

Managing deployment of ERP systems in SMEs using multi-agents

S.F. Huin *

School of Advanced Manufacturing and Mechanical Engineering University of South Australia Mawson Lakes, SA 5095, Australia

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Abstract

Despite the many advantages of Enterprise Resources Planning (ERP) systems, they do not as yet represent a clear and successful management tool to small and medium sized enterprises (SMEs), or at least it is not as easily implementable by SMEs. This paper shares some insight into a research aimed at identifying the strategic and operational requirements of SMEs in the South East Asia (SEA) region. It highlights a set of organizational, operational and supply chain related interdependencies in SMEs which in many aspects influence project management success and methodologies deployed in ERP systems in SMEs. An agent-based model for coordinating the management of enterprise resource in SMEs is also introduced. This model expounds on how the various enterprise resources in an SME can be organized, interfaced and managed. By drawing upon this model, we can relate to how SMEs can better project managed ERP systems in their usually informal systems.

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1. Introduction

Enterprise Resources Planning (ERP) system offers a viable management tool to helping companies in particular manufacturing enterprises manage their resources. The exponential growth in technologies and innovation in manufacturing and information processing is pushing companies into a new paradigm shift. Numerous companies who have successfully implemented ERP systems testified to its 'life-saving' importance. However, SMEs must not blindly embrace ERP projects. The improper project planning and poor adoption of ERP may mean realigning the company's comparative advantage position which SMEs can dearly afford.

Thus far, ERP projects adoption has been the domain of the larger organizations. Features and business process flow have been designed based on practices in the large organizations. Consulting and project management methodologies are normally specified based on such experiences. The needs, operating requirements,

logistics fulfillment and financial capabilities of the SME manufacturers are vastly different from that of the large and medium sized manufacturers. Adoption of information technology by SMEs in managing their ERP projects is also limited. While ERP is sufficiently flexible to cope with the general manufacturing enterprises, we need to take a closer look at the strategic and operational needs of SMEs before we can properly develop a project management strategy for them.

2. Strategic and operational requirements of SMEs

A huge pool of SMEs exist to service the 1st and 2nd tier corporations (huge and fairly large enterprises, respectively) or to provide specialty or outsourcing services to these corporations. Manufacturing has been identified as a key pillar of growth in most economies in SEA. Manufacturing contributes 25% and 35% of Singapore's and Malaysia's GDP [3], respectively. There are more than 100,000 SMEs in Singapore and 500,000 SMEs in Malaysia. In terms of numbers, SMEs form 80% of the companies' entities in the economy and contribute 29% of the Singapore GDP in 2000 [3]. However, ERP projects implementation in SMEs in

*School of Mechanical and Production Engineering, Nanyang Technological University, Nanyang Avenue 639798, Singapore.

E-mail address: msfhuin@ntu.edu.sg (S.F. Huin).

SEA is still fairly low with less than 50% acceptance [5]. This could largely be attributed to the inadequate project management methodologies and systems designed for the SMEs in this newly industrialized region.

SMEs do not function as a collection of formal structured departments. Project implementation of ERP systems in SMEs is simpler in some aspects and more complicated at times. There is a marked lack of research on interdependencies of the various enterprise resources in SMEs especially for the SEA region which is one of the world's major manufacturing hub. A study was conducted [6] to examine the dynamics of enterprise resources planning in SMEs in the SEA and how these are impacted due to internal and external effects on the SMEs. The objective was to establish the strategic and operational requirements (SOR) of SMEs and examine its possible impact on ERP systems project management and deployment. The guidelines of the Infocomm Development Authority of Singapore are used in defining SMEs as entities with: Fixed assets less than S\$15million; and, Number of full-time employees less than 200. Companies, which are “very small” and for which implementation of an ERP system may not be that advantageous, are omitted. These are SMEs which are on the lower spectrum of the above criteria. These constitute a very big number of SMEs.

The first part of this paper presents the dynamics of enterprise resources in the 30 SMEs case study conducted through 95 surveys and interviews with the aid of a prepared questionnaire. The targeted M-SMEs, from the electronics and related precision engineering industry, are selected from a list of 958 representative M-SMEs that have reached a certain critical size making ERP a logical management tool. The understanding of these factors is paramount to any development of methodologies in project management for ERP in SMEs.

2.1. *Low levels of organizational hierarchy*

The average number of structural hierarchies found in SMEs is 3.133. The chief executive officer (CEO) is involved in most strategic decisions and major operational decision-making in the SME. He is usually one of the key founders and has been closely involved in the establishment of the SME. Of the 15 local SMEs, 13 CEOs are major shareholders, founders or closed relatives of the principals. Two are minor shareholders tasked with managing the company. Of the 15 foreign SMEs, 12 CEOs are directly responsible for some key aspects of operations, e.g. major account management and regional sales management.

At the middle level are two distinct groups of direct operational managers: the professionals and ‘upgraders’. The former have graduate or professional education and previous rich experience. Majority of the latter group

managers have years of related work experience and intimate knowledge of the operational tasks, sometimes across different departments in the SME. This knowledge is very useful to the SMEs as it allows cross-checking and network decision-making. At the execution level are the professionals (e.g. the planners, buyers, production supervisors, etc). With globalization and competition, more professionals and graduates are hired into these line execution jobs. This group is usually I.T. literate and spearheads the ERP project adoption.

2.2. *CEO involvement in operational decisions*

The CEOs in SMEs are involved in strategic charting of their enterprises and are also high-level line managers. In spite of having designated line managers, in all 30 case studies, the CEOs directly drive some line functions. In 26 of the 30 companies, the CEO is involved in purchasing operations; in 22 of the 30, the CEO is involved in high-end purchase functions; and in 26 of the 30, the CEOs are involved in sales account management functions. This is common across both local and foreign SMEs. This unique characteristic implies that the CEO may be conductor of the orchestra and at the same time may be a project team member in any ERP implementation, thus impacting how ERP can be project managed at SMEs.

2.3. *“Blurred” departmental walls*

This refers to inter-departmental boundaries with no clear line of portfolio responsibility. In 17 of the 30 SMEs, a manager designated as the manager-in-charge of a department is also directly responsible for another department. E.g. in 6 SMEs, a sales manager is also in-charge of the purchasing department; in 6 SMEs, the production planning manager is also overseeing the production department; in 5 companies, the accountant is also directly responsible for the purchasing department, etc. In these 17 SMEs, the middle level managers are assigned to manage more than one department at the same time. This makes departmental walls “blurred” and may result in conflict of interests. 20 of the 30 companies also reported that some key managers have significant influence over the operations and decision-making in another department which is not under their direct charge. This overlap of departmental boundaries can result in some benefits for the SMEs but issues on such “blurred” departmental walls need to be well contained when project managing a more formal and structured system such as ERP.

2.4. *Production modes in SMEs*

SMEs are usually supporting manufacturers of 1st and 2nd tier corporations with 20 of the 30 companies

being sub-contractors or component manufacturers or outsourcing manufacturing facilities. Even the 6 companies who are producing whole consumer electronic appliances are operating as original equipment manufacturers for the 1st and 2nd tier corporations. More than half of their production goes to these big corporations who sell the finished goods labeled with their own corporate product logo.

This interdependency impacts how the SME's internal and external supply chain network is designed given the geographical span between the US- and Europe-based 1st tier corporations and the Asian-based 3rd tier SMEs especially with the large number of manufacturing facilities outsourced or established in China and the SEA region. Clear supply chain directives need to be sought at both the major customers' level as well as the enterprise level. These could severely realign the project management objectives of the SMEs. To be constantly competitive, the operational characteristics of the 3rd tier made-to-order mass-customization production shops are usually different from those found in the larger corporations, who have better control over their sales and production forecasts, and this has strong implications on how and whether generic ERP systems can be plugged into the SMEs.

2.5. *Planned forecast vs real forecast*

Like the 1st and 2nd tier companies, it is usual for management of SMEs to do forecasting and budgeting for each financial year. Most (26 of the 30) SMEs do conduct such planning exercises. Interestingly, 25 of the companies did not produce or sell the items in the quantities which they forecasted to do so (within 5% margin of their forecasted numbers) at the beginning of the year. Seventeen of the 30 companies produced goods which are different or revised from the original forecasts. The deviation of actual production to planned is significant and is in two forms: the actual finished goods produced and the quantities produced. As product life cycle gets shorter, 1st and 2nd tier companies continuously introduce newer versions and even altogether new products out to the market frequently [12]. Since SMEs are usually 3rd tier supporting manufacturers, the finished items produced are largely dependent on what the larger manufacturers are selling. Thus the yearly planning forecast is at best a rough guide to the directions of sales and production rather than the true production plans of the enterprise. This could disrupt the entire project implementation as the master production scheduling process is the key driver in ERP.

2.6. *Rate of changes in orders*

A given factor in manufacturing is the need to adapt to changes. With the shorter product life cycle and the

constant release of new product versions, demand changes are inevitable. Product changes can significantly impact SMEs. Orders issued earlier are subjected to changes—drastic or minor. Almost all the 30 SMEs experienced frequent changes to orders placed by their customers. Of these, 11 SMEs experienced high degree of changes (more than 30) and 18 SMEs have more than 10 changes to each of their firmed orders. The worse order change comes about when hundreds of different materials have been issued and readied for production. Some of the operation processes may have already being initiated and some materials have already being partially consumed in the manufacturing operations. This high rate of change to orders could derail the resources planning process and subsequently place the ERP project implementation into difficulties.

2.7. *Short lead-time in manufacturing*

Companies are faced with constant pressure to produce the 'best' product at the cheapest price and with the shortest lead-time. An abnormal aberration in the planning mechanism comes about when the sum of the suppliers total delivery lead-time and the manufacturing lead-time may in occasions be less than the customers' stipulated lead-time for delivery. From the time an order is received from the customer, detail planning for the order is activated. Thirteen of the 30 SMEs reported that even if planning time is zero, the total lead-time can sometimes still be more than the delivery lead-time stipulated. This prohibits the adoption of many common logistics methodologies such as JIT. For such SMEs, improved project management strategies and advanced planning techniques need to be adopted.

2.8. *High staff turnover*

Many countries in the SEA region have experienced good growth in the industrial sector over the past 10 years. Prior to 1997/1998, SEA attracted the highest foreign direct investment in the world [4]. This has put great pressure on the small population of countries such as Singapore and Malaysia. Labor as a resource in the enterprise is thus an important input. Three of the 30 sampled companies reported serious labor turnover rate exceeding 30% in normal years and 25 of the 30 SMEs reported turnover rate exceeding 20%. This high turnover rate adversely impacts how SMEs manage their labor resource—a key resource input in any ERP project.

2.9. *Customers' special demands*

Deloitte [2] reported that in their efforts to contain costs and boost competitiveness, more manufacturers are outsourcing their production to SMEs. It is usual for the larger companies to ensure that their suppliers'

management, operational procedures and quality standards are compatible with theirs. Large manufacturers view the contract manufacturers as an extension of their manufacturing facility. In 25 of the 30 SMEs, they are required to fulfill these requirements as part of their contractual obligation. These include 20 of the 30 companies requiring to buy from Approved Vendor Lists; Identification using Customer Part Number; 18 of the 30 companies needed to use Customers' Documents Formats, etc., of the 1st and 2nd tier manufacturers. SMEs must store their own set of part numbers and also maintain cross-reference of their customers' part number and the part numbers of the approved vendors. Likewise in addition to having their own set of invoice number and format, SMEs are required to print invoices based on the running numbers and formats of each of their major customers. All these lead to further complications in the setting up of ERP projects for these SMEs.

3. Enterprise Resources Management (ERM) model

As highlighted above, enterprise resources in the SMEs are subjected to conflicting interactions. By itself, the interdependencies move in different directions to achieve its own set of goals. There is thus a need to coordinate and integrate the various enterprise resources so that enterprise-wide interdependencies can be managed. Given the complexities in understanding the dynamics involved in managing these resources in SMEs, the second part of this paper presents a three-level ERM architecture combining system dynamics modeling with multi-agent-based approach. This model reduces the cluster dynamics existing amongst the various enterprise resources within the SMEs, the understanding will greatly aid in project management of ERP systems in SMEs.

The various enterprise resources in a SME can be segregated into multiple agents. An agent must have at least an objective or goal. When realizing the goal, the agent acts autonomously. This matches the organization dynamics relationship. Like the operational managers in the SMEs, agents can have several roles in the organization processes. A planner can be defined as an agent who establishes its plan and broadcasts this to other agents. An execution agent executes the plan. This agent does not negotiate about plans. An agent acts as a coordinator if it initiates a resolution of a plan relation. Agents can play one or more of these roles in a given process in the SME. However, an agent can also be a planner and coordinator at the same time. As illustrated in the above Study, each agent is close to the point of contact with the real world. The overall system behavior emerges from local decisions and the system can readjusts itself automatically to environmental "noise" or the removal or addition of agents. Thus, models and/or

software created for each agent is much shorter and simpler than would be required for a large centralized approach [10] making it easier to code, debug, maintain and project manage multi-agent-based ERP systems.

In this three-level ERM architecture (see Fig. 1), each agent plays only one of the roles, e.g. execution, planning, and coordination. This design considers the possible decentralization of information, resources, and the decision-making processes commonly found in SMEs. Also this three-level model reflects the "low levels of management structure" typical of SMEs (see Section 2.1). The first level, the operational level, consists of execution agents which receive plans from the planning agent. The second level, the decision level, comprises of the various planning agents (typically associated with the planning and operational management in the SME). At the top level lies the coordination agent, who provides "global" information and strategic directions for the planning agents to produce quality multi-agent plans.

3.1. Execution agents

The execution agents at this lowest level (see Fig. 1) receive the plans from the planning agent and execute them. These agents represent the real world of the multi-flows and in ERP projects, these are the critical triggers. This representation should comply with the system dynamics paradigm where the cause and effects of complex systems is properly demonstrated. This model is based on a state-based representation where the world is viewed as a series of states that are changed by events or actions.

Actions taken by the execution agents are triggered by messages from the planning agents. After execution, the system's states (e.g. inventory level, work-in-progress level, production capacity, etc.) are dispatched back to the planning agents for further actions. In doing so, the execution agent is acting as the controller to ensure that

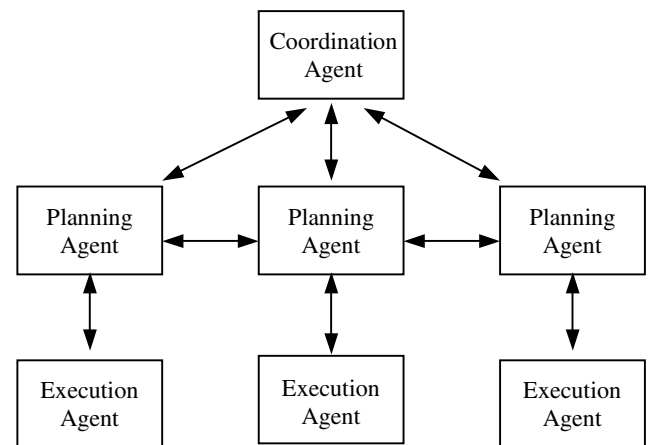


Fig. 1. Three-level system Enterprise Resources Management architecture.

the SME's plans are executed properly and the expected system's states are well maintained.

3.2. Planning agents

The middle level (see Fig. 1) is the planning agent level which is in-charge of the SME's planning functions. To keep the agents relatively simple, it is desirable to limit the number of functions encapsulated to a small number. In pinpointing the planning agents in the SME, we need to first identify the main planning intensive functions and processes in the planning level of the organization. These are selected from a complete set of planning processes which are tasked to the various resources.

As highlighted by Huin et al. [7], there are usually only a limited number of planning agents in a SME and these are likely to be the middle level management. However, if one looks at the interface between any two operational departments, it can be seen that the information transmitted between the agents is in the form of "orders" (e.g. purchase order, material issue vouchers, firmed planned orders, etc.), and the "commitment" to the orders (e.g. confirmed sales orders). These are the "Demands" and "Production Orders" which the SMEs must react to quickly to fulfill the needs of their customers. These should be matched as quickly as possible to ensure the competitiveness of the SME.

Next, we have to analyze from which function or process the information, which comes in the form of "orders", are being generated from. Horizontally, it is a key link between suppliers and customers. For example, the MPS Planning interfaces with marketing, distribution planning, production and capacity planning. These agents enable marketing to make legitimate delivery commitments to customers, and, enable production to evaluate capacity and material requirements in a more detailed manner.

3.3. Coordination agents

The top level in Fig. 1 shows the coordination agent level which acts as a controller and a mediator in the process of reaching an agreement. When the coordination agent receives the plans from the other agents, it checks whether it needs to pursue further negotiation. These negotiations can be both internal and external. External negotiations include charting the directions of the SMEs vis-à-vis its customers and the competitors in the market place, or engaging the customers with new/different delivery schedules, etc. Internal negotiations include reconciling the operational differences between the various enterprise resources (i.e. the planning and execution agents) in the SME.

Through its close interaction with customers (see Section 2.2), it broadcasts the market information in terms of sales, priorities and costs to guide the planning

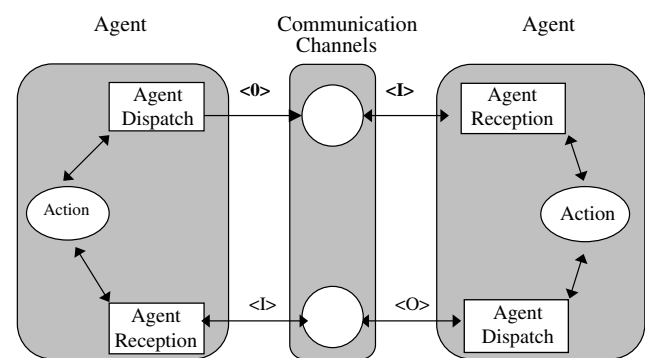
agents' pursuit of their goals. Even with a coordination agent, the detail planning decisions on how and when to make a plan fully workable rests with the autonomous planning agents involved.

3.4. Communication and synchronization of the agents

The three types of agents have the same logical structure. They exchange information with internal entities and the outside world by receiving and dispatching messages through independent interfaces. Action is taken upon the reception of the corresponding message. The changed state, particularly for the execution agents, is transmitted to other agents. Also the planning results from each planning agent may affect the planning process of other agents.

Agents need to exchange information in order to adapt to each other processes (see Fig. 2). This helps ensure that essential project information are collated and communicated at the various levels. There are two possibilities for exchanging messages. The agents can broadcast information about their intended actions to each other. This incurs a large amount of system overhead because more information must be exchanged and because agents may duplicate each other's rational decisions. Such weakness can bog down any ERP project management in the SME. In this three-tier architecture, the agents transfer their plans to the coordinating agents only before it converges.

This arrangement transforms the traditional SME's organizational dynamics of multi-lateral affair between the agents involved into a set of bilateral negotiations. In this case, the planning agents do not only interact directly with each other but each agent must communicate his final plans with the coordination agent. In Fig. 2, the messages exchanged between the planning agents are simply the outcome of the plans as and when they are processed, such as changes to the orders. No other internal information is normally exchanged except those from the execution agents which are submitted and kept



<O> indicates outflow of information. <I> indicates the inflow of information.

Fig. 2. Communication and interface of the various resources agents within SME.

with the planning agents. The information that a planning agent submits to the coordination agent is the final project plan information provided to the adjacent planning agent. In this manner, the information confidentiality and transfer problems are properly handled within the system. The coordination agent is in full control and has knowledge of the project plans and actions.

There are two approaches in representing events and their effects on the execution phase: state-based representation [9] and event-based representation [1]. Actions taken by the execution agents are triggered by the messages from the SME's planning agents. After execution, the system's states are dispatched back to the planning agents for further actions. The various agents act as controller whose responsibility is to ensure that the plans are executed properly and the system's states are well maintained. The agents transfer their plans to the coordinating agents only before it converges. The latter could be the CEO or a senior planning manager. Thus only one agent has to expend resources on reasoning and coordinating consistent views (see Fig. 1) within the SME.

4. Conclusions

This study highlighted the significant SORs and interdependencies in which SMEs operate under. These jointly impact how SMEs utilise and project manage standard ERP systems within their organizations. Some of these SMEs' SORs (summary below) are in many ways departures from the norms of mainstream large companies. Unless these deviations are well understood, managing ERP projects in SMEs will continue to be slow, painful and at times even unfruitful.

1. Low Levels of Organizational Hierarchy.
2. CEO Involvement in Operational Decisions.
3. "Blurred" Departmental Walls.
4. Production Modes in SMEs.
5. Planned Forecasts vs Real Forecasts.
6. Rate of Changes in Orders.
7. Short Lead-time in Manufacturing.
8. High Staff Turnover.
9. Customers' Special Demands.

These research findings provide inputs into further development of a three-level ERP resources management architecture comprising of three types of agents: execution agents, planning agents and coordination agents. To be successful in applying such an architecture to a multi-variant environment, such as the enterprise resources planning in a SME, one must be concerned with the underlying structure of the model, the naturalness of its representation of the system, and the verisimilitude of such a representation. This agent-based model represents the internal behavior of each individual within the SME. One agent's behavior may depend on observable generated by other individuals, but does not directly access the

representation of those individuals' behaviors, so the natural modularization follows boundaries among individuals. This is important as it gives the new model a significant advantage in handling complex projects such as ERP projects [8]. The agents correspond one-to-one with the individuals (e.g., departments or sections within the SME) in the system being modeled, and their behaviors are analogs of the real behaviors. These two characteristics make agents a natural locus for the application of adaptive techniques that can modify their behaviors as the agents execute.

Multi-agent systems offer an innovative way to relax the constraints of centralized, planned and sequential control [13]. They offer good models for systems that are decentralized rather than centralized, emergent rather than planned, and concurrent rather than sequential. The autonomous agent [11] approach replaces a centralized control system with a network of agents, each endowed with a local view of its environment and the ability to respond locally to that environment.

In this agent-based model, each SME has its own set of agents. An agent's internal behaviors are not required to be visible to the rest of the system, so SMEs can maintain proprietary information about their internal ERP projects. This matches the real world functional structure and the organization of the agents is a good mapping of the topography of the SME enterprise. This three-level model can thus be applied to solve organizational dynamics issues in enterprise resources planning projects in SMEs. Understanding of this three-level model will thus aid the SMEs in their project management and implementation of their ERP systems. In addition, agent-based approach can also be deployed in the development of sophisticated systems such as ERP systems where intelligent functional areas can be designated using multi-agents.

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