AUTOMATED SHIPPING CONTAINER TRANSPORTATION SYSTEM DESIGN FOR CHICAGO

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Abstract

For the United States, substantial numbers of shipping containers must be transferred from one side of the country to the other. Chicago receives the bulk of this intercontinental inter-modal traffic, making it one of the largest container ports in the world. (Ferguson,2005) On the horizon is a doubling of traffic within 10years, overloading a capability that is already at capacity.

Illinois Institute of Technology's Inter-PROfessional Projects Program worked on solutions to minimize time delays and reduce traffic congestion by cutting down on the number of trucks transporting containers in Chicago. The student teams of various disciplines developed designs for an elevated between-yard transportation system and an integrated intra-yard system that utilizes linear

induction motor technology(LIM).

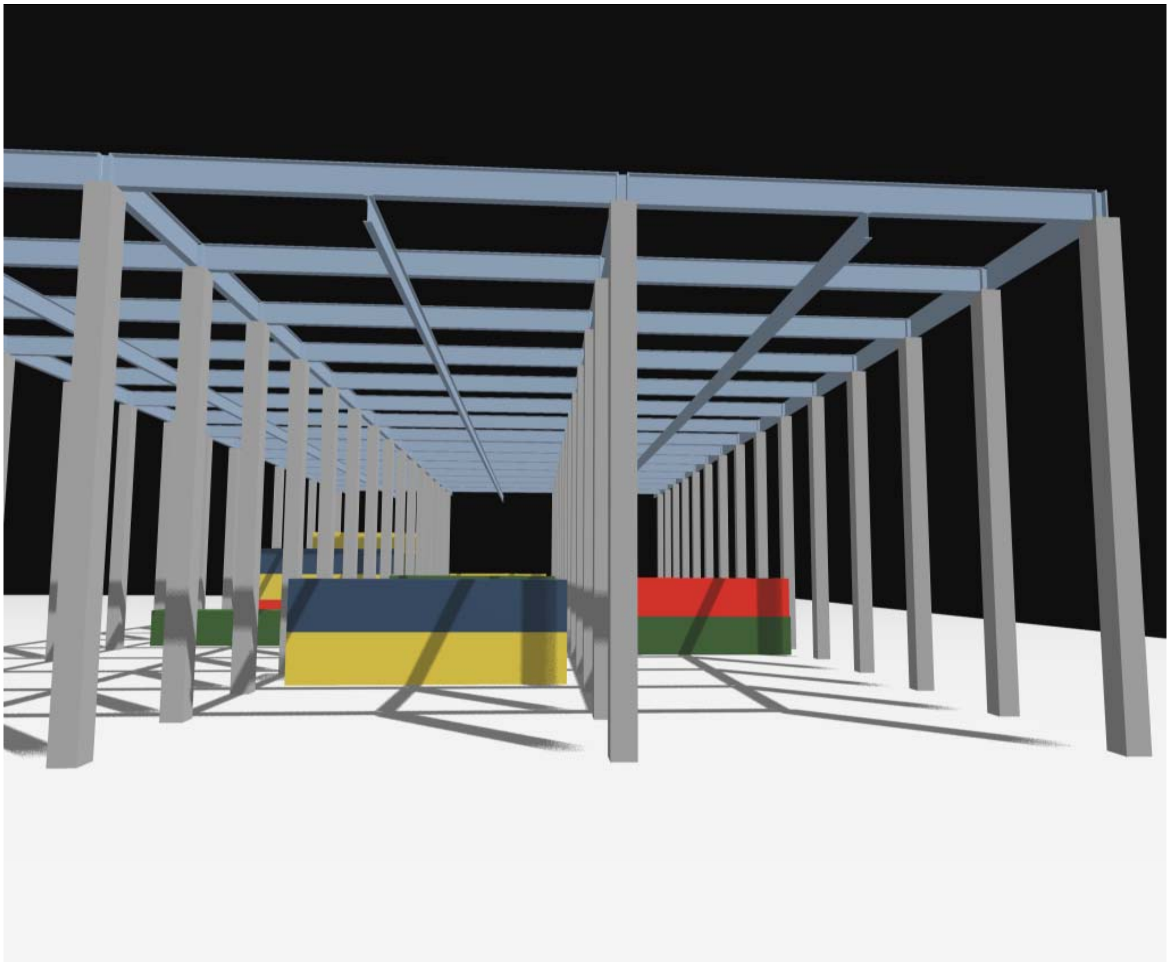
Networks for an area wide system were developed, as well as estimates and templates for a financial scenario analysis. These showed that such a novel capital intensive solution was financially viable in Chicago.

Table Of Contents

Summary of the Project

For the United States, substantial numbers of shipping containers must be transferred from one side of the country to the other. As the major highway and railroad crossroad, Chicago receives the bulk of this intercontinental inter-modal traffic, making it one of the largest container ports in the world. In many instances, containers are even moved from one railroad to another by truck, exhausting street and highway capacity.

FIGURE 1 Grail Lattice Structure



STORAGE AREA VIEW-ground (figure1a)

Starting in January 2004, Illinois Institute of Technology's (IIT) Inter-PROfessional Projects Program (I-PRO) has worked on this problem because:

- inter-modal (rail-highway) transfers are a defining industry in this region, representing 87,000 jobs in the Chicagoland area (Chicago Metropolitan's 2020 Freight Plan, 2004);
- future projections in volume growth indicate serious capacity issues for the actual handling process, with freight doubling in seven years (CATS Intermodal Advisory Task Force 2005);

- and the potential win-win situation in the form of congestion relief, air quality, land and fuel conservation.

Initial funding was from private sponsorship, with continuing resources being contributed by the university, and public agencies. The work was conducted by undergraduate teams of various disciplines with a median size of 10students.

The primary public goal is to substantially minimize the time delays and to reduce traffic congestion by cutting down on the number of trucks transporting containers in Chicago, which in turn will reduce overall operating costs. Secondary goals were to provide relief for congested and overwhelmed infrastructures, and the retention of developed facilities.

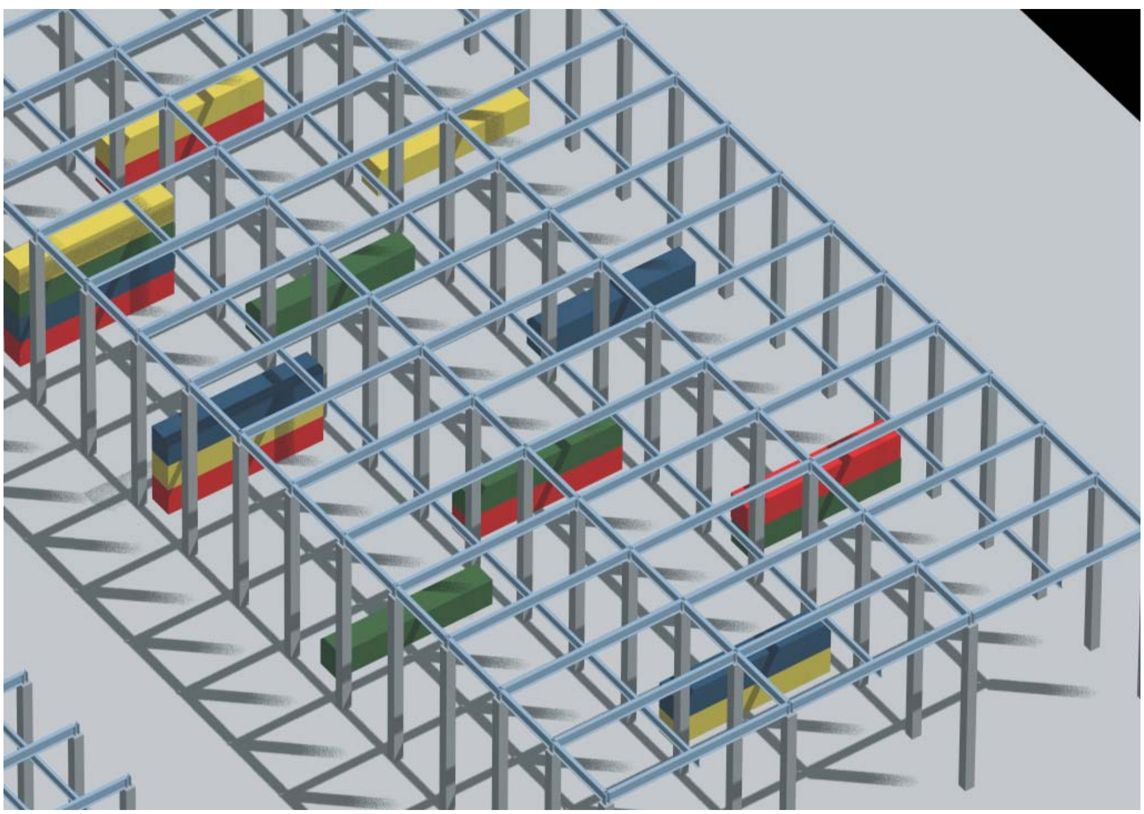
The first Inter-PROfessional team researched possible solutions for the problem and introduced the concept of completely automated container transport and envisioned a system that will move and sort containers within a rail/truck terminal. This team developed preliminary designs for an elevated between-yard transportation system and an integrated intra-yard system that utilizes linear induction motor technology(LIM). Each terminal would utilize an overhead lattice structure for storage and retrieval. To move the containers, a highly agile mobile crane system was envisioned. This highly efficient system lessened direct requirements for precious urban land.

Concepts were developed in detail and with supporting graphics. Prototype designs subsequently detailed operating scenarios and structural analyses for an intra-yard overhead lattice structure and the inter-yard structures between the two busiest terminals: Corwith and 47th Street Yards; GIS maps were developed to demonstrate that route in accordance to zoning specifications.

The mobile crane's mechanical design was completed integrating the effective use of LIM technology for moving freight containers.

Also, network designs and alternative route options for an area wide system were developed, as well as estimates and templates for a financial scenario analysis.

The major conclusion of these sequential studies was that, with the high volumes of container activity in the Chicago area, this capital intensive solution was financially viable, an investment that can be justified in this urban complex whose central location supports a nation.



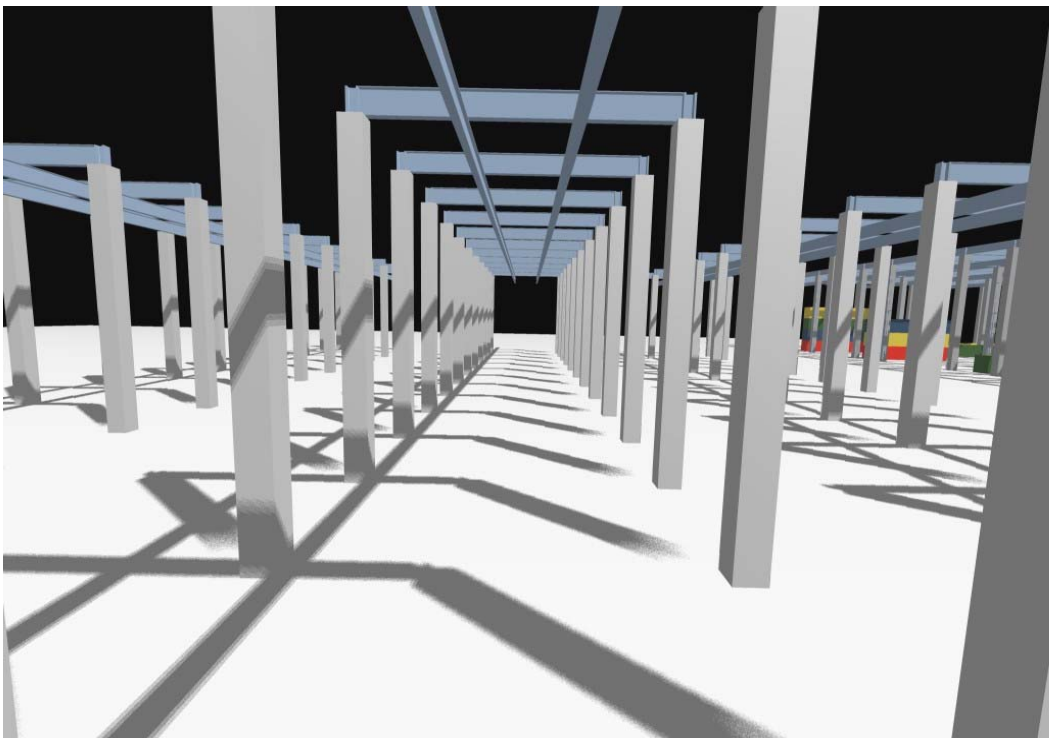
STORAGE AREA VIEW-aerial (figure1b)

The Process of the Project

The Interprofessional Projects Program (IPRO) at the Illinois Institute of Technology was the mechanism for conducting this project. IPROs engage multidisciplinary teams of students in semester-long undergraduate projects based on *real-world* topics from sponsors that reflect the diversity of the workplace: corporations, entrepreneurial ventures, non-profit organizations and government agencies. In addition, a significant number of project topics emerge from faculty research or the ideas of students themselves. Project topics and faculty involvement span research, design, process improvement, service learning, entrepreneurship and international engagement. Bruce Dahnke and Consultants were the seeding sponsor for this initial development of long range plans for improving container transport through Chicago;

All IIT students complete at least two three-credit-hour IPRO project courses to satisfy general education requirements. Approximately 35 teams are formed each semester, involving 350 to 400 students and ~20 faculty members drawn from various academic units and having the technical expertise needed to guide a team in addressing a topic. Since 1995, over 500 project semesters, involving over 3,000 students, 100+ faculty from across the university and 100+ collaborating organizations, have been completed

Each IPRO section constitutes one team, with at least one faculty mentor per team. Teams may include 7-15 students from all academic levels (sophomore through graduate school), and cut across IIT's professional programs (engineering, science, business, law, psychology, design, and architecture), with a typical team size of eleven students. This integration of vertical (bridging academic levels) and horizontal (bridging professional programs) dimensions within a team stimulates student interaction across disciplines and levels of experience that emulates a cross-functional workplace environment. The IPRO course has also been effective in identifying undergraduate students interested in an area of investigation who then decide to pursue this interest in graduate school, or with a company or other organization.



LATTICEWORK OVER STRIP TRACKS (figure1c)

Regardless of the unique problem-solving challenge that each team faces, the interprofessional course has four key learning objectives: (1) Function as part of a multidisciplinary team; (2) Develop and apply communication skills via a variety of means; (3) Develop and apply project management (and leadership) skills through the life cycle of a typical project and (4) Grapple with the ethical and other non-technical aspects of a problem. This experience also strengthens a student's awareness about the need for continuous, i.e., lifelong, learning in order to gain the knowledge and skills that a cutting-edge problem may demand. A sixth objective pertains to the Entrepreneurial IPROs (EnPROs), to develop awareness about business planning principles.

IIT's IPRO teams work with an extremely wide range of clients, sponsors and advisors that include traditional corporations, small businesses, entrepreneurs, government agencies and non-profit organizations of various sizes and types in the greater Chicago area. In the development of these container transport systems concepts, collaborators included the Chicago Area Transportation Study, SkyTech Transportation, and George Scelzo of PRT Systems.

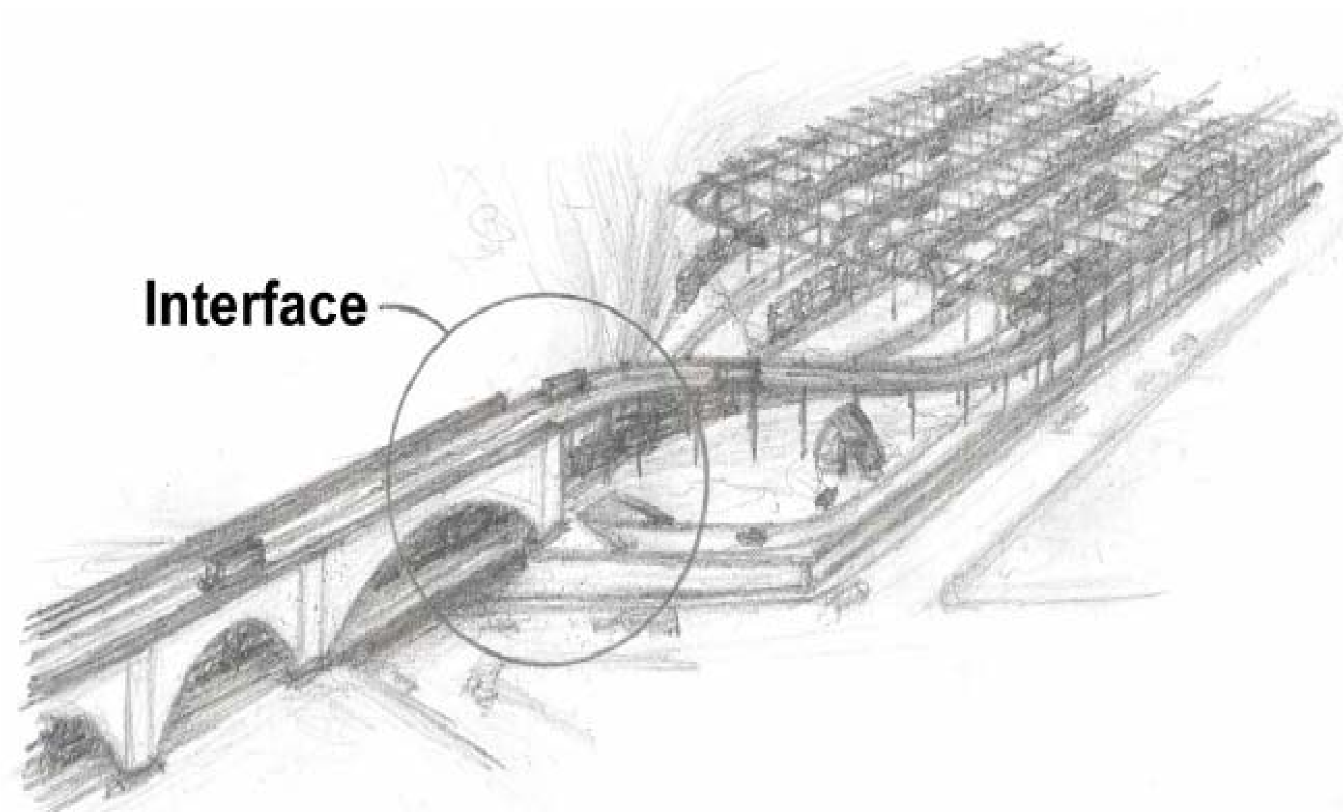
The Product of the Project

These are the teams' designs and findings that delineate an automated container shipping system for Chicago. The students also prepare a continuing series of reports and presentations. (Jackson,2005) All the graphics following were prepared by the teams.

The first team researched possible solutions for the problem and introduced the concept of automated container transport, envisioning a system that will move and sort containers within a rail/truck terminal. This team developed preliminary designs for an elevated between-yard transportation system and an integrated intra-yard GRail (Grid-Rail) system that utilizes linear induction motor technology. Much of this concept was based on the GRail Report written by August Design, Inc., which detailed an overhead high density mobile crane system for storage and retrieval. The GRAIL concept was developed over a period for SeaLand Corporation, originally for ship-to-shore application, and was not widely documented until 2000. See (Khoshnevis,2000) as an example.

The GRail lattice structure provides automation of container movement and lessens direct requirement for precious urban land.

The additional integrated details of the multi-semester IPRO project can be delineated in three primary components: Structures, Networks and Propulsion.



INTERYARD STRUCTURE (figure2)

STRUCTURES

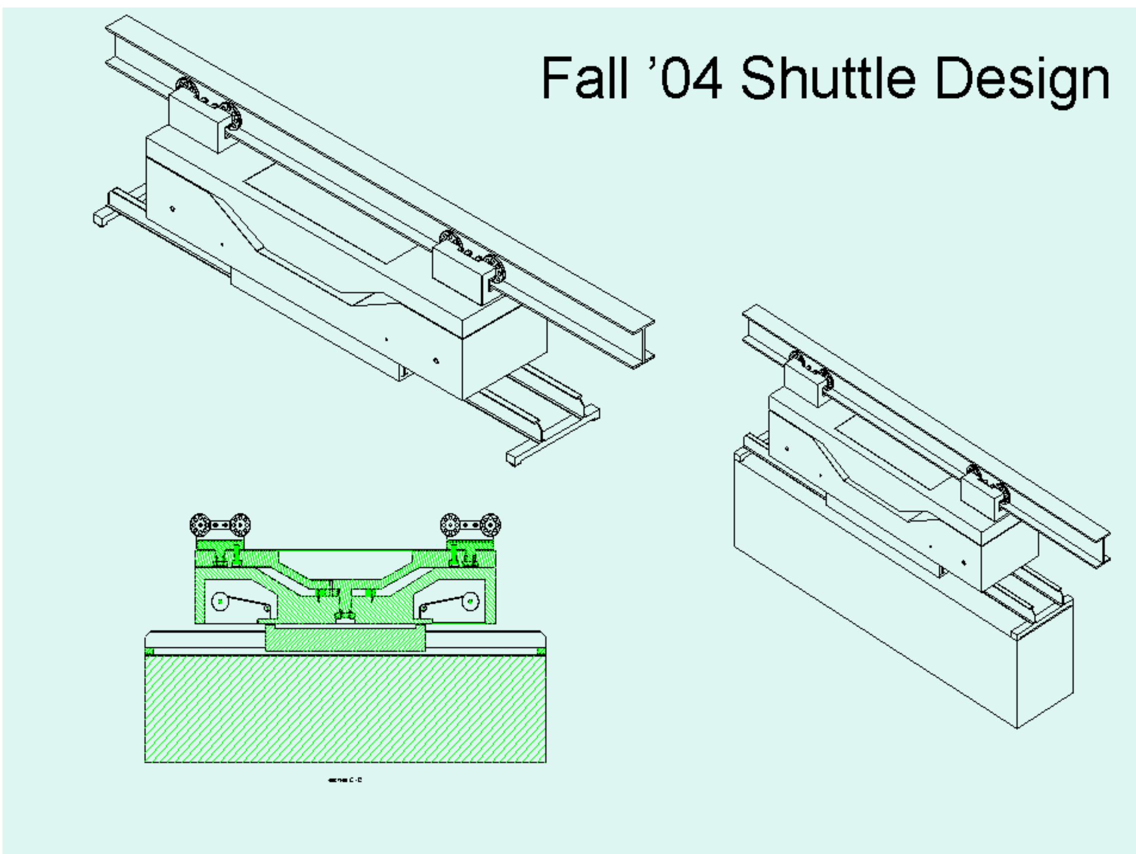
The design of the structures was governed by the requirements of maximum loading and the proper use of space in the rail yards. The lattice work of the Intra-yard/GRail Structure (Figure1), is designed to accommodate 50% coverage of the strip tracks, significantly increasing capabilities; storage capacities can also be increased by possibly stacking containers four high.

Besides the GRail Structure inside a rail yard, a between-yard shuttle system is envisioned that would address the problem where substantial numbers of containers are moved to and from rail-yards by “rubber-tiring” them. This means they are unloaded from the train in one yard, onto a chassis, pulled via truck to move to another train in a different rail yard, to be reloaded. This process exhausts surface streets. Our teams designed an elevated structure that can move containers between terminals using a linear induction based vehicle, or serve as a toll-road. This between-yard structure provides for connecting freight nodes and allows for expansion capability by providing space for the under-hung GRail shuttle. See Figure 2.

To generate revenue a toll-road option was also considered for the upper level of the between-yard structure – a truck toll road - that will provide direct access between these rail-yards. The two systems will interface, making the transfer of inter-modal containers quicker and simpler. If the truck toll road is also opened to other users, additional revenue can be gained.

To further evaluate the systems’ implementation as a feasible reality, the structural analyses for these two distinct systems were augmented. A detailed design of the shuttle and its components were drafted to include dimensions for operating parts such as the spreader bar and gear system (Figure 3).

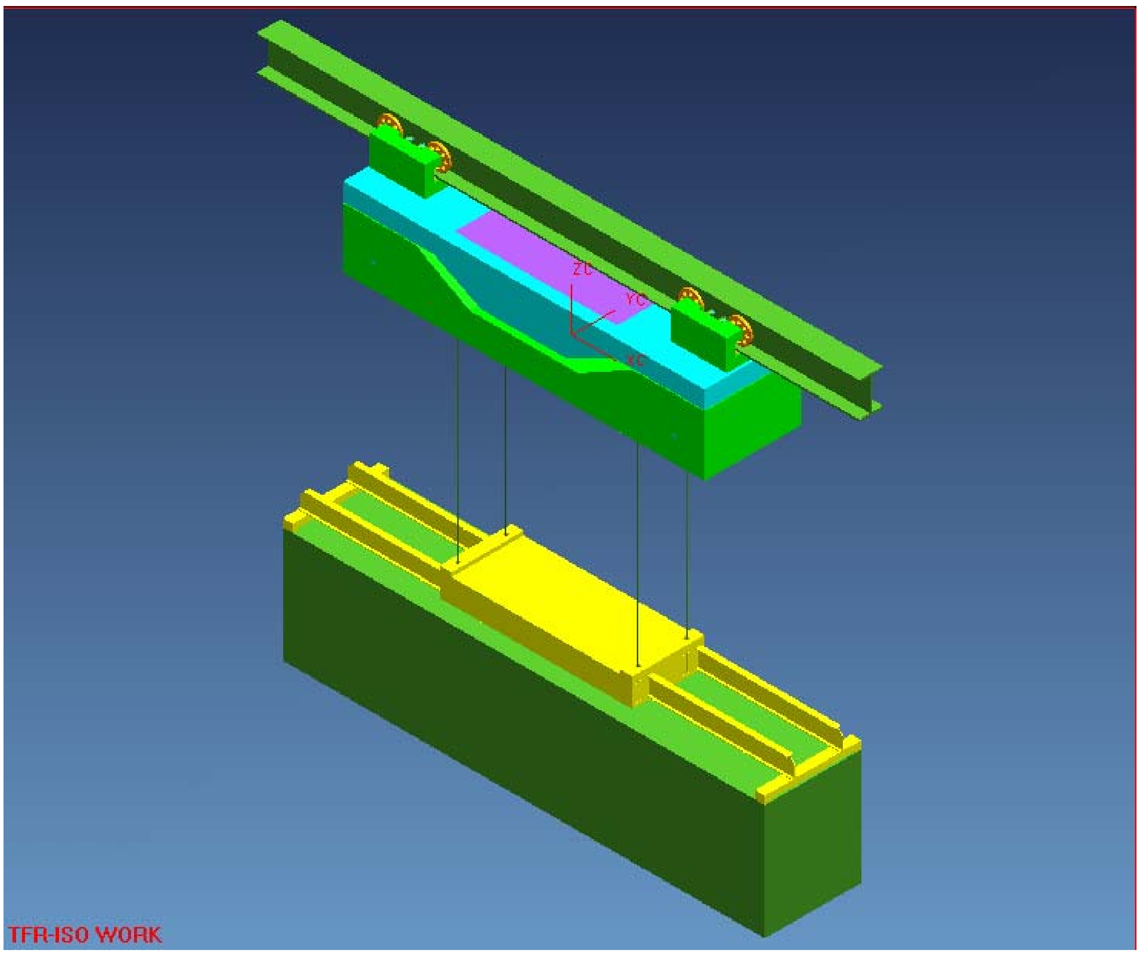
Descriptions of the container identification and shuttle location systems were developed which included a detailed shuttle flow chart of the automated computer procedures that would control the rail yard operations. Detailed estimates for quantities were developed. Preliminary estimates for total costs of construction of both structures and mechanicals in and between the rail yards have also been determined



SHUTTLE & COMPONENTS (figure 3a)

NETWORKS

In accordance to zoning specifications, an actual working scenario for two specific yards considering the real world obstacles going through an existing urban area was proposed. One of the major obstacles that had to be considered for this project was elevations to cross the CTA Orange line. Using the ESRI GIS program ArcView, layouts for the network were produced to demonstrate the route between Chicago's busiest inter-modal transfer corridor, the BNSF's Corwith and NS's 47th Street rail yards. This quantity has been estimated to be



SHUTTLE OPERATION (figure3b)

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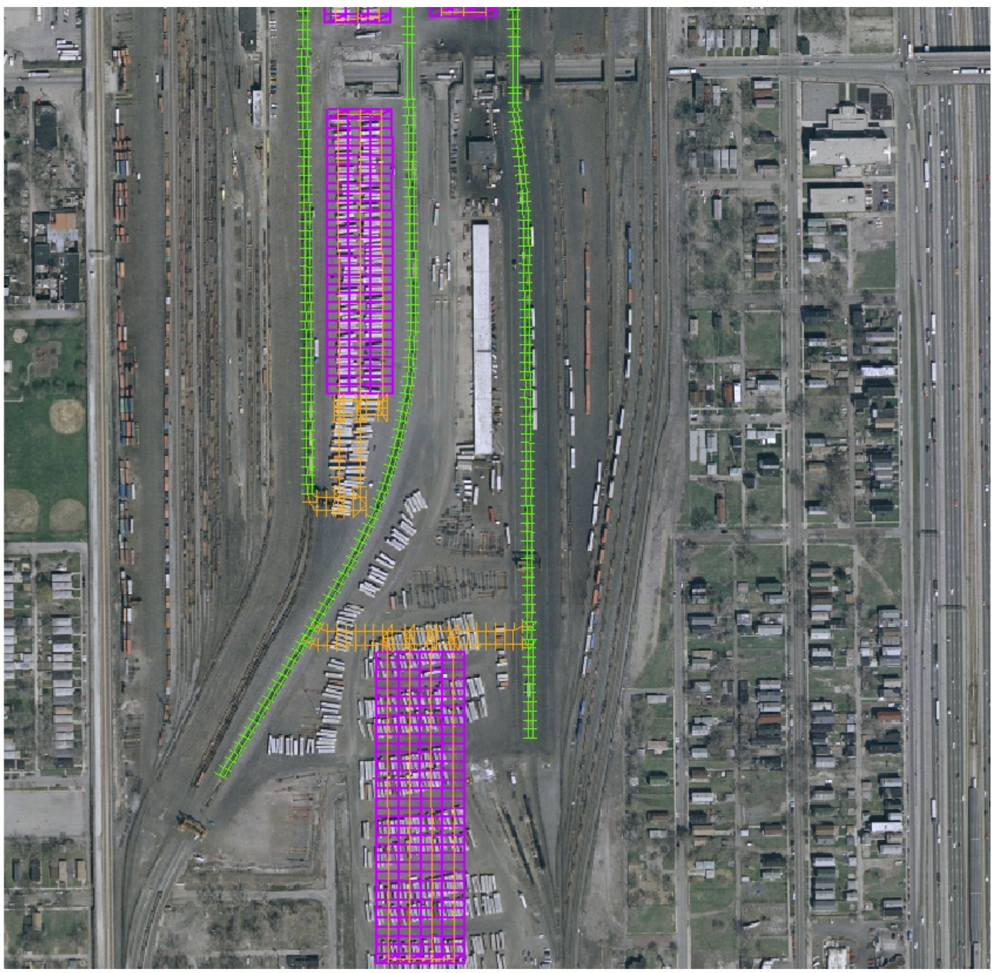
as much as 4000 big trucks per month, adding to street and highway congestion. (Ferguson,2005) The zoning and accompanying aerial photography inventory was necessary for it provided guidelines for specifying what can be built in certain designated areas, size of surrounding areas to include lots and buildings, as the team evaluated the between yard (inter-yard) shuttle route that should have little conflict with existing zoning requirements.



NS47th YARD With LATTICE (figure4)

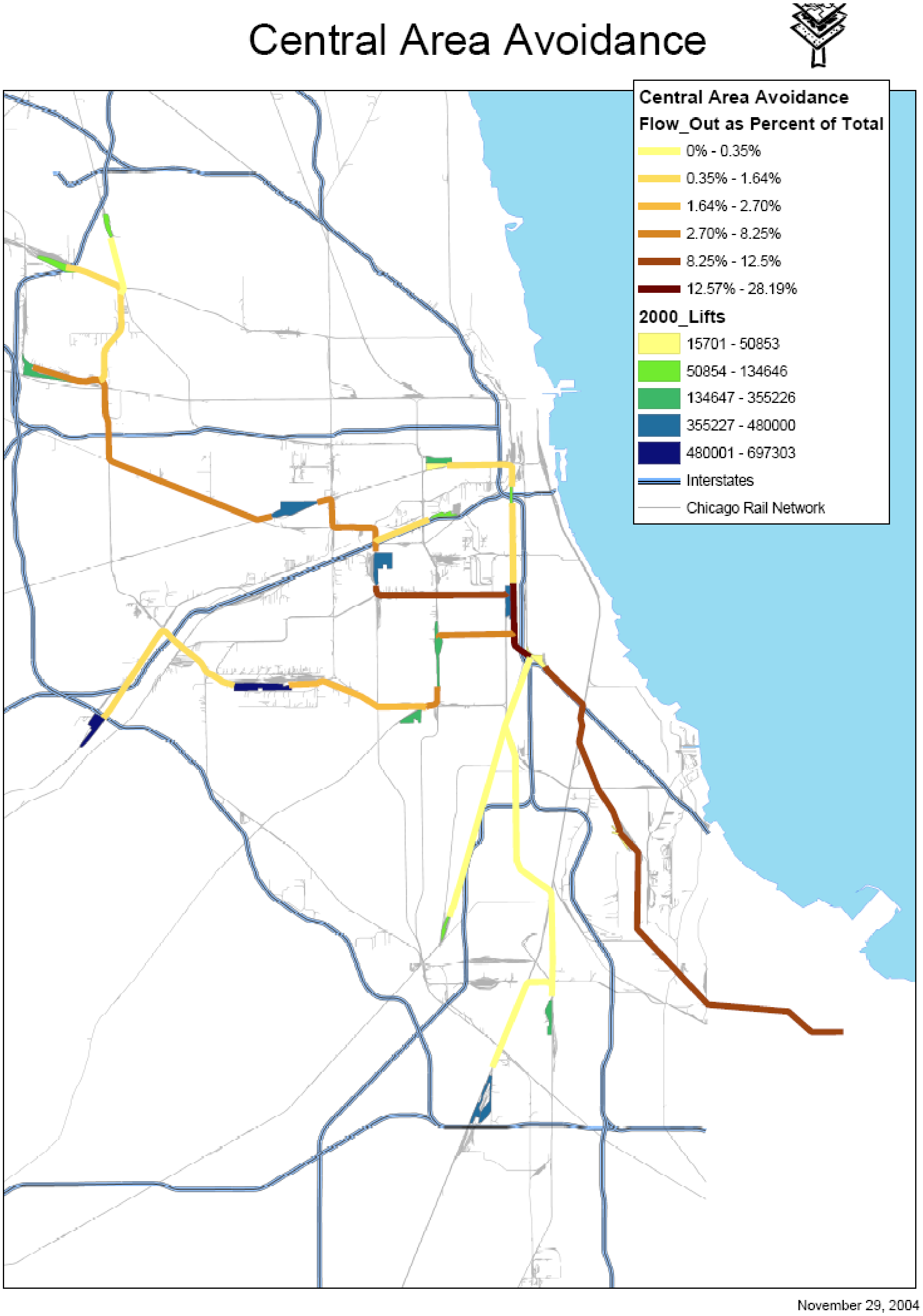
A map that overlaid zoning on recent aerial photographs was completed. Specific yard layouts were also developed showing: strip track coverage (green), the storage area (purple) and the track where the shuttles are elevated to the storage area (orange). (See Figure 4)

The team also provided CAD drawings depicting preliminary design of the network structure that showed the access ramps connecting the Inter-yard system with the Dan Ryan and Stevenson Expressways (I-90/94 and I-55). Estimates and templates for financial scenario analysis of a truck toll road that provides direct access between these yards were also determined. Besides previous estimates that have shown existing cross-town traffic level can support an automated system, one year, ten year and fifty year projections depending on the percentage of trucks using our toll ramps were made. This truck-way opportunely allows for spreading construction costs and advantages over a wider set of stakeholders.

A complete system interconnecting all the Chicago Area rail yards was also laid out using a trial attribute of least distance. An alternative was also developed that avoided the Chicago central area. These are shown in Figure 5.

PROPULSION

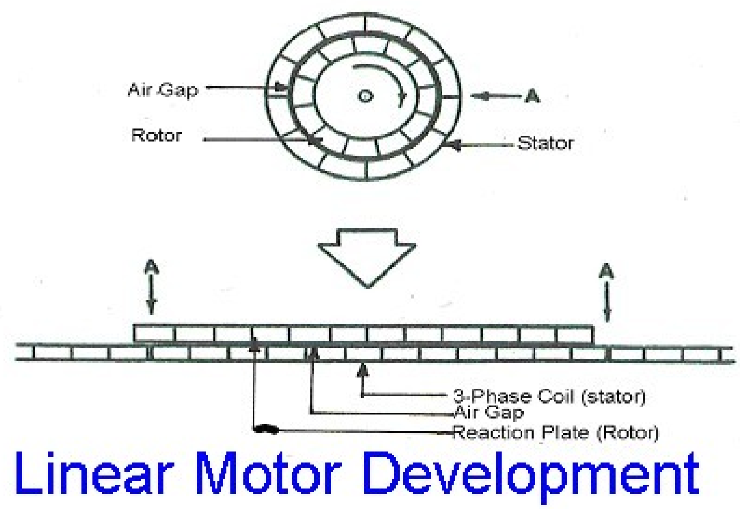
The means of propulsion with a linear induction motor, as a solution to Chicago’s container transfer problems, was inherited from the first semester’s vision of a linear induction track. Because of their overwhelming simplicity and reliability, LIMs have long been regarded as the most promising means of propulsion for future high-speed ground transportation systems.



ENTIRE NETWORK FOR AUTOMATED CONTAINER HANDLING (figure5)

Some of the advantages of this technology include: cost and simplicity to assemble, ignition (self starting), and maintenance (reduction in wear on parts).

A Linear Induction Motor is a mechanism that converts electrical energy directly into linear motion without employing any intervening rotary components. The system consists of a reaction plate and a 3 phase AC coil Assembly. If one were somehow able to slice the rotary motor down the center, the rotor/reaction plate will be on top and the stator/3-phase coil is the bottom section. The layout of a LIM is illustrated in graphic form in Figure 6.

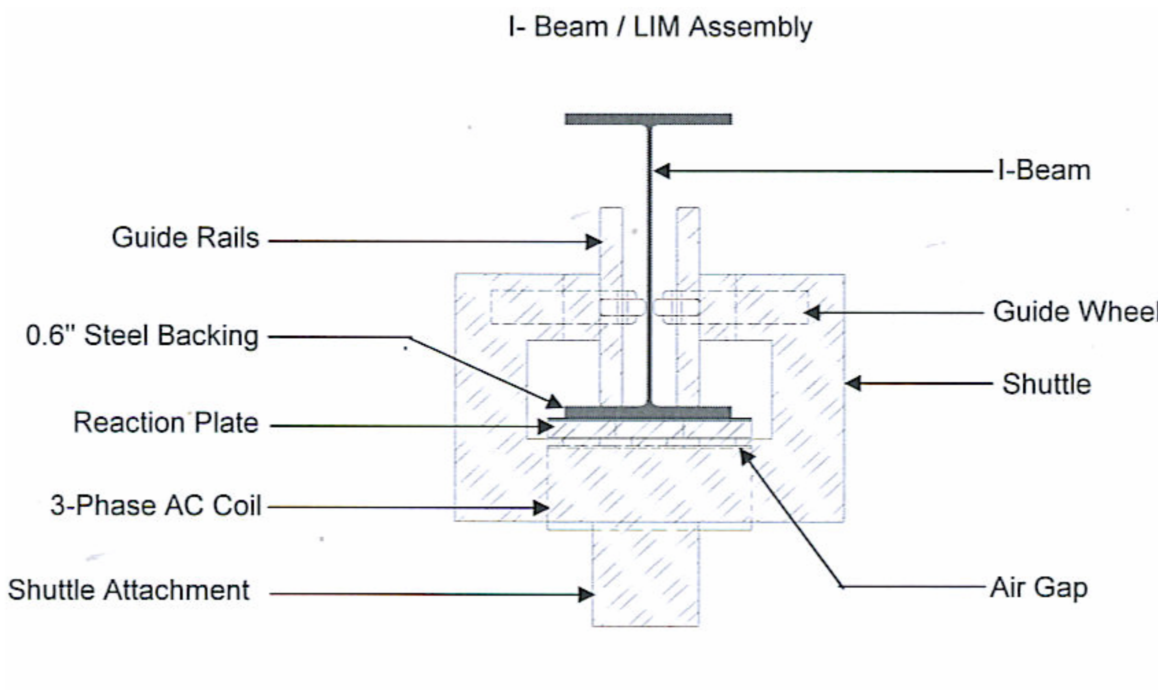


LINEAR MOTOR DEVELOPMENT (figure6a)

Specific estimates were derived for a potential LIM motor with the following design parameters and requirements considered:

- Maximum payload of 180,000lbs for the motor

- Maximum operating speed of 10mph
- Powerful enough to climb a 10% grade incline with a full payload
- Enough acceleration to reach operating speed quickly



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LINEAR MOTOR ARRANGEMENT (figure6b)

From these requirements, two designs for Linear Induction Motors that can accomplish the tasks were developed. They are shown in the following table.

MAXIMUM SPECIFICATIONS	MINIMUM SPECIFICATIONS
45 motors tied in series 22.5 inch width for the reaction plate Total area of the motors is 36.1 sq ft (1.875 ft x 19.25 ft) Acceleration of 0.0166g's Time to reach operating speed is 1 min and 50 sec Power is 175.95 kW or 235.9 horsepower Total cost of motors $67,498.92 Total cost to operate $12.32 per hour	21 motors tied in series 22.5 inch width for the reaction plate Total area of the motors is 16.8 sq ft (1.875 ft x 9 ft) Acceleration of 0.0077 g's Time to reach operating speed is 3 min and 55 sec Power is 82.11 kW or 110 horsepower Total cost of motors $31,449.50 Total cost to operate $5.75 per hour

FINANCIAL ANALYSIS

Finally a financial analysis was performed. Estimates for construction and operation were derived. Even with nearly a $5billion cost to build, under favorable assumptions of use, there could be a favorable return on investment. These results are shown in Figure 7.

Financial Analysis

	IRR	Investment	Return 2006	Return 2016	Return 2026
3% increase in Variable Costs and 3% increase in Volume	12%	$4.86 Billion	$305 Million	$494 Million	$747 Million
3% increase in Variable Costs and 5% increase in Volume	14%	$4.86 Billion	$318 Million	$714 Million	$1.3 Billion
3% increase in Variable Costs and 3% decrease in volume	4%	$4.86 Billion	$265 Million	$43 Million	($150 Million)
3% increase in Variable Costs and 5% decrease in Volume	0%	$4.86 Billion	$251 Million	($55 Million)	($276 Million)

INVESTMENT RETURN (figure7)

The People of the Project

Thirty students in all, from Architecture, Architectural Engineering, Business, Civil Engineering, Computer Aided Engineering, Computer Engineering, Computer

Science, Electrical Engineering, Information Technology, Materials and Aerospace Engineering, Mechanical Engineering, and Psychology participated over a year and a half.

The students who performed this work truly exemplified the guiding principal of communication and collaboration across the boundaries of their curriculums. Starting in spring 2004 and performing interdisciplinary practices, the teams developed designs and options in order to bring these concepts to a point where a fully automated system of container lifting and transport can be implemented. The system incorporating two distinct structures (Intra-yard/storage and Inter-yard/shuttle) provide for the automation of container movement and lessens the direct requirement for precious urban land. Most importantly, by conducting this in-depth research, these future professionals, who must solve this, and similar problems, gained meaningful knowledge and experience.

References

Behrokh Khoshnevis, Ardavan Asef-Vaziri, 3D Virtual and Physical Simulation of Automated Container Terminal and Analysis of Impact on In Land Transportation Metrans, University of Southern California December 2000

Chicago Area Transportation Study (CATS), Intermodal Advisory Task Force 2005

Chicago Metropolis 2020, The Metropolis Freight Plan: Delivering the Goods, 2004

Daniel Ferguson, Bruce Dahnke, Gerald Rawling, Ariel Iris, Jorge Arreola, Adan Perez, (2005) A 21st Century Cargo-handling Regimen for the World's 3rd Largest Port trb05-2137, January 10th, 2005 Transportation Research Board, Washington DC

Carliss Jackson, et al, Automated Shipping Container System Design for Chicago, student paper for Transport Chicago, 2005

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