Innovative Transportation Technologies – an Alternative for Providing Linkages Between Port Terminals and Inland Freight Distribution Facilities

Authors:

Branislav Dimitrijevic, M.S.

Senior Transportation Engineer, International Intermodal Transportation Center,

New Jersey Institute of Technology, University Heights, Newark, NJ 07102,

Tel: (973) 596-6463, Fax: (973) 596-6454, E-mail: dimitrijevic@njit.edu

Lazar N. Spasovic, Ph.D.

Director, National Center for Transportation and Industrial Productivity,

New Jersey Institute of Technology, University Heights, Newark, NJ 07102,

Tel: (973) 642-7214, Fax: (973) 596-6454, E-mail: spasovic@njit.edu

ABSTRACT:

The projected growth in container traffic at ports of New York and New Jersey, along with the expected regional growth of commuter traffic, will cause a significant increase in traffic congestion. This will result in deteriorating performance of the regional transportation system, including highway system providing access to the port. Because of limited ability to expand highway and rail infrastructure in the vicinity of the port, application of innovative transportation

technologies presents an alternative for providing improved land access to principal port terminals and distribution facilities. This paper presents several innovative technologies that can be used to transport marine containers. The paper also describes a methodological framework for their evaluation and comparison with conventional modes applying a multi-criteria analysis approach that considers direct financial effects as well as external effects such as air pollution, congestion, land use disruption, socio-economic effects, and impacts on the transportation system performance. The methodology is illustrated using case studies in the New Jersey port region.

Need for innovative transportation alternatives for providing land access to port facilities

Port of New York and New Jersey is the largest port on the East Coast and the third largest port in the North America (after Port of Los Angeles and Port of Long Beach). The port is located in the heart of the most concentrated and richest consumer market in the world. It is also surrounded by highly urbanized, densely populated areas with little space to expand. At the same time port business has been steadily growing in the past five years and this trend is expected to continue in the future fueled by the increasing consumer demand and growth of import, mainly from Asian markets.

Containerized cargo is the fastest growing sector of port commerce. In 2004 Port of New York and New Jersey handled 2.62 million containers equivalent to 4.48 million TEU. This is more than double the volume handled ten years ago. If the market demand continues to grow in the years to come at the same pace, the port can expect to double today’s container business again by 2015.

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, and other regional transportation agencies, as well as port and rail operators, initiated a number of improvement projects designed to increase the port capacity.

The deepening of key shipping channels to 50 ft will enable the Ports to accommodate a new class of large post-Panamax ships. Many technological improvements have also been made inside the terminals including installation of large cranes with longer reach, introduction of modern cargo-handling equipment, vehicle and driver identification systems at the gates. In addition, terminal layouts have been redesigned to accommodate more containers on the same footprint. These improvements create efficiencies and enable port terminals to increase throughput and capacity.

While these projects focus primarily on improving waterborne access and terminal operations, there is a serious concern as to the ability of the existing regional highway and rail network to handle the anticipated increase in cargo moving through the port complex. Currently truck is the dominant transportation mode used to move containers in and out of the port - according to the Comprehensive Port Improvement Plan (CPIP)[1], 88% of the Port’s containers is transported by trucks. Approximately 12% is handled by rail, and relatively small number of containers is transported on barges via inland waterways (currently barge service to Albany on the Hudson River is the only active route). If we assume that the same mode split between truck and rail would be maintained in the future, it is clear that growing container traffic would place more pressure on already congested highway system in the port area. This will especially aggravate driving conditions and mobility during peak commuter hours when trucks share the road with growing automobile traffic. Furthermore, it will have a negative impact on urban communities along the major highway arteries in the area, as well as shipping industry that will have to deal with decreased velocity and reliability of cargo deliveries.

One of the solutions for this problem is to shift as much of future growth as possible to freight railroads. Port Authority of New York and New Jersey invested heavily in the past several years in improving on-dock and near-dock rail facilities. But in order to be effective these improvements will also require upgrades of the main freight rail lines: double tracking of the key routes, and raising clearances on certain segments of the network to allow for double-stacking. Most of these improvements would affect the container traffic with destinations that are located more than hundred miles inland. Some of the shipments and commodities that currently utilize trucks on those routes can be shifted to rail, but the fact is that most of the cargo handled by the PONYNJ stays in the tri-state area, which is less than a 100 miles radius. Unless a very efficient and fast short-haul rail service becomes available, most of that cargo will continue to move by truck. Hence, problems with congestion, air quality and overall quality of life are likely to get worse.

Bottom line is that we can expect the truck traffic to grow, both as a result of overall growth of fright traffic and growth of the port commerce. So, if conventional rail as an alternative is not enough, is there anything else that can be done to avoid these negative impacts which can put the economic development in jeopardy? An alternative that deserves consideration is implementing innovative transportation technologies and unconventional transportation modes that may have characteristics that conventional railroads do not have when operating on short distances. These new technologies could provide a viable alternative to existing rail and truck service by providing capacity to complement highway and rail network, not necessarily to compete with them. Furthermore, these technologies can do that in a sustainable way by providing landside access to distribution facilities that does not create conflict with commuter traffic, or truck and rail traffic. Many of the new transportation technologies are utilizing electricity for traction, thus reducing air pollution.

Interestingly enough, in addition to infrastructure improvements Port Authority and New Jersey Economic Development Authority recently completed a first phase of a project to identify brownfield and underutilized industrial sites in the port region and promote their redevelopment. The project called “The Portfields Initiative” also includes assistance to private developers, ocean and air freight shipping industry, and big retail companies, in developing modern warehousing and distribution facilities on these sites to support market opportunities emerging as the result of anticipated growth in trade. Due to lack of developable land in the vicinity of the port, most of the new, high-volume import distribution centers are built 20-40 miles away from the port along the I-95 corridor, a major north-south thoroughfare. Most of the “portfield” properties are near-dock sites in the radius of up to 8 miles from the port; if redeveloped they can significantly contribute to improving efficiency of port operations and reducing truck traffic on the local and regional highway network. These “opportunity sites” have a high potential of attracting developers and generating economic benefits for both industry and communities.

Development of “portfield” sites is closely connected with availability of access roads and other transportation infrastructure that would provide access to the distribution facilities to be built there. Some of the sites rely on existing road network that, as explained earlier, may become inefficient due to growing congestion. Innovative transportation technologies may be an important element in development of these sites by providing direct, fast, and efficient access to and from adjacent port facilities.

Review of the most promising innovative transportation technologies

A study conducted at the New Jersey Institute of Technology reviewed several innovative transportation technologies that could be used as an alternative to conventional transportation modes. In this paper we concentrate on several technologies that utilize fixed guideway that have the most potential for application in port-side development projects, based on the findings of this study. The review includes technologies 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.

Automation technology is being increasingly applied to rail systems, and innovative concepts incorporating automation into conventional systems have been developed and applied both in industrial and public transportation sector. **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. Siemens suggests that alternative traction systems, such as electric motors, and even emission-free fuel cell motors can be applied as well. The vehicle is fully automated, controlled by the central computer and directed by wireless communication. 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 the rail network.

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 of 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.

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 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 technology is designed to utilize the European Train Control System (ETCS) and GSM-R (Global System for Communications for Railways)[3] control and wireless systems. These systems are currently being deployed on several railway systems in Western Europe. CargoMover can also operate in conjunction with other train control systems. Siemens is currently testing several CargoMover vehicles.

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

Besides concepts that aim to use the existing railway network, there are numerous ideas and designs for novel transportation systems with dedicated fixed rail guideway. **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.

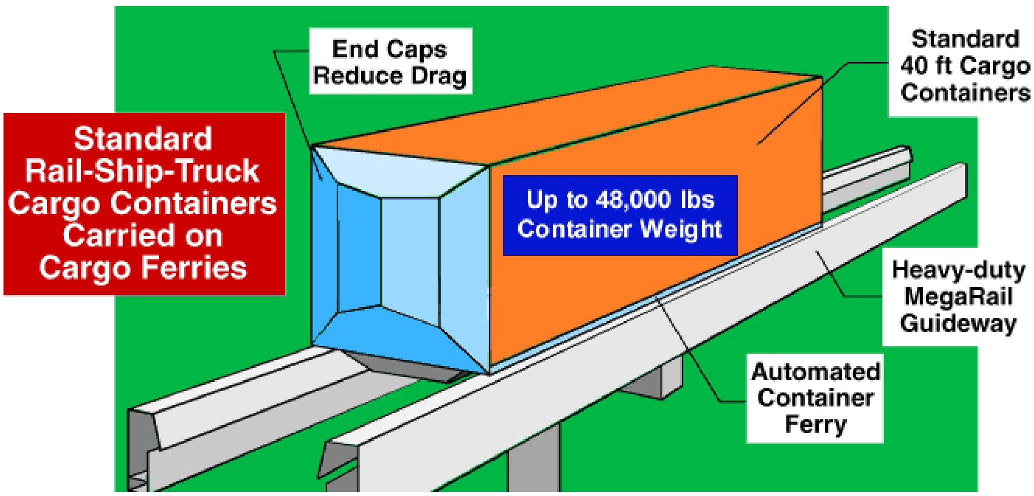

Figure 2. Schematic picture of the CargoRail "Freight Ferry" on the guideway (courtesy of MegaRail Transportation Systems, Inc.)

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.

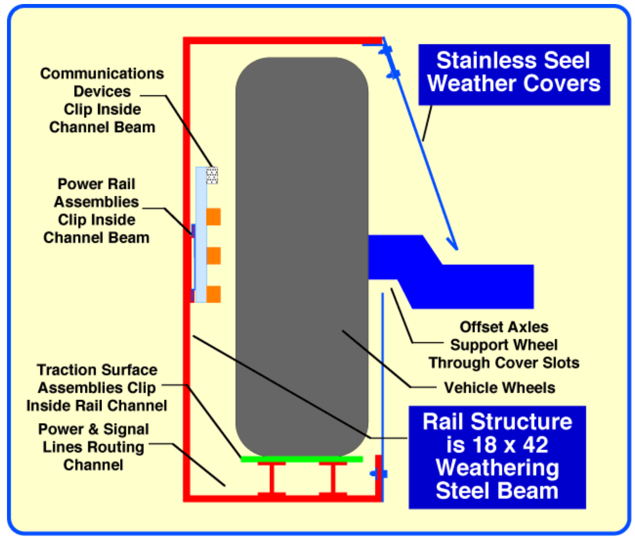

Figure 3. CargoRail enclosed guiderail and wheel (courtesy of MegaRail Transportation Systems, Inc.)

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 piers at the Port’s container terminals.

Monorail systems, similar to those employed for passenger travel, have the potential for being used for container transport. Monorail systems use a single rail as a guideway. In most cases, the rail is elevated, but monorails can also run at grade, below grade or in subway tunnels. Vehicles are either suspended below or straddle above a narrow guideway. Monorail vehicles are wider than the guideway that supports them.

There are many monorail systems currently in operation, but they are all used for various types of passenger transportation. As urban transit systems, they transport passengers between airport terminals (such as Newark’s Liberty International Airport), or visitors in the theme parks. No monorail has been built so far for freight transport.

Most monorail systems currently in operation have electric propulsion using conventional rotary motors. The suspension for most of those monorails is based on combination of vertical and horizontal pneumatic rubber tires on the concrete or steel beams as a guideway.

More advanced types of propulsion that can be used for guided vehicles, especially monorail systems, are **linear induction motors**. Linear induction motors utilize electromagnetic force to produce linear mechanical force, rather than torque as in typical rotary electric motors.

Vehicles that use linear induction motors can have contact with the guideway through the wheels, or they can levitate on the cushion of air between the primary and secondary magnets mounted on the guideway and vehicles. The latter is often referred to as “magnetic levitation” or **“maglev”** technology.

Because there is only one moving part in the motor with no mechanical linkages nor metal-to-metal contacts (thus no wear in the assembly), linear induction motors have much lower maintenance costs than conventional motors. In addition, they can run at much higher speeds. No contact between the vehicle and the guideway also provides for a smoother ride. These systems are conducive to urban environments for they do not require extensive amounts of land. Furthermore, monorail systems can be elevated above the existing facilities, using the medians of existing highways or right-of-ways. Systems that employ linear induction motors are also environmentally friendly as they generate very low noise and minimal air pollutant emissions.

Besides being widely used in manufacturing facilities for conveyors and assembly lines, on airports for baggage handling equipment, as well as in amusement parks, linear induction motors have already found their application in mass transit systems and other smaller people-mover systems. One of the first applications of linear induction motors was in Disneyworld in Orlando, Florida. This monorail system operates small trains that transport visitors of the theme park. Vehicles are propelled by linear induction motors and ride on rubber tires. A larger transit system utilizing technology of linear induction motors called Skytrain was built in Vancouver, Canada, in 1986 for the World Expo. The system is currently successfully operating close to 30 kilometers of track on two lines connecting 31 stations in the Vancouver area. Linear induction motors are also used in AirTrain vehicles at JFK International Airport, as well as in several other smaller scale people-mover systems in the United States, Europe and Japan.

Titan Global Technologies Ltd., a New Jersey based company, developed a unique and very promising freight monorail concept that utilizes linear induction motors called **Auto-GO**. Auto-GO is an overhead cargo container handling system for moving containers from port to other inland intermodal facilities, and vice-versa. The system consists of overhead guide rail and shuttles that carry containers.

Auto-GO shuttles are fully automated using linear induction magnetic propulsion. The transportation process would start inside the terminal where a gantry crane drops off the container. A cargo carrying system that is integrated with the carrying vehicle 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:

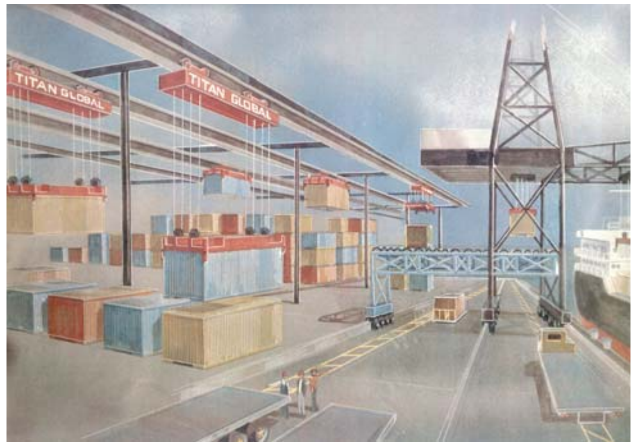

Figure 4. Auto-GO shuttles picking up containers (courtesy of Titan Global Technologies Ltd.)

- 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.

The technologies used in the 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.

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

The German based company *TransRapid* (a joint venture between Siemens and Thyssen-Krupp) has successfully launched its first maglev commercial project in Shanghai, China, with a promotional public ride on December 31st, 2002. This fully automated mass transit system runs between downtown Shanghai and Pudong International Airport, a 19 miles (30 km) long route. The top travel speed of the train is 265 mi/h (430 km/h), and the system is currently in full commercial operation with a fleet of three train units.

Figure 6. TransRapid train featuring cargo section (obtained from TransRapid website)

Maglev trains have not yet been tested for freight transportation, but TransRapid did consider transporting cargo onboard their maglev trains. In addition to passengers, trains could potentially carry high-value cargo in specially designed cargo sections (Figure 6). These could be used for dedicated high-speed cargo trains or added to passenger trains for mixed service. Special container sections could be used for high-speed freight transport.

Methodological framework for evaluation of innovative technologies

It is obvious that implementation of the new, innovative transportation technologies as an alternative to conventional transportation modes would require significant investments and financial commitment. At the same time, there are numerous projects on the table to improve and upgrade existing transportation infrastructure, providing more capacity in the transportation system and making it function more efficiently. Transportation authorities that are responsible for these projects of course have limited financial resources that can be used for this purpose and often have a hard time choosing the most important transportation projects that would be funded and implemented.

Transportation planners have, over the years, used an ever-increasing number of approaches to evaluate, measure impacts of, and compare different transportation projects that compete for scarce financial resources. Most widely used analytical method is the benefit/cost (B/C) analysis. This method estimates the ratio of benefits to costs by expressing all factors in monetary terms. While there exists a number of analytical tools that aid in monetizing the benefits of transportation policies, there are some impacts that are very difficult to quantify in terms of monetary value, such as congestion, safety, various environmental impacts, impacts on community and regional development, etc. These impacts are often referred to as “external” effects of the transportation activities, since they are not directly reflected in monetary costs and benefits resulting from project implementation. This may result in an incomplete rating of a particular project, which is the reason why B/C analysis should not be the sole method for determining whether a project or policy is worth pursuing.

Rastogi and McLeod (1995) give arguments on why pure economic analysis, based solely on costs and revenues or cost savings, can lead to selection of an alternative which doesn’t necessarily provide the most benefit. They argue that importance of external effects can sometimes be very significant, so that it could represent the major factor in the decision making process. However, external effects cannot be always expressed as dollar values and therefore are not always captured in the analysis based on monetary values.

Garrison and Ward (2000) emphasize the growing need for a comprehensive approach to transportation project evaluation and the decision making process. With current growth in population and traffic flows, problems in the transportation system appear to grow at a much faster rate. And the external effects, according to the authors, begin to emerge as major factors in the decision making process. They are particularly concerned with strategies of urban development, and the place that transportation has in this process. Obviously, issues like air pollution, noise, induced economic development, land use, energy conservation, etc., are greatly impacted by changes in the transportation system. That is why these factors must be considered when making decisions about investing in transportation improvement projects.

Inclusion of both direct and external factors is very important when it comes to evaluation of the innovative transportation technologies described earlier. Most of them require new infrastructure and include technologically advanced, automated vehicles that are usually more expensive than conventional vehicles. All this makes implementation of these technologies fairly expensive, usually more expensive than investing in improvements or upgrades of existing rail and highway infrastructure. Short term financial benefits of these innovative technologies, on the other hand, may not be high enough, from the fiscal perspective, to justify the investment. But if one looks at the longer term and includes external effects of implementing innovative technologies that result in benefits for communities and industry, while considering constraints for future development in terms of network capacity and land availability in urban areas, the underlying analysis may prove innovative technologies more desirable alternatives despite higher initial cost. The question is how can we include external factors in the analysis?

While attempts have been made at attaching monetary value to factors such as noise pollution, air pollution, safety, congestion, and other “externalities”, these factors may be more easily comprehended when presented using measures such as noise reduction (in decibels), air pollution reduction (in tons of pollutants), safety improvements (reduction in number of accidents), reduction in travel delay, etc. An alternative to B/C analysis, or better yet an addition to it, would be a method that could capture and evaluate both monetary and non-monetary "costs" and benefits using most appropriate measures. Multicriteria analysis is an approach that can be used to compensate the above stated disadvantages of the pure B/C analysis. This method allows planners to consider factors such as environmental impacts and safety impacts without attaching monetary value to them. In other words, it allows them to select the appropriate factors to evaluate transportation projects and compare their impacts across all of those factors, even when the measures of these factors are not the same, i.e. in monetary or non-monetary terms.

These models allow users to evaluate and assimilate various factors that don't necessarily need to be expressed in the same scale or measure. It is not necessary to convert changes in congestion, or air pollution, or noise to monetary values – they can all be evaluated and compared based on established value scales and weighting criteria. These models also allow for analysis and evaluation of investment alternatives over multiple objectives. In case of transportation these objectives can be to improve mobility, reduce cost of transportation, reduce travel times, improve air quality, induce economic development, reduce maintenance costs, etc. Some of the objectives can oppose each other, in which case one needs to consider trade-offs between these objectives when deciding about projects that need to be implemented. It is possible that in some cases one project is superior in meeting one objective, while it lags behind other projects in satisfying another objective. In a situation when one needs to choose among these projects multicriteria analysis provides for decision-making based on evaluation of the degree in which various projects meet all of the decision criteria, while considering decision makers preferences as to the importance of each particular criteria in the overall evaluation.

Objectives and performance measures are chosen based on the type of projects that are being considered. Many authors offer generic lists of possible objectives and performance measures that can be used for this purpose, and they are usually divided into several major categories, such as:

- ***financial impacts***, including: construction costs, maintenance costs, operation costs, revenues, increase or reduction of fares for transit systems, etc.
- ***socio-economic impacts***, including: land values, reduction of congestion, employment during and after project implementation, induced employment, etc.
- ***environmental impacts***, including: change in noise levels, change in vehicle emissions, change in land use, energy consumption, etc.
- ***system performance***, including: compatibility with existing system, increase in capacity, technology reliability, change in accident rates, etc.

Each alternative is evaluated on each performance measure. Grading scale or valuation functions need to be established for each performance measure. Note that measures can differ from one another in scales and in units. For example, financial impacts will be expressed in monetary terms, noise in decibels, safety in accident rates, and some of the measures would be qualitative, like compatibility with the existing system, which could be graded on the scale from high to low compatibility. Sometimes lack of accurate data can result in developing a descriptive grading scale even for those measures that could be quantified. Literature offers many approaches and methods for developing grading scales and valuation functions. One approach is to define a grading scale, assigning the highest grade to the highest observed value (upper bound) and the lowest grad to the lowest observed value (lower bound); another idea is to determine anchor points (upper and lower bound) that present the most and the least desirable outcome, or an interval that the decision maker is willing to consider, or the one that is based on some standards or expertise. Corresponding values on the established scale for other observed values would then be calculated using some functionality on the interval between the lower and upper bound. This functionality greatly depends on type of measure, but also on judgment of the decision maker, and can be presented as simple as a linear function, or more complicated functions based on special algorithms (Roop and Sondip, 1995; Goicoechea, Hansen, Duckstein, 1982).

Alternatives are compared and ranked based on the total score that combines scores for all of the participating criteria. The total score can be described as an overall index of project desirability. This index combines values for all of the criteria into a single value that will be used to rank the alternatives. In order to calculate this index, each criterion is assigned a weight that reflects its importance. Total scores are then calculated as the sum of products of individual criterion scores and their respective weights.

There are many weighting systems that can be used, but the final decision on which one will be applied is on the decision maker. Weights depend on the nature of the decision that is being made and are a result of decision makers preferences. Often weights are assigned rather arbitrary (Rastogi, McLeod, 1995). Roop and Sondip (1995) described several approaches to establishing weights, such as: standardized, reciprocal, rank sum weighting, ratio rating, and indifference trade-offs method. Explaining these methods is beyond the scope of this paper, but we encourage interested readers to learn more from the referenced literature.

Multicriteria analysis is usually presented in the form of a matrix. The matrix consists of a list of alternatives, list of criteria with performance measures, single-criterion scores for each criterion and each alternative, and total scores for each alternative. An example of an evaluation matrix is given in Table 1. The structure shown in the figure is not the only way to organize the information, but it gives a general idea of what the matrix should contain.

In the Table 1 evaluation of alternative i for the criterion j is denoted by $a_{i,j}$. Weight of the criterion j is denoted by w_j. As shown in the table, total score for alternative i is calculated as sum of products of alternative evaluations and corresponding criterion weights:

$$\sum_{k=1}^{15} a_{1,k} \cdot w_k$$

In the final step alternatives are ranked based on their total scores. Usually total scores are calculated in the number of iterations and sensitivity analysis is performed to analyze the impact of different weighting schemes on the final results. This is especially important in those cases where more than one interest group is identified, since different interests put different weights on criteria.

Table 1 Hypothetical multicriteria evaluation matrix

Criteria	Measure	Alternative 1	Alternative 2	. . . .	Alternative n	Weight*
SOCIO-ECONOMIC IMPACTS						
Land values	% increase in land value	$a_{1,1}$	$a_{2,1}$	. . . .	$a_{n,1}$	w_1
Employment due to construction work	person hours, or # of jobs per year	$a_{1,2}$	$a_{2,2}$	. . . .	$a_{n,2}$	w_2
Induced employment	# of created jobs	$a_{1,3}$	$a_{2,3}$	. . . .	$a_{n,3}$	w_3
Congestion	Reduction in VMTs or time/vehicle-mile, or in congestion cost	$a_{1,4}$	$a_{2,4}$	. . . .	$a_{n,4}$	w_4
ENVIRONMENTAL IMPACTS						
ROW land requirement	Total additional land required (in hectares)	$a_{1,5}$	$a_{2,5}$	. . . .	$a_{n,5}$	w_5
Air pollution	Quantity of each emission component produced or saved (in tons)	$a_{1,6}$	$a_{2,6}$	. . . .	$a_{n,6}$	w_6
Noise	Number of people / area exposed to excessive noise (e.g. 5dB or more)	$a_{1,7}$	$a_{2,7}$	. . . .	$a_{n,7}$	w_7
Energy	Energy consumption or savings	$a_{1,8}$	$a_{2,8}$	. . . .	$a_{n,8}$	w_8
FINANCIAL IMPACTS						
Capital cost	Cost of planning, design, land, and construction ($/year of operation)	$a_{1,9}$	$a_{2,9}$	. . . .	$a_{n,9}$	w_9
Annual operating cost (including maintenance cost)	$/ton-mile or $/pass-mile, or $/veh-mile	$a_{1,10}$	$a_{2,10}$	. . . .	$a_{n,10}$	w_{10}
Revenue	Revenue generated from the users of the innovative technology (in $)	$a_{1,11}$	$a_{2,11}$	. . . .	$a_{n,11}$	w_{11}
SYSTEM PERFORMANCE						
Capacity	Vehicles per day, or passengers per day, or tons per day	$a_{1,12}$	$a_{2,12}$	. . . .	$a_{n,12}$	w_{12}
Safety	Reduction in number of accidents or savings in accident cost	$a_{1,13}$	$a_{2,13}$	. . . .	$a_{n,13}$	w_{13}
Technology reliability	Estimated number of failures per 1000 hours of operation.	$a_{1,14}$	$a_{2,14}$	. . . .	$a_{n,14}$	w_{14}
Compatibility with existing system	Scale 1 - 5	$a_{1,15}$	$a_{2,15}$	. . . .	$a_{n,15}$	w_{15}
TOTAL SCORES		$\sum_{k=1}^{15} a_{1,k} \cdot w_k$	$\sum_{k=1}^{15} a_{2,k} \cdot w_k$	. . . .	$\sum_{k=1}^{15} a_{n,k} \cdot w_k$	

The framework and methodology presented here was illustrated in the study done at the New Jersey Institute of Technology. Innovative freight transportation technologies described in this paper were evaluated and compared to truck and rail service in several case studies in New York/New Jersey port region using multicriteria analysis. Each case study looked at the route between port terminals and envisioned inland industrial park or cluster of industrial and intermodal freight facilities. The objective was to evaluate each technology in providing transportation service between the port and these facilities for given freight (container) demand. The evaluation was conducted using B/C model, as well as multicriteria evaluation model that included factors such as cost of building/upgrading and operating the system, safety, travel time, reliability, intermodal compatibility and expandability of the system, environmental and ecological impacts and socio-economic impacts.

The results showed that pure B/C analysis favored upgrading rail and highway facilities for lower demand levels; however, with increase in demand economies of scale and higher efficiency of innovative technologies yielded lower unit costs for some of the advanced automated systems. In case of multicriteria analysis innovative technologies were more attractive on some routes even with minimum tested demand because of their positive external effects that offset the cost of building the new systems.

The results of the analysis are certainly subject to discussion about the weight structure that was applied to estimate individual importance of each criterion, as well as the choice of performance measures used to measure the impacts as they relate to each criterion. The analysis showed, however, that multicriteria analysis can be effectively utilized to ascertain impacts of investment projects that are not included in the traditional B/C model.

Conclusions

The motivation for this paper was the need to develop strategies to accommodate the growing port traffic at the Ports of New York and New Jersey on the regional transportation network, enabling the regional economy to take full advantage of this growth. The volumes of containerized goods at this port complex are expected to grow in the years to come, but the ability to expand the existing highway and rail network to support this growth is very limited in urbanized and densely populated area surrounding the port. Therefore, the capacity of the transportation network can effectively be increased by improving efficiency of the transportation process, or by implementing innovative transportation concepts as an alternative to conventional rail and truck service. In areas with high traffic congestion and increased air pollution due to heavy truck traffic, these concepts can provide more efficient and fast access to portside industrial parks, warehousing and distribution facilities, helping to reduce congestion on local and regional highways, and improving air quality by implementing cleaner technologies.

Presented technologies include several automated guided systems that can be used for this purpose and complement truck and rail for providing transportation service to industrial facilities on short distances from the port. Some systems are in design or conceptual phase, although they utilize propulsion, automation, and guidance technologies that have been tested and proven in practice (CargoRail and Auto-Go) but mostly for people-movers; others, like CargoMover, are currently undergoing commercial testing.

Innovative technologies are often associated with high costs, especially when it is required to construct a new infrastructure and purchase new vehicles with high level of automation. High costs present an obstacle to implementation of these new technologies because they have to compete with other transportation improvement projects for the same scarce investment funds. Financial benefits of implementing these innovative technologies, on the other hand, do not always offset high costs. However, besides financial, these technologies generate other benefits, such as reduction in congestion on the regional highway network, reduction of air emissions, improved travel times, improved access to industrial parks, etc. It is therefore important to consider all of these benefits when making decision about prioritizing investment alternatives determining their feasibility. In this paper multicriteria evaluation approach was described as one solution that meets this requirement and can be applied in the analysis.

Although the discussion in the paper was motivated by the current and future developments in the Port of New York and New Jersey, it is clear that it can be applied to any other similar port complex. Many other ports in the U.S. and worldwide face problems such as congested highways, lack of space for expansion of port and highway facilities, and increasing air pollution due to the growth of truck traffic, especially if trucks are forced to idle while waiting in lines at the port terminal gates. Presented innovative technologies can address these issues; they can help support the growth of port commerce, and alleviate negative impacts associated with increased demand on highway system. That is why they should be considered as an alternative when planning future development of ports and related freight handling facilities.

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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] More details about ETCS and GSM_R deployment can be found at project websites at: http://etcs.uic.asso.fr/ and http://gsm-r.uic.asso.fr/.