. BoM Tree Transformation Example

BoM Data Structure		
Item No.	Position	Sub_Item No.
1	A	2
1	B	3
1	C	4
3	A	5
3	B	6
3	C	7
4	A	8
4	B	9
7	A	10
7	B	11

Standard BoM Tree



Transformation Rules - Base

Item No.	Source Position	Operation	Destination Position
1	B/A	Move	C/C
1	B/B	High	
3	C	Decompose	
4	A	Delete	

Figure 11. BoM Tree Transformation No. 1

Transformation 1: Move B/A (sub – item No. 5) to C/C

● Transformed Component

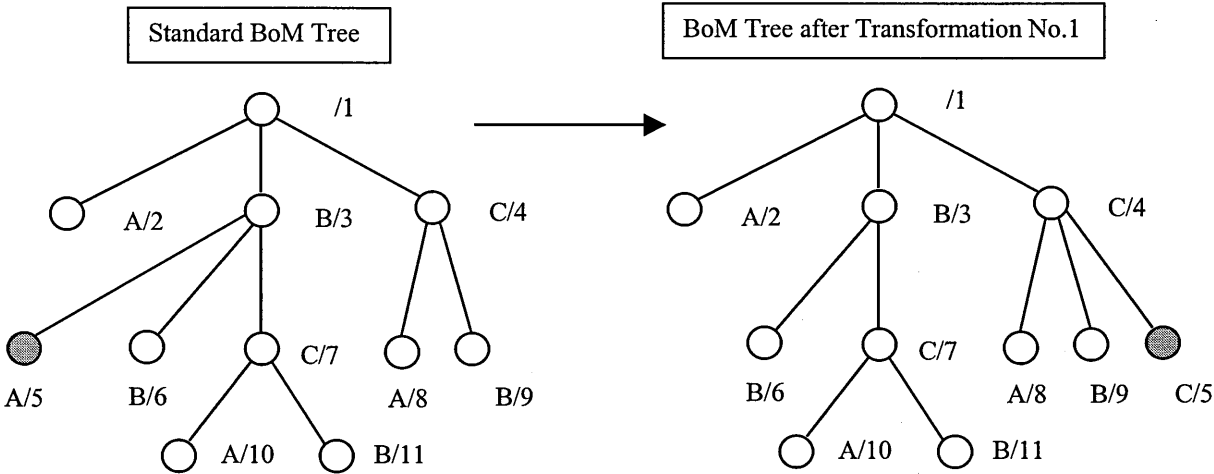


Figure 12. BoM Tree Transformation No. 2

Transformation 2: High B/B (sub – item No. 6)

● Transformed Component

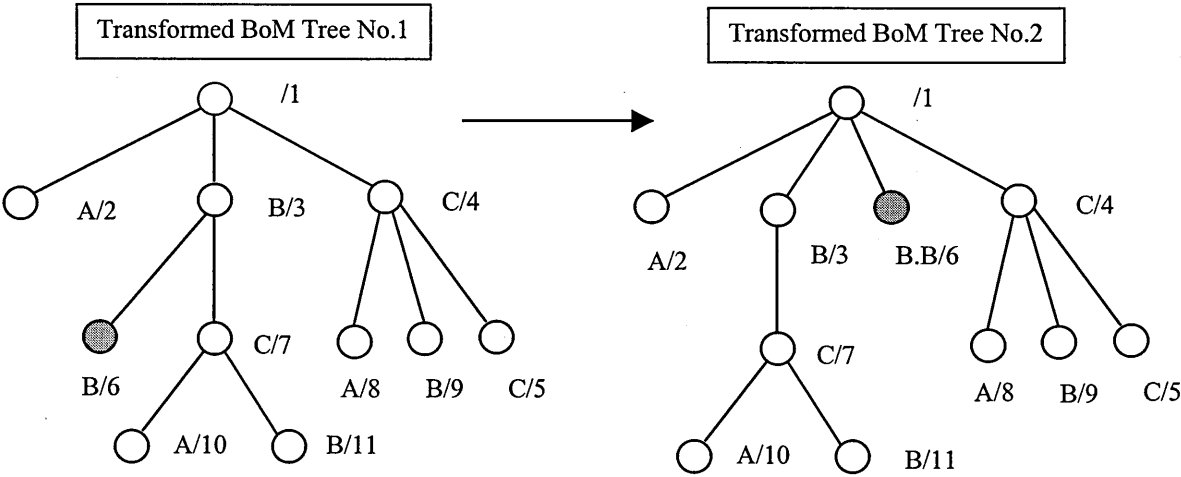


Figure 13. BoM Tree Transformation No. 3

Transformation 3: Decompose B/C (sub - item No. 7)

● Transformed Component

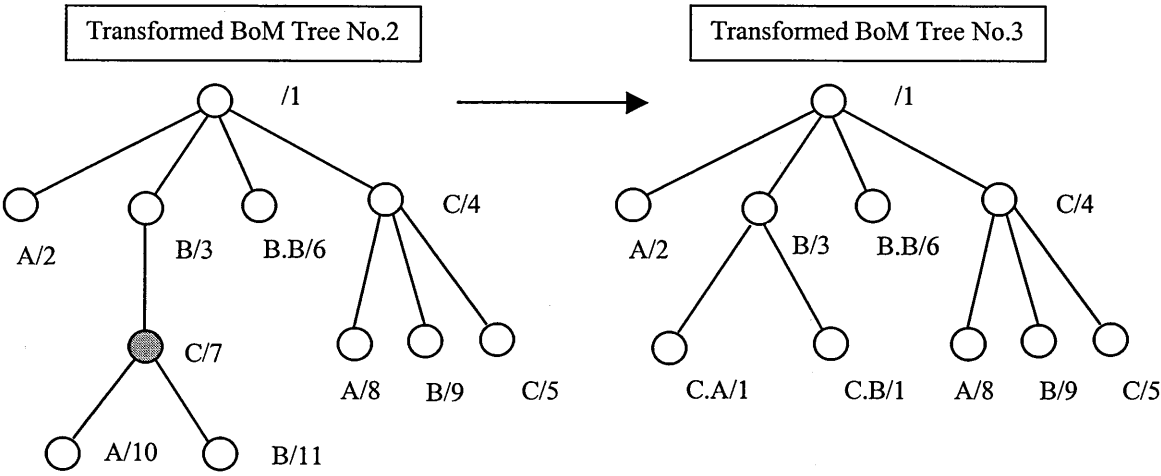
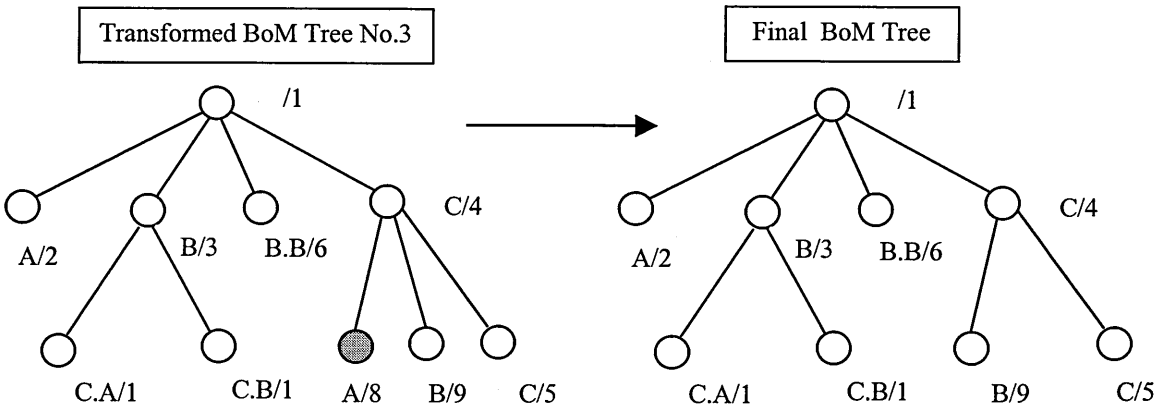


Figure 14. BoM Tree Transformation No. 4

Transformation 4: Delete C/A (sub – item No. 8)

● Transformed Component



The rules are executed from the top down, allowing procedures to be overruled in sub – items (e.g. delete and decompose).

The system proposed allows the use of one central BoM that can be referenced for transformation for any department. This helps to overcome the problem of data redundancy and inconsistency [15]. The next stage of the research is to develop the rule – base to accommodate component variants for generic Product Structures / BoM's. When the system is finalised it should greatly increase the benefits of using Product Structures / BoM's in terms of data accuracy, data distribution and configuration time and costs [15].

2.5 Bill of Material Data transfer from PDM to CAPP and MRP systems

A key element of production / process planning is the information stored in the product's Bill of Materials (BoM) [7]. PDM systems use BoM's within the product structure, but are created with an engineering design context; listing parts as hierarchical assemblies that form the product [7]. In order for the BoM to be of use for manufacturing purposes, the BoM needs to be re-defined to catalogue the manufacturing process details that need to form the parts [15]. This task is usually completed by production engineers, but PDM systems have the potential to assist with the generation of manufacturing BoM's, and with the transfer of data to computer aided process planning (CAPP) software. BoM data can also be utilised for Materials Requirement Planning (MRP) or Manufacturing Resource Planning (MRP II) software [16]. These systems cover a wider range than CAPP software, including assembly planning, scheduling and inventory control.

In order to record the product related information, PDM systems use database management software. The PDM system has a built-in link with a database application that manages and stores all the data recorded within the system. The database also records meta – data, which is 'data about data' [3]. Examples of meta – data are filenames stored in the system, file location paths, file attribute and file revision numbers. This information forms the majority of the BoM data required for transfer, but does not cover assembly relationships for the parts or components. Assembly relationships can be deduced by studying links between meta – data tables, but this is a very laborious and inaccurate process because of the structure of relational databases.

Although many PDM vendors claim that their products give full access to database contents, the reality is that most only allow meta – data to be accessed. The most likely reason for this is that the data contained in files is in a format that would be unusable for applications other than the native software.

Most CAPP and MRP systems are also linked to database applications, storing

manufacturing details and process information. Some systems, LOCAM Process Planning for example, allow the use of database commands within the application, giving automatic data retrieval for use in the application's functions.

2.5.1 Data Transfer Methods

There are two methods of transferring BoM data from PDM systems to other software, each is most suited to certain hardware and software configurations.

The most efficient and accurate method of data transfer is to use database commands from within the destination application, either CAPP or MRP. When using a function in the destination application that requires data input, database commands can be used to directly retrieve the required data. This method is only possible if the PDM and MRP or CAPP systems use the same database.

One of the most commonly used commercially available relational database systems is Oracle, which uses SQL commands. Oracle is used for several PDM systems, EDS Information Manager for example, as well as CAPP software LOCAM and also several MRP systems. Examples of SQL database commands used to access the Oracle database are given below.

```
get_bom_data  
get_line_of_bom  
get_next_line_of_bom
```

The commands above will select all or a large part of the total BoM. Commands to select specific types of data are shown below:

```
select_bom_data  
select ITEM, COMPONENT, REVISION
```

To filter out a specific assembly or sub – assembly, additional commands can be used as shown below.

```
select_bom_data  
select ITEM, COMPONENT, REVISION  
from bom where ASSEMBLY_NO = 2
```

The second method of data transfer is to manually export the information into the destination software. This could be done by copying and pasting the relevant database text into the destination application's entry fields. The problem with this method is that database commands are needed to access and filter the information. A better solution would be to copy all or part of the BoM into a flat text file (.txt). Regular validity checks on the text files would be required but it would eliminate the need for Oracle commands and therefore reduce transfer times.

2.5.2 Feature Representation

One of the main elements of CAPP software is the input of component geometry. This information is used by the software for process time and cost calculations and is usually inputted manually. In order to automate the process part geometry must be extracted from the CAD model and inputted into the CAPP software. Because CAD geometrical data stored in a PDM system can not be accessed through the database, another method is required.

One possible method uses feature based component representation as Proposed by Kase *et al.* Features are simple geometric primitives that can be constrained or parameterised, for example spheres, cylinders and cubes. In combination, features can be used to form most parts meaning a component can be described by only a list of features, parameter values and feature location geometry.

Another major benefit of using features is their suitability for manufacturing analysis and planning [18]. All features that are commonly used can be manufactured with simple machine processes, meaning the process of forming a complex component can be achieved using several simple operations. If a product's BoM contained feature type, geometry parameter values and feature location lists for each component, it could be transferred to CAPP software to automatically produce a process plan. This would greatly save manufacturing time and costs, but the use of features is not yet universally accepted. Most CAD developers use hybrid modelling systems to offer maximum modelling flexibility, but this means that CAD models use non – feature entities.

An example of varying interpretations of the same geometry is shown in Figure 15. A possible format of a feature list is shown overleaf in Figure 16.

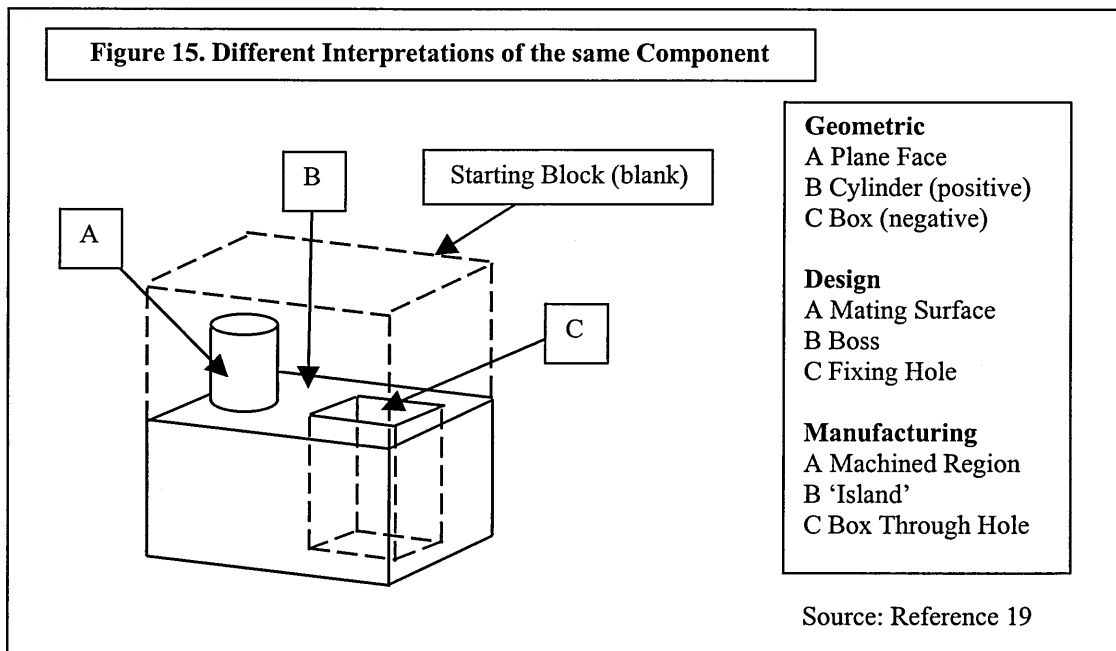
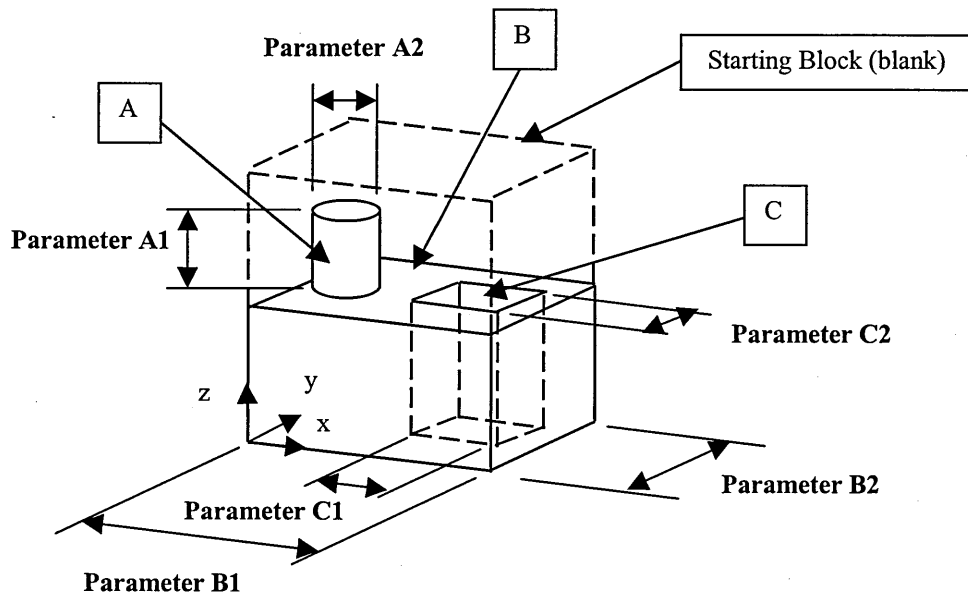


Figure 16. Possible Format of a Feature List (with part diagram)



Feature A: Positive Cylinder, Depth: Parameter A1, Diameter: Parameter A2, Centre (x,y,z), Orientation: 0°.

Feature B: Clear Face, Width: Parameter B1, Length: Parameter B2. Centre (x,y,z), Orientation: 0°.

Feature C: Box Through Hole, Width: Parameter C1, Length: Parameter C2, Centre (x,y,z), Orientation: 0°

The feature list shown above would be automatically called into the CAPP software where sequencing, tolerances, cutting and tool conditions could be added if required.

2.5.3 Feature Recognition

To overcome the immediate problem of a lack of a comprehensive feature representation standard, feature recognition software can be employed. This type of application is able to interrogate a standard CAD model and deduce if it contains any features. This would allow a part of the model to be described purely by features, which can then be used for manufacturing purposes. Because only features are included, manufacturing details for the remainder of the model need to be manually compiled.

2.6 Emerging technologies.

Because of the aim to utilise product structures in several different departments, the internet and intranets enable accurate and fast data flow within the organisation. This extends to remote sites anywhere in the world, allowing effective interdepartmental collaboration [1], [20]. Extranets can be used to include suppliers and filter out relevant data.

Most PDM systems store geometric data in relational databases, which can form links to other CAD / CAM / CAE files. Object oriented database management systems (OODMS) automatically place parts within groups, or classes, with corresponding attributes [1]. Objects or parts within groups inherit common characteristics and understand relationships with other parts. For example, a door would automatically calculate and accommodate clearances, or a gear wheel's dimensions could automatically respond to dimension changes in neighbouring gear wheels. This technology has many potential benefits for part classification and part relationships, and as a result more and more software developers are using OODMS and Java [1], an object oriented programming language.

Kobler *et al.* propose a Product Information System that uses an object – oriented database and is accessed through the internet. The system is aimed at complimenting a PDM systems by giving remote access to specific Product Structure information. The use of object – oriented technology allows complex constructs of Product Structures and constraints, bringing greater control of component relationships and component classification [21]. The graphical interface used by the system supports a full query language (AQL), but also uses a data browser for more general queries. An example of a specific AQL query is shown below [21];

```
//select all products that are member of product group 'kitchen chair'//  
(domain (
```

```
product_member_of_group
    select group in ProductGroups
    having (group@name) = "Kitchen Chair" ))

//intersect group set with: //
intersect

//select all products that are related to value object 'blue' //
(domain (
product_spec_by_valueentity
    select colour in Valueentities
    having (colour@value) = "blue" ))
```

The query above will select all the blue kitchen chairs from the product range, but the search criteria can also be applied to components or assemblies and their attributes.

Since publication of the above research, a few object – oriented internet – based PDM systems have come onto the market [22]. These systems, described as ‘webcentric’, offer the full range of PDM functions and can be tailored for remote access or restricted in – house (intranet) access. Many industry analysts believe that the first few vendors to market a comprehensive and effective webcentric PDM system will be in a very strong market position [2]. This has important implications in the long term because the more powerful vendors are in a stronger position to develop collaboration with other major software companies. This may result in only the largest vendors offering fully integrated design and manufacturing solutions, possibly even as a result of mergers or acquisitions.

2.7 The PDM / MRP Battle

Almost all manufacturers that employ PDM systems already have some form of MRP system in place. Because the scope of PDM systems is widening rapidly, the functionality of both systems is increasingly overlapping [23]. This leads to problems such as data duplication, data redundancy and a lack of control of the flow of data / information. In order to overcome these problems and maximise the benefits of both systems data must be shared or transferred between systems. The specific areas of concern are item master data, part classifications, BoM's / Product Structures and engineering change management [23].

The solution to the problem is to integrate or interface between the two systems [24]. In an interfaced system data is kept in both databases and sent from one to another to update. In an integrated system data is kept in one database and then copied to either system as required. The 'copied' data is deleted from the receiving system after use [24]. There are few fully integrated systems available on the market, mainly because of the lack of co-operation between software developers. This situation is unlikely to change in the near future as PDM and MRP developers look to provide the comprehensive solution independently. Because of this situation, many companies have programmed specific links between their system which are geared towards the company's particular requirements. Although interfacing is effective at transferring data, the script codes contained in the link need re – writing every time software or hardware is upgraded [24]. This leads to pressure on programmers and time delays when implementing new software or hardware. Despite the obvious problems, interfacing is still the best proposition for large sized companies because it can be implemented relatively easily and produces sufficient results.

With the improvement of database technology it is likely that integration will become possible but it will also make interfacing easier. This means that companies need to undertake careful analysis of their business requirements before deciding on

either method. For example, if the system needs to be up and running very quickly, interfacing is the only method that will get results. If a long term view is taken and strides to integrate the two systems are taken the results could prove to be worth the investment in time.

Another recent progression is the fact that PDM and MRP developers are now marketing 'enterprise wide' products such Enterprise Resource Planning (ERP) or Enterprise PDM. The aim of these systems is to provide a comprehensive data / information management solution, but it seems that PDM developers already have the advantage. The reason for this is that MRP systems have traditionally concentrated on manufacturing information, whereas the PDM philosophy has always been to integrate a company's numerous information systems. Only time will tell if PDM, MRP or ERP will continue to exist in parallel or one will encapsulate the other two, but PDM development seems to be significantly nearer to providing a comprehensive solution.

2.8 Implementation Issues

Implementing PDM systems can be a very complicated and time consuming task and many companies often focus on the wrong issues [25]. In order to ensure implementation success, extensive research and consideration is required of issues such as current business processes, industry experience and implementation planning techniques. A methodology for approaching PDM implementation is presented below [26]:

1 Identify Your Needs

The first step involves identifying your needs and requirements from a management and end – user perspective. Consultation with key (or super) users in all departments is essential, ensuring full identification of requirements. Once the critical issues have been recognised, research into possible solutions is required. It is important to note that technology will not always solve all problems, so operational procedures also need to be evaluated.

2 Gain Support and Commitment

Once it has been decided that PDM is a suitable solution, key users at all levels must be identified and involved with the project. One of the main reasons for PDM implementation failure is lack of support and commitment from staff. It is likely that there will be varying responses within an organisation, but support must be gained in every department to avoid failure.

3 Analysing Your Requirements

There are three types of analysis that can be used during implementation planning; As – Is, To – Be and Cost – Benefit. As – Is analysis looks at overall workflow and any data flow bottlenecks or facilitators. The To –Be analysis suggests any solutions to workflow problems or data bottlenecks. The final type of analysis, Cost – Benefit, uses the information from the first two processes to calculate the potential benefits in time and cost of workflow / data transfer. The calculations must relate workflow and data transfer time savings to employee wage figures. The overall cost saving can then be compared with the cost of purchasing and implementing the system.

4 Selecting a Vendor

Once system purchase has been justified, a suitable vendor must be selected. Companies must be wary of marketing information as it will fail to mention any possible problems with the system. Obtaining industrial recommendations and a proof of concept demonstration are the most effective ways of confirming system functionality.

5 Design the System

This process must be done with the guidance of the vendor or a consultant. Elements of concern are the database structure, security, access control, hardware / software configurations (including network specification) and system customisation.

6 Plan the Implementation

The key to smooth implementation is effective planning. Factors to address are resources (people, time, finances), scheduling, training, concurrent or phased implementation, pilot – runs, administration and contingencies. Other issues to look at are the vendor deliverables, project milestones and system acceptance criteria.

7 Maintaining the System

It is important that a plan and a budget is formed for maintaining the system once implementation has been completed. Factors to consider are technical support, system maintenance, upgrades and system failure contingencies.

2.9 Conclusions

The use of Product Structures / BoM's can benefit most departments in all types of organisation. With careful consideration and planning, generic product structure trees can be implemented to provide a comprehensive and accurate catalogue of a company's product configurations.

The use of generic structures allow the information / data to be filtered to provide specific, or precise product configurations. By using preferred variants and links to customers or projects, accurate Product Structures / BoMs can be automatically generated. This system assists the passing of engineering change orders by promptly distributing accurate configuration information to the relevant people.

PDM systems also allow the same Product Structure / BoM to have different views for different departments. This enables all departments to access the data and view it in a format that is geared towards their specific needs. By widening access to the data, all employees will increase their understanding of company product configurations and will therefore have a better understanding of the business as a whole.

Product Structures can also be used to aid the disassembly process when a product is to be recycled. The re – use or recycling of products will have to increase over the next few years due to economic and environmental pressures, and Product Structures can be used to store disassembly methods for as long as a product is in service. The organisations that realise this situation and prepare disassembly procedures will make significant financial savings in the long term.

To help implement different Product Structure / BoM views, a rule – driven data transformer processor has been proposed. The processor can be used to alter the configuration of structures automatically, without having to build separate trees. This system can save time and money when using several Product Structure / BoM views, especially when building structures for new products or altering the standard structure. Of the two BoM data transfer methods discussed, interfacing is currently the most

practical solution available. The examples given show how results can be achieved using quite simple database commands. Despite the fact that some manual work is required for transfer, interfacing between systems is still simpler and more successful than integrating. It is quite likely that integrated systems will eventually come into the market when database technology such as object – oriented is effectively utilised to support such systems.

In order to isolate and access a component's geometric details, the use of parameterised features must become standardised and more widespread. It is impossible to predict if this will happen in the near future, but the use of features has many potential benefits for data flow between design and manufacturing departments.

With the scope of PDM and MRP increasingly overlapping, enterprise wide systems that support all departments (including suppliers and customers) are evolving. It remains to be seen whether these systems will encapsulate all PDM and MRP functionality in an integrated environment or whether they will support effective links to MRP or PDM. The latter scenario seems more likely because the developers of such systems are either specialists in PDM or MRP, not both.

The use of the internet is likely to have big influence on PDM in the next few years with the recent development of commercially available webcentric systems. This will allow Product Structure / BoM data to be accessed anywhere in the world on almost every type of computer. Webcentric systems also enable full integration of supplied components and also allow the customer to define his desired product configuration from his own, generic Product Structure / BoM view.

For the long term future of PDM, MRP and ERP, industry analysts predict that the software developer that produces the most effective webcentric, enterprise wide system over the next few years will be in an excellent position to dominate the market.

3.0 Market Research Survey

In order to fully justify the nature and the direction of the research project a market research survey was conducted on engineering and manufacturing companies. The survey results can be analysed to evaluate industrial demand for the research and potential benefits of the research findings. The market survey conclusions were also used to help the guide the research project by identifying specific areas of industrial concern.

The companies surveyed were all of medium to large size as these are likely to have more experience of PDM and CAPP or MRP software [1]. Businesses were chosen from various industries to ensure the survey sample is representative of the whole market [27]. Respondents were an even split of design and manufacturing engineers to give a balance of views between design and manufacturing departments. It also ensured that the respondents had a good understanding of the issues covered.

The survey sample size was 30 companies due to a lack of time and resources. Ideally the sample size would be at least 100 companies of varying sizes. The survey method chosen was telephone interviews to ensure the correct respondents are contacted.

3.1 Market Research Survey Results and Discussion

The first two questions of the survey were to confirm that the company used, or where considering using PDM, MRP and CAPP software. The other questions cover Product Structure / BoM use, BoM data transfer and developing internet technologies. Analysis of the results is geared towards evaluating industrial demand for the project research and to investigate industrial opinions on specific issues.

Question 1. Are you currently using or considering using Product Data Management (PDM) software?

Yes ☐ No ☐

Question 2. Are you currently using or considering using Computer aided Process Planning (CAPP) or Manufacturing Requirements Planning (MRP) software?

Yes ☐ No ☐

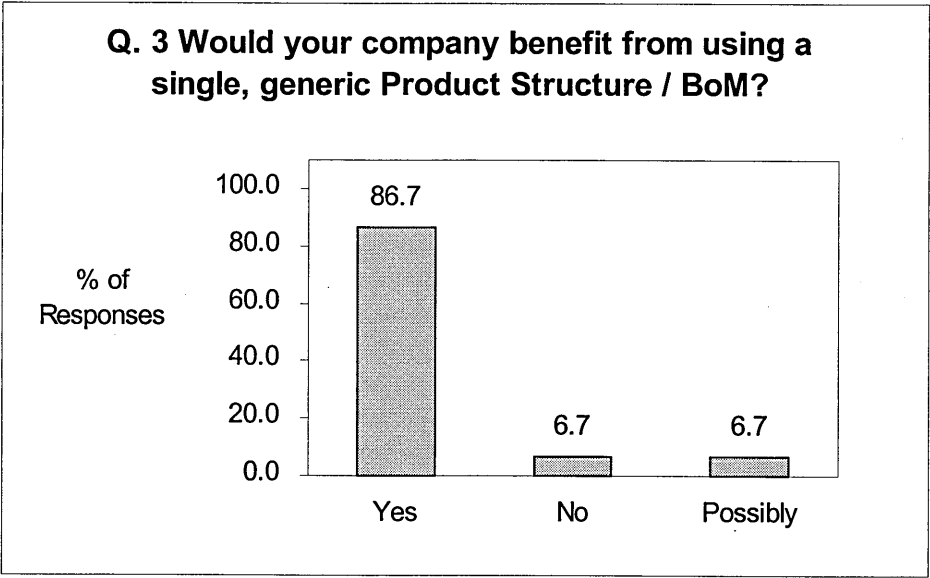
All of the companies involved in the survey had to respond yes to both of the above questions. This allows us to filter out the companies who would have little interest in the research purely because they do not use the relevant software.

Question 3. Would your company benefit from using a single, generic Product Structure / Bill of Material (BoM)?

Yes ☐ No ☐ Possibly ☐

A graph of the results is given below, showing the high level of demand for a generic Product Structure / BoM. Only 6.7% of the respondents believed that their company would not benefit from using a single, generic Product Structure / BoM. This indicates that there is a high level of industrial demand for research towards developing generic Product Structures / BoM's.

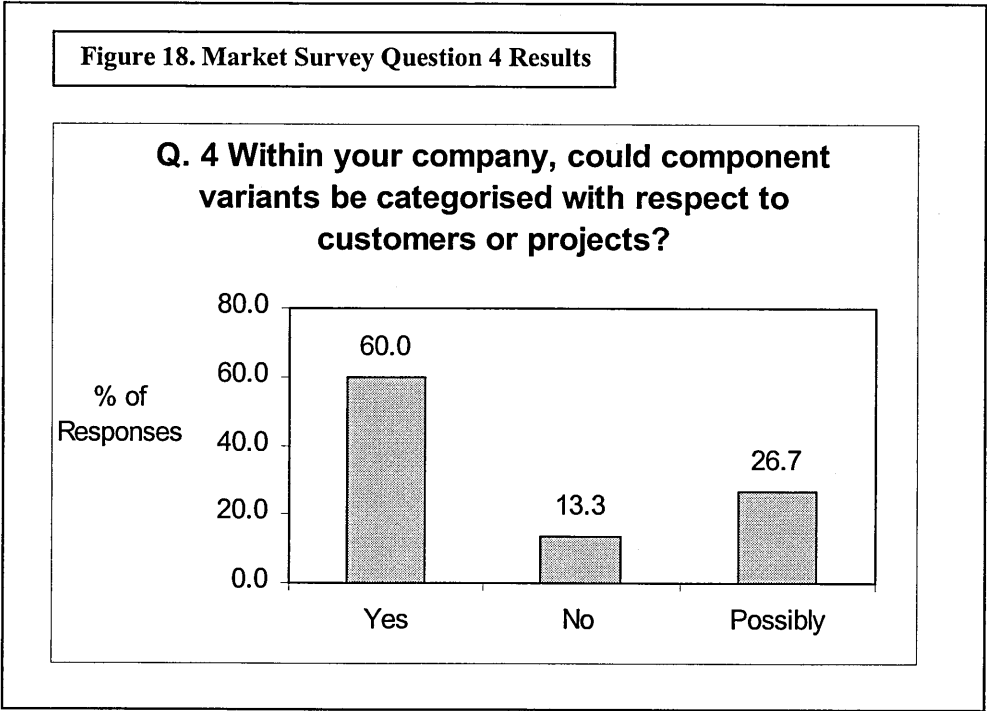
Figure 17. Market Survey Question 3 Results



Question 4. Within your company, could component variants be categorised with respect to customers or projects?

Yes ☐ No ☐ Possibly ☐

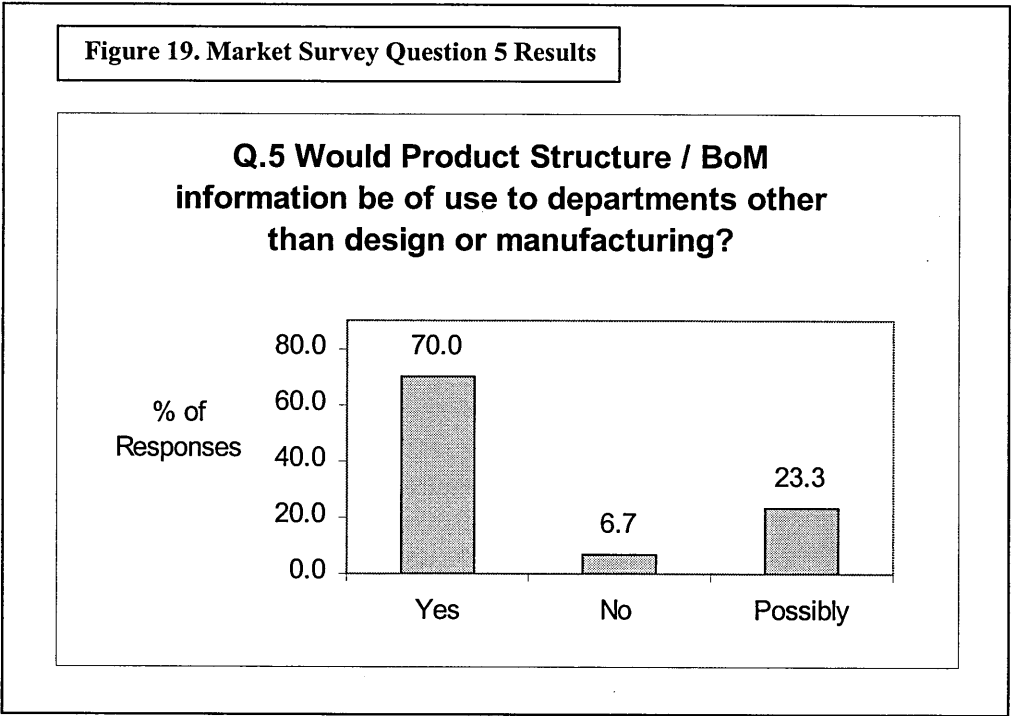
The results of question 4 are shown in the graph below. The responses indicate that there is good potential for component classification with respect to customers or projects. This trend means that the use of preferred variants for automatic product structure tree generation is justified and would be of use to at least 60% of companies surveyed. Because 26.7% of responses were ‘possibly’, it is likely that these companies will be able to achieve some level of variant classification. This further increases the usefulness of the research discussed in section 2.



Question 5. Would Product Structure / BoM information be of use to departments other than design or manufacturing?

Yes ☐ No ☐ Possibly ☐

Question 5 relates to the use of different BoM views as discussed in section 2. The results are shown in the graph below and they support the need for wider access to Product Structures / BoM. Of the 30 companies surveyed, 70% believed other departments would benefit from BoM access, with only 6.7% believing they would not benefit.

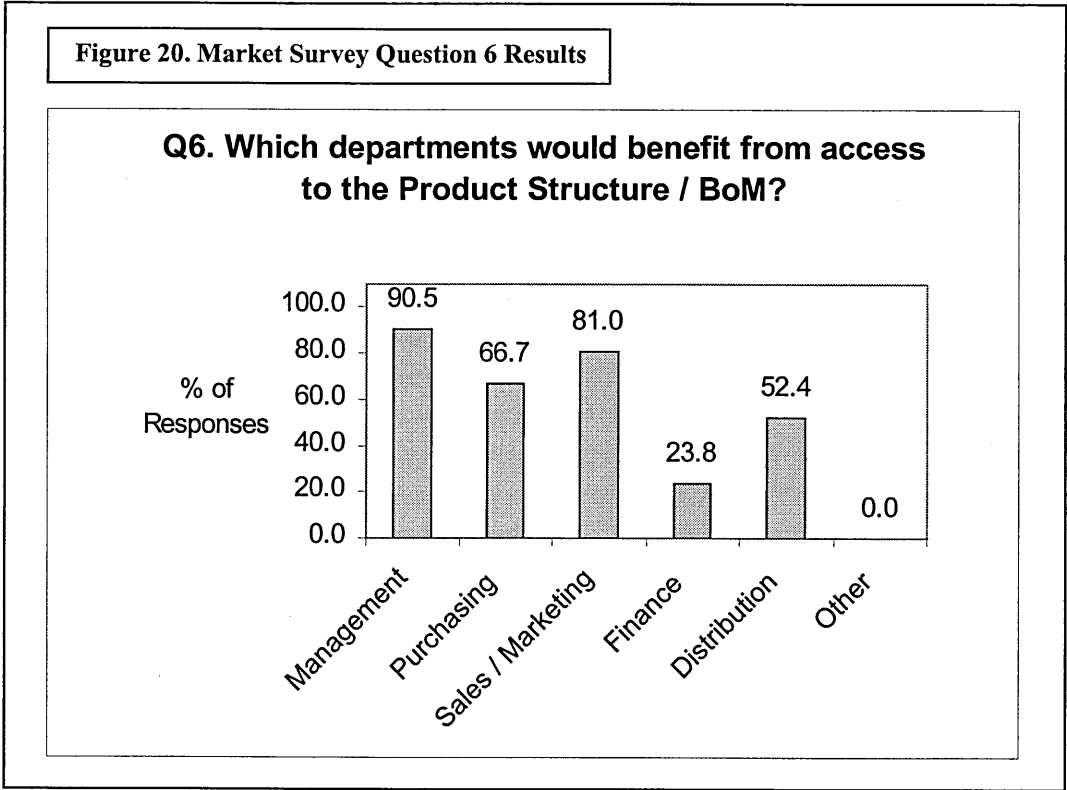


Question 6. If the response to Q.5 is yes, which departments would benefit from access to the Product Structure / BoM?

Management	☐	Purchasing	☐
Sales and Marketing	☐	Finance	☐
Distribution	☐	Other	☐

The results given below show that there is high demand for Product Structure / BoM access within Management and Sales and Marketing departments. This indicates that the use of different BoM views is beneficial to industry, and is therefore a subject that needs research and development.

Purchasing and Distribution departments can also benefit from Product Structure access, as shown in the graph. This response shows the need for inventory links within the BoM, as discussed in section 2.



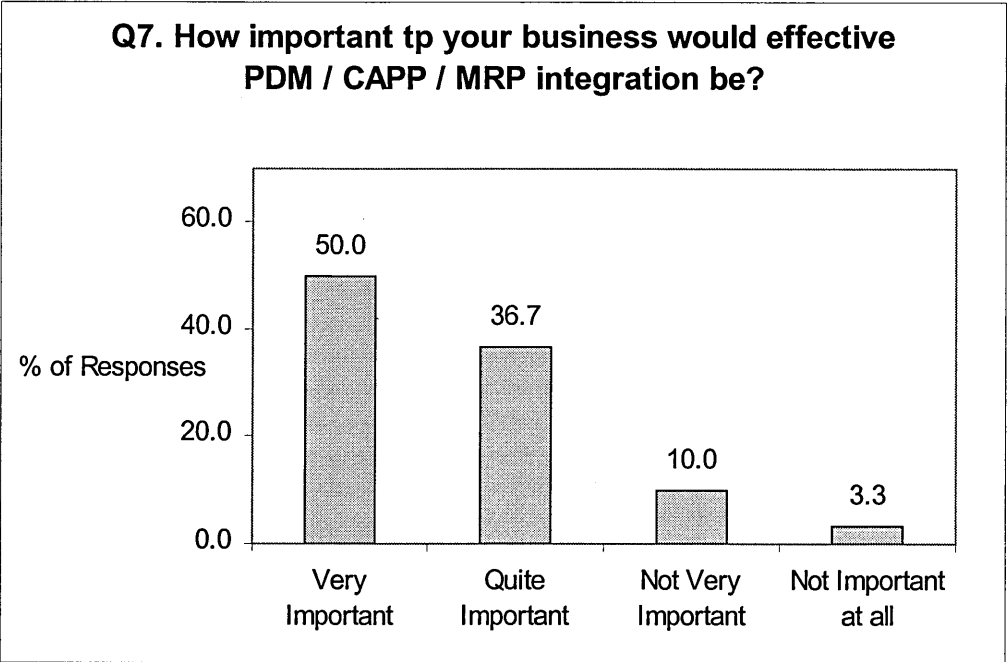
Question 7. How important to your business would effective PDM / CAPP / MRP integration be?

Very Important	Quite Important	Not Very Important	Not Important At All
☐	☐	☐	☐

This general question covers many issues but is used to assess the overall demand for the research area. The results given below show the high industrial importance of effective software integration, with 50% of responses being ‘very important’. Furthermore, only 13.3% of companies believed that effective software integration is not very important or not important at all.

Because of the complexity of PDM / CAPP / MRP integration, any research that solves specific problems contributes to the overall development.

Figure 21. Market Survey Question 7 Results

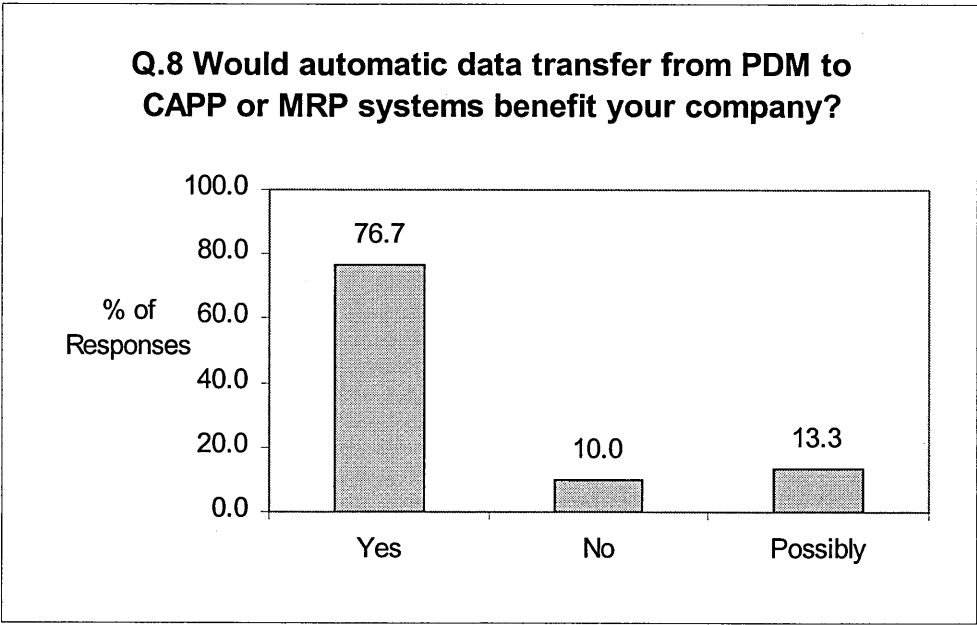


Question 8 Would automatic BoM data transfer from PDM to CAPP or MRP systems benefit company?

Yes ☐ No ☐ Possibly ☐

Question 8 addresses the specific issue of BoM data transfer, one of the main elements of the research project. The results are shown in the graph below and support the research because of the potential benefits of automatic BoM data transfer. Out of the 30 companies interviewed, 76.7% believed BoM data transfer would benefit their company, with only 10% believing it would not be a benefit.

Figure 22. Market Survey Question 8 Results

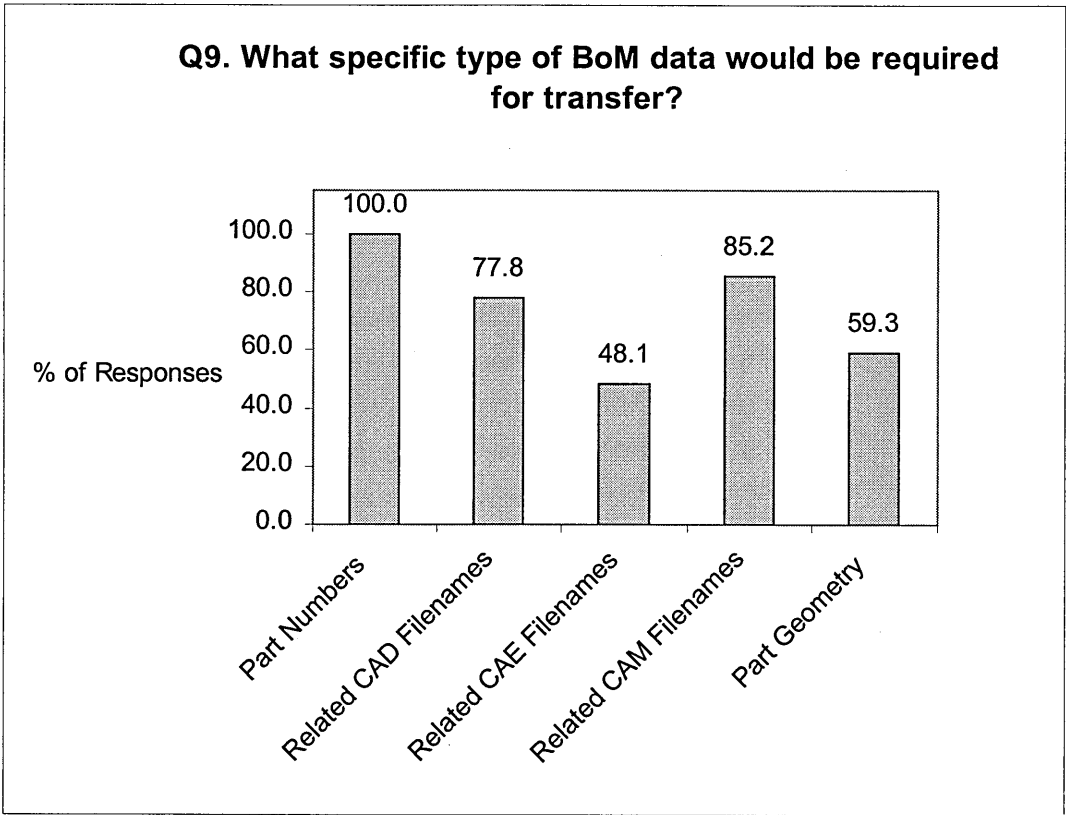


Question 9 If the response was ‘yes’ or ‘possibly’ to Q.8, what specific type of BoM data would be required for transfer?

Part Numbers	☐	CAD Filenames	☐
CAE Filenames	☐	CAM Filenames	☐
Part Geometry	☐		

Question 9 is a follow up to Question 8, asking what specific data would be required for the transfer. All of the options were required by a large percentage of the companies, but part numbers was selected by every company. The responses show that all of the options would be needed for data transfer, as is covered in section 2.

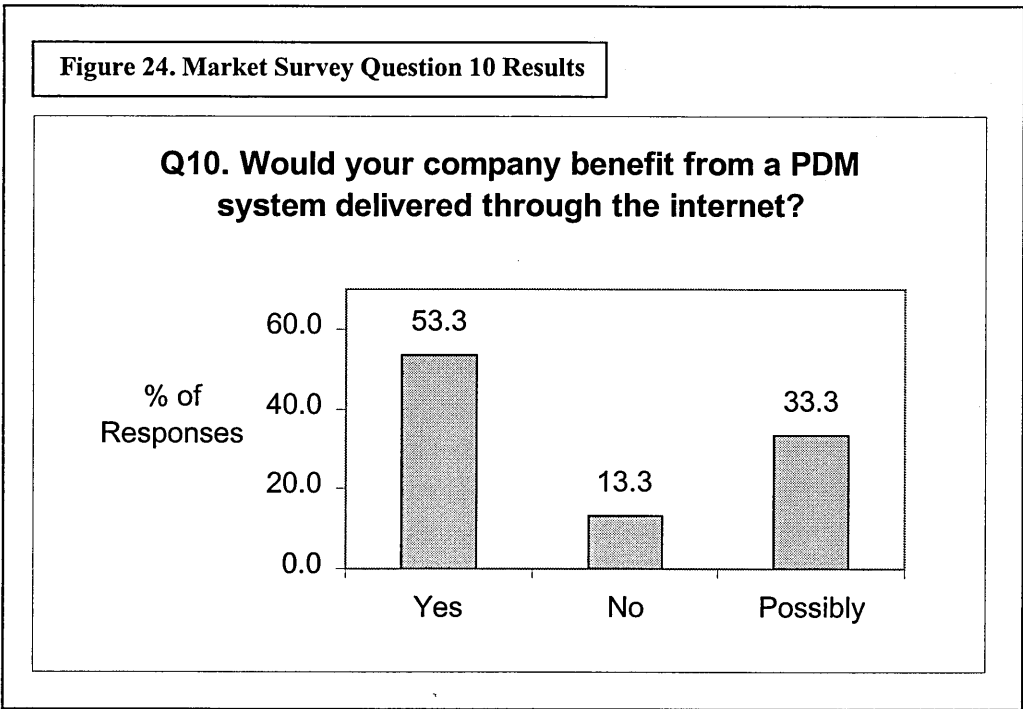
Figure 23. Market Survey Question 9 Results



Question 10 Would your company benefit from a PDM system delivered through the internet?

Yes ☐ No ☐ Possibly ☐

Question 10 investigates the industrial demand for a PDM system that operates through the internet, possibly using intranet or extranet technologies. The responses show that most companies believe that there will be a benefit with 53.3% giving the ‘yes’ response. There is also a high number of people who are unsure if a webcentric PDM system would bring benefits. The likeliest reason for this is because the technology is very new and most people will have seen little evidence of success or benefits. This situation will undoubtedly change as more companies become interested in such systems and more industrial successes are documented.



Question 11 If the response to Q.10 is yes or possibly, which of the following advantages of webcentric PDM systems would benefit your company?

- Remote Access

Ease of Use

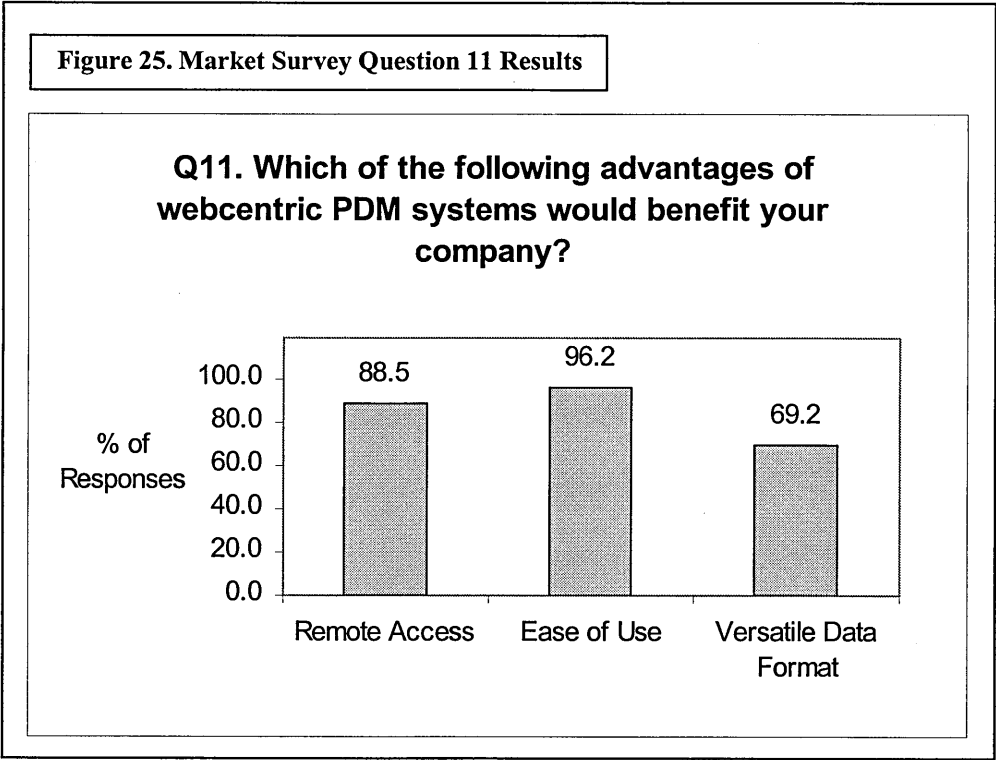
Platform Independent

Data Format
- ☐

☐

☐

☐



This question investigates the perceived benefits of webcentric PDM systems. The 3 advantages suggested are all widely acknowledged suggesting that there is a high level of understanding and enthusiasm for such systems.

3.2 Market Research Survey Conclusions

The market survey confirmed that the main areas of research in the project are of strong industrial importance. This means that the research project will cover the relevant industrial topics and will develop understanding in this area.

Firstly, the need for developing generic Product Structures / BoM's was confirmed by the results to questions 3 and 5. The use of categorised component variants was proved to be viable and desirable for industry by question 4. Investigation into the specific departments that could benefit from Product Structure / BoM access showed the potential for increased use.

The next group of questions were used to investigate and evaluate industrial demand for BoM data transfer methods. From the results it is clear that BoM data transfer would benefit most companies, and it would help to achieve effective PDM, CAPP and MRP system integration. Information covering the type of BoM data required for transfer was used to guide the research direction by addressing the relevant factors.

The final two questions investigate the demand and advantages of webcentric PDM systems. The results show that there is a good level of demand for webcentric systems but it also shows some companies are uncertain if any benefits will be gained. The most common expected advantage of webcentric PDM systems is ease of use, marginally ahead of remote access and independent data format.

4 Industrial Case Studies

In order to link the project research with current industrial problems, two case studies have been formed with industry. The work focuses on general data / information management problems within Matra BAe Dynamics Ltd. and Rolls – Royce – Military Aerospace Division.

Both organisations are investigating the use of PDM systems with a view to wide scale implementation. Rolls – Royce in particular has recently signed a large contract to purchase several hundred seats of a commercially available PDM system. Matra BAe Dynamics Ltd. has already begun using a PDM system but only in a closed local environment. The company aims to solve potential problems through the use of a pilot run before embarking on full implementation.

For the purposes of this project, the case study will concentrate on general long term strategy considerations, as opposed to specific current problems. The reason for this is because lack of time and resources would mean only a fraction of specific problems could be covered effectively. Investigation will focus on long term company objectives, general data / information flow problems, possible solutions and important factors to consider for the future.

The methods used to gather information from the companies were postal questionnaire and personal consultation sessions. The questionnaires were used to tackle specific issues whereas personal consultations were used to give a more general insight into the background, operational procedures and business practices of the company.

4.1 Matra BAe Dynamics Limited

Matra BAe Dynamics Ltd. designs, manufactures and assembles electrical products for use within military weaponry. The organisation uses CAD, CAM and MRP systems in full practice and is investigating the benefits and problems of PDM by using a small scale pilot scheme.

After consultation with company staff, several concerns were highlighted by Matra BAe relating to the use of PDM and the problem of co – existing PDM and MRP systems. Although MRP systems are widely used in the manufacturing department, widespread PDM system implementation has yet to take place. Despite this situation, Matra BAe are well aware of the problems of using both systems and as a result are investigating methods of managing the two systems when in place.

Matra BAe are aiming to extend access of BoM data to departments other than manufacturing and design. This is possible with many PDM systems including EDS Information Manager, the system chosen by British Aerospace and it's subsidiaries. The various BoM views can be manually built in the PDM system or the BoM data transformer proposed on Section 2.5 could be used for automatic view generation. This system could prove to be very beneficial for Matra BAe because of the large amount of product data that would require several BoM views.

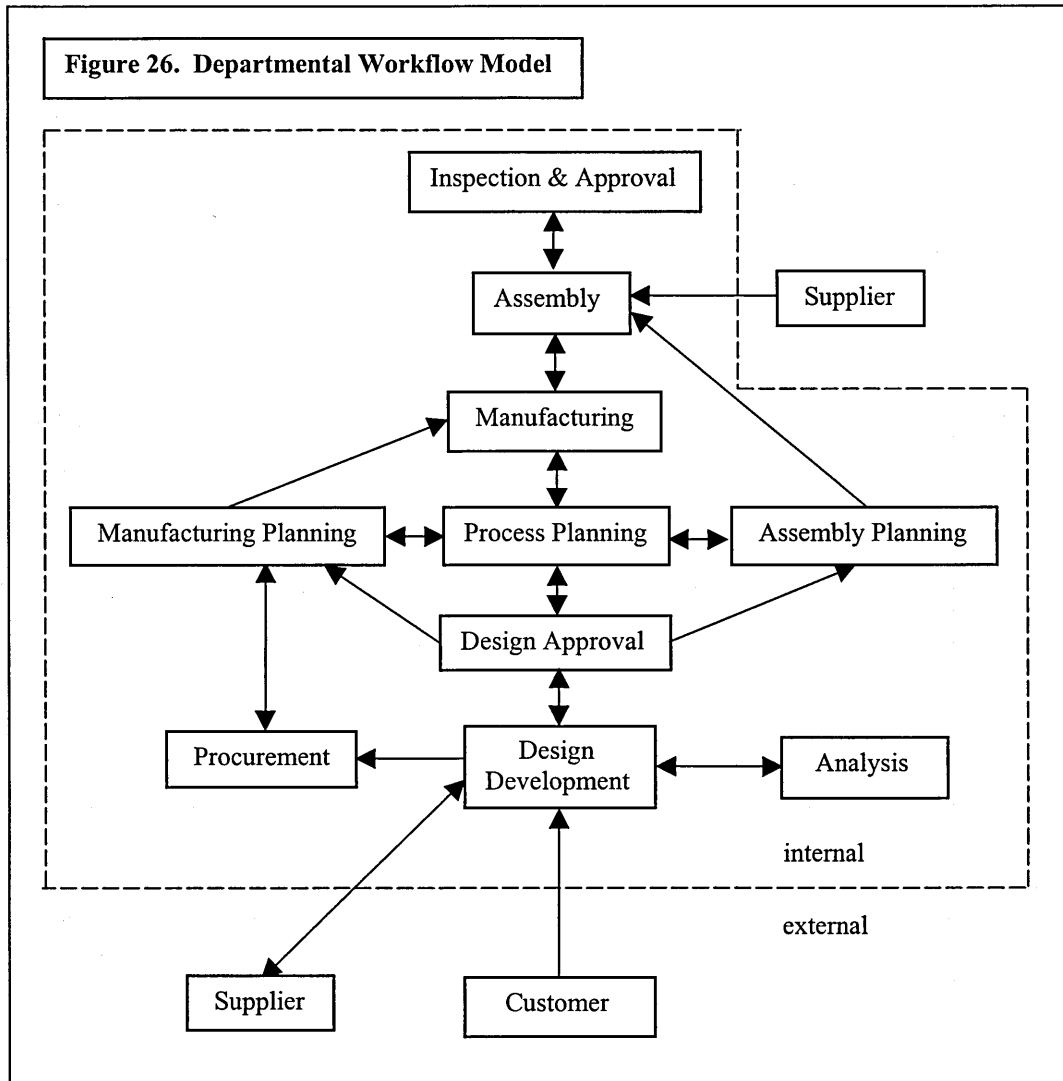
One important issue in this area is the ability to give generic Product Structure / BoM information to Matra BAe's main customer; Ministry of Defence. With the use of internet technology, PDM controlled data can be delivered to customers on remote sites. Improved data security means that information can be restricted to the relevant organisations or departments.

Workflow is another area that Matra BAe are keen to exploit, specifically for management and control purposes. With careful configuration, Information Manager can

be used to monitor and track all levels of workflow in an organisation. Workflow histories can be generated automatically for management review and audit trails. An important consideration when using electronic workflow functions is that automation will not necessarily improve the workflow procedures that are already in place. Analysis and improvement of workflow and operational methods is required before an effective electronic workflow model can be developed.

Another important area of research within Matra BAe is the integration of PDM and MRP systems. Matra BAe believe that using just one definitive BoM is essential, and therefore integration as opposed to interfacing is the objective. As already discussed, there are few PDM and MRP systems that are fully integrated but the aim of using one definitive BoM is achievable. A possible solution would be to store manufacturing data in text files that are linked to the BoM within the PDM system. This would involve the manufacturing department compiling process data and then adding it to the PDM database, ensuring that there is only one point of reference for product configuration information and manufacturing process details. The development of enterprise wide PDM systems, which have increased their coverage of manufacturing information, will also improve the flexibility of PDM based BoM data.

A long term objective of Matra BAe is to determine generic, structured development methods within their organisation. The reason for this is that Matra BAe experience long product life – cycles whereas technology development is very rapid. In order to overcome this problem it would probably be necessary to formulate a paper – based generic workflow model that could be transferred to any software that is in place. As mentioned earlier, this process requires careful and detailed consideration of current workflow methods and streamlining and improvements of processes. An example of a simple, generic workflow model is given overleaf.



Matra BAe clearly have opportunities for improvements concerning their data management problems. The current generation of PDM and MRP software require much work if the two systems are to co – exist, but effective bridges can be made. The use of different Product Structure / BoM views will allow all departments to access the information concurrently. Transfer of all BoM meta – data (part numbers, filenames) can be achieved by using database commands to isolate or select the necessary information.

Workflow procedures can be effectively modelled and managed using almost all PDM systems. This would give effective records of work history and current status reviews, both of which are important management tools.

To enable the long term goals of integration to be achieved, consideration should be given to recently developed enterprise wide systems as well as the effects of improved database technology (object oriented) and webcentric systems.

4.2 Rolls – Royce Military Aerospace Division

Roll - Royce Military Aerospace Division designs, manufactures and assembles the majority of parts for their military aerospace engines. Within the organisation there is extensive use of CAD, CAM and MRP software and there is also limited use of internally developed data management systems. Almost all components are designed, manufactured and assembled in – house, although some suppliers are occasionally used.

After discussions with manufacturing and design engineers several problems associated with their data management systems were identified. One major problem that was evident was the problems of long term archiving of data. Because the development cycle of new military engines lasts 10 – 20 years there can be enormous amounts of data generated. Rolls – Royce also aims to never start a new engine design from scratch, meaning existing designs are required for re – use or scaling. As a result, almost all existing data would need to be included within the data management system. PDM systems can be used to organise, record and manage such large projects although transferring all existing information to a PDM system is a enormous task. Despite this, Rolls – Royce aim to implement a comprehensive and widespread PDM system that encapsulates existing product data. Much of the information required is paper based so scanning would be used for transfer to an electronic format.

Rolls – Royce also has the objective of re – using 80% of the existing BoM for new engine designs. This means that current and redundant Product Structure / BoM data will need to be included in the PDM system. The majority of this information is paper based and can not be scanned into a PDM system's Product Structure / BoM functions. The only solution is to manually create the existing Product Structures / BoM's within the system. This will also be a long and complicated task, but because of the length of the product life – cycle the information will be available for reference for many decades.

Rolls – Royce will reap many benefits of having all their information stored in an electronic format within a PDM system. These include large reductions in data / work flow times and product data search times, both of which will bring significant cost savings on a large scale enterprise such as Rolls – Royce. The overall development and production life – cycle will also be shortened giving improved competitive advantage, an objective to which Rolls – Royce is strongly committed.

Rolls – Royce are involved in several major collaboration deals where they act as the supplier to several aircraft manufacturers. The relationship can be assisted by the use of extended networks such as the internet or intranet. This would enable the aircraft manufacturers to include relevant engine data in their data management system.

The biggest problem highlighted by the manufacturing department was the lack of comprehensive product representation information received from the engineering department. This information includes BoM data, CAM files, 2D engineering drawings, 3D CAD models, design responsibility and assembly relationships. It appears that there is a very segregated ‘them’ and ‘us’ environment which needs to be addressed before widespread PDM implementation is attempted. Although there are company defined workflow procedures, they fail to promote integration between design and manufacturing and as a result there is limited collaboration. The workflow model used by the company needs to be analysed and improved to the benefit of both departments and then built into the PDM system using structured approval and release procedures. The workflow model and workflow procedures must be understood and be readily available for both departments. To address the specific problem of lack of product related data, manufacturing managers need to define requirements and then request the information within the workflow procedures. This means specifying what information must be included for work to be approved and released by the engineering design department. To retrieve BoM data the manufacturing department will need access to the PDM system where the database can be interrogated for the required information.

Another major concern for the manufacturing department is poor approximation of manufacturing operations. There is definitely scope for greater use of CAPP software which will give accurate process time and cost calculations which can be used for machine scheduling. The bigger problem lies in the fact that Rolls – Royce manufacture components with complex curved surfaces. Calculating process times for such surfaces goes beyond the majority of CAPP systems, so estimations could be made using process test runs. Alternatively, Rolls – Royce may decide that investment in specialised CAPP software is justified.

One of the major areas of research within Roll – Royce is investigating the use of co – ordinate measuring machines (CMM's) to improve the accuracy of machining processes. CMM's will offer significant benefits to Rolls – Royce because of the number of manufactured parts with complex curved surfaces. By comparing the inspection geometric data with the 3D CAD model it is possible to highlight differences allowing errors to be easily identified. It has been suggested that it may also be possible to use the inspection geometry to update the CAD model and correct any problems. This proposition is proving to be difficult to realise but it is highly likely that a knowledge based or expert system will be required to help manage the correction decision process.

Rolls – Royce appear to have much to gain from improving their data / information management methods. With an organisation the size of Rolls – Royce it is inevitable that there will be major operational problems in some departments. Although the problems are managed and overcome, the use of PDM systems will greatly improve data sharing, data classification, archiving, workflow procedures and inter – departmental collaboration. In order to maximise the benefits of the PDM system and minimise the implementation problems the business model as a whole must be analysed and improved.

5 Conclusions

5.1 Product Structure / BoM Management

The use of Product Structures / BoM's has many potential benefits for engineering and manufacturing companies. By defining generic Product Structures, businesses can achieve comprehensive electronic definition of their product configurations. These generic structures can then be filtered to provide precise individual product configurations that can be used for specific projects.

As well as providing precise product configurations, Product Structures / BoM's can be re – structured to give relevant information for departments other than design development. This process is usually completed manually but the use of a rule driven data transformation processor can help to automate the task. The processor is implemented by extending the PDM system's relational database to include transformation rules. These rules can be grouped to give a complete Product Structure / BoM transformation for each relevant department.

5.2 BoM Data Transfer

To improve the automation of data flow between design and manufacturing software, methods of BoM data transfer were investigated. The most practical method currently available is to develop interfaces between the two systems involved. This involves interrogating the PDM database and extracting and delivering the required data. This process can be completed manually or by developing customised link programs to deliver BoM data.

To enable effective integration of design and manufacturing systems, the relevant software must be linked to, and use, the same database. This would ensure that there is only one BoM used for reference by all software and that data validity and integrity is maintained. There are very few commercially available integrated systems, but this is likely to change in the near future with the recent development of enterprise wide systems such as ERP and Enterprise PDM.

5.3 Emerging Technologies

Because of the current limitation in scope of PDM and MRP systems, software developers are releasing products that aim to cover the entire product life cycle. Although the first generation of enterprise wide systems do not effectively fulfill this aim, development will inevitably continue to produce full, enterprise wide software integration.

As well as increasing coverage of the product life cycle, recently developed PDM systems are utilising internet technologies. These systems allow remote access to PDM managed data through the use of intranets or the internet. This development will greatly enhance the benefits of PDM systems by allowing access of comprehensive product data to any person, department or organisation in any geographical location.

The use of object oriented database technology for PDM systems will bring many advantages for Product Structure / BoM management. Object oriented databases will improve part classification flexibility and also component assembly relationships, meaning large scale product BoM's can be managed and interrogated for data transfer.

5.4 Suggestions for Further Work

As a result of limited resources, the research project could not cover every relevant issue in sufficient detail. As well as this, the development of new technology requires constant analysis and evaluation. Because of these factors, suggestions for further research work are given below;

- 1 An investigation into the possibility of CAD model geometric data being transferred from CAD or PDM to CAPP software. This will enable full automation of process planning.
- 2 An investigation into the practical benefits of object oriented database management systems with respect to part classification, product structure definition and PDM / MRP integration.
- 3 An investigation into industrial benefits of, and problems with, Webcentric PDM systems. Specific issues in need of research are data security, data integrity, workflow and enterprise wide access to the PDM system.

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