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ENTERPRISE APPLICATION INTEGRATION: AN EMERGING TECHNOLOGY FOR INTEGRATING ERP AND SUPPLY CHAINS

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ABSTRACT

During the last decade, the adoption of ebusiness applications and practices has transformed enterprises and changed the way of doing business. As a result, the competition among companies has increased and organisations are focusing on supply chain co-ordination and collaboration to increase their business benefits. For many years, Enterprise Resource Planning (ERP) systems supported supply chain management. However, the limitations of ERP systems on integrating disparate systems have led organisations to seek for new approaches to integrate their systems and supply chains. Thus, the intention of this paper is to explain why ERP systems have failed to support integrated supply chains and to introduce a new approach on systems integration, which can be adopted by organisations to overcome their integration problems.

Keywords: ERP, Enterprise Application Integration, Supply Chain Management, eBusiness,

1. INTRODUCTION

Christopher (1992) suggests that future competition will not be company against company but rather, supply chain against supply chain. Nonetheless, this presents interesting challenges when it comes to the integration of intra and inter-organisational supply chain systems. As companies strengthen their relationships and collaborate at an inter-organisational level, the chain itself gains more links and therefore, increases management and co-ordination efforts. An enterprise is no longer viewed as a single corporation; it is a loose collection of trading partners that can contract with manufacturers, logistics companies, and distribution organisations (Kalakota, 2000; Kalakota and Robinson, 1999). Therefore, a comprehensive integration of business processes and both intra and inter-organisational applications is needed to support long-term co-ordination, survival and growth. Such integration increases the automation of business processes and significantly reduces manual tasks, redundancy of data and functionality. Also an integrated inter-organisational IT infrastructure reduces costs (e.g. maintenance, management, operational) and supports the achievement of competitive advantages through improving real-time response.

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The integration of Information Systems (IS) is an obstacle to many businesses, as supply chain partners consist of independent systems that in some cases cannot communicate one another. These autonomous and in many cases heterogeneous systems are historically not designed to collaborate with other applications, as supply chain partners have tended to develop their systems independently and without any co-ordination. This may result in a lack of enterprise architecture, common definitions, structures, protocols and business concepts (Duke *et al.*, 1999). There is also the complexity of existing information systems, which in many cases have fixed and rigid structures for messages, interfaces and databases. *As a result the integration of applications along a supply chain is a difficult and complex task.*

In recent years, Enterprise Resource Planning (ERP) systems have been seen as more than resources that support various business processes. It has been recognized that ERP have the potential to act as a force that can be used by companies to integrate their supply chains and gain significant advantages over competitors. In this context, the genesis of organisations supply chain often lies within ERP systems. Interest in the integration of supply chains through ERP has steadily increased since the late 1980s, when the benefits of collaborative relationships with suppliers started to surface. As companies work together in extended enterprises, the chain itself tends to gain more links and become more complex to manage. Such complexity requires a shift in corporate thinking across this form of business network. An enterprise is now no longer a single corporation; it is a loose collection of trading partners that can contract with manufacturers, logistics companies, and distribution organisations. The supply chain has to have end-to-end enterprise application integration to survive in the dynamic and customer-driven digital economy, i.e. the plan, source, make, and move concept.

The benefits of adopting an ERP system impact the supply chain with an outward process conformance view of the supply chain. The reasoning is that ERP requires an organization to be process orientated and for all internal business units to conform to the same precise process. As a result, providing the organization with an infrastructure that is built around value adding activities through efficiency and effectiveness. Such infrastructure has the scope to reach out into the supply chain and thus, impact customers and suppliers.

2. THE INSUFFICIENT NATURE OF ERP SYSTEMS

To support efficient and flexible supply chains organisations need to integrate their applications on enterprise and cross-enterprise level. Through the integration of internal and external business activities, companies are continuing to find ways to further improve their efficiency and streamline key business processes. To accomplish this, organisations have not only coordinated functional staff and business processes but have sought to integrate enterprise applications into systems that can link members of the supply chain together via data, information and knowledge.

Internal ERP enterprise systems are often implemented in a way as to focus on standard data, business processes and re-engineered business logic. Thus, ERP systems have become a great integration challenge, as they are possible to reuse common services through common applications, and share business processes and services (Linthicum, 1999). Despite ERP systems being introduced as "integrated suites", they have failed to achieve application integration and supply chain integration (Makey, 1998; Themistocleous *et al.*, 2001). This can be attributed to (a) ERP do not cover all IT requirements; (b) they can not meet all business processes and (c) according to Korzeniowsky (2000), ERP will never meet them. Chung and Snyder (2000) claim that ERP systems support generic processes and best practices with organisations attempting to parameterise ERP packages to better support their business processes and strategy. However, customisation is a difficult task that causes serious integration problems as ERP systems are complex, non-flexible and often not designed to collaborate with other autonomous applications (Glass and Vessey, 1999; Sumner, 1999).

Linthicum (1999) and Zahavi (1999) characterise ERP systems as monolithic solutions that are not designed to co-operate with other applications. As a result, enterprise integration can be achieved when organisations abandon existing applications and develop a complete ERP solution. Therefore, the more ERP modules adopted, the more incorporation is achieved. Nevertheless, Makey (1998), Markus and Tanis (1999) and Themistocleous *et al.* (2001a) indicate that companies do not adopt *all* ERP modules but a subset of them. Even in cases where organisations purchase all ERP modules from a single vendor, ERP packages can not automate more than 30% of company's application (Seeley, 1999; Stefanou, 2000). In contrast, Makey (1998), Holland and Light (1999) and Kelly *et al.* (1999) report that ERP systems cover up to 70-80% of IT requirements. Regardless, organisations do not abandon all their existing systems when adopting ERP packages, several applications (e.g. legacy systems) often co-exist alongside enterprise systems (Makey, 1998; Themistocleous *et al.*, 2001).

The amount of legacy systems in use remains high as they provide reliable solutions (Lloyd *et al.*, 1999). In support of this, Themistocleous *et al.* (2001a) report that 38% of companies do not replace their legacy systems when adopting Enterprise Resource Planning (ERP) solutions. In addition, Ring and Ward-Dutton (1999) suggests there is often no time to replace legacy systems and Ruh *et al.* (2000) explain that replacement is a high risk process. O'Callaghan (1999) supports the claim that the replacement of legacy systems is too expensive with Brodie and Stonebraker (1995) explaining that it takes too long to realise the benefits. Apart from the incorporation of existing systems, organisations have to integrate new applications (e.g. e-business solutions, supply chain applications) with ERP package.

All observations discussed in this section indicate that ERP systems can be considered as a *partial* solution to enterprise and cross enterprise integration as other applications co-exist along-side ERP packages. Yet, what has been lacking in the continuing development of ERP systems, is a robust contextual architecture to support the supply chain concepts (accessible and accountable data and information), and the supply chain process (business relationships through business logic) (Loos, 2000; Schonefeld and Vering, 2000). Indeed, it is widely recognised that firms can no longer effectively compete in isolation to their suppliers, and as a result are beginning to interact and support their supply chains to achieve a competitive advantage. Consequently IT/IS is being used as an enabler in an attempt to enhance organizational efficiency, by integrating disparate enterprise business applications into highly functional and dynamic application networks (Holland 1995; Lin 2000). There is a growing number of IT/IS architectures that are beginning to represent the development of ERP as well as enabling ebusiness technologies. In exploring this, subsequent sections will discusses a new technology for integrating systems and supply chains. This new technology is called Enterprise Application Integration (EAI).

3. ENTERPRISE APPLICATION INTEGRATION: AN EMERGING TECHNOLOGY FOR INTEGRATING ERP AND SUPPLY CHAINS

Enterprise application integration is an emerging generation of integration software that addresses more effectively the need to integrate both intra and inter-organisational systems. In doing so, it securely incorporates functionality from disparate applications. It combines traditional integration technologies (e.g. database-oriented middleware) with new EAI technologies (e.g. adapters, message brokers) to support the efficient incorporation of information systems. Thus, application integration results in supporting data, objects and processes incorporation as well as custom applications, packaged systems and e-business solutions integration.

Numerous approaches were proposed in normative literature to describe application integration. Duke *et al.*(1999) among others suggest that a solution based on application integration involves the transportation and transformation of information between one or more applications. It also supports (a) the timing and sequencing rules that govern when the transportation and transformation takes place and (b) the integrity constrains that determine the success or failure of the integration. From a technical perspective Themistocleous *et al.*(2000) propose that EAI is achieved at 3 integration layers namely:

- **Transportation layer**, which transfers the information from source application to the integration infrastructure and from the latter to the target application.
- **Transformation layer** that translates the information from source application format to target system structure.
- **Process automation layer**, which integrates the business processes and controls the integration mechanism. This is illustrated at Figure 1.

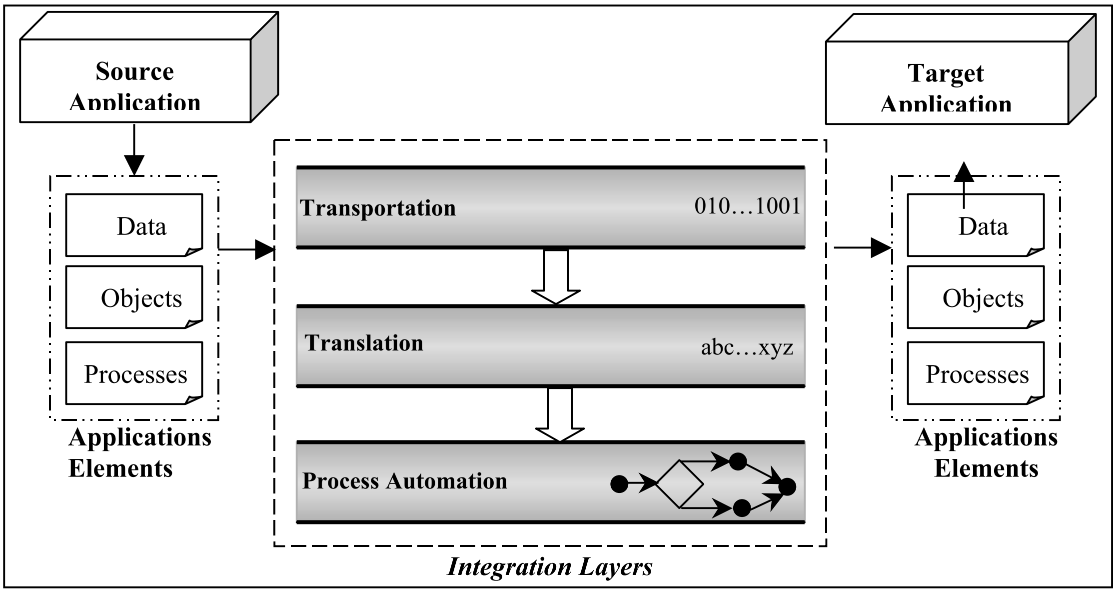

Figure 1: Integration Layers and Application Elements

Figure 1 presents the incorporation of 2 information systems (source and target application) when EAI is used. Source and target applications are integrated by exchanging their *application elements, which include data, objects and processes*. Application elements are transferred from source application to the target through the integration infrastructure using the *transportation layer*. Meanwhile, application elements are translated from source application structure to target application format using the *translation layer*. The reason for using the translation layer is that source and target applications are not based on the same structures (e.g. data structure) or platform. Thus, translation is needed to transform data into compatible format for target application. At a higher level, elements that are used for the integration of processes or the integrity of information (e.g. services, business logic, rules, constrains) are transferred to *process automation layer*. These elements are used by process automation layer to audit integration tasks, incorporating and automating business processes and triggering events. For instance a typical task of this layer could be the following scenario: translate retailer's (source application) stocks data using the translation layer. When the retailer's stocks availability is equal to limit (e.g. stocks = x units of product P) then notify supplier (target application) and order z = y-x units of product P (where y is the maximum agreed quantity of product P).

4. CASE DATA

For confidential reasons the name of the organisation been studied can not be published. Therefore, the authors adopt the name *'OILCORP'* to refer to this organisation. The OILCORP is a multinational organisation operating in the chemical sector in more than 135 countries around the globe. It has more than 100,000 employees and it is organised into five core businesses including (a) oil; (b) chemicals; (c) gas and power; (d) exploration and production and (e) renewables. A Chief Executive Officer (CEO) heads each core business with broad overall responsibility. The CEOs report to a committee of managing directors made up of the executive directors serving on the boards of the parent companies.

Each of OILCORP subsidiaries complies with the same set of business principles but operates independently. Service companies provide a range of specialist advice and resources, and the principles ensure that all companies perform to the same high level in the economic, environmental and social domains. Each company has its own Information Technology (IT) infrastructure, which in many cases includes complex, heterogeneous and incompatible systems and clearly presenting an integration challenge. The diversity of Information Systems (IS) causes delays in giving information as applications are not integrated, and a lot of work has to be done manually. For instance, data from one system has to be printed out and then re-entered in a different format to a target system. The reasoning is that the target system has its own data structure and it is based on a different operating system. Other technical problems include:

- Difficulties in getting data from legacy as the OILCORP is consisted of 1500 different legacy systems with heterogeneous and incompatible data format. Restrictions of existing and ERP systems as they are not able to manipulate all types of data,
- Incompatible ERP systems. The organisation has 90 different ERP systems provided mainly by 2 ERP vendors. However, there are many problems in retrieving data from one system that is running for instance on a mainframe and processing them in another ERP system running on different platform or having a different version. The existence of all these systems (ERP's, legacy and ebusiness) support the claim reported in sections 1 and 2 that ERP systems do not efficiently support the integration of IS.

Among others, this situation causes significant obstacles to OILCORP regarding the integration, automation and coordination of its supply chains. Customers and suppliers demanded a closer collaboration with OILCORP and thus the latter started examining possible approaches to integrate its internal and external supply chains. The first approach focused on developing manual point-to-point connections to interconnect applications. In this case programmers write low-level communication code between 2 applications to exchange messages and data. However, such approach leads to *applications spaghetti*, which increases the complexity of the integration solution as the number of interconnected applications rises. Themistocleous *et al.*(2000) suggest that for *x* applications a total of: **`x*(x-1)/2`** connections are required, to piece together *all x* applications. This means that for 10 applications 45 connections are needed to interconnect these 10 applications. In addition each connection requires 2 interfaces (one for each interconnected application). Clearly, maintenance costs are an issue, with IT becoming ineffective to maintain these interconnected applications. Moreover, interconnectivity has other problems since point-to-point connections have an *invasive nature*, which requires changes to applications (Duke *et al.*, 1999; Serain, 1999; Themistocleous and Irani, 2002; Wijegunarate and Fernandez, 1998). In doing so, new subroutines that support interconnections by mapping all interconnected applications are added and thus, applications code is extended. After interconnecting applications if a system requires changes, all interconnected applications have also to be altered. As the number of applications and the connections between them proliferate, an organisation ends up with a non-flexible, unmanageable jumble of code holding the business system together (Markus, 2000; Wijegunarate and Fernandez, 1998).

In contrast, application integration addresses integration problems more effectively by developing a central integration infrastructure (Linthicum, 2000; Puschmann and Alt, 2001; Zahavi, 1999). In doing so, point-to-point interconnections are eliminated, since each application is connected with the integration infrastructure. In many cases, the integration infrastructure follows a hub and spoke communication mechanism (Bernus *et al.*, 1996), which is often based on a message broker (Ruh *et al.*, 2000; Themistocleous and Irani, 2001). In EAI solutions, when an application requires changes the rest of the system is rarely affected, as it is not interconnected with the application that requires changes. Therefore, only the application that requires changes and its connection to the central integration infrastructure are altered. The cost of a solution based on EAI technology is much less with OILCORP estimating that EAI solution costs approximately the 2/5 of a point-to-point solution.

Even in case of adopting EAI technology, the cost of global integration at OILCORP was extremely high (more than €161 millions). Thus, OILCORP took the decision to implement a pilot project to demonstrate the integration of a supply chain and evaluate the benefits of EAI. The projected lasted for 9 months and was aiming at integrating custom, packaged and ebusiness applications so that integrate a supply chain among the mother company and 2 subsidiaries. As illustrated in figure 2 disparate applications such as ERP systems, supply chain management applications and other systems that are used for the co-ordination of a supply chain are incorporated into a single integrated infrastructure. These applications are pieced together based on application integration technology, which integrates not only applications but also business processes. The central integrated infrastructure receives application elements from one application and translates/formats it into a compatible format for the target solution. In addition, the integration infrastructure synchronises and routes the data to the appropriate applications. The integration achieved is non-invasive and thus limited (or no) changes to existing applications code are needed. As a result, the integration solution is manageable, flexible and maintainable as the altering of one application does require changes to the code of other solutions that collaborate with it.

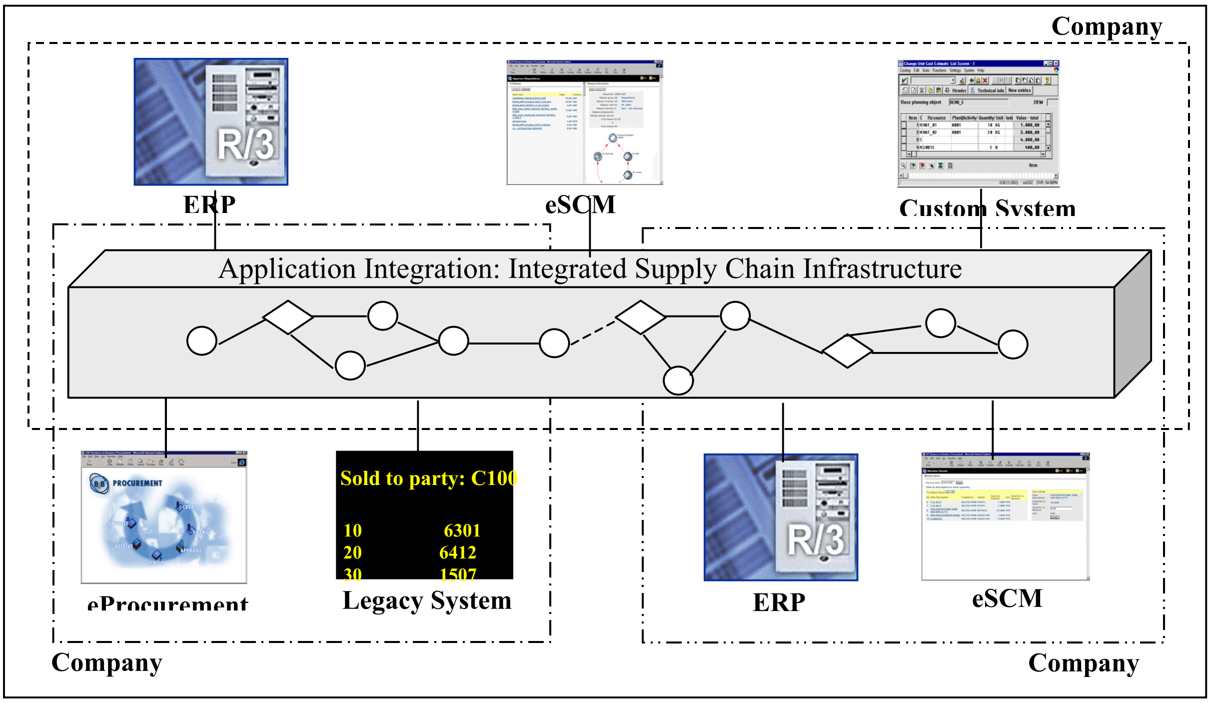

Figure 2: Integrating ERP and Supply Chain Solutions through Application Integration

The selection of appropriate EAI products and technologies was a significant issue for OILCORP, since there is a technological confusion surrounding EAI. The reasoning is that a diversity of products and technologies address integration problems but there is no single technology or EAI product solving all integration issues (Ring and Ward-Dutton, 1999). Thus a combination of integration technologies is needed. To address this issue, the OILCORP assess various EAI products using an evaluation framework. Evaluation criteria test integration requirements such as maintainability, flexibility etc. Some of the criteria focus on vendor and test (a) whether the vendor has a global presence; (b) collaborates with OILCORP; (c) is reliable etc. This set of criteria affects somehow the selection of EAI products since the OILCORP selected products from its existing vendors (e.g. IBM) or from collaborators of its vendors (e.g. CrossWorld is SAP partner for EAI). Nonetheless, the adopted solutions supported the majority of evaluation criteria. CrossWorld's software complied with the majority of evaluation criteria set by OILCORP and it can collaborate with other software solutions to achieve process integration. Based on these, an expert group made the decision that

CrossWorld's integration software could be adopted for development. Also, OILCORP adopted IBM's Message Queuing Series Integrator (MQSI) as message brokering software. Both software solutions can collaborate and provide a reliable platform for integrating OILCORP applications. Apart from these products a variety of other tools were adopted such as Tibco middleware, screen wrappers etc. This proves that there is no single EAI product solving all integration problems.

Another important issue came out from this case study is that the OILCORP spent around the *60%* of overall time to redesign its business processes. In doing so, OILCORP maximises the benefits from EAI adoption, as data and application redundancy was significant reduced. Due to business process reengineering the 90% of custom systems and the 96.4% of ERP systems that used for the automation of the specific supply chain were phased out. As a result, OILCORP reduces the operational cost from running these systems and shorten the business cycle. However, this has an impact on employees as the operators and the users of those systems that were phased out resisted in change. At a technical level the integration of packaged, custom and ebusiness solutions was achieved as described below:

Legacy Integration: Most legacy systems follow a monolithic model (Zahavi, 1999) in which data, processes and interfaces are not separated but are built together (Bernus *et al.*, 1996). As such, legacy systems have limited number of interfaces that can be used for integration with other applications. In most cases, user interfaces are used to access the data and the logic of legacy systems (Andrew, 1998). In the case of OILCORP screen wrapping tools were used to capture data from a legacy systems screen, or map them as objects. Data or objects were then sent to the message broker, which translates the data into an appropriate format and forward them to target application.

ERP Integration: Data extracted from ERP's database can be transformed into XML format and then transmitted to the target application. In addition, a message broker was used to support the distribution of XML messages (in cases of ebusiness applications). Apart from XML technology, data integration was achieved through traditional database middleware such as Open Database Connectivity (ODBC). Message based technologies such as IBM MQSI were also used to transfer the data from source application to the target using the integration infrastructure.

At interface level, Application Programming Interfaces (API) are provided by ERP systems to allow other applications to access ERPs functionality or data (Zahavi, 1999). In the case of OILCORP applications communicate with APIs and gain access to the data or the processes they demand. As a result, applications send or retrieve data through APIs or invoke an ERP service to obtain some value in order to integrate their functionality. In many cases, information extracted from one API needs to be mapped so as to be compatible to target application. For that reason, adapters and/or message brokers were invoked to map the data and interconnect the ERP system with the target application.

In many cases Distributed Object Technologies (DOT) such as Microsoft's COM/DCOM, CORBA and Enterprise Java Beans collaborate with ERP systems through APIs. ERP systems are attempting to perform like distributed object applications by supporting APIs that provide access to ERP data, processes, services and objects. As a result the integration of objects is easier as DOT technologies can communicate, share data and reuse ERP objects and services through APIs. Such technologies were also used in the case of OILCORP to support objects integration.

Ebusiness Integration: ebusiness solutions are often integrated more easily than the rest of applications due to the fact that are designed to collaborate with other systems and are based on more flexible and open architectures (Kalakota and Robinson, 1999). In the case of OILCORP data, objects, semantics and logic were extracted from e-business applications using database technologies, DOT, XML, application servers etc. Data, objects and logic were extracted from legacy systems and ERP applications (as described above) and sent to the message broker. The latter, maps, translates and routes the information to the target application.

The implementation of the pilot EAI project provided advanced capabilities to the OILCORP and increased the functionality and efficiency of their IS. A number of business processes related with internal and external supply chains were redesigned, automated and integrated. The IT department used this pilot system to run various business cases and demonstrate systems functionality and benefits. The integrated infrastructure resulted from the implementation of this project increases organisation's performance and systems efficiency and functionality as it automates business processes and integrates applications. The integration provides more understanding and control of business processes, as activities have been improved through reengineering. In addition it supports better coordination and collaboration among treading partners. The integrated infrastructure reduces the redundancy of systems, components and data and eliminates manual integration tasks that result in reduced employees, tasks, and systems that are needed for process fulfilment. The pilot system provides more reliable data and it is more flexible as integration was achieved with minimum changes to systems code. Thus, the systems are more manageable and maintainable. The advantages of the pilot system were so significant that led the managing board to take the decision for a global EAI project.

5. CONCLUSIONS

Supply chains are considered integral to virtual organisations and the delivery of globalised competitive advantage. Although the concept of enabling a supply chain is fundamental to those seeking to develop responsive organisations, in reality the implementation and realisation of such a business entity can be complex and time consuming due to the limitations of existing IS.

Although many organisations have sought to automate and integrate their supply chains through ERP systems, in reality, such software solutions have proved to be limited in the delivery of benefits and integration. ERP systems have historically been good at capturing classic business processes like supply chain functions but only from a process perspective. It is also widely recognised that ERP systems are very internally focussed within the organisation. The sharing of resource planning data with business partners and suppliers is typically seen as a complex and traditionally verbose process, and not one that naturally lends itself well to the monolithic architecture of ERP. In addition, ERP systems have problems in exchanging and integrating data and processes from other applications that co-exist alongside such enterprise systems.

However, to support the linkages in supply chains, application-level integration is required to automate and integrate key business processes. Such integration is required internally, within an organisation as well as externally within business partners. The emergence of application integration technology is gaining pace as a means of incorporating information systems that automate parts of a supply chain (e.g. legacy systems, ebusiness solutions) and to establish a common information infrastructure along a *whole* supply chain.

This paper has discussed the need for integrating supply chain and explained why ERP systems have failed to integrate supply chains. In addition, the authors of this paper have presented a new approach on integrating the supply chain based on application integration technology. The case study presented in this paper focuses on explaining how EAI technology efficiently integrates custom, packaged and ebusiness solutions and thus, resulting in integrated supply chains. Based on the case study analysis a number of interesting issues have been highlighted and summarised below:

- There is a technological confusion surrounding EAI, which forms a barrier to the adoption of EAI. Disparate integration technologies and products exist in marketplace with no single tool addressing all integration problems. As a result a combination of integration technologies is required to support applications integration. It could be argued by the authors, that a framework that evaluates EAI solutions and technologies will support organisations in selecting and combine appropriate EAI technologies.
- When integrating applications there is a need to pay attention on process reengineering since, the purpose of integration is to integrate and automate business processes and applications. In the case study presented in this paper, it is estimated the redesigning business processes takes

up to 60% of the overall integrated solution. Such, redesigning has resulted in phasing out the majority of existing systems (90% of legacy and 96.4% of ERP systems). This means that EAI solutions and reengineering reduces operational cost and shorten and improve business processes. However, this had an adverse impact on employees, which manifested itself in the form of resistance to the change initiative.

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