Virtual Organization and Supply Chain Management

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Abstract

In the center of supply chain management initiatives are the series of applications that synchronize demand and supply, manage inventory, ensure service-level commitments, and provide greater visibility into the manufacturing operations. At the same time the concept of Virtual Organization (VO) challenges the way industrial production systems are planned and managed. The topic is analyzed in context of vertically integrated public limited company Eesti Energia AS (EE) located in the Republic of Estonia where for the companies that are related with electricity grid management is implemented software in the framework Tehnonet (TN), which uses concept of VO.

1. Introduction

Traditional organizational boundaries are a thing of the past. New realms of technology and convergence have created a new business opportunities and challenges. To compete successfully in today’s marketplace, organizations need concurrently to manage effectively and efficiently the activities of design, manufacturing, distribution, service and recycling of their products and services to their customers. Velocity, visibility, scalability, innovation and cost govern competitive advantage for organizations viewing the entire world as their market. Serving the right customers, finding the right suppliers, and fostering trust with the right partners have a great impact on todays as well as future business performance. To attain these objectives, it has become imperative for organizations, all over the world, to tap the concepts of Supply Chain Management (SCM) [1].

A supply chain can be defined as the set of activities required providing products and services to customer, starting at the point of product design and ending with the delivery and installation of the product or provision of a service for customer. That all can be effectively linked through information technology solutions, better planning and forecasting, efficient manufacturing practices and tighter, closely linked relationships with suppliers [2][3].

At the same time the manufacturing process is not carried on by a single enterprise anymore. Companies are feeling the need to focus on their core competencies and get involved with others in order to fulfill the requirements of the new products / services / - quality demanded by the market. But if company cannot communicate effectively with partners and suppliers, the benefits of specialization are diluted because of the cost of coordinating activities across companies.

In cooperative networked organization, every company is just a node that adds some value to the process – a step in the manufacturing / supply chain. Cooperative networked organizations can be modeled as a Virtual Organization (VO), which materializes by selecting skills and assets from different companies and synthesizing them temporarily into single functional business entity to respond to business opportunities [4]. VO can be defined as temporary alliance of enterprises that come together to share skills and resources in order to better respond to business opportunities and which cooperation is supported by computer network.

This paper offers an approach that can be used by cross-functional supply management tears using VO approach to integrate companies business processes more effectively, offering same time process visibility, adaptability, traceability properties.

The motivation of this research was to renovate Tehnonet Connection layer to give it a better ability to support supply chain demands. A Tehnonet framework [5] is layer-based approach of VO for electricity production, transmission and distribution, in order to assist different task related to the internal management of information. Project was funded by EE.

2. Previous research in SCM

The concept of supply chain management is often traced back to Forrester [6][7] who identified the dynamics of response to changes in demand in supply chain situations. Forrester identified that typically there is a distortion in demand patterns created by the dynamic complexity present in transferring demand from end users along a chain of supply to manufacturers and material suppliers. One of the key implications of this work was that the inter-dependence of participants in
supply chain was highlighted, such that any participant’s potential to optimize performance would be constrained by the limitations inherent in the overall system. The complexity of the dynamics of the supply chain has led to the isolation of many different sources for this distortion such as flows of information between and within companies, material flows between companies and chaos theory [8-10]. Some authors [11-14] regard it as “management philosophy” to deal with integrated material and information flow right from raw materials to consumption of finished goods by the end-user. Cooper et al., Novack et al. [16] and Tyndall et al. [17] emphasized that SCM is integrated and synchronized “operational efforts” to improve flow of material and product. Another stream of authors [18-20] believe that SCM is a “management process”. Handfield and Nichols [21] state that the supply chain encompasses all activities associated with the flow and transformation of goods from the raw material stage [extraction], through to the end user as well as all information flows. Analytically, a supply chain is simply a network of material processing cells with the following characteristics: supply, transformation, and demand [22]. The essence of supply chain management is as a strategic weapon to develop a sustainable competitive advantage by reducing investment without sacrificing customer satisfaction [23]. While reduced cost is typically a result, supply chain management emphasizes leveraging the skills, expertise, and capabilities of the companies who comprise this competitive network referred to [24]. Besides, it also represents a paradigm shift that extends one’s appreciation for the concepts of co-operation and competition in such a business environment [25].

3. Problem formulation

Over the last few years, EE which is a 100 per cent state-owned vertically integrated public limited company, engaged in oil-shale mining, power production, transmission, distribution and sales as well as other power-related services, have evolved supply chain practices and systems from industrial age concepts to the information age – an age rich in connectivity and data [26]. This has allowed changing the foundational structure on how to manage the enterprise. The information age that brought us supply chain systems has allowed us to begin to control the chaos that we had found about us.

A chaotic system is defined as one that appears to behave randomly, but is, in fact, governed by rules. Chaotic systems are highly sensitive to initial conditions, the seemingly insignificant and arbitrary events that ultimately can have profound and seemingly unpredictable results. But in reality, the results are fairly predictable if our measurement devices sense these inputs.

Market formulation is like these chaotic systems, where the confluence of many activities ultimately creates an organized storm or system. What is true is that many of these events are understood and the outcome of them can be predictable. But today, these are not modeled in the systems Eesti Energia AS have. Supply Chain systems to date have represented the back-end of that process of servicing markets, which heretofore appeared to be the tail end of the chaotic system – the least powerful and uncertain.

The supply chain, in embracing the digital world, has taken us a long way in replacing assets with information. But the fact is, building products still takes a long time. Contrastingly, markets require short response times – days.

Companies belonging to EE have tried various methods to deal with this – outsourcing many processes to dump risk down the chain, reduce product selection and specialization, and charge more (when they can) for customizations. Some of the thought process around this is healthy, since it forces companies to think about their differentiation.

So the goal is to use IT and new approaches to manage demands, supply, manufacturing, distributor and retailer processes (Fig. 1).

4. Supply chain challenges

Tackling the supply chain is no simple task. Optimizing the supply chain comes with its own set of business challenges. There are two ultimate supply chain challenges:

▪ Instant Needs – the instant needs means the ability to respond quickly to short-term change in the demand to manage external disruptions more effectively. Virtually all businesses face unexpected and sudden new demands and disruptions to their supply chain from time to time. The key to instant response to the unexpected is preparation. Planning and practicing for various scenarios and putting the tools, procedures and relationships in place, better prepare businesses for unanticipated events as well.

▪ No Central Command - as with any supply chain, it is critical for relief efforts to know their “markets”- who needs what, how much, and where. Lack of centralized command can lead to chaos and waste. It is possible to solve these business challenges with concept of Virtual Organization and using software techniques as SOA and BPEL, described in the following sections.

Actually, there is a third challenge, which is lack of infrastructure. Infrastructure is a very important
component for supply chain, because it gives possibility to supply services and/or goods. The military has the most experience creating instant supply chains in areas lacking of infrastructure. They are trained and organized to construct their own bridges, airports, and roads, when needed, as well as landing on shorelines and travelling over rough terrain. Mostly the response had included creative approaches. This challenge is not analyzed in current article, because it was not the subject of research.

Traditionally producers and manufacturers “driving products to market” have driven the supply chain from the back. The dominant action in a traditional supply chain was to push products downstream towards end customers. Companies in the supply chain were merely acceptant of demand based on the orders received from businesses in front of them. They rarely had any visibility into the true market demand for a product. To maintain downstream momentum in order to reduce inventory investments, upstream businesses constantly had to exert pressure on the downstream businesses to place orders. In this environment, demand could often be unstable and therefore hard to predict. Items could go from a situation of under-stock to over-stock in very short spaces of time, and businesses across the supply chain did not have timely and accurate information in order to balance the turbulence.

Nowadays, there is tendency that supply chain are driven from the front by customer demand [27]. That kind of network is called in literature as demand-driven supply networks (DDSN) or customer centric supply networks (CCSN).

DDSN defines that companies in a supply chain will work more closely to shape market demand by sharing and collaborating information. In doing so, they will have greater and more timely visibility into demand. The aim of this collaboration is to better position everyone with the ability to more closely follow market demand and produce, in tandem, with what the market wants. Rather than replace the force of pushing, product to market, the DDSN strategy is to match a pull from customers with an equal and opposite push from supply chain members. Instead of leading the market from a push and artificially inducing unsustainable market demand, the concept behind DDSN is to react in tandem with demand. The methodology behind DDSN is to bring the supply chain eco-system into balance, as concept of VO.

5. ERP movements

Topic of supply chain management has a long history. After advancing from Material Requirements Planning (MRP) to Manufacturing Resource Planning (MRP II) in 1975, a new vision for the enterprise resource planning (ERP) domain was established in 1990. That vision centers on resource planning and inventory accuracy and visibility beyond the plant and throughout the manufacturing enterprise, regardless of whether the enterprise was a process manufacturer, discrete manufacturer or the both. That vision has since evolved beyond manufacturing and beyond resource planning to “extended ERP,” as many industries turned to ERP systems to provide “backbone” financial transaction-processing capability. However, as ERP deployment became less capable of providing competitive advantage, enterprises looked to applications like supply chain management (SCM), customer relationship management (CRM) and, more recently, e-business functions to jump ahead of their competitors. ERP vendors responded by pursuing the vision of the enterprise application suite (EAS) through partnerships, acquisitions or native product development [28].

The vision of ERP II (ERM) addresses the future by focusing on deep industry domain expertise and on conducting inter-enterprise, not just enterprise, business. For users, the ERP II represents a business and application strategy that builds on current ERP deployments and converts the information within the enterprise into a tool for collaboration within communities of interest.

ERP II includes six elements that touch business, application and technology strategy. These elements are the role of ERP II, its business domain, the functions addressed within that domain, the kinds of processes required by those functions, the system architectures that can support those processes, and the way in which data is handled within those architectures. For ERP II, with the exception of architecture, all of these elements represent an expansion out from ERP.

The role of ERP II expands from ERP’s design to optimize the enterprise’s resources to include leveraging the information involving those resources in the enterprise’s efforts to collaborate with other enterprises within a community of interest. ERP II’s domain expands beyond ERP to include non-manufacturing industries. Functions addressed within those industries expand beyond the traditional manufacturing, distribution and financial areas to include – within a focused industry domain context – traditionally complementary ERP web-centric functions such as CRM, HR or SCM.

The ERP vendors who also focused on SMEs like Microsoft, Oracle, SAP are started to pioneer to support radio frequency identification (RFID) capabilities by embedding a specific middleware layer within their feature-rich ERP solutions [29].

This strategy goes counter to the philosophy of providing a stand-alone RFID facility, which could require a dedicated IT staff for maintenance, support, and training. Realistically, the services component would be significant as integration with the various business applications must be designed and constructed. Not only does this reduce IT complexity by eliminating otherwise required external software, the embedded approach also reduces training and promotes familiarity as users access the RFID capabilities through common and existing user interfaces. Additionally, expected benefits and savings
are realized sooner as out-of-the-box integration is provided with core business processes or content.

By providing a common interface to access RFID capabilities, the embedded RFID strategy for SMEs provides also a flexible and extensible framework for partners to implement customer specific and unique solutions, thereby acknowledging that no one vendor can support the myriad of potential RFID applications.

6. VO as SCM strategy

First mentions of VO, sometimes referenced to as “virtual corporation”, dates only at the beginning of this century. During the last years a large number of new collaborative networked organizations have emerged, namely as a result of the progress on computer networks and communication systems. In terms of research projects, there are various levels of required infrastructures, to support not only inter-enterprise collaborative networks but also more human-oriented networks. According to VOSTER IST project analysis in Europe there exists at least 32 research projects in the field of VO infrastructure [30].

The ‘typical’ VOs have been mostly focused on the basis interaction to support business collaboration among companies, including safe communication, distributed information management, and information sharing (e.g. using standards as EDIFACT, EDIEL, ebXML, STEP), coordination, and (minimal) distributed business process management, with little focus on the human collaboration.

The second level of infrastructure is mostly dedicated to support collaboration among humans, although some of the projects also consider the organizations behind the professional virtual communities (e.g. networks of consultants, Concurrent / Collaborative Engineering in networked organizations).

The third level is focused on special case of human collaboration. It combines both inter-organizational and human collaboration, but including the access to remote equipment (e.g. machines, sensors), collaborative experiments involving teams located close to the equipment and teams located remotely.

Not depending on infrastructure, when the VO is used as a supply chain strategy, it gives us three main advantages:

- Shaping demand - participants in the supply chain are all able to take part in shaping demand as opposed to merely accepting it. Where businesses traditionally had little or latent visibility into market demand, the collaborative technologies employed in implementing VO have the overall effect of reducing and even eliminating the gap between upstream businesses and the end customer. This gives them a more accurate and timely insight into market trends to increase the accuracy of their forecasts and hence their ability to interpret and respond to demand fluctuation.

- This type of market intelligence impacts more than just a business ability to plan operations; it translates directly into reduced inventory holdings across the supply chain, which, in turn, means an overall reduction in the amount of capital invested therein and the associated risks.

- The customer centric approach, as opposed to the factory-centric approach of VO accepts that product design and ongoing product innovation are key requirements in creating competitive advantage and shaping demand. Early feedback from customers can help product designers better understand what customers like and don’t like about their products. In addition, product designers can also interface more readily with manufacturing facilities to assist in solving production problems that may arise, especially in the early stages of production setup.

- Deterministic optimization is replaced with probabilistic optimization that uses stochastic optimization methods to handle variability. Probabilistic models do a better job of accounting for the uncertainties that exist in the supply and demand equation. Probabilistic modeling also enables simulation of "what-if" scenarios so managers can randomly vary their initial conditions.

In our project we hope that the improvements in demand forecast accuracy instill increased levels of responsiveness and cuts costs throughout those members of a supply chain who participate using the VO model.

Before looking at integration technologies in VO closely, let’s clarify the concept of Web service, SOA and BPEL.

7. Service oriented architecture

During the last few years, the topic of service-oriented architecture has been very popular, but still there are some misconceptions.

SOA is an application architecture in which all functions, so called “services`, are defined using a description language and have evocable interfaces that are called to perform business processes. Processes, transactions, and special functional components all have to be exposed as services allowing composite, diverse applications to be exposed too. Each interaction should be independent of each and every other interaction and the interconnect protocols of the communicating devices (i.e., the infrastructure components that determine the communication system does not affect the interfaces), SOA would be a set of services (which are, again, groups of software components executing certain business processes, such as processing a payment order, calculating or updating currency exchange rates, or authenticating users), on a network that can communicate to each other.

Though built on similar principles, SOA is not the same as Web services, which indicates a certain collection of technologies, such as the SOAP, UDDI, WSDL, and XML. In simpler terms, XML is used to tag
the data, SOAP is used to transfer the data, and WSDL is used for describing the services available, while UDDI is used for listing what services are available. Used primarily as a means for businesses to communicate with each other and with clients, Web services allow organizations to communicate data without intimate knowledge of each other's information technology systems behind the firewall. Being Web-based applications that dynamically interact with other Web-based applications using open standards, Web services act analogically to electronic data interchange, with the difference of being an electronic process interchange instead.

SOA is closely related to the Business Process Management (BPM). BPM entails a broad set of services and tools provide for explicit and complete process management, where the companies can flexibly change the way transactions, queries. At the same time communications are handled, and dealt with exceptions or glitches. BPM is not like every other information technology project, rather, it is a strategic, high-visibility company-wide initiative - and it is essential to get it right for both competitive and compliance reasons.

BPM based approach supports Business Process Execution Language (BPEL)-based products which work by encapsulating the orchestration facilities necessary to coordinate, manage, and monitor the service-oriented business processes.

Three years ago, understanding the need for a new standard for implementing business processes in the emerging SOA world, the corporations IBM, Microsoft, and BEA submitted a proposed Web services workflow specification to OASIS, called Business Process Execution Language for Web Services BPEL4WS, commonly called BPEL. BPEL is a specification that models the behaviour of Web services in business processes. The original specification was submitted to OASIS in 2002, with royalty-free terms; Version 1.1 was published in April 2003.

The BPEL specification defines the syntax and semantics of the BPEL language, which contains a variety of process flow constructs defined in an XML format.

By using BPEL to define business processes, companies are empowered to select best-of-breed processes and services to incorporate into their operations. This provides flexibility to replace or upgrade certain aspects of a business process without impacting the systems that are working well. For instance, a company can change their warehouse service provider without impacting their order management system, even though both may be participants in several business processes.

BPEL makes sense for environments that already have many exposed Web service interfaces. The greater the number of Web services available, the more valuable BPEL will become. Ease of integration is the reason that Web services have emerged as one of the hottest trends in information technology.

8. Integration technologies in VO

As described above, supply chain management is the practice of coordinating the flow of goods, services, information and finances as they move from raw materials to parts supplier to manufacturer to wholesaler to retailer to consumer. This process includes order generation, order taking, information feedback and the efficient and timely delivery of goods and services.

For many years, ERP systems have continued to refine practices such as Just-in-Time (JIT) manufacturing and vendor managed inventory in order to streamline the flow of goods and thus reduce costs [3]. However, until the recent advent of XML document processing and the ability to transport documents over the Internet, the flow of information between systems has been mired in the complex arena of Electronic Data Interchange (EDI), which has changed little since the 1970’s.

Even with the use of XML to simplify the EDI document format, the EDI paradigm is still such that the systems are loosely connected via a document-based interface. When customer requests a quotation, or wishes to place an order onto manufacturing system, they may send a document in an agreed format containing the structured data for that transaction. That document is delivered either via a Value Added Network (VAN) or, over the Internet. When the document is received, an adaptor will evaluate the document, extract the data and interact with the business system to perform the necessary function. A response, if any, will be constructed and delivered back to the VAN, or through the Internet to the customer. The EDI interface is prone to errors and complexity due to potential problems with delivery of documents and problems when document formats change or they are not consistent between partners.

Systems that support Web services, on the other hand, can easily be connected into a service-oriented architecture in order to allow direct interaction with the business logic. The SOA allows functional areas within the manufacturing system to be made available to other authorized systems. Using Web services, the quoting functions of companies system can be made available directly to customers purchasing systems allowing direct access to the data and business rules that form a quote. Essentially, companies computer system and customer’s system function as one system through the SOA. Web services will truly transform your relationship with your business partners to a real-time relationship. Ensuring that business is running 24x7 both send and receiving transactions. At the same time usage of BPEL gives to the company documented workflow with possibility to analyze its performance, optimization and effectiveness.

Making business nowadays without phone or e-mail would be imaginable, because company just wouldn’t be
competitive, as it wouldn’t be able to react in time. Web services will be just so pivotal in the near future.

At the same time the manner in which data is being stored and accessed plays an important role in defining the proper integration mechanism, what has to be adopted for a given application. In most applications that are from the system engineering domains, the data processing mechanisms require the information being fetched and processed on-line, and on the basis of that the proper decision has to be made on-line when necessary.

Similarly to the access mechanism, the data processing requirements may differ from one application to another – certain applications keep results locally and private, others publish the results immediately after generation, while a third type may require an evaluation time in order to validate the data before they get published and made available to the outside applications or users.

According to Ben Abdelkader [31], to connection between VO-s can be developed also in the level of database. There are two different concepts – concept of Distributed Systems and concept of Integrated Systems. Distributed Systems typically support applications that share common database software at both Distributed Database Management System (DDBMS) servers and their applications. Integrated Systems however, support database applications that address similar tasks in different manners or using different representations and data modelling systems. DDBMS can follow horizontal-, vertical-, or hybrid fragmentation. On the other hand, when the application becomes more complex and requires additional functionalities, most research on related approaches, focusing on the needs for data heterogeneity resolution, result in a variety of integrated systems. Although, a number of researchers in this area still consider all these approaches as heterogeneous distributed systems.

Concept of integrated systems have two approaches respectively Materialized approach (also known as Physical Integration) and Multi-Database System. In Materialized approach the data originating from local and remote sources are integrated into one single database on which all queries can operate. In Multi-Database System data remains on the local/remote sources, queries operate directly on them and information integration has to take place on the fly during the query processing.

The Materialized approach expands into centralized databases and data warehouses. In a centralized database, information is migrated from various sources into a universal DBMS, while in data warehousing information may be imported in different form and volume than it exists in its originating sources.

The Multi-Database System derives into federated and non-federated systems. Each of these systems can be either loosely or tightly coupled.

9. Tehnonet approach

A general requirement for Tehnonet infrastructure is to support concept of VO. It can be pointed out that the VO collaborators (VOC) must be able to interoperate and exchange information on-line so the VOC can work as a single integrated unit at the same time keeping its independence and autonomy. It must also be taken into account that legacy systems were not designed with the idea of directly connecting to corresponding system in other VOC. Every VOC is autonomous, developed independently of other enterprises and uses distinct information management and control strategies that serve its purposes best.

![Fig 2. Concept of VO](image)

Our selected strategy in Tehnonet is to separate the VOC’s internal functionalities from the network-related ones and to develop the necessary mappings to the legacy systems [5]. At the same time we have a centralized Data Warehouse to analyze data and to offer services that concerns whole VO.

To support this environment a basic infrastructure of VOC considers two main modules - internal Module and Connection Layer). Similar approach has e.g. PRODNET project [32].

![Fig 3. TN approach to VO](image)

The Internal Module represents the autonomous unit of a particular company. It includes the complete structure of the company’s information (e.g. databases, information systems) and all internal decision making processes and enterprise activities, such as the internal production planning and control and engineering systems.
The Connection Layer contains all functionalities for the inter-connection between the company and the network. It represents the communication and coordination role.

The Connection Layer includes five modules:

- **Infrastructure Manager** - the aim of this manager is to identify system that performs the query for each external connection and to maintain a log of failures. For that it uses information from the TN VOC Engine and information from the Communication Manager.
- **Synchronization Manager** - the task is to guarantee data completeness of appointed data tables in this way, that some data are synchronized with other VOCs.
- **VOC Management** - module is used to identify VO collaborators, which inside VO will collaborate with presented VOCs. Only those VOCs that are described in this module could be used to connect by other Connection Layer modules.
- **Configuration Module** - This module is used to integrate all TN Connection Layers modules error messages and handle these transferring to the administrator. The main functionality of that module is to configure the Connection Layer modules – e.g. how frequently send out the checking messages, which data tables must be synchronized.
- **Communication Manager** - the task of this manager is to control data exchange between other IT solutions.

Communication manager by itself consists of Protocol Handler, Internal Communication Module and External Communication Module.

Protocol Handler is used for maintaining the communication interfaces – it has functionalities as error logging, performance monitoring and configuring. The idea of protocol handler is to collect all these functionalities for all communication interfaces to one place to maintain. This approach decreases the level of system complexity.

Internal Communication Module is used for data exchange between VOCs and sometimes with other IT solutions – depending on necessity. This interface is created mainly in the level of database.

External Communication Module is used for the integration of VOC with external IT solutions via Web Services – e.g. offering commercial measurement data to the front-office solution, getting weather forecast data, using services like *.pdf generation, *.xml generation, authenticate or sending out purchase orders, invoices etc to other VOC-s linked with VOC-s BPEL workflow description. So, the main emphasis of that module is the BPEL, which is essentially a layer on top of Web Service WSDL. With WSDL, the specific allowed operations are defined and BPEL defines how the operations can be sequenced.

The Tehnonet leverages a BPEL document WSDL as a Web service using WSDL. The WSDL describes the public entry and exit points for the process. Next, WSDL data types are used within a BPEL process to describe the information that passes between requests. Lastly, WSDL can be used to reference external services required by the process.

BPEL deals explicitly with the functional aspects of business processes: control flow (branch, loop, parallel), asynchronous conversations and correlation, long-running nested units of work, faults and compensation. BPEL addresses directly these business process challenges: coordinating asynchronous communication between services, correlating message exchanges between parties, implementing parallel processing of activities, manipulating data between partner interactions, supporting for long running business transactions and activities, and providing consistent exception handling.

Combining VOCs workflows together with the help of Tehnonet Communication Layer which uses BPEL, the VO centric workflow that supports needed supply chain functionalities, is established.

![Fig. 4 BPEL usage in SCM process](image)

10. Conclusion

Across all industries exist needs for aligning supply chain management with business strategy, as well as for collaborating with supply-chain partners.

One of solutions is to use concept of Virtual Organization, which is an emerging and surviving element for enterprises operating under the increasing pressure of global markets with new quality requirements challenges the way industrial production systems are planned to manage.

The architecture developed by the Tehnonet project, addresses some of VO challenges, which offer an environment for the cooperation between autonomous enterprises. We believe that using emerging technologies like SOA and BPEL gives us more flexible environment to build up communication interfaces with others VOCs, to document and manage enterprise business processes, reuse and combine individual existing applications. By reducing the cost of interaction between companies and their partners, the usage VO concept allows companies
to limit their operations to what they do best and to outsource non-core activities.
It seems that the VO approach with usage of BPEL would appear to be suitable for any group of small and medium size companies who intend to integrate their operations.

References