Enterprise application integration systems and architecture – the case of the Robert Bosch Group

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Keywords

Integration, Information systems, Business planning

Abstract

Today, most organisations are using packaged software for their key business processes. Enterprise resource planning, supply chain management, customer relationship management and electronic commerce systems enable organisations to improve their focus of using information systems to support their operational and financial goals. This article argues that the need to integrate these packaged software applications with each other as well as with existing or legacy business applications drives the need for a standardised integration architecture to more flexibly implement new business processes across different organisations and applications. To illustrate the components of such an architecture, a case study undertaken at the Robert Bosch Group provided necessary empirical evidence. The Robert Bosch Group has evaluated different enterprise application integration (EAI) systems to achieve a standardised integration architecture. The article describes a reference architecture and criteria for the classification of EAI systems which are derived from different integration approaches.

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1. Introduction

One of the most fundamental developments companies face today is the deconstruction of existing value chains. Traditional vertical integrated organisations are giving way to more flexible networked forms of coordination. What characterises this development is the increased relevance of shaping intra-organisational and inter-organisational relationships among independent business units. Efficient coordination and control of these cross-organisational business processes can only be achieved with integrated information systems that deliver timely exact and right information at every point in the value chain (Kalakota and Robinson, 2001). Many companies have addressed this integration problem by focusing on a single application provider. However, the results have not lived up to the expectations. The reasons behind this include (Connelly, 1999; Themistocleous and Irani, 2001):

- *Software drivers.* The inability for one standard software provider to deliver 100 per cent of the business software today's organisations require combined with the need to integrate legacy applications has created heterogeneous IS architectures.
- *Financial drivers.* Organisations spend at least 40 per cent of their IT budget for integration. That is why the costs of integration when implementing and maintaining packaged applications in 1998 already reached a worldwide volume of US$85 billion.
- *Internal drivers.* The support for fast reorganisations of business processes and integration to legacy or internally developed systems force organisations to be able to change their integration environment very quickly.
- *External drivers.* The integration of business partners, such as customers and suppliers, not only at the data, but also at the process level, requires a time and cost-efficient integration approach.

In this complex and dynamic environment, homogenous IS architectures are no longer practical options. Many organisations are changing their strategies from a single sourcing

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

or traditional point-to-point integration strategy to a more proactive approach of building and evolving a standardised integration architecture capability that enables fast assembly and dis-assembly of business processes and corresponding business software components.

In the following we will outline how EAI systems can yield benefits for a standardised integration architecture. We believe that today's available EAI systems address different integration levels and support organisations in different problem areas. Therefore organisations need to have a clear understanding of their future IS architecture and balance their integration approach among different solutions. In the first step, we will therefore discuss different integration approaches (Section 2) and develop a reference architecture for EAI systems (Section 3). Based on this, a case study will present how the Robert Bosch Group has implemented an EAI system using this reference architecture to achieve more flexibility of its IS architecture (Section 4). This will include a description of the solution and an evaluation of the major benefits. From this project, important lessons and critical success factors emerged which will be presented. Finally, Section 5 offers some conclusions for managing an integration architecture.

2. Analysis of intergration approaches

2.1. Focus of existing approaches

Integrating information systems means establishing communication between these systems. Österle (1996) differentiates between three types of applications to be addressed by integration:

(1) *Homogeneous with one instance.* One process is supported by one application and one data base. This model avoids the problems emerging from redundant data storage and asynchronous data exchange between separated applications.

(2) *Homogeneous with several instances.* Several identical processes in different business units are supported by several identical applications that run on different computers and rely on logically separated data bases. An example for that kind of integration is the Application Link Enabling (ALE) from SAP, which provides a mechanism for the coordination of master and transactional data in physically distributed SAP environments.

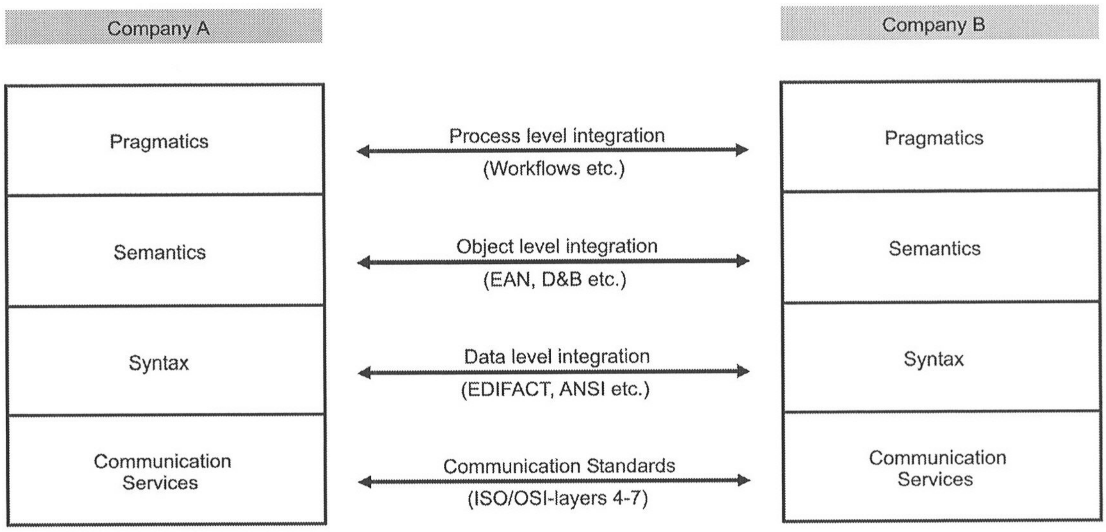
(3) *Heterogeneous.* Several different processes in different business units are supported by several different applications. An additional problem compared to the integration in a homogeneous environment is that the concerned applications are built upon divergent data models, which means that they provide different semantics of the data to be exchanged.

From the perspective of the well-known communication model a common language is required for the integration of heterogeneous systems which has four levels (see Figure 1). As long as the communication involves human participants, there is a high degree of flexibility in interpreting the intended meaning. However, this form of integration is hardly efficient in the context of business applications where productive and high volume data has to be re-entered manually in the system. Therefore, the following will only focus on inter-process integration, i.e. the direct coupling of applications. A prominent example for inter-process communication is EDI. Information is not only transmitted electronically but also processed automatically to the receiving IS.

Inter-process integration requires that all aspects of the communication are identical between both systems. As Kubicek showed, the ISO/OSI-model has to be extended to include all necessary aspects (Kubicek, 1992; Themistocleous and Irani, 2001). In addition to the communication services which are still covered by ISO/OSI, another three layers are required which mainly stem from communication theory. In the first place, a common syntax is required which defines the order, length and the type of data being exchanged. But the definition of a common syntax is not sufficient for an automated integration of systems. In addition, semantic is needed to assign real world subjects and notions to the transmitted characters. Semantics add a certain meaning to individual data fields (e.g. the data field "price" is more accurately

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

Figure 1 Integration levels



Source: Kubicek (1992)

specified by the filed "currency" and an automated interpretation of the content, like "CHF" as "Swiss Francs", is enabled). The basis for such interpretations are key fields that today are mostly defined by each company itself. Some attempts have also been made to reach a broader geographical community. The European Article Number (EAN), for example, not only specifies a 13-character syntax but also makes sure that each article has a unique identification number. By referring to this unique number, meaning is added since it always leads to the same article name. Without open semantic standards an automated exchange of information among anonymous business partners will remain illusive because it will require a human interpreter. The third element – the pragmatic element – is a feature of sophisticated workflow systems. It makes sure that transmitted data has not only been understood but that subsequent actions are triggered. For instance, the IS would automatically issue an invoice once a product has been delivered.

An analysis of current research approaches shows that they lack in two dimensions (see Table I). First, most of them have an intra-organisational integration scope. Only a few approaches consider inter-organisational integration as their focus. Second, nearly all approaches encompass only one or two integration objects concerning data, object and process integration. Most of the approaches show very technical standards for data or object integration. The reference architecture, which is developed in Section 3, includes these approaches and considers all integration objects (data, object and process) for an inter-organisational approach.

2.2. Research methodology

The research method used in this article is action research (Checkland and Holwell, 1998). This method consists of five steps:

(1) Research and practice together define research questions.
(2) The research er structures the research area and develops suggestions for the design of the possible solution based on his theoretical knowledge and practical know-how.
(3) Research and practice together check the suggestions and refine them.
(4) In the next step, practice adopts and uses the solutions.
(5) Finally, the results are reviewed in a joint process, in order to improve the solutions.

The EAI architecture in this article was developed on the basis of this research process. The research question was defined together with the Robert Bosch Group. This company participated in the two competence centers, inter-Business Networking (iBN) and Business

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

Table I Integration focus of research approaches

	Integration scope		Integration object		
	Intra-organisational	Inter-organisational	Syntax: data integration	Semantics: object integration	Pragmatics: process integration
Distributed processing architecture (Bond *et al.*, 1998)	●	❍	●	❍	❍
Integration backbone (Connelly, 1999)	●	❍	❍	●	❍
Distributed architecture (Ferstl and Sinz, 1996)	●	❍	❍	●	●
B2B integration (Linthicum, 2001)	●	●	●	●	●
Event-driven infrastructure (Ranadivé, 1999)	●	●	●	❍	❍
EAI-architecture (Ruh *et al.*, 2000)	●	❍	❍	●	●
Enterprise integration architecture (Sandoe *et al.*, 2001)	●	●	●	❍	❍
Integration infrastructure (Weston *et al.*, 1998)	●	❍	●	❍	❍
Horizontal integration (Hasselbring, 2000)	●	❍	❍	❍	●

Notes: ● = fulfilled; ❍ = not fulfilled

Networking (BN), between 1998 and 2002 from the Institute of Information Management of the University of St Gallen. The EAI architecture was derived from existing theoretical work in EAI (see Sections 2.1 and 3) and integration architectures and practical experience from several other projects within this competence center. This architecture was reviewed in serveral workshops with the Robert Bosch Group and other companies. The theoretical input from research and the practical input from Bosch and the other companies finally lead to an EAI architecture which is described in Sections 4 and 5. The architecture model was validated in several other projects, e.g. at Hoffmann La-Roche AG, headquartered in Basel, Switzerland and in many discussions with other interview partners from practice.

3. Enterprise application integration systems

Systems that enable companies to implement inter-process communication are traditionally known as middleware. Middleware is primarily concerned with data level integration, which means that these systems do not provide any functionality that enables higher levels of integration, such as object or process integration (Bernstein, 1996; Linthicum, 2001). In contrast to this, EAI systems encompass the technologies as well as the process definition to enable custom-built and/or packaged business applications to exchange semantic level information in formats and contexts that each system understands (Linthicum, 2000). This means that these products not only integrate applications on a technical layer, but also provide a communication framework that underpins the integration of information systems on a semantic and pragmatic level. EAI systems offer several types of services in addition to classical middleware – but just like middleware, none of these services alone is new (Bernstein, 1996; Linthicum, 2000; 2001; Ruh *et al.*, 2000):

- *Interface services.* Connectors and adapters ease the burden of programming by providing pre-built interface communication. They extend the concept of classical DBMS drivers which are used in client-server development tools for many years.
- *Transformation services.* Transformation services ease the development burden of encoding rules that translate message formats and routing messages based on their content. These transformation engines have been implemented in message brokers since the early 1990s.
- *Process management services.* Process management services gather messages and execute multiple transformations by ensuring that the flow of information

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

between a set of resources follows the flow defined in an established business process. These services are traditionally in the heart of each workflow management system but were up to now not available independently.

- *Development services.* Development services help programmers in the development and adoption of adapters, e.g. for the integration of custom-built systems. They also help in the definition of mapping mechanisms and process definition.
- *Runtime services.* Runtime services ensure performance, scalability, availability and reliability for all applications that are integrated over an EAI system. Therefore they offer distribution, scalability and monitoring services.

While these services are all well known in integrating data, objects and processes, their added value for integrating heterogeneous applications derives from their integration in one single application called EAI system. These kind of systems offer further functionality which can be described in a reference architecture (see Figure 2).

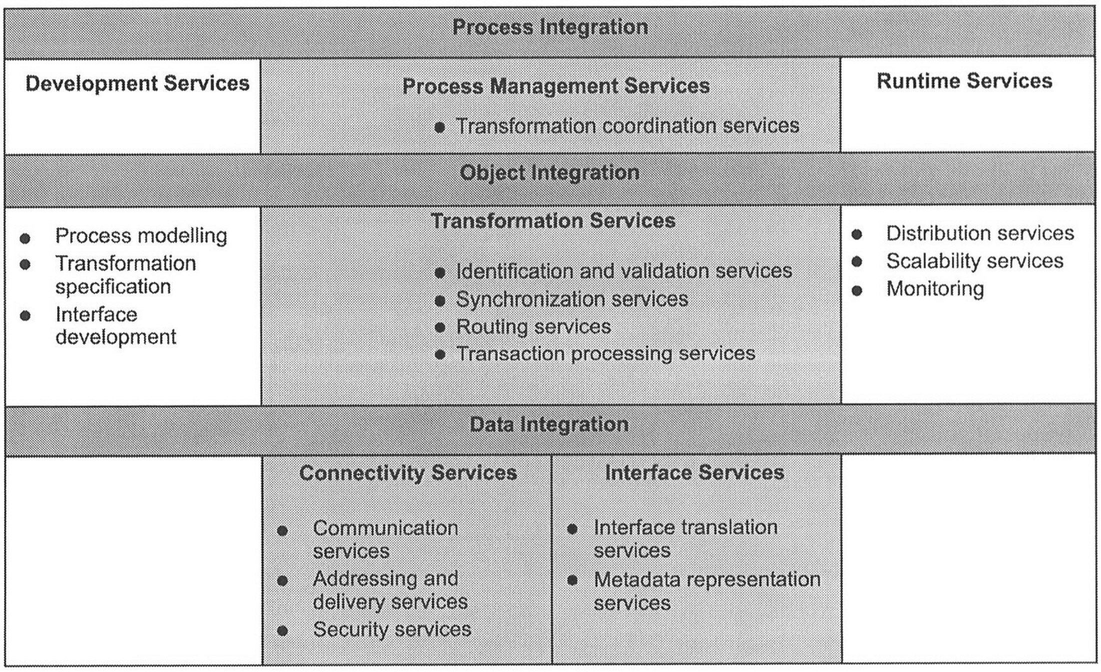
The services included in this architecture address different integration levels. Connectivity and interface services lay the basis for data integration whereas transformation services provide functionality for object integration. Process management services enable intra- and inter-organisational process integration by coordinating sets of transformations. Finally, development and runtime services are tools that are necessary independently of the integration level addressed. These services are needed to secure availability, reliability and performance as well as for the support of individual problem domains.

4. Case study: enterprise application integration at the Robert Bosch Group

4.1. Goals and areas of enterprise application integration at the Robert Bosch Group

The Robert Bosch Group is an international company with 190,000 employees in 132 countries and annual revenues higher than US$25 billion. Today, Bosch is composed of approximately 250 subsidiaries and affiliated companies in 48 countries. The Bosch Group has 185 production plants worldwide, 142 of which are located outside Germany, i.e.

Figure 2 Levels of integration and corresponding functionality of EAI systems



Europe, North and South America, Africa, Asia and Australia. Throughout the world, Bosch holds interest in 37 joint-venture companies. Traditionally, the name Robert Bosch is closely associated with the automobile. Today, however, Bosch is not only a name for automotive equipment such as ABS, brakes, fuel-injection technology, and driver information systems – but also for a whole range of further product areas. Examples are communications technology, power tools, household appliances, thermotechnology, automation technology, and packaging machinery. These worldwide activities of the Bosch Group are divided into the four business sectors automotive equipment, communication technology, consumer goods and capital goods.

One major critical success factor for a manufacturing company like Bosch is that its intra- and inter-organisational business processes are supported by a homogenous information systems architecture. The European IT activities are therefore bundled in a cross-business unit called QI. As an internal service unit, QI supports the automation of business processes with information systems for both business and technical functions. As Bosch is a historically grown company, the same can be said about the information systems architecture which is very heterogeneous. That is why QI is currently faced with the following challenges in integrating its information systems:

- *Software drivers.* The migration of its legacy systems to SAP R/3 and the integration of custom-built systems into the new application architecture combined with Bosch's best-of-breed approach require the management of hundreds of new interfaces.
- *Financial drivers.* The costs of managing the new evolving interfaces are enormous. Bosch estimates that the time to configure one interface will be about 15-20 person days, which are even multiplicated by the time for maintenance when implementing new systems or changing existing business processes.
- *Internal drivers.* The organisation in business areas requires flexible, cross-organisational core business processes, such as development, controlling, sales, quality management, and finance and accounting, which must be based on a homogenous IT infrastructure that can easily be reconfigured.
- *External drivers.* The strong need in the automotive industry for the integration of inter-organisational business processes requires the integration of new systems into the existing application architecture. In order to streamline business processes between Bosch and its suppliers and customers, Bosch uses eProcurement systems and online stores. Additionally, there is a strong need to integrate SCM and CRM systems in order to improve coordination and relationships with suppliers and customers.

Because of the step-by-step migration of the historically grown application architecture to the new ERP, EC, SCM and CRM systems, QI estimates that it would have to manage about 700 new interfaces. In order to solve these problems, Bosch's goal is to implement a standardised integration architecture called the "business bus". The term "business bus" is used to describe the totality of technical, applications and business standards on which software solutions at Bosch are based (Österle, 2001).

4.1.1. Integration of ERP systems

As with most enterprises that have a strong historically grown organisational structure, Bosch also faces the challenge to more centrally coordinate its IS architecture in order to achieve a more flexible, standardised IS architecture company-wide. Most of the 250 subsidiaries and 185 production plants individually developed information systems that were suitable for their specific needs. As a result, it is not astonishing that Bosch needed to harmonise its architecture by migrating to a standard ERP system like SAP R/3 in order to achieve a homogeneous finance and accounting infrastructure. One major problem in migrating to SAP R/3 is that the regional subsidiaries have different requirements for the customisation of their systems. Although specific configurations are provided for each business unit, the core business processes are integrated over the whole enterprise. As most companies, Bosch follows a step-by-step approach by rolling out its new SAP R/3 architecture into the different business

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

units. Figure 3 shows that Bosch pursued a point-to-point approach in integrating new systems into its existing IS architecture.

Bosch estimates that with the implementation of SAP R/3 about 300 new interfaces to existing IS would have to be programmed and maintained. Actually, it is not quite sure how many interfaces will result from the EC applications.

4.1.2. Integration of electronic commerce systems

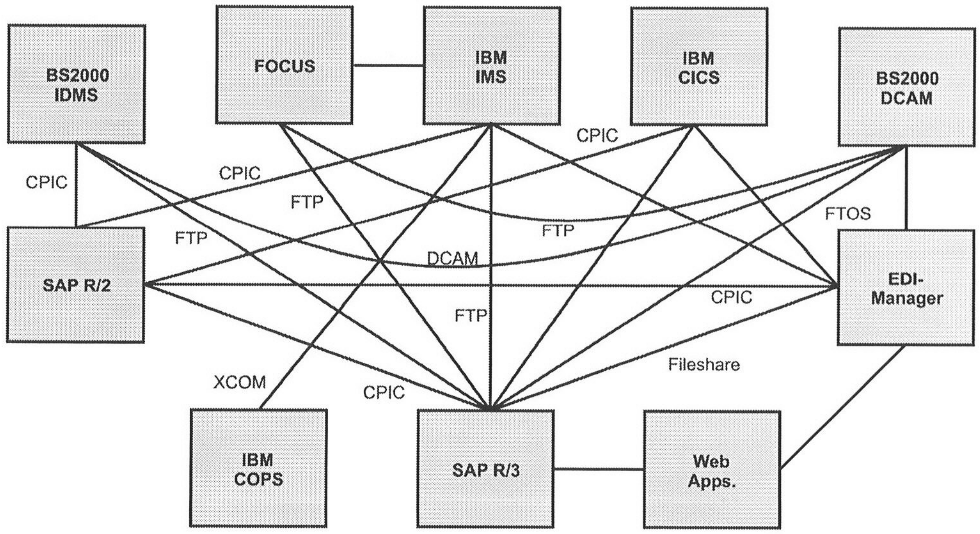
EC denotes the electronic support of information, contracting and/or settlement processes (Schmid and Lindemann, 1998). Within EC, various fields have been distinguished (Kalakota and Whinston, 1997):

- EC can be conducted within an enterprise (intra-business), with business partners such as suppliers and corporate customers (business-to-business), and with end-customers (business-to-consumer).
- Depending on the underlying business processes, EC applications evolved for procurement (buy-side) and sales processes (sell-side).

Bosch uses systems for both business-to-business EC on the one hand and buy-side and sell-side EC on the other hand. Bosch sees the integration of its intra-organisational business processes and the harmonisation of its internal IS architecture with SAP R/3 as a prerequisite for the integration of inter-organisational processes with its suppliers and customers via EC applications. One of the first systems that Bosch implemented was the solution of the affiliated company Blaupunkt. Blaupunkt's Extr@Net is an example of a sell-side EC application. Blaupunkt is a manufacturer of car communication technologies, e.g. car audio, traffic telematics, and radiophones. With about 7,000 employees (2,600 in Germany) and a volume of five million car radios per year, Blaupunkt is European market leader in car radios (Blaupunkt, 2000). In July 1998, Blaupunkt introduced an Internet-based electronic catalog which enables specialised traders and aftermarket customers to order products and to obtain information about products, prices, delivery status and backlogs.

In order to provide a corporate identity against its customers, Bosch wants to unite the sell-side applications and catalogs under the same roof, a Bosch Portal, which shall be used to bundle up cross-business unit processes for business-to-business as well as business-to-consumer. By providing an overall Bosch Group portal, several ERP and custom built applications, even from different business units, have to be integrated. That is where the business bus comes into play as a standardised integration architecture. Corporate identity is not the only reason for an overall portal strategy. As some of the Bosch customers order products from different business units, Bosch wants to profit from the synergies of an integrated solution.

Figure 3 Applications and interfaces at Robert Bosch



The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

4.1.3. Integration of SCM systems

Another business networking strategy which mainly evolved from the logistics discipline is supply chain management. SCM aims at optimising the flow of goods between multiple processes (Handfield and Nichols, 1998). First logistics approaches were geared to overcome the functional orientation within an individual company which involved the coordination of materials management along procurement, production, warehousing, and distribution activities in order to reduce inventories and increase flexibility to react to changing market demand. With the advent of ERP systems many companies have achieved considerable levels of internal supply chain optimisation.

As a manufacturer, Bosch uses SCM systems for the coordination and optimisation of its internal supply chain for a long time. The requirements evolving from the implementation of EC systems, such as reduced cycle time and available-to-promise checks, drive the need for a tighter integration between Bosch's plants, central and regional warehouses and finally the suppliers. The availability of a new era of SCM systems that gain their legitimacy primarily from the three technological innovations – main memory residence, constraint-based planning and cross-organisational and real-time coordination – enable Bosch to develop an inter-organisational model of the supply chain in order to integrate its business processes more tightly with those of its suppliers. Therefore, an SAP Advanced Planner and Optimiser (APO) system is currently projected for the retail business units. With the implementation of this system several custom-built applications, SAP R/2 and SAP R/3 systems have to be integrated, which will result in about 200 new interfaces. Because of the complexity that evolves from this implementation project, the business bus will offer a more flexible approach to Bosch.

4.2. Description of solution

4.2.1. Evaluation of EAI systems

The analysis of the different integration approaches in Section 2 showed that available EAI systems address different integration levels such as data, object and process integration. The analysis of different vendor's approaches at Bosch signified that today one EAI system alone does not cover all aspects of a specific information systems architecture that can be found in a specific company. In order to decide which of the available EAI systems is suitable for the Bosch business bus, the company evaluated five different EAI systems from BEA Systems, CrossWorlds, IBM, Level 8 Systems and Mercator Software by applying four criteria derived from the generic component architecture described in Section 3.

First, with the implementation of SAP R/3, Bosch needs to integrate several mainframe and custom-built applications, for which no standard adapters can be used. Additionally, Bosch already uses IBMs MQ Series for the physical transport of data between applications. Therefore, the EAI system must be like a toolkit application, which first allows the developers to individually build adapters for in-house developed systems and, second, can be used with existing tools that are already used as a standard for application integration.

Second, the connectivity services of an EAI system enable data integration by using synchronous and asynchronous mechanisms. By applying one of these mechanisms, it can be differentiated if the systems support a more tight or a more loose coupling of applications. EAI systems that support tight coupling of application assist companies with synchronous integration, whereas systems that support loose coupling assist companies with asynchronous integration. In most organisations, both mechanisms are applied. A prominent example for asynchronous data integration is the exchange of master and transactional data between distributed ERP systems. On the other hand, synchronous mechanisms are very often used for EC applications that support available-to-promise checks in the ERP system. Because Bosch needs a flexible architecture that supports both asynchronous and synchronous integration scenarios, the company needs an EAI system that supports both.

Third, one major component of an EAI system is interface services that provide functionality for the translation of different application's APIs and object models. Most of the EAI vendors, such as CrossWorlds and Level 8 Systems, have concentrated on APIs and object models of standard business applications like SAP R/3 Oracle and Baan. Only a few vendors like BEA or Mercator

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

Software that originally built traditional middleware solutions deliver EAI systems that support the customer with functionality for the integration of legacy systems such as IBM CICS or Siemens BS2000. Especially for historically grown, multinational companies like Bosch that already use these systems, the support of such systems is crucial as the replacement of them is often not profitable.

Fourth, the distinction between an intra- and inter-organisational integration focus is another differentiation criterion. The history of the EAI vendors provides good insight into whether one or the other approach is followed. Both BEA Systems and Level 8 Systems, for example, have a strong middleware background, whereas CrossWorlds is a relatively new player in the EAI market and therefore has specialised in providing EC processes. CrossWorlds offers standard EC process configurations which can be customised easily with a graphical workflow modeling tool. Mercator Software on the other hand has its company background in the integration of EDI and backend systems. That is the reason why Mercator Software integrated a wide range of EDI scenarios such as UN/EDIFACT and Odette in its Mercator product suite. Table II summarises the different vendor approaches that we extracted from the experiences in the Bosch project.

4.2.2. Implementation of the Bosch business bus

> An infrastructure designed around information flow will be the "killer application" for the twenty-first century (Gates, 1999).

Ranadivé defines this kind of infrastructure as a hub that integrates and circulates content among partners (Ranadivé, 1999). Another approach is the "integration backbone", developed by the Open Applications Group (Connelly, 1999). Figure 4 applies the metaphor of the business bus to the elements of the information systems architecture of Bosch as they were described in Section 4.1. Each business unit uses specific customised versions of the SAP R/3 system, such as the retail units and the automotive equipment unit. In order to implement intra- and inter-organisational business processes across all business units and with customers and suppliers, Bosch uses SCM systems and EC systems from SAP and other vendors such as Intershop. Finally, Bosch consolidates enterprise-wide financial and accounting data in a SAP R/3 world system. All these systems have to be integrated into the existing information system architecture via the Bosch business bus. Bosch selected IBM, Level 8 Systems and Mercator as EAI tools for its business bus because these three systems all support different integration scenarios. The business bus at Bosch is the aggregation of these three systems that support all necessary business processes and applications.

The advantages of a homogenous business bus are as follows. Weston *et al.* (1998) characterise the purpose of the business bus concept for the organisation and control of interoperation between different systems, so that their collective behavior can be targeted at specific company-wide goals. The major benefits derived from the business bus architecture at Bosch are:

- supports a best-of-breed approach;
- provides more flexibility in intra- and inter-organisational process integration and change of business processes across different heterogeneous IS;
- provides a backbone for the flexible integration of suppliers and customers with CRM, EC and SCM systems; and
- cost savings in implementing new and maintaining existing applications.

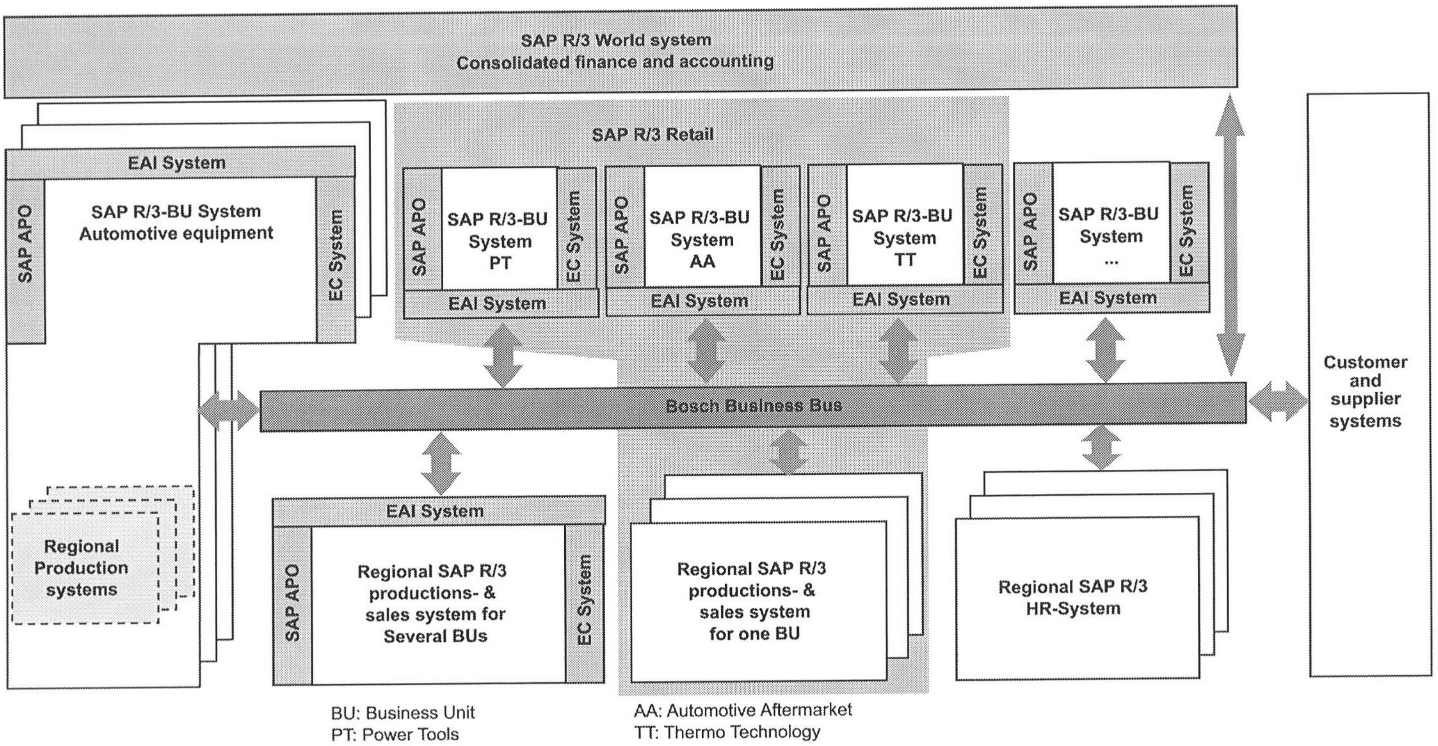
As investments in information systems are always scrutinised, the argumentation basis for EAI systems must be even stronger as they only provide functionality for the integration of other information systems. To look at the cost savings mathematically, the number of possible integration points between any two applications (assuming two-way integration) grows at a rate of $n \times (n - 1)$. For two software components, the minimum number of connections between them is two. When we apply this model for an example where 702 interfaces are involved in an integration project, the formula is $27 \times (27 - 1) = 702$. Each interface usually requires some amount of time to be build and then some amount of time and effort to be maintained. For example, if it takes 10 per cent of a full time person to maintain an interface, which is roughly two days a month, and one has 27 software components to integrate, this environment would require 70.2 full time

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

Table II Differentiation criteria for EAI systems

Systems	Development and runtime services	Connectivity services	Services: Interface and transformation services	Process management services
BEA Systems eLink	Toolkit application	Tight and loosely coupling	Custom-built application integration	Intra-organisational integration
CrossWorlds United Applications Architecture	Integrated application	Tight coupling	Standard application integration	Intra- and inter-organisational integration
IBM MQSeries Integrator	Toolkit application	Loose coupling	Custom-built application integration	Intra-organisational integration
Level 8 Systems Enterprise integration template	Toolkit application	Tight and loose coupling	Standard application integration	Intra-organisational integration
Mercator Software Mercator	Toolkit application	Loose coupling	Custom-built application integration and SAP R/3	Intra- and inter-organisational integration

Figure 4 Bosch's IS architecture



The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

equivalent (FTE) persons to maintain interfaces ($702 \times 0.10 = 70.2$).

When using the business bus model for integration, the cost formula looks very different. Because this calls for a "many-to-one" integration concept, the mathematical formula is simplified to a flat growth rate of $n \times 2$. If we assume the same costs for maintaining an interface, the formula is $27 \times 2 = 54$ as the minimum number of connections between 27 software components. Multiply 54 times 0.10 FTEs and the result is 5.4 FTEs. The full monetary costs are revealing when compared side by side. When we assume that the expense of a software engineer is €100,000 a year, with fully loaded costs such as salary, benefits, vacation, health care, etc., we can compare the cost of traditional point-to-point integration to the business bus integration approach (see Table III).

5. Conclusions

This paper described EAI as an instrument for the standardisation of an integration infrastructure. Effectively managing the transformation to a process-centered organisation will be critical to the success of the twenty-first century organisation. Every aspect of the modern organisation is being transformed by integration of disparate processes. Fundamentally, enterprise business systems are process systems. Systems, such as ERP, CRM, EC and SCM systems, form the backbone of the modern enterprise. The migration of companies toward these enterprise applications is a big challenge. Emphasis on enterprise applications increased significantly in the mid-1990s as companies scrambled to find ways to root out old legacy systems incapable of meeting the stresses of the global economy. Today, as companies race toward the information economy, their structures are increasingly made up of interlocking enterprise applications. With the emergence of so-called EAI systems, isolated, stand-alone applications fade further into history.

As our project activities at Bosch and other companies have shown, EAI systems can generate benefits in two areas. First, EAI systems sustain integrated information flows and improve flexibility of business processes within and between organisations. Second, EAI systems are instruments to reduce the cost of implementing and maintaining distributed, heterogeneous IS inside large multinational companies. However, assessing and introducing EAI systems are complex processes which call for a systematic and homogeneous approach with suitable criteria.

Besides the complexity of the business bus to be defined, other factors were found at Bosch to have impact on realisation. First, EAI systems presuppose an effective information system architecture planning. For example, when regional subsidiaries implement new IS, not considering the compatibility with the business bus, the legitimacy of EAI systems becomes obsolete. Therefore, the implementation of IS in decentralised organisation structures strives for a central coordination unit in order to maintain a homogeneous integration architecture.

Second, EAI systems are associated with significant scale economics. Each implementation of a new IS within the IS architecture will decrease the implementation cost. Consequently, organisations should strive for a high degree of utilisation of the business bus when integrating new applications.

Third, the different integration approaches of EAI systems drive the need for the use of different EAI systems in one company. For example, the CrossWorlds product provides a highly integrated system for the integration (intra- and inter-organisational process integration) of packaged standard software whereas the Mercator solution is currently one of the best solutions for the transformation

Table III Comparison of costs for point-to-point and business bus integration

Integration model	Implementation of applications	Maintenance of existing interfaces
Point-to-point	$[(100{,}000:365) \times 15] \times 702 =$ €2,884,932	$70.2 \times 100{,}000 =$ €7,020,000
Business bus	$[(100{,}000:365) \times 5] \times 702 =$ €961,644	$5.4 \times 100{,}000 =$ €540,000
Savings	€1,923,288	€6,480,000

The Journal of Enterprise Information Management
Volume 17 · Number 2 · 2004 · 105-116

(object integration) of message formats. As all these systems differ in terms of flexibility, functionality, performance and complexity, companies will need to rely upon a best-of-breed approach in using EAI systems for their business bus. Given the requirements for an optimal combination of EAI systems by applying systematic differentiation criteria, the solution of a business bus as a standardised architecture has shown a practicable way of how to solve the integration problem driven by software, financial, internal and external drivers.

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