MARIT. POL. MGMT., JULY–SEPTEMBER 2003
VOL. 30, NO. 3, 197–210

Taylor & Francis
Taylor & Francis Group

An ERP approach for container terminal operating systems

HYUNG RIM CHOI*, HYUN SOO KIM, BYUNG JOO PARK
Department of MIS, Dong-A University 840, Hadan-dong, Saha-gu, Busan 604-714, Korea

NAM-KYU PARK
Department of Distribution Management, Tongmyong University of Information Technology, Busan, Korea

and SANG WAN LEE
Department of Industrial Systems Engineering, Dong-A University, Hadan-dong, Saha-gu, Busan 604-714, Korea

The major characteristics of ERP (Enterprise Resource Planning) are an enterprise-wide system that covers all the business functions and information resources, integrated database, built-in best industry practice, packaged software and open architecture. ERP enables reduction of system development time, flexibility, standardization of workflow and effective business planning capability. ERP is mainly for the manufacturing industry. However, the principles of ERP can also be applied to container terminal operating systems. This paper presents an ERP system approach for a container terminal. It has clustered the workflow of a container terminal and analysed the business process to generate the best workflows. The integrated database is designed to eliminate redundancy and keep integration. The core of ERP for container terminal is the planning facility such as berth planning and yard planning. The planning capability is very tightly coupled with data flow from client entities such as shipping companies. The ERP can handle the existing problems of container terminal operation that are mainly caused by lack of integration of a whole information resource in a container terminal, ad-hoc and poor planning capability, disconnected and incorrect data from client companies. The ERP approach can not only resolve the problems of container terminals but also promote adoption of information systems for container terminals in the world that have not yet implemented terminal operating systems.

1. Introduction

Recently, vessels are becoming more large-scale and high-speed because of the increasing quantity of cargo transported, shipper's requirements for lower transportation fee and shipping companies' effort toward retrenchment of transport cost per shipping unit. Furthermore, shipping companies become more interested in

* To whom correspondence should be addressed. e-mail: hrchoi@daunet.donga.ac.kr

Maritime Policy & Management ISSN 0308–8839 print/ISSN 1464–5254 online © 2003 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/0308883032000089549

maximizing vessel turnover by minimizing the length of staying time at ports for economical reasons.

These situation forces rival terminal companies to develop into the latest technology of loading and unloading, as well as the renovation of their terminal facilities in order to reduce the length of staying time of vessels at their terminals. The efficient operation of terminals is another very important factor that is very necessary for improving the competitive status and productivity in the fierce competitive environment between container terminals. However, the investment in software systems for the efficient operation of a terminal and its standardization has been relatively neglected compared with the large investment in the expansion of terminal facilities and infra-structure.

Usually, each terminal developed their own terminal operating systems by ordering them from a software development company. Therefore, each terminal's operation system is different from each other. Gamman container terminal, in the Port of Busan, is the typical example of the situation. There are four different terminal operating systems, because four different shipping companies operate the terminal [1].

This paper's purpose is to explore the way to develop ERP systems for container terminals in order to reduce the development time by standardization and increase the software quality. The ERP system is a general purpose and integrated operating system to fully utilize and cover all the information resources and business operation in an enterprise, packaged software with built-in business process model, and has an integrated database and open architecture. Existing ERP systems are mainly for the manufacturing industry. However, it also has important features such as integrated database and operating system, and it has the capability of curtailment of developing time and retrenchment of developing cost. So, the ERP concept can also be applied to a container terminal operating system.

With this background, this paper suggests a container terminal ERP system that can solve problems of existing container terminal operating systems such as high developing cost, prolonged developing time and non-integration. For this purpose, one has analysed the existing terminal business processes to produce a new one for reducing data redundancy, and suggested an ERP framework for the integrated terminal operating system.

2. Container terminal operating system and ERP system

2.1. *Container terminal operating system*

Container terminal operating systems are necessary and should be prepared for the efficient operation of the container terminals and to raise service levels for the customers of container terminals.

Computerized container terminal operating systems have functions and roles as follows [2]:

(1) Manage the flow of containers through the terminal by relocating the containers in the right places in the most efficient manner;

(2) Plan loading/unloading schedule and yard transfer operation by receiving information from shipping companies, describing position of containers on vessel coming into the port and which ones need to be taken off at the terminal;

(3) Process the containers transported into the terminal by rail or road, receiving notification from shipping companies and trucking companies about them; and
(4) Notify shipping companies and trucking companies about the locations of containers.

Most container terminal operating systems consist of separated functional modules. The modules are database module, planning module for loading/unloading sequences from vessels and movements of containers through the yard and control modules for operating processes [3].

2.2. *The current state of container terminal operation*

Referring to the reports from Cargo Systems, a port consulting institution for the status of container terminal operation abroad [3], one has made in-depth interviews with the operation managers of the terminals for the current conditions of Korean container terminals. Container terminal operating systems consist of main service modules and added service modules. The main service modules are EDI systems for communication and exchange of information with outer institutions, yard planning and vessel planning systems, loading and unloading operation systems, systems for billing, gate systems and wireless communication systems.

The added service modules are advanced modules that combine information processing technology and intelligent processing in a system. The examples are container location and tracing systems at the Kolka terminal in Finland and automatic recognition system of container numbers at the gate [3].

2.3. *Characteristics of ERP*

ERP (Enterprise Resource Planning) is a management technique implemented with information technology for all the business process of an enterprise such as manufacturing, materials, distribution, sales and financing processes. It covers all the functions of an enterprise as an enterprise-wide solution by integrating the management resources as a whole through business process reengineering. It is a strategic approach to harmonize information technology and business rather than with only an information technology level [4].

ERP systems can be developed by adopting ERP packages adjusting parameters and customizing to fit for user companies. Currently, most companies adopt the ERP package in developing ERP systems, because the ERP package has many advantages such as retrenchment of developing cost and reducing risks as well as rapid adjustment and fully utilizing the most recent information technology to be implemented in the ERP package [5]. As shown in table 1, ERP systems are characterized by the aspects of information exchange, information sharing and information service.

In the aspect of information interchange, ERP has linkage with EDI; open architecture that enables exchange of information of different format and compatibility with different system software and platforms; globalization that implements global standards and best practice with multiple languages. In the aspect of information sharing, ERP can integrate and standardize business processes, link with groupware and EIS (Executive Information Systems). Therefore, ERP can make personnel in charge do real-time processing of business transactions with a lightened workload.

Table 1. The characteristics of the ERP system.

Classification	Characteristics of ERP system
Information interchange	• EDI (Electronic Data Interchange) connection • Open system • Globalization
Information sharing	• One fact one place (Integrated Task System) • Standard business process model • Groupware connection • EIS (Executive Information System) function
Information service	• End-user computing • Integrated database

In the aspect of information services, ERP integrates a variety source of information in an enterprise and share the information in the whole levels of business processes. So, ERP can reuse information and simplify workloads raising efficiency of workflow.

3. The ERP system for container terminal

Even though container terminal operating systems are currently being used, the systems can be enhanced in the aspects of open system architecture, global best practice, integration of operation, standardization of business process, friendliness of user interface, SCM (Supply Chain Management) compatibility, decision support and high-speed network.

This chapter will discuss the shortage of current terminal operating systems such as insufficient functions, inconvenient user interface, disconnection of data flow and business process and non-standardization of operation and will discuss how to improve these problems.

3.1. *Analysis of existing terminal operating systems and problems*

From May–July 2000, personnel in charge of the operating terminal operating systems of a terminal in the Port of Busan, Korea were met. The terminal operating systems and their design manuscript were examined and the following problems were found.

3.1.1. *Problems in the view of interconnection with outer institution.*

(1) *Vessel and berth planning*. Weekly-based notice of vessel arrival/departure for the vessel planning is given. However, shipping companies frequently change these schedules and this lowers the efficiency of the planning. The results of berth plan of the terminal operating systems are informed to shipping companies via fax or telephone call without using EDI. This means that the utilization of EDI is not sufficiently implemented.

(2) *Booking prospect information and yard planning*. The booking prospect for terminal the shipping companies inform before the arrival of the containers has information such as numbers of containers per size, type and destination. However, this information is not always correct and the containers do not arrive at the right time and that lowers the efficiency and the utilization rate of the yard and equipments.

(3) *Container arrival pre-notification*. The container arrival pre-notification should be transmitted before the arrival of the container-carrying trailers for the automation of the gate-in process. However, if the EDI is not available for the trucking companies, the transmission of container arrival pre-notification has to be processed by hands, delaying gate-in processing.

(4) *Arrivals after the deadline*. Arrival of containers after the deadline at the container terminal makes loading/unloading planning and operation ineffective.

(5) *Lack of integration with outer information systems*. The information systems of shipping companies and trucking companies may lack some functions and data so that the system sends information missing some items. In this case, the terminal has to re-enter the missing data lowering the efficiency of data processing and, even worse, causes incorrect processing.

The major missing data is whether a container is bypassing the terminal. The lack of this information causes the loading planning system difficulties to calculate the stability of the ship.

3.1.2. *Problems in the view of interconnection between departments in a container terminal*.

(1) *Lack of systematic managing of unexpected cases*. When exceptional cases happen, the situation is reported to control office via telephone or voice and there may be conflict in decision rerouting to cope with the situation lowering efficiency of the terminal operation.

(2) *Lack of interconnectivity because of the excessive fragmentation of business processes*. It is difficult for personnel to cooperate with each other when they are processing inter-related works because of the excessive fragmentation of businesses and responsibilities.

(3) *Insufficiencies of the unloading orders*. The unloading planning system cannot generate detail orders so the field personnel has to decide detail operation with their own judgement that may cause re-planning and re-handling of operations and waste of resource and lowering of confidentiality of the terminal operation.

3.1.3. *Problems in the view of system integration*. Whether a container terminal operating system is integrated or not is very tightly related to the quality of its database design. However, the current fact that each application has its own database can cause redundancy and inconsistency of database. This also causes delay of updating.

(1) *Independent operation of process that is tightly coupled*. Berth planning, yard planning, vessel planning and railway transport planning are very closely related processes. However, the processes are independently executed and that causes waste of computing resources and difficulty in consistent usage and system management. Lack of standards in business processes make it difficult to interconnect related operations and to set up a clear boundary and interface for each operation. The lack of standards in business processes is one reason of conflicts between departments. A typical example of this case

is that the registration of the vessel arrival date, berth schedule and unloading time is not automatically connected with equipment operation scheduling and manpower planning

(2) *Lack of integrated operation of yard and ship operation*. The yard operation system and ship operation system is independently implemented. If some congestion or exceptional situation occurs in one operation, the other operation system may not be controllable.

3.1.4. *Problems in the view of optimal planning and simulation function*. The current way of planning depends on human judgement and manual operation that causes a delay of planning process and mistrust of the result concerning its optimality. Personnel in charge are required to plan manually and that causes a time delay. Manual planning may cause mistakes and make it hard to maintain the consistency and the stability of the planning. Time delay and error in planning is a critical factor that lowers competitive power of container terminals and may cause a loss of physical and non-physical terminal resources.

(1) *Lack of simulation function*. It is difficult to predict the actual situation of operation and preparation of exceptional or undesirable accidents because of the lack of simulation functions for the system that simulate ship stability, state of equipment such as container crane and transfer crane, interference between operation and line of moving.

(2) *Lack of automation of planning function*. Berth planning and yard planning are performed by personnel based on their experience. A lack of optimization and automation of planning function lowers the efficiency of terminal operation [6].

(3) *Utilization of material and personnel resource*. Lack of a planning system for optimal allocation of equipment and personnel resource by capturing the correct status and situation of the resources lowers the efficiency of terminal operation.

3.1.5. *Problems in the view of management decision support and information service*.

(1) *Lack of decision support and knowledge sharing*. Current terminal operating systems are online transaction processing systems. The system dumps out the data that has expired into a separate database used only for transaction evidence and statistics. Therefore, there are no decision support functions by multidimensional analysis and knowledge accumulation and sharing.

(2) *Information service for customers*. The system also lacks in information service for customers by a single point of contact. Customers' inquiries about their cargo processing status via telephone increase the cost of personnel as well as lower the quality of the information service level.

Based on the analysis so far, the problems of current container terminal operating systems were summarized as shown in table 2. It has been found that the main causes of problems are information interconnection, information sharing and information service. One will try to find solutions to the problems by linking the causes with ERP characteristics.

Table 2. The problems of an operating system.

Problem	Characteristics of ERP		
	Information interchange	Information sharing	Information service
Information connection with outside parties	×		
Business connection among departments in container terminal		×	
Integration of system function		×	×
Optimal planning and simulation function		×	
Management decision support and information service		×	×

3.2. *Container terminal ERP system approach*

This paper will now approach the current problems of container terminal operating systems by use of ERP and discuss the ways of solving the problems.

3.2.1. *Information interconnection with outer institutions of a terminal.* There are two main problems that arise in the view of interconnection with outer institution of a terminal. First, the data from the outer institution such as shipping companies is incorrect, not transmitted. Also, the data is fed repeatedly or omitted because the internal information systems of the outer institution are not integrated into the EDI system.

Secondly, the current EDI system is based on VAN/EDI using X.25. The fees of the transmission VAN/EDI and the leasing of communication lines are so expensive. For this reason, the expansion of the EDI is difficult. Delay and reluctance of adopting EDI cause poor interconnection between the outer institution and terminals.

The problems can be approached by using both XML/EDI, based on the Internet, and VAN/EDI, based on X.25. XML becomes the new standard of data transmission through the Internet. However, VAN/EDI is still the existent standard that current personnel in charge are already familiar with. Therefore, in the short-term approach both XML/EDI and VAN/EDI are installed in the container terminal ERP, so the outer institution can choose what they are equipped with. The ERP system has modules that handle XML/EDI messages by translating and managing it. The outer institutions also have the client version of container terminal ERP, so the institutions can send XML/EDI messages to terminals and integrate their internal information systems with it. The standard format of XML/EDI can be spread to outer institutions from a terminal so the outer institution does not have to worry about the change of message format.

3.2.2. *Business connection among departments in a container terminal.* The problems in interconnection of business process between departments in a container terminal are mainly caused by a lack of standard of business process. When a terminal opens, the terminal operating systems opens at the same time. Therefore, the operation system's operation procedures become the terminal's business processes. When a new terminal operating system opens, the new terminal operating system may analyse or benchmark the existing operation systems and adopt the system flow. Therefore, the main system flow may be inherited to following

terminal systems only after revising parts of the system while maintaining the skeleton. When new requirements for integration or new business flow arise, it is remedied by performing a partial revision of the existing terminal systems. The insufficiency of system coverage over newly emerged business processes causes conflicts between departments and ad hoc procedures that are far from standard processes.

The problem can be solved with an ERP system that can have characteristics of completeness, consistency, cohesiveness and integration. After business process reengineering, the ERP system can suggest an optimal enterprise-wide integrated business process.

Another advantage of ERP is that the maintenance is fully supported by the software development company, including version upgrade and configuration following new information technology and business requirement. This point is very different from the existing container terminal operating systems where the internal staff personnel of the terminal have the duty of maintainance.

3.2.3. *Integration of system functions.* The necessity of database sharing among users to implement system integration of functions has already been discussed. Following consideration, it is a necessary as well as a common database. First, the database should satisfy criteria of availability by supplying data from related tables when an independent process requires the data. Secondly, the database should keep entity integrity and referential integrity to maintain the whole database error free [7].

3.2.4. *Optimal planning and simulation functions.* It is necessary to design a berth planning module that adopts constraints and objects to determine optimal berth plan and container crane assignment and schedule. It is required to develop an heuristic programme to assign orders of values of variables to minimize calculation time of the modules.

For the yard planning, it is necessary to assign yard bays to containers according to types of containers to maximize yard operation efficiency. The loading and unloading plan for a vessel requires scheduling of the operation sequences of container cranes to minimize operation time and interference from other container cranes. The plan should cope with an abnormal situation and re-plan to adjust it promptly.

3.2.5. *Management decision support and information service for customers.* Online analytical processing by multidimensional analysis such as usage rate by berths, mechanical trouble rate by equipment, processing time and processing cargo amount by season is necessary to support the decision-maker and manager for their effective strategic decision-making. Visualization, prompt response time and easy to use are important requirements for executives [8].

Information services for customers require tracing cargo location and status functions in ERP systems. Customers can contact the information in one contact point. The system can be implemented by Web, CTI (Computer Telephony Integration) or ITI (Internet Telephony Integration).

3.3. *The composition of a container terminal ERP system*

An ERP system is a set of programmes to be used according to separated functions. It consists of functional modules. The main modules of the ERP package applied to

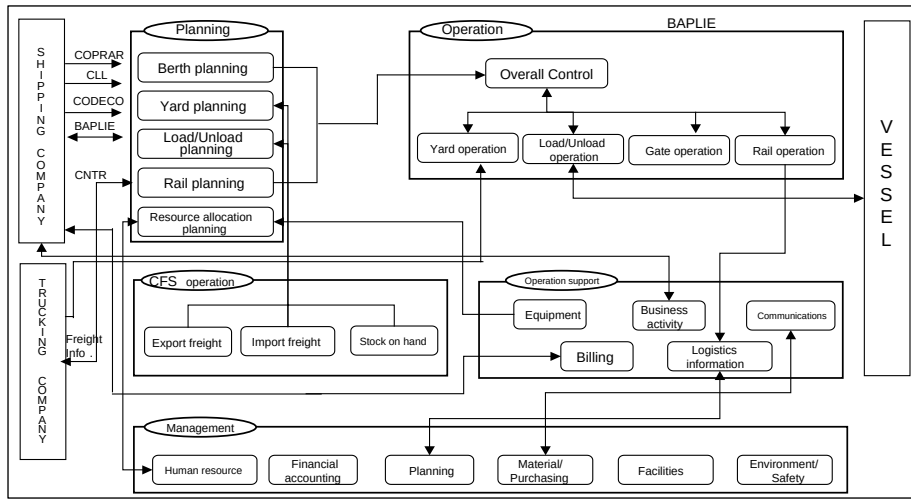


Figure 1. The process of the container terminal ERP system.

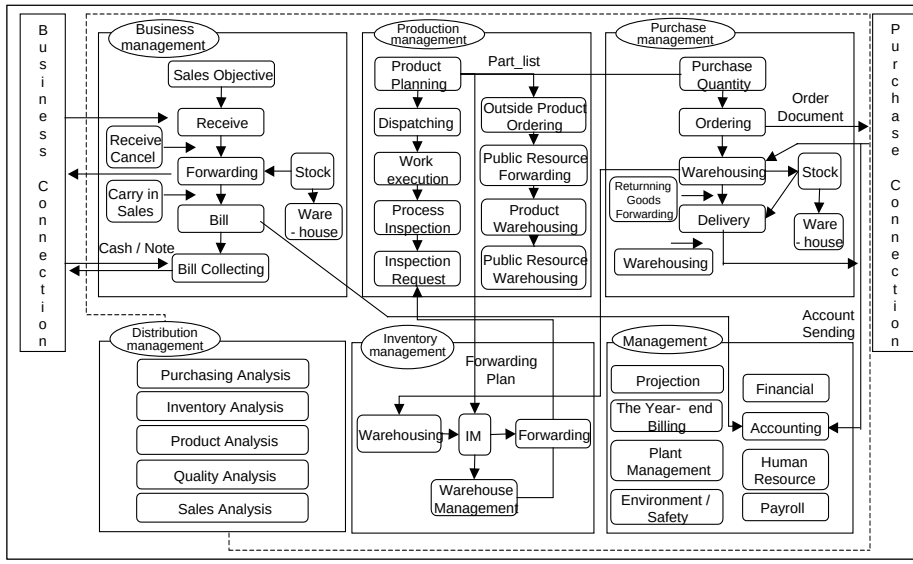


Figure 2. The process of the manufacturing industry ERP system.

the manufacturing industry are purchase and materials management, financial management, production management, physical distribution management, human resource management, account management and business management modules. The manufacturing industries apply modified ERP systems suitable to the firm's constitution and they apply an ERP system to include additively developed modules as occasion demands.

This study proposes construction schemes of the ERP system for the container terminal through modulization of container terminal work to differ from the manufacturing industry. The container terminal ERP system consists of planning, operating, CFS operation and operation support modules, as in figure 1, instead

Table 3. The functions of container terminal operating systems.

Port operation tasks				
1. Planning	2. Operation	3. CFS operation	4. Operation support	5. Management
1.1. Berth planning	2.1. Overall control	3.1. Export freight	4.1. Equipment	5.1. Human resource
1.2. Yard planning	2.2. Yard operation	3.2. Import freight	4.2. Business activity	5.2. Financial accounting
1.3. Load/unload planning	2.3. Load/unload operation	3.3. Stock on hand	4.3. Billing	5.3. Planning
1.4. Rail planning	2.4. Gate operation		4.4. Communications	5.4. Material/ purchasing
1.5. Resource allocation planning	2.5. Rail operation		4.5. Logistics information	5.5. Facilities
				5.6. Environmental/ safety

of business, production, purchase and inventory management modules in the manufacturing industry ERP system of figure 2.

The proposed container terminal ERP system is not a new idea, but a requirement for doing integration, standardization and systematic maintenance of modules of existing container terminal operating systems. The top modules of existing container terminal operating systems are categorized as planning, operation, CFS operation, operation support and general management, as shown in table 3.

4. Module design principles of a container terminal ERP system

This chapter will discuss design guides of each module for their definition of operations and detail functions proposed in table 3. The design guides are proposed for berth planning, yard planning, load/unload planning in planning module, overall control, yard operation in operation module and logistics information in operation support modules. Since the above-mentioned problems of terminal operating systems and solution are converged on these functions, one will only discuss these functions.

4.1. *Planning modules*

The planning modules include the modules of berth planning, yard planning, loading/unloading planning, railway planning and resource allocation planning.

4.1.1. *Berth planning*. Berth planning includes berth configuration, vessel information management—which covers general information of vessels such as service route and navigation features, vessel arrival/departure schedule management and berth allocation—which includes allocation management of berth and container cranes.

What one has to consider in berth planning is to give priority to regular time/day or week service over other irregular berth allocation service requests. The system must also be flexible to adapt to and cope with frequent changes of vessel arrival/departure schedule by interconnecting related system modules, database, personnel and equipments.

For the allocation of container cranes, berth planning decides only what container crane will serve for what vessel. The detailed time of allocation is left to a resource allocation step by a 2-step crane allocation method.

4.1.2. *Yard planning*. Yard planning modules include yard configuration management, yard planning for export cargo, yard planning for import cargo, yard planning for transshipment cargo, yard planning for empty container and relocation within yard boundary.

The yard configuration management includes management of location of yard operation-related facilities such as illuminators, as well as management of configuration of the container yard. Yard planning for an export cargo module should consider a berth that is ready for a vessel coming alongside, yard status by types and, by vessels, to plan the allocation for export cargo. It is necessary to receive timely data about cargo that will be loaded for export. The cargo information should be categorized by container type. Booking prospects for terminals are occasionally accepted, the module has functions to cope with the frequent change in status. The overall condition of the yard for export cargo should be grasped.

Yard planning for import cargo modules should accept the plan for unloading cargo and consider cargo that will be transferred to other piers, navigation type and size of vessel. Generally, yard allocation for import cargo is performed after the accomplishment of unloading planning. However, the module should support the case when it is necessary to adjust the yard plan, while import cargo are being unloaded from a vessel.

4.1.3. *Loading/unloading planning*. The loading/unloading planning module consists of management of vessel data, container crane planning, unloading planning and loading planning. Vessel data is information for loading/unloading planning. This includes detail specification of the vessel, structure of cargo holder and tank, draught, displacement tonnage, special data for calculation of the stability of the vessel and strength of the structure and anything else which may be required.

The C/C (container crane) planning module identifies the cargo amount in each hatch by each port where the cargo will be unloaded, berthing side, what C/C is allocated for the vessel, its starting time of work and status and location of the C/C. The C/C planning module also evaluates the effect of ebb and flow of the tide to the C/C work. Then, the C/C planning module assigns working time of each C/C and sets the order of which hatch to work, dividing the work by loading and unloading following the principles of working.

Unloading planning modules estimates workload according to type of work, such as general unloading and moving in a ship. It also estimates workload according to type of cargo, such as whether the cargo is frozen and dangerous or not.

The loading planning module sets the order of work to ensure the safety by calculating displacement, longitudinal strength and torsion moment.

4.1.4. *Railway planning*. Railway planning includes platform and freight train configuration, arrival/departure control and loading and unloading planning for railway transportation.

The arrival date and amount of containers should be notified before planning or loading and unloading planning for railway transportation.

4.1.5. *Resource allocation planning*. Resource allocation planning includes resource analysis, equipment allocation and personnel allocation. Resource allocation planning function should perform suitability analysis, whether the plan can be completed in the given time based on all the experience and actual results.

4.2. *Operation module*
The terminal operation module includes overall control, yard operation, load and unloading operation, gate operation and railway operation.

4.2.1. *Overall control*. Overall control is composed of vessel control, yard control and gate control. Vessel control sends working order to workers of container crane, yard tractor and RMGC, based on the details of loading/unloading planning and equipment allocation planning. Vessel control also monitors the progress status while cross-checking with loading/unloading plan. When unexpected conditions happen, overall control issues orders that remedy the states.

4.2.2. *Yard operation*. Yard operation consists of loading and unloading on and from vessels, gate-in yard management, gate-out yard management, reefer container and dangerous goods container management.

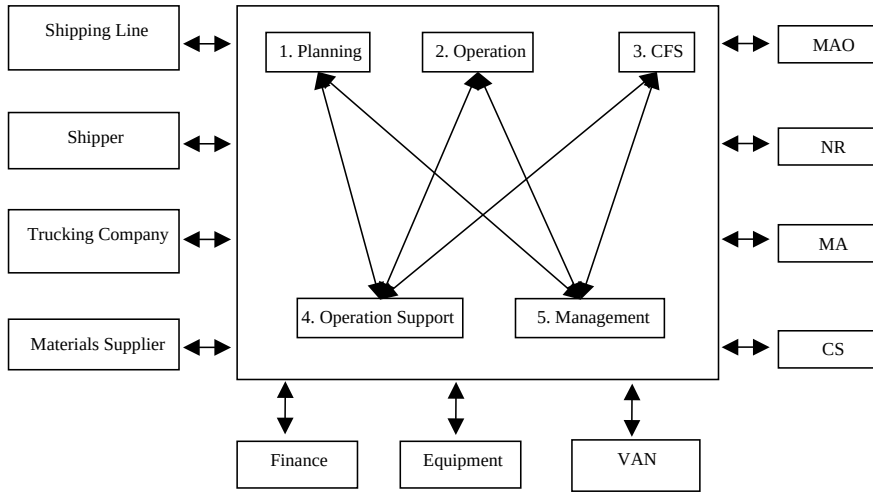
Yard operation for unloading proceeds based on the unloading plan from vessel and yard plan. Yard operation includes the relocation of the unloaded containers and manages the positions of them. At the time of completion of relocation of unloaded containers on the yard, the reports are transferred to the overall control with the data of container number, equipment number, working time, working detail and position of the equipment. The automatic tracking function for container location should be included in yard operation and the location data should be supplied to outer institutions that are chained in the logistics.

For consideration with yard operation for gate-in/gate-out, the order of loading/unloading onto/from trailers should be determined considering extra workload needed. Reefer container operation should include such operations as power plugging, temperature setting and monitoring. The prompt alarm is necessary when sudden problems happen. Dangerous goods container management includes the reception of a dangerous goods list, examination of the level of danger of the goods, gate-in/gate-out operation and yard operation for the containers. The operation should keep the regulation of handling dangerous goods such as keeping some distance between containers and positioning the containers on the isolated yard blocks.

The whole architecture of ERP modules is illustrated in figure 3 to solve the interconnection with the outer institution and internal departments, system integration, enforcement of planning and confirmation function and enhancement of service level.

5. Conclusion

This paper presents an ERP system approach for a container terminal. This paper analyses the existing problems of the container terminal operating systems and suggests an ERP concept to solve the problems. The existing systems have problems in the view of interconnection with client companies, workflow between internal departments, system function integration, optimal planning and verification, management decision support and customer service. The ERP can handle the



MAO: Maritime Affairs Office
NR: National Railroad
MA: Metrological Administration
CS: Customs Service

Figure 3. The context diagram of container terminal operating systems.

existing problems of container terminal operation that are mainly caused by the lack of integration of the whole information resource in container terminal, ad-hoc and poor planning capability, disconnected and incorrect data from client companies. The existing container terminal operating system is developed for one terminal. This may cause problems of productivity of software development and standardization of business processes.

One has clustered the workflow of container terminals and analysed the business process to generate the best workflows. This paper suggested the whole architecture of container terminal ERP systems into five modules and discuss the detail functions.

A container terminal is a central pivot of maritime and land logistics that links all the logistics companies. Therefore, the compatibility and standardization of business process is the main issue of the future container terminal operating system, and this paper will be helpful for the approach.

Acknowledgement

This work was supported by the Korean Science and Engineering Foundation (KOSEF) through the Center for Intelligent & Integrated Port Management Systems (CIIPMS) at Dong-A University.

References

1. Yi, D.W., Kim, S.H., Choi, H.R., Park, N.K. and Lee, T.W., 2000, Developing a conceptual model for sharing container terminal resources: a case study of the Gamman container terminal. *Maritime Policy & Management*, **27**, 155–167.

2. Lui, E. and Poh, H.Y., 1993, Computerized container terminal management. *UNCTAD Monographs on Port Management*, UNCTAD/ SHIP/494(10) (New York: United Nations).
3. Jeffery, K., 1999, Recent developments in information technology for container terminals. *Cargo Systems* (London: IIR Publications).
4. *The Weekly Economist*, 1996, ERP innovation: enterprise total integration—extreme productivity, 5 November.
5. Yun, J. M., 2001, *UniERP practical case study* (Korea: Sangjosa).
6. Kim, K.H., 2000, Deriving decision rules to locate export containers in container yard. *European Journal of Operation Research*, **124**, 89–101.
7. Weber, R., 1988, *EDP auditing* (New York: McGraw-Hill), p. 209.
8. Kim, H. S., Park, N. K., Choi, H. R. and Kim S. H., 2001, Development of XML/EDI based data warehouse for customs clearance of maritime exports. *IAME Annual Conference 2001*, July, 468–480.