A Decision Support Tool For Locating an Impact of an Inland Port in Inland Empire

Ardavan Asef-Vaziri
Department of Systems and Operations Management
California State University, Northridge

1. Introduction

By diverting port-related truck trips to rail, the development and operation of an inland port in southern california (*i*) increase transportation efficiency by switching from truck to train, (*ii*) create a smoother flow on the highways, (*iii*) create a cleaner environment, (*iv*) increase the capacity of the ports, (*v*) reduce demands on port land, and (*vi*) promote inland economic development and logistics integration. The secondary functions could be: (*a*) empty container depot, (*b*) air cargo consolidation, (*c*) transloading, *(d)* free trade zoning, (*e*) agile port container sorting. (*f*) value-added services, and (*g*) trade processing. In several reports, Inland Empire has been named as an attractive location for an inland port serving ports of Los Angeles and Long Beach. The main reasons for its attractiveness include proximity to the Colton intermodal facility, potential for finding an appropriate site, and relatively low initial investment. The purpose of this research project is to develop a decision support tool to identify the optimal location of the Inland Empire inland port. Given the daily origin-destination data from the ports to the distribution centers and processing centers in the Inland Empire, the model identifies the optimal location of an inland port. Due to environmental, legal, land availability, and economical concerns, it may not be feasible to locate an inland port on the theoretical optimal site. The decision support tool will also provide a set of contour lines showing the total truck miles traveled for the sites other than the theoretical optimal site.

The remainder of this paper is organized as follows: Container handling in southern California ports will be discussed in section 2. The concept of inland port is described in Section 3. The optimal location of the inland port is identified in Section 4. Sensitivity analysis using the concept of contour lines are described in Section 5. Conclusion follows in section 6.

2. Container Handling in Southern California

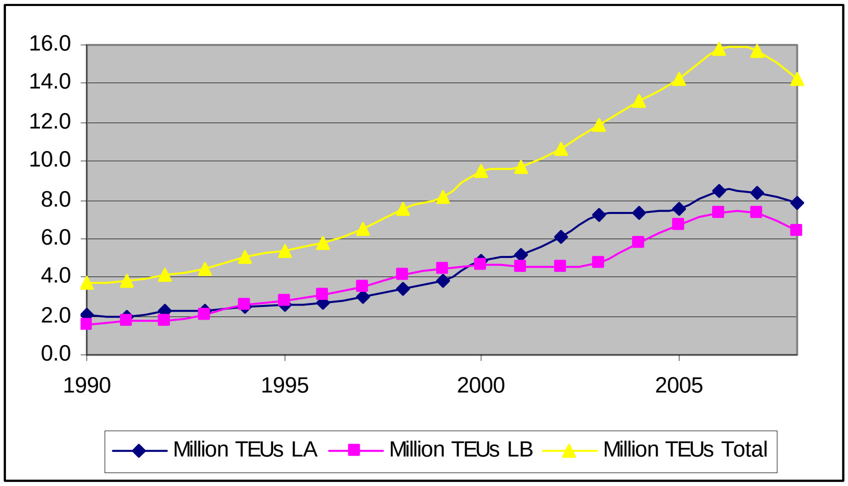
In this section, we first present a set of data regarding container handling activities on the land side of southern California ports.

California, with the largest state economy in the U.S., accounts for more international trade than any other state in the nation. In 2007, the total value of trade using the southern California trade infrastructure network was $340 billion, creating $37 billion in state and local taxes and two million jobs or full time equivalents (we have estimated these numbers using the BST Associates report for 2005 data and AAPA data for 2007). These numbers differ from the previous estimates for 2007 which were 17.2 TEUs volume of activities and $375 billion value of activities. As shown in Table 1, based on the volume of containerized cargo, the combined ports of Long Beach and Los Angeles are ranked fifth in the world.

Table 1. The worldwide ranking of the ports based on volume of containerized cargo in 2007. Source: American Association of Port Aluthorities (AAPA).

RANK	PORT (Country)	Million TEUs
1	Singapore (Singapore)	27.9
2	Shanghai (China)	26.2
3	Hong Kong (China)	24
4	Shenzhen (China)	21.1
5	Los Angeles & Long Beach (US)	15.7
6	Yingkou/Liaonian (China)	13.7
7	Busan (South Korea)	13.3
8	Rotterdam (Netherlands)	10.8
9	Dubai Ports (UAE)	10.7
10	Kaohsiung (Taiwan)	10.3
11	Hamburg (Germany)	9.9
12	Qingdao (China)	9.4
13	Ningbo (China)	9.3
14	Guangzhou (China)	9.2
15	Antwerp (Belgium)	8.2
16	Port Kelang (Malaysia)	7.1
17	Tianjin (China)	7.1
18	Tanjung Pelepas (Malaysia)	5.5
19	New York / New Jersey (US)	5.3
20	Bremen (Germany)	4.9

Figure 1. Growth of container handling in SPB Ports.



Despite 0.6% reduction from 2006 to 2007, and 9.6% reduction from 2007 to 2008, still all forecasts point to continued growth (notwithstanding the development of alternative transportation corridors in the U.S. for international trade). Given the 2008 data for SPB ports, on average a box is 1.7 TEUs, average weight of a TEU is 14,000 pounds, and each pound of weight has $1.5 of value. The present level as well as long term forecasts for SPB port container handling operations in million TEUs are shown in Table 2.

Table 2. Actual and forecast volume of container handling operations at SPB port terminals in million TEUs: actual (2004-08) and forecast (2010-30).

Actual		Actual/*Forecast*	
Year	**TEUs**	**Year**	**TEUs**
2004	13.1	2008	14.2
2005	14.2	*2010*	*19.7*
2006	15.8	*2020*	*36.0*
2007	15.7	*2030*	*44.7*

Source: Ports of LA/LB

Any diversion from SPB ports to competing ports will have a profound impact on Southern California's economy. It is worthwhile to reiterate the main two goals of a competitive strategy to retain the strategic position of the SPB ports: (*i*) to relate strengths and weaknesses of the SPB ports for opportunities and threats in the environment, and (*ii*) to present a high customer value proposition as a set of benefits that the SPB ports offers to customers in four dimensional space of cost, time, quality, and variety. Flow time reduction is the most important facet in customer value proposition of SPB ports. According to Leachman (2005), without congestion relief, even a small container fee would drive trade away from these ports. An example of the alternative routes under consideration by the other states is shown in Figure 2.

Figure 2. Alternative routes under consideration by the state of Texas.

The 19 million residents of the region incorporating the five counties of LA, San Bernardino, Riverside, Orange, and Ventura comprise the final market for about 32% of all the imports coming through the SPB ports. Another 27% is handled in this region and then moved elsewhere through its value chain.

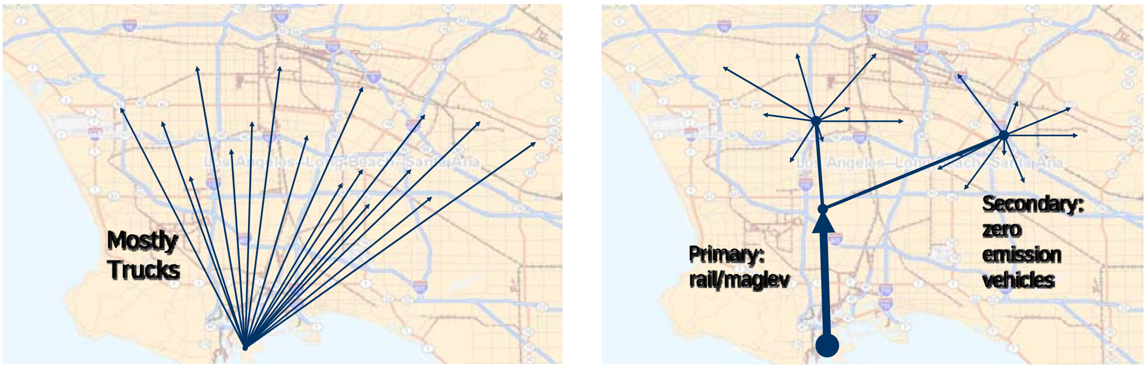
There are around 20,000 truck trips (including off-dock trips) per day from SPB ports to the five counties. This number will grow to about 54,000 truck trips per day in 2030. This growth may result in unintended economic, social, and environmental consequences. Southern California government branches and agencies are confronting serious long-term freight mobility issues. Straightforward capacity increases that worked in the past, such as more highways and larger ports, are not enough for the future. Moreover, capacity increases that compromise the environment, tax the budget, and impinge on sensitive communities may no longer be possible or desirable.

3. Inland Ports

In this section we introduce the concept of inland ports to create a strength in the system, thereby matching the opportunities and threats that emerged in the data analysis phase.

An inland port is a site located away from traditional coastal borders, and is designed to facilitate and process international trade. It provides multi-modal transportation assets and promotes value-added services as goods move through the supply chain. The concept calls for a rail shuttle linking a seaport with an inland terminal functioning as a satellite port. Schematic representation of the current regional transportation network in Southern California is shown in the left side of Figure 3 where all trips are made by truck. The figure on the right side shows the network after integration of two inland ports, where the major part of the trips is made by train. The trains will move using clean air locomotives or magnetic levitation (a system of transportation that suspends, guides and propels trains, using magnetic forces). A typical train can move a ton of freight 423 miles on a single gallon of fuel. Shifting 10% of long-haul freight from the highway to the railway would reduce annual greenhouse gas emissions by more than 12 million tons.

Figure 3. Schematic representation of the inland port concept.



Transportation planners are recognizing that inland ports have the potential to enhance multi-modal trade corridors in important ways. Several sessions at the Transportation Research Board (TRB) annual meetings address port-linked inland ports in Texas, New Jersey/New York and California. The Regional Transportation Plan (RTP) of the Southern California Association of Governments (SCAG) recommends a feasibility study on the creation of one or more inland ports. The pictorial representation in Figure 4 shows the industrial/distribution activities at Westport Alliance, an inland port in Texas.

Figure 4. Pictorial representation of Westport Alliance inland port in Texas.

The SPB ports are increasingly dependent on the capabilities of the Inland Empire logistics network to alleviate congestion and air pollution. In several reports, Mira Loma has been named as an attractive location for an inland port. The main reasons for its attractiveness are its proximity to the Colton intermodal facility, the potential for finding an appropriate site, and its relatively low development cost. According to SCAG, to address eventual deficiencies in container handling, the RTP recommends the creation of one or more inland port facilities in the Inland Empire.

By diverting port-related truck trips to rail, the development and operation of an inland port in the Inland Empire would (*i*) increase transportation efficiency by switching from truck to train (a train can replace 150 trucks), (*ii*) create a smoother flow on the highways since thousands of truck trips per day are taken off the I-710 and I-110, (*iii*) create a cleaner environment since hundreds of thousands of truck-miles-traveled are replaced by train trips, (*iv*) increase the capacity of the ports since loading and unloading of a train takes much less time than that of a fleet of trucks to carry the same number of containers, (*v*) reduce demands on port land, and (*vi*) promote inland economic development and logistics integration. The secondary functions could be: (*a*) empty container depot, (*b*) air cargo consolidation, (*c*) transloading (unloading the content of 20- or 40-feet containers and reloading in 56-feet containered-trucks), *(d)* free trade zoning (FTZ), (*e*) agile port container sorting. (*f*) value-added services, and (*g*) trade processing.

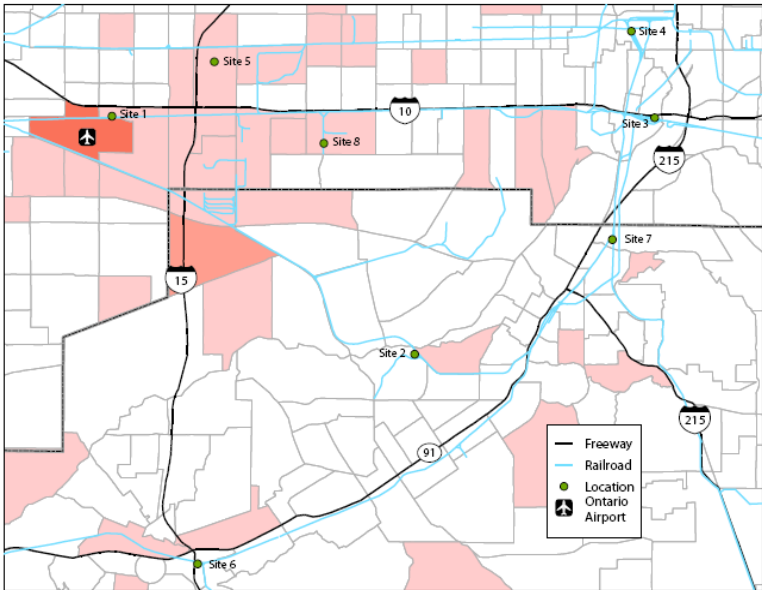
4. Optimal Location of the Inland Port.

In this section and next section we develop a decision support tool (DST) to identify the optimal location of the inland port. The DST takes advantage of the mathematical models available for single facility location problem. Given the daily origin destination (O/D) data from SPB ports to the distribution centers and production centers (DC/PCs) in the Inland Empire, the DST identifies the optimal location of an inland port. Due to land availability and costs, as well as environmental and legal concerns, it may not be possible to locate an inland port on the theoretical optimal site. The DST will provide a set of contour lines showing the total vehicle (truck) miles traveled (VMT) for sites other than the theoretical optimal site. All the nodes on the same contour line have the same transportation and environmental costs.

The decision support tool makes it possible to conduct a sensitivity analysis in the evaluation of the impact of changes in O/D data on the optimal location and contour lines. This is especially important because the O/D data between SPB ports and Inland Empire DC/PCs are not too reliable. Moreover, as the available data from diverse resources are integrated, and more reliable estimates on container flows in the Inland Empire are available, the model can quickly reflect their impact on potential change in the optimal solution. More accurate data may gradually become available using the ports truck driver surveys, ports Truck Trip Reduction Program results, CalTrans truck counts, SCAG heavy duty truck model, and MTA Comprehensive Truck/Freight Modeling effort. Furthermore, use of the decision support tool to evaluate the impact of O/D data aggregation on the optimal location and the contour lines is straightforward. In addition, the software can also evaluate the tradeoff between train trips and truck trips. Finally, by defining a set of weights as the negative environmental impact of one mile of travel, the objective function could be entirely transformed into emissions minimization.

We implement rectilinear distances as adequate approximations to street distances. Indeed, another name for rectilinear distance is Manhattan distance, because the street network of Manhattan is rectilinear (Francis et al., 1992). To test the accuracy of the rectilinear distances, we have compared street distances with rectilinear distances for a set of candidate sites in Inland Empire. These sites were originally proposed by the Tioga Group, a private consultant of SCAG. If the distance between all pairs of sites, as shown in Figure 5, is computed using both street distances and rectilinear distances, with 95% confidence level the rectilinear distance is between %7 to %17 greater than the street distance. We have observed that when the street distances are used on GIS maps, a substantial volume of flow may occur on a single link leading to the shortest distances. A slight congestion on the streets can easily cause such a deviation in the time of the travel. Accordingly, the rectilinear distances are implemented as a tight upper bound for the street distances and as a reasonable surrogate for travel time.

Figure 5. Geographical region in Mira Loma proposed by Tioga Group (a consulting firm for SCAG) for candidate inland port locations in Mira Loma.

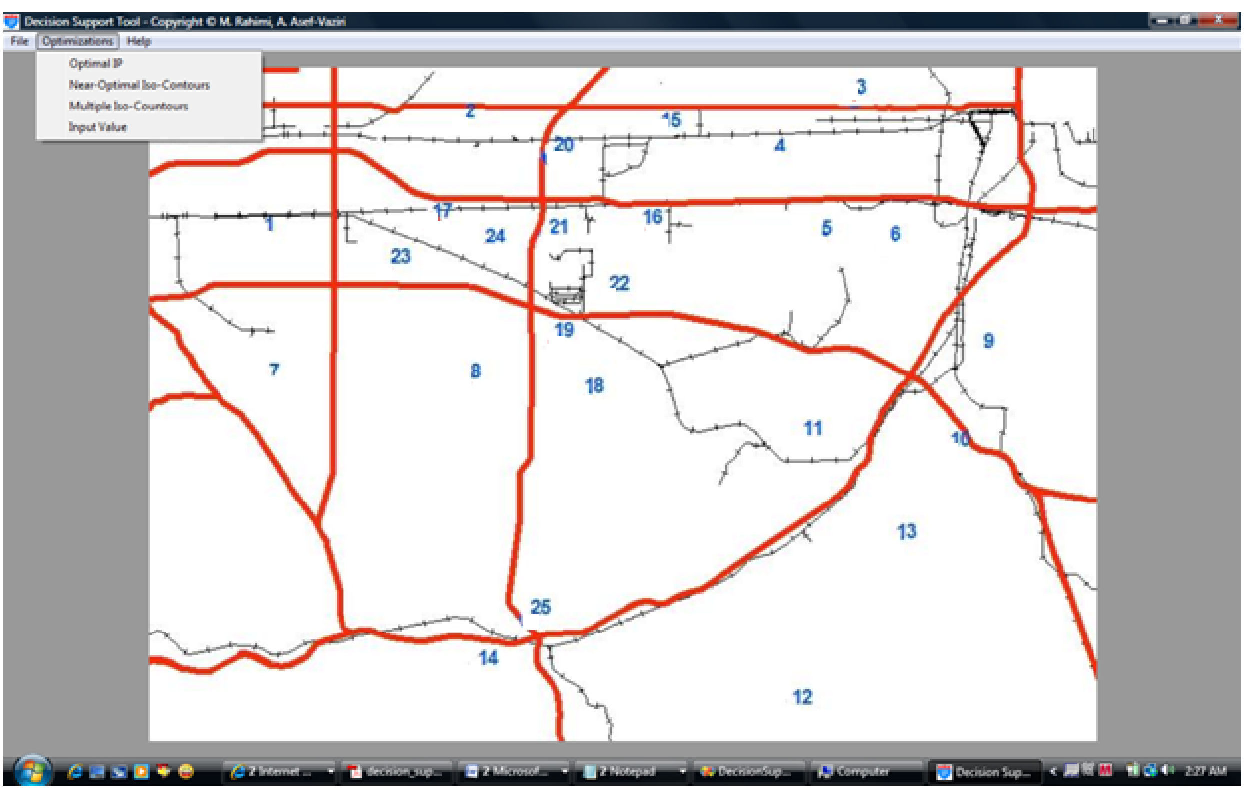


We assume that the total travel distance is the major driver of both the total travel cost and the total environmental pollution. The inland port location model can be formulated as a single-facility location problem on the theoretical foundations articulated in Francis et al (1992).

Suppose m denotes the number of DC/PCs, and P_i denotes the location of DC/PC$_i$. Let t_i denote the daily number of trips between P_i and O where O is the location of the inland port. Thus, if $d(O, P_i)$ denotes the distance between O and P_i, the total distance of transportation is $t_i d(O, P_i)$. Suppose the average speed of a truck to location P_i is equal to v_i ($i=1,2,\ldots., m$). Then $t_i/v_i d(O,P_i)$ is the total transportation time between the inland port and DC/PC$_i$. Hence, if c_i is the transportation cost per hour, then $c_i t_i/v_i d(O, P_i)$ is the daily transportation cost between the inland port and DC/PC$_i$. Define $w_i = c_i t_i/v_i$ as the weight of DC/PC$_i$, and, therefore, the daily transportation cost between the inland port and DC/PC$_i$ is equal to $w_i d(O,P_i)$. The objective function to be minimized is then defined as: $Z = \sum_{i=0}^{m} w_i d(O, P_i)$. A choice of O that minimizes Z will thus be an optimal location for the inland port, which minimizes the total cost of container handling movement to and from DC/PCs. Similarly, by defining w_i ($i=0,2,\ldots, m$) as the negative environmental impact of one mile of travel, the objective function can be transformed into emissions minimization.

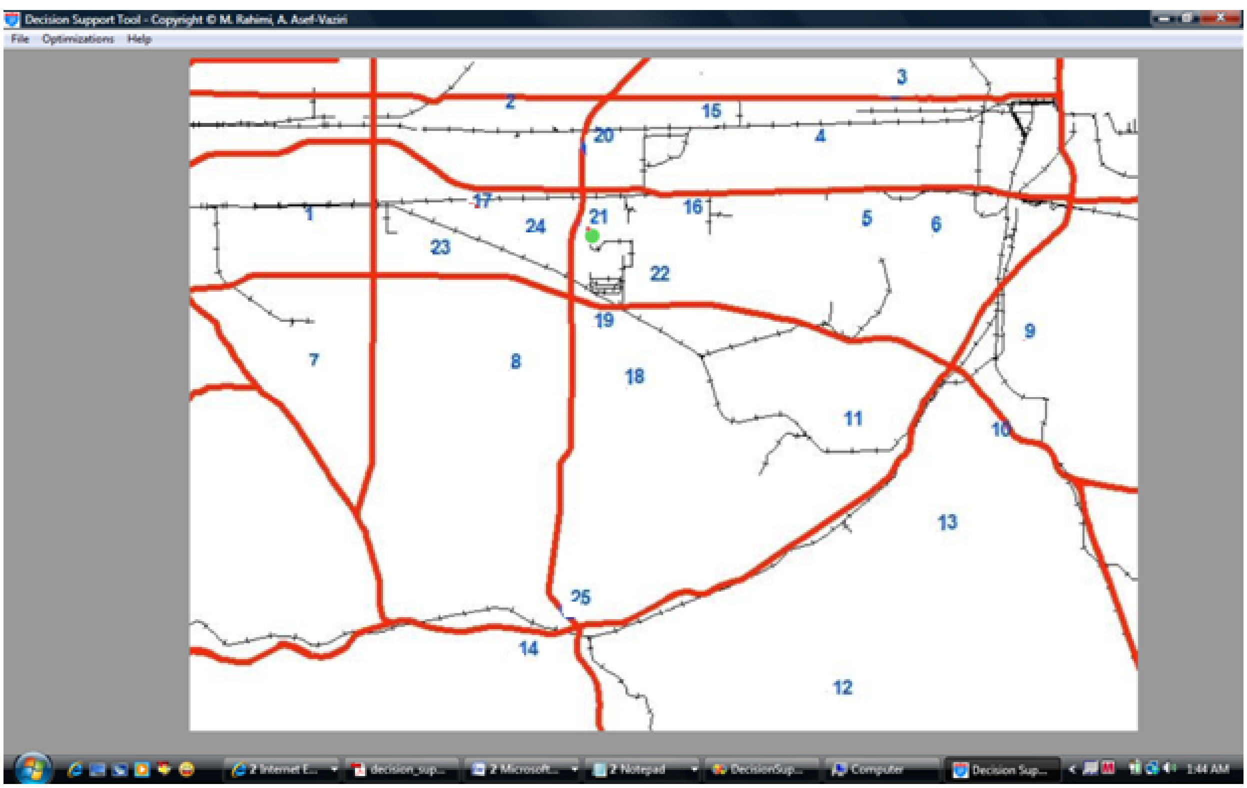
In a rectilinear transportation network, where x and y show the coordinates of the inland port, $P_i = (X_i, Y_i)$ are the coordinates of DC/PC$_i$, the previous objective function is replaced by $Z = \sum_{i=0}^{m} w_i(|x - X_i| + |y - Y_i|) = \sum_{i=0}^{m} w_i |x - X_i| + \sum_{i=0}^{m} w_i |y - Y_i|$. That is to minimize the two separate functions of $Z_X = \sum_{i=0}^{m} w_i |x - X_i|$ and $Z_Y = \sum_{i=0}^{m} w_i |y - Y_i|$. In other words, the total cost of movement can be minimized by solving the two smaller and independent problems of minimizing the cost of movement in *x-direction* and minimizing the cost of movement in *y-direction*. Since the two cost functions have exactly the same form, the problem of minimizing either one can be interpreted as a one-dimensional location problem on a line. The relative locations of the Inland Empire DC/PCs are shown in Figure 5.

Figure 5. The relative locations of the DC/PCs in Inland Empire.



If a horizontal and a vertical line are drawn through each DC/PC, an optimal location lies on the intersection of the two lines. Following Francis *et al*. (1992), the weight of each vertical (horizontal) line is defined as the sum of the weights of the DC/PCs lying on that line. The use of the median conditions determines a point minimizing *f (x)*. In order to do this, first the *partial sum of the weight* W_i is defined for the vertical line *i* as the weight of line , plus the weight of all lines with smaller *x-coordinates*. Similarly, the *partial sum of the weight* W_i is defined for the horizontal line *i* as the weight of line *I*, plus the weight of all lines with smaller *y-coordinates*. Figure 6 shows the partial weights of the horizontal and vertical lines passing through the DC/PCs in Inland Empire. The optimal solution is at the intersection of the first horizontal and the first vertical lines that have the *partial sum of the weight* W_i greater than or equal to the half of the total weights: $W_i \geq W/2$. The optimal location is the node which minimizes the total travel distance to be the major driver of both the total travel cost and the total emission and noise pollution. Following the procedure elaborated above, the optimal inland port location is shown in Figure 6.

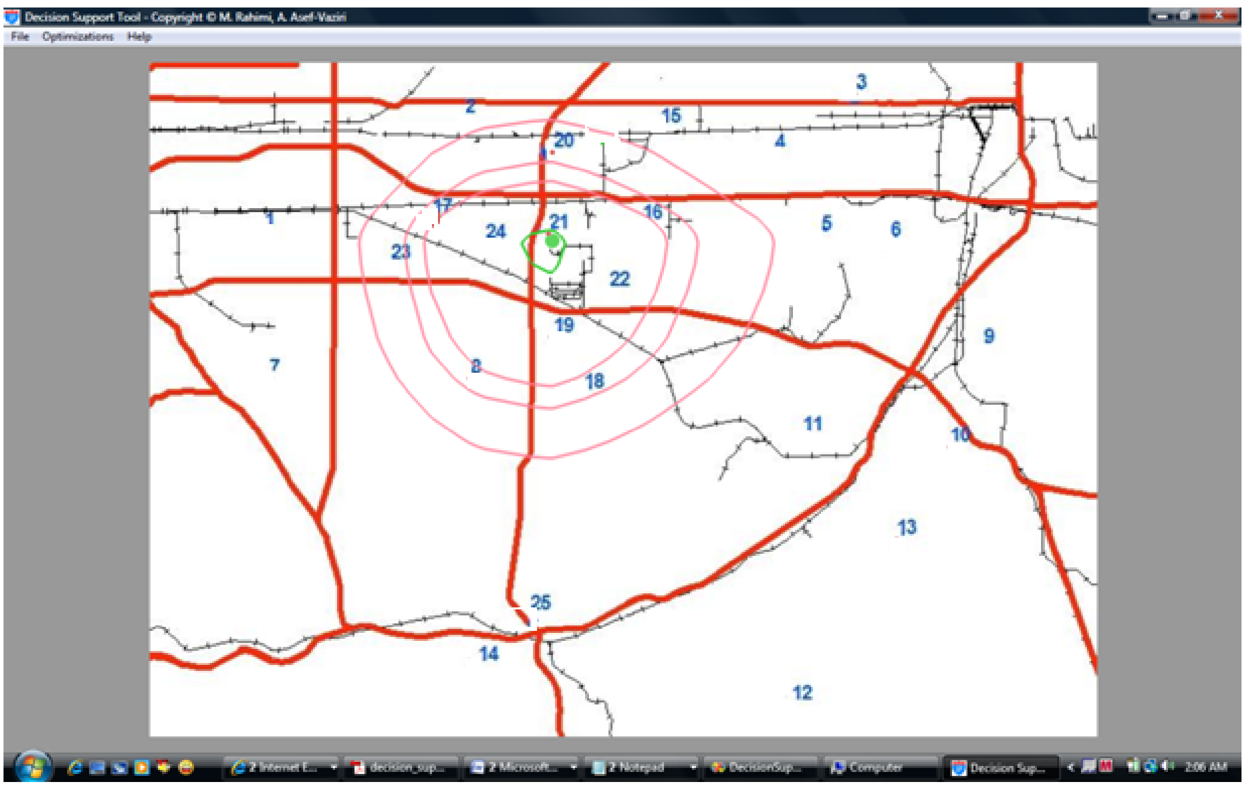
Figure 6. The optimal location for the inland port.



5. The contour Lines

What if for practical reasons such as environmental protection, land use designation, regulations, or sizing (including dimensions and orientation of the proposed site), an inland port cannot be developed on the optimal location? In this case, it would be useful to have a general procedure to evaluate the costs of using the next nearest possible location. Given the eight sites proposed by Tioga Group as potential inland port locations in Mira Loma, how much TMT is added to the optimal value if one of these sites is selected as the inland port serving Inland Empire? Following Francis *et al.* (1992), we develop a set of *contour lines* (*level curves)* such that every point on the contour line has the same value of the function *f(x).* Each contour set, whose boundary is a contour line, is the set of all points having values of *f(x)* no larger than those of the points on the contour line. Hence, to evaluate other possible sites for an inland port, we first consider locations in the innermost contour set. If none of these sites is suitable, consideration would go to locations inside the second innermost contour set, and so on. Given any box formed by two vertical and two horizontal contours lines, compute the *coefficient-of-x* as the sum of the weights of the lines to the left of the box minus the sum of the weights of the lines to its right. Similarly, the *coefficient-of-y* is the sum of the weights of the lines below the box minus the sum of the weights of the lines above it. The slope for every contour line passing through a given box is the negative ratio of the *coefficient-of-x* to the *coefficient-of-y*. To construct a single contour line, start with any point inside any box other than a point that minimizes *f(x).* Compute the value *f(x)* for that point. Pass a line through the point that has the slope computed for the box, and extend the line until it intersects the boundary of the box. Choose either of the points intersecting the boundary. Such a point will be in another box, so the same procedure can be used to construct another line segment through the second box. Continue until a complete contour line is constructed. The last contour line ends at the original starting point. The optimal location of Mira Loma inland port is shown in both the previous and the following graph. The total daily TMT for this solution is 6600. However, considerations such as physical restrictions, unreasonable costs, or environmental impact restrictions may not allow locating the inland port at its theoretical optimal site. Should the optimal location prove unavailable, then the level curves represent all the nodes with the same total TMT, which is greater than the optimal solution. Figure 7 shows the optimal inland port location in Inland Empire and its related contour lines. The green dot shows optimal location, the green polygon shows the contour line for points 5% worsen than the optimal location. The red polygons show three additional contour lines, the green square is a point chosen to draw the last contour line. If the inland port is located on any point on the contour line passing the green square, then the total TMT will increase by 54%. Our decision support tool automatically generates this type of representation on the screen and allows sensitivity analyses and what-if queries.

Figure 7. The optimal location and the contour lines.



6. Conclusion

In this paper we developed a decision support tool to obtain the optimal location of an inland port in inland Empire. Due to environmental, legal, land availability, and economical concerns, it may not be feasible to locate an inland port on the theoretical optimal site. The decision support tool will also provide a set of contour lines showing the total TMT for the sites other than the theoretical optimal site. The computational capabilities and graphical interface of the decision support tool are especially valuable because the O/D data between SPB ports and Inland Empire

DC/PCs are not reliable. As the available data from diverse resources are integrated, and more reliable estimates on container flows in the Inland Empire are available, the model could quickly reflect the impact of the more accurate data. More accurate data may gradually become available using the ports truck driver surveys, ports Truck Trip Reduction Program data, CalTrans truck counts, SCAG heavy duty truck model output, and MTA Comprehensive Truck/Freight Modeling effort. Furthermore, it is straightforward to use the decision support tool to evaluate the impact of O/D data aggregation on the optimal location and the contour lines. In addition, the software can also evaluate the tradeoff between train trips and truck trips. Finally, by defining a set of weights as the negative environmental impact of one mile of travel, the objective function could be entirely transformed into emissions minimization.

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