Brief Introduction to CCDoTT and the Electric Container Conveyor System (ECCO)

CCDoTT is the Center for the Deployment of Transportation Technologies, a chartered center at CSULB dedicated to advance technology development relating to Maritime transportation and cargo. Through a partnership with commercial, military, government and academic experts, we have conducted over 150 projects, leading the CSU system for federally funded projects. We are unique in that we focus on Dual-Use Military and Commercial technologies, exploiting the developments in both areas to the advantage of the transportation system as a whole. We have been involved with the Agile Port System Concept since 1995 when we wrote the Operational Concept Document for the U. S Transportation Command on High Speed Sealift and Agile Ports. The term "Agile Ports" essentially came into common usage from this document and CCDoTT has been working on projects relating to the movement of cargo through "Agile Ports" since that time.

Early on we recognized the potential of freight corridors and remote port sites although initially they were called Intermodal Interface Centers (IIC) that served to organize cargo flowing out of and into ports for more efficient handling at the terminal. Numerous studies in the Pacific Northwest, were focused on Remote Ports (IICs) and how best to select sites and best utilize them. The recent announcement of the development of a remote port to serve the Seattle/Tacoma area is a direct outgrowth of those efforts. The Agile Port Systems Concept was initially tested in 2003 with an actual demonstration conducted resulting in throughput increases of 140% to 300%. This particular approach incorporated On-Dock Rail concepts beginning to be accepted in our local ports. The full APS concept demonstration is planned for later this year involving the Port of Tacoma and Fort Lewis.

This above background information is provided to establish CCDoTT credibility in cases where people are unfamiliar with us. We prefer to work in the background without much publicity, develop and apply technology to a specific task and hand off that technology to an end user for the final exploitation of the technology. CCDoTT is looking for workable solutions and as a University Center, we endeavor to maintain neutrality in the process. The results should speak for themselves.

This brings us to the ECCO System. Nearly all the Agile Port Concepts we have worked with over the years are dependent on a dedicated freight corridor to connect the Information Technology improved efficiency of a terminal with the organizational capability of an Intermodal Interface Center or Remote Port located on readily available, expanded and significantly cheaper land. All of the models utilized rail as the dedicated corridor. We became concerned that at some point rail would not be able to keep up with the ever expanding requirements of container throughput. What other options are there? Expansion of truck requirements ran headlong into environmental and congestion. Current fixes expand the same technologies that caused the problem and add the cost of mitigation and probably litigation as well. To avoid that quagmire, advance technologies seem to provide the only SOLUTION - solution being something that meets the economic needs (container throughput) and the quality of life/environment requirements without further mitigation. ECCO is a system that evolved out of our search to find a technology that meets the competing requirements. We applied over 3 years and $1.5 million of CCDoTT project funds to determine the feasibility of using Maglev Technology as a cargo mover in a dedicated freight corridor. Our presentation is the result of that effort. We very much appreciate the opportunity and look forward to your questions.

Presenting:
Dr. Ken James, CSULB College of Engineering, ECCO Principal Investigator
Steve Hinds, CCDoTT Program Administrator
Ed Thicksten, CCDoTT Chief Consultant
Leo Rodriguez, Senior Research Fellow, CSULB

Contact:

Steven M. Hinds
CCDOTT Program Administrator
6300 State University Drive, Suite 220
Long Beach, California 90807
Phone # 562.985.2259
e-mail shinds@csulb.edu

CDDoTT Website ccdott.org
ECCO Document Repository edms.engr.csulb.edu/public

CSULB ECCO System

World's First ECCO Container Move, San Diego, 6/15/06

Center for the Commercial Deployment of Transportation Technologies

California State Dept. of Transportation- Division of Planning - Senior Forum

October 29th, 2007

CSULB ECCO

Growth in Port Throughput is an Economic Issue

- **Port Growth Provides Regional Economic Prosperity**
  - **1 Out of 12 Local Jobs are Directly Related to the Port of LA/LB**
  - **843,111**
  - **Over ~~half-million~~ Jobs Indirectly Related to Ports**
  - ~~**Port Growth Continues to Produce Good Paying Logistics Jobs While Supporting Southern California Manufacturing Base**~~

    Jobs Increased by 200% 1994-2005
  - ~~**State and Regional Governments Derive Significant Income From Port Operations**~~

    Generated 6.4 Billion in State and Local Taxes
- **Near Half the Nation's Imports Pass Through the Ports of LA/LB (Adds Pollution and Congestion)**

Total Value of Containerized Trade through ports of LA/LB 2005

2

CSULB ECCO

ECCO is an OVERALL Solution to Southern California Cargo Movement, not a Temporary "FIX"

- **Sufficient Throughput Capacity to Accommodate Port Volume through 2035**
- **Removes Diesel Pollution (DPEs)—Exploits Renewable Energy to Eliminate all Pollution**
- **Relieves Most Congestion with Least Impact on Existing Transportation Infrastructure**

3

CSULB ECCO

Total Long Term Solution to Pollution / Congestion / Throughput

ECCO Moves Transcontinental Containers From Ports to Class 1 Rail Terminals at Victorville & Beaumont

~~Alameda Corridor East~~

~~Freeway Expansion~~

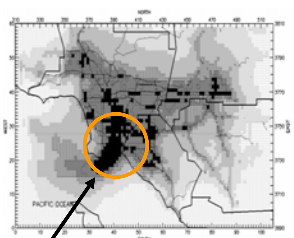
Clean Trucks: Local Deliveries to Commercial & Industrial Customers in LA Basin.

Electrified Rail Shuttle Trains to Inland Empire Transshipment Facilities

4

CSULB ECCO

Growth in Port Throughput is a Health and Safety Issue



According to Participants of Town-Hall Meetings, Diesel Particulate Emissions (DPEs) Produce a "Death Zone"

5

CSULB ECCO

Children Should Not Have to Pay the Excessive Environmental Cost of Traditional Transportation

Click on video to play

6

ECCO Significantly Reduces Pollutants and Can Be Powered by Renewable Energy Sources

OR

OR **ZERO** Pollution Wind &Solar

PM_{30} 78 tons/year
NO_x 1572 tons/year

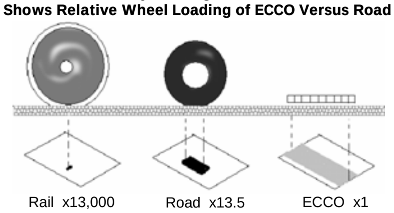
PM_{30} 0 tons/year
NO_x 39 tons/year

Environmental Cost of Draying 1.8 Million Containers vs. "ECCOing" 1.8 Million Containers

7

"No Wheels" is ECCO's Major Benefit Over Road and Rail

- **Replaces Wheels with Arrays of Magnets for Realistic Guideway Elevation (Sketch Shows Relative Wheel Loading of ECCO Versus Road and Rail)**



- **Small Footprint Produces Many options for Rights-of-Way in Congested Urban Areas. Able to Climb 10% Grades (Cajon Pass)**
- **Computer Controlled and Elevated for Container Security**

8

Motor Moved Off the Carriage and into the Guideway

Click on video to play

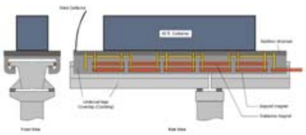
- **Uses Levitation Magnets for Linear Synchronous Motor (LSM) Traction**
  - **Allows for Many "Passive" Carriages on a "Active" Guideway**
  - **Guideway is the Motor and Activated Only When Carriage is Present—Saves Energy**
  - **No Need for Dangerous "Third Rail" Power Pickup or Overhead Wires**
- **Utilizes Existing Rail Load/Off-Load Equipment, Processes, and Labor Crews**

9

Background to ECCO Solution 2005/2006

2005

- **Years of Public Transportation Proposals Leave Public Impression that "Maglev Costs Too Much"**
- **European Approach Requires Tight Tolerances Requiring Expensive Guideways**
- **CCDoTT Contracted with TransRapid to Determine Maglev Container Feasibility**



2006

- **Innovations in Material and Design Lead to "American" Technology**
  - **Invented in Lawrence Livermore Labs**
  - **Reduced to Practice by General Atomics**
- **Relaxed Guideway Tolerances reduce Freight System costs**

Click on video to play

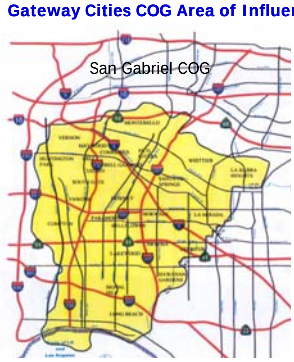
10

Team Building 2007

- CSULB will partner with Gateway City Council of Governments (COG) on Investigating and Recommending Alternate Technologies and Freight Corridors.
  - *Conceptualized a Separate Freight Movement Corridor for ECCO Using Utility Rights-of-Way.*
  - *Co-Sponsoring Envisioning Workshop for Southern California Freight Corridors with Gateway Cities COG*
- Coordinating with SCAG's Maglev Task Force on Regional Transportation Plan
- CCDoTT and IBI will Partner in Future Assessment Programs on Technology Proposals and other Government Transportation Agencies
- Commissioned a Proposal From BEC on their GRID application to Support ECCO Load/Unload

11

Gateway Cities COG Area of Influence



12

CSULB ECCO

Principles to be adopted by GATEWAY CITIES COUNCIL OF GOVERNMENTS SR-91/I-605/I-405 Corridor Cities Committee

- **Confine New Freeway Construction (Including Adding Lanes) to Existing State Right-of-way in Order to Preserve and Enhance Local Economies and Environments.**
  - Address Freeway Operational Deficiencies, Relieve Freeway Congestion “Hot-spots” and Decrease the Impact of Truck Bypass Traffic on Communities as Soon as Possible.
  - Secure Funding for Major Corridor Studies and Improvements as Soon as Possible Without Affecting the Funding for the I-5 or I-710 Freeway Improvements
- **Support a Separate Freight Movement Corridor Provided it is Evaluated and Constructed Along Non-freeway (E.G., Rail Or Utility) Alignments Using Minimally or Non-polluting Technologies.**
  - Implement Additional Intelligent Transportation Systems (Its) Improvements in the Sr-91/I-605/I-405 Corridor and Advocate a Broader Regional Approach to Support this Initiative.
  - Continue Metro/Octa/Gccog Inter-County Transportation Planning Efforts.
  - Collaborate with Sgvcog to Engage Metro in Immediate Development of Los Angeles County Goods Movement Strategy.
- **Aggressively Advocate with all Responsible Agencies to Preserve and Enhance Health and Quality of Life in the Corridor.**
  - Engage Corridor Cities in an Ongoing Process of City Consultation and Interactive Communication.

CSULB ECCO

Federal Rail Safety Act Amendment, October 2007

Amendment to H.R. 2095, as Reported Offered By Mr. Rohrabacher of California

Page 12, line 16, insert the following new paragraph before the close quotation mark:

“(5) Of the amounts appropriated to the Secretary pursuant to paragraph (1) for each of the fiscal years 2008 through 2011, such sums as may be necessary shall be available to design and develop a pilot electric cargo conveyor system for the transportation of containers from ports to depots outside of urban areas. .”.

the Amendment Passed with the Bi-partisan Support of Rep. Laura Richardson (D-CA), who Replaced Former Rep. Juanita-Millender Mcdonald, also a Supporter and with Enthusiasm from Transportation Committee Chairman, Rep. James Oberstar (D-MN).

CSULB ECCO

Multi Phase ECCO Project to Eliminate LB Port Drayage Starting With "Concept Demonstrator"

Phase I

ITS Rail Yard Used by CUT

Eliminates 600 Drayed Containers/day

Bombcart to ECCO to Railcar

Length 1.0 Miles, Cost $65M

Completed 2011

Terminal To Terminal Rail Yard

Phase II

SSA ECCOs Containers directly to 8th St. Rail Yard

Eliminates 500 Drayed Containers/day

Bombcart to ECCO to Railcar

Length 0.67 Miles, Cost $45 M

Completed 2012

Terminal To 8th St. Rail yard

CSULB ECCO

Multi Phase ECCO Project to Eliminate LB Port Drayage Starting With "Concept Demonstrator"

Phase III

Connecter Segment Joins CUT and ITS to 8th St. Yard

Eliminates Need to Form Rail Segments

Increased throughput due to individual Movements.

Length 0.67 Miles, Cost $60 M (Includes $10 M for 2 Switches)

Completed 2013

Terminal to 8th St. Rail Yard

Phase IV

Connecter Segment Joins LBCT to ECCO ICTF Yard

Eliminates 300 Drayed Containers/day

Bombcart to ECCO to Railcar

Length 0.44 Miles, Cost $40 M ($5 M for 1 Switch)

Completed 2014

Completed ECCO Feeder System

16

CSULB ECCO

Multi Phase ECCO Project Starting With "Concept Demonstrator"

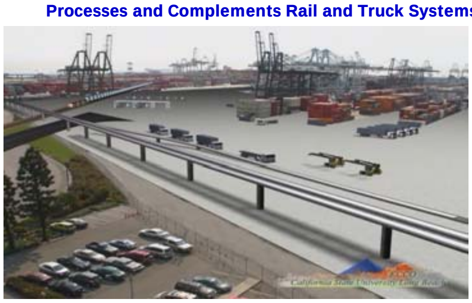
Phase	Length Miles	cost Mils.	Anticipated Container per day	Anticipated Container Fee	Operational and Financing Cost per Container Trip (25yrs @ 6%)
I) System connecting the CU terminal with insufficient rail to the ITS terminal's rail yard, eliminating the need to dray containers to the Alameda Corridor via the ICTF or Hobart	1.00	$65	600	$40 -$60	$ 36
II) System connecting the SSA terminal to the developing 8th Street Intermodal eliminating the need to dray containers to the Alameda Corridor via the ICTF or Hobart	0.67	$45	500	$40 -$60	$ 30
III) System connecting the CUT and ITS Terminals to the developing 8th Street Intermodal eliminating the need to dray containers to the Alameda Corridor via the ICTF or Hobart	0.67	$60 Includes 2 Switches	700*	$40 -$60	$ 28
IV) System connecting the LBCT terminal with insufficient rail to the ECCO ICTF Yard, eliminating the need to dray containers to the Alameda Corridor via the ICTF or Hobart	0.44	$40 Includes 1 Switch	300	$40 -$60	$ 44
Total operating System Connecting 4 Terminals to 8Th Inter-modal Yard	2.78	$210	2100 (620,000 Container /Year)	@ $40 -$60 ($31 M Revenue/Year)	$ 21 M ($10 M Profit/year)

* ITS no longer using their train track

17

CSULB ECCO

ECCO is Compatible with Existing Terminal Processes and Complements Rail and Truck Systems



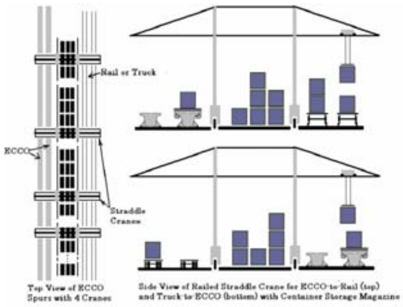
Click on video to play

No Change to Terminals Processes, Automation Required After 2025

18

CSULB ECCO

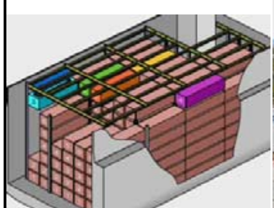
ECCO Load/Unload from Road and Rail with Container Magazine (State-of the-Art)



19

CSULB ECCO

BEC Self Organizing Container Buffer (Prototype Funded by USTRANSCOM)



Demonstrated on U.S. Red Cloud

Click on videos to play

20

CSULB ECCO

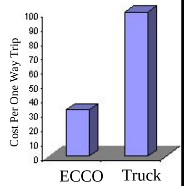
Customized Grid Rail System for the ECCO

Click on video to play

21

LB Port Gateway Route

- ✓ Length = 2.78 Miles
- ✓ Containers per day = 2500
- ✓ Agency: Port of Long Beach
- ✓ Annual Operating Cost = $5.5 M
- ✓ Construction Cost = $210 M*
  - *this does not include Grecco costs
- ✓ Operating and Maintenance per 40' Container = $9
- ✓ Capital Amortization per 40' Container = $22 (25 years at 6%)



	Clean Air Action Plan	ECCO[2]
Total Cost (excluding operations and maintenance)	Replace 2485[1] trucks @$130K each = $300M/1st generation 2 generations to 2025 = $600M	2.78 miles @ $75/M + 30 Container Carriages at $.05M = $ 225M
Pollution Reduction in tons/year	DPE 90 tons/year NO_x 1500 tons/year	DPE 120 tons/year NO_x 2250 tons/year

1 Number of Trucks Required for Equivalent ECCO Moves
2 Power Plant Emissions for Powering ECCO for One Year

"Phase V" I-710 Corridor to Downtown LA's ICTFs

Rail Capacity Reaching Limits

Train Delays on Existing Trackage

Year	Train Type	Average Delay per Train
2000	BNSF Freight	31.9 minutes
	UP Freight	30.4 minutes

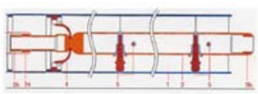
Forecast Train Delay

(Year 2000 passenger trains and no system capacity improvements)

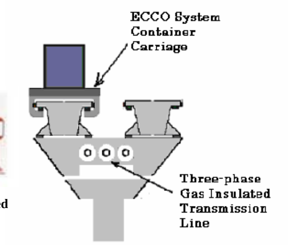
Year	Train Type	Average Delay per Train
2010	BNSF Freight	206.3 minutes
	UP Freight	196.9 minutes

Source: Leachman and Associates Mainline Rail Study for SCAG

Enclosed Power Lines Share Rights-of-Way with Maglev Guideway



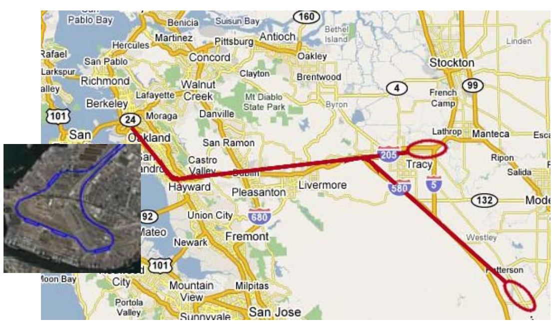
Cross-section of a Single Phase Gas Insulated Transmission Line



* CSULB Awarded Metrans Contract for Transmission Line Easement Study 8/31/06

25

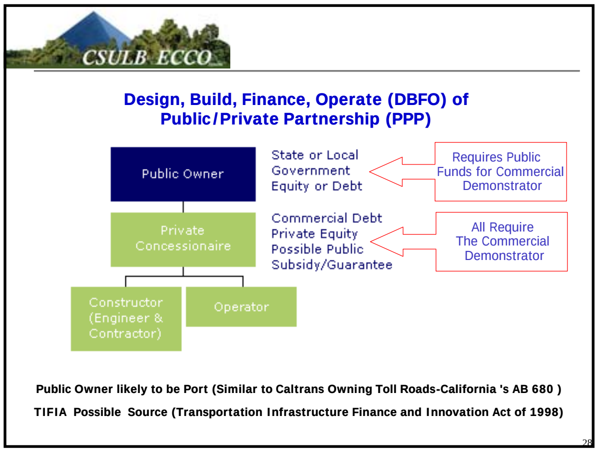
Oakland Cargo Conveyor to Inland Port



26

Total Long Term Solution to Pollution/Congestion Throughput

27


CSULB ECCO
Design, Build, Finance, Operate (DBFO) of Public/Private Partnership (PPP)
Public Owner
State or Local Government Equity or Debt
Requires Public Funds for Commercial Demonstrator
Private Concessionaire
Commercial Debt Private Equity Possible Public Subsidy/Guarantee
All Require The Commercial Demonstrator
Constructor (Engineer & Contractor)
Operator
Public Owner likely to be Port (Similar to Caltrans Owning Toll Roads-California 's AB 680)
TIFIA Possible Source (Transportation Infrastructure Finance and Innovation Act of 1998)
28


CSULB ECCO
For Further Information:
Kenneth James
Principal Investigator
Phone (562) 985-4123
email: james@csulb.edu
Steven Hinds
Program Administrator
Phone (562) 985- 2259
email: shinds@csulb.edu
Edward Thicksten
Senior Consultant
Phone (562) 985-2412
email: ethicksten@csulb.edu
Leo Rodriguez
Senior Research Fellow
Phone (562) 985-4123
email: lrodrig@csulb.edu
Additional project information can be obtained at:
http://edms.engr.csulb.edu/public
29

The Maglev Freight System – Electric Cargo Conveyor (ECCO) System
A High-Speed Intermodal Corridor for the San Pedro Bay Ports: The Non-Polluting Alternative to Road and Rail

Opportunity: Recent cargo growth projections for the economic engine that is the Port of Los Angeles/Long Beach (LA/LB) have the container traffic tripling over the next 10 to 15 years. A majority of these containers will pass through the LA basin and on to the rest of the country. The port facility is approaching the maximum size and infrastructure capabilities of the harbor area. One concept to accommodate the anticipated growth in trade is an inland port such as the one proposed to be built in Victorville, CA. The site is well positioned due to its proximity to LA, the conversion of George AFB to the Southern California Logistics Airport, and immediate rail and highway access. However, the continental bound container traffic will increasingly clog the already stressed road and rail systems through the LA metropolitan area, and generate diesel pollutants beyond the already unacceptable levels. Efficiently moving this large volume of containers through the LA basin with minimum pollution and congestion is both a local and national concern.

Solution: With the origination of the easily elevated, non-polluting Electric Cargo Conveyor (ECCO) concept by the CSULB College of Engineering through CCDoTT funding, two commercial embodiments for container transport—both with military application—have become apparent: (1) an immediate ECCO application for moving 5000+ containers per day between the Ports of LA/LB and the I-710 Corridor ICTFs, and (2) a longer term ECCO conveyor system capable of moving containers between the Ports of LA/LB and both the inland port warehouse concentrations and transcontinental rail terminals at Victorville and Beaumont.

What makes ECCO Different: ECCO uses the proven, highly reliable passenger technology: magnetic levitation ("Maglev") applied to freight movement. One of CCDoTT's technology providers, General Atomics (GA) of San Diego, licenses the Lawrence Livermore Lab's "inductract" approach to both freight and passenger Maglev, and is the nation's leading developer of Maglev propulsion systems for the military. On June of 2006, CCDoTT and GA configured the *world's first* ECCO prototype (above photo) at GA's San Diego facility. Instead of wheels where a shipping container's entire weight is focused on a small contact area, the ECCO system uses a large area of permanent magnets under the carriage to distribute the container weight uniformly over the carriage and the underlying guideway. Thus, ECCO not only has the largest payload-to-carriage ratio of any land transport, but also—due to minimum stress on the guideway—is the most reliable and economical method to *elevate* freight transport!!

In addition to eliminating wheels and their accompanying noise and vibration, ECCO further advances land transport by having its electric motor within the guideway, and not in each carriage. This Linear Synchronous Motor (LSM) powers only the short portion of the guideway where a container carriage is present thus assuring minimum energy use and maximum safety. Extra power for steep grades can be built into the guideway where needed, rather than augmenting on-board propulsion. Using stationary electrical power, ECCO produces no pollution along its path. ECCO's manpower and overhead costs are minimal in that the entire system is computer controlled and there are no moving parts to wear out. This results in lower, more cost effective life-cycle costs when compared to other systems.

6300 State University Drive, Suite 220, Long Beach, California 90815
562.985.7394 • 562.985.2583 Fax • www.ccdott.org

Finally, system security is insured not only by the containers being rapidly moving, unmanned, and elevated, but also the application of numerous optical-pattern-recognition cameras along the length of the system.

Mitigation Plans Are Not the Answer: While plans for replacing present day diesel trucks and locomotives with cleaner self-propelled systems is necessary (Port's "Clean Air Action Plan"), continued port growth will nullify much of the pollution reduction. The required mitigation expense does nothing for congestion and noise. As previously mentioned the ECCO system uses clean, stationary electrical sources. Delivering power through the electric grid also allows for application of renewable energy sources like wind and solar. Also, since the ECCO system has no moving parts or contact friction, particulates of rubber, asphalt and concrete are nonexistent. Diesel-powered road and rail systems require costly pollution mitigation approaches. We can build a better transport system which produces no pollution, is more reliable, and is less expensive to operate.

First Application and Cost of a Port ECCO System: A number of terminals at the San Pedro Ports do not have the capacity for moving all containers destined to pass through the LA basin and on to the rest of the country directly by rail. Upwards of two (2) million containers must be drayed from those terminals to railheads between the Ports and downtown LA. The first application of the ECCO was defined in a 2006 contract from the Port of LA to GA (with CSULB's ECCO concepts supporting the system architecture) to be a preliminary cost estimate for an ECCO system between the Port and Intermodal Container Transfer Facilities (ICTFs) near the Port moving 5000+ containers per day. The team of CSULB, GA, and nationally recognized civil engineering and railroad signaling safety companies determined the cost of a totally elevated Port system to be $90M/mile. This is considerably less than a trenched rail corridor ($125M/mile) or a new, at grade, freeway ($150M/mile) that can carry the same container volume but slash though the community and the environment. In addition, the operating cost of the port ECCO system is $2.20/container-mile; of which $1.00 is the cost of electricity. The present cost of trucking containers from the Port to the major ICTFs along the I-710 indicates the ECCO system's "farebox" has the potential not only to pay for its day-to-day operation but also its amortized capital costs. The ECCO is totally compatible with port operations. Being elevated—except when configured as an at-grade spur or siding—the ECCO does not impact rail or truck-gate operation. The system utilizes the same equipment and labor procedures that are presently used at terminals to load and unload near dock rail. However, to fully utilize the capacity of ECCO more automated equipment with computer managed container storage is required

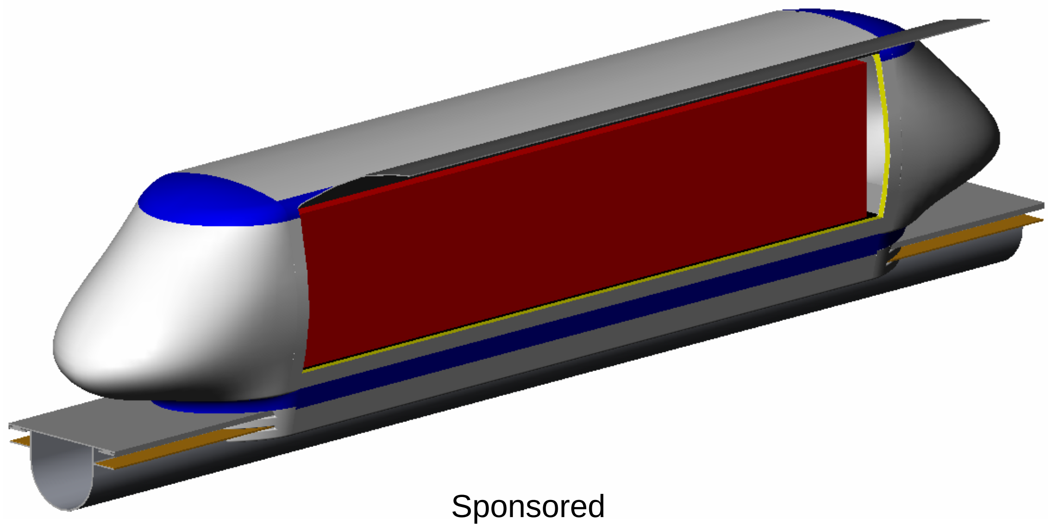
The Southern California Application: The more recently developed ECCO technology can move containers out of the Port to ICTFs, inland ports, and beyond more effectively than road and rail. The long term solution to port growth, congestion, and pollution is to complement existing as well as proposed road and rail expansion in Southern California with the ECCO system. Trucking containers from the Port to inland warehousing complexes, and cumbersome rail movement of containers through the LA basin to the origins of transcontinental rail at Victorville and Beaumont will then be minimized.

For further information contact Dr. Ken James, Project Task Manager at (562) 985-2412, or Steve Hinds, CCDoTT Program Coordinator, at (562) 985-2259.

--- DRAFT---

The Impact of Magnetic Levitation Technology Development for Civilian and Military Utilization

Final Report



Sponsored
by

The Office of Naval Research

Cooperating Agencies:

Los Alamos National Laboratory (LANL) Sandia National Laboratories (SNL)

US DOT/Volpe National Transportation Systems Center (Volpe)

General Atomics (GA)
Lockheed Martin (LM)
MagLev Transit Group, LLC (MTG)
Magtec Engineering (ME)

September 2006

Prime Conclusion from *The Impact of Magnetic Levitation Technology Development for Civilian and Military Utilization – Final Report (Sept. 2006 - Sandia/Los Alamos Labs Draft Study)*

Based on our research, the most promising initial option for a U.S. MagLev system today is for cargo transport in a high-usage, high-density region such as moving cargo from the Port of Los Angeles (or Port of Long Beach, CA) to a less-congested transfer site inland. There are several reasons for this recommendation. First, the Los Angeles corridor from the ports of Long Beach and Los Angeles is very congested resulting in significant noise, traffic congestion, and airborne pollution. A MagLev system that transfers cargo from either of the ports to a distribution point inland would significantly reduce large-truck traffic on the already crowded freeway system. Second, the ride-quality, infrastructure, and safety constraints are less stringent on a cargo transportation system than on a personnel-transport system. As a result, it would cost less to implement a cargo-based system, and it would still provide meaningful cost and performance metrics.

Maglev Freight Conveyor Systems

Dr. Kenneth A. James
Professor of Electrical Engineering, Chair of Computer Science and Computer Engineering
California State University at Long Beach
1250 Bellflower Boulevard, Long Beach, CA 90840

Introduction

This paper is submitted in response to a request arising out of a meeting with high level representatives of DOT/FRA, MARAD and the National Transportation Policy and Revenue Study Commission to provide the commission with information about the ECCO Project as a potential solution to growing congestion and pollution in and around the ports of our nation.

Cities naturally grow up around ports, reducing availability of low cost land for port expansion. Inevitably, the result is traffic congestion along road systems originally intended for local deliveries and commuters. It makes sense to move containers to inland locations for processing and transport to their final destinations. A system to quickly and effectively move containers from the Port is needed, and such a system is the Electric Cargo Conveyor or ECCO system. ECCO does not rely on thousands of Diesel trucks congesting roadways to move containers, but rather uses a small footprint, grade-separated, elevated cargo conveyor, powered by the existing electrical grid. Being all electric, this system emits no pollution along its path and can directly utilize renewable energy sources.

ECCO presently uses a form of maglev (magnetic levitation) technology different than the maglev technology associated with numerous passenger systems proposed and built over the last half century. The ECCO system is an American maglev technology invented by Lawrence Livermore National Laboratory, licensed and prototyped by General Atomics (GA) of San Diego, CA. The ECCO shows such promise that the Office of Naval Research investigating military applications of freight movement, states: "The most likely first commercial application of maglev technology in the United States will be a freight conveyor."[1]

This paper describes background and public policy considerations that went into the ECCO concept development, including the economic, social and institutional benefits of implementing such a system. Particular benefits of the ECCO system are reduction of congestion, air, and noise pollution, higher container throughputs than road or rail, potential to pay for itself with the farebox, and a long predicted operational lifetime.

Background of ECCO Development

California State University, Long Beach (CSULB), which is adjacent to the Port of Los Angeles/Long Beach (LA/LB), originated the ECCO concept in response to the community's need for reducing congestion and pollution due to container movement at the Port. Approximately 43% of the containers coming through this Port go through Southern California and continue on to the rest of the country. The projected increase in Port activity of 8% per year infers a healthy Southern California goods movement economy for years to come. The ECCO architecture offers a container throughput capacity exceeding those of conventional road and rail to allow such economic growth. Alternative proposals to enhance port throughput have involved expansions to conventional road and rail infrastructure, which only increases congestion and mobile source emissions, including NO_X, carbon monoxide, greenhouse gases, and Diesel Particulate Emissions, or DPEs.

Catalytic conversion and adoption of alternative fuel combustion engine technologies will certainly reduce emissions; unfortunately, increasing the number of container moves due to port growth off-sets these gains. Additionally, these emission reduction technologies do not resolve the problem of increased congestion leading to lost productivity, which can be measured in billions of dollars per year.[2] It is understandable that communities near the Port and along rail and road corridors connected to the Port have expressed health and safety concerns regarding port expansion and its associated transportation infrastructure. Port communities, environmental groups, business leaders and elected officials have all expressed considerable interest in the ECCO system as a potential solution for reducing the pollution and congestion around the ports.

Figure 1. ECCO Will Greatly Reduce I-710 Truck Traffic from Ports of LA/LB.

When CSULB first developed the ECCO concept a few years ago, the only commercial maglev system in the world was the Shanghai maglev that uses a technology developed by TransRapid of Germany. The University contracted TransRapid to determine if moving shipping containers with maglev was possible. They had not previously considered the many advantages that freight transport offered over passenger transport, such as having a known ridership requiring few, fixed destinations with a willingness to travel anytime, 24/7. TransRapid confirmed CSULB's position that containers were a more predictable and likely more profitable ridership than passenger transport provides; they determined that container movement was not only feasible but would require only slight changes to their present passenger system design.

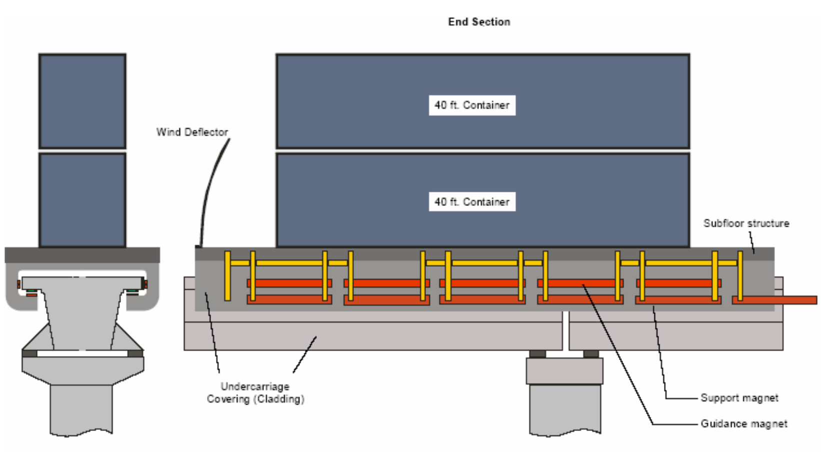


Figure 2. TransRapid's Design Response to CSULB Container Mover Concept (2005)

TransRapid began development some 50 years ago on what is referred to as an *Electro-Magnetic* system. Batteries on board such a system energize powerful electromagnets wrapped around the guideway which lift the carriage up to ferrous metal plates on the bottom of the guideway. Levitation is accomplished by electronic feedback balancing the magnetic *attractive* force upwards with the gravitational force downwards. Desk toys that "float" model globes employ a similar concept, but in the case of the ECCO transportation system, the floating carriage with container is moving on the guideway at 90 miles per hour.

The most recent form of ECCO concept implementation utilizes a magnetic levitation technology developed in the United States. GA has built the only operational full-scale maglev test track in the United States, and the first full-scale cargo container chassis. The levitation technology is an *Electro-Dynamic* system which pushes off the guideway instead being attracted to it. While this technology has been appealing for decades due to its simplicity and ruggedness resulting from its utilization of passive levitation, implementation has been possible only recently due to improvements in permanent magnet material residual field strength. In this approach, levitation is accomplished by moving permanent magnets mounted on the underside of the carriage over an electrically conducting metal surface such as copper or aluminum. This forward movement produces currents in the metal which in turn produce a magnetic field *opposing* the on-board magnets causing the carriage to lift off and levitate about an inch above the guideway. Just as an airplane uses wheels to reach forward speed until aerodynamic lift is achieved, the ECCO uses wheels until magnetic lift is achieved—the speed of a brisk walk—after which it can accelerate to speeds of up to 90 miles per hour or more. As compared with the older Electro-Magnetic technology used in other maglev systems around the world, the GA Electro-Dynamic technology can reduce vehicle costs and weight by eliminating the amount of electrical equipment that must be carried on board the vehicle. This is an especially important consideration for a cargo-carrying system transporting heavy loads. Another appealing feature of Electro-Dynamic maglev technology is that it increases the gap between the guideway and vehicle, reducing the precision with which the guideway must be manufactured and maintained.

Figure 3. World's First Maglev Container Move at General Atomics San Diego, CA, June 2006.

To date, all forms of the ECCO concept use a Linear Synchronous Motor (LSM) mounted on the guideway to propel the chassis forward; which can be conceived of as similar to a typical round electric motor, unwound and laid lengthwise along the guideway to form a "linear motor."

In 2005, CSULB demonstrated the **feasibility** of moving containers on an ECCO system; in 2006, CSULB in conjunction with GA demonstrated the **reality** of the ECCO system with a full-scale container-carrying prototype. The photograph shows a twenty foot container (1 TEU) on the GA maglev test track. Note that there is no mechanical contact of the container vehicle with the guideway, and furthermore there is no motor or operator on board.

Figure 4. ECCO Is Contact-Free, Resulting in Very Low Maintenance Costs.

Since the system is contact-free when levitated, this assures low lifecycle maintenance costs, an important factor in evaluating freight transport systems. High maintenance costs over decades of road and rail usage add greatly to these systems' total costs. The expected operational life for the ECCO civil infrastructure is greater than 75 years.

ECCO Reduces Urban Congestion

Floating on a magnetic field rather than using wheels, ECCO exhibits enhanced flexibility over road and rail options via two inherent aspects; elevated infrastructure and superior grade climbing ability. When containers are placed on a rail car the entire weight is concentrated on a small area of the track. The same container loaded onto a truck chassis puts all its weight on the area where the tires are in contact with the road. In both cases the container's weight is focused onto small areas of rail or road and generates a moving pressure wave on the rail or road that requires a significant supporting infrastructure. This pressure wave can account for misalignment of rails, the unevenness of cement plates on highways, and washboards on asphalt surface streets. ECCO distributes a container's weight over a large bank of magnets whose surface area is thousands of times larger than the corresponding weight-bearing points of road or rail, thus eliminating the severe pressure gradients of wheeled vehicles. This produces minimum stress on guideway infrastructure, and reduces the size and cost of structures needed to elevate the system. The ECCO "footprint" (land requirement) is a series of reinforced concrete posts approximately one hundred feet apart to support the guideway. This reduced footprint permits the use of a number of existing rights-of-way, such as freeway medians, power line corridors, land adjacent to riverbeds, elevated over conventional rail, etc.

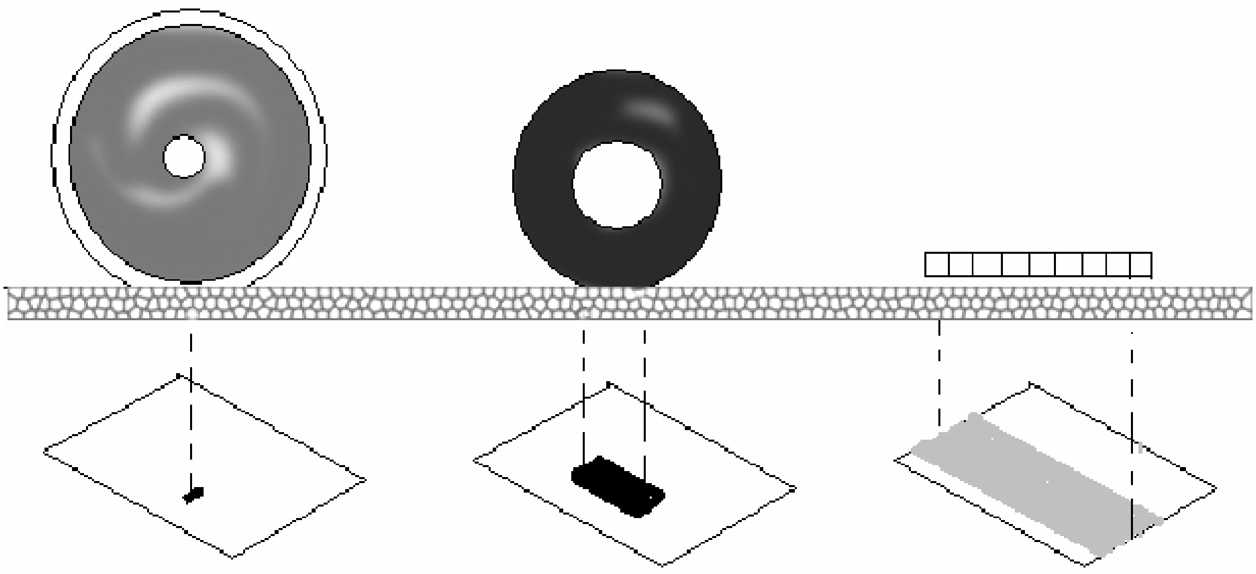


Figure 5. ECCO Replaces Wheels with Arrays of Magnets which Greatly Reduces Stress on the Guideway.

Because an elevated guideway is the preferred architecture for the ECCO system, its superior grade climbing ability allows it to conform to existing geography and infrastructure. By using the linear synchronous motor built into the ECCO guideway, denser motor windings can be employed in guideway sections where extra power is needed, such as in climbing steep terrain or gaining height for water and grade crossings. This makes the climbing of uphill grades more efficient than the use of conventional motors on wheeled vehicles, which must be sized to climb the steepest grades even though they are infrequently used for hill-climbing. On downhill grades, the same dense motor windings in the ECCO guideway enable regenerative braking, where much of the vehicle's kinetic energy can be recaptured as opposed to being burned off in the form of wasted heat energy by conventional braking systems.

Even with appropriately sized conventional diesel power plants, rail-based transport can only climb a 3% grade and road-based transport a 6% grade, whereas ECCO can climb a much steeper 10% grade or more. An awkward issue faced by planners laying out a road or a rail system in an urban infrastructure is the approach to gain height for crossing navigable waterways and other transport thoroughfares. Large areas of at-grade land are required to bring the road or rail up to, and down from the necessary elevation. ECCO's steep climbing ability and its naturally elevated configuration provide planners with a flexible means of positioning high throughput container transport on top of an over-burdened urban road and rail infrastructure.

Anytime a new form of transport is introduced into a community with an already congested infrastructure and complex economy, like ports and cities, compatibility with existing conditions must be considered. The figure demonstrates how the elevated ECCO might function at a port terminal with a main, elevated conveyor loop running parallel to a terminal's perimeter over existing rail and road, and a switched siding that quickly comes down to grade level for loading and unloading the containers in the terminal. The sketch shows that ECCO uses typical truck or rail load/unload labor and equipment processes. The process and equipment depicted are not necessarily for a high-throughput system.

Figure 6. ECCO Is Compatible with Existing Road and Rail Infrastructure

Urban congestion caused by rail-based transport is somewhat different from congestion produced by trucks on the highway. For container moves by rail to be cost competitive with trucks, several containers must be moved on a single train. A typical train segment can be a half-mile in length or longer. Congestion (and concomitant pollution) caused by a train slowly moving through numerous grade crossings entails roadway vehicles idling at these crossings and cannot be easily quantified.

ECCO Reduces Pollution

Compared to the use of drayage trucks for transporting containers, the ECCO system can greatly reduce emissions of oxides of nitrogen (NO_X), greenhouse gases such as carbon dioxide (CO_2), and Diesel Particulate Emissions or DPE. Reducing all of these emissions is a high priority, evidenced by California's recent allocation of $1 billion in bond proceeds to mitigate the emissions resulting from goods movement. DPE is different from gaseous pollutants in that it is concentrated in areas where diesel engines operate such as the port, truck/train intermodals, and along freeway and rail corridors. The effects of DPE are devastating. More than thirty (30) human epidemiological studies have found that diesel exhaust increases cancer risks; and one 1999 California study found that diesel exhaust is responsible for seventy (70) percent of cancer risks from air pollution[3]. Recently, the danger of having homes and schools close to sources of DPE has been recognized[4]. The ECCO container transport approach can use electricity generated by modern natural gas fired power plants, which emit very low NO_X (as little as 0.1 grams/kWhr – 10 to 20 times less per unit of energy consumed than typical container trucks) and emits *zero* DPE.

A quantitative discussion allows a visualization of the pollution reduction benefits of an ECCO conveyor system in an urban area. Assume first a scenario wherein 1000 (500 in both directions) 30 ton containers are moved per day (200,000 containers per year) through 10 miles of typical urban traffic using trucks with a 32 year age distribution peaking at around 10 years. The California Air Resources Board (CARB) EMFAC2007 model predicts baseline levels for the assumed scenario of DPE and NO_X as shown in the following table. The baseline ECCO system for this scenario is a single bidirectional guideway system covering the same distance with a capacity exceeding 1000 containers a day, moving containers at speeds averaging 90 mph between two terminals. The ECCO local pollution production estimates are shown in the table below (based on stationary electrical plant local pollution for generating the energy required for moving the 1000 containers per day).

Many communities are currently proposing mandatory replacement of older polluting trucks with newer trucks having expensive pollution mitigation equipment. Although timely, this measure does not address the problem of traffic congestion and the resultant increase in pollutant levels.

	Diesel Particulate Emission, PM_{30}	**Oxides of Nitrogen NO_X**
Baseline Truck {typical truck fleet moving 200,000 containers/year, 20 miles round trip }	6.9 tons/year	124.4 tons/year
New Truck {new truck fleet moving 200,000 containers/year, 20 miles round trip }	1.8 tons/year	48.5 tons/year
ECCO System {200,000 containers/year, 20 miles round trip}	0.0 tons/year	2.8 tons/year

Table 1 – ECCO Offers Substantial Pollution Reduction Over Truck Transport.

ECCO Reduces Dependence on Fossil Fuels

ECCO is projected to be at least (and potentially several times) as energy efficient as using container trucks. A typical container truck carrying a 20-ton load and achieving a fuel economy of 5 miles per gallon achieves 100 ton-miles of cargo transport per gallon of diesel fuel consumed. Based on an equivalent energy content of 40 kWhr per gallon of diesel fuel, this works out to 2.5 ton-miles per kWhr. GA has already achieved this level of energy efficiency on its ECCO test track in San Diego, and believes that future improvements could increase ECCO efficiency several times again.

Independently of fuel efficiency benefits, ECCO provides greater flexibility with respect to energy source. ECCO can use energy produced with renewable hydroelectric, wind, and solar power, as well as the new generation of nuclear power plants—completely eliminating cradle-to-grave emissions and reducing dependence on fossil fuels. Natural gas-fired power plants, although fossil fuel based, are significantly cleaner than oil or coal power plants, and can also be a source of clean power for ECCO.

As previously explained, the motor of the ECCO container carriage is in the guideway. Electrical power is conserved by powering only those sections of the guideway where the ECCO carriage is traveling. This segmented powering design format has a number of additional safety and control advantages, as described in the next section.

ECCO Potential for Increased Safety and Security

The removal of container traffic intended for remote locations from the urban highway infrastructure and placing them on ECCO will improve traffic flow, increase productivity, and improve highway safety. Being entirely automated and grade-separated, the ECCO system has important safety benefits. The segmented linear synchronous motor in the guideway is operated by activating alternate sections of the guideway, which achieves a safe separation between container carriages as well as increasing the system's energy efficiency.

An elevated, continuously moving container conveyor is implicitly more secure than a grounded, stationary container. The ECCO system includes state-of-the-art closed circuit TV monitoring systems along the entire length of the guideway. Since the field of view for these systems is limited to the upper and lower portions of the guideway where the only motion is scheduled container traffic, any unscheduled movement or anomalous changes are recognized by machine vision software which can generate an alarm for real-time scrutiny by an ECCO system operator.

In addition to external monitoring along the system, unmanned ECCO carriages can have their contents examined by X-ray and neutron activation for contraband—while in transit. Present container X-ray imaging and active neutron scanning processes require a container be removed from the goods movement path for examination in facilities where humans are isolated from radiation. Every container moving along the ECCO conveyor, however, can pass through a shielded, active radiation security portal, thus providing a 100% safe and secure screening process. Again, machine vision software automates the inspection process and those images flagged for further analysis can be viewed at remote locations via the internet. The ECCO lends itself ideally to automated security inspection processes.

ECCO Profitability Pays for Itself Through the Farebox

The first application of the ECCO was defined in a Port of LA/LB contract with GA using CSULB's ECCO concept supporting the system architecture[5]. This study produced a preliminary cost estimate for a 4.7 mile ECCO system between the Port and an Intermodal Container Transfer Facility (ICTF) near the Port moving 5000+ containers per day. The team of CSULB, GA, and nationally recognized civil engineering and railroad signaling safety companies determined the cost of a totally elevated Port system to be $90M/mile for a dual guideway system. This is considerably less than a trenched rail corridor ($125M/mile) or a new, at-grade freeway ($150M/mile) which could carry the same container volume, but at the cost of slashing though the community and environment. In addition, the operating cost of the port ECCO system is projected to be $2.20 per container-mile, of which $0.80 is the cost of electricity.

The present cost of trucking containers from the Port to the major ICTFs along the I-710 and beyond is a $50 base fee plus around $5/mile. This amount includes the driver's labor, tractor and chassis maintenance, fuel, taxes and licensing, amortized cost of the equipment, and profit. The truck drayage trip from the port to the ICTF specified in the referenced ECCO study (4.7 miles) costs from $65 to $80. A cost comparison of conventional truck drayage with ECCO requires the amortized cost of constructing the ECCO be added to the operational cost. Assuming that funding is provided by a bonding agency or by a Public/Private Partnership (PPP, to be discussed in the next section), the amortized cost per container ranges from $26 to $30—depending upon financing options.

Figure 7 Alignment for Port of LA/ECCO Project

Hence, the total cost per container of the "turn-key" ECCO system, including guideways, energy, terminals, security, operating personnel, and "rolling stock" comes to under $40. Neither estimate (for truck drayage or ECCO) includes load-on and load-off expense, assumed to be the same for both cases. Charging $60 for an ECCO move that reduces truck presence on highways, is non-polluting, quiet, energy efficient, and secure should pay off the debt of construction in less than eight (8) years and provide a very attractive return on investment. The financial benefits of the ECCO are expected to attract private investors.

ECCO Is Ideally Suited for Public/Private Partnership

Public/Private Partnerships (PPPs) are envisioned as the preferred form of constructing ECCO systems in urban areas, similar to the manner by which toll lanes on existing freeways have been built and financed. With this model, a public infrastructure owner awards a franchise to a private sector partner to Design, Build, Finance, and Operate (DBFO) a transportation project for a pre-determined concession period. In exchange, the private sector partner has the right to collect all revenues generated by the project during the franchise period. ECCO's ridership (containers) is more predictable and reliable than are toll lane customers, hence the financial options are potentially very attractive to private investors. The public sector may provide limited financial assistance, such as development period cost-sharing, right-of-way provisions, or limited revenue guarantees, but the private sector partner bears the revenue risk, and determines that the funds generated will be adequate to paying off the underlying project loans and interest and make a fair profit on the investment of time, expertise, and money.

DBFO concessions can be awarded for the construction of a new asset or for the modernization, upgrade, or expansion of an existing facility. DBFO concessions often extend for a period of 25 to 30 years or even longer, and are awarded under competitive bidding conditions. Under a DBFO approach, the ownership of all assets, both existing and new, remains with the city/state government or transportation authority. However, the government agencies usually stipulate maintenance protocols and specific improvements to be made over the franchise period to ensure that the assets are properly used and maintained during the initial concession period and are in good condition when the period is over.

Case Study: ECCO Relation to Energy and Energy Distribution

As an example of how the ECCO concept can influence urban planning, consider a possible relationship of a hypothetical urban ECCO system with an urban electric power grid. ECCO's additional use of the grid, of course, impacts the capacity of an urban area's electrical distribution system. Consider in addition the difficulty of building new electrical generating plants near cities. Such plants can be built and operated effectively in isolated areas away from urban regions, but this option traditionally has not been exercised because of the expense of requisite power distribution lines to deliver power to the city from outlying plants. The postulated ECCO system's ability to share the same rights-of-way as power distribution lines is pertinent here. A fundamental premise of this paper is that the ECCO runs on an elevated alignment through the city, reducing congestion and simultanteously moving freight to a remote area for container processing and storage; this is the same land use requirement as that for remote power plants. Generating power in the same location as the (remote) inland terminus allows the ECCO route to be the backbone of the power grid and vice versa.

An additional benefit of this right-of-way sharing approach is the possible elimination of transmission line towers in these swaths of land by shielding the electrical lines in conducting cylinders—gas insulated transmission lines (GITLs), allowing these lines to transmit power more effectively, and to require less space.[6] Many urban communities would prefer to consolidate overhead lines into shielded line enclosures; but the cost of these enclosures is significant. Moreover, due to the necessity for maintenance, these enclosures are still visible at ground level. The integration of gas-insulated transmission lines into ECCO guideways could simultaneously reduce the cost of consolidating overhead electrical power transmission and allow existing and future transmission line rights-of-way to be used for other purposes, such as goods movement corridors.

New Paradigm for Container Movement

Maglev technology is a solution that can help alleviate the problems created by the technology which is responsible for the congestion and pollution many urban areas face today. This technology facilitates the needed balance between more and better jobs inherent in an expanding economy and quiet, clean, and congestion-free neighborhoods. Thus, ECCO's slogan, attributed to Albert Einstein: "One cannot solve problems with the same technologies that caused them."

End notes:

[1] The Impact of Magnetic Levitation Technology Development for Civilian and Military Utilization Final Report. (Sept. 2006 Sandia/Los Alamos Labs Study). Sponsored by the Office of Naval Research.

[2] The 2005 Urban Mobility Report. http//mobility.tamu/ums/report/

[3] Bailey Diane et. all Harboring Pollution The Dirty Truth About U.S. Ports, Natural Resources Defense Council Mar. 2004. http://www.nrdc.org/air/pollution/ports/ports2.pdf

[4]"Effect of exposure to traffic on lung development from 10 to 18 years of age", by Gauderman, et.al. dated 1/26/2007 www.thelancet.com

[5] Conceptual Design Study For The Electric Cargo COnveyor (ECCO) System . http://www.portoflosangeles.org/DOC/REPORT_ECCO_102706.pdf

[6] A Basic Study on Hybrid Gas Insulated Transmission Line (H-GIL) (Part 3): Estimation of Breakdown Characteristics and Transmission Line Properties CRIEPI Report No. T95048, 1996 http://criepi.denken.or.jp/en/e_publication/a1996/96seika28.html