AUTOMATION: A PROCESS REDESIGN

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INTRODUCTION

Containerization has developed into an overall door-to-door transportation system with efficient vessels whose capacities exceed 4,000 20-ft equivalent units (TEUs); large high-tech terminals; intermodalism; inland load centers; and worldwide dedicated information systems. So far, economy of scale has succeeded in reducing operating costs and providing more predictable transport times, but shippers of cargo are still demanding better service at a lower cost.

The need to control the complexity of intermodal hub centers, the increasing labor costs in most of the world's leading container ports, and the availability of technology from industrial manufacturing have made some container terminal operators decide to introduce automation. The first step is to automate information processing (tracking and tracing); the next step is to automate the handling process itself. Automation of container-handling processes is a phenomenon in which mechanized physical handling, computerized process control, high-density data transmission, standardized electronic data interchange, and a new approach to operations management should be fully integrated.

Human resources will remain the key element in an automated container terminal, especially from a performance point of view. Teamwork and team self-control are becoming increasingly important. Therefore the introduction of automation must include the development of the labor organization and the involvement of employees. There are no recipes available, and there are no off-the-shelf automation packages. Some container terminal operators, therefore, have had to take the lead themselves, and in doing so, they have discovered that the design of automation in container handling includes a redesign of the entire operating process.

TRENDS

The transportation industry shows a variety of trends that must be carefully considered if we want to achieve durable designs for automated handling systems.

Increased Vessel Sizes

The introduction of large vessels (5,000 TEUs and more) will enforce the demand for increased handling capacity during vessel berthing. Economic vessel deployment may result in fewer ports of call per voyage, which will increase the call size 3,000 and more lifts per call. This will result in a demand for berth production up to 150 containers per hour.

The type of lashing system, design of cell guides, and application of hatch covers or hatchless bays with continuous cell guide systems (Fig. 1) will determine the feasibility of automated crane handling and the possibility for peak productivity of 50 or more containers per crane per hour.

Multimillion TEU Hub Centers

In the Far East, the United States, and Western Europe there are a limited number of steadily growing hub centers, yearly processing millions of TEUs between mainline vessels, feeder vessels, shuttle trains, road trucks, and river barges. These intermodal hub centers require simultaneous processing of high-density container flows. Moreover, the irregularities in all inbound and outbound flows must be controlled. "Just-in-time" deliveries in container transportation are still wishful thinking.

The nature of shipping, the large number of parties involved in inland transportation, and the complexity of information control and documentation will continue to demand flexibility and short-term storage capacity from the major hub centers. Flow characteristics may improve, but at the moment, peaking can be as much as 2.5 times the average flow: quite a demand when daily average flows of 10,000 TEUs must be handled.

Demand for Increased Service Levels

Because high-capacity transportation equipment (large vessels, double-stack trains, and push-barge systems) is tremendously expensive, container handling onto that

FIGURE 1 Large vessels with hatchless bays and continuous cell guide systems.

equipment, both at ports and inland load centers, must be fast. Besides, the intermodal terminals must be able to cope with last-minute changes and still meet the planned interchanges between intermodal links. More and more containers are carrying cargo that forms part of a global just-in-time system, in which manufacturing, assembling, and consumption can cover two or three continents. Shippers are looking for a way to reduce their capital costs and this requires fast connections in intermodal centers. The time between arrival and departure of a container is often less than 12 hr, which puts a heavy demand on planning and operations management.

Off-Standard Activities

Container-handling systems must have some flexibility, but in the past decade, off-standard container dimensions and off-standard operational procedures have thwarted the handling process. Off-standard dimensions require special adaptable equipment and all kinds of additional drives, interlockings, and the like (Fig. 2). Reefer, over-height, over-wide, break-bulk, and dangerous cargo require special operational procedures and additional facilities, which results in additional costs. Moreover, all off-standard activities require special attention from operations management and require special features in information and control systems. Increased productivity and reliability in automated handling systems can be realized only through consistent use of standard dimensions, standard facilities, and standard work procedures.

Off-standard containers should be handled separately from the main production line. Additional costs and increased processing time must be accepted as an inevitable consequence.

Increased Labor Demands

Changes in our society are reflected in our labor systems. People want improved working conditions and more comfortable and safe equipment. The work week is approaching 36 hours and even 32 hours for a continuous-shift system. Employees are justified in demanding more information, more freedom in their daily decision making, and less monotonous jobs. The emphasis on the individual human being will result in more flexible working schedules; however, these schedules will complicate the design of shift systems.

Technological development and the increased complexity of logistics put high demands on education and training. Workers must support companies' objectives, which requires that they be more directly involved in the development of new handling systems, information control systems, and work procedures.

Technology Development

In recent years there have been a variety of technological developments in manufacturing, retailing,

FIGURE 2 Off-standard dimensions require special adaptable equipment.

warehousing, and banking. As a result, automation of container-handling processes finds ample support in the technological innovations in adjacent industries.

Remote reefer monitoring; automated equipment identification; smart card applications; electronic seals; high-speed, radio data transmission with spread-spectrum techniques on the 2-GHz band; voice recognition systems; electronic notebooks; and the Global Positioning Systems are available to terminal operators. But all participants in container transportation must decide on one or two methods per technology. Moreover, especially for automated systems, the technology must be developed to about 100 percent reliability at acceptable cost levels. A joint effort between vendors, terminal operators, shipping lines, and inland transportation companies is needed to develop technologies that will become worldwide-accepted design components for a reliable automated system.

More Cost Control

For many years the transportation industry has not been very profitable. Despite annually increasing volumes, it is expected that the coming years will not bring any improvements in the overall profitability of transportation. The strong emphasis on cost control does not allow large investments in research and development activities. Besides, there is only a limited market, in perhaps 20 ports in the world, in which manufacturers might find a market for automation developments.

Intermodal centers that offer continuous service 24 hours a day, 7 days a week, will be required to monitor their costs constantly. The costs for labor, maintenance, and information control represent the majority of costs. For this reason, it is likely that automation will be focused on these areas.

The major trends discussed here may differ from continent to continent, but in general, the design of automated container-handling systems will have to take these trends into account.

DESIGN DEMANDS FOR AUTOMATION

Despite developments in fuzzy logic control and neural networks, automation is still an exercise based on computerized control over properly defined activities connected by a chain of logical decisions and represented in mathematical algorithms. The container handling process is characterized by PLC and computer-controlled, specially designed equipment suitable for handling heavy loads. Processing is done through the help of massive information systems that support the control over all variables that determine each unique movement of a single, special container at a specific time from one mode to another.

A major objective for hub centers is to simultaneously handle large container flows from and onto three or four modes of transportation, with guaranteed handling productivities. The design of automation for such complex container-handling systems requires a parallel development of handling techniques and handling equipment, information and process control systems, and labor organize. All of these must be designed within one integrated systems approach. The comprehensive design should recognize some specific areas, which follow:

Limitation of Types

Simplicity is a key factor for success in automation, and it can be achieved by limiting the number of handling techniques, equipment types, and major components. Simplicity helps; complexity kills. Variety in functionality should be reduced to a minimum so that almost all movements in the yard can be realized with two or three types of equipment.

Reliability of Components

The performance of automated handling systems is largely determined by the reliability of equipment and software. The current mean time between failure (MTBF) for equipment is 25 to 75 running hours, which

FIGURE 3 Equipment to operate in the open air under all weather conditions.

is highly inadequate. An automated container-handling system may comprise several hundred pieces of major equipment; in such situations the MTBF for equipment must be increased to several hundreds and preferably, to more than a thousand running hours.

When a component breakdown brings the entire process to a halt (for safety reasons or maintenance accessibility), special provisions must be made, either by upgrading the equipment or by changing the process so that most activities can continue while the broken component is exchanged or repaired. Early warning systems can induce preventive actions before a random breakdown occurs. It is recommended that proven designs from off-the-shelf components and standard software packages be used for warning systems. In case of custom-built components, lengthy trials with prototypes will eliminate most start-up problems.

User Involvement

The design of process control systems should focus on the requirements of the final operational user. When designing from scratch, this is a difficult task, but prototyping and user involvement in design teams are effective ways of arriving at user friendly control systems. Process monitoring is essential for the user; he or she should be able to interfere in cases of process stoppages or off-standard activities. Reporting of condition and maintenance status also should be available to the user.

Weatherproof Equipment

Handling equipment must be designed to operate in the open air under all weather conditions (See Fig. 3). High and low temperatures, heavy (tropical) rains, fog, storm winds, snow, and ice should not affect their proper functioning. This requires special housings, overdesigned drives, standstill heating, military specifications for electronic components, noncorrosive fasteners, and the like. In general, limit switches, interlockings, and sensors have been designed for the manufacturing industry, and their design may need modification to withstand the environment in the open (seaside) air.

Environmental Control

Increasingly, society's demands are translated into directives and regulations issued by national and international authorities. Pollution control and sound control are important in selecting equipment. Selection of materials and design of working places is important for offices, maintenance facilities, and control centers. Automated handling of hazardous cargo requires fast access to hazardous cargo data bases. Storage directives will complicate storage control systems. Fortunately, automation usually results in development away from diesel power toward electric power, which contributes to better environmental control.

Container Positioning

Almost all container-handling techniques require manual control for precise positioning of containers. In design of vessels, railcars and road chassis tolerances of ± 1 cm are required for the positioning of containers onto transportation equipment and for multilayer stacking in the yard.

FIGURE 4 Process control center guiding the whole automated process.

Automated stacking of three containers or more requires stacking in special guide structures (similar to cell guides onboard vessels) or the application of special positioning techniques supported by sway control, positioning sensors, and precise drives. The mass of containers and handling equipment and the marine environment impose heavy demands for reliable positioning.

Backup Facilities

Operators guide automated processes from control centers (Fig. 4). Operators are vital when breakdowns and process changes occur. In such cases, they must have the tools, procedures, and skills to handle off-standard situations and to work around system failures, equipment breakdowns, and last-minute changes. They must have access to all kinds of backup, from spare equipment to online shadowing control systems. Especially at the landside modes (trucking, barge, and rail), system delays cause tremendous problems, such as blocking infrastructure and creating the need for rescheduling. Therefore, special backup systems that will take over control if major systems break down are recommended. Operators must be regularly trained in switching to backup devices, with the help of manuals and programmed instructions. Recovery monitors should be installed to reboot software fast and reliably.

Modular Design

Especially for software, modular design is recommended. Planning modules and assign modules may require changes during the lifetimes of handling systems. Fault finding and recovery are simplified by modular designs. Besides, a modular approach can benefit from fourth-generation software tools, if available and suitable for typical process control software. Interface software between equipment control and process control should be universal to allow the application of specific equipment control packages without any interference to users and maintenance engineers.

New Approach to Vendors

For large, complex automated systems, there is a great variety of equipment and software offered by a multitude of vendors. In manually controlled handling systems, equipment is commissioned on the basis of specifications for functional requirements and technical details. Automated systems require more. Vendors must support the integrated approach concentrated in interface engineering. Benchmarking and functional tests under peak conditions must be carried out to see whether vendors have met the requirements. Operations and maintenance personnel must be involved in design, construction, and commissioning, not only for training purposes but also to gain practical experience. Maintenance requirements should be met when feasible. It is not only MTBF but also mean time to repair (MTTR) that counts in automation. All vital components should be interchangeable within 30 minutes, including a complete gantry truck assembly, main transformer, radio data processor unit, and disk drive. This requires special provisions in the design stage: modular design, accessibility, special tools, and the like. There is plenty of room for improvement here.

PROCESS REDESIGN: AUTOMATION IS THE TRIGGER

Automation requires proper structuring of all handling processes and that all information be collected before an activity starts. Decision policies, priority rules, performance criteria, and off-standard procedures must be known before any activity can be performed. The absence of equipment operators results in an ongoing question: What will happen if...? This simple question is the basis for extensive analysis of the entire process.

The major objectives of container-handling automation are increased capacity, flexibility, and cost control. The design of automation follows a number of stages, which follow.

Process Analysis

This analysis of all activities, which is required by customers, should be conducted with properly defined performance criteria and quality requirements in mind. All major flows must be quantified, which will require extensive measurement activities. Existing information must be analyzed, and special analysis programs may be required. In this stage, a critical approach is required for all activities in the process: Is the activity required by the customer? Is it necessary for our own process control? Can it be simplified? Is new technology available that may reduce the activity's cost or eliminate it?

Information Technology

The application of information technology too often results in partial solutions. Even though it is a challenge to control handling processes with a minimum of information, more data results in more complexities and difficulties. Information technology should follow and support automation through an exchange of potential benefits from new technologies. When evaluating information technologies, it is important to estimate the lifetime of tools and their payback times. Information economy is a new approach requiring a cost-revenue analysis for every information technology project, and this can be helpful for automation design as well.

Logistics Model

The setup of a logistics model is instrumental in testing the feasibility of technical concepts for further information of handling systems. A logistics model is client driven and represents all major activities and processing principles. Service products are clearly defined as well as flow characteristics, areas for electronic data interchange, required flexibility, and so forth.

Equipment Development

Automation of container handling is not merely a matter of purchasing automated equipment and controlling it with the help of computers. Up until now it has been necessary for terminal operators and vendors to work together to develop special equipment. Remote

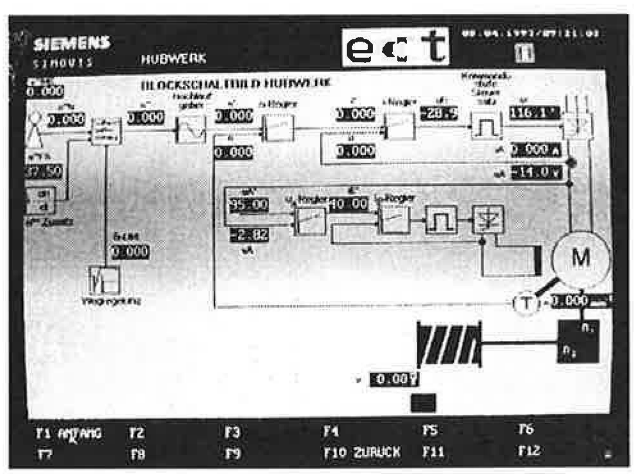

FIGURE 5 Siemens system for crane diagnostics.

monitoring, diagnostics, and readout features will reduce MTTR (Fig. 5). Special attention is needed for provisions that will accelerate rescue operations in case of breakdowns (jack ups, access, emergency drives, etc). It might even be necessary to install special rescue equipment. Interfacing between equipment control and process control is a delicate item that and should be taken into account from the beginning, in the design stage.

Process Control

During the 1970s information technology entered container handling in the fields of tracking, tracing, administration, and documentation, but mainly data processing. Decision-making programs recently have been introduced in the areas of vessel stowage planning and stack planning. For automation, much more intelligent programs are required. Limited resources, whose use must be planned, should meet operational priorities. All kinds of side characteristics must be dealt with every movement (e.g., type, size, door location, and IMO class), which makes the design of software (routing and stacking algorithms, data base design, and network design for data processing) a challenge. Process control systems must have monitor functions for both the operator and the information technology specialist (Fig. 6). Control decisions and logistic algorithms should be transparent. This will facilitate the monitoring by operators. Synchronization and data integrity are of great importance, especially when various equipment types are applied in one system.

Simulation and Prototyping

These activities are probably the most important ones in the entire design process for automated handling. Simulation is helpful for the assessment of alternative technical designs (handling systems, decision algorithms, reliability, and data communication), and simulation typically is used in an iterative process of optimizing performance versus costs.

Special attention is required when using simulation in feasibility studies for various automated systems. The assumptions for cycle times and response times of equipment and for control operators and process control

FIGURE 6 Process control systems must have monitor functions both for the operator and the IT specialist.

systems should be based on real-time measurements or should be obtained from benchmarking. Too often the ideal conditions in a design environment are far removed from the reality of an actual situation under peak conditions (access times, breakdowns, operator faults, power supply failures, and deadlocks).

Prototyping is recommended for increasing the user's involvement. Human imagination is limited, which tends to restrain new designs for control and monitoring. An investment in prototyping has a very short payout time. It stimulates the addition of practical experience and increases the acceptance of new developments.

New Labor Organizations

In general, automation will result in changes in the handling process. Operational procedures will be modified, manual operations will disappear, planning activities will change, and process monitoring and breakdown recuperation will increase. The labor environment will develop parallel to these developments. Therefore, during the automation design stage, management must create a new labor organization with meaningful jobs and more control at lower levels (Fig. 7). The result will be a comprehensive system of job descriptions, written procedures and programmed instruction sets. Subsequently, operators, maintenance engineers, and management must receive proper training. This will prevent "operator faults" and will accelerate start-up after breakdowns.

It will take time for employees to trust the decision power and behavior of automated systems. In the beginning there will be a tendency to check the decisions, recheck data processing, and so forth. Transparency, online process monitoring, and involvement in information systems design will promote the acceptance of automated systems. This redesign of the labor organization and jobs will result in more job satisfaction, fewer mistakes, higher service quality, and thus a better product.

Commissioning and Training

The commissioning of an automated system is comprehensive. A working environment is hardly available, operators are not yet on the site, vendors pass responsibilities to each other, and newly appointed management is suspicious about the performance. Under these conditions all elements must be put together, tested, modified, and improved. It is recommended that, during the design stage, proposals be made for the commissioning period. The start-up should follow an expanding approach: every acceptance of a part of the system is the start for a new (to be tested) addition.

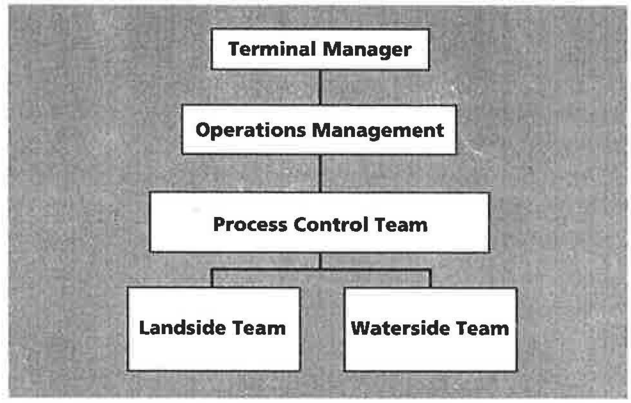

FIGURE 7 A new labor organization with meaningful jobs and more control at lower levels.

Training activities must start well before commissioning and can include special training modules, mock-ups, classroom training, and management games. Education and training on the job are essential to ensure the proper control of an automated terminal. New technologies need to be carefully introduced; the basic education level of employees has to be increased (basic information-technology knowledge). Extensive training may require up to 5 percent of the total investment but it is an essential condition for the successful implementation of an automated handling system.

In the automotive and electronics industry, there are a variety of highly developed automated manufacturing processes. In all cases the high-level of automation could be obtained through one simple approach: control the entire process, and eliminate nonpredictable influences. Material characteristics, product design, tooling, transportation equipment, subcontractor quality, and so forth are properly specified and subordinated to the computer-controlled manufacturing process.

Unfortunately, the terminal operator does not control the majority of the terminals process characteristics (e.g., flow patterns, transportation equipment, and documentation standards). Automation, therefore, must be limited to the processing flows that can be standardized. Exceptions must be detected as soon as possible and handled outside the automated, standard process through manual control and must be reported to the overall information control system.

Standardization supports automation but causes rigidity at the same time. A large investment in automated handling systems requires a long depreciation

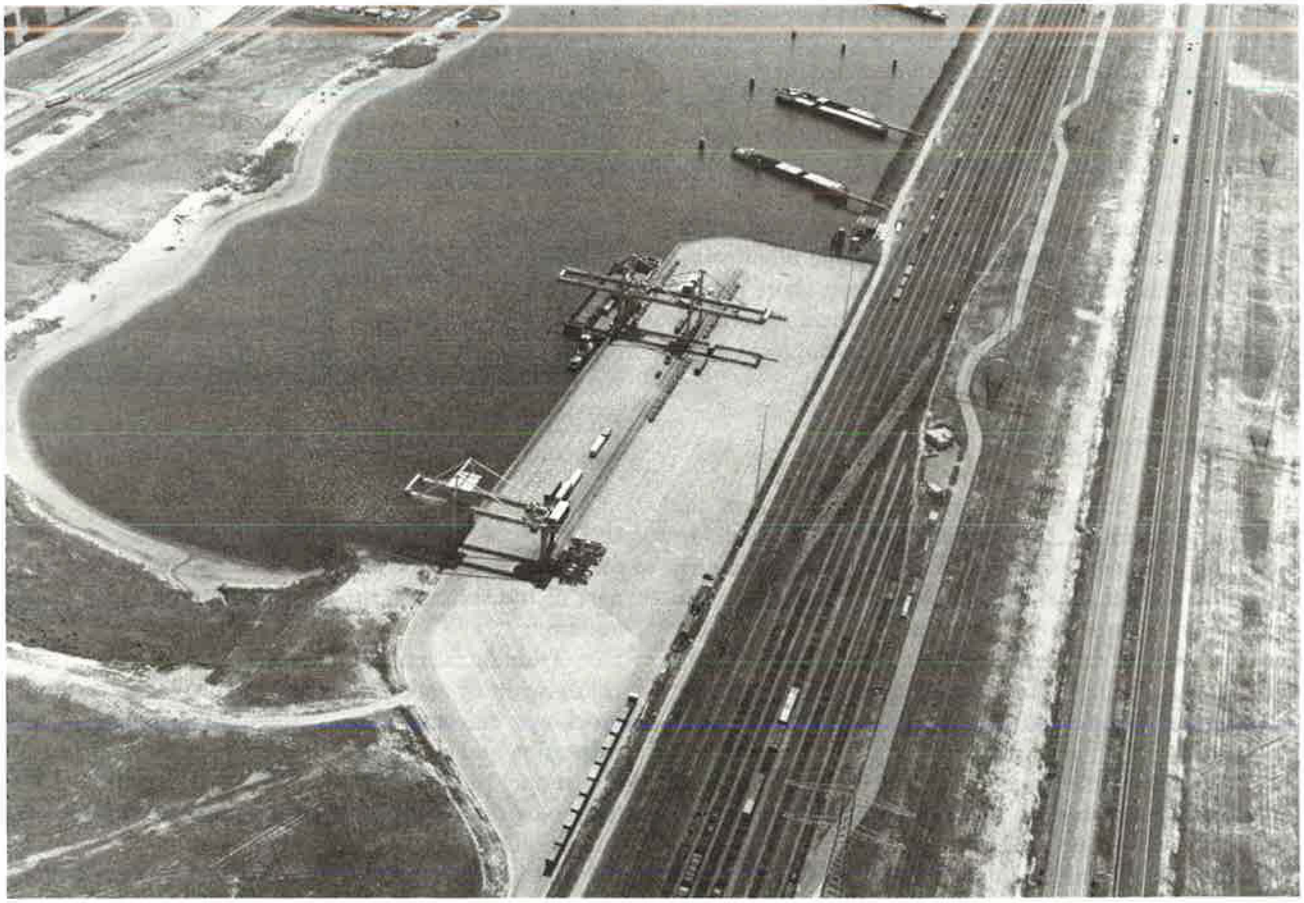

FIGURE 8 Major breakthroughs can only be expected from teamwork, including intermodal parties.

time for cost control reasons. This is in conflict with the rapid developments in process automation and information technology. Nevertheless, it is recommended that all parties involved in container terminal automation should aim for process stability. Major changes in automated handling systems are very costly; handling systems in terminals must run 10 years or more before a complete return on investment can be expected.

FACILITATING THE INTRODUCTION OF AUTOMATION

From a technology point of view, the introduction of automation in container handling might seem easy: design the process, install the equipment and systems, train the people, turn the switch. Unfortunately, it is not that simple. Automation requires commitment from management, customers, vendors, labor, shareholders, and a project team.

There are many conditions that will help introduce automation and contribute to its success. Some major conditions follow:

- The availability of an in-house research and development group is helpful for the development of new handling methods, equipment, control systems, and so forth. Industrial engineering is a helpful skill for process improvements and redesigns.
- Involvement of operators and maintenance engineers can help ensure that the in-house research and development group and vendors will learn from the practical experience collected daily on the floor. Operations people know the stumbling blocks and know how to decrease complexity. Maintenance departments have a lot of ideas about equipment and software improvements, provisions to prevent breakdowns, spare-part policies, and so forth.

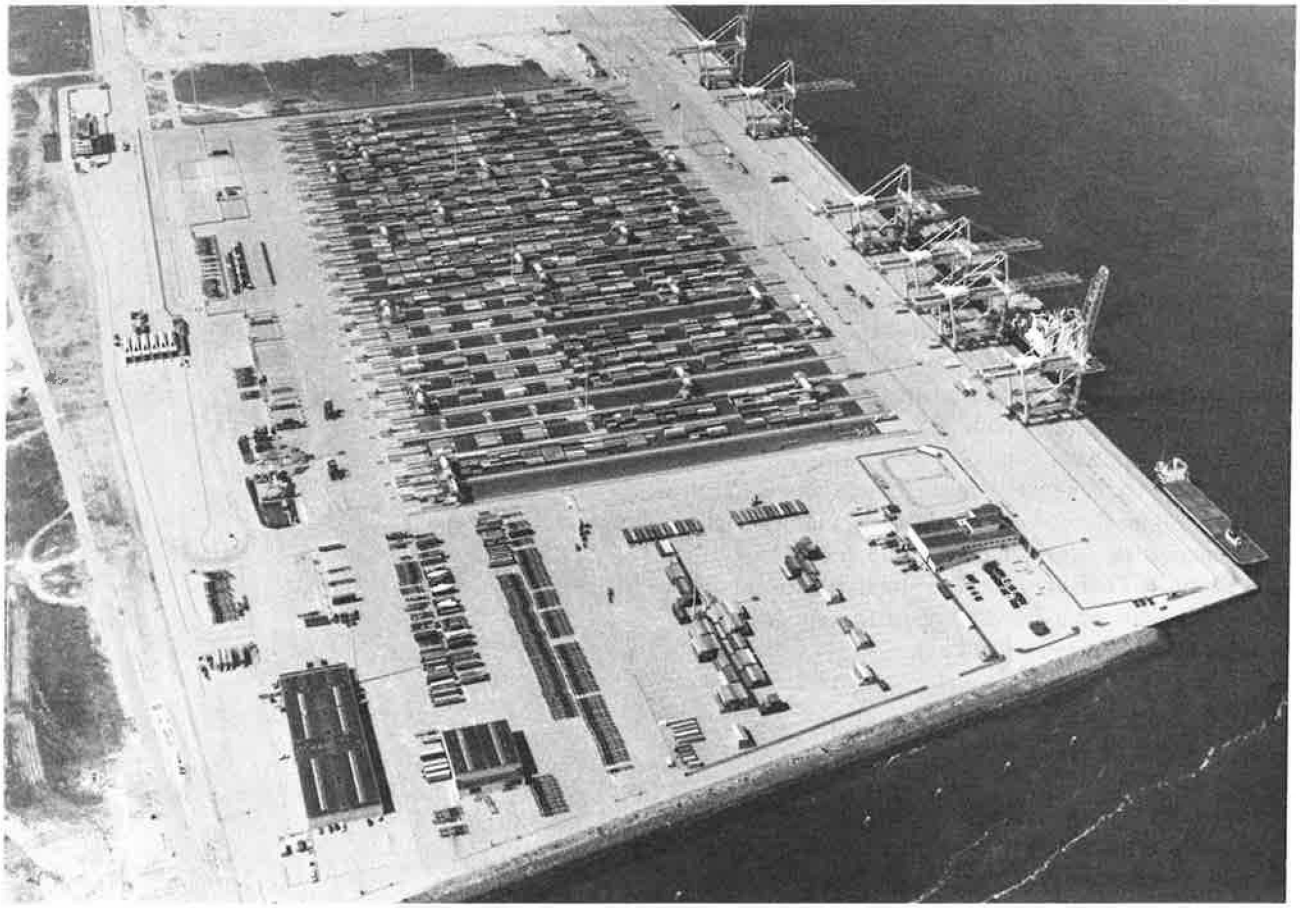

FIGURE 9 ECT's Delta/Sea-Land Terminal, realized through the combined efforts of many parties.

• Technical specialists within maintenance departments—both for equipment and control systems—should be integrated in design and commissioning teams. These teams are the experts for nitty-gritty fault finding and bug fixing, and they will come up with improvements in prototypes. Such specialists will help control all the details, which is still the dominant factor of success in automation.

• Sound relationships with work councils and labor unions are required. Right from the beginning these bodies must be involved in the design process. They will make requests, sometimes even demands, related to working conditions, labor involvement, training programs, job enrichment, and employment guarantees. Because automation brings a major change into a company, employees must be shown how automation can contribute to company objectives.

• The culture in the company must support an innovative approach. Success is infectious: small-scale improvements and partial mechanization can prepare the way for full-size automation.

• A project team approach is required to manage a large automation project. Project objectives, deliverables (in quality and time), and budgeting benefit from a multidisciplinary team that controls the difficult process of creating new systems. Proper information, regular briefings, and a breakdown into understandable work elements will facilitate a design process that may take 3 to 4 years and require contributions from hundreds of people.

• Major breakthroughs such as automation in container handling can be expected only if there is teamwork between terminal operators, vendors, shipping lines, intermodal parties (Fig. 8), customs, and even shippers and consignees. All parties involved should cooperate in finding ways for further simplification and better control. Partnership does not cause dependency; partnership creates a new dimension for improvement and cost control.

All these conditions were met during the design and building of the world's first automated container-handling facility in Rotterdam (Fig. 9). ECT's Delta/Sea-Land terminal was realized through the combined efforts of many parties.

CONCLUSIONS

Automation in container handling contributes to better flow control, operational flexibility, and long-term cost control. However, the handling process and the labor organization should be redesigned to benefit from the potentials of information technology, mechanization, and computerized process control.

It is a challenge for management of all parties involved to pull the strings, keep dangers under control, and encourage developments in technology and organization. Globally accepted standards for methods and technology must be developed to support further automation in container handling.