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Business process oriented design of ERP systems for small and medium enterprises

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Abstract

In the last years, many organizations have used business process modelling as an effective tool for managing organizational changes. However, process modelling has rarely been exploited for supporting the entire business process management lifecycle. This includes the design of business processes as well as their implementation and control. The adoption and implementation of ERP systems is a crucial issue if referred to SMEs. The main problem is that the cost of implementation of ERP, intended as the process of customization of the ERP system towards the actual enterprise business processes, overtakes the cost of ERP acquisition. Thus, there is a need for using the same workflow systems for both modelling the enterprise business processes and designing the ERP. This paper presents the results of a collaborative project of Academia and Industry aimed at developing a business process management integrated approach to the design, implementation and control of an ERP information system.

Keywords: business process management, business process modelling, enterprise resource planning, simulation.

1 Introduction

Enterprise Resource Planning (ERP) systems are considered to be the most effective computer application in the modern manufacturing industry, and they are recognized as successful management systems (Ormsby *et al.* 1990). ERP systems present an excellent planning and scheduling capability which leads to significant gains in productivity and at the same time a dramatic increase in customer service (Ng *et al.* 1998). Moreover, ERP system innovations present the introduction of relational database management systems (RDBMS) as well as a graphical user interface (GUI), open systems and client/server architectures. ERP systems achieve a radical change in the design field of information systems: management solution designers and vendors direct their planning efforts to a general framework of applicative solutions, rather than focusing attention only on the functional characteristics of individual elements. Basically, ERP systems exchange data with a central database which contains all information concerning the enterprise.

The system is built to manage all the enterprise activities through independent software modules, while constantly updating the database. Thus, all of the activities are connected and interact simultaneously.

A ERP system does not operate using functions as in old systems, but it adopts processes, which are activities that involve several modules. This last ERP feature is very important because, the competitiveness among enterprises is based not only on the quality of products and services (what they do) but also on the efficiency of internal processes (how they do it). These two characteristics (quality and efficiency) are often difficult to analyse separately. Products generally result from the specific business processes of the enterprise as well as from the adopted methodologies and tools. Enterprise business processes show a strong influence on the characteristics of the final product or service.

Business processes, which are managed by the ERP system, should not be considered as static: once they are defined, a monitoring activity is needed during the process operation and improvements should be made when possible. As such systems are usually off-the-shelf software packages, their implementation involves a process of customizing the generic package and aligning it with the specific needs of the enterprise (Ehie and Madsen 2005). Due to the need to adapt the enterprise to the software package rather than the other way around, it is often necessary to redesign enterprise business processes. The business process alignment, affected by various environmental aspects, such as existing

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3 information systems prior to the ERP implementation and organizational culture, bears crucial
4 consequences on the success of the ERP implementation project and on the future business practice of
5 the enterprise (Soffer et al. 2003).
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8 Improvements or radical changes could be needed due to market or other external requirements.
9
10 Business process management comprises exactly all of the activities needed to handle business
11 processes according to such a perspective. Specifically, the business process management lifecycle is
12 structured in the following phases:
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- 15 1. assessment and modelling of organisational structures;
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- 17 2. assessment and modelling of business processes (Business Process Engineering);
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- 19 3. analysis of weaknesses;
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- 21 4. modelling of advanced business processes (Business Process Re-engineering);
- 22
- 23 5. control of business process (Business Process Simulation);
- 24
- 25 6. implementation for the enterprise (Change Management);
- 26
- 27 7. management and performance monitoring (Business Process Management).
28

29 When an ERP system, which is intrinsically process oriented, needs to be planned, implemented and
30 controlled, the above mentioned phases are strictly necessary. This is particular critical in dynamic and
31 diversified environments such as those of Small and Medium Enterprises (SMEs). Indeed, thus far, ERP
32 projects adoption has been the domain of the larger organizations. Features and business process flow
33 have been designed based on practices in the large organizations. Consulting and project management
34 methodologies are normally specified based on such experiences. The needs, operating requirements,
35 logistics fulfillment and financial capabilities of the SME manufacturers could result vastly different
36 from that of the large and medium sized manufacturers (Huin 2004).
37
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39 Although small and mid-sized companies are increasingly embracing ERP, research indicates that many
40 of them fail to achieve their goals in terms of ERP utilization and overall expected improvement.
41 Stefanou (2001) suggested that the main cause for this underachievement is poor ERP implementation.
42 Also, Davenport (1999) attributed many failures of ERP implementation to the lack of the alignment
43 with business needs and Yen and Sheu (2004) identify that implementation failures are usually the
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3 result of business problems, such as alignment of implementation practices with firm competitive
4 strategy, instead of technical difficulties. For these reasons, a number of research projects are focusing
5 on developing implementation frameworks and procedures in order to overcome such failures (Sun et
6 al. 2005, Umble et al. 2003). However, the authors believe that the overall ERP development (from the
7 software house perspective) and acquisition (from the SME perspective) processes need to be re-
8 designed in an integrated fashion by considering since the ERP first development stages (ERP
9 planning) its business process orientation. Specifically, this paper aims at presenting an integrated
10 approach to support business process management lifecycle when applied to ERP development. Such
11 an approach, which is based on the adoption of all of the business process management lifecycle steps,
12 has been developed within a research project which has been conducted by the University of Palermo in
13 conjunction with an Italian primary software house and it has been successfully applied in the ordinary
14 ERP development and dispatching processes of the same software house.

15
16 This article is structured as follows: section 2 presents a methodology for requirement analysis,
17 planning and design of the ERP system for SMEs based on the adoption of IDEF3 technique. In section
18 3, a methodological approach for ERP implementation and business process customization is described.
19 Section 4 demonstrates how discrete-event simulation can be utilised in the control and test phases of
20 business processes before they are implemented in the ERP. Conclusions and further developments are
21 reported in the last section.

2 ERP Planning

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24 The design of ERP systems entails a series of steps. The design begins with a master plan aimed at
25 organising resources and directing activities (project scope, goal definition, feasibility study and final
26 project plan). As detailed in (Ng *et al.* 1998), the project group defines the scope of the project and
27 fixes a set of goals. Subsequently, the project group identifies the constraints and controls of the project
28 which must be carefully examined. During this phase, operating requirements, data requirements and
29 processing requirements are also obtained as inputs for the feasibility study. Finally, a project plan is
30 written to specify the scope, system performance, timing and budget allocated to the project.

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32 Referring again to the seven phases of the business process management lifecycle, the ERP planning
33 activity mainly requires the first two modelling phases, basically business process modelling. This
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3 activity consists of: identification of input and output (products, services, information, rules,
4 procedures, principles, norms etc.), definition of activities sequence, tasks and information exchanges.
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6 The process model obtained at the end of the modelling activity allows the visualization of the
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8 sequence of the component activities with the corresponding executors, the information and material
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10 flows and their utilization and control, the necessary resources, the mechanisms on which activities are
11
12 based. The different activities belonging to a given process can be grouped into logic units (sub-
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14 processes).

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16 Actually, the modelling phase is not standard but it is strictly related to the aims of the analysis to be
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18 performed. In this way, process modelling provides a map of the process itself aimed at symbolizing the
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20 way how the process operates and even how it can be improved. For such reasons, a method-based
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22 approach is needed as well as standard notation needs to be used. IDEF3 methodology is characterised
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24 by these two features (www.idef.com). IDEF3 is a standardized method (graphic notation and
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26 language), that can be univocally understood by the users, for the modelling of internal business
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28 processes, of their evolutions and of the information and resources which they utilise. This language
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30 was developed by KBSI, Inc. (www.kbsi.com).

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32 Authors also believe that, despite the well known IDEF0, utilised for instance in (Johnny *et al.* 1998),
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34 has proven to be effective in detailing the system activities for function modelling, IDEF3 results more
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36 adequate in representing business process models that need to be afterward implemented in the ERP
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38 system because it captures precedence and causality relations between situations and events in a natural
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40 way to domain experts by providing a structured method for expressing knowledge about how a system,
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42 process, or organization works.

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44 The top-down IDEF3 business process modelling approach starts with the identification of the main
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46 processes from which all of the other processes derive. A wide analysis of the processes typical of
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48 SMEs leads to the identification of some major processes, as reported in figure 1, which are crucial for
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50 the investigation of all the processes included in a strategic business unit. Such major processes
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52 represent the scenarios to be supported by the ERP system and can be differently utilised according to
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54 the aim of a given implementation project.
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7 Each scenario includes processes and sub-processes represented by IDEF3 formalism and it consists of
8 data, objects and performing actors belonging to the processes themselves. Each IDEF3 business
9 process model is neither a constraint nor a fixed scheme; on the contrary, it can be utilised in a planning
10 phase to support and facilitate the implementation and customization of the processes within a specific
11 enterprise environment.
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15 Figure 2 shows a sample model referring to the business process “Manage purchase order requests”
16 which the ERP should support and which can be found within the “Administration and Finance”
17 scenario. In particular, the process consists of the following activities:
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1. *Purchase order creation*: the created order should provide some information such as purchasing object, quantity, assigned cost center, and so on.
 2. *Quote order request*: such activity aims at obtaining a request bid.
 3. *Order typology identification*: the identification should indicate whether the required material concerns objects already registered in catalogue and/or inventory.
 4. *Availability check*: this check activity should verify whether the required material is available in the catalogue.
 5. *Check in the inventory*: this check activity aims at verifying the actual availability of the materials in the inventory.
 6. *Obtain order request authorization*: this sub-process concerns all of the authorization activities that are needed before the purchase order request can be transformed in actual purchase order.
 7. *Delete order request*: in this case the authorization failed.
 8. *Elaborate order*: this activity consists on preparing the purchase order.
 9. *Order emission*: the purchase order is dispatched.

3 ERP Implementation

The ERP implementation phase consists on the seamless transfer and adaptation of the mapped and modeled business processes to the operational application software with no loss of information. The implementation of ERP systems is the most critical issue as it requires a global reconsideration of the business procedures. This reconsideration should involve both the system workflow and its organization. The implementation of ERP systems is a difficult task as it entails a great deal of time and it results in large costs. The introduction of ERP systems defines a strategic choice which leads to a series of risks such as high costs and long installation time for the ERP package. In addition, ERP systems present a large number of functions, generally built for meeting the needs of a large number of business clients. To implement an ERP system it is often necessary for the enterprise to activate a business process engineering/reengineering project so that enterprise processes can be adapted to those built within the ERP system. Furthermore, this activity could be very crucial and somehow “negative” for a small enterprise whose business relies on its specific and proper business process.

This is the reason why one of the main scopes of the research project presented in this paper was to develop a *ERP configurator* system which might simplify the process of implementing the ERP system. In particular, this tool is intended at allowing the *Vendor-Customer* system to configure the ERP system in accordance with the customer needs. Such a configuration concerns all of the business processes that the system should or should not support. Thus, on one hand, the configurator, starting from a generic IDEF3 model, should allow the user configuring the ERP system by selecting the appropriate processes and sub-processes and by supporting him in such a choice by forbidding all of the inconsistent processes’ configurations. A process configuration can be considered consistent when it consists of an order of activities with a beginning and an end able to support a given business process. For example, the elimination of an activity within the process which is crucial for the process operation should not be allowed by the configurator. Looking at the process “Manage Purchase Order Request” of figure 2, if the user would try to invert activities 6.1 and 7.1 or to eliminate activity 7.1 the process becomes inconsistent and the configurator should not allow those configurations.

On the other hand, another crucial requirement of the configurator is its easiness to use. Indeed, the process-oriented nature of the designed ERP represents a good start point for customizing the ERP

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itself. In few words, the customer should be able to modify the IDEF3 business process models in order to make the implemented processes matching its own. But, of course, the IDEF3 models are very complex and large. As an example, consider that the IDEF3 model which has been developed for the ERP system, as discussed in section 2, consists of more than 5000 activities and sub-activities represented in more than 500 diagrams. The configurator needs, thus, to support the vendor-customer in this complex process by also offering a given set of initial configurations.

The core elements of the ERP configurator are a multi level matrix and a configurations database (repository).

3.1 Multi-level matrix

According to the hierarchical architecture of the IDEF3 model, each process can be decomposed in sub-processes and these sub-processes can be further decomposed. The multi-level matrix consists of a set of worksheets each representing a process map at a given abstraction level, starting from the main processes till the units of behaviour constituting the sub-processes. The LEVEL 0 matrix lists the main processes together with a brief description which supports the user in selecting the right main processes to be implemented in the ERP. Analogously, the user can select the right processes of the subsequent levels. The LEVEL 0-1 matrix, depicted in figure 3, consists of columns containing the macro-processes of LEVEL 0 and of rows including their sub-processes. A brief description for each process and sub-process is also provided in order to support the user in choosing the proper processes. As the reader can observe in figure 3, each process of a given column is related to its sub-processes (in the rows) by a binary variable a_{ij} which is equal to 0 if the i -th sub-process is not included in the j -th process, while it is equal to 1 otherwise. Also, processes in rows are differentiated according to their possible further decomposition in lower levels.

3.1.1 ERP configuration procedure. The first step of the procedure concerns the analysis of macro-processes of level 0 and the assignment of value 0 (or 1) to the cell a_{ij} in order to disable (or enable) those main processes that need to be deleted (implemented) in the specific ERP system implementation. Then, the lower level can be analysed. The columns of the lower level (LEVEL 0-1) matrix only include the main processes which have not been excluded at level 0, while in the rows of the same matrix their sub-processes are reported. At this point, the analysis continues by setting the proper

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2 values for the elements a_{ij} of this level. The system configuring procedure proceeds by applying the
3 same activation/exclusion procedure to all the others levels. Such configuration is supported by the
4 processes descriptions and by their classification. Indeed, their classification helps in understanding the
5 interdependence and relationships among processes and identifying those which can be disabled
6 without influencing other processes.
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11 **3.1.2 Process Classification.** Processes have been classified in: free, locked, and constrained. A
12 process is *free* when its exclusion brings to the deletion of all its sub-processes. *Locked* processes
13 cannot be excluded because they are strictly needed by other processes that have already been selected
14 in a higher level. Thus, they cannot be deleted. Finally, *constrained* processes are those whose deletion
15 influences the regular functioning of other processes.
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27 In the multi level matrix, locked processes are represented by a coloured cell within which $a_{ij}=1$, and
28 can not be modified. On the other hand, constrained processes are supported by a comment and warning
29 button which advises the user with a message box listing all processes that would be modified and their
30 path within the system (see Figure 3). Once the consequences of deleting the process are evaluated, the
31 user can decide whether delete the process or not.
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36 **3.1.3 Matrix Pool.** At the end of the configuration process, processes which have been deactivated are
37 automatically transferred to a Matrix Pool (see figure 4). This is an alphabetically list of all processes
38 and activities which have been deleted during the configuration process. The Matrix Pool has been
39 created to allow the user, once the configuration phase is concluded, to re-engineer the IDEF3 business
40 process models according to the configuration activity which has been previously conducted. Indeed,
41 the IDEF3 models have been developed within the KBSI Prosim[®] software-tool and this tool is
42 provided with a Process Pool within which all the system processes are listed alphabetically, as shown
43 in Figure 5. This step leads to the deletion of the relative process from the Prosim process pool and, as a
44 result, from the IDEF 3 diagrams.
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3.2 The repository

Another important piece of the configurator is the configurations database (repository) containing a set of basic configurations to be used as a starting point when implementing the ERP system. Indeed, some ERP models, represented by customised multilevel matrices, have been settled up for different kinds of enterprise typologies and standard business processes. Such models can be utilized and modified during the configuration phases to meet client requirements.

4 Business Process simulation

Business process simulation has been proven to be a very efficient approach for controlling business processes and, especially during the process engineering and re-engineering phases. Simulation should be intended for measuring performance and actual costs of company processes before the actual ERP system is developed for supporting them (Hlupic and Robinson 1998).

Starting from the business process design, the process models can be utilized to simulate the process itself by including information on activities sequence and duration, and resource capacities and availability. In order to have a better rate of success in BPM implementations, an evaluation of alternatives solutions should be performed. A number of authors (Giaglis and Paul 1996), (Tumay 1996), (Giaglis *et al.* 1999) have reported the applications of simulation to the evaluations of these alternatives and have come to the conclusion that simulation allows:

- Enhancement of corporate capabilities to achieve in-depth understanding of internal process performance and correct resource allocation.

[Insert Figure 4 about here]

[Insert Figure 5 about here]

- Detailed analysis before incurring the risk of making majors changes to existing processes or implementing new processes.

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- Incorporation of the stochastic nature of business processes and the random behaviour of their resources (Irani *et al.* 2000).
- A greater understanding of the key drivers in resource management and increase dependability in terms of the decisions made (Dennis *et al.* 2000).

As it can be gathered from these reports, simulation has a great potential for the analysis of business process change and it represents a decision support tool which increases the confidence in the decision taken by analysing multiple scenarios across the process.

The integration of business process modelling techniques with discrete events simulation tools allows reducing projects failure to minimum risk and to provide the opportunity to test several scenarios. Business process modelling allows to identify illogical areas within processes and to represent new scenarios. At the same time, business process simulation might be used to evaluate the best alternative through performance indices which need to be optimized, like process flow time, work in process, resources' utilization, throughput, and so on. In this section, a methodology used for building up a discrete event simulation model is reported (in the example Arena® 5.0 platform is adopted).

4.1 Simulation model development

The methodology is composed by 7 main steps: 1) qualitative analysis of the IDEF3 model; 2) simplified elaboration of the simulation model; 3) quantitative analysis of the IDEF3 model; 4) revision of the starting model; 5) insertion of input data; 6) simulation; 7) results analysis.

The description of these steps together with a sample of their implementation are reported in what follows for a given sample business process.

4.2 A sample business process

The case study concerns, once again, the “Manage purchase order request” process, showed in Figure 2.

4.2.1 Qualitative analysis of the process. The purchase order request can be originated from different departments, as inventory, production or purchase department. Once the different departments generate the specific order request, this, after having flowed through a given set of activities, is either emitted or not.

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3 **4.2.2 Simplified elaboration of the model.** Initially a simplified simulation model of the process has
4 been built up by considering its basic characteristics. As shown in Figure 6, activities of the IDEF3
5 diagram correspond to specific modules of the Arena Simulation model (CREATE, PROCESS,
6 DISPOSE modules). In particular, activity 1.1 corresponds to three CREATE modules, one for each
7 department which originates the arrival of the orders entering the system. Activities 2.1, 6.1, 8.1 and 9.1
8 are represented by the PROCESS modules, which incorporate all of the necessary information. The
9 outcomes of activities 7.1 and 9.1 are represented by the DISPOSE module.

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11 **4.2.3 Quantitative analysis of the model.** At this modelling level, it is necessary to identify some of
12 the main process performance measure, even in relation with the top management goals. For instance,
13 for the mentioned process, the following measures have been identified: Resource utilization, flowtime,
14 and number of order requests in queue. Also, important assumptions have to be made in the simulation
15 model such as:

- 16 - purchase order request are classified into three categories in relation to the order cost;
- 17 - from historical data it was possible to highlight that during the authorization activity 90% of the
18 activities included in the first category are accepted, as the 80% of the activities included in the
19 second category and the 40% of the activities in the second category;
- 20 - order inter-arrival times and process times have been taken from historical data;

21
22 **4.2.4 Revision of the starting model.** At this level, ASSIGN and DECIDE modules have been added to
23 the model for modelling different request typologies (ASSIGN module) and some decision making
24 phases (DECIDE module). Also, new and more detailed process performance indicators need to be
25 defined and introduced in the model, such as activities costing.

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27 **4.2.5 Insertion of input data.** In this modelling phase, other input data are added to the model, such as
28 simulation time, number of entities per arrival, and so on.

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[Insert Figure 7 about here]

4.2.6 Simulation and results analysis. In this phase, due to the randomness of the inputs, some simulation runs need to be conducted in order to gain a given level of output precision. Then, sensitivity and ANOVA analysis need to be performed in order to compare different scenarios and parameters settings.

5 Conclusions

The adoption of ERP systems represents, nowadays, one of the major symptoms of a SME innovation capability. The barrier towards ERP adoption is not anymore given by the high cost of ERP acquisition (many low-cost ERP systems for SMEs are nowadays commercially available) but due to the costs and efforts coming from the BPR project that needs to be undertaken by the given enterprise for aligning its processes with those implemented in the offered ERP solution. Also, when it comes to an Industry domain characterized by very small firms, such as the South Italian one, it has to be considered that unique and specific business processes often make the strength of the small firms and changing or removing them could threaten its survival and flexibility features. The paper presents the results of a collaborative research project with a primary Italian ERP manufacturer and vendor aimed at developing a structured approach to the design and configuration of ERP systems for small enterprises. The idea was that it should be the ERP able to align its processes with those of the enterprise and not vice-versa.

Such challenging goal has been achieved by adopting an integrated approach which is process oriented in all of its phases. The first phase consists in designing the structural ERP model by using a process oriented formal language. This model consists of more than 500 IDEF3 diagrams and 5000 processes. The second phase concerns the ERP processes implementation and customization by a configurator system. This tool allows the *Vendor-Customer* system to easily configure the ERP system in accordance with the customer needs. The last phase focuses on the process control activity and discrete event simulation has been proposed as effective tool for this purpose.

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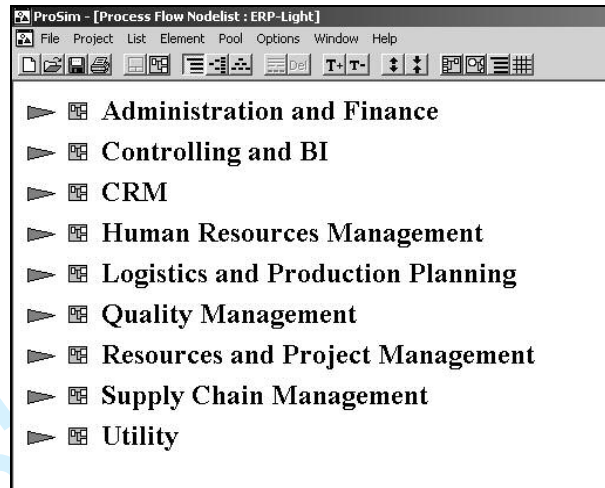


Figure 1. Main scenarios of ERP processes IDEF3 model

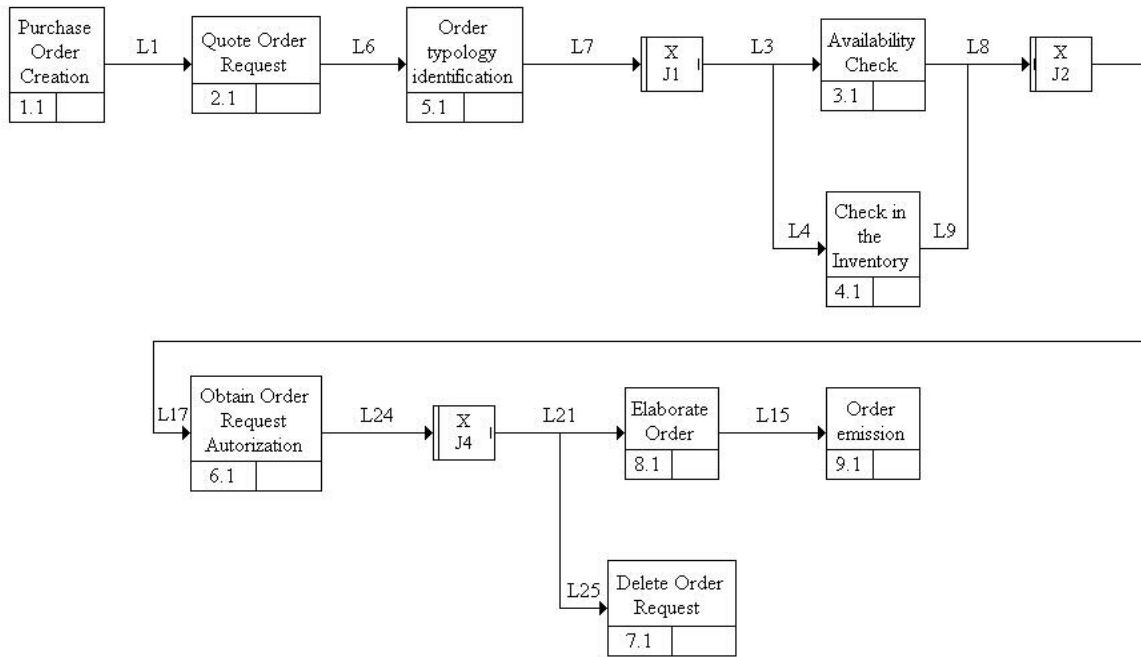


Figure 2: The “manage purchase order request” process

	A	C	D	E	F	G	H	I	J
1									
2		Administration and Finance			Controlling		CRM		
3	LEVEL 2	General Ledger	Purchasing management	Selling Management	Product management	Reporting	Customer management	Customer satisfaction	project management
4	Accounting ABC				1				
5	Accounting per Centri di Costo				1				
6	Assistenza clienti on-line						1		
7	Budgetizzazione progetti								1
8	Comunicazioni al cliente			1					
9	Comunicazioni al fornitore								
10	Consuntivazione dei carichi di lavoro								
11	Contabilità Analitica	1							
12	Contabilità Clienti			1					
13	Contabilità costi esterni								1
14	Contabilità Fornitori								
15									
16									
17	Contabilità Generale								
18									
19									
20									
21	Controllo del progetto	1							
22	Controllo e tracciabilità degli ordini di acquisto								
23	Gestione acquisti on-line								
24	Gestione Agenti e Provvigioni				1				
25	Gestione Anagrafica Categoria								

WARNING

La disattivazione di questa cella comporta modifiche ad altri processi, visibili cliccando sul pulsante.

Conferma disattivazione

Se si disattiva questa cella, nel processo 'Amministrazione e finanza/Gestione Acquisti/Contabilità Fornitori/Gestione delle note di credito' non sarà possibile l'Emissione di richiesta di nota di credito; e nel processo 'Amministrazione e finanza/Gestione Acquisti/Contabilità Fornitori/Gestione piano dei pagamenti' non sarà possibile l'Emissione di una Richiesta di dilazione Pagamenti'. Inoltre nel processo 'Amministrazione e finanza/Gestione acquisti/Gestione richieste di acquisto servizi-mercè' la funzione 'Consulta listino fornitore' non richiederà la selezione di un modello di documento; in 'Gestione acquisti/Controllo e tracciabilità degli ordini di acquisto' il processo 'Avvia un sollecito' non richiederà la selezione di un modello di documento, e in 'Gestione acquisti/Contabilità fornitori/gestione delle fatture' il processo 'Notifica al fornitore la presenza di discrepanze' non richiederà la selezione di un modello di documento. Si vuole comunque disattivare il processo?

Si No

Figure 3. Multi-level matrix

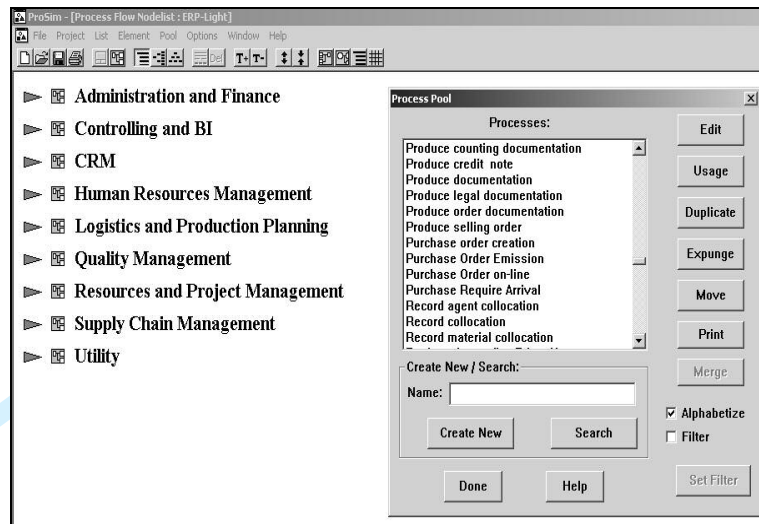


Figure 5. The Prosim process pool.

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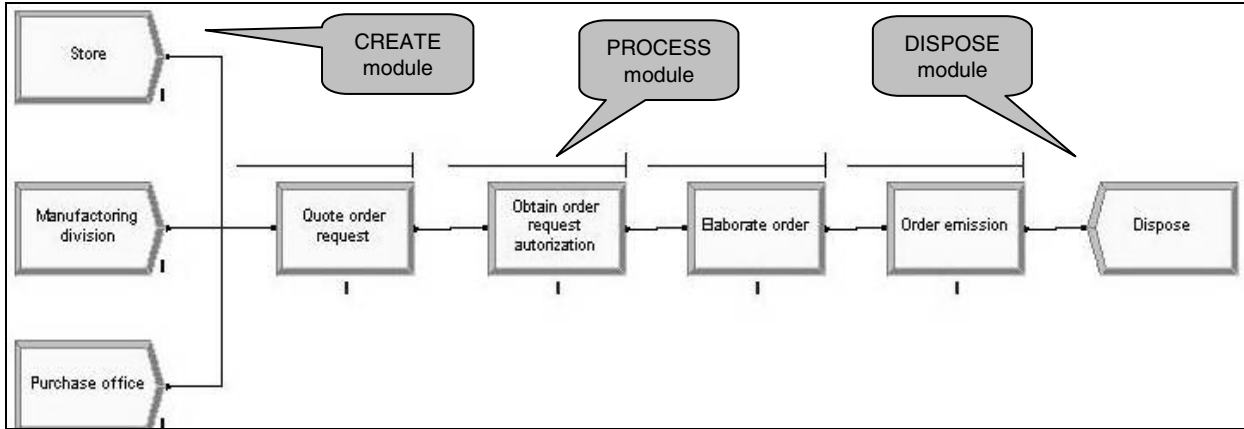


Figure 6. Simplified simulation model

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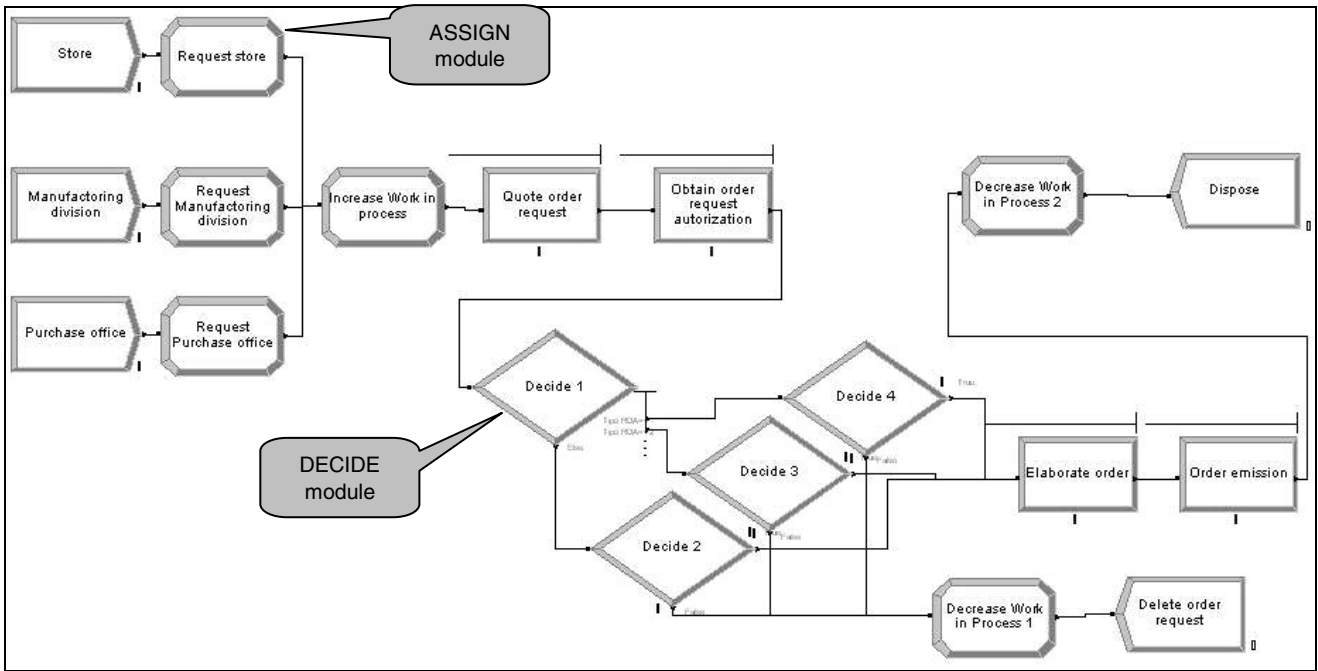


Figure 7. Complete simulation model

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