Analysis of Applicability of Innovative Systems for Transport of Marine Containers

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ABSTRACT:

New Jersey ports have been experiencing tremendous growth in container volumes in recent years and it is anticipated that this trend will continue in the future. This presents a serious challenge for the transportation network supporting the traffic related to port facilities' operations. Currently most of the containers (around 90%) are transported to and from the port by trucks, while approximately 10% of containers are handled by rail. The projected growth in container traffic along with the expected growth of commuter traffic in the region will cause a significant increase in congestion which will ultimately completely deteriorate performance of the regional transportation system as well as the performance of the transportation network around the port and within the port terminals. In this situation, the port authority and port operators are seeking innovative ways to improve land access to and from New Jersey's principal port terminals. One way to do so is to apply new, innovative transportation systems as an alternative to existing rail and highway modes. The research presented in this paper had three main objectives: to identify and describe innovative technologies that can be used to transport marine containers, to develop a methodological framework for evaluation and comparison of the innovative technologies, and to apply the evaluation framework and test feasibility and applicability of selected innovative technologies using case studies in New Jersey. Once the technologies have been reviewed and the most promising ones selected for further consideration, the multicriteria evaluation and decision making model has been developed that allows for the analysis and evaluation of alternative technologies over multiple objectives using different decision criteria. The methodology considers direct financial effects as well as external effects such as pollution, reduction in congestion, landuse disruption, socio-economic effects, and impacts on transportation system performance. The case studies were developed in order to test the applicability of proposed methodology and feasibility of implementing alternative technologies in the New Jersey port region. The analysis showed that some of the innovative technologies are very competitive with existing rail and truck service, and even perform better, especially in case of increased container demand.

INTRODUCTION

The northern New Jersey region houses the third largest port in the country and the largest on the East Coast as well as one of the nation's largest air cargo hubs. Port Newark and Port Elizabeth, the State's premier intermodal facilities, have been experiencing tremendous growth in container volumes in recent years and it is anticipated that this trend will continue in the future. The current annual container volumes in these two ports of approximately 2.5 million TEUs are projected to double within ten years, and by the year 2040 the volume is expected to increase by more than six-fold (NCTIP, 2003). This presents a serious challenge for the regional transportation network supporting the traffic related to port facilities' operations.

In order to accommodate the increase in container traffic, and to capitalize on the tremendous economic growth opportunities, the Port Authority of New York and New Jersey (PANYNJ), New Jersey Department of Transportation, other regional transportation agencies, and port operators, initiated a number of improvement projects designed to increase the port capacity. While these projects focus primarily on improving waterborne access and terminal operations, there is serious concern as to the ability of the existing regional highway and rail network to handle the anticipated increase in goods movement.

According to the Comprehensive Port Improvement Plan (CPIP)[1], 88% of the Port's current container volume is transported by trucks, while rail carries approximately 12%. The predominant movement of goods via truck coupled with the tremendous growth in the Port's container traffic places more pressure on already congested highways in the port area. In addition to congestion, which according to a recent study (NCTIP, 2001) grows at a higher rate than a corresponding growth of traffic volumes, increased truck volumes would create many other problems, such as decreased energy efficiency and deterioration of air quality. While rail operators would gain additional revenue from increased intermodal operations, it is questionable if they will be able to significantly grow with the current infrastructure. Rail infrastructure that supports the Port's operations is already struggling to meet the needs of the rail-bound port traffic and will need significant improvements and capacity upgrades to support future growth.

Under these conditions, the regional transportation network requires a major expansion to create the much needed additional freight transport capacity. With limited ability to expand current highway and rail network in northern New Jersey research and implementation of innovative ways to improve land access to and from New Jersey's principal port terminals will be crucial to keeping the transportation system efficient, reliable, and safe.

In this paper we examine “unconventional” transportation modes that can be used to move intermodal containers between port terminals and inland intermodal facilities or even their final destinations. The objectives of the research are threefold:

- ☐ To identify and describe innovative transportation technologies suitable for transport of intermodal containers;
- ☐ To develop a methodological framework for evaluation and comparison of the innovative technologies;
- ☐ To apply the evaluation framework to test feasibility and applicability of selected innovative technologies using several case studies in New Jersey.

The presented case studies provide stakeholders, especially regional transportation agencies and organizations, as well as nearby communities, with a better understanding of the impacts of implementation of these technologies and their advantages or disadvantages compared to the existing conventional transportation modes, trucks and rail. The case studies also provide real, comparative data for real technologies serving real locations in New Jersey.

INNOVATIVE TECHNOLOGIES FOR INLAND TRANSPORT OF MARINE CONTAINERS

The reviewed technologies include those currently in commercial operation, emerging technologies that are undergoing prototype tests, and those that are still in design and conceptual stage. Some of the technologies have been applied in people mover systems (conveyors, amusement parks, manufacturing facilities), and, if modified, could have a high potential for use in container transport. Information about these technologies has been gathered through a variety of sources, including transportation industry magazines and publications, research reports, technology vendor’s brochures, Internet, and contacts with public, quasi-public and private sector companies and organizations involved in the design, development, and popularization of innovative transportation systems.

The reviewed innovative technologies were classified into three major categories:

1. Technologies utilizing fixed guideway – rail and monorail;
2. Automated guided vehicles (AGV);
3. Fast freight ferry technologies.

Technologies utilizing fixed guideway

There are several innovative designs of vehicles utilizing fixed guideway. Based on initial review of available information three most promising technologies were selected for the analysis: AutoGo (suspended monorail), CargoRail (rubber-tired vehicles on the steel guideway), and CargoMover (automated self-propelled flatbed railcar).

CargoMover is an example of automated rail technology developed by the German company Siemens Transportation AG in collaboration with Aachen Technical College and the Technical University of Braunschweig. CargoMover is, in essence, a redesigned, self-propelled, automated flatbed rail freight car with a payload of up to 60 tons. The current design uses low-emission, low-noise diesel motor, but alternative traction systems can be successfully implemented as well, such as electric motors and emission-free fuel. The vehicle is fully automated, controlled by the central computer and directed by wireless communications. The path of the vehicle is pre-programmed. The algorithm that supports the system controls and manages interactions between the CargoMover and other vehicles along the way, so that higher priority passenger and freight services on a given corridor are not blocked or delayed. This type of control leads to better utilization of the capacity available in a rail network.

Figure 1. CargoMover (Siemens Transportation) at the tradeshow in Berlin, Germany (courtesy of Siemens Transportation)

The system provides for high level of safety through a combination of electronic interlocking system controlled from the main control office that monitors movement of each vehicle in the network. CargoMover also features pioneering sensor technology mounted on the vehicle itself that substitutes for the driver’s eyes and hands. The vehicle is equipped with laser and radar sensors to constantly monitor the area ahead the vehicle for blockages, and to stop the vehicle in the event that any obstacles occur on its way. The video camera enables the control office to get a direct picture of what is happening in front of the CargoMover.

Siemens also developed a system called *Mobiler* for trans-loading swap bodies[2] or containers between railcars and trucks. This equipment can be installed on CargoMover and thus eliminates the need for intermodal ramps and cranes, or other special equipment for container transfer between railcars and trucks.

CargoMover is designed for local and regional freight transport, of up to 100 miles (150 km) with a top speed of 55 mi/h (90 km/h). It automatically transports cargo without delays from traffic congestion, without switching or train-formation and with minimal air pollution emissions.

Siemens is currently testing CargoMover vehicles and is expecting a series production to start in 2005

CargoRail, a concept developed by the MegaRail Transportation Systems, Inc. of Fort Worth, Texas, employs rubber-tired vehicles (referred to as “Cargo Ferries”) that would move along an elevated guideway that is separated from other modes (Figure 2).

The electrical motors mounted on each wheel propel Cargo Ferries. Three-phase electric power is supplied through electrified rails and conventional carbon power shoes mounted on the vehicle that contact power rails. Multiple motor systems and power collector assemblies at each wheel provide back up for continued operation.

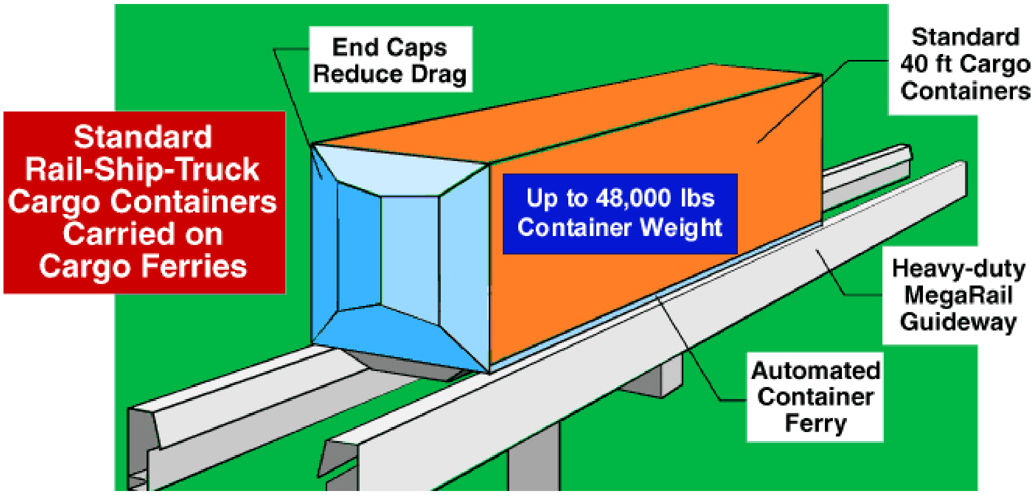

Figure 2. Schematic picture of the CargoRail “Freight Ferry” on the guideway (courtesy of MegaRail Transportation Systems, Inc.)

While each vehicle operates individually, they are fully automated and controlled by a computer. Vehicles operate on enclosed weatherproof guideway, which ensures safe, all-weather operation shown in Figure 3. Their tires are flat-proof, avoiding roll-overs.

MegaRail Transportation Systems claims that this system is ready for a non-stop, 24-hour, 7-day a week operation at operational speeds of up to 75 mi/h (120 km/h). The maximum designed payload per vehicle is 50,000 lbs. Vehicles could be used for transport of trailers and trucks, as well as containers.

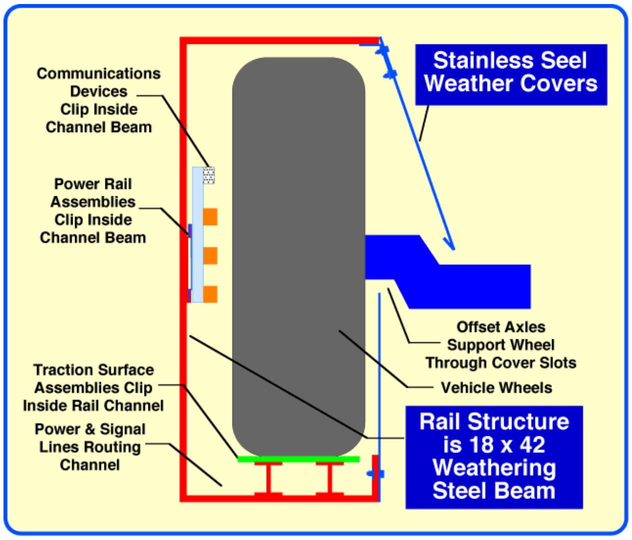

Figure 3. CargoRail enclosed guiderail and wheel (courtesy of MegaRail Transportation Systems, Inc.)

This system is still under development. In 2000, the concept was presented to the Port of Houston Authority in Houston, Texas, as a possible solution to the problem of transporting containers to and from the container piers at the Port’s terminals.

System designers proposed to connect the Port’s terminals directly with a remote intermodal terminal 35 miles inland. This proposal is currently not being pursued and neither prototype nor tests have been made. However, MegaRail Transportation Systems is currently testing its Personal Rapid Transit (PRT) system called MicroRail at the testing facility near Fort Worth, Texas, on the same type of guideway and with the same propulsion that would be used for the CargoRail system.

Auto-GO is an overhead cargo container handling system for moving containers from port facilities to other inland intermodal facilities, and vice-versa. This unique and very promising freight monorail concept was developed by Titan Global Technologies Ltd., a New Jersey based company. The system consists of overhead guiderail and shuttles that carry containers. The shuttles are fully automated and use linear induction magnetic propulsion. The transportation process would start inside the terminal where a gantry crane drops off the container. The cargo carrying system picks up the container and raises it by means of a specially designed bogie-spreader bar combination (Figure 4). The container is then secured on the container shuttle, and transported at 50 to 75 mi/h (80 – 120 km/h) to its final destination (Figure 5). The advantages of this technology, which combines overhead monorail system and linear induction propulsion, are as follows:

- ❑ No interaction with surface traffic and therefore no accidents or delays in shipment due to surface traffic conditions.

- Reduced cargo handling (each container is handled only once from the point of origin to the point of destination).
- Improved security due to the cargo being high above ground.
- Economic efficiencies achieved through reduced operating and handling labor costs, since the system is fully automated, reduced waiting in traffic, and reduced administrative cost.
- Ability to operate in nearly any weather conditions. As the system does not rely on the use of ground transportation infrastructure, prevailing weather and road conditions would not impact operation of such a system. The only potential disruption may exist in heavy wind conditions, such as hurricane. In those cases the system would probably be out of operation.
- Low noise and very minimal air pollution emissions.

Titan Global Technologies Ltd. has built and tested 1:6 scale model of Auto-GO system in their facility in New Jersey. The model has all the capabilities of a full-scale system, including use of a linear induction motor, bogie-spreader, hoists, and a locking system that secures the container.

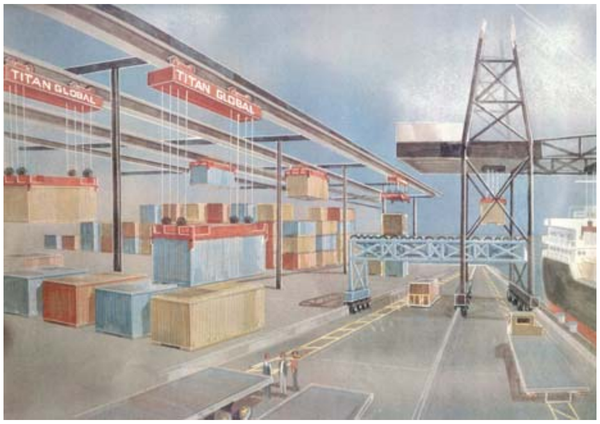

Figure 4. Auto-GO shuttles picking up containers (courtesy of Titan Global Technologies Ltd.)

Figure 5. Transport of containers by the Auto-GO system (courtesy of Titan Global Technologies Ltd.)

The technologies used in Auto-GO system guideway, switches, and movement control system, have been tested in the field and use of linear induction motors have been proven in operation of the monorail people-movers that Titan built in Miami, Florida, Pomona, California, and Love Field in Dallas, Texas. The system in Miami was in full commercial operation for almost 30 years until 1992 when the operation ceased due to a severe hurricane. However, the guideway and vehicles had almost no damage. Bogie-spreader and locking system were designed in collaboration with August Design, a Pennsylvania based company that has designed several similar models in operation in various container handling systems.

Automated Guided Vehicles

Automated Guided Vehicles (AGVs) employ driverless vehicles navigated and controlled by a computerized system. AGVs are no longer a new technology having been successfully used for many years in manufacturing plants, warehouses, airports, and other facilities, and for automated transport of various goods. Although most of the mentioned applications are indoor, several systems have been developed and deployed for various outdoor applications, some of them for moving large freight containers within or even outside marine container terminals.

Most notable example of such operation is Sea-Land's Delta Terminal in Rotterdam, Netherlands, also known as European Combined Terminal (ECT). ECT is the very first fully automated container terminal (ACT) in the world. All the containers in the terminal are handled by the Automated Stacking Cranes (ASC) and AGVs. Today, ECT operates more than 150 AGVs.

The latest generation of AGVs used at ECT can carry 20, 40, 45 and 50 ft containers, with the payload of up to 40 tons. They can reach speeds of up to 15 mi/h. The vehicles are produced by Gottwald Port Technology and they use a guidance system called Free Ranging On Grid (FROG), developed by Frog Systems of the Netherlands. FROG systems use a network of guide wires embedded in the pavement, and wire guidance controls inside the vehicles to navigate around the terminal. Today, more advanced navigation technologies are available and are being used for other types of AGVs, such as laser and radar navigation systems and "spot technology" that is similar to gyrocompass.

Figure 6. AGV operating in European Combined Terminal (ECT) in Rotterdam, Netherlands (obtained from Frog Systems website)

Figure 6 shows an AGV used in the ECT. Vehicle is entirely symmetrical and it can move in both directions at the same speed. The symmetry of the vehicles is required, since the orientation of the container placed on the AGV is very important for the container tracking and monitoring system. The vehicles have four driving wheels and are equipped on both sides with object detection sensors, which are in charge of detecting any obstacles to the AGV movement. AGVs in the ECT are navigated by a supervisory software control system. The supervisory software packages used in industrial and people mover applications are typically based on optimizing utilization of space. The supervisory control system used at ECT has been developed on the basis of a different philosophy, which optimizes container delivery based on the ship's loading/unloading order plan.

Fast Freight Ferries

Growing congestion and limited capacity of the landside transportation network have recently led to many initiatives to utilize coastal waters and inland waterways to provide a feeder service for the large seaports. Container-on-barge feeder service has been successfully implemented in Western Europe for years, especially on the river Rhine waterway system. At the same time, only few examples of similar service could be found in the U.S., mostly because this kind of service was previously considered more expensive and less efficient than conventional truck or rail service.

Figure 7. Example of Fast Freight Ferry Technology – West Pac Express vessel currently being built by the Austal for U.S. Army

One of the reasons for the limited use of barge feeder service to transport containers is the large amount of time required to deliver goods. Freight ferries lack the ability to effectively compete with more versatile truck and rail service, particularly for short haul movements and when transporting more expensive time sensitive cargo. However, this situation could be changed with the introduction of a new generation of vessels that could provide faster service. Several studies done by the Center for the Commercial Deployment of Transportation Technologies (CCDoTT) at the California State University, Long Beach, National Ports and Waterways Institute (NPWI), and the Maritime Administration (MARAD) are looking at designing, building and deploying fast, ferry-like vessels for transporting containerized cargo.

One example of new generation of high-speed ferry-like vessels that can be used for transport of cargo containers are the vessel designed by Australian shipbuilder Austal. These vessels would be catamarans and trimarans and would be capable of traveling at speeds of up to 40 knots, depending on hull designs and propulsion, and could carry 80 to 140 TEUs. Austal is currently building similar vessel for U.S. Army Marines (Figure 7). This vessel will be able to carry 950 soldiers and 550 tons of cargo at speed of 40 knots. The estimated cost of this vessel is $50 Million.

EVALUATION OF INNOVATIVE TRANSPORTATION TECHNOLOGIES

Traditional engineering economics methods can be used to ascertain the merit of transportation projects. These methods include: benefit and cost ratio, net present worth (or value), internal rate of return, payback period, to name a few (Morlok, 1978, Roop and Mahur, 1995). All of these methods try to identify, calculate, and compare costs and benefits of alternative projects and select the one with the optimal output.

While the assessment of costs is relatively straightforward in these methods, quantifying non-monetary benefits associated with implementing a transportation project is complex, as engineering economics methods typically require that they be assigned a monetary value. There are a number of analytical tools to assign the dollar value to the benefits; however, some impacts such as congestion relief, safety improvements, air quality are often difficult to quantify financially. Some may not even be quantifiable: e.g. aesthetic appearance of the new transportation facility (Morlok, 1978). These kinds of impacts are often referred to as “external” effects of the transportation activities, since they are not directly reflected in monetary costs and benefits of project implementation. By externalizing these factors, benefit/cost analyses often does not capture the full value of beneficial impacts. However, the significance of all impacts, both positive and negative, needs to be considered in the decision making process.

An alternative to traditional engineering economics methods is an approach that captures and evaluates non-monetary as well as monetary costs and benefits of transportation projects. Multicriteria analysis is allows planners to evaluate projects and evenly compare their impacts in both monetary and non-monetary terms. Impacts of noise, air pollution and safety may be more easily comprehended by using volume-based measures such as noise reduction (in decibels), air pollution reduction (in tons of pollutants) and safety improvements (reduction in number of accidents), rather than dollars. Multicriteria analysis allows evaluation of potential transportation investments without attaching a monetary value to external effects.

Multicriteria Analysis of Transportation Investment Alternatives

Given the complexity of transportation project analysis, a multicriteria approach was adopted for the study of innovative transportation technologies. The main advantage of this approach is that it allows for analysis and evaluation of investment alternatives over multiple objectives and using various performance measures. In case of transportation, these objectives can include improving mobility, reducing cost of transportation, reducing travel times, improving air quality, inducing economic development, reducing maintenance costs, etc

The authors of a recent study that was conducted at Texas Transportation Institute proposed a new framework for multimodal freight investment analysis – Multicriteria Cost Benefit Analysis (MCCBA) (Roop and Mahur, 1995). The outlined methodology can be summarized in several basic steps:

- Identify multiple investment alternatives.
- Identify objectives and criteria by which the alternatives will be evaluated.
- Evaluate performance measures for each criterion. This is done based on the developed rating scale of valuation functions for each performance measure.
- Assign weight to each criterion that will reflect tradeoffs and conflicts associated with investment decisions. The weight structure reflects the importance of criteria relative to each other.
- Rank the alternatives based on final scores.

Following this general approach of the multicriteria decision analysis the following objectives are defined for the selection of innovative technology for transport of cargo containers between port terminals and inland intermodal stations:

- Minimize investment and operating costs of the future system.
- Increase velocity and improve performance of the freight transportation system.
- Maximize social benefits for the nearby communities.
- Improve quality of life and minimize negative environmental impacts.

The above objectives are defined considering specific transportation and quality of life issues facing northern New Jersey, most notably, traffic congestion, lack of capacity on the highway network, increasing truck traffic, air pollution, and expected growth in the number of intermodal containers entering the region over the next two decades.

For each objective, several criteria have been defined to evaluate specific impacts. Table 1 relates the stated objectives to the criteria and associated performance measures. Since different criteria have different measures, it is necessary to develop a common denominator for all these measures. This is usually done by converting values of the performance measures for each alternative to numerical scores. Single-criteria value functions are defined for each performance measure to translate criteria-specific values into single-criteria scores, which follow a certain scale, e.g. 0-10 or 0-100. Depending on the value of performance measure and associated value function alternative technologies receive scores for each criterion.

Total scores for each alternative are calculated as the sum of products of individual criteria scores and their respective weights. Weights depend on the nature of the decision that is being made and are a result of decision maker’s preferences. Many different weighting systems can be used including analytical procedures for developing weighting schemes, but very often weights are assigned arbitrarily (Rastogi and McLeod, 1995). Weights should reflect relative importance of criteria. Thus, the total score can be described as an overall index of project desirability. The alternative that receives the highest total score is selected as the best or the most desirable alternative.

Table 1. Description of evaluation criteria and performance measures

Objectives/Criteria	**Description**	**Performance Measure***
MINIMIZE INVESTMENT AND OPERATING COSTS OF THE FUTURE SYSTEM		
Cost per container trip	Cost per container trip represents the ratio of total annual system cost and total annual number of container trips on selected route. The total cost includes construction cost, ROW land acquisition, fleet cost, operating and maintenance cost.	$/container trip
INCREASE VELOCITY AND IMPROVE PERFORMANCE OF THE FREIGHT TRANSPORTATION SYSTEM		
Travel time	Average container travel time between the terminals (port terminal and inland intermodal station), including loading and unloading.	Hours
Congestion relief	This criterion is measured as the reduction in number of truck trips on the highway network between two terminal points, as the result of diverting the containers to the new transportation technology. It is assumed that one container diverted will eliminate one truck round-trip of the highway.	Daily number of diverted truck trips
Safety	This criterion addresses safety level of each technology by assessing possibility of accidents or incidents with human casualties or injuries, or property damage, related to system operation. This is usually difficult to calculate, especially for new technologies that have not been tested in full commercial service. Experience with similar technologies and professional judgment of the research team members is used to assess the safety level for each technology.	Qualitative grading scale: 1 = Worst, 5 = Best
System reliability	This criterion measures the probability of system or vehicle failure. Using available data and comparison with similar technologies, research team assessed system reliability for each technology. Status of the technology (whether it is proven in operation, or if it is testing, proto-type or design phase) has been considered as a factor in evaluating reliability.	Qualitative grading scale: 1 = Low, 5 = High
Intermodal compatibility	This criterion measures the ability of the system to be efficiently integrated with the current container handling system inside the port terminal. It is assessed based on preliminary analyses of interactions between candidate technologies and handling system.	Qualitative grading scale: 1 = Low, 5 = High

Table 1. (Cont.) Description of evaluation criteria and performance measures

Objectives/Criteria	**Description**	**Performance Measure**
Increase velocity and improve performance of the freight transportation system		
System expandability	This criterion measures the ability of the innovative technology to efficiently expand its capacity.	Qualitative grading scale: 1 = Worst, 5 = Best
MAXIMIZE SOCIAL BENEFITS FOR THE NEARBY COMMUNITIES		
Employment during construction	Employment related to the construction of the system.	Number of created jobs annually
Induced employment	Employment related to the long-term operation and maintenance of the system, and as a result of economic development in the region following the implementation of new technology	Number of created jobs annually
IMPROVE QUALITY OF LIFE AND MINIMIZE NEGATIVE ENVIRONMENTAL IMPACTS		
Air pollution	This criterion addresses negative impacts of the vehicle emissions related to alternative technologies. Average vehicle-born pollutant emissions are assessed for each alternative technology.	kg/TEU-mile
Land Requirement for ROW	Total additional land required for the system ROW. Since the project area lacks available space it would be desirable to use technology that can utilize existing ROW (or at least its part) without disruption of current freight operations.	Qualitative grading scale: 1 = Low, 5 = High
Hazardous and solid waste risk	Expected risk of encountering o hazardous and solid waste materials during construction related to technology implementation.	Qualitative grading scale: 1 = Minimum Impact, 5 = Maximum Impact
Disruption of the natural habitat	This criterion considers negative impacts of innovative technologies on the flora and fauna and disruption of wetlands.	Qualitative grading scale: 1 = Minimum Impact, 5 = Maximum Impact

* Note that overall assessments of qualitative measures would be calculated as the average of scores assigned by members of the research team.

Multicriteria analysis is usually presented in the form of matrix. The matrix consists of a list of alternatives, list of criteria with associated performance measures, single-criterion scores for each criterion and each alternative, and total scores for each alternative. An example of evaluation matrix sed in this study is given in Table 2. The single-criteria score of alternative i for criterion j is denoted by $a_{i,j}$.

Table 2. Structure of the multicriteria evaluation matrix

Criteria	AutoGo	CargoRail	…………..	Rail	Weight
FINANCIAL IMPACTS					
Capital cost	$a_{1,1}$	$a_{2,1}$	. . . . . .	$a_{n,1}$	17.5
Annual operating cost (including maintenance cost)	$a_{1,2}$	$a_{2,2}$	. . . . . .	$a_{n,2}$	17.5
SYSTEM PERFORMANCE					
Travel time/speed	$a_{1,3}$	$a_{2,3}$	. . . .	$a_{n,3}$	7
Congestion relief	$a_{1,4}$	$a_{2,4}$	. . . . . .	$a_{n,4}$	7
Safety	$a_{1,5}$	$a_{2,5}$	. . . . . .	$a_{n,5}$	7
System reliability/implementation of proven technology (in operation, tested, not tested,…)	$a_{1,6}$	$a_{2,6}$	. . . . . .	$a_{n,6}$	3
Intermodal compatibility	$a_{1,7}$	$a_{2,7}$	. . . . . .	$a_{n,7}$	3
System expandability	$a_{1,8}$	$a_{2,8}$	. . . . . .	$a_{n,8}$	3
SOCIO-ECONOMIC IMPACTS					
Employment due to construction work	$a_{1,9}$	$a_{2,9}$	. . . . . .	$a_{n,9}$	5
Induced employment	$a_{1,10}$	$a_{2,10}$	. . . . . .	$a_{n,10}$	15
ENVIRONMENTAL IMPACTS					
ROW land requirement	$a_{1,11}$	$a_{2,11}$	. . . . . .	$a_{n,11}$	5
Air pollution	$a_{1,12}$	$a_{2,12}$	. . . . . .	$a_{n,12}$	5
Hazardous and solid waste risk	$a_{1,13}$	$a_{2,13}$	. . . . . .	$a_{n,13}$	3
Disruption of the natural habitat	$a_{1,14}$	$a_{2,14}$	. . . . . .	$a_{n,14}$	2
TOTAL SCORES	$\sum_{j=1}^{14} a_{1,j} \cdot w_j$	$\sum_{j=1}^{14} a_{2,j} \cdot w_j$	. . . .	$\sum_{j=1}^{14} a_{n,j} \cdot w_j$	$\Sigma = 100$

CASE STUDIES

In order to test the applicability of innovative technologies for container transport four case studies have been developed. Each case study represents a potential route for transfer of containers between Port Newark/Elizabeth and inland intermodal terminal or industrial park. The following routes were selected for case-study analysis:

1. Port Newark/Elizabeth – Irvington, Essex County (route length is 8.7 to 9.5 miles depending on the technology)
2. Port Newark/Elizabeth – Tremley Point, Union County (7.2 to 7.7 miles)
3. Port Newark/Elizabeth – South Kearny, Hudson County (6.2 to 8 miles)
4. Military Ocean Terminal Bayonne (MOTBY) – Greenville Yard, Jersey City, Hudson County (2.7 to 3.5 miles)

Port Newark/Elizabeth was chosen because it handles the majority of containerized ocean born cargo in New Jersey. It also has an active rail intermodal terminal, which means it has existing rail right-of-way that can be utilized by innovative technologies. MOTBY, on the other hand, was selected as it is planned to be redeveloped into a small container terminal and currently has very limited road and rail access. The study team in collaboratring with the NJDOT and the PANYNJ deemed it worthwhile to analyze if innovative technologies would provide an optimal solution for the container movement in and out of the these terminals.

Rationale behind the selection of inland sites is the following:

- ☐ Sites in Irvington, Tremley Point, and South Kearny are all in industrial zones and already house manufacturing and warehousing facilities.
- ☐ All of these sites have potential to be redeveloped into industrial parks.
- ☐ They have direct rail access through industrial sidings to the National Rail Network.
- ☐ They have direct highway access to the National Highway Network.
- ☐ Greenville yard currently serves as an intermodal rail yard and is operated by Conrail and New York Regional Railroad. It is close to MOTBY and it can serve as a satellite intermodal connector (or yard).

Technologies were then analyzed based on their technical characteristics. Based on the review the following innovative technologies were selected for the case studies:

- ☐ CargoRail
- ☐ CarrgoMover
- ☐ AutoGo
- ☐ AGV

Although Fast Freight Ferry Technology is very promising, it has not been proven to be cost effective for short haul moves. Therefore it was not included as an alternative in the case study analysis.

In each case study route alignments were defined for each alternative technology. Wherever possible existing rail and highway infrastructure was considered for future service, assuming that certain upgrades and expansions would be necessary to serve the future demand. For technologies requiring new infrastructure it is assumed that new infrastructure would need to be built. Geotechnical and ROW limitations were also considered in designing route alignments.

Four selected technologies were compared to each other and to conventional transportation modes - truck and rail, to determine both their feasibility and competitiveness. Based on the information obtained from industry sources and literature, operating regimes were defined for each technology; for each technology measures were calculated for all criteria and transformed into single criteria scores. This procedure was repeated for each case study. Multicriteria analysis was then used to evaluate, score, and rank alternatives for each case study. Weighting scheme used in the analyses was designed based on research team members' professional judgment, but it also reflects extensive consultations with NJDOT and PANYNJ experts.

Operating regimes for alternative technologies were defined under following assumptions:

- ☐ The system would operate 365 days per year, 16 hours per day, divided into two 8-hour shifts.
- ☐ Outbound direction is defined as a movement from the port terminal to the intermodal station. The inbound direction is the reverse of the outbound.
- ☐ Vehicles would always be loaded in the outbound direction, while 80% of time they would have a loaded backhaul in the inbound direction.
- ☐ Fleet size is determined as a minimum number of vehicles needed to serve given container demand.
- ☐ The identical container handling equipment would be available in the port terminal and the intermodal station to load and unload containers. The capital cost and the operating cost of this equipment did not depend on the type of container mover technology. Therefore, it was not included in the total system operating cost analysis.
- ☐ All containers are 40ft long (a two TEU equivalents).
- ☐ Useful economic life of the infrastructure is 20 years.

Performance measures and corresponding criteria scores for alternative technologies were calculated for seven demand levels ranging from 50 to 350 thousand containers in loaded (outbound) direction.

Findings

The final scores for alternative technologies are shown in graphs in Figures 7. Graphs show the change in rating as function of demand. For example, in case study Irvington for the demand level of 150,000 containers, the Cargo Rail (line with triangles) is the highest rated technology with the score of 3.44. Graphs in Figure 7 can be used to find the alternative scores for each case study.

As the graphs show, CargoRail and AutoGo are dominating other technologies as the volumes increase. CargoMover and AGV are less successful mainly due to longer travel times, thus needing more vehicles for the same capacity.

Conventional transportation technologies of truck and rail are dominated by innovative technologies in all case studies. Overall ratings for trucks drop with an increase in volume. Conventional rail, on the other hand, receives very stable ratings in Irvington and Tremley Point case studies, but is ranked between second and fourth place for all analyzed container volumes.

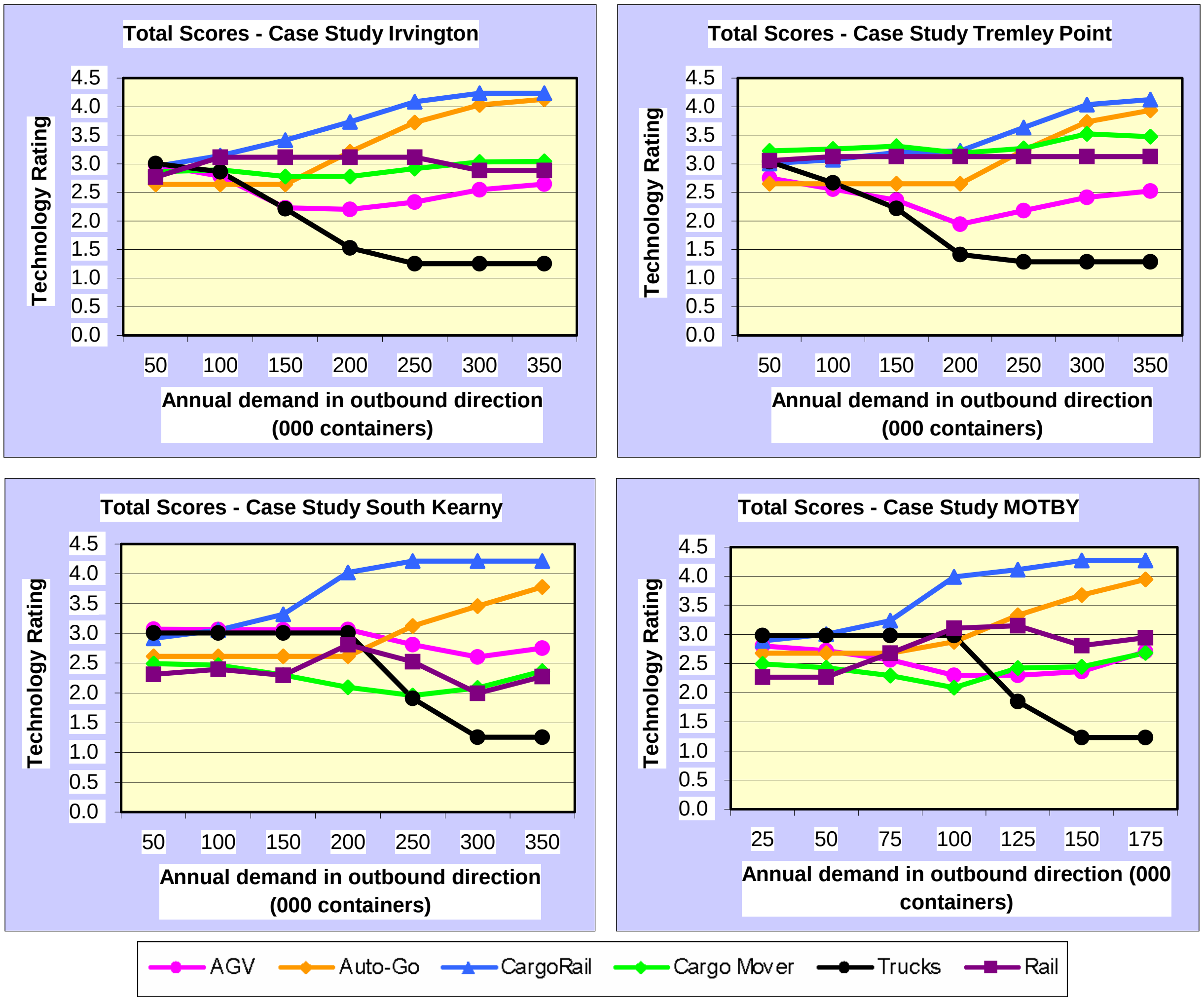

Figure 7. Total scores for alternative technologies

The presented rankings are composite scores of the criteria weighted by a subjective level of importance attached to these criteria. It is interesting to look at the “cost only” analysis of the innovative cargo mover technologies. The graphs in Figure 8 show the cost advantage of truck and rail for annual volumes between 50,000 and 250,000 containers. This result is intuitive since they have lower capital cost than innovative technologies. However, as volumes grow capital cost per unit decreases, making the difference between technologies smaller. CargoRail and AutoGo are the most expensive technologies for lower container volumes in all case studies, but after certain brake-even point their unit costs become lower than those for trucks, and very close, in some cases at high demands even lower than rail unit cost (e.g. CargoRail in Soth Kearny case study). This is mainly result of low operating costs for these two technologies, as well as the velocity of service they provide creating more capacity for container transfer than other alternatives.

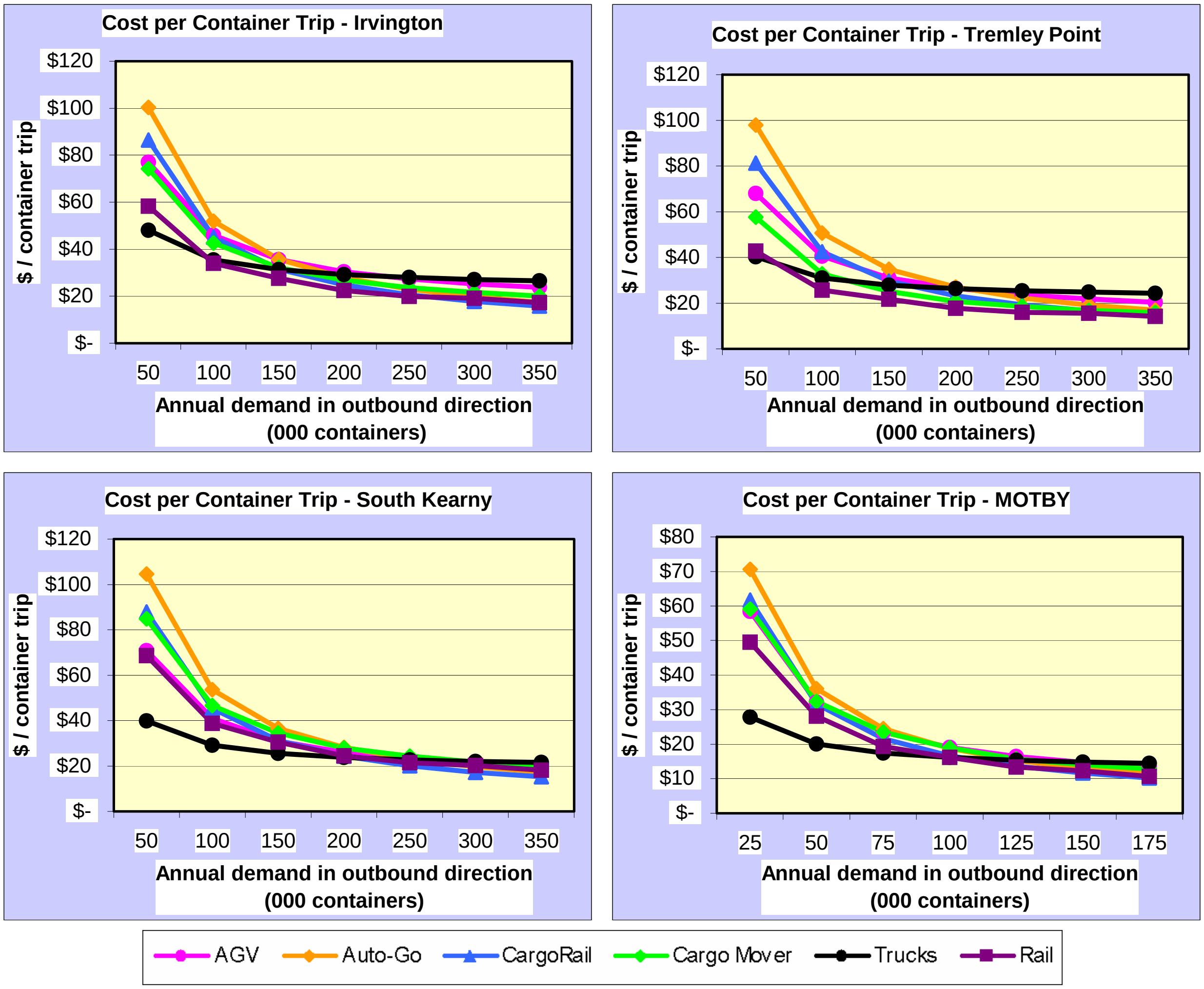

Figure 8. Total system cost in dollars per container trip for alternative technologies

Another problem that was tested was impact of criteria weights on overall ratings. Sensitivity analysis was conducted by increasing and decreasing the values of original weights placed on each criterion were by 10%[3]. This was done for each case study and each volume level (there were 182 instances for each case study). It was found that the ratings are very stable. The sensitivity analysis showed that rankings were impacted by a change in the weighting scheme in 7% – 12% instances, depending on the case study. The most impact, as one would expect, has weight assigned to the cost per container trip. Also, changes occurred more frequently for scenarios with lower container volumes. The analysis indicates that rankings are the most stable in Irvington case study (in 93% of instances rankings remain unaltered), while MOTBY showed the least stable rankings, but still quite satisfactory (in 88% of instances rankings remain unaltered).

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are reached as the result of the study:

- ☐ Analyzed innovative technologies have very good potential to be efficiently used for container transfer between port terminals and inland intermodal stations.
- ☐ CargoRail, an automated system with fixed guideway and rubber-tired vehicles, has the highest overall scores. Based on this, it can be considered the most promising of all tested technologies.
- ☐ All of the innovative technologies evaluated become more attractive as the container volume increases. There is a definite presence of economies of scale of traffic density wherein the unit cost will decrease as the result of an increase traffic volume on the route.
- ☐ The criteria weighting scheme has some impact on the ratings, however the scheme used in the analysis appears to yield robust results.

Research efforts following this study should concentrate on several aspects of implementation of innovative technologies for container transport:

- ☐ Look with some more detail into technical and economic characteristics and performance of innovative technologies. Lack of accurate and reliable information is probably the most sensitive part of this analysis.
- ☐ Extend the routes and analyze the characteristics of innovative freight transportation systems in longer haul.
- ☐ Develop a detailed analysis of actual applications for the most promising innovative technologies. This analysis should include optimization of operating regimes, simulation of system operations, and detailed cost analysis.
- ☐ Examine potential interactions between innovative technologies and existing and planned transportation improvement projects and initiatives in the region, such as Portway, Brownfields Redevelopment, Port Inland Distribution Network (PIDN) concept, etc.

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[1] Comprehensive Port Improvement Plan (CPIP) for the Port of NY and NJ is a project initiated by a team of Federal, State and local agencies to determine how best to plan for handling the region's future cargo volumes, while protecting the environment and being a good neighbor to the surrounding communities. It focuses on developments related to Ports of New York and New Jersey. More information on CPIP can be found on it’s website at http://www.cpiponline.org/.

[2] SWAP bodies are lightweight containers that are usually 23.6 feet long, 8.5 feet wide, and 9.5 feet high, used mostly in Europe but not used much in the US because of incompatibility with American cargo handling equipment. They have the added advantage of having their own “legs” which can be extended when not loaded on a chassis, thus freeing the chassis to haul other SWAP bodies.

[3] In each iteration all other criteria weights were also modified accordingly, so that total sum of weights remains 100. This is done by preserving the original ratios among criteria weights.