ENTERPRISE RESOURCE PLANNING (ERP) MODEL FOR SMALL AND MEDIUM SIZED MANUFACTURING FIRMS BASED ON UML

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Abstract

With the opening up of the global economy, manufacturing small and medium enterprises (SMEs) have found it necessary to utilize the benefits of Enterprise Resource Planning (ERP) system. The functional modules of ERP systems in large scale manufacturing SMEs cannot be treated similarly. Hence, there is a need to develop ERP system functions to meet the specific characteristics and needs of manufacturing SMEs. In this paper, conceptual ERP model for small and medium-size manufacturing firms has been proposed by using "4+1" views, based on Unified Modelling Language (UML). Three ERP modules were selected to be included in the proposed conceptual ERP model: manufacturing, inventory control, and human resources management. These modules were considered as being commonly used major ERP modules within manufacturing SMEs. The proposed ERP model overcomes the issues that hinder the ERP system adoption within manufacturing SMEs sector; and sustains their competitiveness and survives in global markets.

Keywords:

ERP, SMEs, Manufacturing, UML, "4+1view" architecture model.

1. Introduction

The vast development of Information and Communication Technology (ICT) in the last decades is a result of the growth occurs in various industries such as electronic, computer, telecommunication, and others that have had dramatic effects on different aspects of organizations' functions. An optimal introduction and integration of a primary technology that effectively utilizes an ICT system in the organization and workforce, specifically an Enterprise Resource Planning (ERP) system, will have an enormous positive long-term effect on large, medium or small enterprises (Ravarini, 2010). One of the key business applications that help enterprises to manage their resources is ERP, which is a multi-module application software package system that integrates key business and management processes across an enterprise (McGaughey and Gunasekaran, 2007).

A successful implementation of the ERP system helps enterprises to manage and integrate all the business functions within their borders. The ERP typically contains a set of mature business application and tools for financial and cost accounting, sales and distribution, materials management, human resource, production planning and computer integrated manufacturing, supply chain, and customer information (Boykin, 2001; McGaughey and Gunasekaran, 2007). Furthermore, an ERP system can be used as a tool to help in improving the performance level of a supply chain network by helping to reduce cycle times (Gardiner, Hanna, and LaTour, 2002; Lambert, García-Dastugue, and Croxton, 2005; Stadtler, 2015).

With the opening up and opportunity of the global economy the Manufacturing small and medium sized enterprises (SMEs) whose headcount or turnover falls below certain limits have found difficulties to sustain, since they do not have the strength to compete with large enterprises (Singh et al, 2008). Manufacturing SMEs have to tap the power of IT and integrated information systems to stay competitive and customer oriented (Ghobakhloo et al, 2011). As stated earlier, ERP is often considered the answer for enterprises survival (McGaughey and Gunasekaran, 2008; Rao, 2000; Shehab et al., 2004). Since ERP software market has become one of today's largest IT investments worldwide (Moon, 2007; Shehab et al, 2004), as enterprises, and SMEs in particular, realized the abilities and promises of ERP.

Despite local and international ERP vendors have come up with various solutions or packages to cater the needs of SMEs, it is inadequate to raise awareness for the targeted markets to embrace the system (Johansson and Sudzina, 2008; Olson, 2003). Most SMEs are proving to be laggards of the ERP system (Safavi et al, 2014; Shahawai and Idrus, 2010a). SMEs could not afford the risk of investing time,

ISSN 2076-9202

money and effort for a system that could ultimately fail (Haddara and Zach, 2011). The current trend in handling the SME market for ERP vendors is still a huge grey area (Supramaniam and Kuppusamy, 2010). The adopted ERP solutions within SMEs found to be either, of-the-shelf ERP system, in which enterprises purchase the ERP system offered by the vendors from the IT products markets. The other form, In-house ERP system, where enterprises utilize their own IT departments to develop a specific system functions (Shahawai and Idrus, 2010a). The provided ERP solutions have not met the mark with the majority of Manufacturing SMEs that it was targeting (Noudoostbeni et al, 2009; Shahawai and Idrus, 2010b).

To sum up of the foregoing, small and medium-size industries have smaller information technology departments and less experience with large-scale projects such as ERP. Thus, the researcher proposes a new approach to obtain ERP systems for SMEs efficiently. This approach harmonize with that ERP systems must be simple, cheap, compact size and easy to meets needs of an enterprises, budgets and culture (Park and Lee, 2006).

In this paper, conceptual ERP model for small and medium-size manufacturing firms has been proposed by using "4+1" views, based on Unified Modelling Language (UML). Three ERP modules were selected to be included in the proposed conceptual ERP model. These modules are: (1) manufacturing, (2) inventory control, and (3) human resources management. These modules were considered as being commonly used major ERP modules within manufacturing SMEs.

2. Literature Review

Through a review of previous studies has been realized that the ERP modelling untapped enough the object oriented technology and its properties to develop business information system. Object-oriented technology has been highlighted to overcome software obstacles (Park and Lee, 2006). Therefore, object-oriented is a well-adopted programming style that uses interacting objects to model and solve complex programming tasks in business information systems. Object-oriented system development is commonly recognized as improving efficiency and reducing system maintenance costs (Larman, 2012).

Traditional approaches to the modelling of complex manufacturing systems are expensive, time consuming, and of limited value. Recent developments in several areas (i.e., knowledge engineering,

ISSN 2076-9202

software engineering, modeling formalisms, engineering workstations, and database systems) are now to the point that a meaningful convergence can be crafted to yield a modelling environment far superior to any we have known in the past. Fundamental to this new approach to modelling are the recent developments in object-oriented programming and related technologies (Fellow et al., 1992). A research team at Oklahoma State University has been exploring alternative approaches to the modelling and simulation of complex manufacturing systems since 1985.

UML is an industry standard modelling language adopted by Object Management Group in 1977 (Park and Lee, 2006). The UML is derived of a shared set of commonly accepted concepts which have successfully been proven in the modelling of large and complex systems, especially software systems. With the UML extension for business modelling, a first object-oriented UML terminology has been defined for the domain of business modelling (Eriksson and Penker, 2000). UML are based on integrated Meta models supported by several modelling tools (Evans et al, 2014; Fowler, 2004). The core business modelling concepts of both methodologies will first be introduced and compared afterwards (Nüttgens et al, 1998).

3. Architecture Model

The “4+1” architecture model is a view model, designed by Philippe Kruchten for "depicting the architecture of software-intensive systems, depending on the employment of manifold, simultaneous views” (Kruntchen, 1995). The views are employed to depict the system from the viewpoint of stakeholders, such as end-users, developers and project managers.

According to UML and Rational Unified Process (RUP), the viewpoint of depicting system is based on the “4+1” views. Fig. 1 below, represents the “4+1” views of UML to describe system architecture (Kruntchen, 1995; and Park and Lee, 2006).

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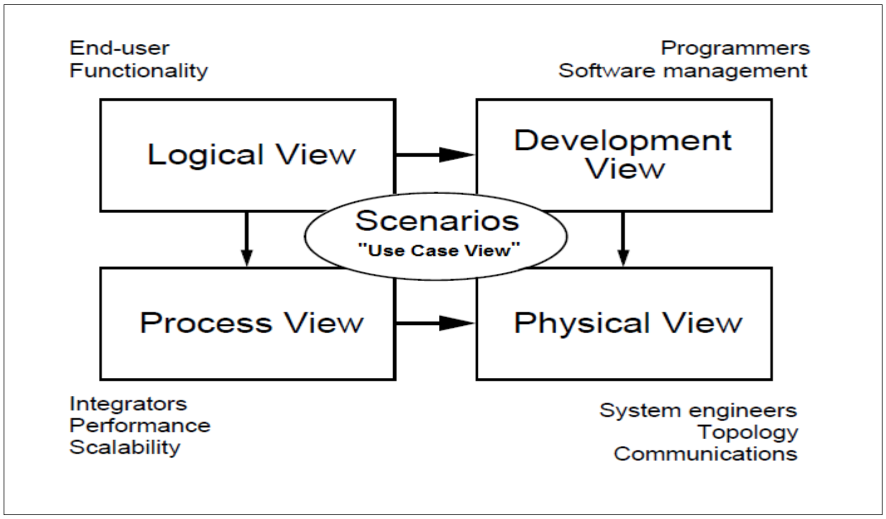

Fig. 1“4+1view” architecture model

Source: Park and Lee 2006

- The “4+1View” architecture model comprises of five views, which have been adopted using UML diagrams to model the ERP system as follows:
- Logical view: The logical view is associated with the functionality that the ERP system offers to end-users and relationship from the terminology of the problems and their solutions. The logical view facilitates the functional needs of the system. Fundamentally the UML diagrams, including class diagram and depict the logical view.
- Development view: the development view an ERP system is also is also known as the implementation view, which constitutes the components and files, which are employed to accumulate and discharge the physical system. It employs the component diagram and package diagram.
- Process view: the process view covenants with the active features of the system, elucidates the system processes and how they correspond, and concentrates on the runtime behaviour of the system. UML Diagrams are employed to symbolize process view including the sequence diagram and activity diagram.
- Physical view: physical view of a system is also known as the deployment view and encloses the nodes, which constitute the system’s hardware topology, on which the system functions. It is associated with the topology of software components on the physical layer, and the physical link

ISSN 2076-9202

among these components. UML Diagrams employed to symbolize physical view include the Deployment diagram.

- Scenarios: The depiction of architecture is exemplified using a small set of use cases, which become a fifth view called as use case view. The use case view of a system encloses the use cases that describe the performance of system in the context of end users, analysts, and testers. Furthermore, it also illustrates the proposed functionality of the system, as professed by external actors and it states the aspects that shape the system's architecture. In UML, it is captured by use case diagrams.

The five "4+1" views are typically demonstrated using the UML approach. As aforementioned the UML is a language for identifying, building, envisaging and documenting the software system and its components (Ngadiman et al, 2008). The UML is selected based on its affinity as a modelling language, which enables to identify, design, and develop and document the aspects in software. It has also been established as a language, which can successfully model a huge and multifaceted system by generating normal and simple design, for making the users to comprehensively utilize it (Ngadiman et al, 2008; Park and Lee, 2006). In the following section, the researcher represents results of modeling conceptual ERP system for small and medium size manufacturing companies by using "4+1" views

4. Conceptual ERP Model

Even though, the implementation of ERP system involves some risks, the ERP systems have become very important aspect in business operations among large organizations (McGaughey and Gunasekaran, 2008). These systems have a lot of advantageous features and values, which have driven a lot of large to endow time, endeavour and millions of Ringgits in ERP system (Shahawai and Idrus, 2011a). Nevertheless, the acceptance of ERP system in small and medium size manufacturing enterprises is still low as against the large enterprises. The reasons for the low level acceptance is the complication of the system, huge cost incurred from the pre-implementation until the post-implementation, irrelevancy of business operation and the low level consciousness towards ERP system or ICT (Shahawai and Idrus, 2010a). Based on the previous studies of pre-determined factors towards the adoption of ERP system in manufacturing SMEs, a lot of SMEs in are slow in employing the

ISSN 2076-9202

ERP system (Seethamraju, 2015; Shahawai and Idrus, 2010b).

With respect to the manufacturing SMEs, which have implemented ERP system, all the sub-sectors of manufacturing SMEs and their industries chose one of the forms of adopting ERP. A number of industries require a different kind of ERP modules for their business operations, based on the type of industry; hence, the ERP system has to be customized. While other industries have implemented generic ERP system (Shahawai and Idrus, 2010a). Both forms seem to have own risk of implementation, where the complexity and high cost are the major concerns.

The need of design custom ERP modules using "4+1view" architecture model has emerged because of the benefits offered by the customization, these benefits meet the manufacturing SMEs needs as follows: (1) developing uncomplicated ERP functions fit the organizations' business process, (2) compatible and adequate ERP functions, and (3) low cost and time of implementation, where that customization will shorten the business processes re-design as much as possible, which require time and high cost (Raymond and Uwizeyemungu, 2007).

In this section, the functions of the ERP system have been envisaged and described, based on "4+1" views architecture model using the UML diagrams. As discussed in previous, the "4+1" views of UML comprise five views such as: use case view, logical view, process view, physical view and development view. Each "4+1" view is carried out using UML diagrams for the purpose of depicting the architecture of the proposed ERP system.

Three ERP modules were selected to be included in the proposed conceptual ERP model. These modules (subsystems) are: (1) manufacturing, (2) inventory control, and (3) human resources management. These modules were considered as being commonly used major ERP modules within manufacturing SMEs.

4.1Use Case View

A use case is distinctive interactions between the user and ERP system and it describes the functionalities of an ERP system (Dennis et al., 2008; Park and Lee, 2006). The principle of employing use case diagram is to show use cases of a system, actors, and relationships between actors and use cases

ISSN 2076-9202

among ERP system. In this analysis step, two levels of use case diagrams have described. One level illustrates the division of the whole system into subsystems (system modules). Whereas, the second level illustrates how to thoroughly depict each subsystem such as, manufacturing, inventory control, and human resource.

As the ERP system is a huge and composite package, it has been divided into number of subsystems. Generally, the subsystems are employed to manage a large-scale information systems into smaller units and to make it more clear or convenient, hence they can be more easily elucidated to others (Park and Lee, 2006; Youngs et al., 1999). As illustrated in the Fig. 2, each ERP module is considered as a subsystem, the ERP system can be classified into three subsystems such as: manufacturing, inventory, and human resource.

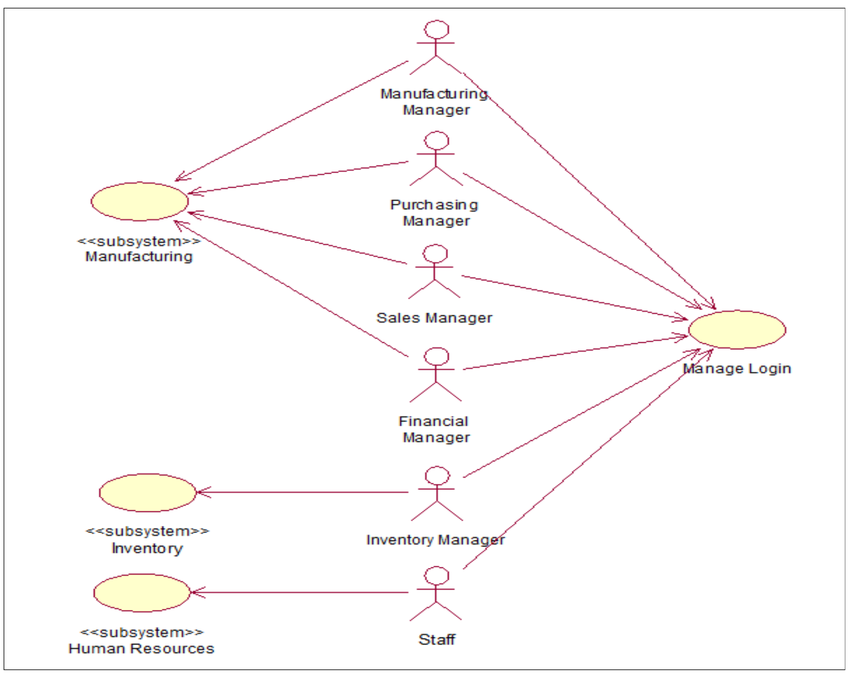

Fig. 2 Use case diagram at high level

The use cases represent a subsystem unless for “manage Login” use case. Each actor of use cases including, manufacturing manager, sales manager, purchasing manager, inventory manager, human resource manager and enterprise’s staff, embody external persons linked with subsystem. For instance, when portray the human resources subsystem in detail, the actor staff can be separated into “HR admin”, and “enterprise’s staff”.

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The proposed ERP system consists of three main subsystems, which are “Manufacturing”, “Inventory”, and “Human Resources”. The “Purchase” and “Sales” subsystems are not included in the proposed ERP system. But there are some purchasing and sales functions required for manufacturing system functions, therefore the required purchasing and sales functions have been integrated into the manufacturing subsystem and the purchase and sales managers can access them through the manufacturing subsystem.

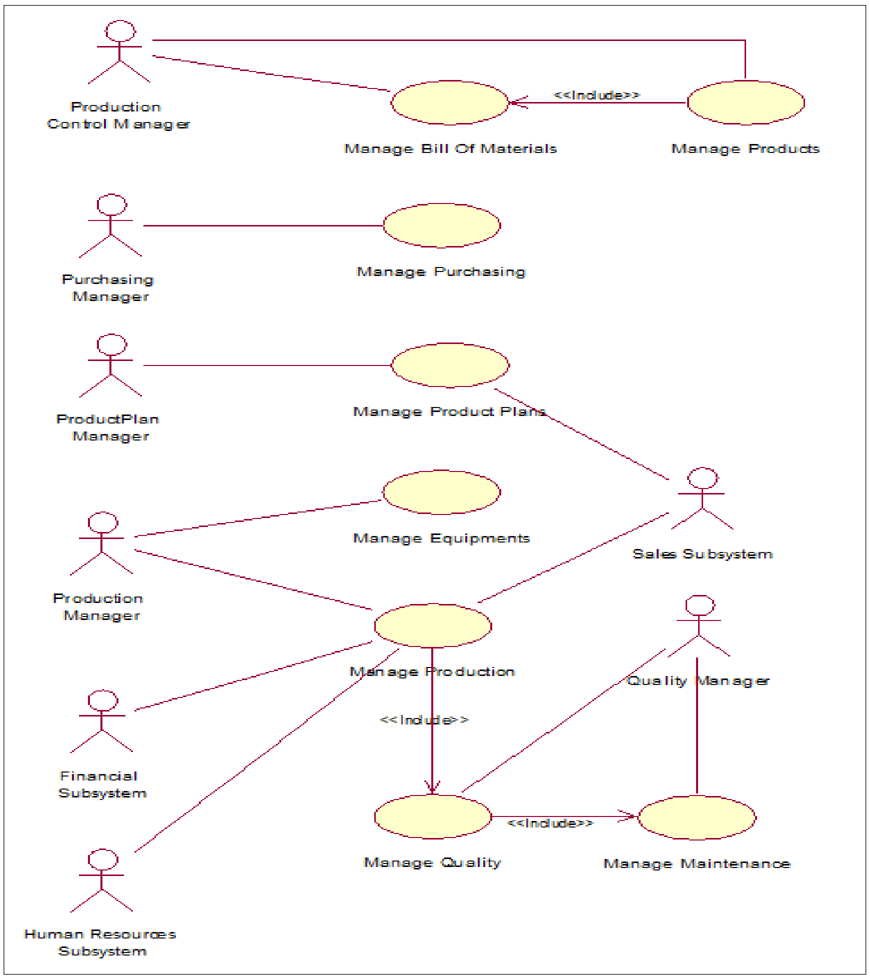

Fig. 3 Use case diagram of manufacturing subsystem

The proposed ERP subsystems (modules) in this study have been modelled using expanded use case diagram. Fig. 3 as above, has described the use case diagram for manufacturing subsystem, the manufacturing modules consists of eight main functions such as: “Manage Bill of Materials”, “Manage Products”, “Manage Purchasing”, “Manage Product Plan”, “Manage Equipments”, “Manage Production”,

ISSN 2076-9202

"Mange Quality", and "Manage Maintenance".

The Simple normal use-case dependency with the stereotype of <<include>> and <<extend>> have been used to describe the relationships between use cases. In the manufacturing use case diagram, the manage quality use case shares the manage production use case functions, in addition the manage quality use case share functions and include in manage production, and manage maintenance share functionality of the manage quality, finally manage bill of material is included in manage item. Each of the "Sales Subsystem", "Financial Subsystem", and "Human Resources Subsystem" are ERP modules (subsystems) related with manufacturing module, which the subsystem actor can be related with other subsystems.

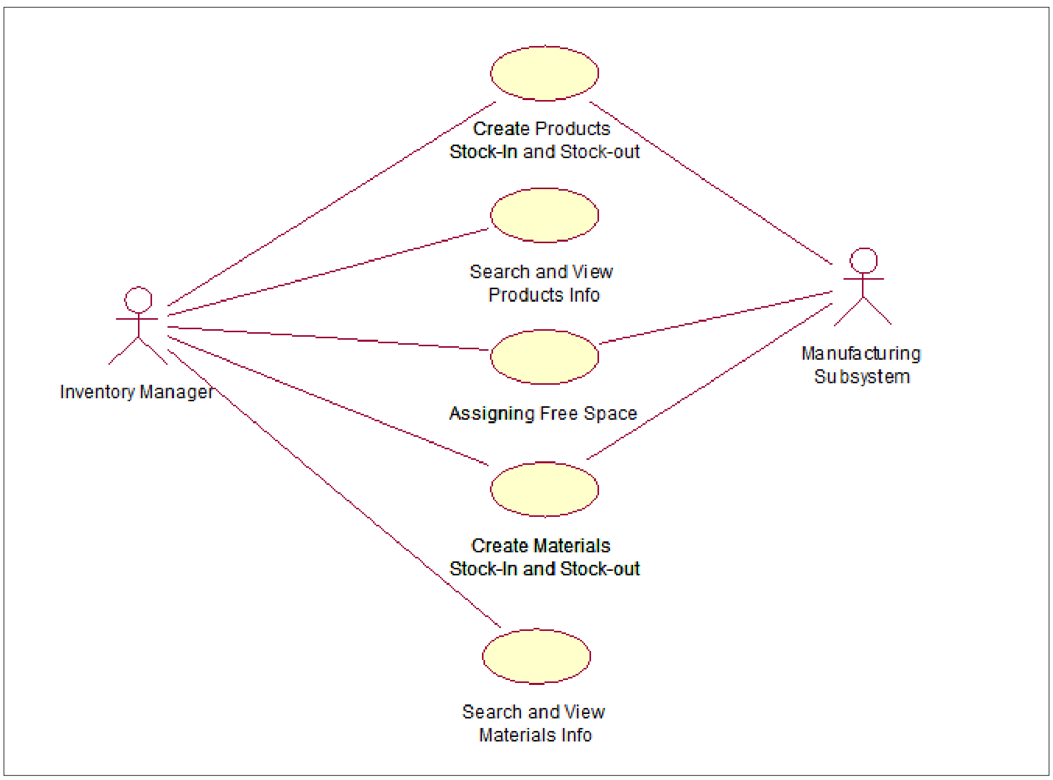

Fig.4 Use case diagram of inventory control subsystem

In the Fig. 4, the use case diagram of inventory control subsystem is illustrated. The inventory control modules are composed of five main functions: create product stock-in and stock-out, search and view product info, assigning free space, create material stock-in and stock-out, search and view material info. The inventory manager is the only person who interacts with these functions.

ISSN 2076-9202

Manufacturing subsystem actor is external subsystem considered as actors related with inventory control functions. As shown in the above Fig.4, the manufacturing subsystem interact with create product stock-in and stock-out, assigning free space, and create material stock-in and stock-out use cases.

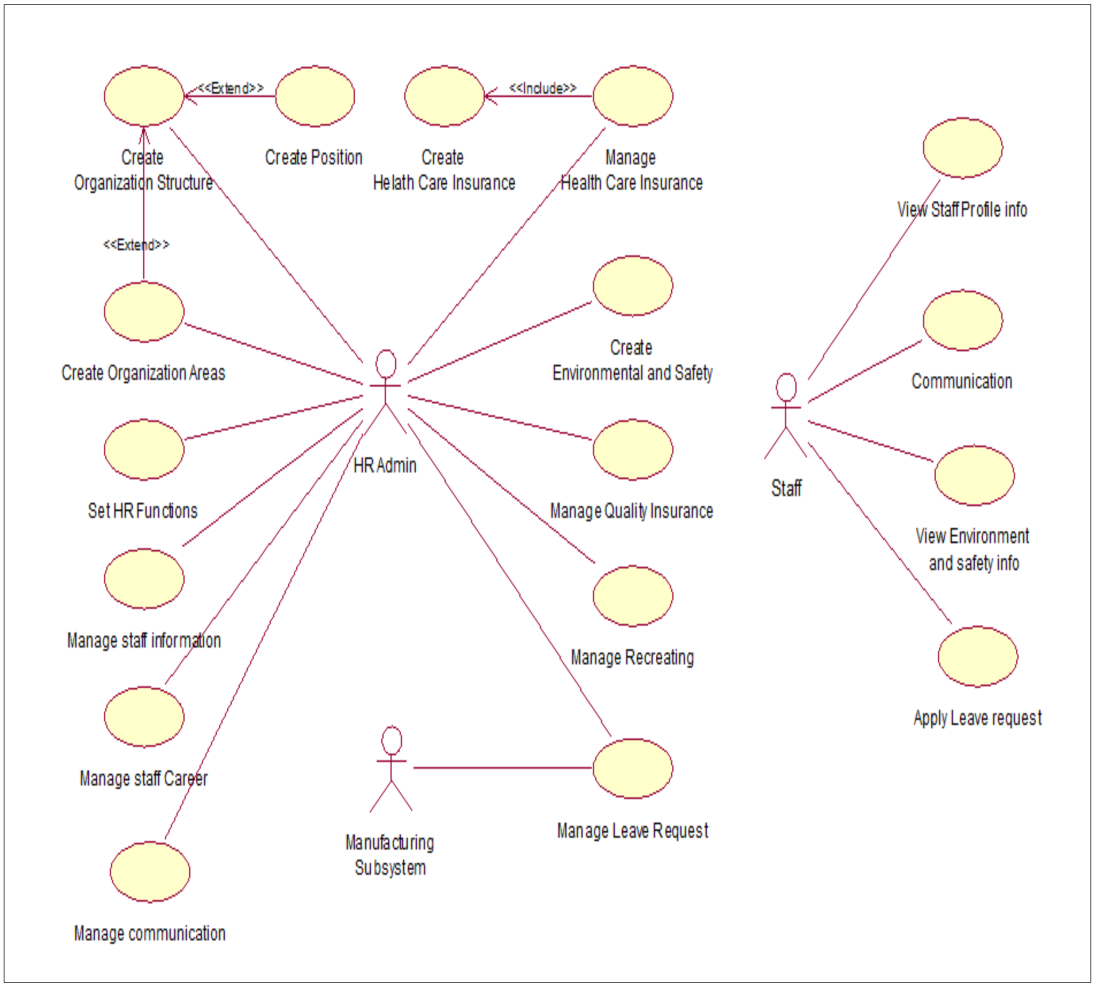

Fig. 5 Use case diagram of human resources management subsystem

Fig. 5 describes the use case diagram of human resources module, the human resources subsystem consist of seventeen functionalities, thirteen of these functions interact with HR administrator and only four functions interact with enterprise's staff as follows:

- Use Cases Accessed by HR Admin:

1. Setting HR functions	2. Manage health care insurance
3. Create organization structure	4. Manage environmental and safety

ISSN 2076-9202

5. Create position
6. Manage quality insurance
7. Create organization areas
8. Manage recreating
9. Create health care Insurance
10. Manage leave request
11. Manage staff information
12. Manage communication
13. Manage staff career

- Use cases accessed by Staff

1. View staff profile info
2. View environment and safety info
3. Communication
4. Apply leave request

Manufacturing subsystem actor is external subsystem, which interact with the manage leave request use case. In terms of the relationship between the use cases in human resources use case diagram, the create health care insurance use case is included in manage health care insurance use case, in addition the create organization structure use case can be extended to the create position use case, which means that the create position use case is a special case behaviour of the create organization structure use case.

4.2Logical View

The logical view is concerned with the functionality that the ERP system provided to end-users and collaborations from the vocabulary of the problem and its solution. It supports the functional requirements of the system. UML Diagrams have been used to represent the logical view include Class diagram.

4.2.1 Class Diagram

A class diagram describes ERP system in terms of classes and relationships among the classes (Warmer and Kleppe, 1998). The class diagram of the three proposed ERP modules have been described as follow: The class diagram of "Manufacturing" subsystem and "Inventory" subsystem described in one class diagram, while the "Human Resources Management" subsystem are described in a separate class diagram.

The manufacturing and inventory subsystems' class diagrams, consists of 32 classes grouped into

ISSN 2076-9202

12 class packages shown in Fig 6 and Fig 7. Each class package matches to manufacturing use case as illustrated in Fig 3, while each class in manage inventory control class package corresponds to inventory control use case as in Fig 4.

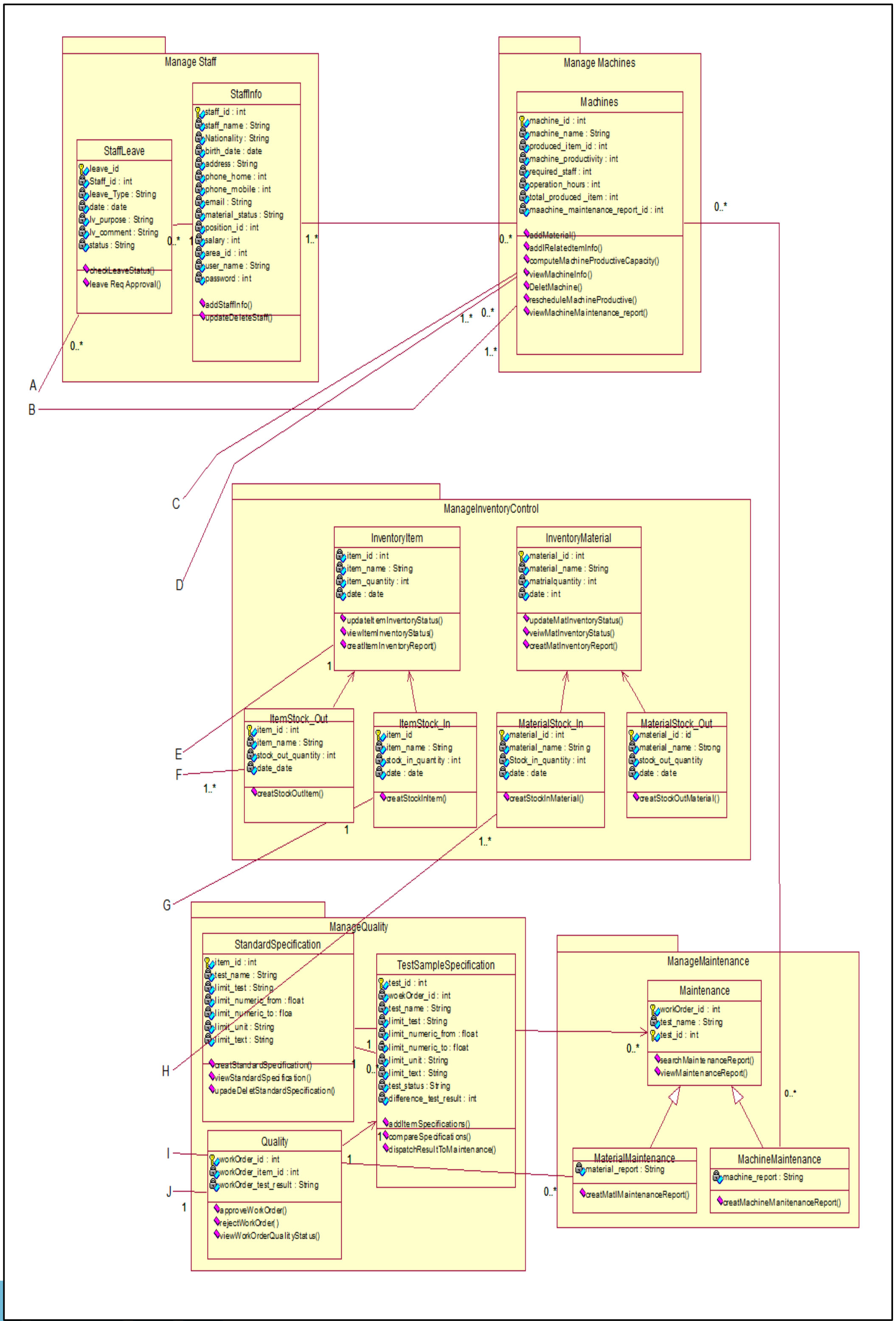

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Fig 6. Class diagram of manufacturing and inventory control subsystem (1)

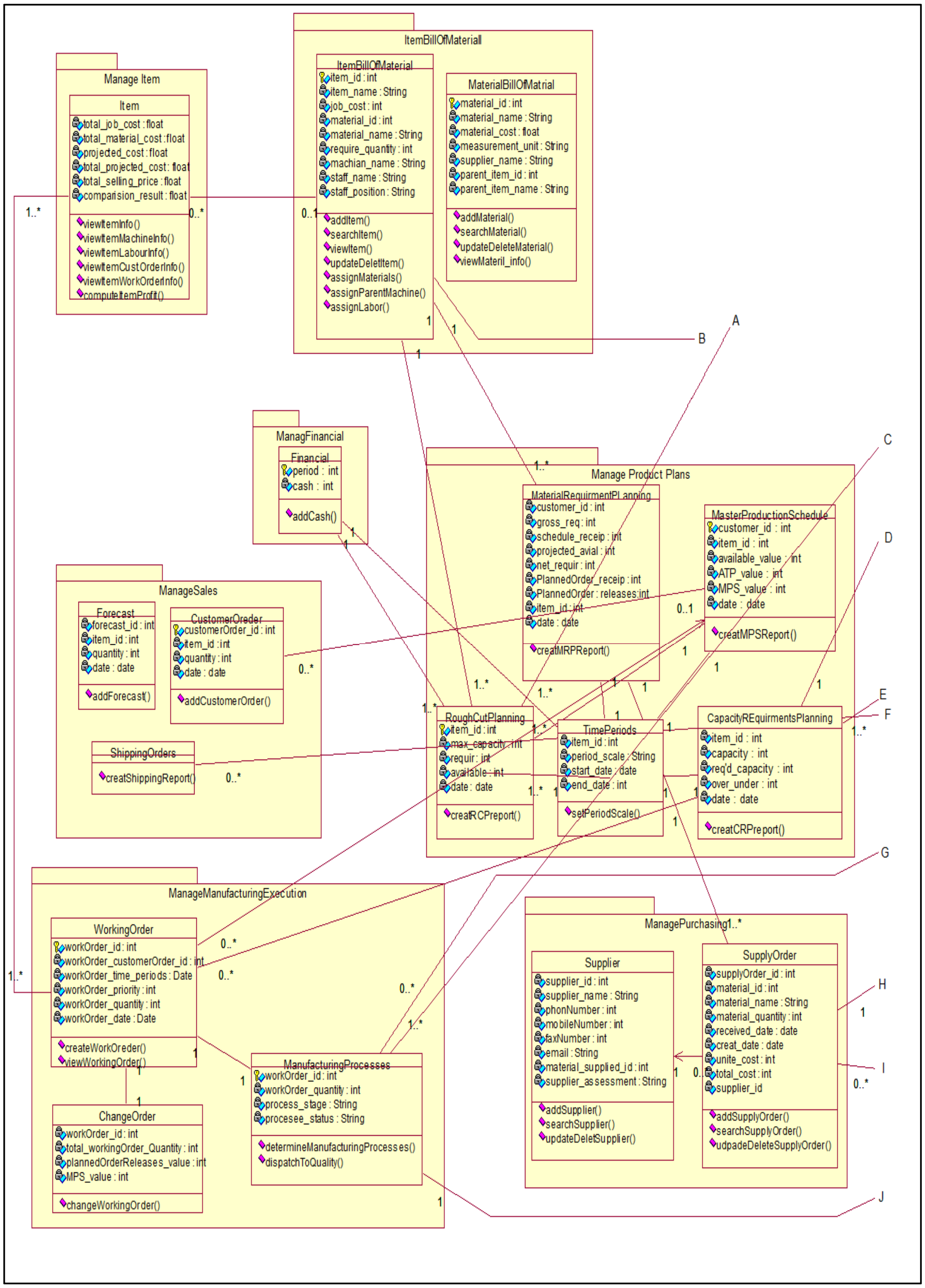

Fig. 7 Class diagram of manufacturing and inventory control subsystem (2)

Fig.s 6 and 7 describe the structure of a "Manufacturing" and "Inventory Control" subsystems by

ISSN 2076-9202

showing the system's classes, their attributes, operations (or methods), and the relationships among the classes. The class diagram of “Manufacturing” and “Inventory Control” subsystems describes the relationships among the classes with <<usage>> dependency relationship, association relationship, and inheritance relationship.

As shown in Fig.s 6 and 7, the “Inventory Control” subsystem is integrated with “Manufacturing” subsystem via association between the interior classes of manage inventory control class package and the interior classes of manage purchasing, manage manufacturing execution, and manage product plan class packages. The class diagram of “Human Resources” subsystem is shown in Fig.s 8 and 9. Nineteen classes that have been grouped into nine class packages constitute the “Human Resources Management” class diagram; each class package corresponds to human resources management use case in Fig. 5.

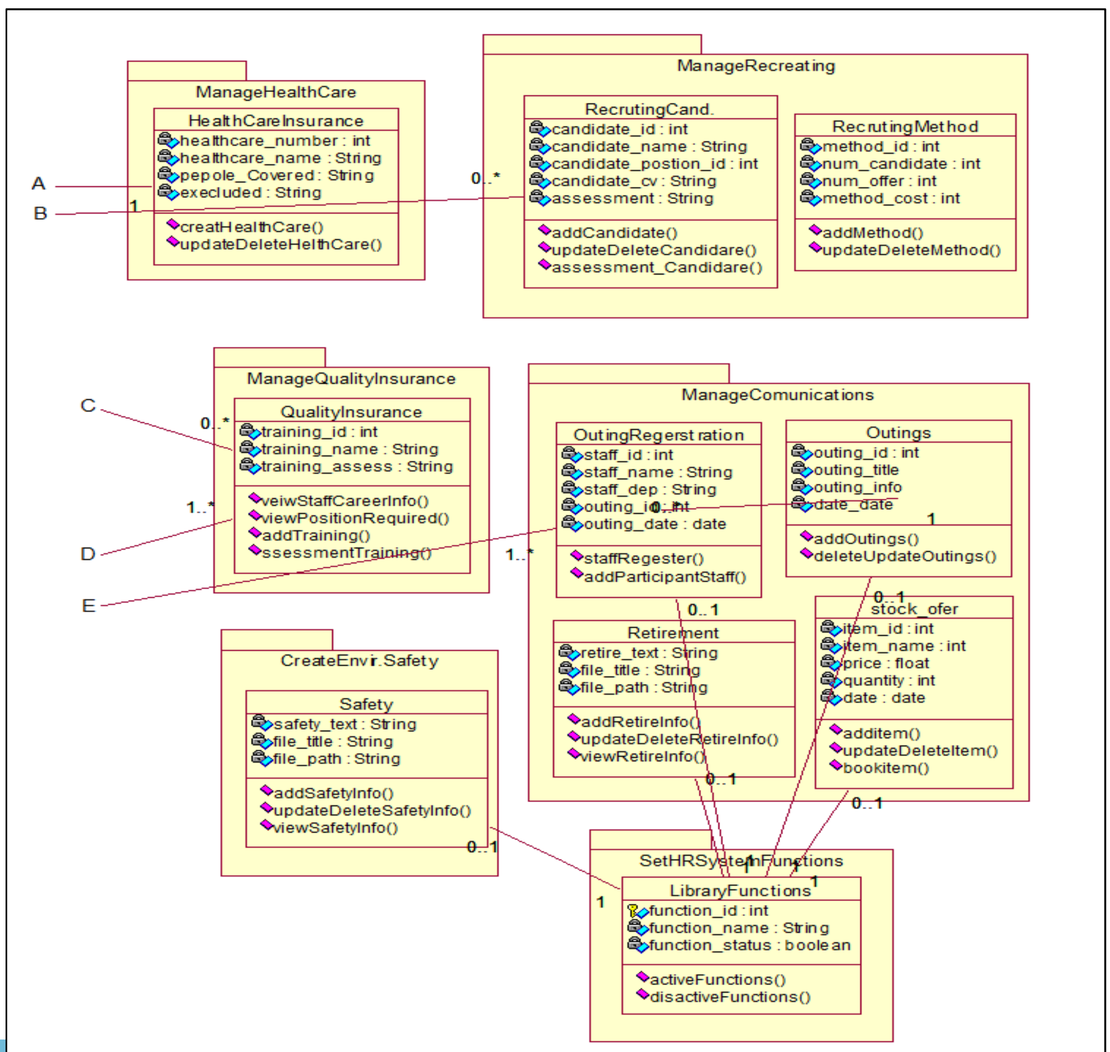

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Fig. 8 Class diagram of human resources management subsystem (1)

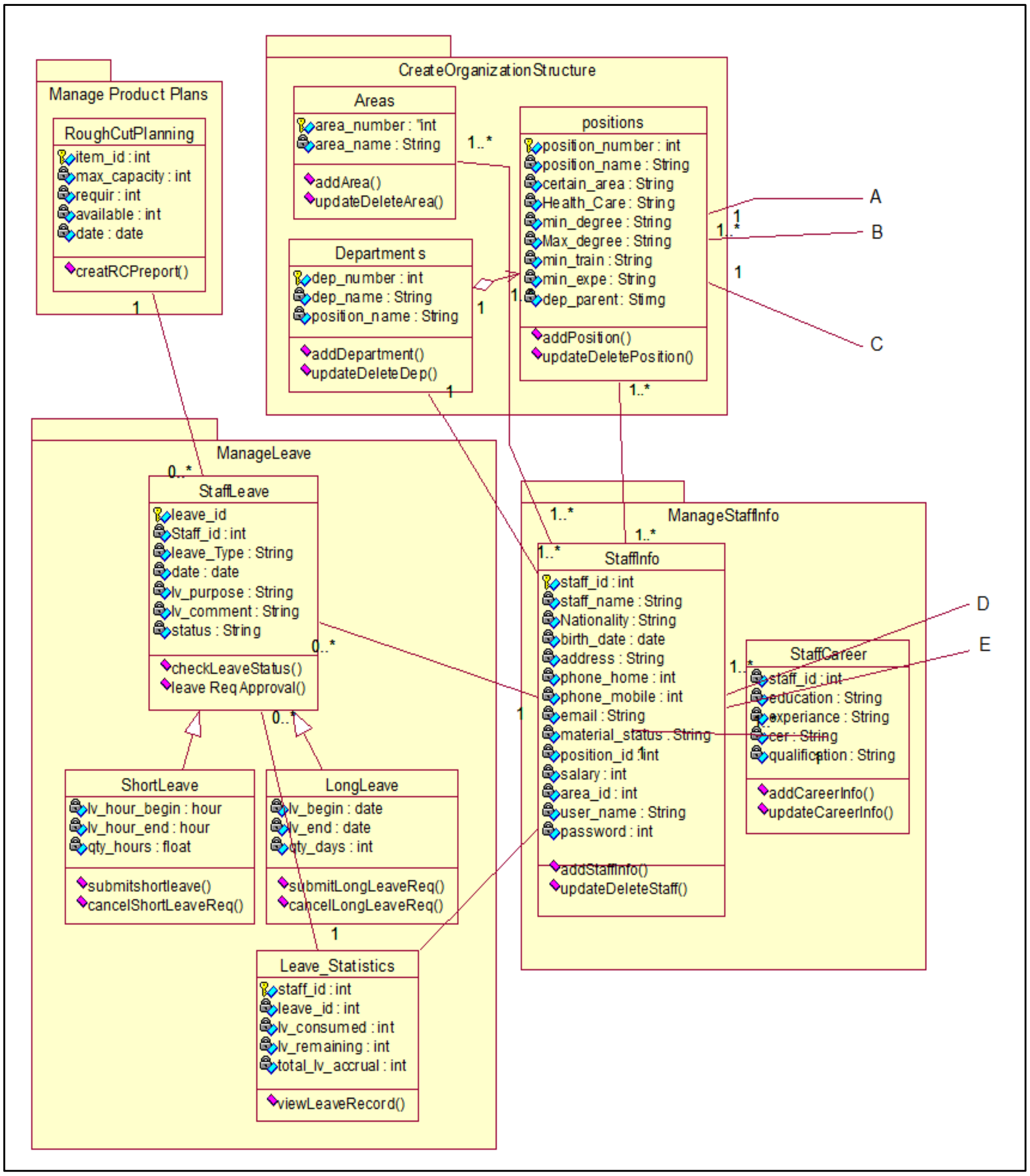

Fig. 9 Class diagram of human resources management subsystem (2)

"Human Resources Management" subsystem describes the relationships among the classes with association, aggregation, and inheritance relationships. In addition, the "Human Resources Management" subsystem integrated with "Manufacturing" subsystem through association relationship between manage leave class package and manage product plans class package.

4.3Processes View

The process view deals with the dynamic aspects of the system, explains the system processes and

ISSN 2076-9202

how they communicate, and focuses on the runtime behaviour of the system. The process view addresses the concurrency, distribution, integrators, performance. The UML Diagrams are used to represent process view including the sequence diagram.

4.3.1 Sequence Diagram

According to Kobryn (2000), the sequence diagram (interaction diagram) describes the sequence of actions between related objects that is triggered by a cut operation. The sequence diagram captures the behaviour of single use case by showing the messages passed between those object of the case and describe the sequence of operation in that use case (Booch et al, 2005). Manufacturing modules includes eight main use cases; the objects interact with each among these use cases described using sequence diagrams for each use case separately. To represent the example of sequence diagram, the "Working Order" has been chosen among use cases of manufacturing subsystem to be shown.

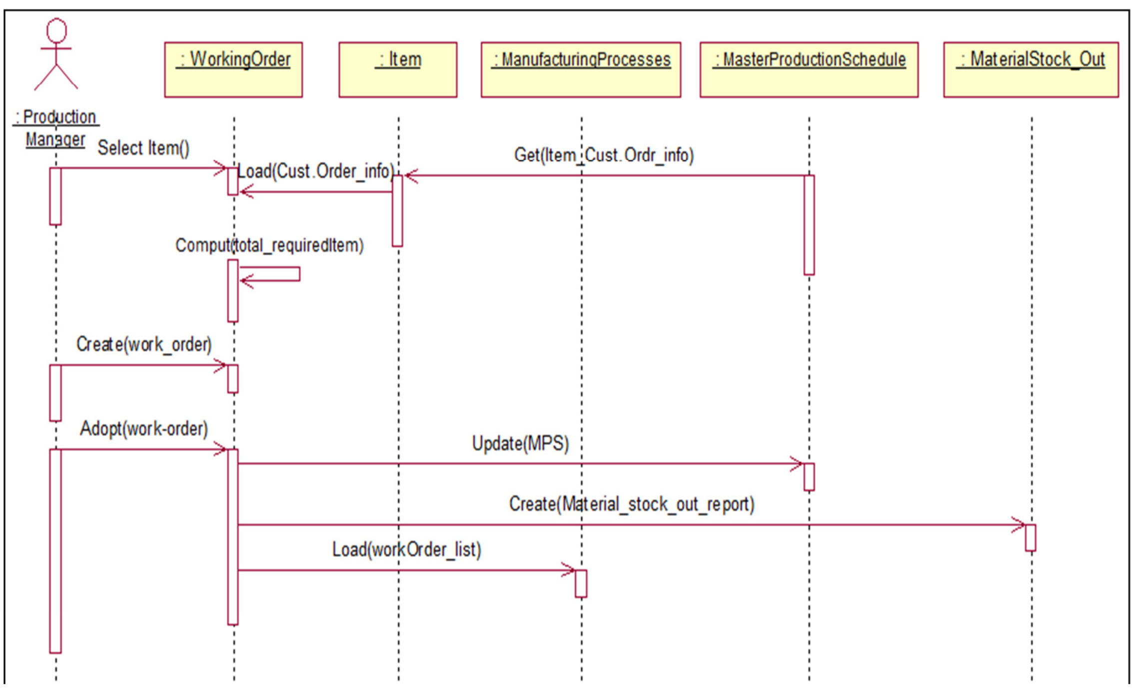

Fig.10 Sequence diagram of working order use case

Fig. 10 illustrates the sequence of create working order. The production manager is the actor who deals with the working order function. The production manager begins creating working order by selecting the targeted item, the system will load all of the customer orders classified under the selected item from "MasterProductionSchedule" class, the production planner can view the customer orders, total

ISSN 2076-9202

required item, and related info, finally the production planner will select the customer order to be created as working order and press on creates button, when production planner create working order, three functions will be activated as follow:

1. Update the "MasterProductionSchedule" entity in term of the converted customer orders to working orders.
2. Create stock out report includes the created working order info and send it to "MaterialStock_Out" entity.
3. Send the created working orders to Manufacturing Process to start the manufacturing process of the created working orders.

4.4Physical View

The physical view of a system encompasses the nodes that form the system's hardware topology on which the system executes. It is concerned with the topology of software components on the physical layer, as well as the physical connections between these components. This view is also known as the deployment view. UML diagrams used to represent physical view include the deployment diagram.

4.4.1 Deployment Diagram

The deployment diagram illustrated a static view of the run-time constitution of processing nodes and the components that run on those nodes. Nevertheless, the deployment diagrams illustrate the hardware of the system, the software and the middleware used to connect the different machines with each other (Booch et al, 2005). This corresponds with the weak budget of small and medium enterprises (Ahmad et al, 2010), and they are looking to adopt cheap ERP system.

To describe the physical view of the system we have used cube to describe the device nodes and used the shaded cube to describe the process, to describe the relationship between the subsystems, pipe and filter architectural has been adopted as shown in Fig. 11.

ISSN 2076-9202

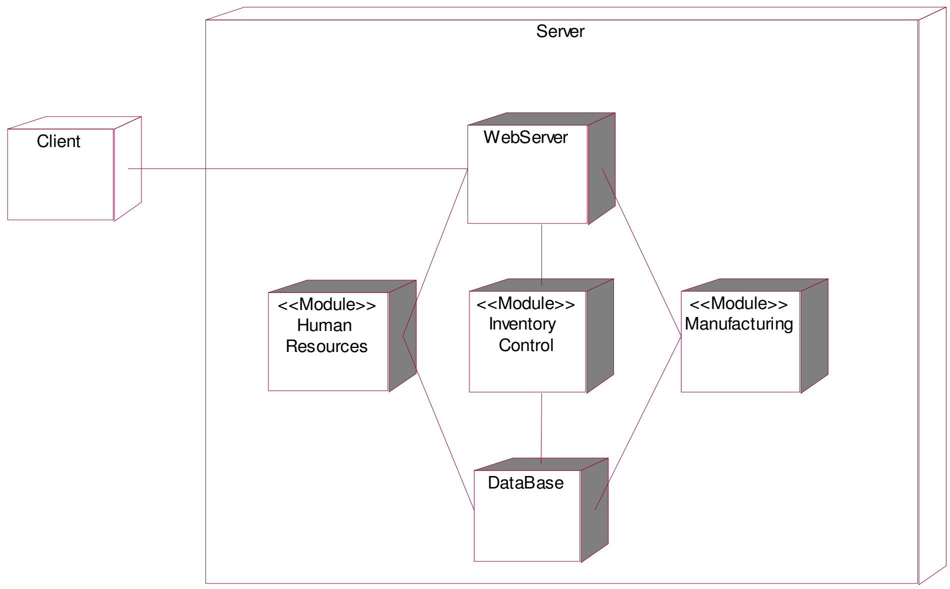

Fig. 11 Deployment diagram of the ERP system

As illustrated in the Fig. 11, the deployment diagram of the ERP system contains two nodes client and server. The server node consists of web, database and three subsystems. The database manages the incorporated data associated with all subsystems and web assist, to link the client and subsystems. It is crucial to adopt the web technology to ERP as internet business is related with the information technology and business area (Park and Lee, 2006).

The high cost of In-house ERP system (customized ERP system) is considered as one of the issues that prevent these enterprises from adopting the ERP system. Besides this, the SMEs do not allocate adequate budget for information technology development (Hashim, 2015; and Khaleel et al, 2011). To address the above mentioned issues, the proposed ERP system in this study has been built on the foundation of web.

As the SMEs do not allocate the adequate budget to develop and update the information technology system and therefore they tend towards a reduction of the cost of the hardware required for adopting ERP systems (Malhotra and Temponi, 2010). Thus, the server consists of one hardware piece including web, application, and database server is suited.

ISSN 2076-9202

4.5 Development View

This is a view of an ERP system, which constitutes the components and files that are used to accumulate and release the physical system. This view is also known as the implementation view. It employs the UML component diagram to depict the system components.

4.5.1 Component Diagram

The main purpose of the component diagram is to illustrate the structural relationships between the components of a system, and describe the structure of the code (Booch et al, 2005). The component is not analysis or design diagram. The component diagram can be depicted after implementation phase. Hence, the component diagram will not be captured in this research work.

5. Conclusion

ERP framework consolidates most of the business processes and permits access to the information progressively. Moreover, ERP enhances the execution level of a supply chain by helping to lessen the process durations (Esteves, 2009; Gardiner et al, 2002). There are likewise some advantages that an enterprise may appreciate by adopting an ERP framework including, better consumer fulfilment, enhanced seller execution, expanded adaptability, lessened quality costs, enhanced asset utility, enhanced data precision and enhanced basic leadership ability. In order to tap the above mentioned advantages within manufacturing SMEs, this research work represent conceptual ERP model by using “4+1” views, based on UML.

The proposed conceptual ERP model has customized to fit manufacturing SMEs business processes rather than re-designing these unmatched processes. In addition, it is provide a suitable ERP modules and functions for manufacturing SMEs, able to overcome the issues that impede the ERP system adoption, such as of-the–shelf system complexity and high cost of in-house system.

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