

An Illinois Institute of Technology Interprofessional Project (IPRO)

Automated Shipping Container Transfer in Chicago

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Introduction

The Problem

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 the third largest container port in the world. In many instances, containers are even moved from one railroad to another by truck, exhausting street and highway capacity. Meteoric growth in container movement is expected to continue.

The Needs for Our Solution

1. Expected doubling in the demand for freight transportation every 7 years (6% per annum in the U.S. & 9% globally)
2. Congested and overwhelmed infrastructures
3. Land use concerns (right of way and street usage) and retention of developed facilities in the Chicagoland Area
4. Environmental concerns include clean air and noise pollution

Resulting Benefits

1. Reduced highway congestion and reduced need to build more highways and other infrastructures
2. Continuation of the existing landuse pattern that supports current economic activities without further capital intensive and open land devouring development.
3. Enhanced highway safety and reduced fuel use and lower harmful emissions

Objective

The primary public goal in IPRO 307 is to substantially minimize the time delays and to reduce traffic congestions by cutting down on the number of trucks transporting containers in Chicago, which in turn will reduce overall operating costs. This semester, we have continued the development of designs and options conceived in two previous semesters to bring it to a point where it can be implemented. To make its implementation a feasible reality, we've proposed an actual working scenario for two specific yards considering the real world obstacles going through an existing urban area.

Project Background

This project is a continuity of the previous two semesters 307 IPROs. The accomplishments of these projects are described below:

Spring 2004 team accomplishments

The team created a system that will move and sort containers within the rail/truck terminal. Much of this system was based on the GRAIL Report written by August Design, Inc. This report detailed a modular high density automated container storage and retrieval system that uses overhead handling. The team also designed an elevated linear induction track that will move the containers between the two terminals. The two systems will interface, making the transfer of intermodal containers as quick and simple as possible.

Fall 2004 team accomplishments

GIS Maps of two possible interyard networks and CAD drawings depicting preliminary design of the network structure.

CAD drawings depicting the basic design of the shuttle and its components.

Descriptions of the container identification and shuttle location systems as well as a detailed flow chart of the automated computer procedures that would control rail yard operations.

IRR, volume numbers, and estimated total costs of construction for both proposed network designs as well as IRR and estimated total cost of construction for a network/GRAIL implementation solely in Chicago's busiest intermodal transfer corridor (between the Corwith and 47th Street rail yards), determined using an Excel model.

Issues emphasized for this project

LIM Process Design/Integration which includes:

- Research linear induction motor technology for model and full scale application
- Find resources to either build or purchase system prototype

Civil/Structural Engineering which includes :

- Profile network (elevation of ramps)
- Align routes
- Finalize structure analysis for two sample designs: inter-yard structures and the intra-yard GRAIL structure
- Determine quantity of steel, concrete and other materials
- Find best overall solution

Economic Feasibility which includes :

- Update the Corwith to 47th Street analysis
- Develop a financial analysis software that will allow us to extend the analysis
- Determine costs and most profitable application for both systems
- Compare results obtained from analysis of optional network scenarios and suggest improvement
- Determine Capital/Operating Costs
- Compare/Contrast Implementation costs of inter-yard structures
- Find best overall solution

Our Project's Requirements were:

- Delineate and divide various responsibilities among team members
- Develop and maintain up-to-date and thorough representations of the team's progress and milestones
- Continuing monitor individual participation and performance to ensure everyone gets a sufficient background of all aspects of the project

Team members responsibilities:

•Project Aspect:

- Librarian
- LIM
- Propulsion
- Between-yard
- Structures
- Civil
- GIS and Network
- Modeling, Animation and Zoning
- Cost Analysis Database
- Plans/Reports/Drawings

Sub team Leader:

Carliss Jackson #
Rafiu Amolegbe * #
Paul Prusa
Charles Medrano #
Vladimir Grozdanov #
Mira Racheva
Keegan Adcock * #
David Smreczak
Joseph Tomal
Kallinikos Kechagias

Major:

Psychology Project
Electrical Eng.
Mechanical Eng.
Civil Eng.
Civil Eng.
Civil Eng.
Computer Science
Information Tech.
Information Tech.
Civil Eng.

second semester in an I-PRO

*** second semester with I-PRO 307**

LIM Sub-team Report

Introduction

As the United States has no transcontinental railroad, shipping containers must be transferred between railroad companies in order to cross from one side of the country to the other. As a major point of interchange between many of the nation's railroads, Chicago is the third largest intermodal port in the world, and the location where many of these transfers take place – mostly by truck. 2 million containers pass through Chicago a year, and containers are getting stuck for up to two days! Railroads are looking to bypass the city and truck transfers are crowding the streets. Chicago has exhausted its capacity. Our primary purpose in IPRO 307 is to minimize the time delays and cut down on the number of trucks transporting containers between rail yards in Chicago. To do this, *a fully automated system of container lifting and transport* was conceived over the spring 2004 semester, incorporating an overhead mobile crane network (called GRAIL) and an interyard transit network. This semester, we have continued development of the system with a number of objectives aimed at making its implementation a feasible reality:

Project Background

Since its inception as a solution to Chicago's container transfer problems, the GRAIL network has incorporated the Linear Induction Motor as its propulsion system. This

premise however had not been adequately researched to deserve the commitment it had enjoyed from past groups.

Project Purpose

The main purpose of this semester's LIM sub team was to determine once and for all whether or not the chosen propulsion system for the GRAIL network was indeed our best option for moving container-laden shuttles between the designated rail yards. A second objective will be determined by the results of our research. Barring adequate reasons to disqualify LIM as the propulsion system of choice, we must then proceed to acquire a working LIM model.

Project Research Methodology

Although, previous IPRO 307 groups had accomplished a lot in the GRAIL network, much remains to be done with the propulsion unit. And this is the task to which we applied our resources this semester.

LIM members

Rafiu Amolegbe, Paul Prusa

Rafiu is a senior EE holdover from last semester's group and Paul is a junior ME first timer. Paul was originally brought in to help where needed, but as the semester wore on; his knowledge of *AutoCAD* helped the group design two LIM models, adequate for our purpose. Paul also contacted vendors to gather information on LIMs. Rafiu was able to add to the group's knowledge of Linear Induction Motors and together with Paul, liaised with vendors to assist in design specifications and with other sub teams to acquire pertinent information.

A. Linear Induction Motors

A LIM is a mechanism that converts electrical energy directly into linear motion without employing any intervening rotary components. The development, of a LIM is illustrated in graphic form below. A conventional rotary induction motor, such as that powering an electric clock, is made up of two rings of alternating north and south magnetic poles. The outer ring (the stator) is stationary, while the inner one (the rotor) is free to rotate about a shaft. The polarity of the magnets on one (either) of these rings is fixed, this element is known as the field. The magnets of the other ring, the armature, change their polarity in response to an applied alternating current. Attractive forces between unlike magnetic poles pull each element of the rotor toward the corresponding element of the stator. Just as the two poles are coming into alignment, the polarity of the armature magnets is reversed, resulting in a repulsive force that keeps the motor turning in the same direction. The armature poles are then reversed again, and the motor turns at a constant speed in synchronism with the alternating current that causes the change in polarity.

If one were somehow able to slice the motor to its center at point A and then lay each element out flat, with the rotor on top, and then add additional stator elements *ad infinitum*, as shown in the lower illustration, one would have a linear induction motor. Here the moving element undergoes the same forces of attraction and repulsion as in a rotary induction motor, but its motion becomes linear instead of rotational. 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. The proposed system, while not strictly qualifying as high-speed, still derives some advantages from the utilization of a LIM. Within the broad range of possible propulsion systems, at least, one other alternative is put up against the LIM. Comparisons are made between Linear Synchronous Motors and LIMs and the results are stated below.

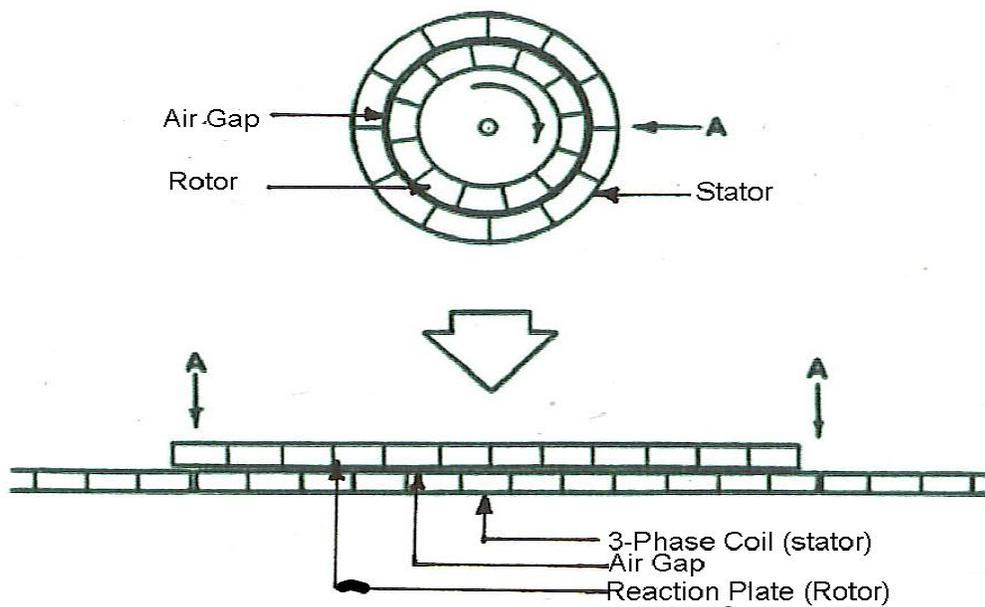


Fig. 1 Linear Induction Motor Development

B. Advantages

1. Cost and Simplicity: LIMs are simpler and less costly to construct. The stationary element of the motor consists of nothing more than a rail or plate of a conducting material, such as aluminum or copper. Alternating current applied to the coils of the moving electromagnets induces a fluctuating magnetic field around this conductor that provides the propulsion force. By contrast, Linear Synchronous Motors requires the installation of alternating north and south magnetic poles on both moving and stationary elements.

2. Ignition: LIMs are self-starting, with the speed of motion being infinitely variable from zero up to the design maximum. LSM'S, on the other hand, exhibit no starting torque; rotary motors of this type are generally equipped with auxiliary squirrel-cage windings so that they can act as induction motors until they reach operating speed.

3. Ease of Assembly: Because linear induction motors do not contain permanent magnets there are no attraction forces during system assembly, greatly simplifying this task. Conversely, the assembly of LSMs are quite difficult.

4. High Power Applications: LIMs are Ideal for high-power applications. They are used extensively in high force linear motor applications, as they are available with continuous force ratings in the hundreds of pounds.

5. Maintenance: the non-contact design of a direct drive linear motor eliminates friction induced wear. There is no lubrication or periodic adjustment required. Also, there is typically a reduction in parts count as the system is simplified.

6. Travel: linear motors have no reasonable limit on length of travel. Unlike most mechanical actuators there is no loss of performance commensurate with travel length.

Disadvantages

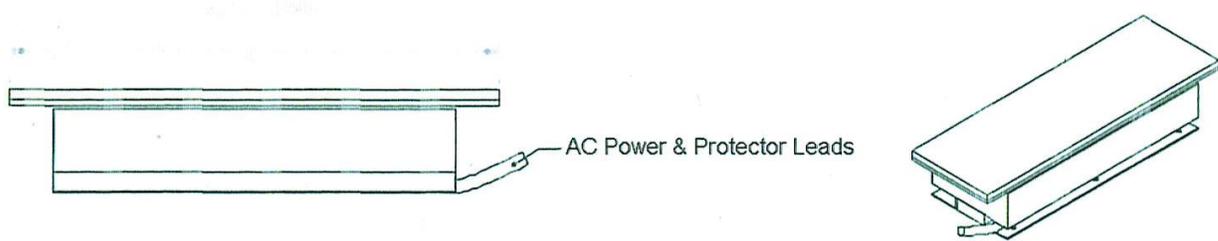
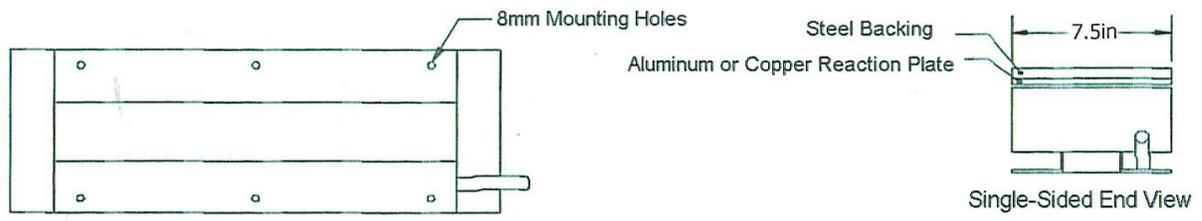
- 1. Efficiency:** The highest value of efficiency yet attained for an LIM scarcely exceed 70%, while models of LSM have been built with 95% efficiency or more. Apparently, the conversion to a linear geometry has a far greater effect on induction motor performance than on that of synchronous motors.
- 2. Speed vs Efficiency:** The efficiency of an LSM is relatively unaffected by the speed of travel; LIM's, on the other hand, do not reach peak efficiencies until they attain velocities which are well beyond those being considered here.
- 3. Large attractive forces during operation:** While LIMs do not have permanent magnets, large attractive forces are still produced during operation. These forces must be supported by the bearing system, and affect the life of the linear bearings.
- 4. No force at standstill:** Linear induction motors do not produce a force at standstill unless an AC Vector drive is utilized.
- 5. Large physical size:** Compared to permanent magnet motors, these motors are large for a given continuous force rating, thus package size is a disadvantage.
- 6. High power consumption:** Because of their low efficiency, Linear Induction Motors produce more heat for a given continuous force output than LSMs. As a result, they often require forced air or water cooling to achieve published specifications.

C. Components

- 1. 3-Phase Coil Assembly:** The stator of an induction motor is replaced with the coil assembly and is comprised of a 3-phase winding that is wound and inserted into a steel lamination stack with thermal protection devices. The entire assembly is then encapsulated with thermally conductive epoxy. Steel Angles with mounting holes are provided for mounting the coil assembly to the host contraption. The coil assembly can be used in a single sided or double-sided configuration. The single sided configuration consists of a single coil assembly that is used in conjunction with an aluminum plate backed by a steel reaction plate. The double-sided configuration is where 2 coil

assemblies are facing each other, separated by a gap of .25" [6 mm] and only an aluminum reaction plate passes thru the gap. Multiple coil assemblies can be used together to produce larger forces. The standard sizes for the coil assemblies are shown below in Fig. 2

2. Reaction Plate: The rotor of an induction motor is replaced with a reaction plate in the LIM. The reaction plate is made up of standard, readily available 1018 steel, aluminum, and / or copper. For single sided operation, the required reaction plate consists of a .125" [3 mm] thick aluminum or a .080" [2 mm] thick copper plate that is backed by a .25" [6 mm] thick ferrous steel plate. The steel plate can be omitted but the force will be dramatically reduced. For double-sided operation only a conductive plate of copper or aluminum is required.



Single-Sided Induction Motor

D. Design

1. Design Parameters

In designing the LIM motors, the following requirements were 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
- Maximum area for LIM of 38.5 sq.ft

And from the requirements, we were able to design two Linear Induction Motors that can accomplish the tasks.

LIM Specifications

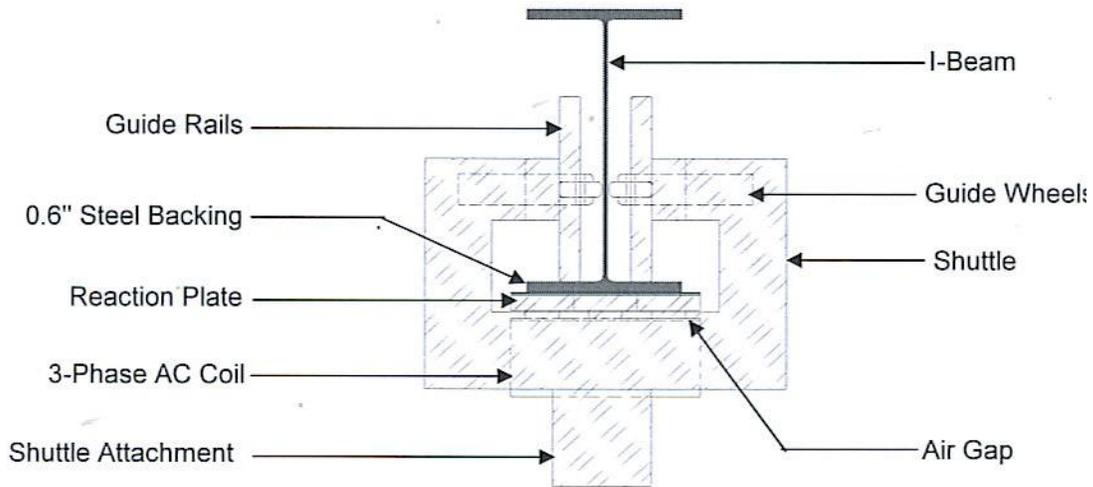
– Maximum System

- 45 motors tied in series
- 22.5 inch width for the reaction plate
- Total area of the motors is 36.1 square feet (1.875 ft X 19.25 ft)
- Acceleration of 0.0166 g's
- Time to reach operating speed is 1 minute and 50 seconds
- Power is 175.95 kW or 235.9 horsepower
- Total cost of motors \$ 67,498.92
- Total cost to operate 12.32 \$ per hour

– Minimum System

- 21 motors tied in series
- 22.5 inch width for the reaction plate
- Total area of the motors is 16.8 square feet (1.875 ft X 9 ft)
- Acceleration of 0.0077 g's
- Time to reach operating speed is 3 minute and 55 seconds
- Power is 82.11 kW or 110 horsepower
- Total cost of motors \$ 31,499.50
- Total cost to operate 5.75 \$ per hour

I-Beam / LIM Assembly



Barriers and Obstacles

Our first major obstacle was the paucity of research material on LIM left by previous IPRO 307 groups. What little experience the team had was limited to ECE 319 which only deals with Rotary Synchronous Motors. There were no LIMs to test or parts to learn from. No field trips was taken to a LIM operation and no expert was available to help us. What little knowledge we garnered from the internet were often conflicting. Well, engineers have persevered in the face of such aridity and so did we.

Results and Conclusion

Our task: a definitive research proving the LIM concept for shuttle and chassis vehicle propulsion in the network has been accomplished. We were unable to prove conclusively that the Linear Induction Motor is the best propulsion system for the GRAIL network. We arrived at this position, after weighing the disadvantages of LIMs, how it compares with the Linear Synchronous motor and the final design specifications –the maximum and the minimum design. For instance, our best design takes about 2 minutes to reach maximum operating speed of 10mph and utilizes 235.9hp in the process. This reflects one of the major disadvantages of the LIM: low speed inefficiency. Even if we were designing for 100mph, we may only expect about 70% efficiency at best, while our power requirement will increase considerably. For a 10mph speed within a 50-mile distance, a Linear Induction Motor would not be the most effective motor. LIMs are at their best at high speeds and long distances.

Recommended next step

We hope that our research has debunked the notion that the LIM is uniquely suited to propel the GRAIL network. We would suggest that researches be conducted to determine the best options. We would also suggest that the Linear Synchronous Motor be a part of this research. For as we have stated above LSM offers a few advantages over the LIM.

Structures and Civil Sub-teams Report

The tasks of the structures and civil teams were to produce a particular design for the Inyard and Interyard structures according to requirements from the LIM shuttle and available area in the yards. Also the Civil part was to identify the location for all the major parts of the project – mapping out the coverage of the both yards with the GRAIL and Storage facilities and also the route of the proposed highway/LIM transfer line. Another part was alignment of the on and off-ramps connecting the Interyard system with I-55 and I-90/94.

Since the tasks of the teams were very closely related, it seems out of order to produce separate reports.

The start was to consider the dimensions of the yards, the needed coverage of the strip tracks, capacity of the yards for storage, the capacity of the containers. The design was governed by the maximum loading and clearance requirements.

One of the biggest problems encountered was to identify all the details of the yards from the aerial maps – the zooming capability only allowed for marginal dimensioning and identification of obstacles. In particular the strip tracks in Corwith yard were identified as triples and doubles, but it seemed very hard to distinguish between them. The field trip to 47th street yard (with Bruce Dahnke, Skytech Transportation) actually produced the only hard facts about the capacity of the particular yard and the total length of strip tracks.

The design went through several stages:

- deciding on the size of the structure and materials of use
- actually performing the calculations for particular members
- checking and verification of the designed structure

Design of the structure in the 47th street yard was more diverse in terms of alignment of the typical frames over the strip tracks, because of the curvature and also the location of the storage areas. The layout of the Corwith yard was much easier to accommodate in terms of placement of the structures- all the strip tracks were straight line through the yard and the storage space was at one location.

The size of the facilities was governed by several requirements: double stacked trains running on the railroad – 23 ft of clearance needed, 4 ft clear space between moving containers, container dimensions etc.

Structures were designed to accommodate up to 80000 lbs containers, carried by the 100000 lbs proposed shuttle vehicle. There were several different frame designs that could be used – single monorail, double and triple. Calculations were performed for all types, but for simplicity – the largest frame was chosen to be used for all the GRAIL typical frames, and one for the Storage structures.

The design of the structure was governed by the requirements of maximum loading and the proper use of space in the rail yards.

The structure design started out as an entirely steel structure, but the large clearance prevented the possibility of lateral bracing in both directions. That was the main reason for changing the design. Single W- shaped steel sections did not have the

needed strength to prevent lateral buckling and sway, because of the clearance requirements over the strip tracks.

The solution was to encase the steel sections in substantial amount of reinforced concrete, so the composite column formed would have enough stiffness and rigidity to prevent failure in any mode.

Since there were single, double and triple strip tracks, the design of a typical GRAIL frame was governed by the worst loading combination – the three monorail girder. Then the design of the heaviest frame was used for the lesser loading. The reason was simplicity and repetition of the process so same formwork can be used for all the concrete columns. Similar procedure was performed for the steel girders, where the heaviest design section was used throughout.

Based on the calculations the following section and sizes were chosen:

-W44X335 for all the girders (GRAIL and Storage)

-W14X455 for all steel column sections

-W36X210 for all monorails

-38''X38'' (40 #10 steel bars) square concrete column to encase the steel section (intyard)

-48''X48'' (40 #10 steel bars) square concrete column to encase the steel section (interyard)

-Typical GRAIL frame:

a) 50ft clearance from the ground

b) 45ft maximum clear span of the girder

c) 14ft minimum distance between monorails

d) Three monorails maximum capacity

-Typical Storage Frame:

a) 60ft clearance from the ground

b) 60ft maximum clear span of the girder

c) Monorail at midspan

d) One monorails capacity

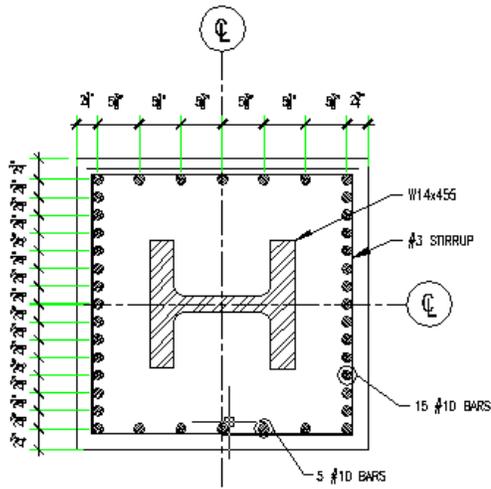
-Footings

a) 12'X12'X3' reinforced concrete (7 #5 bars bottom mat in both directions & 7 #9 bars in top mat in both directions with 11 inch spacing throughout)

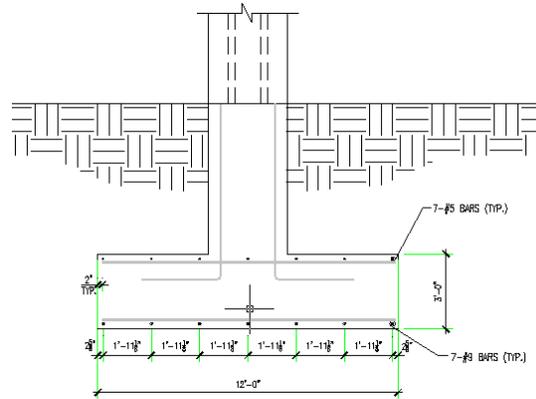
b) Used 60ksi steel reinforcement bars and 5ksi concrete

c) Used 3 inch covers on each side of the footings for protection of the steel from corrosion as a result of wet soil exposure.

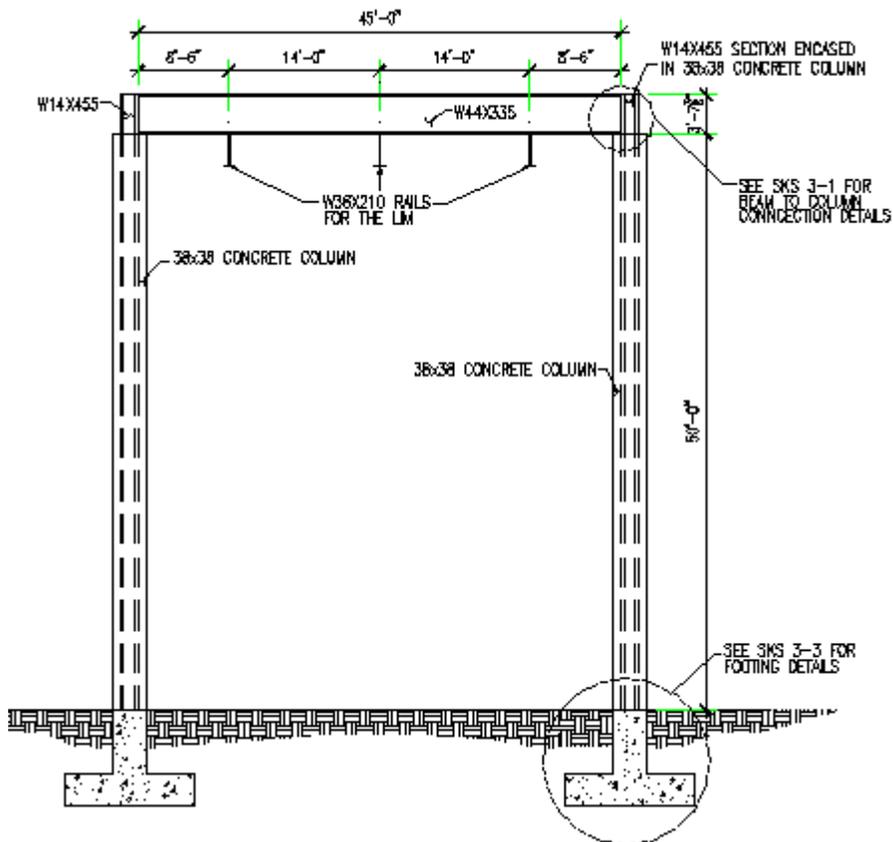
d) Used crack width control safety factor for severe exposure with wet/dry cycles and harmful chemicals in the soil for conservative design calculations



Typical column cross section



Typical footing detail



Typical frame above rails- three shuttle capability

INTERYARD STRUCTURE:

-W44X335 for all the girders

-W14X455 for all steel column sections

-W36X210 for all monorails

-48"X48" (40 #10 steel bars) square concrete column to encase the steel section

-10" concrete slab

-3.5' parapet

-Typical Interyard frame:

a) 50ft clearance from the ground

b) 50ft maximum clear span of the girder

c) 14ft minimum distance between monorails

d) Two monorails capacity

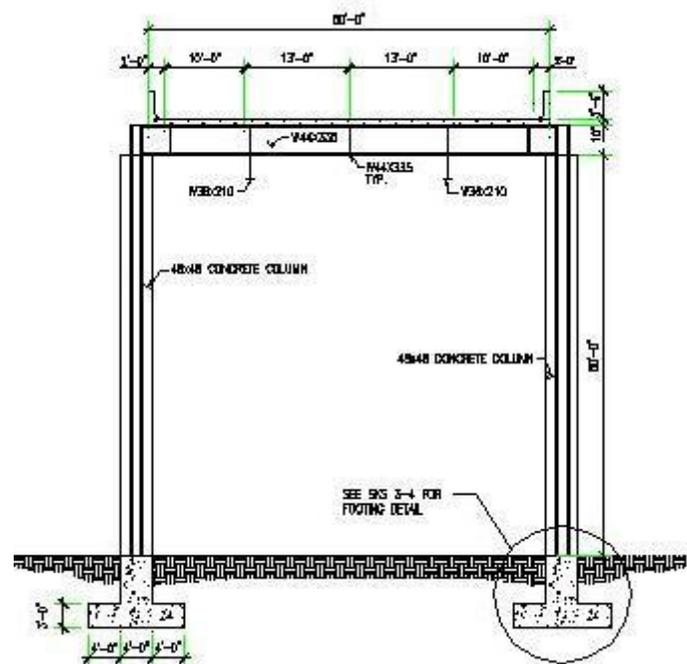
-Footings

a) 12'X12'X3' reinforced concrete (7 #5 bars bottom mat in both directions & 7 #9 bars in top mat in both directions with 11 inch spacing throughout)

b) Used 60ksi steel reinforcement bars and 5ksi concrete

c) Used 3 inch covers on each side of the footings for protection of the steel from corrosion as a result of wet soil exposure.

d) Used crack width control safety factor for severe exposure with wet/dry cycles and harmful chemicals in the soil for conservative design calculations



Typical inter yard structure

The configuration started out as fifty percent coverage of the strip tracks in both the 47th street and Corwith yards, but later was decided to be increased to nearly hundred percent. The aerial maps were updated with the shape files of the specific coverage for the yards.

The difference in elevation between the GRAIL and Storage areas was ten feet and special elevating sections of the structure were designed to accommodate the shuttle capabilities of climbing with full load (presented in orange on the aerial maps).

The connections design was not completely finished, but in general end plates are welded to all girders (all around) and the bolted moment connections are performed on site. Eight bolts connect each end plate to a flange of a column and stiffener plates are welded between the flanges of the column matching the location of girder flanges.

End plates are also welded to one end of each column, so that a bolted connection can be established using the dowels coming out of the reinforced concrete footings.

The connections between girders and monorails are bolted as the top flange of the monorail is attached to the bottom flange of the girder. Also gusset plates are welded to the girder running parallel to the monorail and welded to it (provides lateral bracing for the compression flange of the girder).

All welding, if possible, should be performed in a shop for quality control issues. The bolted connections between the elements have to be done with the erection of the structure on site.

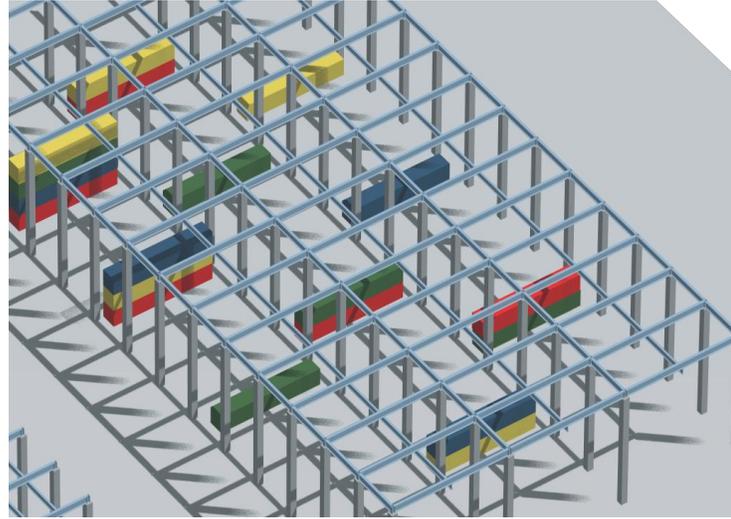
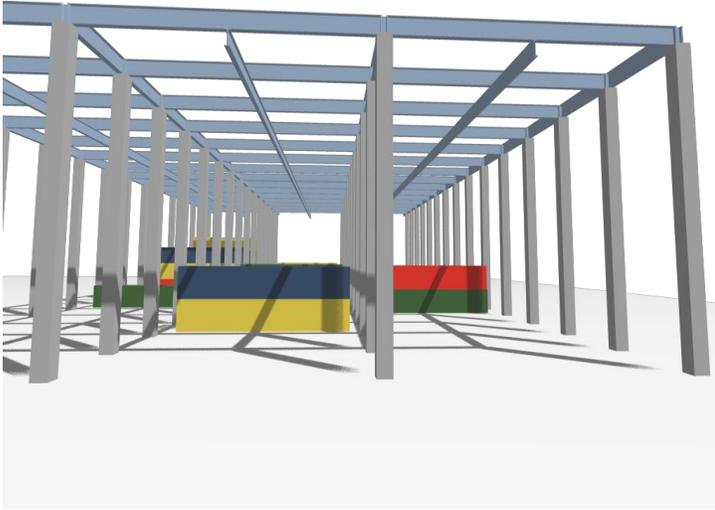
The columns could be used as supports for erecting the formwork and placement of the rebar cage for the concrete encasings.

- Issues not covered by the current stage of the project:
- Soil analysis that will guarantee the stability of the foundations
 - Structures fine tuning according to detailed LIM shuttle design (turning, climbing inclines etc.)
 - Detailed connection design
 - Capability of changing monorails (layout of transfer areas)
 - Areas of transfer between the interyard and intrayard facilities

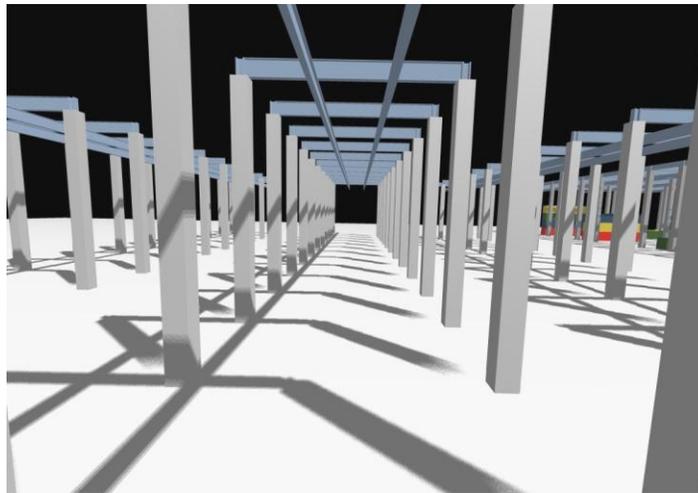
The structures and civil groups worked on the engineering aspect of the project throughout the entire semester. This consisted of selection of 50 ksi grade steel, 5000 psi grade concrete and the detailed design work of typical structural members for both the Inter-Yard Structure and the Intra-Yard Structure. This included the design of typical girders, columns, connections, and footings. The structural analysis was primarily done using SAP2000 for deflection, buckling and serviceability considerations which naturally influenced the scope of the design work. For the calculations required of the design work MathCAD, AISC Steel Manual and the ACI Code for concrete design were used extensively. Attached below are the calculations for each structural member.

3D drawings

Storage area views



Intrayard view



GIS Sub-Team Report

This semester the GIS sub-team was tasked with reviewing the Corwith to 47th corridor, establishing a feasible link between the two, and creating coverage maps for both yards. Much of this was done with the help of the Structures and Civil team.

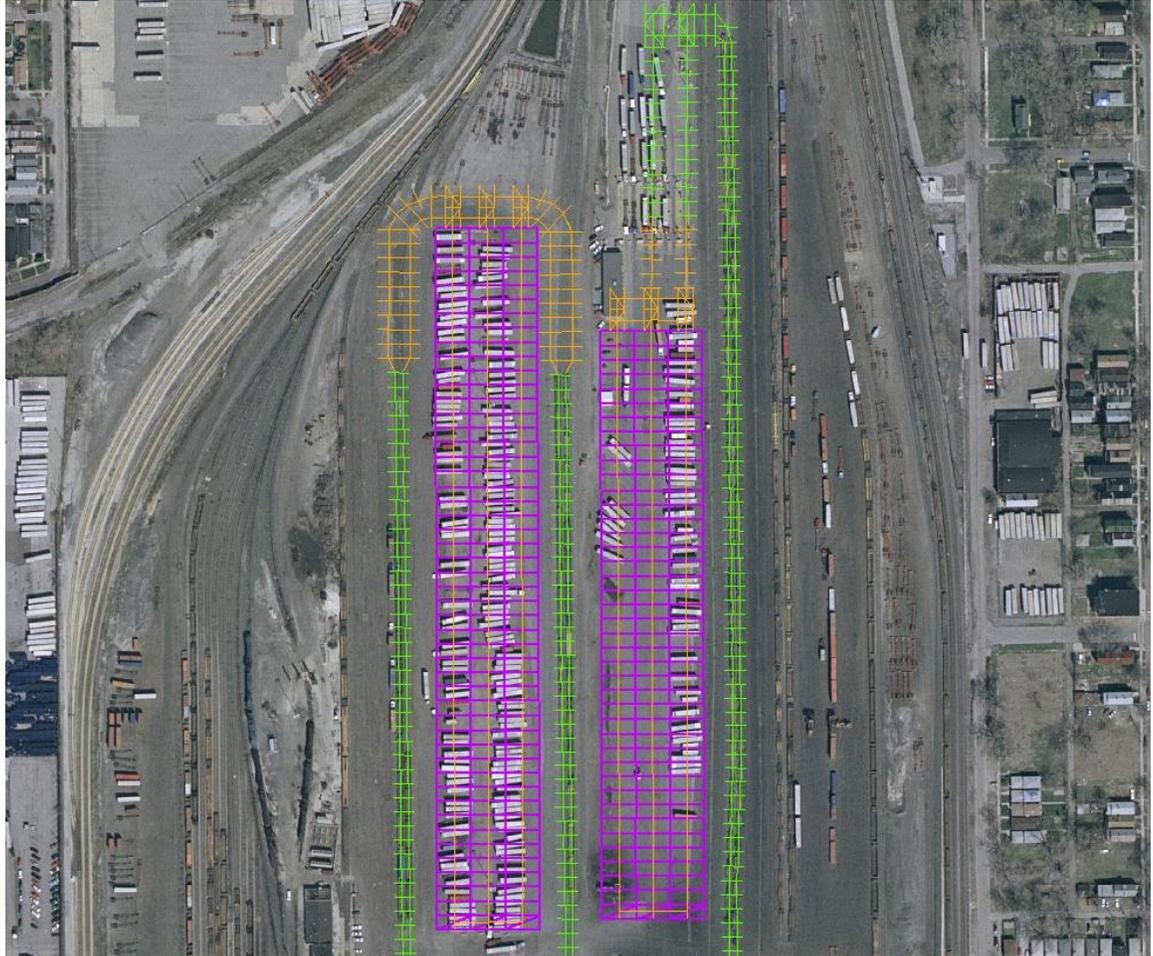
To begin, aerial photographs of the corridor were acquired and coordinates were applied. With these pictures, we were able to view the entire corridor to pick the best route for our interyard connection. Also, since the photographs were such high resolution, we could easily see obstacles, such as crossing the CTA tracks, and plan accordingly.

Later, similar photographs were overlaid with the city of Chicago zoning categories. The resulting zoning map allowed us to select a route that had as little conflict with existing zoning as possible.



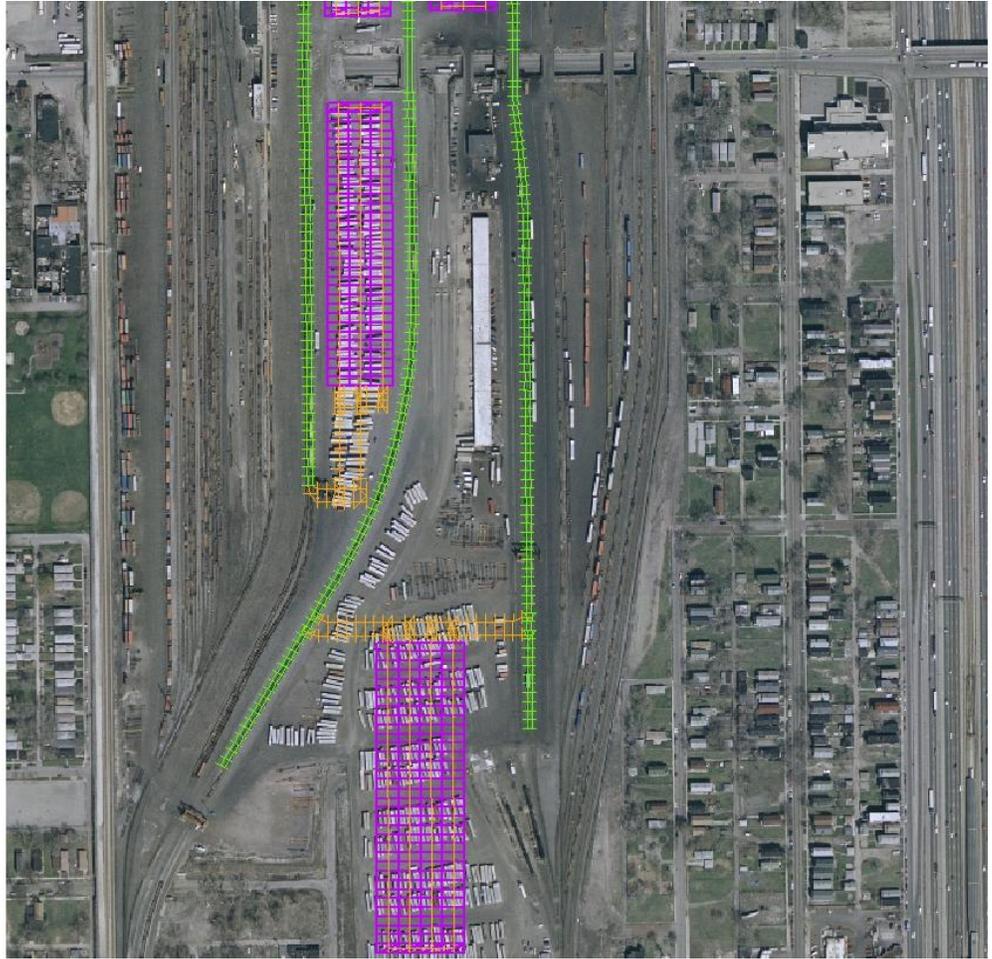
This was the resulting corridor .jpg. It shows the connection to the I-55 above Corwith, and the entrance and exit ramps. Unfortunately, several problems arose for the 47th end. For one, the ramps were smaller and harder to see. Also, the connection ends at a street that leads into the I-94, but later we found out trucks can not use this street. Worst of all, however, was the discovery that the original aerial photographs of the city were not aligned in the same way as the zoning map. The shapefiles were drawn on the aerials, then when they were put over the zoning map, the alignment was off on the 47th end. So in the picture it looks as if the connection runs out of the yard and into the neighborhood to the east of it when it should run just along the edge of the yard.

The individual coverage maps turned out much better. The goal was to display exactly how the structures would be built over the existing yard layouts. The maps would have to display 3 parts: the strip track coverage, the storage, and the elevating track between the two. It was also important to incorporate the Structures team's discoveries in the map as accurately as possible, so they were an integral part in the maps' creation.

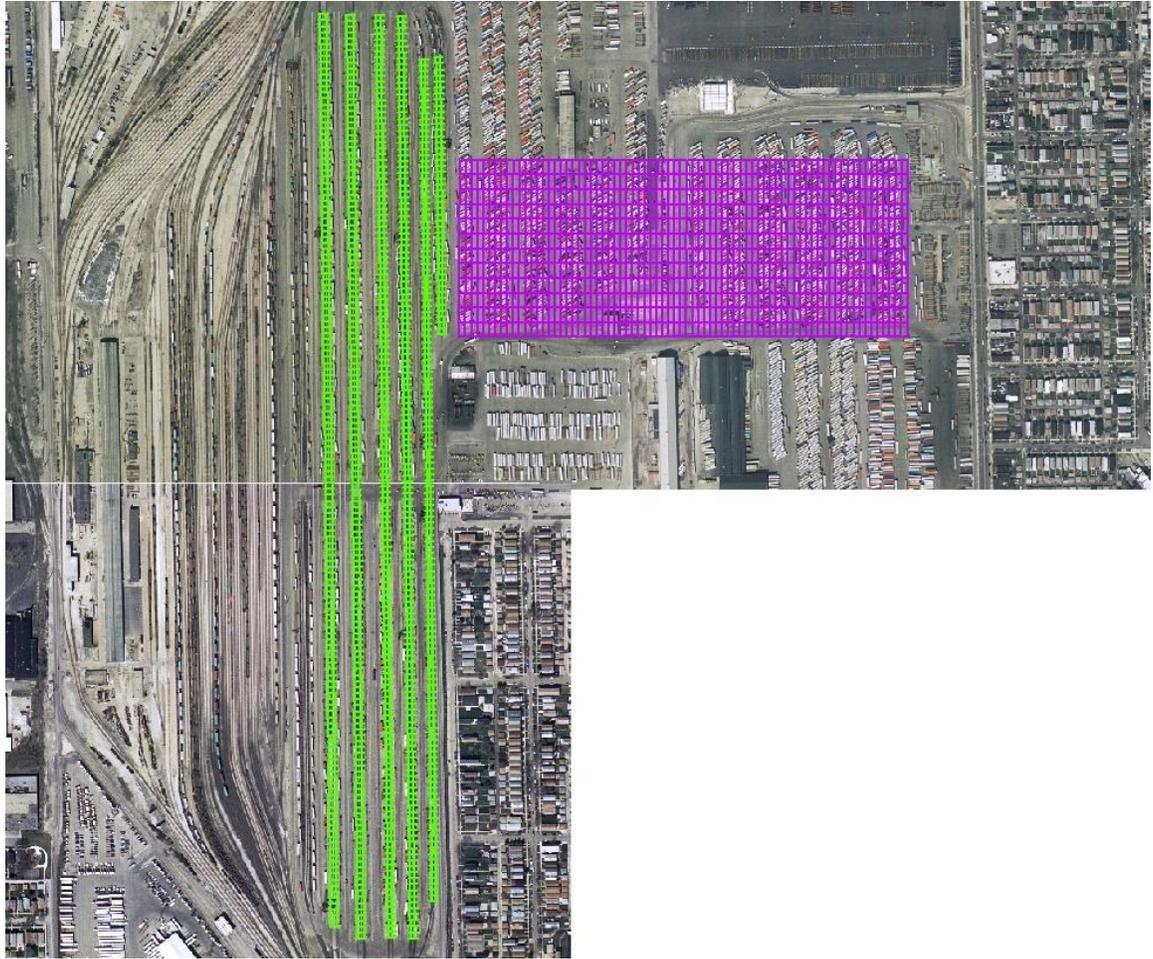


This is the north section of 47th street. In the picture, the green lines represent strip track coverage; the purple represents the storage area coverage; the orange lines represent the region of track where the shuttles are elevated from the strip track height of 50 feet to the storage height of 60 feet. This section also shows the area where trucks will be loaded and unloaded, right where they line up to get into the yard in the picture.

These lines were drawn with exact specification from the structures team, with each strip track having a frame 45 feet long every 20 feet and each storage segment being 60 feet long and spaced apart 20 feet. The orange lines in the storage area represent the monorail track the shuttles will run on.



This is the southern section of 47th. This picture shows another potential design issue in that our strip track coverage must span a bridge at 2 areas. These are the areas without frames at the top part of the picture, across the right 2 (green) strip tracks. Barring this setback, this yard layout will accommodate 100% coverage of the strip tracks and increase storage capacity 4 times.



This was the strip track and storage coverage design for the Corwith yard. An issue in designing the strip track coverage for this yard was that the strip tracks came in 4 variations, each requiring a separate framing design. After recalculating the framing requirements for each variation, the strip track coverage was completed, leaving one of the 5 strip tracks uncovered to be left open for use by the interyard connection coming down from the I-55. This connection was not shown here, but did appear in the large poster print outs displayed on Ipro day.

Maps of the entire corridor with connection and both yards with coverage were printed out in 3 posters, with the corridor split among 2 halves of a poster and each yard shown on its own poster. The maps were created using ARCVIEW GIS and printed by Ariel Iris of Chicago Area Transportation Study.

Economic Feasibility Sub-Team Report

In order to create some revenue, we set a toll at \$5.00 in between both yards, so it wouldn't matter whether you travel on the Stevensen 55 East to the Dan Ryan 94 South or whether you are traveling from the Dan Ryan 94 North to the Stevensen 55 West, you will still pay the toll entering the yards. Doing research, we found that that 2000 trucks travel from Interstate 55 East to the Interstate 94 South daily, as well as 1800 trucks travel from Interstate 94 North to Interstate 55 West daily. Using these figures, we made projections depending on percentages of trucks using our toll ramps in which we created over a period of a year, ten years, and fifty years.

If ten percent of the trucks use our toll ramps, there will be an estimate of 380 trucks total using both ramps. At \$5.00 set at the toll, daily revenue will be \$1,900.00. One year will bring us revenue of \$693,500.00. Ten years will bring revenue of \$6,935,000.00, and fifty years will bring us revenue of \$34,675,000.00.

If twenty-five percent of the trucks use our toll ramps, there will be an estimate of 950 trucks total using both ramps. At \$5.00 set at the toll, daily revenue will be \$4,750.00. One year will bring us revenue of \$1,733,750.00. Ten years will bring revenue of \$17,337,500.00, and fifty years will bring us revenue of \$86,687,500.00.

If fifty percent of the trucks use our toll ramps, there will be an estimate of 1,900 trucks total using both ramps. At \$5.00 set at the toll, daily revenue will be \$9,500.00. One year will bring us revenue of \$3,467,500.00. Ten years will bring revenue of \$34,675,000.00, and fifty years will bring us revenue of \$173,375,000.00.

A comparison with the lease of the Chicago skyway was made. The Chicago skyway was leased for 99 years. The revenue was \$45 million dollars per year and the payment \$1.8billion dollars.

In conclusion, unless the price of the LIM/shuttle system is less than the revenue we will bring in over the next fifty years; our system will not be economically feasible. We can raise the price of our toll ramps, but that would bring down the number of trucks that will use our ramps. For the next semester's IPRO, we will be trying to figure out a system to create more revenue to pay for the LIM/shuttle system in which we are trying to create.

Why a \$5.00 Toll?

- \$4.00 = Truck Plaza Rate on all Tollways
- \$6.00 = Truck Skyway Rate
- \$7.50 = Waukegan Exit on the Tri-State
- \$5.00 = Truck Toll on Golf Road, Willow Road, Lake Cook Road, and Touhy Avenue Ramp Exits on the Tri-State

***An average toll of \$5.00 a truck was found on all plazas, the skyway, and major street exit ramps so we find a \$5.00 toll sufficient for the truck tolls on our ramps.

Percent of Trucks	Number of Trucks	Amount of Money Produced
10%	200	\$ 1,000.00
25%	500	\$ 2,500.00
50%	1,000	\$ 5,000.00
Percent of Trucks	Number of Trucks	Amount of Money Produced
10%	180	\$ 900.00
25%	450	\$ 2,250.00
50%	900	\$ 4,500.00
Equal Percentage of Trucks On Each	Total Combined Trucks at % From Both Ramps	Total Revenue Produced Daily From Combined
10%	380	\$ 1,900.00
25%	950	\$ 4,750.00
50%	1,900	\$ 9,500.00

Fall 2005 team Accomplishments

- Completed detailed drafts and structural analyses for the intra-yard GRail structure and the inter-yard structures between the Corwith and 47th Street Yards.
- Used GIS to produce network maps demonstrating the route in accordance to zoning specifications and alternative route options between these two locations.
- Developed estimates and templates for financial scenario analysis of a truck toll road that can provide direct access between these yards.
- Explored the system requirements and specifications for the use of Linear Induction Motors (LIM) technology in these two distinct systems.

Conclusions

Despite its potential advantages, our research has failed to identify the Linear Induction Motor as the best option for propelling the shuttle. Much improvement was made this semester in regards to the structural analysis and design of columns, girders, beams, monorails, and foundations. Use of a toll collecting truckway opportunely allows for spreading construction costs and advantages over a wider set of stakeholders.

Recommended Next Steps

Much still remains to be done to prove/disprove the feasibility of this solution and to have it implemented:

- Development of automated computer programs to directly control rail yard systems operations
- Determine process - efficiency - cycle time
- Assess additional corridors and incorporate local opportunities
- Update financial/feasibility analysis as the project progresses towards a completed design

