ITS Opportunities in Port Operations

LONNIE E. HAEFNER AND MATTHEW S. BIESCHKE

Intelligent Transportation Systems (ITS) reduce congestion and increase safety and efficiency on our streets, highways, railroads, and airways, in an attempt to create an intermodal system which facilitates passenger and cargo transfer. Considerable research has been and will be conducted in these areas. However, ITS applications concerning intermodal freight operations have not been explored as rigorously. When speaking of freight operations, intermodalism refers to the complex interactions of surface transportation and water and rail modes to move goods, both domestically and internationally. The efficient movement of freight is essential to the economy. The economic value of moving goods via water transportation has been demonstrated and proven in many industries. ITS technologies can increase this economic value by improving the productivity and safety of intermodal freight operations. The global trade demands of the intermodal freight transport industry are growing at unprecedented rates and the available land on which infrastructure improvements can be built is dwindling. Operations must become more efficient if these increased demands are to be met. ITS-related technologies address operational efficiency problems. Cost savings and competitive advantages must be realized quickly if these often-expensive upgrades are to be implemented. Therefore, research must be conducted to evaluate these individual systems and their compatibility and coordination with each other and existing management systems, before large implementation investments are made. This paper attempts to evaluate these ITS-related systems and their applicability to intermodal freight operations by way of an in-depth examination of their effects on intermodal port operations around the world. Key words: ITS, port operations, intermodal, freight.

INTRODUCTION

Port operations and planning must take into account the current increasing demand as well as future demands expected to be handled by the system. Ports must provide efficient links between water and surface transportation and concentrate on information flows as well as the movement of the cargo itself. Advanced technologies must constantly be examined and implemented to enhance the overall efficiency of the port. The global trade demands of the intermodal freight transport industry are growing at unprecedented rates while the available land on which infrastructure improvements can be built is dwindling. This leads to operation under severe constraints of land in addition to human resource controls. New infrastructure cannot always be constructed, thus existing infrastructure must be managed more efficiently to create additional capacity. Advanced applications are required to maximize the efficiency of ports and to provide for this increase in capacity. Intelligent Transportation Systems (ITS) can offer opportunities to optimize the use of the existing transportation system to generate additional capacity using the existing infrastructure. The application of advanced and state-of-the-art technologies have, and will continue to, transform the freight transportation industry.

Transportation systems provide mobility for our nation's commerce. The economic value of moving goods via water transportation has been demonstrated and proven in numerous circumstances. ITS technologies can add to this economic value by improving the productivity and safety of intermodal freight operations. This freight movement encompasses multiple modes. Intermodal terminals are a critical transfer point for moving cargo through the transportation and distribution process, but the transfer between vessels and inland transportation is one of the weakest, least efficient, and most costly links in the intermodal chain (*1*). Pressure on intermodal terminal operators to cut costs, diminish congestion, reduce damage claims, and attain higher overall levels of yard efficiency are forcing advanced technology, particularly information technology, to revolutionize impacts on the physical distribution of freight. Effective intermodal shipment of freight requires not only the transfer of the cargo itself, but also the transfer of information between transportation modes. Advanced technologies are likely to improve transportation productivity with new equipment and vehicle systems to increase capacity, new state-of-the-art terminals using advanced technology for cargo interchange and handling to reduce transfer times and costs, and new information and communication technologies which offer opportunities to generate additional system capacity through sophisticated management of the existing transportation infrastructure.

CARGO AND EQUIPMENT TRACKING

The use of state-of-the-art material and cargo handling technologies including tagging, tracking, and information management systems can offer the ability to expand the capacity of commercial terminals. These systems offer the ability to track, identify, and monitor cargo and equipment in real time. By electronically monitoring the movements and locations of equipment, operators can track the movement and location of all containers entering, exiting, or remaining in the terminal. Equipment and cargo visibility allows for a higher degree of inventory control, which leads to faster, more efficient, and reliable operations.

Currently used automated equipment identification (AEI) technologies include radio frequency (RF), bar coding, smart cards, and satellite-based operations. RF tags use radio signals to communicate real time information including location coordinates, weight, size, and identification numbers to the centralized control/management system. Warehousing and manufacturing applications

Department of Civil Engineering, Washington University, Campus Box 1130, One Brookings Drive, St. Louis, Missouri 63130.

have used RF technology for years to manage traffic flows through gates and to track yard equipment.

Utilizing bar codes on containers dramatically reduces the tedious and error-prone tasks of reading and recording cargo information. Another technology for reading and recording identification letters and numbers on containers and trailers is Optical Character Recognition (OCR). OCR systems use high-speed linescan video technologies to electronically read identification numbers stenciled on containers. Systems such as these can provide accurate asset tracking and can create load lists automatically, while significantly improving data accuracy and location information.

Smart cards are being implemented for managing the entry and exit of vehicles within the terminal yard as well as for payments of tolls and gasoline. These credit card sized integrated circuit cards have the ability to store and process information. Satellite-based location determination technologies provide unparalleled accuracy to within meters. These satellites use either the Global Positioning System (GPS), geosynchronous orbital satellites, or Low Earth Orbit satellites (LEO) to track vehicles, seacraft, aircraft, etc. The major advantage of a GPS is its ability to operate with minimal additional infrastructure (*2*). GPS satellites have been functioning for years, and tracking vehicles or cargo only requires a GPS receiver to pinpoint its exact location. Other great advantages of LEO are that they are relatively inexpensive to use, they are small, typically 45 kg, and can be launched from a single small rocket fired from an aircraft at an altitude of only 12.2 km. LEO orbit at approximately 800-1000 km, and are close enough to receive signals from handheld devices (*3*).

The main objective of AEI is to track containers the entire time they are in the terminal and feed back location and status information to the central information systems in real time, where the data can be compared with the selected location (*4*). Dramatic improvements in container throughput, accuracy levels, and overall container management can be expected from these technologies. Other benefits include reduced container stowage times, reduced labor costs associated with identifying, locating, and moving containers within the yard, and simplified inventory checks.

AUTOMATED GUIDED VEHICLES

Automated Guided Vehicles (AGV) utilize unmanned vehicles which are self-propelled by using automated controls. An AGV system includes the vehicle, navigation system and guidepath, automated controls (including the traffic management system to monitor moves, inventory, and vehicle status), obstacle detection system, and appropriate interfaces with other computers and terminal operation systems. AGV systems are used in terminal operations for the retrieval and storage of containers. Onboard computers on each AGV communicate using wireless transmissions with the control center to allow the vehicle to navigate to any point within the terminal. AGV provide efficient and flexible maneuvering with minimum manpower, high container throughput at reduced costs, continuous operation possibilities (24 hours a day, 7 days a week), and consistent container handling operations. AGV systems are generally suited to repetitive actions and can provide benefits to both the port and its customers. The lack of use of AGV technology in the US is a result of labor agreements between port/terminal operators and labor unions (*5*).

AGV systems can be designed to interface with other automated systems such as automated storage and retrieval systems that can provide even greater levels of flexibility. Current AGV navigation systems include vehicles that follow a path of buried wires below the surface, photofluorescent and reflective material applied to the path in stripes, laser based systems which utilize triangulation to determine location, onboard gyroscopes which track the precise heading of the vehicle, and other systems which utilize a grid marked on the floor. AGV are highly maneuverable and can be equipped with GPS or similar AEI technologies to track their movement and location throughout the yard.

The major problem with conventional AGV systems appears to be the interface between the crane and the surface transports, as they must operate in conjunction, invariably leading to one waiting on the other (*6*). If AGV are queuing under a crane, the problem is not so important, but when a crane has to wait for an AGV, then the performance of overall cargo handling can be seriously disrupted. Overall, AGV can still offer a safe and reliable alternative to human operators in environments where material transport requirements are well defined and reasonably static. The overwhelming benefits of AGV include increased efficiency, reduced labor costs, improved safety, and improved inventory tracking.

COMMUNICATION AND DATA EXCHANGE TECHNOLOGIES

The exchange of information is as important to freight movement as the movement of the cargo itself or the equipment that is moving it. In freight transportation, if information doesn't move, cargo doesn't move. The more seamless the information flow is, the quicker cargo can get from its origin to its destination. With these points in mind, it is appropriate to realize that considerable savings in time, safety, and efficiency could be realized by the adoption of electronic forms of data exchange.

Electronic Data Interchange (EDI) communications facilitate the smooth hand-off of cargo from mode to mode, as well as automating billing, data entry, tracking functions, and other information exchanges such as cargo manifests, bills of lading, vessel arrival times, in-bond movements, and status notifications. These and other newly developed Information Technologies (IT) are becoming common practice and can provide reduced in-terminal processing and inspection times, increased vehicle throughput, improved data accuracy, enhanced yard efficiency, and eliminated gate paperwork. IT can reduce cycle times, forward documents, manage inventory, plan schedules, and make purchases, all electronically and automatically.

Communications, information, and integrated data systems are the fundamental sectors of IT. IT has already had a revolutionary impact on freight distribution, and as many ports are somewhat constrained in expansion plans to acquire more land they must look to efficiency advancements to increase cargo productivity and expand their EDI interchange (*5*). EDI can allow a user to select any container and gain instant data on the container's location, weight, and identification number, all through electronic communications. EDI systems can link Customs, shiplines, inland carriers, importers, and exporters. This helps shipping lines transact business conveniently and expeditiously within the port and to transship their containers in the fastest way possible, since automation results in quicker release times.

The automation of information management through EDI allows actions to commence within hours instead of days or weeks. These and other advanced technologies have dramatically changed

the freight industry, and will continue to do so only if standardized communication occurs across all modes. The transfer of data between business parties must use very specific industry standards, data sets, and protocols. As shippers, ports, freight forwarders, and transportation companies have computerized their record systems, the only major impediment to transmitting more paperwork electronically has been the incompatibility of the many data systems (*7*).

ITS programs offer opportunities to apply concepts such as dynamic flow control, as developed in the aviation and rail transportation systems, to enhance the mobility of urban freight (*8*). Dynamic flow control is defined as the active, intelligent balancing of transportation and logistics demand and supply to minimize congestion and maximize capacity and flexibility. It requires real time, or near real time data on vehicle locations and network conditions, powerful analytic capabilities, and management's ability to affect and control operations. Efficient and centralized control systems are essential to ensure efficient and highly controllable operations of ports and terminals. The various data collected at the port and terminal must be integrated into a computerized terminal operating system that can maximize gate throughput and reduce costs.

TERMINALS

Techniques can be applied within the terminals themselves that greatly improve container-handling and overall operational efficiencies. One change that requires no new technology is operating 24 hours a day, 7 days a week (*9*). For this innovation to be cost effective, changes in long-standing overtime pay and labor hiring practices must be implemented. Cargo can be delayed in terminals for lack of clearance or problems in communication between parties. Advanced technologies can help to alleviate these inefficiencies. Increased terminal efficiencies can be realized through applying advanced information systems such as smart cards and RF readers and tags at entry/exit gates. The volume of truck traffic at marine intermodal terminals is large, and each truck arriving at the terminal must stop at the entry gate for processing, which includes matching truck and container numbers to shipping orders, identifying the driver for security, and assigning a pick-up or delivery location for the container or chassis. The use of variable message signs for vehicle guidance has been identified as an appropriate approach for certain port terminals to alleviate truck congestion.

AEI technologies will speed up entrance procedures, reduce queues and bottlenecks in the terminals, and enable a quicker throughput. Ports should also improve access to their infrastructure: on the waterside, channels should be kept dredged to depths necessary to handle the larger next generation vessels; and on the landside, adequate highway connections should be built with railroad clearances and yards adjusted to handle doublestack railcars. By using advanced cranes with improved capabilities, new port facilities may be able to accommodate loading and unloading from both sides of a container ship at the same time. These advanced cranes may also be capable of lifting more than one container at a time and could provide semi-automated systems in which learned paths might be developed to ultimately rely less on human operators.

With greater accuracy in container location and identification and computerized information bases, terminal managers can develop and apply management information systems to improve the flow of containers through the terminal with reduced handling (*10*). Intelligent terminal management software, including expert systems and automated planning tools, can control tracking, parking, staging, stacking, loading, stowing, and planning, as well as provide real time inventory and traffic management functions.

NEEDS FOR FURTHER RESEARCH

It is obvious that there are many benefits to applying ITS and related advanced technologies to port and terminal operations to improve efficiency, safety, and productivity through improved technology and information sharing. The difficulty lies in finding ways to promote these applications as major improvements and thereby attracting the public investment needed for implementation. The US Department of Transportation must provide leadership for the private sector and state and local governments, while closely working with the US Department of Defense (DOD) (the largest user of the transportation system) to develop a shared vision of benefits, promote the adoption of industry-wide standards, and to encourage research on, and the dissemination of, industry innovations in freight transportation. Research should be conducted on topics such as freight movement through terminals, improving information exchange, as well as examining some newer technologies being introduced by DOD for military operations that would operate simultaneously with commercial operations.

CONCLUSIONS

Remarkable productivity gains in intermodal transportation over the past 30 years have been achieved due to hard side technology improvements (containerization, larger ships, improved cranes, and doublestack trains). Further productivity gains most likely will come from soft side innovations relying mainly on information technologies. Engineers and planners must apply advanced cargo management and control systems, both shipboard and ashore, to provide the mechanisms for timely and dependable deployment of cargo from origin to destination on a sustained basis. These technologies must be applied to existing problems and integrated with current operational and informational structures and systems at port terminals.

Terminals must be continually upgraded if they are to efficiently handle the increasing volume demands placed on them, a challenge made even more difficult by the fact that many ports will need to handle this increased volume without increasing available physical space. Therefore, advanced information and communication technologies applied consistently across the entire intermodal system can offer important opportunities to increase existing system capacity. Data standards and communication protocols used in control and tracking systems must be coordinated to facilitate data exchange between parties, reduce dwell time of cargo, and increase terminal throughput. Improved terminal designs, advanced computer modeling and simulation systems, and advanced technologies for moving cargo and information, operating in concert with focused logistics and advanced information management systems can be applied to accelerate the movement of freight through intermodal port terminals. State-of-the-art ports such as Charleston, Tacoma, Los Angeles, Rotterdam, Singapore, Hong Kong, and Saudi Arabia have effectively implemented many of the technologies overviewed in this paper. These ports are therefore excellent study sites in efficient port operations and technological implemen-

tation. Appropriate research and policy efforts directed at the above technology based opportunities will yield significant gains for the US and global economies and improved cost-effectiveness in the US and world transportation systems.

REFERENCES

1. Transportation Research Board. *Special Report 238: Landside Access to US Ports.* National Research Council, Washington, D.C., 1992.
2. Hopkins, J.S. Feasibility of Advanced Vehicle Control Systems for Freight Terminals. *Transportation Research Record 1602*, 1997, pp. 65-70.
3. LEOs Shine in the Star Signs. *World Cargo News.* February 1998, p. 20.
4. A Marrige of Convenience? *World Cargo News.* September 1997, p. 55.
5. Collinge, A.M., P. Ioannou, and G. Fleischer. *Advanced Technologies for Transportation Applications Technical Report.* University of Southern California Center for Advanced Transportation Technologies, Los Angeles, California, 1997.
6. A Glimpse of Things to Come? *World Cargo News.* March 1998, p. 18.
7. Too Many Systems. *American Shipper.* March 1988, p. 38.
8. Aylward, A.D. *Intelligent Transportation Systems and Intermodal Freight Transportation.* DOT-VNTSC-FHWA-96-7. FHWA, U.S. Department of Transportation, 1996.
9. Chadwin, M.L. and W. Talley. Vessel and Port Technologies at the Turn of the Century. *Transportation Research Record 1333*, 1992, pp. 1-8.
10. Chadwin, M., J. Pope, and W. Talley. *Ocean Container Transportation: An Operational Perspective.* Taylor and Francis, New York, 1990.