Available online at www.sciencedirect.com
SCIENCE DIRECT®
Int. J. Production Economics 87 (2004) 251–266
international journal of production economics
www.elsevier.com/locate/dsw

Enterprise information systems project implementation: A case study of ERP in Rolls-Royce

Yahaya Yusuf[a,*], A. Gunasekaran[b], Mark S. Abthorpe[c]

[a] *Business School, University of Hull, Hull HU6 7RX, UK*
[b] *Department of Management, University of Massachusetts, 285 Old Westport Road, North Dartmouth, MA 02747-2300, USA*
[c] *Department of Mechanical and Manufacturing Engineering, Nottingham Trent University, Burton Street, Nottingham NG1 4BU, UK*

Abstract

Economic globalisation and internationalisation of operations are essential factors in integration of suppliers, partners and customers within and across national borders, the objective being to achieve integrated supply chains. In this effort, implementation of information technologies and systems such as enterprise resource planning (ERP) facilitate the desired level of integration. There are cases of successful and unsuccessful implementations. The principal reason for failure is often associated with poor management of the implementation process. This paper examines key dimensions of implementation of ERP system within a large manufacturing organisation and identifies core issues to confront in successful implementation of enterprise information system. A brief overview of the application of ERP system is also presented and in particular, ERP software package known as SAP R/3, which was the ERP software package selected by Rolls-Royce plc. The paper takes an in-depth look at the issues behind the process of ERP implementation via a case study methodology. It focuses on business and technical as well as cultural issues at the heart of the Rolls-Royce implementation. The case study also looks at the implementation time scales and assesses the benefits from the project both tangible and intangible.

Keywords: ERP; Information systems; Implementation; Success factors; Rolls-Royce

1. Introduction

The global nature of modern marketplace requires active players to internationalise their operations. In the past, companies were used to competing based on one or two competitive performance objectives such as price and quality. However, present markets demand both price and quality in addition to greater flexibility and responsiveness and thus today's organisations must compete based on all competitive objectives. In order to achieve such simultaneity in performance objectives, some organisations have decentralised their operations by global outsourcing of activities. This places enormous challenge on companies to achieve a co-ordinated and integrated supply chain. The emergence of various information technologies such as the Internet, electronic data interchange (EDI) and WWW facilitate the attainment of an integrated supply

*Corresponding author. Tel.: +44-1486466933; fax: +44-1482466216.
E-mail address: yahaya.yusuf@hull.ac.uk (Y. Yusuf).

0925-5273/$- see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2003.10.004

chain and in turn flexibility and responsiveness in meeting changing market requirements. Information systems such as manufacturing resource planning (MRPII) and enterprise resource planning (ERP) in particular have gained ground in providing support for achieving an integrated supply chain.

Firms around the world have been implementing ERP systems since the 1990s to have a uniform information system in their respective organisations and to re-engineer their business processes (Rajagopal, 2002). ERP system as a packaged software has the advantages of reduced cost, rapid implementation, and high system quality (Lucas et al., 1988). Although application packages have these benefits over custom design software, packaged software have problems of uncertainty in acquisition and hidden costs in implementation. Successful ERP implementation must be managed as a program of wide-ranging organisational change initiatives rather than as a software installation effort. Such IT-driven initiatives require change of the organisation's socio-economic system, which is intertwined with technology, task, people, structure, and culture. Thus organisational resistance to change is identified as a critical success factor for ERP implementation (Hong and Kim, 2002).

Organisational fit and adaptation are important to implementation of modern large-scale enterprise systems that are built with pre-determined business process methodology. As a result, customisation is a crucial, lengthy, and costly aspect in the successful implementation of ERP system, and has, accordingly, become a major speciality of many vendors and consulting companies. Gefen (2002) examines how such companies can increase their clients' perception of engagement success through increased client trust, that is brought about through respective and dependable customisation.

Considering the importance of ERP in SCM, an attempt has been made in this paper to analyze the implementation issues of ERP in a major UK company. The lessons learned from this company would be useful for other companies in their efforts to successfully implement modern ERP system.

2. Enterprise resource planning

In the 1990s innovations in information technology led to the development of a range of software applications aimed at integrating the flow of information throughout a company, and these commercial software packages were known as Enterprise Systems. During this period one particular enterprise system called ERP caught the attention of some of the worlds largest companies. It has been estimated that businesses around the world have been spending almost $10 billion per year on ERP systems. ERP aims to integrate business processes through the support of an integrated computer information system (O'Brien, 1999).

ERP allows the corporate management of a business, and aims to integrate individual functional systems such as manufacturing, finance, procurement and distribution. The systems allow companies to replace their existing information systems and also help to standardise the flow of management information and have been regarded as the next step in the evolution of MRPII. The MRPII model actually forms the basic core of ERP and uses similar modules, however some ERP systems do contain certain modules that were not originally used within MRPII such as computer aided design (CAD), distribution resource planning (DRP), tool management systems (TMS), and product data management (PDM) (Yusuf, 1998; Prasad et al., 1999).

ERP uses Internet technologies to integrate the flow of information from internal business functions as well as information from customers and suppliers. The system uses a relational database management system, within client/server network architecture, to capture valuable management data. The key principle behind the system involves entering the data from a series of modular applications only once. Once stored, the data automatically triggers the update of all related information within the system. The systems can support virtually all areas of an organisation, across business units, departmental functions and plants. The development of an ERP system within a large manufacturing organisation requires the integration of working practices and the

information systems (Davenport, 1998; Mandal and Gunasekaran, 2002).

Companies that use ERP can gain a competitive advantage from the way they implement the system and then exploit the resulting data. Many companies that have installed ERP have claimed to be more nimble within the marketplace than their competitors with hard-to-change custom made systems (Latamore, 1999).

ERP systems offer companies the following three major benefits:

- Business process automation.
- Timely access to management information.
- Improvement in the supply chain via the use of E-communication and E-commerce.

A vital task when implementing an ERP System is to understand the difference between functions and modules. Functions are defined as actual physical tasks that are performed within a company. Whilst modules can be considered as pieces of software that help to provide the functions, different ERP vendors have different modules that perform the functions. The enormous growth of the Internet and Microsoft Windows packages, complementary as they are as collaborative tools has made the argument for ERP more compelling (Loizos, 1998). It is now a general industry view that ERP will take them to new heights of efficiency by enabling them to move financial and other data speedily from one department to another (Holt, 1999).

Companies have spent billions of dollars and used numerous amounts of man-hours installing elaborate ERP software systems. The ERP software vendor market has experienced rapid growth in the late 1990s. In 1998 there were five major software vendors offering ERP solutions to businesses worldwide. The largest of these was SAP AG (http://www.SAP.com) who earned over $5 billion in revenue. The Oracle Corp. was the second largest with $2.4 billion in sales. Followed in third place by PeopleSoft (http://www.Peoplesoft.com) who earned $1.3 billion. In fourth place was J.D. Edwards with $979 million. And finally in fifth place was the Baan Co. (http://www.Baan.com) with $743 million in sales (Holland and Light, 1999).

Van Stijn and Wensley (2001) focus on problems that may arise after ERP systems have been implemented—the in-use phase. Various problems have been identified regarding the ERP systems in-use. Because of the organisational unwillingness or inability to make technology upgrades (Markus and Tanis, 2000), the enterprise system may take on the appearance of a legacy system in disguise.

3. Implementation of ERP

ERP when successfully implemented, links all areas of a company including order management, manufacturing, human resources, financial systems, and distribution with external suppliers and customers into a tightly integrated system with shared data and visibility (Chen, 2001). Potential benefits include drastic declines in inventory, breakthrough reductions in working capital, abundant information about customer wants and needs, along with the ability to view and manage the extended enterprise of suppliers, alliances and customers as an integrated whole (Escalle et al., 1999).

The term ERP stands for enterprise resource planning, however it is not good enough to just plan resources required to run the enterprise, they need to be managed as well. An organisation must assess itself, to see if it is ready for ERP. It must determine if it is ready for the competitive business environment of today and then strengthen its position for tomorrow's changes. Some of the companies that implement ERP systems do not realise the full benefits that the system offers because most organisations are not organised in the correct fashion to achieve the benefits. Many companies that attempt to implement ERP systems run into difficulty because the organisation is not ready for integration and the various departments within it have their own agendas and objectives that conflict with each other (Langenwalter, 2000).

While companies such as Cisco Systems, Eastman Kodak, and Textronix have reaped the expected benefits of ERP systems, many businesses are discovering that their ERP implementation is a nightmare. FoxMeyer Drug, a $5 billion

pharmaceutical company, recently filed for bankruptcy (Al-Mashari and Zairi, 2000; Chen, 2001). Dell Computers spent tens of millions of dollars on an ERP system only to scrap it because the system was too rigid for their expanding global operations (Trunick, 1999). ERP implementations involve, in truth, broad organisational transformation processes, with significant implications to the organisation's management model, organisation structure, management style and culture, and particularly, to people (Wood and Caldas, 2001).

ERP software is very adaptable but not very malleable and companies that wish to use them correctly have to change their working practices to fit the software. The key factor of an ERP implementation is the way in which the software is configured. The most important issue to identify before an implementation is the 'core' of the business, which can be identified by the use of the business model (Chung and Snyder, 2000).

One original motive for buying an ERP system was to automate business processes, but the modern view has shifted to the quick access of up-to-date and timely management information. The majority of difficulties experienced by ERP implementations have been the costly development of additional software to help 'bridge' or retrieve information from legacy systems. Before ERP management reports can be generated and distributed to managers, the data has to be created first which can be a costly and inefficient process. In an attempt to improve the timeliness and accuracy of management data, many software vendors are making end-users responsible for updating their own information rather than relying on IT resources.

ERP software consists of a number of modules that link together to form a complete business solution, however the main difficulties experienced by ERP users have been in manipulating the data stored within the system. Software developers have begun to address the need for additional information tools. Some of these tools include the need for detailed and advanced planning and advanced scheduling and customer relationship management. Abdinnour-Helm et al. (2003) discussed the pre-implementation attitudes and organisational readiness for implementing an ERP system. Huang and Palvia (2001) analyze the ERP implementation issues in advanced and developing countries. Umble et al. (2003) presents the empirical findings on implementation procedures and critical success factors for ERP. Van Stijn and Wensley (2001) address some concerns, methods and directions for future research on organisational memory and the completeness of process modelling in ERP systems.

Most ERP software vendors supply their customers with an implementation programme as part of an overall solution package. For example SAP provides some of its customers with accelerated SAP (ASAP). ASAP suggests the adoption of a 'big bang' implementation. This programme opts for a quick implementation that is specifically designed for small and medium sized companies. 'Big bang' implementations offer lower costs and generally use only a few of the software's interfaces; however the risks are greatly increased as less time is spent on development and assessing business needs. There are several more papers on ERP implementation and some of the most recent ones include Mabert et al. (2003), Olhager and Seldin (2003), Umble et al. (2003) and Wood and Caldas (2001).

4. Systems, applications and products in data processing

Five former IBM employees originally founded systems, applications and products in data processing (SAP) in Mannheim, Germany in 1972. Their aim was to produce standard software application programmes that could integrate with each other to form a business solution. SAP has been dedicated to produce products that improve the return on information gathered by an organisation. The company began its life with the name 'Systemanalyse Und Programmentwicklung' and eventually became known as SAP.

SAP's first product known as R/2 was built and prototyped for a subsidiary of ICI. The system they produced was simply known as system 'R', which stands for 'Real-time' processing. This system was fully integrated and could be used on the IBM mainframe. The R/2 solution was

launched in 1979 and was developed for a computer mainframe environment, at the time it was perceived as the most comprehensive system available to businesses in the world, and it received great interest from industries in the 1980s.

SAP saw the future potential for the delivery of information to the end-user via the PC, so SAP reinvented and developed their product further by developing a business solution for the client/server architecture environment, this became known as R/3 and was released in 1992. In the 1990s SAP and its R/3 solution would go on to become the dominant ERP solution, and also become one of the worlds biggest software houses.

SAP R/3 applications are a range of software modules. They can be used either alone or combined to form business solutions. SAP state that their R/3 applications offer comprehensive functionality for all standard business needs within an enterprise. SAP R/3 uses a programming language called advanced business application programming (ABAP).

The following are SAP R3's 12 application modules: financial accounting, treasury, controlling, enterprise controlling, investment management, production planning, materials management, quality management, project system, human resource management, sales and distribution, and plant maintenance and service management.

5. Rolls-Royce—case study

In this section, a case study conducted at Rolls-Royce investigating the implementation of ERP (SAP) is discussed. The case study starts with introducing the company and its background, presenting the status of IT before and after the implementation of SAP, and giving the detail chronological phase of the implementation of SAP in Rolls-Royce. Also, the research methodology is discussed. The implementation of SAP in the company and project risks is presented.

5.1. Company background

Rolls-Royce returned to the private sector in 1987 and acquired Northern Engineering Industries in 1989. This acquisition allowed Rolls-Royce to consolidate its capabilities in the area of industrial power. A further acquisition was made in 1995 when Rolls-Royce bought the Allison Engine Company in the United States, thus enlarging the company's presence in aero propulsion and industrial gas turbines. The acquisition allowed Rolls-Royce a major foothold within US markets. The most modern family of engines is the Trent series, which are also powerful three-shaft turbofan engines similar to the RB211, and are used to power the Airbus A330, A340-500/600. The Trent series of engines offer greater thrust, long range flight capabilities and economical operating and maintenance costs. The Rolls-Royce Power Generation Market includes both electrical and nuclear power, which also includes marine applications, such as providing power plants for nuclear and naval vessels. Rolls-Royce is a truly global business offering a range of first class-world leading products. It has facilities over 14 different countries and also offers first rate after sales services, covering mechanical overhauls and spare part distribution. In March 1998 a new organisational structure was adopted that recognised the strategy and the need for change to reflect customer requirements.

5.2. The situations before ERP

Rolls-Royce used over 1500 systems before the ERP project was started, many of which were developed internally by Rolls-Royce over the last two decades. These legacy systems were expensive to operate and difficult to maintain and develop. They did not provide accurate, consistent and accessible data that was required for good and timely decision-making and performance assessment (e.g. delivery performance, quality metrics). These ageing systems often did not lend themselves fully to a modern manufacturing environment. Some of the legacy systems were so old that they had year 2000 compliance problems. Work within Rolls-Royce was functionally orientated and various departments worked in isolation.

The last major manufacturing system to be developed and implemented by Rolls-Royce was MERLIN, which stands for mechanised

evaluation of resources, logistics and inventory, the system was basically a scheduling system which ran on MRPII system principles. The system was developed in the 1980s and, although it was capable, it was prone to manual manipulation. One particular down fall of the system was the lack of communication between individual sites. MERLIN often had difficulty communicating with another manufacturing system named IBIS, which stands for inventory based instructing system. IBIS was an older manufacturing system that was used at the Bristol and Ansty facilities. Work in progress was often transferred between sites and could not be tracked accurately, often causing inventory and stock take problems.

An additional system named corporate cost accounting (CCA) was used to financially monitor transactions, which covered pipeline inventory and inter-site transport. Rolls-Royce also had a range of individual systems for controlling and monitoring commercial, financial and procurement functions, these systems had problems interfacing with each other, as they had different databases and file formats. The legacy systems did not allow Rolls-Royce to establish direct, on-line communication with customers, partners and suppliers. In fact, these systems did not support significant growth of the business and were not sufficiently agile to keep pace with the changing business environment.

5.3. IT at Rolls-Royce

In 1996 Rolls-Royce formed a partnership with electronic data services (EDS). The Rolls-Royce IT department was outsourced to EDS, which meant that EDS were responsible for the development of the company's IT systems as well as taking over the existing structure and providing adequate IT resources. This move was made in order to allow Rolls-Royce to concentrate its efforts on its main area of expertise—the making and selling of aero engines. Rolls-Royce decided that a partnership with a world leading IT outsourcer would benefit the company far more than designing and maintaining their own IT systems. EDS were chosen because of their substantial experience within the aerospace industry. EDS also had the responsibility for employing specialist consultants.

In 1998 changes were made to flatten the structural hierarchy. The customer focused business units (CFBU) were made responsible for making sales deals within the various market segments. Whilst the operational business units (OBU) formed the manufacturing support for producing the product, the Executive Group controls the whole business and makes decisions on the overall direction of the company.

5.4. The implementation project

The ERP project consists of a management team of specialists from the external outsourcing company EDS. EDS also have the specialised talents of SAP consultants. Within the project team are specialist internal managers and staff that have vital knowledge of cross-functional business relationships and experience of the old internal systems. In conjunction with this team each OBU has its own ERP planning team, which is responsible for implementing working changes and training. The project implementation problems can be grouped into three areas of cultural, business and technical difficulty.

5.4.1. Cultural problems

The implementation project team expected a high acceptance of the system in areas that provide just as good or better functionality than the old system. However some functions and processes might not get the full appreciation the legacy systems once had. The project team decided to resolve this by illustrating the improvements made to the company as a whole, thus breaking the traditional segregation of OBUs and departments. The original implementation plan was increased in an attempt to address training and cultural changes. Training took the form of organised seminars, which were split into two distinct groups of specialists and mass users. The specialist training was carried out and conducted by SAP and was technically based. These specialist experts then in turn trained expert users. The remaining training for end-users was conducted internally in collaboration with EDS consultants. The training carried out within the seminars was supported by demonstrations within the workplace, along with

information meetings and presentations to relay information to all employees about the changes of working practices. In all, more than 10,000 people would have been trained.

5.4.2. Business problems

SAP R/3 requires a fairly rigid business structure for it in order to work successfully. The participants of cross-functional workshops soon understood that their working practices must be adjusted in order to fit SAP, ultimately changing the way Rolls-Royce does business. They achieved this by using an internal business process re-engineering (BPR) programme. The programme consisted of four steps, the first involved drawing and mapping the current processes. The second step involved identifying any problems or issues raised from the mapped process. The third step involved applying some of these issues to a demonstration of SAP to identify potential problems within the new system. The fourth step involved the re-mapping or modification of the processes in line with SAP. The modifications to the Rolls-Royce business process meant that the SAP R/3 software need not be modified. Modifications to the software would have been extremely expensive both in terms of implementation resources and the fact that newer software versions would be difficult to install in a modified system. SAP named this unmodified software implementation 'Vanilla SAP'.

5.4.3. Technical problems

The main technical problems that Rolls-Royce has encountered have been with the accuracy of data. The new system requires the retrieval of old data from the legacy systems that has to be normalised, screened and stored in a sensible data format within the new systems data repository. The duplication of data was a major concern that Rolls-Royce had to address. In some special areas the old systems was kept running until such time as they could be phased out by the new systems, and to do this EDS built interfaces between the systems. The CAD system used by Rolls-Royce remained the same, as the process to alter the file formats would be too expensive and require use of valuable resources that are needed for the core implementation.

Rolls-Royce has nine principal business processes, which when taken together describe everything the company does. Fig. 1 is a schematic representation of the business processes and the interfaces.

Rolls-Royce decided to adopt and utilise the SAP solution offered for the aerospace and defence industry. The SAP aerospace and defence industry solution is the market leader in its

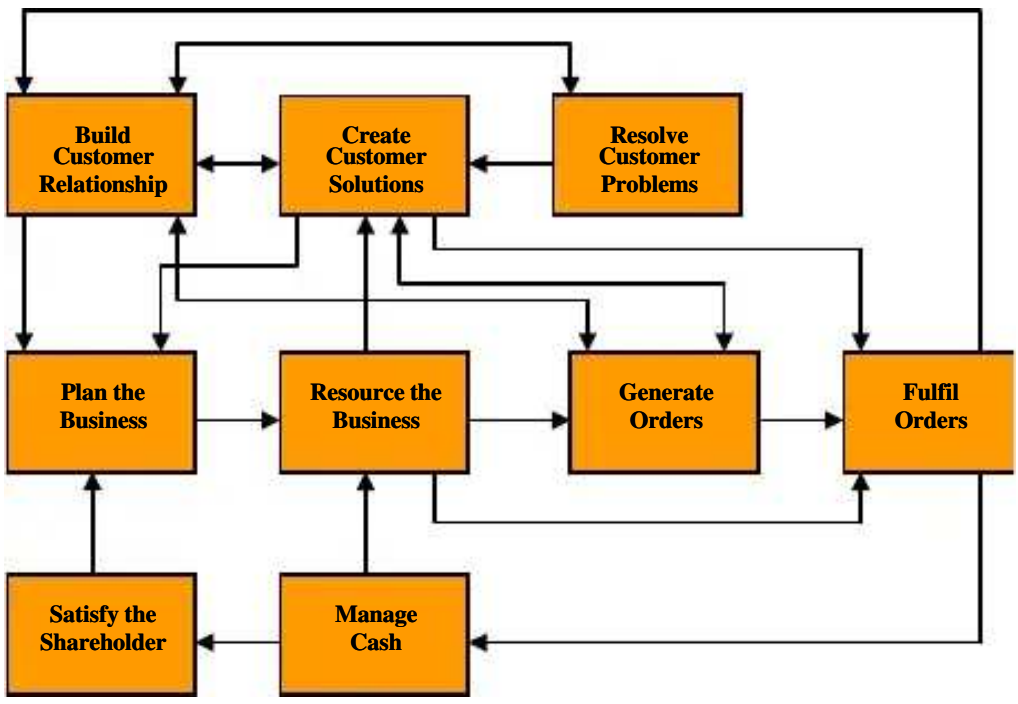


Fig. 1. Business process model.

industry and is highly configurable for flexible 'vanilla' implementation. Predetermined implementation points from the Rolls-Royce Steering Committee and Implementation Team defined the release strategy for the project. Any future third party software products must first be accredited by SAP to safeguard the upgrade process and would require a justified business case. Business reports that are generated by SAP have to be fully justified in a business case, which follows a standard format for internal use. Data entering the project has to be identified, validated, cleaned, loaded, archived and then maintained within a Data Warehouse.

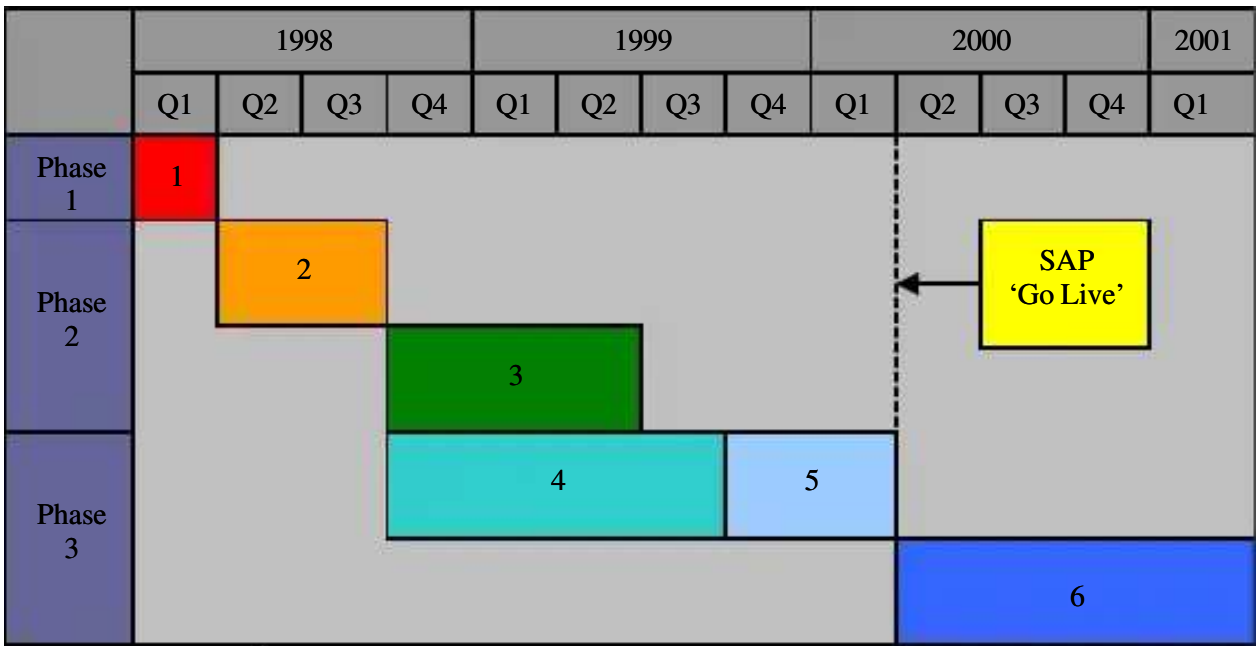
Rolls-Royce have estimated that over 1000 additional PCs will be required and the total cost for the network infrastructure was about two million pounds. The company required over 6000 SAP licences for users across all the business. The server was provided by Sun Microsystems and in excess of 2 Terabytes of disk space. The system required almost 35 weekly MRP runs cascaded by plant. A UNIX server bridges the data from legacy systems and testing and training required an NT server. The detail implementation model plan with project time-scale is shown in Fig. 2.

5.4.4. Phase 1 (strategy and direction)

The first phase of the project was a short intensive study to set the scope of the project and provide an outline plan and costing. A steering committee was formed to administer the financial guidance of the project and a 'ERP Core Team' was formed to control and oversee the actual implementation process.

5.4.5. Phase 2

During the second phase a detailed plan was created and a prototype system was installed. An



	Key	
Phase 1	1	Strategy & Direction
Phase 2	2	Planning Analysis & Convergence
	3	Early Deployment
Phase 3	4	Wave 1 – Focus on Operations
	5	Wave 1 – Pilot
	6	Wave 2 – Focus on Assembly & Spares

Fig. 2. ERP implementation model with project time-scale.

enterprise model was developed based on the Rolls-Royce Allison model, and all the existing projects within Rolls-Royce were drawn together and merged. Many issues were addressed including the integration of Better Performance Faster (BPF) initiatives. A series of workshops known as 'High Level Process Confirmation Workshops' took place, which involved over 200 line personnel and the ERP core team, and took into consideration the various business processes within the scope of the project. These workshops were closely followed by 'Business Simulation Workshops', which involved approximately 300 line personnel and were used to forge a strong relationship between the ERP core team and line personnel and avoid possible pitfalls, such as initiative fatigue or lack of co-operation. Activities carried out during the second phase of the project included:

- Preliminary design review—developing a design and implementation strategy, defining the scope of the project, and developing the business process model.
- High level design review—analyse the enterprise model, and develop 'Vanilla' prototype.
- Critical design review—detailed design and customisation of the prototype.
- Implementation realisation—integration testing.
- Technical/operation review—user acceptance testing.
- Post implementation review—system deployment, systems conversion, user training before the 'Go Live'.

During phase two the projects core structures were identified. Integrated programme management (IPM) was also adopted for research and development and would eventually cover the whole business. Additional activities included the support of finance and staff work booking. Phase two was completed at a cost of £5.2 million, within two weeks of the plan.

5.4.6. Project changes

During phase two a significant change was made from the original timing of phase one, the completion of wave one was deferred for about 6 months. This has resulted in a knock-on delay to wave two by a corresponding amount. The change in schedule was possible without a significant increase in cost because the problems were addressed early enough in the programme. There were four main reasons for the change:

- To give the line organisations more time to prepare, train and clean up data.
- To provide an additional 5 months period for pilot running and early development of the system.
- To provide additional time for the completion of other pre-requisite projects being managed by BPF. Specifically the deployment of product data manager (PDM) and shop floor data manager (SFDM) on which SAP is critically dependent.
- To provide additional time for resolving difficulties with successful use of SAP at RR Allison.

5.4.7. Phase three (implementation)

This phase was too large to implement in one go, and thus was divided into two 'waves'. Both waves were concerned with the physical implementation of the system and its architecture. The waves were also concerned with changing working practices within the company.

5.4.8. Wave one

This wave was concerned with the replacement of legacy systems. IPM was also introduced for new production projects during wave one. The new manufacturing execution system, known as shop floor data management (SFDM) was also introduced during wave one. The ultimate end to wave one was a SAP pilot project at one of Rolls-Royce facility. The pilot laid the foundation for the full 'go live' throughout the company about a year afterwards. The first wave had the ultimate aim of providing new capabilities for gas turbine operations.

5.4.9. Wave two

The second wave was approximately 1 year in duration, and was not operational until after the

first wave finishes. The second wave was concerned with implementing engine assembly, spares, logistics and human resource elements within the project. By this time the legacy systems was switched to 'view only' as SAP becomes the executive system. Once the new system shows a positive response the older systems was phased out. IPM completely covered the whole business by the end of the second wave.

5.5. Changes to the existing system

During phase two, modifications were made to the legacy systems. These modifications were adopted in a series of suites.

5.5.1. Suite 1

Plan the supply chain: This takes place as part of the corporate business planning activity with a 2–5 year horizon. A review was undertaken of all potential future sales, including engines and spares, identifying the probable minimum and maximum levels. The supply chain capacity was compared to the range of possible sales scenarios.

Master schedule key programmes: Suite 1 supports the sales and operating review board (SORB), which is a director level meeting, which strategically plans engine sale and factory capacity on a 2–5 year rolling forecast. The SORB makes decisions affecting changes to achieve capacity in terms of manpower, machines, technology, and ultimately for factories to meet the potential sales forecast. The SORB process has often been referred to as the 'Evaluation and Commitment Acceptance Program'. The SORB meet every 3 months to decide what has to be made and when. The SORB records baseline data from the previous meeting and then identifies new changes. For example if 20 engines were required last, it does not necessarily mean that 20 were actually built, a particular manufacturing unit may have had machine breakdowns, which could have effected the amount of work leaving the factory. A copy of the plan gets taken from the Project System module within SAP and then the new requirements are input into an inactive version of the SAP module Demands Management. This copy can then be used in 'what if' simulations before finally being transferred to the master copy as the latest SORB.

5.5.2. Suite 2

Plan and schedule the factory: This converts the agreed schedule from suite 1 into a production plan and enables all the manufacturing units to plan capacity to produce the required components. The production plan may include schedule smoothing. Schedule smoothing is a process, which converts erratic customer requirements into a consistent production plan that allows the facility to operate efficiently on a regular pattern. The operations businesses will have the responsibility of holding excess inventory that is created by schedule smoothing.

Schedule the shop: This converts the production plan into a detailed shop plan. It generates when to launch material (either raw material or part-finished details) onto the shop floor, and when the material should meet identified stages of the manufacturing process.

5.5.3. Suite 3

Operate the factory: Suite 3 covers the control of workflow through the shop from the initial generation of launch paperwork, right through to delivery of finished products. It gathers information on the booking of work at identified stage points in the manufacturing process, and collects operating data for cell level management. It controls inventory between the manufacturing units and controls the flow of components through the make process. Once SAP has become executive these suites will be replaced by SAP modules and SFDM, which will handle and perform these tasks.

The complete systems architecture for the project is extremely complicated, however for the purpose of this discussion a brief overview can be seen in Fig. 3. The core business operations are supported by SAP and integrate with other strategic software products (highlighted in brackets). Rolls-Royce are using 11 out of 12 SAP modules. They decided not to use the plant maintenance module as they already have an adequate system called MAXIMO (Fig. 4).

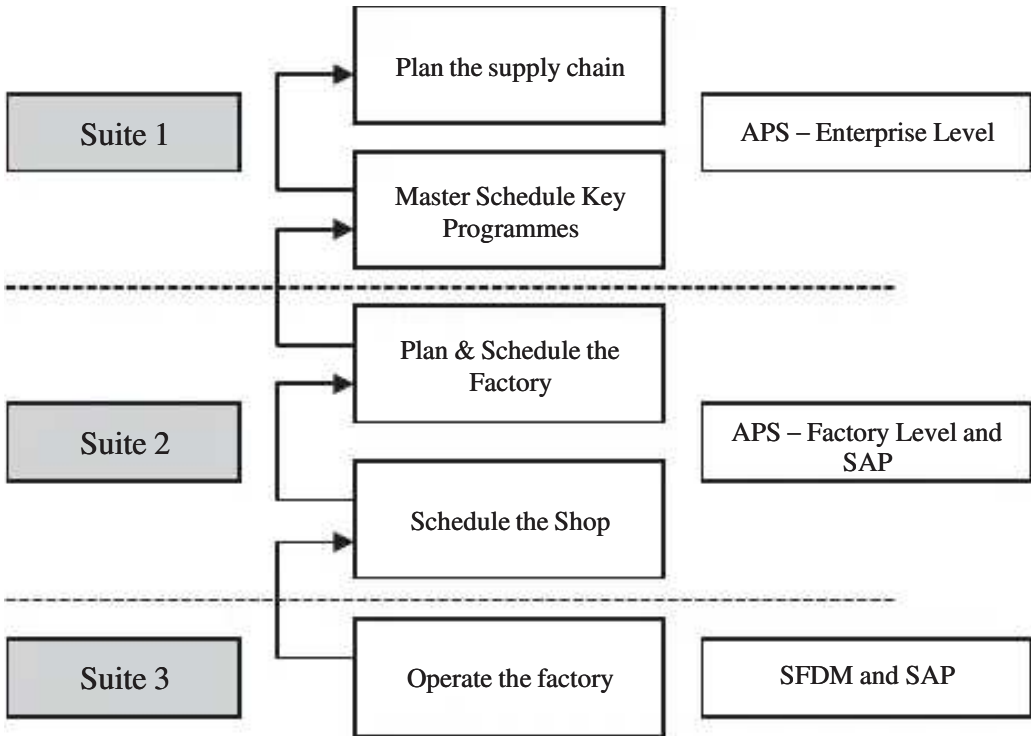


Fig. 3. The five box diagram of suite implementation.

5.6. The ERP pilot

A small-scale pilot of the system was run for 3 months and throughout this period, a facility known as number 4 shop, which was part of the transmissions and structures operations unit became the central focus of attention for the whole company. This facility was chosen for the pilot run because the facility only produced 280 parts, and material flowed into the facility at low volumes from external suppliers and internal operational units. The purpose of the pilot was to demonstrate:

- business principles;
- processes;
- procedures;
- role definitions and behaviours;
- software, hardware and data transfers.

> "We initially looked at over 1000 part numbers, identified which ones had a schedule against them, its the ones that have a schedule that we did the data clean up on, which came down to 280 part numbers. If we had to do it across the 1000 part numbers we would never have got it finished. For each part number there are around about 30/40 operations, there had been 7 of us working full time on it, that's included Saturdays and Sundays as well!"—Core Implementation Team Member (a).

The implementation of ERP has created two new roles at Rolls-Royce, these key roles were:

- MRP controllers;
- Capacity owners.

> "We had to go through symmetric tests, aptitude tests, interviews, it was quite daunting really, I mean to think that here I am, quite settled but I've got to make these moves. I'm told that I've got to spend X amount of time around a PC, it's a bit strange as I must spend around 80 percent of my time on the shop floor to day, and that's going to change dramatically. I will own the men and machines, the capacity …"—Core Implementation Team Member (b).

> "An MRP Controller is going to be in charge of the inventory, and getting the raw material in, and talking to the supplier and the customer. But they've also got to release the material to the shop floor, and then release the material when its finished as a component to the customer."—Core Implementation Team Member (c).

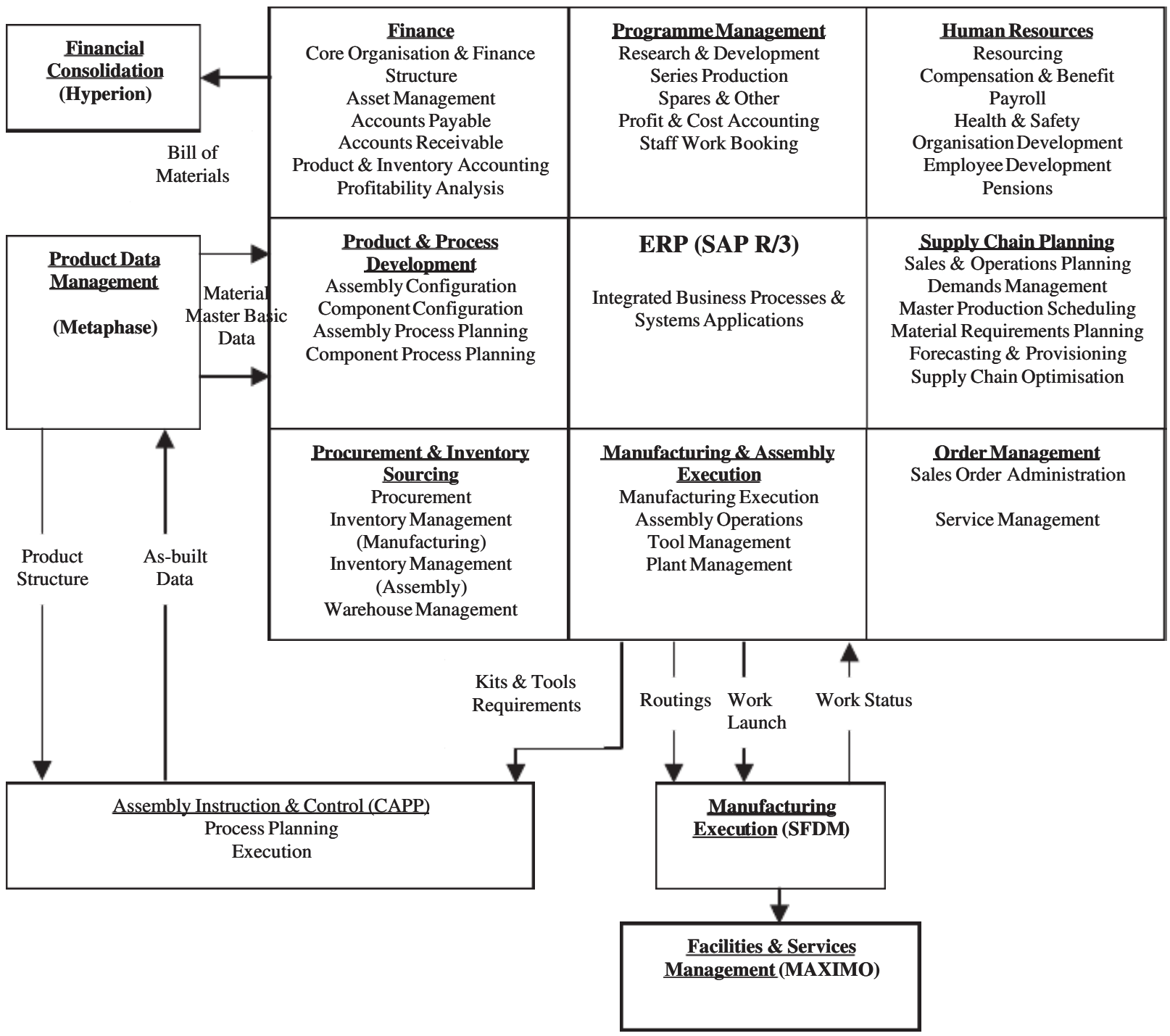


Fig. 4. Systems applications architecture overview.

MRP Controllers and Capacity Owners were sent on a residential behavioural course for 2 weeks and for most of them this was their first glimpse at how they would be working in the future.

> "We've got 20 users at Ansty, in the pilot and to connect those users we've had to install a lot of fibre network throughout the Ansty site. Its such a huge task of delivering the infrastructure, that's the reason why people have been so frustrated, saying things like, I go live in 4 weeks and I haven't got a piece of kit yet! Once they've been trained and know how to use that piece of kit they will have it there and then. The second thing to bear in mind is to really understand what roles the user is going to play in the pilot. This is to ensure that we have the right access permission correctly set-up for the user so they can use SAP correctly."—Core Implementation Team Member (d).

Systems testing and getting the user to accept the system were important roles undertaken in the

pilot. The following quotes give some insight:

> "Before the system can go-live the team needed to check that it works properly in their operational environment. User acceptance training is all about buy off, we're trying to make sure that the ownership is with the business not the core team. They have to say we're happy!"—Core Implementation Team Member (e).

> "I thought that when we first started the programme it would be pretty black and white, finishing the unit testing, starting the integration testing, starting the user acceptance testing, its not that simple! What you have are different bits of either configuration or bridges that you have to phase in at different parts of the testing cycle. They cannot be missed but they cannot be finished in time to say, I've finished all unit testing, I've finished all integration testing its actually quite blurred."—Core Implementation Team Member (e).

Loading clean data into the new system also produced many difficulties. The following quotes give some insight:

> "Its not until you actually try and load the data, get the data in the system and then hopefully let it feed into SAP that you really start to understand that things aren't quite right. We've lost something like a week and a half so far trying to get the bill of materials into metaphase and then feed them into SAP."—Core Implementation Team Member (e).

> "We are going to load into SAP about 2 percent of the part numbers that we would actually load in wave one, and we are finding it incredibly difficult!"—Core Implementation Team Member (d).

The initial problems experienced on 'going live' were:

- User authorisation problems, such as, password and user level clearance.
- Work was temporarily halted on the shop floor, as route cards were unavailable.
- Values between the systems were incorrect, so comparisons were made on the values from the legacy system with those on the new system, such as inventory levels and WIP.
- Transaction problems occurred from the first MRP run, so comparisons were made, between the old and new systems, and corrections were made.

A second pilot was also carried out for non-production purchasing. The second pilot ran executively, covering Derby-based purchasing of ground support equipment. A third pilot also was run by the Airline Business. The third pilot was non-executive, but designed to specifically explore the interplay between Metaphase PDM and SAP.

5.7. The 'Go Live

As the main 'Go Live' of the new system was planned, the most difficult part of the cut over process was in transferring the data from legacy systems. The shear volume of data that has to be transferred is far greater than any normal transaction load that will be carried out by the system thereafter. In order for this process to be successful the data must be kept in a 'stable' state for a period of roughly 10 weeks. The initial data to be transferred includes some transaction data and master data, for example, lists of suppliers. If any changes occur to the data on the old systems after the transfer, they are logged and then passed through to the new system. The remaining data was loaded in after the 'Go Live'.

The next step during the 'Go Live' process involved running the MRP system to initialise the whole system. Purchase orders and purchase requisitions was not transferred from the old system, instead the MRP run should create them fresh. The whole 'Go Live' process took roughly 2 weeks to complete, and during this time the new system was 'off the air'.

Immediately after the 'Go Live' the existing legacy systems was switched to view only mode. The view only mode enabled comparisons to be performed between the old and new systems. However, the legacy systems ceased to be executive.

5.8. Project risks

The ERP Project at Rolls-Royce covers many different departments and many different topic areas, all of which have associated risks. In order to address and take positive action to avoid failure or potential errors the ERP implementation team maintained and recorded in a great detail, a risk register. Every issue within the company, which involves risk has been catalogued and continuously reviewed. The risk register is very large, however the Rolls-Royce ERP Intranet page offers a brief summary of some of the major risks:

- The possible failure or inability to align goals through conflicting directions within the organisation.
- The non-delivery or non-availability of reliable IT hardware and infrastructure both before and during implementation.
- The possible failure of providing inadequate and ongoing support after implementation, from both Rolls-Royce and EDS.
- The resistance of change to new process methods by management and supervision.
- Management and supervision may treat the project as merely an IT implementation, rather than change in process methods.
- Inadequately educating the workforce to operate the new system properly.
- Possible failure to cut over to the new system through an inability to load data.
- Possible failure to cut over to the new system through the inappropriate systems testing of volume, stress and data conversion.
- Possible failure to give ERP adequate priority due to the number of existing and ongoing business improvements.
- Maintenance difficulties may occur on bridged legacy systems.
- The project may impact on company interim and end of year accounts.
- The PDM project may not be sufficiently positioned in time with the ERP project.
- Possible changes to kitting demand during ‘go live’ may stretch the new system and those operating it on a learning curve beyond capacity.
- The decision to implement Wave 1 separately from Suite 3 may fail to integrate the new systems.
- Airline Business After-sales may not be able to analyse and manipulate inventory investment in stock target groups (MERLIN functionality which helps to control forecasting for Airline Spares stock targets will be removed in Wave 1).

6. Summary and conclusions

Rolls-Royce has a large complex business process and the project has had to assess the effects throughout the whole business, which is equivalent to ten medium sized companies pulling together as one. This has caused administrative difficulties, particularly in the first phase of the project, whilst setting the strategy and overall direction. Rolls-Royce decided to make these radical changes to their business, in response to increased orders from the market place, and also from the fact that ERP has become a standard solution world-wide within the Aerospace and Defence industry. The introduction of SAP R/3 at the facility in the USA was a major factor in influencing the UK implementation. Rolls-Royce produce a range of quality world class turbine engines, and have recognised that they must change in order to compete effectively with their competitors. Accurate information systems and direct communication with suppliers are vital when offering customers a committed promise to deliver.

Rolls-Royce has understood the business, cultural and technical difficulties of such a large project, and has developed a solid core implementation team. The team has used the specialist skills of consultancy specialists. The partnership with EDS has produced a sound architectural framework for the project, thus allowing Rolls-Royce to concentrate its efforts on manufacturing turbine engines. A project of this size would never run smoothly and difficulties have occurred throughout the implementation and will no doubt occur in the future. The company have taken a different approach to IT systems but have not let the project

become just another IT system. The core implementation teams have taken into account the needs of both the managerial and end-user. The following list contains just some of the problems encountered:

- Matching the process to the software configuration.
- Training people to accept change, and getting them to do business in a totally new way.
- Teaching employees to use modern IT equipment.
- Equipment not delivered on time, or delays in technical equipment installation.
- Data clean up has been particularly time consuming as many legacy systems have been involved.
- Training the behaviour of SAP users such as MRP Controllers and Capacity Owners.

Many activities have taken place, which have been vital to the overall success of the project, such as:

- Bridging the legacy systems and cleaning up suspect data has given the company more trust in its management of information.
- Training senior management, particularly the executive group, who are responsible for the overall direction of the company and are not technically orientated.
- Managing effective relationships and leading teams in both technical and non-computer based environments.
- Manufacture simulation exercises.
- Transactional training.
- Shop floor communication with line workers was an exercise that occurred during the implementation of suite 3. This required line workers to attend workshops to learn new PC skills in order to book work.

SAP guarantee that newer versions of their software will upgrade SAP reports, whilst specially created reports will require re-writing of the software. The future of the project will eventually lead to the need for a Data Warehouse. A Data Warehouse is an integrated collection of data. The data is stored centrally and is extracted from operational, historical and external databases. The data is first screened then edited and finally standardised for future retrieval. The data is stored in a logical user-friendly format. It allows non-technical users to create database queries allowing the simple retrieval of management information for business intelligence and managerial decision making. The database continually absorbs new data and integrates it with the previous data.

The full benefits of the project will not be fully experienced or achieved until the system becomes executive and has a period of stability, for at least a whole year. Once the system has become stable and users have had time to adjust to new working practices the benefits of lower IT cost will become visible. An immediate benefit that will be achieved by the system will be the ability to promise and then deliver to the customer on time. This was something that the older systems could never achieve, as they often used due dates that were in the past. SAP can only use current information. The ability to deliver on time will improve customer satisfaction and also improve customer confidence, which should lead to an increase of orders in the future. The system will also improve the relationship in the supply chain, as transactions will be made easier via the use of Electronic Communications.

The sustainability of enterprise information systems (EIS) during the post-implementation period needs to be looked into. There is a lack of clear understanding about the strategic needs and requirements for sustaining the effectiveness of large-scale information systems after a period of relative stability following initial implementation. Sustainability management of EIS is therefore a very important research dimension that needs to be explored to maximise the benefits of an expensive information system investment such as ERP.

Acknowledgements

The authors are very grateful to two anonymous referees for their constructive and helpful

comments which helped to improve the presentation of the paper considerably.

References

Abdinnour-Helm, S., Lengnick-Hall, M.L., Lengnick-Hall, C.A., 2003. Pre-implementation attitudes and organizational readiness for implementing an enterprise resource planning system. European Journal of Operational Research 146 (2), 258–273.

Al-Mashari, M., Zairi, M., 2000. The effective application of SAP R/3: A proposed model of best practice. Logistics Information Management 13 (3), 156–166.

Chen, I.J., 2001. Planning for ERP systems: Analysis and future trend. Business Process Management Journal 7 (5), 374–386.

Chung, S.H., Snyder, C.A., 2000. ERP adoption: A technological evolution approach. International Journal of Agile Management Systems 2 (1), 24–32.

Davenport, T., 1998. Putting the enterprise into the enterprise system. Harvard Business Review 76 (4), 121–131.

Escalle, C.X., Cotteleer, M.J., Austin, R.D., 1999. Enterprise Resource Planning (ERP): Technology Note. Harvard Business School Publishing, Boston, MA.

Gefen, D., 2002. Nurturing clients' trust to encourage engagement success during the customization of ERP systems. Omega 30, 287–299.

Holland, C., Light, B., 1999. A critical success factors model for ERP implementation. IEEE Software (May/June) 30–35.

Holt, L., 1999. Competition heats up in ERP. Info World 21 (6), 65.

Hong, K.-K., Kim, Y.-G., 2002. The critical success factors for ERP implementation: an organizational fit perspective. Information & Management 40, 25–40.

Huang, Z., Palvia, P., 2001. ERP implementation issues in advanced and developing countries. Business Process Management Journal 7 (2), 276–284.

Langenwalter, G.A., 2000. Enterprise Resource Planning and Beyond—Integrating Your Entire Organization. St. Lucie Press, Boca Raton, FL.

Latamore, G., 1999. Flexibility fuels the ERP evolution. APICS—The Performance Advantage, October 44–50.

Loizos, C., 1998. ERP: is it the ultimate software solution? Industry Week 7, 33.

Lucas, H.C., Walton, E.J., Ginzberg, M.J., 1988. Implementing packaged software. MIS Quarterly 537–549.

Mabert, V.A., Soni, A., Venkataraman, M.A., 2003. Enterprise resource planning: Managing the implementation process. European Journal of Operational Research 146 (2), 302–314.

Mandal, P., Gunasekaran, A., 2002. Application of SAP R/3 in on-line inventory control. International Journal of Production Economics 72, 47–55.

Markus, M.I., Tanis, C., 2000. The enterprise systems experience—from adoption to success. In: Zmud, R.W. (Ed.), Framing the Domains of IT Research: Glimpsing the Future Through the Past. Pinnaflex Educational Resources, Inc., Cincinnati, OH, pp. 173–207.

O'Brien, J., 1999. Management Information Systems. McGraw-Hill Inc., London.

Olhager, J., Seldin, E., 2003. Enterprise resource planning: Survey of Swedish manufacturing firms. European Journal of Operational Research 146 (2), 365–373.

Prasad, B., Sharma, M.K., Godla, J., 1999. Critical issues affecting an ERP implementation. Information Systems Management 16 (3), 7–14.

Rajagopal, P., 2002. An innovation-diffusion view of implementation of enterprise resource planning (ERP) systems and development of a research model. Information & Management 40, 87–114.

Trunick, P.A., 1999. ERP: Promise or pipe dream? Transportation & Distribution 40 (1), 23–26.

Umble, E.J., Haft, R.R., Umble, M.M., 2003. Enterprise resource planning: Implementation procedures and critical success factors. European Journal of Operational Research 146 (2), 241–257.

Van Stijn, E., Wensley, A., 2001. Organizational memory and the completeness of process modelling in ERP systems: Some concerns, methods and directions for future research. Business Process Management Journal 7 (3), 181–194.

Wood, T., Caldas, M.P., 2001. Reductionism and complex thinking during ERP implementations. Business Process Management Journal 7 (5), 387–393.

Yusuf, Y., 1998. An empirical investigation of enterprise-wide integration of MRPII. International Journal of Operations & Productions Management 18 (1), 66–86.