Executive Summary

Ports and the associated freight transport network are fundamental to the supply chain of goods. Ports however are major source of pollution while trucks serving the ports and intermodal facilities have a detrimental effect on traffic congestion which is also another source of pollution. The cost of congestion and pollution is enormous both financially as well as health wise.

With the expected increase of population in urban areas and the rising volume in international trade, congestion will worsen and pollution will increase unless drastic measures are taken.

The small steps usually taken such as adding more capacity on the road network, improving diesel engine combustion to be cleaner etc. are unlikely to catch up with the impact the increase in volume of freight will have. The most optimistic result with small changes is for pollution and congestion increasing at possibly lower rates than without these changes. While these smaller steps may ease political pressure for a cleaner environment in the near term, in the long term the situation will get worse. What is really needed is a new approach that puts efficiency and the environment as top priority.

The purpose of this study is to assess the feasibility of a new concept referred to as Green Rail Intelligent Development (GRID) and the GRID SuperDock. In this concept, containers are loaded/unloaded by a very efficient facility referred to as SuperDock which interfaces directly
with the ships and also serves as temporary container storage. The containers are then transported underground via specially made water pipe like tunnels to intermodal hubs to be served by trucks by using electrified rail. GRID will eliminate thousands of truck trips to the port and will cut down truck travel miles considerably. The number of trucks on the road network will be highly reduced alleviating congestion and cutting down on pollution. The GRID concept is designed to work by taking into account all mechanical and energy issues associated with loading/unloading containers. The next step is to perform an extensive evaluation of the performance of the system, its cost in terms of capital to build and maintain, and environmental impact in comparison with the existing multimodal system. To achieve this elaborate task we propose to build a microscopic simulation model of the GRID system including the SuperDock and associated freight transportation network as well as a cost model. The microscopic simulator will simulate all parts of the system in great detail in order to assess the performance of the system under different demand levels, under normal and emergency situations where certain parts of the system may break down as well as its interface with intermodal hubs, ships, ordinary rail and trucks. The cost model will take into account all relevant construction cost, maintenance, power, labor etc. in order to assess the cost of moving containers through the port using the SuperDock and compare with the cost of current equivalent operations. A vehicle emissions model will be used to assess the impact of GRID on the environment by calculating the reduction in fuel consumption and pollution due to the reduction of truck trips. This simulation study will demonstrate the size of the benefits that are expected from the GRID under all possible operating conditions. A constructability study will focus on pipeline specifications and constructability in relation to all topographical and sub-terrain conditions along potential pipeline routes.

For the region of Southern California the GRID concept is of significant importance. It offers an opportunity to bring a project of a national significance to the region. It will greatly improve surface traffic congestion and safety on southern section of 710 freeway and have a great impact on the environment. In addition it offers a strong potential for private financing and investments in the region that will lead to many jobs and a revived local economy.

The Center for Advanced Transportation Technologies (CATT) have worked on similar advanced technology concepts and automation and developed expertise and the appropriate simulation, optimization, performance and cost evaluation tools for intelligent transportation
systems such as the GRID. CATT can provide an unbiased evaluation of systems such as GRID by using its experience with similar systems. For these reasons CATT researchers are ready to partner with transportation authorities and regional stakeholders to perform an unbiased evaluation of GRID by first developing an elaborate microscopic simulation of the GRID system and SuperDock and then exercise the model using if scenarios and different operating conditions.
1. Introduction

Globalization and rapid economic growth have vastly increased the volume of commodity flows in all transport modes. It is anticipated that the growth in containerized trade will continue as more and more cargo is transferred from break-bulk to containers. Every major port in the US is expected to double its container traffic by 2020 even though the recent economic recession modified some of these estimates. The largest container ships operating today have a capacity of about 11,000 TEUs. 18,000 TEU-range vessels will be coming on line within the next few years. The rapid escalation in vessel size is ahead of schedule. Larger capacity ships have influenced shipping patterns, concentrating volumes at those locations with sufficiently deep channels and terminal capacity to serve large ships.

Container terminals in most metropolitan areas and areas where land is very scarce have to make significant changes in order to keep pace with increasing demand under environmental, road network congestion, labor force, land costs and other constraints. The choices are limited and include the following:

**Expand port land where possible and cost effective.** A traditional way of adding capacity but not always feasible due to scarcity and/or cost of land and political opposition

**Move cargo from trucks to rail.** This is a trend that is expected to continue even though trains are reaching their capacity too.

**Automated Container Terminals (ACT):** Automated container terminals are one way of improving productivity and increasing capacity while cutting labor cost, without the use of additional land. While a few automated container terminals have been operating overseas for some years, the concept is not spreading rapidly. Furthermore how an ACT will interact with the rest of the supply chain has not been adequately addressed. A highly efficient ACT has to be served efficiently too otherwise a bottle neck will be created that will reduce the benefits of automation.

**Inland Ports:** Inland ports, intermodal hubs, logistic centers, dry ports etc. are some of the names used to identify facilities away from marine terminals that process cargo in order to
reduce congestion at the ports. Inland ports serve as an opportunity for direct links with seaports using zero emissions container transport systems bypassing the use of the roadway network.

**Environmental-related technologies:** The environment is on the agenda of most government departments, ports, local communities and many non-profit organizations. While most immediate efforts focus on cleaner trucks and equipment and ways to reduce ship pollution at the terminals, several more revolutionary concepts developed by different innovators over the recent years are still alive even though none of them has been implemented yet. These concepts are mostly based on fixed guideway systems using magnetic field to hover containers over air gaps and linear motors or electricity to move them along the guideway. The gate appointment system is also viewed as a way to reduce pollution by having trucks avoid peak hours and reduce idling by waiting at the gates. The performance of several zero emission container transport systems have not been analyzed when used in the supply chain under different volume demands. Some of them assume a high container volume to justify their cost and effectiveness.

**Los Angeles/Long Beach Port Environment**

As the fifth largest container port complex on Earth, the San Pedro Bay combined ports of Los Angeles and Long Beach exert a certain influence on ports and related logistics sectors throughout the continent. The amount of trade-related activity LA and Long Beach draw to the West Coast provides a critical mass of actors who help to shape the development and adoption of technologies for the port sector.

LA/LB exhibits scale economies in international shipping, has a large local consumer market, offers good connections to the US national market as well as an extensive network of supporting industries. Its role as a gateway has been further defined as a result of the tremendous growth in trade from Asia. Because of its proximity to Asian production centers, California in general, and the Los Angeles region in particular, has accommodated a large share of this growth. This growth has created a demand for technologies that improve system capacity and make supply chain operations more efficient.

The rapid growth in trade has come with an increasing awareness on the part of local communities of the negative environmental impacts of that growth. This has also created a
demand for technology-based responses. Elected officials, particularly at the State level, have responded on their part with a series of legislative measures designed to bring about changes in the way the supply chain in general, and ports in particular, operate. Environmental lawsuits were pursued with the same outcome in mind.

The success of policy measures and court action – and sometimes merely the threat of the same – has played a critical role in encouraging the port and logistics sector to become environmental innovators. In addition, the presence of a vibrant research community provides a test bed for many port-driven innovations.

The LA/LB port complex is a natural place for innovation as this is where some of the most serious problems associated with multimodal freight transport are located. Due to political pressures to reduce emissions and traffic congestion in and around the twin Ports of Long Beach and Los Angeles, the Ports and the Alameda Corridor Transportation Authority (ACTA) have been seeking new, non-polluting technologies to move containers between the marine terminals and an intermodal rail yard next to West Long Beach. As a result a Request for Concepts and Solutions (RFCS) for a Zero Emission Container Mover System (ZECMS) was issued in June of 2009 with a deadline for response October 23, 2009. Seven concepts have been proposed and came from the following corporations:

- American Maglev Technology of Florida Inc.
- Bombardier
- Flight Rail Corp.
- Freight Shuttle Partners
- Innovative Transportation Systems Corp.
- Magna Force Inc.
- Tetra Tech Inc.

The ports, ACTA and independent experts including the University of Southern California (USC) Keston Institute for Public Finance and Infrastructure Policy evaluated the proposals in 2010.

Some of the key requirements for the proposed systems indicated in the RFCS were:
• The proposed system is not intended to either diminish or replace on-dock rail loadings.
• The system would still need to compete financially with drayage i.e. the Ports will not ban the use of trucks to the near-dock rail yards
• Respondents should assume the responsibility for the costs of all non-port, private right-of-way (including terminal leaseholds).
• Respondents should assume that this would be a stand-alone project i.e. one that would be financed without contribution or subsidy by the Ports or ACTA.

The above requirements put a lot of pressure on the proposers as most if not all of the automated container transport concepts are based on high container volume demand to justify the cost. If they have to compete with existing facilities, that means the demand would be shared increasing the uncertainty for success. The requirements also make it clear that the financing of the system will not be the responsibility of the Ports or ACTA and there is no indication anywhere that the local government will finance any of the projects either. For these reasons the proposers have to assume that the financing will be done solely by the private sector. The conclusions of the review were the following:
• Even though a ZECMS appears to be technologically feasible none of the systems proposed are sufficiently mature to commit to a full-scale operational deployment at this time; additional testing that simulates port environment is needed;
• A full understanding of port duty cycles was absent from all responses none of the submissions adequately address the risks of insufficient market demand.
• Technology and financial risk cannot be fully evaluated until the robustness and reliability of the systems have been demonstrated.
• Given best case assumptions regarding growth in container volume, market share, capital costs, and system availability, absent other drivers (e.g., environmental regulations and/or a subsidy provided by Ports or others), ZECMS will have difficulty competing economically with conventional truck drayage
• Great variation in submissions for assumptions regarding construction, terminal right-of-way, and other costs.
• None of the respondents have shown that they can deliver a reliable and financially sustainable ZECMS at no cost to the Ports.

The above conclusions indicate that a ZECMS operating in a Port environment is at its infancy. From the technical point of view more work is required to demonstrate the reliability and robustness of the system in a port environment.

The purpose of this project is to study the feasibility of a new ZECMS by not only looking at the system itself and its cost but also how it operates and performs in a Port environment and more important as part of the supply chain in a multimodal transportation system.

2. GRID Concept

GRID (“Green Rail, Intelligent Development”) and the GRID SuperDock [1]: At the 2007 METRANS Conference in Long Beach, California, David Alba and Jack Hogue of SkyStorage Systems Inc. presented a container terminal designed primarily to store empty containers to consolidate storage at ports. Four years later, this system has been further developed into a total logistic solution for the transfer of containers (loaded or unloaded) from ships to trains to trucks, that completely redesigns and reconfigures the forty year old logistics model still in use today. The concept involves the development of a Super Dock for ship to rail operations at the ports and an underground pipeline for fully automated electric cargo trains that will transport cargo inland to various mini inland ports for further processing and transport to nearby destinations by trucks. The concept is developed for application to the Ports of LA/LB. 

![Figure 1 Grid SuperDock](image)
The SuperDock converts the space under shipping cranes into a computerized storage facility for empty and loaded containers as shown in Figure 1. Containers are moved to and from ships directly into the SuperDock. Full-length trains drive under or adjacent to the facility to be loaded or unloaded within the Port, (see Figure 2) so there is no intermediate shuffling of containers to off-site container transfer facilities to assemble trains for transport beyond Southern California. According to the designers of the system unloading and reloading time for cross-country trains can be reduced from 36 to less than 4 hours, at a lower total cost than today’s port facilities. An underground powered rail “container conveyor” freight pipeline is proposed to run from the SuperDock to inland rail hubs connected to existing warehousing and trans-loading areas of the Inland Empire, central California and beyond (see Figure 3). This pipeline would move containers using clean electricity, drastically reducing diesel fume emissions and congestion due to reduction of truck traffic in the roadway network. Portions of the lower I-710
freeway, Los Angeles, Rio Hondo, and San Gabriel River beds were identified by the designers as the ideal right-of-way locations for an unobstructed “container conveyor” freight pipeline. The proximity to power lines which can also go underground avoiding the urban blight of high-voltage transmission towers, offers another opportunity to free thousands of acres currently occupied by power line rights-of-way. By going underground issues such as right of way, noise and impact to neighborhoods are avoided. Another opportunity the designers see is that the approval of GRID will obviate the need for each railroad’s independent new container transfer facilities, planned Ports upgrades, the widening of I-710, and could serve as an alternate version of the recently proposed East/West Freight Corridor. Ultimately if GRID were adopted, savings from the $15B to $23B estimated cost for those projects can be applied as funding for some form of public-private partnership. However, according to GRID designers and their conversations/impressions from business leaders, they believe project costs could largely come from private sector interests leading to significant savings in public financing. According to the designers the total cost for GRID is as economically feasible as existing proposals that expand and exacerbate the problems they attempt to resolve. The underground pipeline is expected to be cost effective and already a construction company specializing in large underground water pipes and crane manufacturing is ready to take up the project provided clarity on project demand coming from the region’s key leadership and decision making apparatus at local, state, and federal levels emerge to become strongly evident. In addition, the Sierra Club endorsed the system as environmentally friendly.

While some of the benefits are obvious to the inventors of the concept, proceeding to implementation is not an easy decision without considerable in depth evaluation of the system itself but also its interactions with the rest of the supply chain. Technical feasibility of operation, performance under different operating conditions and container volume demand during normal and emergency situations, cost of development and operation, environmental benefits etc are
some of the major issues that need to be addressed. Computer simulations offer a powerful low cost tool to evaluate and transportation concept without disturbing current operations and consider many if scenarios.

3. Proposed Investigations

Task 1: Microscopic Simulation Evaluation

A microscopic simulation model of the SuperDock and associated transport network will be developed. The simulator will simulate the movement and dynamics of each piece of equipment, such as loading/unloading equipment shuttles, in time and space and their interactions with ships, intermodal hubs etc. The simulator will be used to examine the following:

- Performance under different container volume demands
- Identify possible bottle necks
- Evaluate impact of equipment break out or maintenance cycles
- Evaluate impact of interactions due to delays, randomness
- Use the simulator and optimization tools to optimize operations
- Compare performance of the proposed system with current operations
- Run any if scenarios any user may come up with associated with the system

Task 2: Cost Evaluation Model

Costs associated with container handling and storage operations within a terminal can be classified into the following three categories:

- **Cost of activities:** that is the costs of locations where activities (operations) take place i.e. buildings and facilities such as gates, customs, etc.

- **Cost of land:** the capital investment for land in different areas, e.g. berth area, storage area, etc.

- **Cost of equipment**, the cost of yard equipment e.g. yard cranes, quay cranes, AGVs, etc.

- **Labor costs.**
Currently a cost model for container terminals has been used to evaluate several terminal concepts. This model written in C++ will be modified to apply to the SuprDock facility in order to generate various cost estimates that will also include an average cost to move a container through the facility. Since cost is related to the volume of containers handled the cost model will be integrated with the microscopic simulator which will be generating the volume of containers handled under different operating scenarios.

**Task 3: Impact on Congestion and Environment**

The GRID system is expected to reduce the number of trucks on the road network. Under this task we plan to use a microscopic traffic simulator that simulates traffic on a large network adjacent to the complex port of LA/LB together with a vehicle emission model to assess the benefits with respect to traffic congestion and environment the GRID system will bring. The traffic simulator and vehicle emission model are already built and available to use to evaluate different traffic scenarios that will result from the use of the GRID system.

**Task 4: Freight Pipeline Constructability**

Another goal of the study is to analyze the constructability of the freight pipeline. Aspects to be reviewed include but are not limited to installation process for the pipe wall, (i.e., segmented tunnel liners, jacked pipe, or cut-and-cover pipe), joint requirements, seismic and fault crossing design, and review of stabilization of native soils for repeated loadings from drone trains, plus installation procedures for track and linear electric motors.

**Estimated Budget**

The estimated budget for performing Tasks 1-3 is about $700,000 and is calculated as follows:

- Task 1 Estimated Cost $400K
- Task 2 Estimated Cost $100K
- Task 3 Estimated Cost $100K
- Task 4 Estimated Cost $100K
Curriculum Vitae – Petros A. Ioannou

Professional Preparation

- University of London, London, England; Mechanical Engineering; B.Sc. First Class Honors, 1978
- University of Illinois, Urbana, Illinois; Mechanical Engineering; MS, 1980
- University of Illinois, Urbana, Illinois; Electrical Engineering; Ph.D., 1983

Appointments

- 1982 to present University of Southern California (USC), Professor of Electrical Engineering Systems and Aerospace and Mechanical Engineering
- 2011 to present Joint Appointment with Industrial Engineering and Systems Department
- 1992 to present Director for the Center for Advanced Transportation Technologies at USC
- 2006 to present Associate Director for Research of the University Transportation Center METRANS,
- 2010 to present Adjunct Professor University of Cyprus,
- 2008-present Director of the Masters Program in Financial Engineering at USC
- 1995-1996 Dean of the School of Pure and Applied Science at the University of Cyprus

Ten Most Relevant Publications


Synergistic Activities and Awards

- **2008 IEEE ITSS Outstanding ITS Application Award**, June 2009
- **2009 IET Heaviside Medal for Achievement in Control**, November 2009
- **Fellow of the Institution of Engineering and Technology (IET), since 2009**
- **Fellow of the Institute of Electrical and Electronic Engineers (IEEE) since 1992**
- **Fellow of the International Federation of Automatic Control (IFAC) since 2006**
- **Presidential Young Investigator Award** in 1985
- **Best Research Paper Award** by the IEEE Control System Society in 1984.
Established the Center for Advanced Transportation Technologies at the University of Southern California in 1992 and directed the center from 1992 to today

Author of 8 books and more than 200 papers in the area of Control Systems, Dynamics and Transportation

Rated as the 2nd most productive author and the 6th most cited author in the IEEE Transactions on ITS (see study in, L. Li et.al. IEEE Trans. on ITS vol.11, no.2, June 2010 pp 251-255)

Supervised and graduated 29 Ph.D. (4 from underrepresented groups) students, supervised 6 Postdoctoral Students (2 from underrepresented groups). Four of the former PhD students are Fellows of IEEE and 11 are Professors.

Served as Associate Editor of IEEE Trans. on Automatic Control, Automatica, International Journal of Control and IEEE Transactions on Intelligent Transportation Systems (ITS) and Associate Editor at Large of the IEEE Trans. on Automatic Control.

Organizer and National Organizing Committee Chair 12th IFAC Symposium on Transportation Systems, September 2-4, 2009

Organizer and General Chair of the 2008 International Trade and Freight Transportation Conference, September 1-3, 2008, Ayia Napa, Cyprus

Technical Program Chair of the 2007 IEEE Intelligent Vehicles Symposium, June 13-15, 2007, Istanbul, Turkey

Organizer and Program Chair of the International Conference on Intelligent Systems And Computing: Theory And Applications (ISYC), July 6-7, 2006, Ayia Napa, Cyprus

Technical Program Chair of the 2nd Annual National Urban Freight Conference, Dec. 5-7, 2007

Chairman of the IFAC Technical Committee on Transportation Systems, 2005 to 2008

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