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REALIZATION OF THE VIRTUAL ENTERPRISE PARADIGM IN THE CLOTHING INDUSTRY THROUGH E-BUSINESS TECHNOLOGY*

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This paper presents a methodology and a case study for supply chain management in the clothing industry that makes extensive use of the virtual enterprise paradigm. The main research goal was to design and implement a prototype e-business software component and carry out tests in several industrial users. The research effort resulted in the extended production data management system (EPMS), which supported the business processes of customer order management, subcontractor selection, and multi-site/multi-firm production orders release. The enablers of this software application were business-to-business (B2B) e-commerce technologies in the operating context of application service providers (ASPs).
(SUPPLY CHAIN MANAGEMENT; VIRTUAL ENTERPRISE; CLOTHING INDUSTRY; E-BUSINESS TECHNOLOGIES)

1. Introduction

Today's global economy, enhanced and hastened by rapidly changing technologies of all types, is putting pressure on companies to increase the efficiencies of all their business processes (Davenport and Short 1990). Competition forces all firms to concentrate on "core competencies" while transforming themselves to participate in emerging inter-enterprise formations following the virtual/extended enterprise paradigm.

Like all major vertical sectors, the clothing industry has witnessed a boom of announcements of new business-to-business (B2B) exchanges over the last years. Retailers and manufacturers of all sizes have reacted to these innovative technologies, and many of them have embraced new business model visions with enthusiasm. Others have responded more cautiously, taking careful steps forward and looking more for an established solution rather than an opportunity to define one. In both cases, it has become clear that a leading edge communication system and a reengineered business model are crucial to the development of an extended clothing enterprise using e-business technologies.

This paper presents a methodology and a case study for supply chain management in the clothing industry sector, which has pioneered if not invented the virtual/extended enterprise paradigm. The main research goal was to design and implement a prototype e-business software component and carry out tests in several pilot industrial users. After the construction

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of the AS-IS and TO-BE business models with the use of an enterprise modeling methodology, the research effort resulted in the extended production data management system (EPMS), which supported the reengineered business processes of customer order management, subcontractor selection, and multi-site/multi-firm production orders release. The enablers of this software application were B2B e-commerce technologies in the operating context of application service providers (ASPS). The reengineered business models were evaluated through the use of simulation and activity-based management (ABM).

This introduction is followed by a review of the emergence of virtual/extended enterprises in Section 2. A description of the objectives and the methodology used is given in Section 3, while Section 4 presents the case study. The implemented software systems are presented in Sections 5 and 6, and the conclusions are presented in Section 7.

2. Toward the Virtual/Extended Enterprise Paradigm

In the beginning of the 1990s, the concept of virtual/extended enterprise emerged in the literature with strongly descriptive articles (e.g., Bensaou 1996; Loebbecke and Jelassi 1996; Sieber 1996) that present notions of a virtual organization. For example, Loebbecke and Jelassi (1996) claim that "the virtual organization concept aims at creating a customer/service oriented company, which overcomes geographical constraints, alleviates the traditional dichotomy between centralized and decentralized organization structures and processes." The term virtual organization (VO) has been widely used since Malone and Davidow published their book in 1992 (Davidow and Malone 1992). The first solid definition of this newly emerging production scheme was given in 1993 by Byrne (Byrne 1993), stating that a virtual organization can be defined as a temporary network of independent companies—suppliers, customers, and rivals linked by information technology (IT) to share skills, costs, and access to one another's market. This rather demanding and strict definition of the virtual organization through the years gave way to a more flexible one, which takes into account the problems that could emerge such as legal aspects and trust. Later, Jarillo (Jarillo 1995) argued against the company centric value chain of Porter (Porter 1995) in favor of a business system referring to the whole set of companies that are involved in the value adding process starting from the raw materials.

The problem statement of the virtual enterprise is "how can a whole business system be organized in a way that combines the advantages of vertical integration and the advantages of subcontracting." The clothing industry is the archetype of the virtual/extended enterprise, many years in advance of the emergence of the term in the international literature (Browne, Sackett, and Wortmann 1996). The Benetton story (Jarillo 1993) is a well-referenced example of success that can be attributed to the virtual/extended enterprise organization concept. Benetton, as well as many other clothing industries, is a vertically de-integrated company in all the activities that make up the business system: styling, design, manufacturing, logistics, distribution, and sales. They rely on external people and companies for the major part of these crucial activities.

Global manufacturing trends spell considerably increased competition among manufacturers in both developed and non-developed countries. The new information and communication technologies (ICT) and the processes of globalization have already changed the face of manufacturing (Sheehan 2000). Today, manufacturing exhibits the following characteristics:

- globalization, in the sense that a wide range of functions from Research & Development and marketing to distribution are now undertaken on an integrated global basis
- networking, meaning that the coordination of these functions makes intensive use of electronic networks and of virtual and geographical clusters of expertise
- mass customization, in that methods of production must allow for detailed customization of products to meet the needs of individual markets and customers

- digitization, in the sense that many of these processes are controlled by advanced computer systems, which limit the need for human intervention.

The most compelling example of a virtual/extended enterprise using e-business and Internet technology (B-webs according to Tapscott, Ticoll, and Lowy 2000) is undoubtedly CISCO, which has designed, developed, and delivered a service to manage suppliers, business partners, and end customers (Cisco Connection Online, Tapscott, Ticoll, and Lowy 2000). Specifically, in the clothing industry, the most successful examples of companies operating as virtual enterprises can be met in certain U.S. high fashion apparel companies. They have kept only a small number of processes in-house: those identified as strategic and core competencies that support the overall coherence of the brand. Such companies like Ralph Lauren, Calvin Klein, or Donna Karan, having been unable to build on a locally embedded community of potential partners and subcontractors, decided to create networks their own way (Bonaparte, Cangemi, Lopez, and Pierantoni 1999). In doing so, they established a flexible membership framework in order to follow organizational needs and market transformations.

3. Objectives and Methodology

The objectives of our research project for the clothing industry were to apply newly emerged e-business technologies in order to improve the virtual/extended enterprise core business processes in terms of cost and lead time. A short description of the processes and the related objectives is given below.

CUSTOMER ORDER MANAGEMENT. This process accesses customer orders from the sales department, arranges product specifications, and assigns a delivery date. The reengineering effort was supported by the introduction of an electronic order management/workflow system.

SUBCONTRACTOR SELECTION. The clothing industry is characterized by networks of cooperating companies, each one specializing in different production stages. There is usually a primary contractor that collects customer orders and is responsible for transforming them to production orders. The latter are distributed to subcontractors who deliver final or semi-final products to the primary contractor. The subcontractor selection is a time- and cost-consuming process aiming at the best possible selection from a group of candidate firms. The project's objective was to improve this complicated process with the introduction of an Internet portal that would provide information on manufacturing skills and capacities of potential partners.

PRODUCTION ORDER RELEASE. This refers to the transformation of customer orders into production orders and their distribution to the selected subcontractors. The objectives of the project was to reengineer this time consuming process through the introduction of two IT solutions.

1. A software application for the electronic handling of production orders and their attached product and process specifications (technical data file).
2. A web-based software system responsible for the communication with the subcontractors (technical data file transmission, subcontracted production monitoring).

The enterprise modeling methodology followed in this paper in order to model the above mentioned business processes was developed during a European research project (REALMS II–ESPRIT 23,357, Doumeingts et al. 1999). An overview of the methodology is depicted in Figure 1.

According to this approach, the first steps were the analysis and modeling of the existing system (AS-IS). The established IDEF-0 technique was used to model business processes and their activities, as well as the necessary resources to operate them. Raw data were obtained through interviews and meetings with the appropriate focus groups. The AS-IS analysis phase aimed at identifying discontinuities within existing business processes and their specified

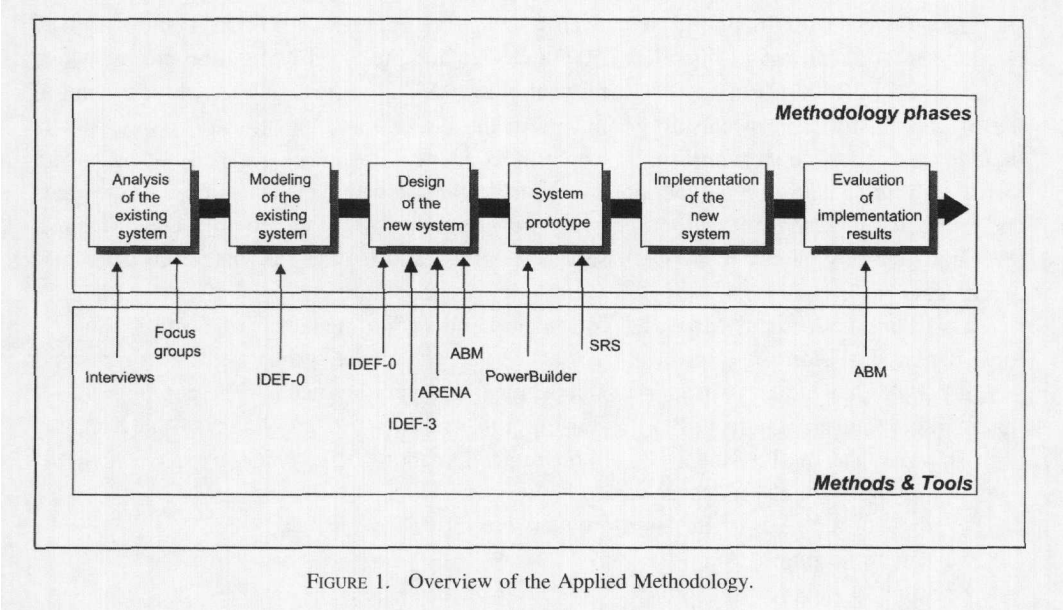

FIGURE 1. Overview of the Applied Methodology.

intent. By discontinuities, we mean anything that prevented the process from achieving the desired results. In essence we identified symptoms of shortfalls and then tried to isolate root causes. Performance indicators such as lead times and cost were used as a basis of judging future improvements of the business processes.

The design of the new system (TO-BE) started with the elaboration of both IDEF-0 and IDEF-3 diagrams and ended with runs of the simulation model of the future business processes. The presence of IDEF-3 diagrams was particularly helpful to the construction of the simulation model with ARENA. The design step was further enriched through the application of activity-based management (ABM) that complemented business process simulation by using its results in the analysis of processes to identify inefficiencies and non-value added activities. It dealt with effectively managing activities to yield continuous improvement by answering "why" and "how well" activities were adding value to products and services.

According to the requirements of the redesigned business processes, a software prototype of the new e-business system B2B was produced in order to examine its functionality through exhaustive testing in the pilot user's environment. This step led to frequent modifications of the prototype based on restrictions of standardized IT development tools. Therefore, the definition of the new system and the selection of the IT structure was done in iterative steps so as to achieve a solution that best fitted the newly designed system and fulfilled an economic implementation of the future IT structure. The IEEE/ANSI 830 standard was used for developing the software requirement specification (SRS) of the software product. The user implementation model was defined including the automation boundary of the system, the basic functions with input and output formats, communication interfaces, and manual support activities, as well as performance requirements and other system's operational constraints.

After the implementation of the solution, the last step of the methodology was the evaluation of the results achieved by the installation of the new B2B application. To assure comparability, the evaluation of the new system was based on the same performance indicators as the old one. The comparison led to conclusions concerning the added value of IT in supporting the selected business processes.

4. Case Study

Mass Fashion SA is the largest and more representative of the three pilot users that have participated in this research. The firm was established in 1976 and is located in Drama

(northern Greece). At that time, it had an annual production of 100,000 T-shirts and 50 employees. Today, Mass Fashion has 250 employees and produces 2.5 million pieces, which are exported all over Europe. According to the 2001 ICAP report, Mass Fashion is one of the biggest T-shirt and sweatshirt producers in the Greek clothing industry. Its customers include the biggest department stores, wholesalers, and catalogs. The company operates in a virtual enterprise environment, acting as a primary contractor for major European customers and using many permanent and temporary subcontractors both in the country and abroad. It does not own any shops, it does not sell to retailers, and it does not make any franchise agreements.

Mass Fashion SA mainly produces cotton garments for women such as T-shirts, blouses, tops, pants, skirts, dresses, and nightgowns. The target market group for the company is young people that prefer a casual dress code for their everyday needs. The competitors for this market mainly come from the Far-East region, and the strategic vision of the company is to improve the quality and to focus on more demanding consumer groups, where the competitors are difficult to approach.

The production phases of the final products are the following:

- Raw material purchasing
- Knitting
- Dyeing
- Cutting
- Sewing
- Quality control and packaging

A broad network of smaller enterprises is used to add value to the semi-final products and reduce the total costs. Figure 2 depicts the Mass Fashion's supply chain.

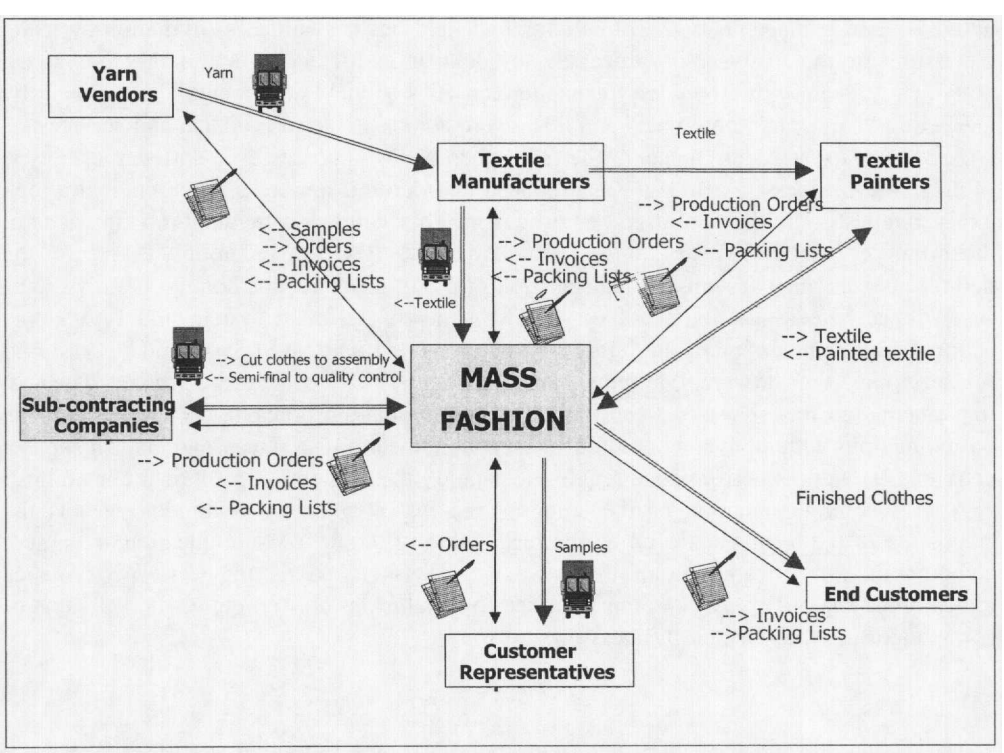

FIGURE 2. Mass Fashion's Supply Chain Model.

4.1. *Analysis and Modeling of the Existing System*

The project team conducted individual interviews with the employees involved in the customer order management and the subcontractor selection business processes. Additionally, meetings with focus groups took place in order to clarify the characteristics and requirements of each business process. This phase was supported by questionnaires and job descriptions for each employee who participated in handling customer or production orders. The objective of this analysis was to collect all the necessary data to be used in the next phase, which was the modeling of the existing system (AS-IS) using the IDEF-0 method (Figure 3).

This phase resulted in the recognition of weaknesses in the present situation that prevented the company from delivering the customer order at the promised time. The most critical weakness identified were long customer order data entry and process times, extensive market research times for subcontractor selection, and high resource costs. Another drawback was the fact that middle- and higher-level employees were devoting a considerable amount of their time in non–value-adding activities.

4.2. *New System Model*

4.2.1. MODEL OF THE NEW PROCESS. The design of the new reengineered business processes introducing the e-business system resulted in the elaboration of IDEF-0 and IDEF-3 diagrams. The IDEF-3 diagrams provided us with the ability to represent aspects of the process such as concurrent activity executing and alternative routing. These aspects enabled us to build the simulation model much easier.

4.2.2. SIMULATION. The simulation model was based on the following assumptions:

- The time between two successive order arrivals was exponentially distributed with a mean value of 2.06 h. This was based on past observations during four selling seasons (2 calendar years).

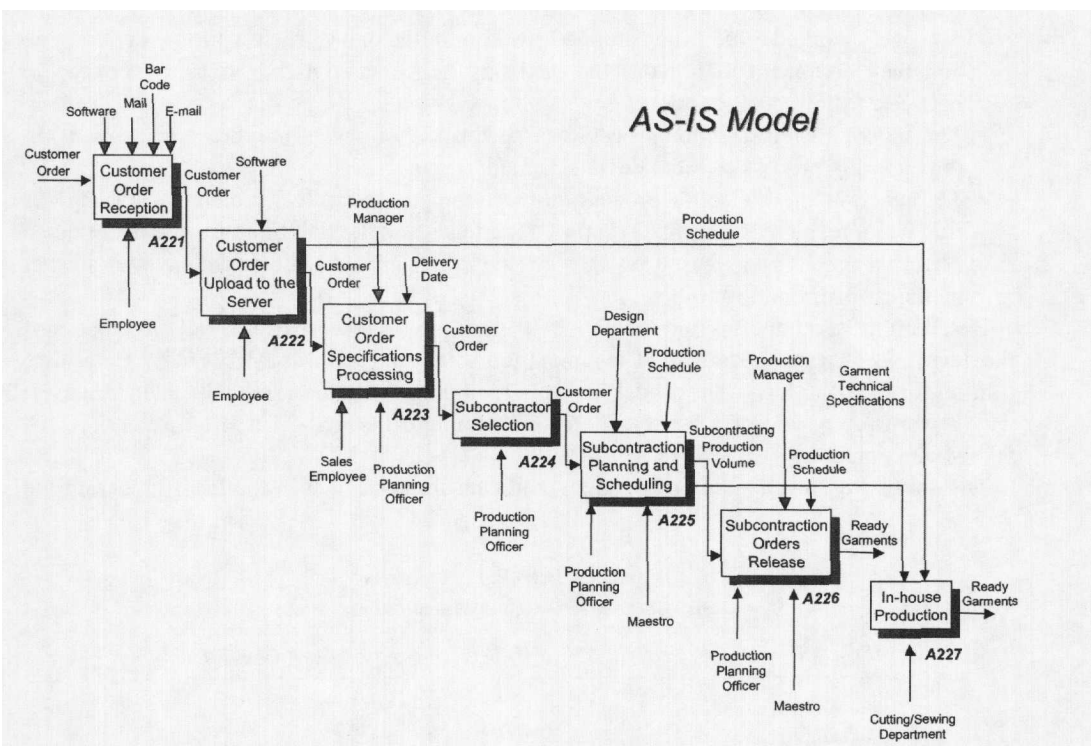

FIGURE 3. IDEF-0 Representation of the AS-IS Situation.

TABLE 1
Incoming Order Categories and Types

Order Category	System Entry Type	Type	Occurrence (%)
Department stores	E-mail	1	40
Department stores	Bar code	2	50
Department stores	Post	3	10
Catalogs	E-mail	4	30
Catalogs	Bar code	5	50
Catalogs	Post	6	20
Wholesalers	E-mail	7	20
Wholesalers	Bar code	8	50
Wholesalers	Post	9	30

- Orders were entering the system either alone (60.3%), or in batches of two (24.7%) or three orders (15%).
- The arriving orders were divided into three main categories: wholesaler orders (87%), department store orders (7%), and catalog orders (6%).
- The orders were categorized in nine different types (as shown in Table 1), depending on the way they enter the system (e-mail, bar code, or post). The last column of Table 1 shows the percentage of the occurrence of the different system entry types within each order category. For example, there are three types of incoming orders from department stores. Type 1 represents the 40% of the orders, which enter the system by e-mail; Type 2 represents the 50% of the orders, which enter the system by bar code; and Type 3 represents the rest 10% of the orders, which enter the system by post.
- There was a one-to-one relationship between the system servers and the employees.
- The server process times were normally distributed.
- Routing time between servers was negligible.
- The users worked 8 h/d. They stopped working in the end of each working day or week and they continued their work the next day or Monday if there was a weekend in between from the exact point they had stopped.
- The subcontracted selection process was performed with web-based reverse auctions. In the past this process was conducted manually.
- The subcontracted selection process followed the business rule depicted in Table 2. This rule was a result of the company's past experience and the duration of the subcontracted selection process was based on information collected from direct contacts with other members of the industry.

Based on the assumptions and the IDEF-3 diagram presented earlier, a simulation model of the new process was constructed. The simulation software used was ARENA 2.2 Enterprise Edition for MS Windows. The model ran for 63,360 h (60 selling seasons/30 calendar years) with a warm-up period of 5,000 h. The actual running time was 23 min on a Pentium III, 500-MHz computer.

The simulation results demonstrated a significant improvement in the lead-time from the

TABLE 2
#Reverse Auctions/#Production Orders Business Rule

Order Category	#Reverse Auctions/#Production Orders Ratio
Department stores	1/3
Catalogs	1/5
Wholesalers	1/5

TABLE 3
Lead-Time Simulation Results (in hours)

Order Type	Average Lead Time (Simulation)	Half-Width Interval (95%)	Average Lead Time (AS-IS)
Type 1	64.153	0.1069	112
Type 2	64.332	0.1051	112
Type 3	68.738	0.1019	112
Type 4	29.639	1.5605	96
Type 5	28.881	1.5451	96
Type 6	33.763	1.3728	96
Type 7	28.734	1.5640	72
Type 8	30.009	1.5212	72
Type 9	30.497	1.4828	72

customer order reception to the selection of the subcontractor. The decrease in lead times ranged between 41.5 (Order Type 9) and 67 h (Order Type 5). The results for the different order types are shown in Table 3. The measure of variability of the simulation output results is given by the information of the column labeled Half-Width Interval (95%). This information represents 95% confidence intervals calculated via the batch means approach (Kelton, Sadowski, and Sadowski 1998).

Utilization data was also collected from the simulation. This information was important for the determination of the necessary number of employees needed in the reengineered process.

4.2.3. ACTIVITY-BASED MANAGEMENT. The simulation results combined with future cost estimations provided the necessary information for the development of an activity-based costing (ABC) study. The results of this study (in EURO per year) are summarized in Table 4.

Four cost categories were used for the calculation of the process costs. The calculations were carried out for both the AS-IS and the TO-BE situation.

The ABC study results proved that the implementation of the new system would induce a decrease into the cost of the process. In particular, it was observed that a substantial decrease in the cost of carrying out the subcontractor selection activity would be realized. This cost reduction was due to the fact that the cost of equipment in the new process was estimated to

TABLE 4
Activity-Based Costing Results (in EURO per year)

	Personel Cost	Administrative Cost	ASP Cost	Cost of Equipment	Activity Cost
Activity-based costing: TO-BE					
Customer order reception	2465	9443	1800	1256	14964
Customer order upload/data entry	22170	1437	2930	628	27165
Customer order processing (owned stores)	14780	9850	0	1884	26514
Customer order (franchise-retail stores)	14780	13548	0	2513	30841
Subcontractor selection	29560	9850	7040	6282	52732
Total	83755	44128	11770	12563	152216
Activity-based costing: AS-IS					
Customer order reception	4920	8620	0	1596	15136
Customer order upload/data entry	44340	2870	0	1995	49205
Customer order processing (owned stores)	17243	15600	0	2394	35237
Customer order (franchise-retail stores)	17243	13548	0	3192	33983
Subcontractor selection	49260	13548	0	30724	93532
Total	133006	54186	0	39902	227094

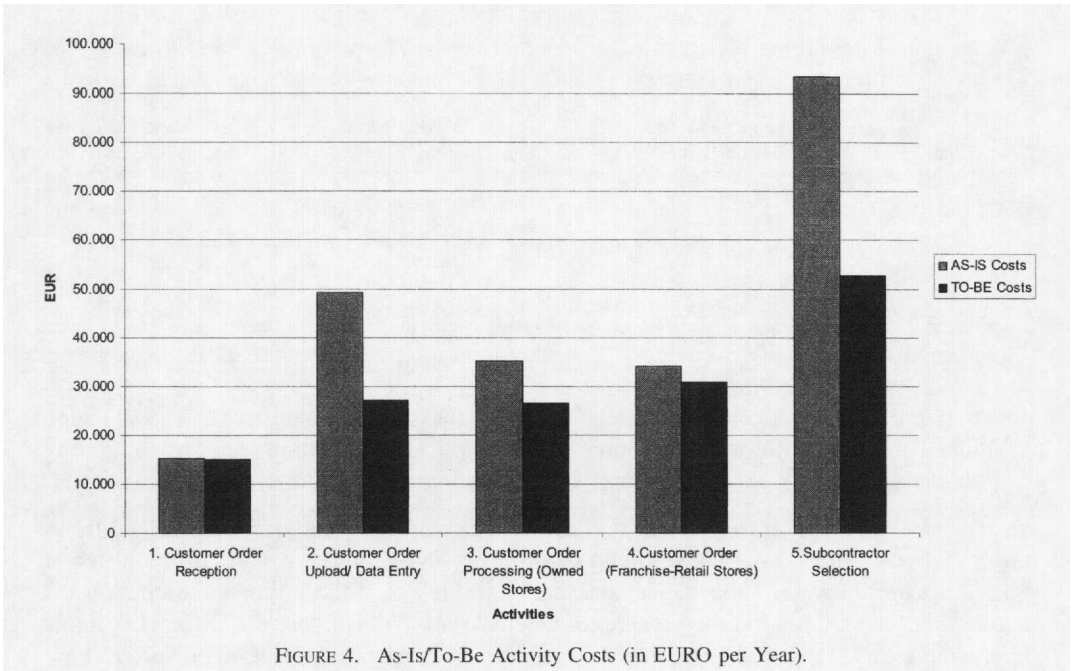

FIGURE 4. As-Is/To-Be Activity Costs (in EURO per Year).

be (by far) less than the one of the old process (less faxes, phones, and photocopies). Figure 4 shows a bar chart comparison of the AS-IS and TO-BE cost per activity.

The costs of four out of the five activities (2–5) of the process were reduced in the reengineered situation.

Figure 5 provides a different view of the estimated cost after the introduction of the IT system by analyzing the different cost categories. It is worth stating that although the biggest absolute cost reduction came from the personnel category (EURO 49.251), the highest percentage of reduction was traced in the equipment category (68.51%).

4.2.4. EVALUATION OF SIMULATION AND ABM RESULTS. The simulation and ABM results justified the proposed design of the system. The evaluation was based on two crucial performance indicators:

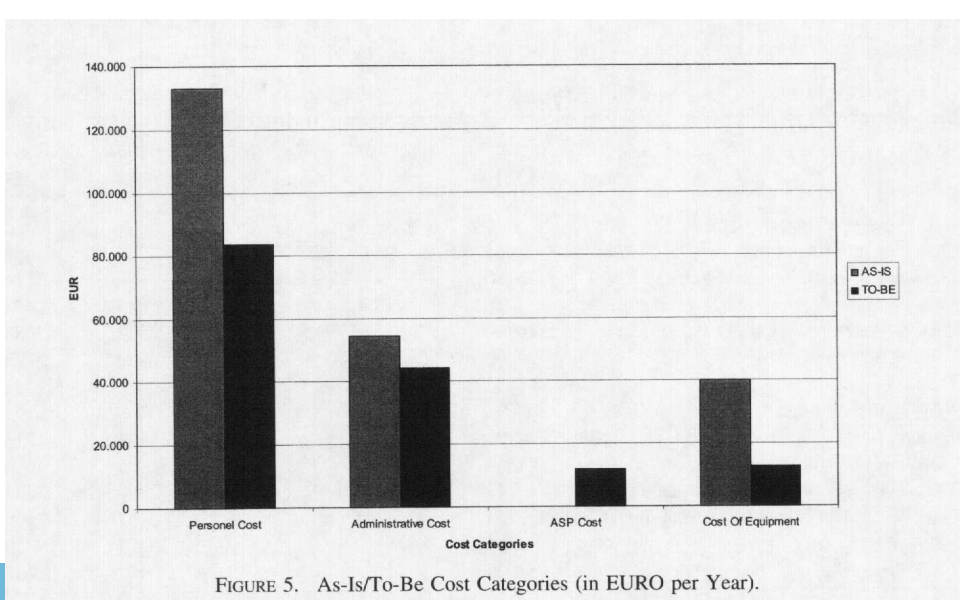

FIGURE 5. As-Is/To-Be Cost Categories (in EURO per Year).

- Total lead time (time period from the customer order reception to garment to shelf): the analysis of the process starting with customer order reception and ending with the subcontractor selection showed a decrease in lead time of approximately 1 week on average. It was assumed that this reduction reflected at least an equal amount of reduction for the whole process.
- Cost: the cost for carrying out the process starting with customer order reception and ending with the subcontractor selection showed a decrease of EURO 74.88.

5. Implementation of the EPMS Software

The EPMS software aimed at being a universal, transparent-access, Internet-based application. It consisted of two discrete submodules:

- A portal and supplier's electronic market for the clothing industry: this application aimed at being the information source for the whole Greek clothing sector by supporting the web-enabled tracking, selecting, and evaluating of qualified partners. The application's front end is an Internet site acting as a web contractor-subcontractor information pool.
- B2B System for production orders release: this module is responsible for technical file data management (TFDMS; product and process specifications attached to production orders) in an e-structured manner and for establishing an ongoing web monitoring of the B2B relationship.

Both systems, with the exception of the technical file data management submodule, were accessed remotely by the users. The pilot applications were hosted by an ASP (Advanced Services Group Ltd.) who was responsible for integrating software with hardware and networking technologies, providing IT maintenance, and consulting services in a 7 × 24 enterprise-class level. The EPMS application workflow is depicted in Figure 6.

Intercommunication between the two EPMS modules is achieved through the use of an intermediate application called capacity manager. This is a bridge application running on both submodules. On the portal's side, it is responsible for the management, successful retrieval, and exporting of the subcontractor capacity data in request. On the other side, it downloads and imports the data set into the capacity availability function of the B2B submodule. After that, the capacity workload function is ready to calculate the subcontractor's potential loading and therefore can determine its ability to undertake the production order in demand. The application's workflow is depicted in Figure 7.

5.1. *Portal and Suppliers' Electronic Market*

The portal and supplier's electronic market is an integrated submodule that provides bilingual (Greek/English) information about Greek clothing industry issues and is empow-

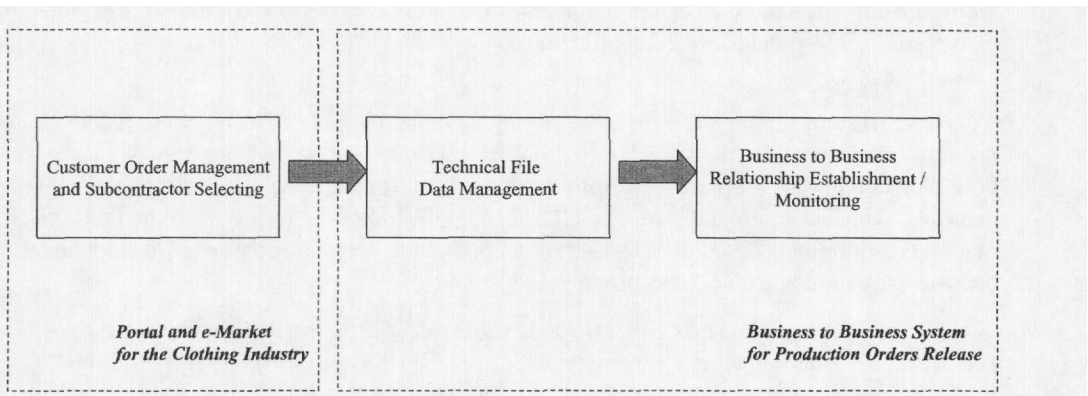

FIGURE 6. EPMS Application Workflow.

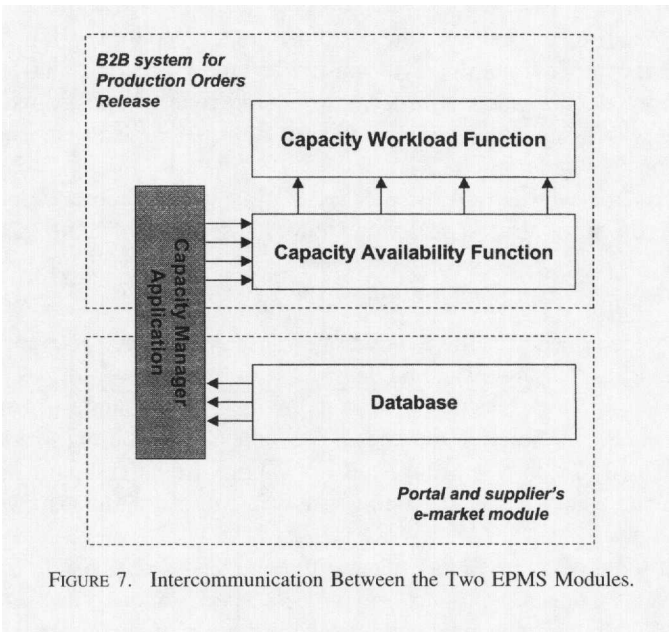

FIGURE 7. Intercommunication Between the Two EPMS Modules.

ered by a real-time help utility. It is based on a thin client/server Internet architecture, utilizing a three-tiered scaled structure on the server side: web server, application server/web-database connectivity server, and relational database management system-RDBMS. This architecture offers the advantage of easy access to system users along with expandability and load balancing benefits to the system platform. This is achieved through the three tiers' physical separation and the Open DataBase Connectivity (ODBC) standard adoption that allows the migration of structured system data into any relational open architecture platform.

The system uses a star topology: the clients (browsers) are connected to the main server through internet service providers (ISPS) and backbone applications as intermediaries. The data packs are transferred with TCP/IP-based protocols (such as HTTP, HTTPS, and FTP), while in the local network level, other data transfer protocols are supported.

The system produces dynamic HTML pages, the appearance and the context of which depend on the database content and the user-submitted criteria. The module architecture is depicted in Figure 8.

5.2. *B2B for Production Orders Release*

This submodule of the application consists of two parts: the first one is responsible for technical data file management and is implemented at the local company database level, while the second handles the communication between the primary contractor and its subcontractors using e-business Internet technologies.

5.2.1. TDFMS

This subsystem supports the creation, editing, and handling of the technical data file by the primary contractor. The activities carried out by TDFMS are shown in Figure 9. The technical data files contain all the necessary information for outsourced production (technical specifications, sketches, color and size sets, etc.). The application runs locally in cooperation to an materials requirements planning (MRP) application, which helps the contractor to calculate the necessary quantities to meet the promised customer orders.

5.2.2. B2B COMMUNICATION SYSTEM. This subsystem is responsible for the secure projection of the production orders with their technical data file to the Internet. Additionally, it monitors the production order progress. In doing so it uses three different functions:

- The order documentation function, which used by the subcontractors to upload and

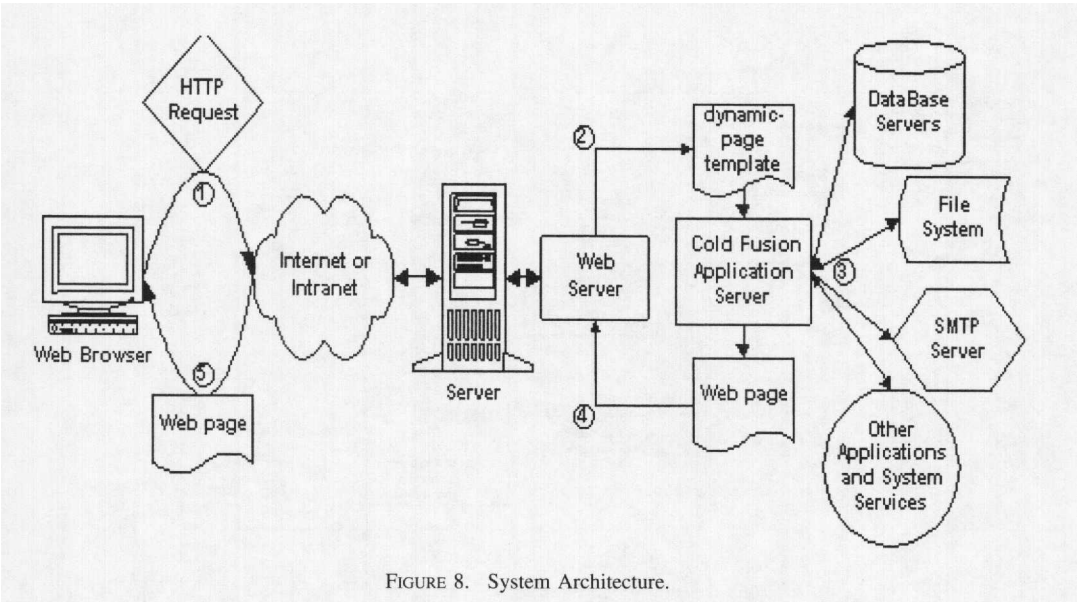

FIGURE 8. System Architecture.

browse attached technical data files of production orders released by the prime contractor.

- The capacity and material control function, which is responsible for the subcontractor's work centers loading.
- The shop floor monitoring function, which is responsible for delivering a report to the primary contractor that includes:
- Production Process Information
- Early Start Date, Late Due Date Information
- Item Production Data
- Production Quality Feedback

The process model that contains the activities supported by the B2B communication system is depicted in Figure 10.

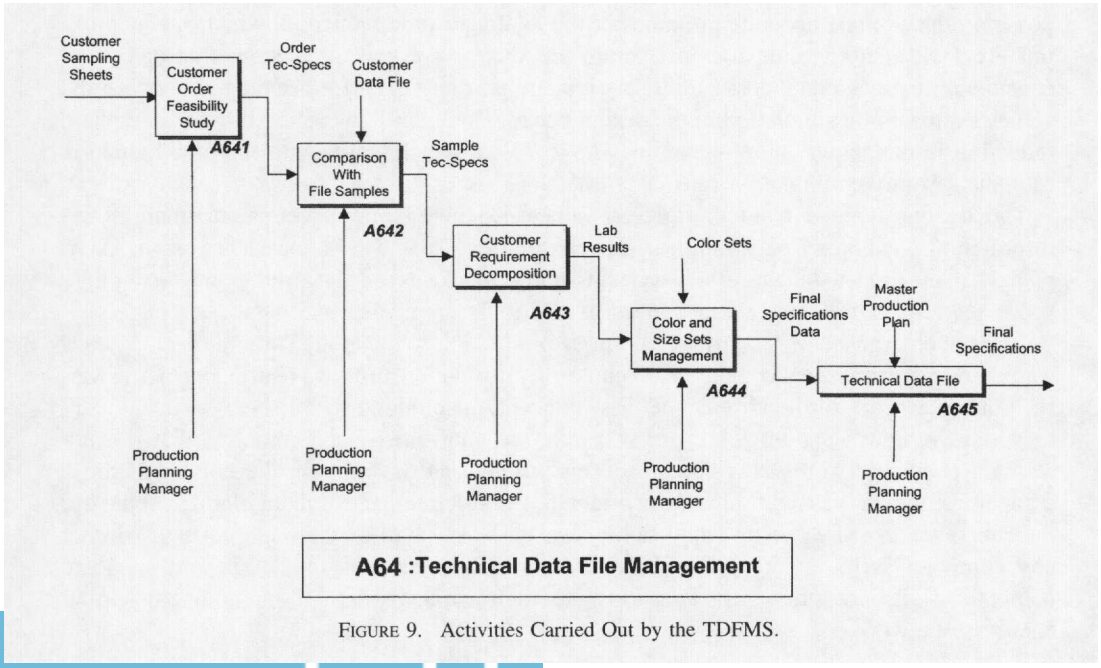

FIGURE 9. Activities Carried Out by the TDFMS.

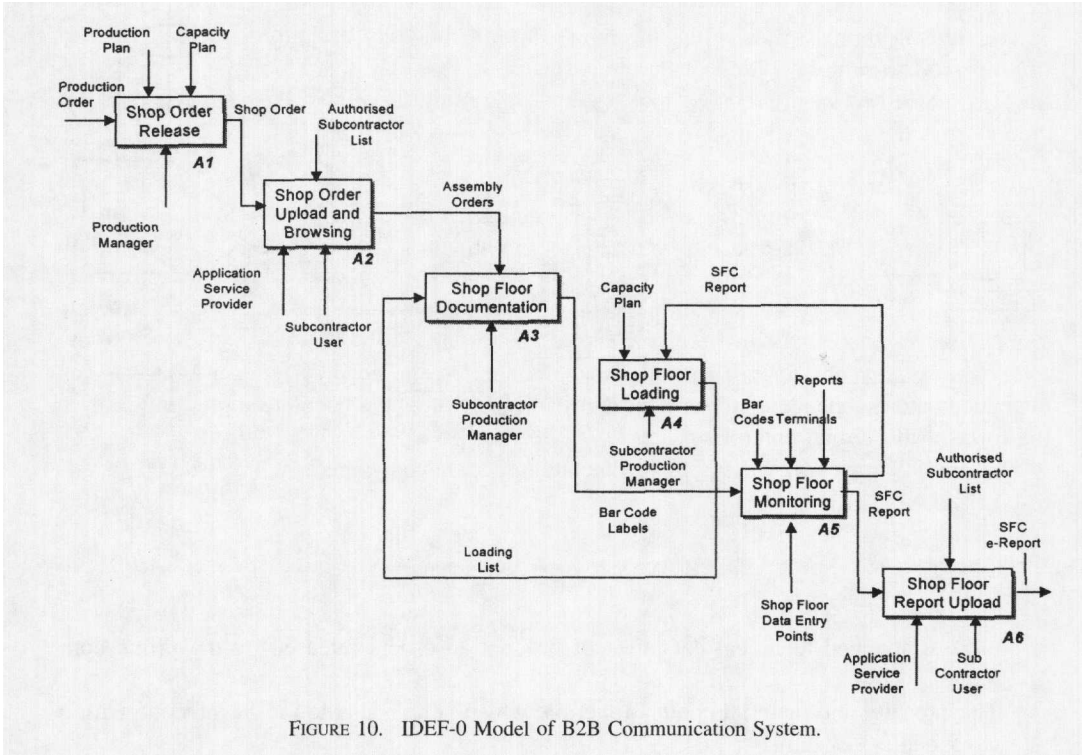

FIGURE 10. IDEF-0 Model of B2B Communication System.

5.3. *Evaluation of Implementation Results*

In order to evaluate the results of the research undertaken, two performance indicators were utilized. These performance indicators were lead-time and cost of the business processes under consideration. The case company has been using the EPMS software for 3 mo to support the customer order management, subcontractor selection, and multi-firm production order release processes. The results of the new system application have already justified the company's decision to introduce these new technologies.

More specifically, as far as lead-time is concerned, the simulation carried out in the design phase produced quite accurate estimates of the total lead-time reduction, which was approximately 1 week. Regarding the cost parameter, there were two dimensions that had to be considered: the personnel cost and the equipment used cost. The former ranged between the values estimated by simulation in the design phase. The latter however, exhibited a dramatic reduction in the actual value (sometimes up to 75%), which was bigger than the reduction estimated from the simulation runs.

The lessons learned from this project concerned mainly the level of automation and information technology penetration in the clothing industry. The inexperience of the companies' management on these new systems and their focus on the production technology processes left them behind the advances in electronic commerce and database technology. Before the emergence of the virtual enterprise production scheme, the communication needs were limited to trade data; thus, the volume of information flow was sufficient. However, with the emergence of the virtual enterprise concept, the clothing sector seems to be unready to adopt the new technology. In our research, we confronted subcontractors that did not respond positively to the new situation. This attitude had its roots in the culture of those companies, which was anything but IT oriented. In the Greek and Balkan clothing industry, the subcontractors are mostly small family business (as small as three employees) without any computer skills. On the other hand, subcontractors of substantial size and adequate computer skills are often reluctant to share their capacity data throughout the virtual enterprise network.

The overall impression was that the information technology brought about a number of improvements in the operation of the case company. However the majority of the subcontractors seemed to be unprepared for efficiently adopting the new e-business technologies emerging in the industry.

6. Conclusions

The business relationships between clothing companies and distribution factories with complementary skills and manufacturing abilities become much closer and more important if they adopt new logistics, communication, and management techniques that rely on computer-integrated logistics, Internet, and quick-response e-business systems. As the delivery times between supplier and customer get shorter, the need for cooperation between dependent and independent clothing factories and their suppliers becomes more long-term in the form of the virtual enterprise.

The application of B2B e-commerce technologies enabled the company studied in this research to:

- Enhance monitoring of the partner network in the virtual enterprise
- Apply business process improvement regarding the business dialogue processes
- Reduce business transaction lead-time
- Increase flexibility and quick response to the market needs
- Improve resource management

References

BAKOS, J. Y. (1991), "A Strategic Analysis of Electronic Marketplaces," *MIS Quarterly*, 15, 3, 295–310.

BENJAMIN, R. AND R. WIGAND (1995), "Electronic Markets and Virtual Value Chains on the Information Superhighway," *Sloan Management Review*, 36, Winter 1995, 62–72.

BENSAOU, B. M. (1996), "7-Eleven Japan: Creating the Virtual Corporation," *Proceedings of the 4th European Conference on Information Systems*, Lisbon/Portugal, 1275–1292.

BOLLINGER, J. G. (2000), "A Vision of Manufacturing for 2020," presented at IMS Vision 2020 Forum, Irvine, CA.

BONAPARTE, L., R. CANGEMI, H. R. LOPEZ, AND C. PIERANTONI (1999), Donna Karan International, Case Studies, Lubin School of Business, Pace University, New York, USA.

BROWNE, J., P. J. SACKETT, AND J. C. WORTMANN (1996), "Future Manufacturing Systems—Towards the Extended Enterprise," *Computers in Industry*, 25, 3, 235–254.

BYRNE, J. A., R. BRANDT, AND O. PORT (1993), "The Virtual Corporation," *Business Week*, February 8, 36–40.

DAVENPORT, T. H. AND J. E. SHORT (1990), "The New Industrial Engineering: Information Technology and Business Process Redesign," *Sloan Management Review*, 11–27.

DAVIDOW, W, H. AND M. S. MALONE (1992), *The Virtual Corporation: Structuring and Revitalising the Corporation for the 21st Century*, Harper Collins, New York.

DAVIS, M. AND D. O'SULLIVAN (1999), "Systems Design Framework for the Extended Enterprise," *International Journal of Production Planning and Control*, 9, 9, 846–853.

DOUMEINGTS, G., N. PANAYIOTOU, A. RIHNN, I. TATSIOPOULOS, G. ZUELCH, AND C. VILLNEUVE (1999), *A Methodology for Re-engineering and Information Technology Implementation, European Series in Industrial Management*, Shaker Verlag, Karlsruhe, Germany.

DRUCKER, P. (1992), *Managing for the Future*, Butterworth-Heinemann, Oxford, UK.

EPET II-EKVAN 6 (2000), *Modelling and Automation of Business Communication Among Clothing Enterprises with the Application of Electronic Commerce Technologies*, Technical Report WP 1.2–1.5, National Technical University of Athens, Athens, Greece.

FRITZ, M. B. AND M. L. MANHEIM (1998), *Information Technology Tools to Support Virtual Organization Management: A Cognitive Informatics Approach*, P. Sieber and J. Griese (Editors), Organistional Virtualness, Proceedings of the VoNt Workshop, April 27–28, 1998, Bern, Simowa Verlag.

HELEN'S CLUB SA, NTUA (1996), *Extended Network Enterprises in the Clothing Industry*. National Technical University Athens, Greece.

ICAP (2001), *Annual Report, Greek Financial Directory*. ICAP, Athens, Greece.

JAGDEV, H. S. AND J. BROWNE (1998), "The Extended Enterprise—A Context for Manufacturing," *Production Planning & Control*, 9, 3, 216–229.

JARILLO, C. J. (1993), *Strategic Networks*, Butterworth-Heinemann. Oxford, 1993. 2nd edition 1995.

KEEN, P.G.M. (1991), *Shaping the Future*, Harvard Business Press, Boston, MA.

KELTON, W. D, R. P. SADOWSKI, AND D. A. SADOWSKI (1998), *Simulation with Arena,* DCB McGraw-Hill Inc., Princeton, USA. 232.

KORHONEN, P., K. HUTTUNEN, AND E. ELORANTA (1998), "Demand Chain Management in a Global Enterprise—Information Management View," *Production Planning & Control*, 9, 6, 526–531.

LOEBBECKE, C. AND T. JELASSI (1996), "Building the Virtual Organization at Gerling," *Proceedings of the 4th European Conference on Information Systems,* Lisbon/Portugal, 1245–1258.

PAPPAS, A. I. AND I. P. TATSIOPOULOS, (Eds.): Advances in Production Management Systems, Proceedings of the IFIP TC5/WG5.7 Fifth International Conference on Advances in Production Management Systems-APMS '93, Athens, Greece, 28–30 September, 1993. North-Holland 1993, ISBN 0-444-81598-8, The Netherlands.

PASTERNACK, B. A. AND A. J. VISCIO (1998), *The Centreless Corporation*, Fireside Simon and Schuster, New York.

PIDDINGTON, C. AND M. PEGRAM (1993), "An IMS Test Case—Global Manufacturing," in *Advances in Production Management Systems*, I. A. Pappas and I. P. Tatsiopoulos (eds.), Elsevier.

PORTER, M. E. (1985), *Competitive Advantage—Creating And Sustaining Superior Performance,* The Free Press, New York.

SHEEHAN, P. (2000), *Manufacturing and Growth in the Longer Term: An Economic Perspective,* paper presented to IMS Vision 2020 Forum, Irvine, CA.

SIEBER, P. (1996), "Materna GmbH on Its Way to a Virtual Company?," *Proceedings of the 4th European Conference on Information Systems,* Lisbon.

SKYRNE, D. J. (1998) "The Realities of Virtuality," *Workshop on Organizational Virtualness,* Bern, 25–34.

TAPSCOTT, D., D. TICOLL, AND A. LOWY (2000), *Digital Capital,* Harvard Business School Press, Boston, MA.

TATSIOPOULOS, I. P. (1997), "An Orders Release Reference Model as a Link between Production Management and SFC Software," *Computers in Industry* 33, 2–3, 335–344.

YOURDON, E. (1989), *Modern Structured Analysis,* Prentice-Hall, NJ, USA, 1989.

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