# Location Problem for Intermodal Terminal in North Dakota

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**ABSTRACT**

Container drayage trips have become a major concern for agricultural products exporters in the Northern Great Plains region. In addition to the increase in number of trips and the cost of travel along with the efforts of acquiring empty container and truckers, this increase generates congestion and emission in the metropolitan hub cities. In this research, distance between farm manufacturers to intermodal terminals is considered.

The research is conducted ideally under the indifference of current situations of the capacity and financing issues. When the location is selected, the intermodal terminal can be an alternative for the future development in the consensus of various stakeholders for the economic impact and public issues. Origin-Destination distance matrix from ORNL was used to connect demand points to the nearest intermodal terminal using GIS.

From the analysis, Scenario I (Dilworth) was selected as an appropriate intermodal location for the shippers in the research area. The selection was measured by the total intermodal logistics cost and service distance. The selected scenario presents more travel on highways and less rail mile than the scenario for which nothing was selected as well as lower total logistics cost.

## INTRODUCTION

Containerization of the agricultural products is growing fast due to the market demand. The U.S. exported 39% of 302 million tons of the world grain in 2007 (UNCTAD 2008) which was a 2.4% increase from the previous year. The number of containers used for exporting agricultural products from the U.S. is expected to increase dramatically due to increasing price of bulk shipping, increase in the export market for grains, shippers' opportunities for better pricing, Identity Preservation (IP) program, and increasing capacity of the vessels. The state of North Dakota exported $45.4 million in crop production value and another $16 million in processed foods to Asia in 2007 (U.S. Department of Commerce 2008). It is a 73.8% and 34.4% increase for the two categories, respectively, from the previous year.

Container drayage trips have become a major concern for agricultural products exporters in the Northern Great Plains region (Minnesota, Montana, North Dakota, South Dakota,). In addition to the increase in number of trips and the cost of travel along with the efforts of acquiring empty container and truckers, this increase generates congestion and emission in the metropolitan hub cities in the northern plains. A hub-and-spoke system is used in the railroad industry for reducing the cost of operations. This is preferred over the point-to-point system due to the cost reduction and decrease in number of operations.

The goal of this research was to determine the hypothetical intermodal location which minimizes the total logistics costs using a distance Origin-Destination (OD) matrix for decision making in this region.

## LITERATURE REVIEW

The surveys were conducted by Upper Great Plains Transportation Institute (UGPTI) in Fargo, N.D. to evaluate the prospective intermodal terminal locations. Berwick (2000) analyzed the intermodal transportation costs for the potential locations and the traffic volume using the 1996 Public Use Waybill sample. The costs associated with the intermodal terminal operations in North Dakota are well analyzed using engineering economic analysis. As part of ongoing efforts for the intermodal location issues in North Dakota, Berwick et al. (2002) surveyed the shippers in Minnesota, Montana, North Dakota, and South Dakota. From the survey, 2% of the shippers used containers to share modes for outbound products. They can choose three locations or cities in North Dakota for new intermodal facilities: Fargo, Minot, and Valley City and with the different levels of radius (100, 150, and 200 miles-radius) as the service boundary. The model included the factors for shippers to determine; types of goods, distance to intermodal terminals, shipping rates, and the operating costs at a terminal. The reports analyzed the area in wide view in terms of financing, policy, and capacity of the current facilities. Canadian Pacific was not included in the survey research. Berwick (2007) surveyed the intermodal traffic in eastern North Dakota, western Minnesota, and north eastern South Dakota within the 200 mile-radius from Fargo, ND. The report estimated a 7% growth rate for intermodal traffic in the research area, and concluded that 20,000 units of containers is the break-even point for a potential intermodal facility.

Vachal et al. (2003) surveyed the exporting farmers in the Unites States. The survey showed that the farmers are interested in an intermodal system with containerization considering the significances of the ocean liner's services and routes distance to container terminal, and buyer information. By this report, 30% of the survey respondents travels under 100 miles and 76% of them moved the containers under 350 miles to the container terminals in the grain and oilseed market.

Luo (2002) simulated an intermodal network in the U.S. to select ports to export containers. Hypothetical seaports were added in the study to show that a fluctuation in product value will also affect route selection. Low-value cargoes are shipped through the Panama Canal against west coast ports for the trade between New York and East Asia.

In this research, the service route and distance between farm manufacturers to intermodal terminals are considered based on several factors in addition to the cost involved. The locations of manufacturers are assumed in the center of counties, and the locations of intermodal terminals are collected from the dataset of Oak Ridge National laboratory (ORNL). For the analysis, Minnesota, Montana, Nebraska, North Dakota, South Dakota, and Wyoming were selected to research a hypothetical intermodal facility while competing with the existing locations in Minneapolis, MN, Omaha, NE, and Billings, MT for a base scenario.

## MATHEMATICAL MODEL

**Assumptions:**

To develop a Linear Programming model, it is assumed that

- Trucks and rails only stop at their destinations.
- Single origin and destination are considered.
- The terminals and train cars are uncapacitated.
- Container shipment for inbound process for unloading is not considered.

**Nomenclature of the Model:**

$CT_{jk}$ Terminal operations cost at destination $j$ for mode $k$

$Q_{ijkr}$ Number of quantity from origin $i$ to destination $j$ by mode $k$ in period $r$

$S_{ir}$ Number of containers which will be supplied from origin $i$ in period $r$

$D_{ijk}$ Distance from an origin $i$ to an destination $j$ for mode $k$

$CC_k$ Transportation cost per container/mile for mode $k$

$a_{ijk}$ Blocked routes from an origin $i$ to a destination $j$ by a transportation mode $k$

$W_{ijk}$ Weight of transportation rate from origin $i$ to destination $j$ by mode $k$

$f_j$ Fixed cost to open an intermodal terminal

$CG_{ijkr}$ Congestion cost at origin $i$ to destination $j$ by mode $k$ during the period $r$

**Objective Function:**

The total logistics cost is consisted of haulage cost, terminal cost, and congestion cost (1).

(1) Minimizing the Total Cost: $\sum_{i}^{I}\sum_{j}^{J}\sum_{k}^{K}\sum_{r}^{R} Q_{ijkr}(CH_{ijk} + CG_{ijkr}) + \sum_{j}^{J} f_j FT_j$

Haulage cost ($CH_{ijk}$) from an origin $i$ to a destination $j$ for a container by a mode $k$ is the multiplication of the total travel time between origin and destination and the time cost for each mode type (2).

(2) $CH_{ijk} = T_{ijk} * CC_k$

**Decision Variables:**

$Q_{ijkr}$ The number of containers moving from an origin $i$ to a destination $j$ by a mode $k$ in period $r$

$$FT_j \begin{cases} 1 & \text{if a terminal serves the area} \\ 0 & \text{otherwise} \end{cases}$$

**Constraints:**

Balancing constraints are issued for the quantity of supply and demand. The number of inbound containers is balanced with the sum of supply points (3), and the total number of containers transported from origin $i$ to destination $j$.

(3) $\sum_{k}^{K} Q_{ijkr} = S_{ir}$

In the case of interrupted routes, the value should be zero for the specific segment from origin $i$ to destination $j$ (4) incurring larger costs.

(4) $Q_{ijrk} = 0$ when $a_{ijk} = 0$

Non-negative constraints are assigned. The number of containers from origin $i$ to destination $j$ cannot be assigned with negative numbers (5).

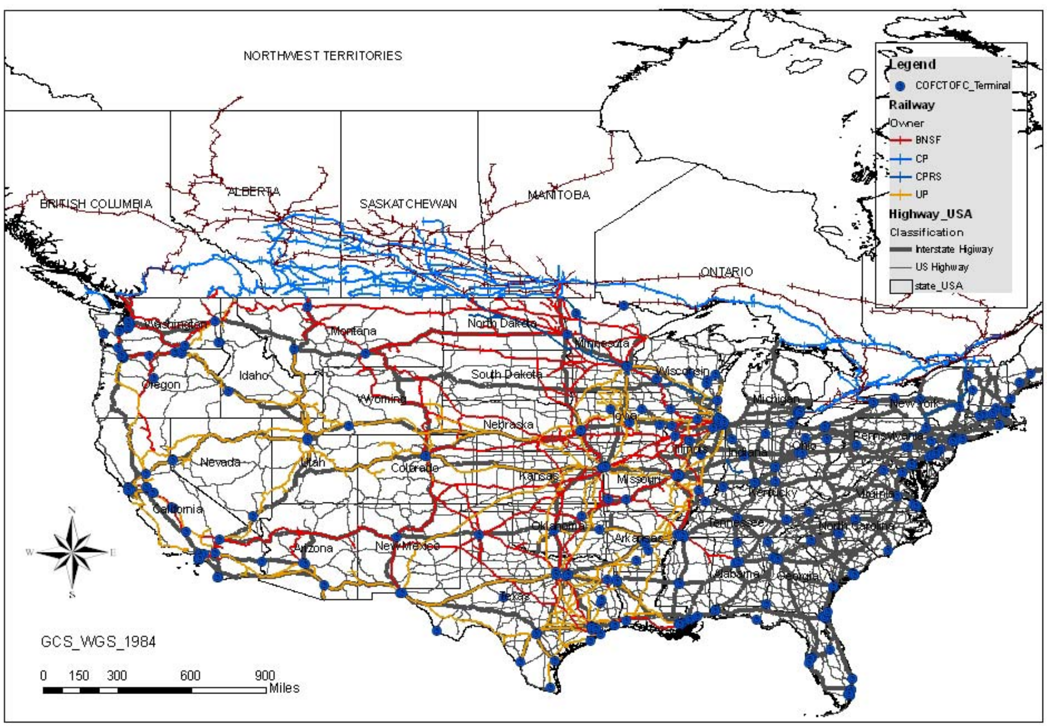
(5) $Q_{ijkr} \geq 0$

## CASE STUDY

### Research Area

For the location problem, the Northern Great Plains is selected for this case study excluding Manitoba and Saskatchewan provinces in Canada. Two Classification I carriers operate in the area: Burlington Northern Santa Fe (BNSF) in the U.S. and Canadian Pacific (CP) railway in the U.S. and Canada. The route going through Canada is not in this research, but it will be included in the next extended research for competing model with different levels of prices. All highways, railways, intermodal terminals, and rail terminals are shown in the map (Figure 1). No intermodal terminals are located in North Dakota and South Dakota. Three intermodal terminals located at Saskatoon and Regina in Saskatchewan and Winnipeg in Manitoba are connected from Minneapolis-St. Paul and Thief River Falls intermodal terminals in Minnesota operated by CP. The CP railway company moves cargo from South Dakota and North Dakota to those terminals in Canada.

**Figure 1: Railroad, highway, and intermodal terminals in the US and Canada**




The selection included four railroad terminals and two truck terminals in ND and the closest intermodal terminal to ND in Dilworth, MN are selected for this study. For this research, only the Classification I carrier, BNSF, running through ND to the east coast in the U.S. is selected. Three railroad terminals located in Valley City, Minot, and Fargo are selected as the alternative intermodal locations for this research. Winnipeg in Manitoba and Saskatoon in Saskatchewan province in Canada are not included due to the crossing border issues, such as waiting and inspection time and documentation works for trips. Two intermodal terminals are located in Minot; however, those are excluded in this research since they are privately owned elevators.

## Research Method

The model is composed of modules as shown in Figure 3: preprocessing, modeling, scenario analysis, and discussion.

### Preprocessing

In the preprocessing module, the transportation network including the highway, railway, intermodal terminal nodes, highway nodes, and railway nodes are constructed in Geographic Information System (GIS). Demand generation plays an important role for the research. The volume of demand is converted into the containerization FEUs by disaggregating the BEA level of data from the Bureau of Transportation Statistics to a county level. Costs are adopted from Luo (2002) and Mohring and Anderson (1994).

The 2006 Public Access Waybill was used to extract the volume of containers and trailers in the research area in Table 1. Only three BEA zones had COFC/TOFC demand in the four states. In 2006, 202,840 carloads were carried and around 2 million tons were loaded in the region. The waybill tells us the information, such as origin and destination, weight, charges, revenues, number of container/trailers and, etc. The disadvantages of the waybill are that some data are missed and ambiguous to interpretation. For example, some information does not provide exact origins and destinations based on BEA zones and the size of the containers, such as Twenty-foot Equivalent Unit (TEU) or Forty-foot Equivalent Unit (FEU).

**Table 1: Items for TOFC/COFC in the 2006 Public Access Waybill in the BEAs crossing four states (MT, MN, ND, and SD)**

| BEA | STCC | STCC Description | Carloads | Tons | TOFC/COFC |
|---|---|---|---|---|---|
| 107 | 01 | Farm Products | 360 | 8,080 | 360 |
| 107 | 20 | Food or Kindred Products | 2,440 | 42,680 | 2,440 |
| 107 | 24 | Lumber or Wood Products, excluding Furniture | 80 | 1,720 | 80 |
| 107 | 26 | Pulp, Paper, or Allied Products | 120 | 2,640 | 120 |
| 107 | 29 | Petroleum or Coal Products | 40 | 920 | 40 |
| 107 | 37 | Transportation Equipment | 40 | 800 | 40 |
| 113 | 01 | Farm Products | 760 | 17,360 | 760 |
| | | Sum | 3,840 | 74,200 | 3,840 |

BEAs included: 107, 109, 110-116, and 144

Costs for shipping containers are categorized into haulage cost, terminal cost, and congestion cost.

- Haulage cost is a cost to move the freight from origin to destination by a mode. Different modes have different costs and policies to calculate the cost.
    - Highway: $2 per container-mile
    - Railroad: $0.5 per container-mile
- Terminal cost is for handling the containers and using the terminals. It is a cost to switch mode.
    - Handling cost: $2 per container
- Congestion cost is applied to metropolitan cities with the population over one million.
    - Minneapolis: The congestion cost for an auto was $2.25 between I-35W and I-94 through I-694 during the morning peak (Mohring and Anderson 1994). The converted value is $3 when it is used by GDP Implicit Price Inflator.
    - Omaha: The ratio of total congestion cost in Minneapolis-St. Paul to Omaha is applied to the congestion cost calculated for Minneapolis ($1.63 = $394/$722 *$3.0).
    - Other locations: $0

**Modeling**

In the modeling module, the basic information from the preprocessing module has been integrated. The O-D matrices are generated by the distance, cost, and blocking information for each mode (truck and rail). O-D Matrix for distance is provided by ORNL with miles and impedance information between counties. BEA and ORNL data have different levels of detail which should be matched (Table 2). The public waybill is aggregated into BEA levels, and ORNL's OD Matrix is generated for a county level.

**Table 2: The relationship between data sets**

| | **Level of Detail** | **Code** | **PW** | **CBP** | **FIPS** | |
|---|---|---|---|---|---|---|
| | | | | | **State** | **County** |
| Public Waybill (PW) | BEA | STCC | - | N/A | m:m | 1:m |
| County Business Pattern (CBP) | County | NAICS | N/A | - | m:1 | 1:1 |
| FIPS | State | FIPS | m:m | 1:m | - | - |
| | County | FIPS | m:1 | 1:1 | - | - |

Note: *"m"* means "multiple"

For the integration process, the demand data from the waybill sample is disaggregated into the county level by the matching process between NAICS (North American Industry Classification System) and STCC (Standard Transportation Commodity Code). Converting the BEA level of the Public Waybill into the county level of the Public Waybill which is coded by NAIC is explained below:

Step 1: Match NAIC into STCC with the relationship of (*NAIC : STCC = 1 : m*)

Step 2: Sum up the total employment from CBP (County Business Pattern) grouping by STCC

Step 3: "Expended trailer/container count" data originated in a BEA is multiplied by the ratio of industrial employment for each county from the county business pattern (U.S. Census Bureau 2008) (7).

(7) $WB_{bcg} = (IE_{bci}/\sum_{c}(IE_{bci})) * WB_{bg}$

s.t.

$\sum_{c}[(IE_{bci}/\sum(IE_{bci}) * WB_{bg})] = 1.0$

where

$WB_{bcg}$ Number of TOFC/COFC of county level $c$ in BEA zone $b$ for each commodity (NAICS)

$WB_{bg}$ Number of TOFC/COFC of BEA level $b$ for each commodity (NAICS)

$IE_{bci}$ Number of Employment of county level $c$ in BEA zone $b$ for each industry $i$ (STCC)

The STCC data are summarized from the Waybill data of 2006 in Table 1. In the four states, two BEA zones produced 3,840 COFC/TOFC and 74,200 tons in 2006.

**Optimization and Scenario Analysis**

The routes are optimized by minimizing the total logistics cost. Economic parameters are used from Berwick (2001 and 2002) for the intermodal terminals and Luo and Grigalunas (2003) for transportation costs of all modes.

- Start: Six states were initially selected for the scope of the study. These were narrowed down to four states due to the radius of the hypothetical locations.
- Scenario I: The location in Dilworth, MN was selected for the alternative. The intermodal terminal is being operated by BNSF. The place can be accessed from I-94, I-29, US highway 10, and Minnesota state highway 336 in 2 miles radius.
- Scenario II: The location in Valley City, ND is examined. It can be accessed from I-94 and US highway 281.
- Scenario III: The location in Minot, ND is reviewed. It is accessible from US highway 2, 281, and 53. The terminal is the crossing point of two Classification I railroad companies; BNSF and CP. CP railway has connection to the two intermodal terminals at Regina and Saskatoon, SK in Canada.
- Scenario IV: It is assumed that any intermodal location will not be considered near North Dakota for the AS-IS scenario. Most of eastern North Dakota uses the intermodal terminals at Minneapolis-St. Paul, MN.

**Analysis and Discussion**

In part of the analysis process, the measurements are calculated and analyzed to interpret the output. Performance parameters used are:

- Total logistic cost (dollar)
- Service area (mile)
- Average distance to an intermodal facility (mile)

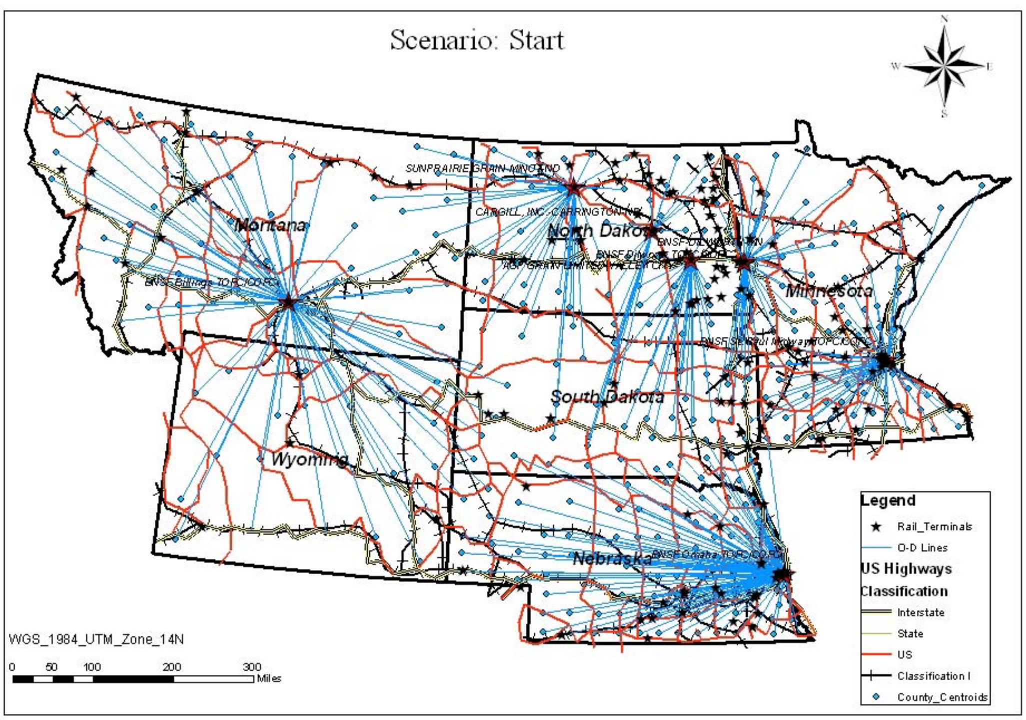
The outputs from the performance measures are summarized in Table 3 to help compare different scenarios.

**Start:** Nebraska and Wyoming do not have any relevance to the intermodal terminal in North Dakota, thus the two states have been excluded from the results in the other scenarios. From the Start, the original four alternatives include north eastern Montana, a north portion of South Dakota, and western Minnesota. The virtual location of Carrington, ND is omitted from further analysis, since it has a small portion of demand from the area which competes with other locations.

**Table 3: The summary of distance, cost, and demand distribution of the scenarios**

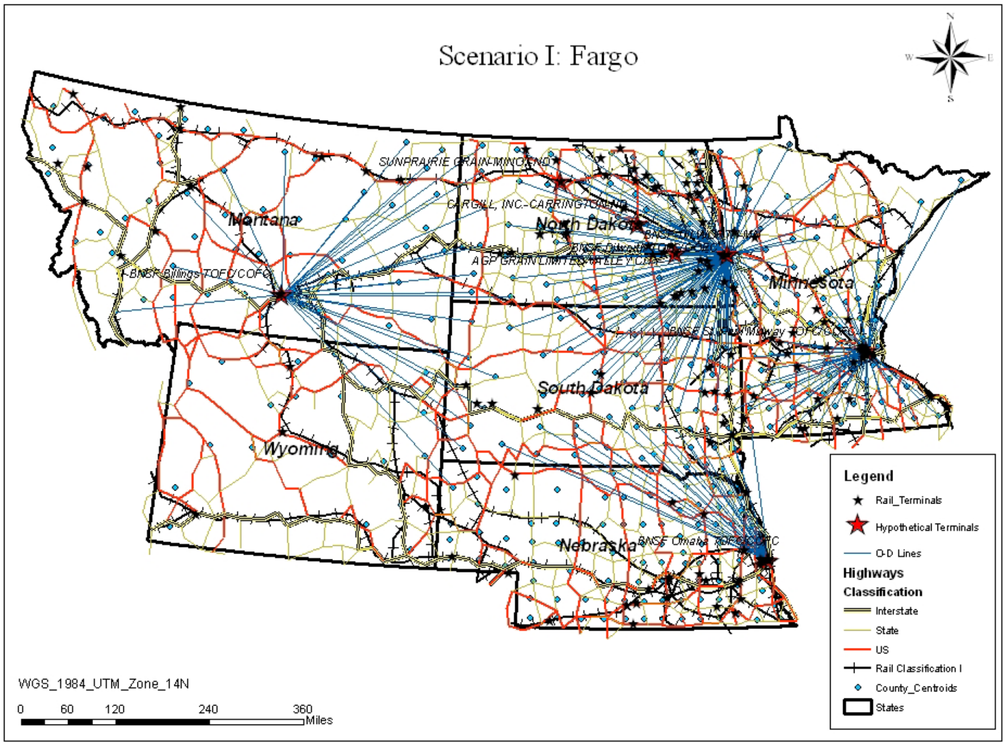
| | | Start | I | II | III | IV |
|---|---|---|---|---|---|---|
| Total Distance (K-miles) | Highway | 150 | 160 | 187 | 288 | 302 |
| | Rail | 7,537 | 7,540 | 7,542 | 7,474 | 7,494 |
| Average Vehicle Miles Travelled (VMT) | Truck | 43 | 45 | 53 | 82 | 86 |
| | Rail | 2,145 | 2,146 | 2,147 | 2,128 | 2,133 |
| Cost ($K) | Total | 2,160 | 2,188 | 2,235 | 2,422 | 2,455 |
| | Highway | 301 | 320 | 375 | 576 | 605 |
| | Rail | 1,507 | 1,508 | 1,508 | 1,494 | 1,498 |
| | Terminal | 350 | 351 | 351 | 351 | 351 |
| | Congestion | 7.9 | 7.9 | 8.1 | 10.2 | 10.5 |
| Demand - Containers (FEU) | Total Area | 3,513 | 3,513 | 3,513 | 3,513 | 3,513 |
| | Hypothetical Terminal Area | 857 | 857 | 790 | 110 | 0 |

**Figure 2: Hypothetical intermodal terminals and O-D matching in six states**



**Scenario I.** The Dilworth intermodal terminal was selected for Scenario I in lieu of Fargo. It competes with Minneapolis, Omaha, and Billings. It is estimated to generate the demand by 3513 carloads from North Dakota and Minnesota. It will lose demand from the western part of North Dakota and the eastern area of Montana, if the two areas start to produce containers. Scenario I shows longest average highway miles than Scenario II, but shortest average rail miles and highway miles per container than Scenario III and IV. The total cost is the least than other scenarios. It saves around $3.07 million compared with Scenario IV.

**Figure 3: Service Area for Scenario I**




**Scenario II.** Valley City was selected for Scenario II. The location covers the same area as Scenario I from Dilworth; however, it may lose some part of western Minnesota, so the total demand is smaller than Scenario I by about 67 carloads per year. It travels less in highway miles than Scenario III and IV; in the meanwhile, it shows longer rail miles than other scenarios.

**Scenario III.** Minot indicates longer highway travel: however, it causes shorter rail miles since the western part of Minnesota can avoid transporting products to Minneapolis with longer reverse rail trip. The total cost is higher than that of Scenario II since the highway transportation cost is higher than railroad versus Scenario I and II, even if the railroad cost is less than the scenarios. This scenario has higher total costs and longer average travelling distances. By this scenarios, most of the demand moves to the other hubs.

**Scenario IV.** No new location is selected in the NGP region for this scenario. Scenario IV presents the longest highway miles than the other scenarios; however, it shows shorter travel distance of railroad than Scenario I and II. This scenario incurs the highest congestion cost in the metropolitan areas (Minneapolis-St. Paul and Omaha) than the other scenarios.

**Figure 4: Service Area for Scenario II**

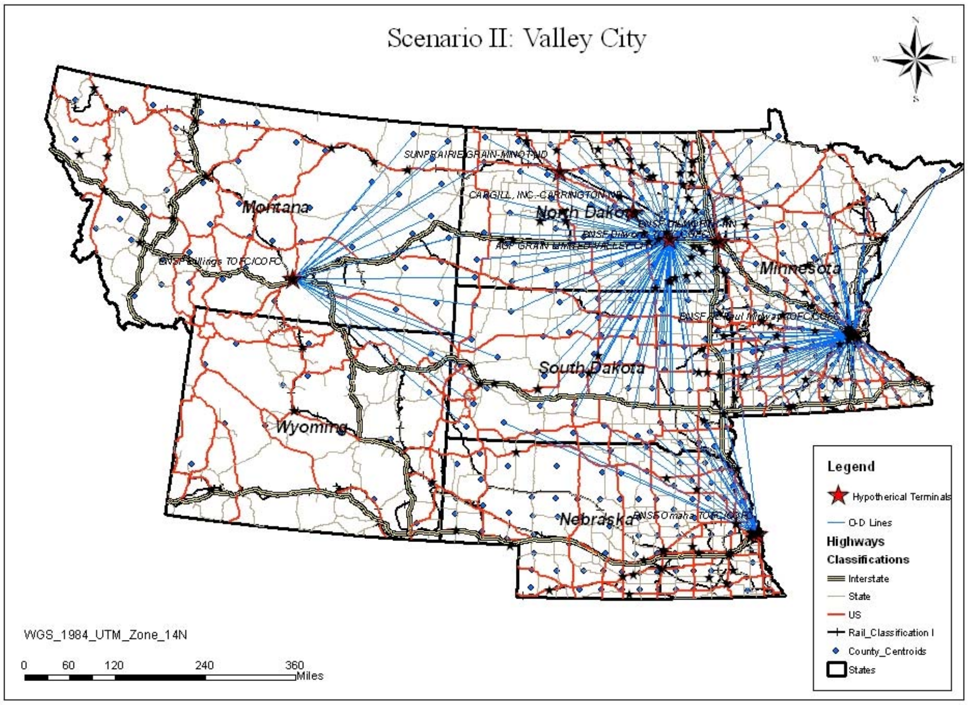
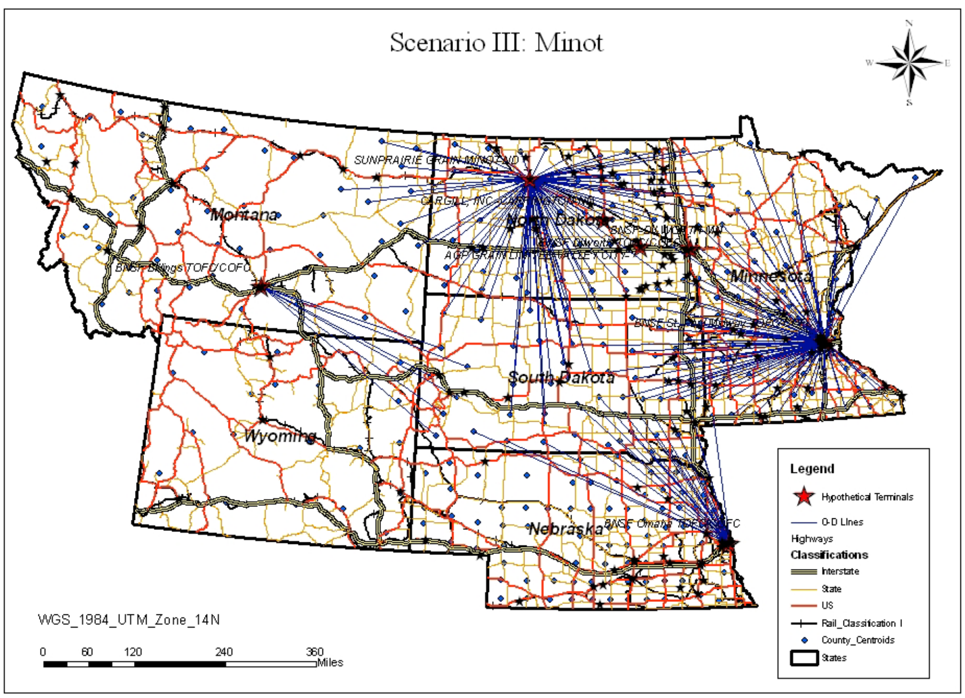



**Figure 5: Service Area for Scenario III**



**Discussion.** Total demand for the Dilworth intermodal terminal is concentrated along Interstate Highway 94 (Figure 7) in BEAs of 107 and 113. The total COFC/TOFC derived from the Waybill sample was 3513 summarized in Table 4. The results shows that Scenario I is the best way to save the total cost and to decrease the average highway miles and rail miles as well as congestion in metropolitan area.

**Figure 6: Service Area for Scenario IV**

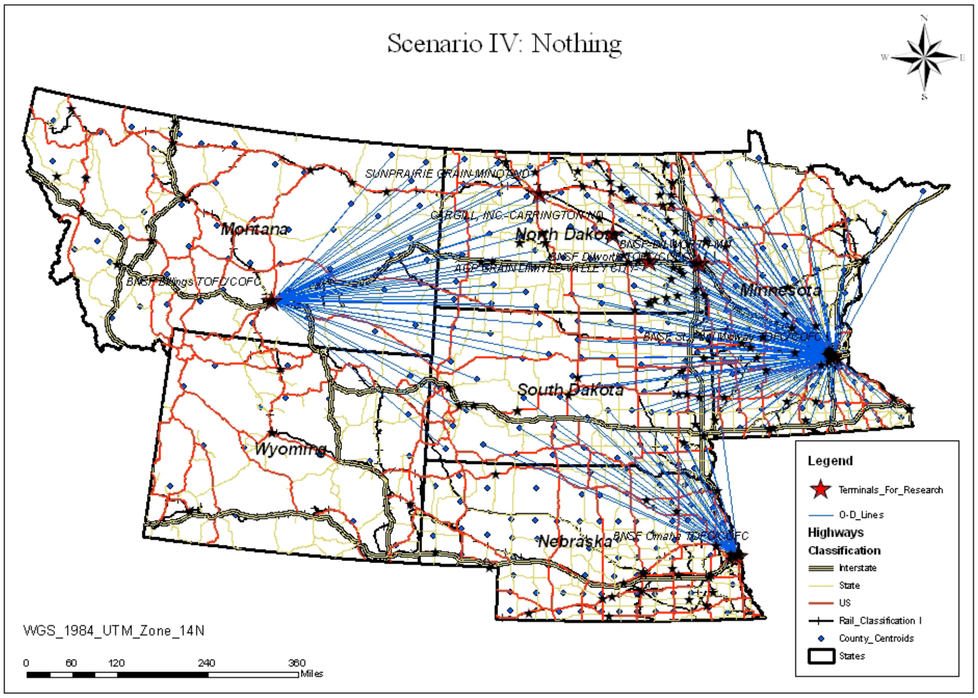
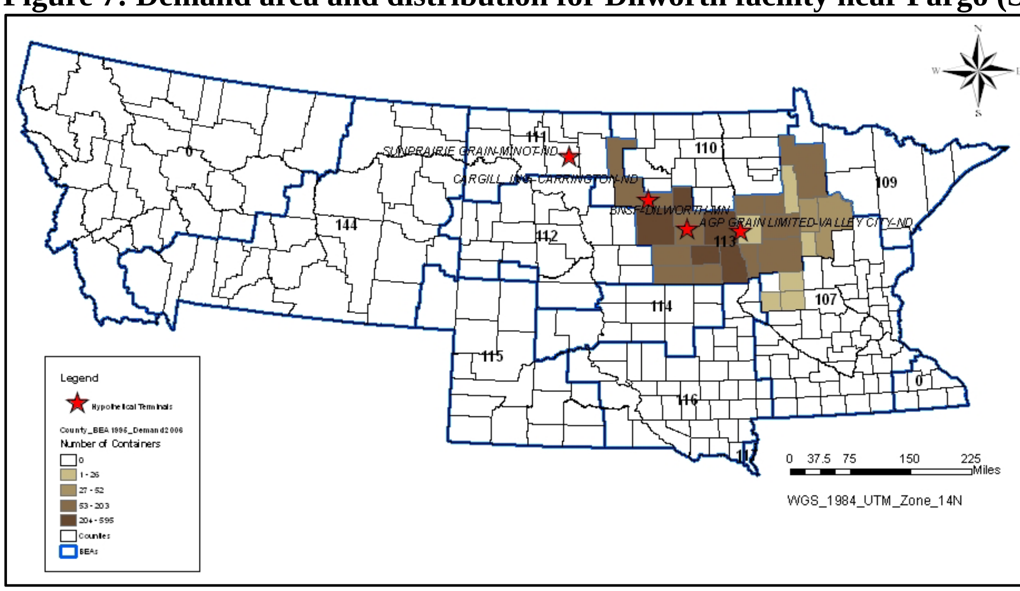



**Figure 7: Demand area and distribution for Dilworth facility near Fargo (Scenario I)**



The selected counties are from eastern North Dakota and western Minnesota. In Minnesota, 15 counties may use the new intermodal terminal by 335 containers per year. In the other hand, 13 counties from North Dakota for 525 containers are main users for the intermodal terminal in Dilworth.

Those areas are from BEA 107 (Minneapolis-St.Cloud, MN) and 133 (Fargo-Moorhead, ND-MN). The top crop item at Cass and Clay counties in BEA 133 was farm products including soybean and wheat. Soybeans were the number one crop at Cass and Stutsman counties in BEA 113 by acres and value of sales. By the market value, 64.4% is from grains, oilseeds, dry beans, and dry peas; 19.3% from cattle and calves, 7.2% from other crops and hay in the state of North Dakota for the agricultural industry. The value–added soybeans and other grains are major containerization in BEA 113. In BEA 107, farm product and food products are the major products for the intermodal terminals (Table 5). The selected origins produced 859 COFC/COFC carloads in 2006. It is much smaller than 20,000 which BNSF and Berwick (2002) recommend for the intermodal terminal at the location to set up new facility. The number of containers in BEA 110 in 1996 was 340 of beans and seeds (Berwick 2000).

**Table 4: Demand for the intermodal location by Scenario I (selected counties)**

| **Minnesota** | | **North Dakota** | |
|---|---|---|---|
| **County** | **TOFC/COFC** | **County** | **TOFC/COFC** |
| Beltrami(27007) | 16 | Barnes(38003) | 23 |
| Cass(27021) | 3 | Cass(38017) | 282 |
| Clearwater(27029) | 4 | Dickey(38021) | 16 |
| Douglas(27041) | 26 | Foster(38031) | 10 |
| Grant(27051) | 1 | Griggs(38039) | 6 |
| Hubbard(27057) | 10 | LaMoure(38045) | 4 |
| Pope(27121) | 9 | Pierce(38069) | 6 |
| Stevens(27149) | 5 | Ransom(38073) | 10 |
| Todd(27153) | 18 | Richland(38077) | 70 |
| Wadena(27159) | 6 | Sargent(38081) | 61 |
| Becker(27005) | 70 | Sheridan(38083) | 2 |
| Clay(27027) | 33 | Stutsman(38093) | 32 |
| Mahnomen(27087) | 1 | Wells(38103) | 2 |
| Otter Tail(27111) | 127 | | |
| Wilkin(27167) | 6 | | |
| Sub Total | 335 | Sub Total | 524 |
| | | Grand Total | 859 |

**Table 5: Items produced from the demand area by Scenario I (selected)**

| BEA | STCC | Description | TOFC/COFC |
|---|---|---|---|
| 107 | 01 | Farm Products | 12 |
| | 20 | Food Kindred Products | 77 |
| | 24 | Lumber or Wood Products, excluding Furniture | 3 |
| | 26 | Pulp, Paper, or Allied Products | 4 |
| | 29 | Petroleum or Coal Products | 2 |
| | 37 | Transportation Equipment | 1 |
| 113 | 01 | Farm Product | 760 |
| Total | | | 859 |

**SUMMARY AND CONCLUSION**

The research is conducted ideally under the indifference of current situations of capacity, and financing issues. When the location is selected, the intermodal terminal can be an alternative for the future development in the consensus of various stakeholders for the economic impact and public issues. This research used different approach from Berwick's studies conducted for more than one decade in the perspective of economic engineering approach. O-D distance matrix from ORNL was used to connect demand points (centroids of counties) to the nearest intermodal terminal using GIS.

From the analysis, Scenario I (Dilworth) was selected as an appropriate intermodal location for the shippers in the research area. The selection was measured by the total intermodal logistics cost and service distance. The selected scenario presents more travel on highways and less rail mile than scenario IV (nothing was selected) as well as lower total logistics cost. The scenario I is also most attractive by 24.4% of the demand in the two BEAs. The average highway travel distance was 160 miles from the origin to the intermodal terminal. This shows a shorter distance than the average distance of 366 miles in the previous survey (Vachal et al. 2003). Besides the output result, additional reasons could be found in other literature (Berwick 2001; Berwick 2002; Berwick 2007; Vachal et al. 2003) to include:

- The industry as a hole is experiencing growth in this region.
- The agricultural exporting industry including grains is highly interested in containerization.
- Congestion and fuel consumption are a major public concerns.

The case study in this research is conducted on the US railroad system. However, Canadian Pacific operates railway in the research area as well. The CP rail also can be included for the extended research. A competition model could be developed for further case studies. Furthermore, context analysis would be required to be successful including; various stakeholders of the communities, railroad companies, and the sound financing, infrastructure, and environmental issues.

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