Development of a GIS-based Automated Routing System for Overweight/Oversize Vehicles Traveling Through Border Regions

Conducted for the NAFTA Intermodal Transportation Institute

December 2001

Center for Highway Materials Research
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Development of a GIS-Based Automated Routing System for Overweight/Oversize Vehicles Traveling Through Border Regions

by

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Task L

AUTOMATED ROUTING OF OVERWEIGHT/OVERSIZE VEHICLES THROUGH THE EL PASO DISTRICT

Conducted for the

NAFTA
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Octavio Melchor-Lucero, M.S.C.E., E.I.T.
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The North American Free Trade Agreement (NAFTA) between the U.S. and Mexico is, and will continue to have an impact in the transportation infrastructure of both nations. About 50% of the total U.S/Mexican freight trade is transported through the highway system. Consequently, the border communities are being heavily impacted by the increase of the trade. These issues imply an increase in traffic volume, heavier trucks, more passenger vehicles, more pedestrians, etc., all of which will put a strain on the physical infrastructure, accelerating its deterioration and its life expectancy, moreover having potential impacts on the safety and welfare of the U.S. public.

TxDOT issues permits, through its Motor Carrier Division, for oversize and overweight vehicles to travel along the On System highways of the State of Texas. The current procedure for processing a permit is time consuming and costly. In order to reduce the processing time of issuing the permits, it is customary to reuse portions of the routes already analyzed for greater loads, thus potentially having the risk of creating future problems on the bridges because they are subjected to repeated loading.

A software program based on GIS is proposed to automate the evaluation of bridges and clearances along routes under the On-System jurisdiction for heavy and oversize vehicles in the El Paso border region. The potential benefits of using this program include (a) a reduction in the time it takes to find an adequate route and issue the permit for oversize/heavy vehicles, (b) the prevention of the deterioration of bridges in the El Paso border region due to repetitive heavy loading, and ultimately (c) to have a safer bridge infrastructure.
EXECUTIVE SUMMARY

The objective of this research was to develop a GIS application to automate the selection and evaluation of On-system routes and bridge infrastructure in the El Paso border region, for vehicles exceeding legal size and weight limits to avoid inadequate structures with insufficiencies and protect them.

A survey was performed on available GIS software with routing capabilities, available GIS information, such as maps and databases, and current routing methodologies.

Two critical factors were addressed when developing the routing application: a) the accuracy of the highway network model with directions of travel, and b) the correct location of each bridge for proper identification during the route selection and evaluation. A substantial amount of work was carried out to prepare the network for routing purposes, specifically in verifying and correcting the location of the bridges. The highway network model representing the On-system roads of the El Paso District required the completion of road attributes, such as traffic flow directions, highway identification, definition of overpass/underpass intersections, and the creation of a relational database between the roads and the bridges.

The overall criteria to determine the adequacy of a proposed route between an origin and a destination entails assessing the legality of the vehicle (dimensions, group axle weights and tire pressure) according to the Texas Administrative Code requirements. The bridge infrastructure adequacy (clearances and load-carrying capacity) is then evaluated through the Bridge Load Formulae. The Bridge Load Formulae uses bridge ratings and span information, as well as vehicle characteristics, to determine the allowable axle-group weight for each critical axle-group combination.

The entire routing evaluation process is encoded into a macro which consists of a customized toolbox that interfaces and integrates TransCAD’s shortest path algorithm and a few editing capabilities.

Road segments with inadequate bridges due to clearances or capacity are disabled from the network, to avoid them in the next route search. The program results are always reported in a text file, and a graphical representation of the route found is displayed and highlighted in the map.

Two feasibility studies were conducted, one to incorporate network restrictions into the routing analysis, and the other to test the application in a northern border region.
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CHAPTER 1
INTRODUCTION

1.1 Introduction

The North American Free Trade Agreement (NAFTA) between the U.S. and Mexico is and will continue to have an impact in the transportation infrastructure of both nations. About 50% of the total U.S/Mexican freight trade is transported through the highway system. Consequently, the border communities are being heavily impacted by the increase of the trade. These issues imply an increase in traffic volume, heavier trucks, more passenger vehicles, more pedestrians, etc., all of which will put a strain in the physical infrastructure, accelerating its deterioration and its life expectancy, moreover having potential impacts in the safety and welfare of the U.S. public.

A recent survey/appraisal rated the US’s infrastructure as now bordering on poor condition and increasing. Thousands of bridges built in the 50’s and 60’s which are approaching the end of their useful lives, without preventive maintenance will soon become problems for travelers and shippers.

The Texas Department of Transportation (TxDOT) issues permits, through its Motor Carrier Division (MCD), for oversize and overweight vehicles to travel along the On System highways of the State of Texas. The current procedure for processing a permit is time consuming and costly. The process consists of (a) proposing a tentative route with adequate clearances; (b) manually identify all bridges along the proposed route; (c) retrieve the files and drawings of each bridge; (d) perform a structural analysis of the bridges to assess the adequacy of each structure for the incoming vehicle, and (e) if a structure is not adequate, investigate an alternate route. In order to reduce the processing time of issuing the permits, it is customary to reuse portions of the routes already analyzed for greater loads, thus potentially having the risk of creating future problems on the bridges because they are subjected to repeated loading.

This project proposes a software program based on Geographic Information Systems (GIS) to automate the evaluation of bridges and clearances along routes under the On-System jurisdiction for heavy and oversize vehicles traveling through border regions.

1.2 Objective

The objective of this research was to develop an application to automate the selection of routes and the evaluation of the bridge infrastructure in the El Paso border region for vehicles exceeding legal size and weight limits, using GIS technology, to avoid inadequate structures with insufficiencies and protect them.

To accomplish the overall objective, the following issues were addressed:
1) Survey existing GIS platforms suitable for transportation modeling
2) Survey available information to develop a routing program
3) Develop an automated procedure to find routes for heavy and oversize vehicles traveling through the El Paso border region using GIS technology.
4) Develop a framework to transfer and use the program and GIS technology to other border regions.

The potential benefits of using the application include (a) reducing the time it takes to find an adequate route and issue the permits for oversize/heavy vehicles, (b) preventing the deterioration of bridges in the El Paso border region due to repetitive heavy loading, and (c) ultimately, having a safer bridge infrastructure.

In this report, the results from the efforts made during the past two years of the project are summarized. The success of this project relies on the collaborative efforts between The University of Texas at El Paso (UTEP), TxDOT, and New York State Department of Transportation (NYSDOT) personnel.

1.3 Scope of Report

Chapter 2 summarizes background information on vehicle loads, structural safety, permit regulations and procedures, as well as permit evaluation methodologies for overloads. In chapter 3, the route selection criteria followed by the State of Texas is discussed. An alternative bridge load formula (BLF) developed to rapidly assess the load-carrying capacity of bridges is presented. Chapter 4 addresses the data and GIS software selected to develop the proposed routing application. Chapter 5 describes the framework for developing the routing application for El Paso District in Texas. In addition, problems encountered and solutions provided during the preparation of the network for routing, are discussed. The integration of the different geographic data and routing capabilities of the GIS software, as well as the evaluation algorithms of the BLF into a customized interface is briefly addressed. Chapter 6 demonstrates the feasibility of the GIS routing application with three case studies. Chapter 7 reports a feasibility study to incorporate real-time highway conditions into the routing application, including temporary road closures and prohibited turns. In chapter 8, the feasibility of transferring the framework developed in Chapter 5 to a northern border region is reported. The last chapter contains the conclusions of the research effort in this project. Finally, Appendix A includes the output reports of the case studies presented in Chapter 6.
CHAPTER 2
LITERATURE SURVEY

2.1 Introduction

Concerns about the impact of trucking on the infrastructure due to the increase in NAFTA trade flows have been the subject of federal and state research for the past decade. Statistics show that both the weight and the number of overload vehicles have been increasing nationwide and in many other countries. Overloads are recognized as one of the major modes of bridge failure. Several attempts have also been made to harmonize the differences between the three countries regarding truck size and weight limits. Research efforts have addressed several issues including:

a) the accurate determination of truck weights [Harrison et al 1998], [Mohammadi and Shah, 1992], [Nowak and Nassif, 1992];

b) the collection and analysis of truck loads from field data to develop live load models [Lie et al 1998];

c) the assessment of existing bridge and pavement conditions [Fernando, 1997], [Chen et al 1997];

d) the revision of design criteria to handle overweight trucks [Ghosn and Moses, 1987], [Fu and Hag-Elsafi, 1994] and [Fu and Hag-Elsafi, 1996] and

e) the determination of guidelines and regulations to issue permits for nondivisible truck overloads, exceeding legal limits to travel on the highway system [James et al, 1986], [Middleton et al 1988], [Nozick et al, 1998].

This chapter briefly presents findings from the literature review addressing issues regarding overweight/oversize vehicle permits.

2.2 Literature Survey

The following paragraphs briefly summarize the content of the most relevant surveyed publications. The papers and reports are classified under three categories based on its primary focus:

I. Vehicle Loads and Structural Safety;

II. Permit Regulations and Procedures, and

III. Permit Evaluation Methodologies for Overloads.

Several other publications and NAFTA studies, not mentioned in this report, were cross-referenced for their contents addressing traffic operations, but are not considered relevant for this research project.

2.2.1 Vehicle Loads and Structural Safety

In the past, researchers [Liu et al. 1988] have also attempted to develop site-specific load models for bridge rating by incorporating uncertainty analysis accounting for the site-to-site
variability in the truck live loads. Realistic assessment of the variability in the gross vehicle weights, in the superposition effect of multiple truck presence and in the dynamic impact effect is required to minimize conservative predictions of the maximum load effects over a specified period of time.

Several highway agencies follow safety factor based criteria (similar to AASHTO’s WSD or LRFD) to evaluate highway bridges before issuing a permit. AASHTO requirements are intended to cover only normal traffic, not overloads. Researchers Ghosn and Moses [1987] and Fu and Hag-Elsafi [1994, 1996], have developed methodologies to calibrate reliability based evaluation formulations. The formulations account for overloaded truck configurations, simultaneous occurrence of overloads and normal trucks, number and type of permits allowed (annual permits for divisible loads, annual permits for nondivisible loads, and trip permits for nondivisible loads), general truck traffic at the site, and variability in the aforementioned and other factors.

Other researchers [Nowak and Nassif, 1992] have focused on determining the actual truckloads imposed on selected bridges due to the concern that truck weight station data is biased to less heavy vehicles. By using equipment not visible to truck drivers, such as strain gages and other devices, the deformations (strains and vibrations) are recorded and later analyzed to determine the actual truckloads.

Damage to pavements and bridges depends on both the intensity of truck weights and on the frequency of truck passage. Truckloads exceeding the legal limits are expected to occur less frequently, however, due to their great potential to cause damage, even a less frequent overload occurrence may dramatically contribute to the damage done to the infrastructure.

Mohammadi and Shah [1992] analyzed the load spectrum of truck overloads finding that overloads generally appear with a distinctly different pattern than lower load levels. The research proposed mixed-distribution models (two-function distributions) to derive a theoretical probability distribution model for the overloads. The functions are linearly combined and adjusted to represent the overload statistics. The overload statistics are used along with a damage estimation model, formulated in terms of load intensity and frequency, to determine to what extent the overloads are responsible for damage done to bridges and highways. The authors suggest that the information can then be used along with routine engineering analysis to determine the issuance of an overload permit.

In other NAFTA countries, such as Canada, surveys have also been conducted to collect information on commercial vehicle movements, including loads, drivers and origin/destination characteristics [Gorys et al., 1993]. The Ontario Ministry of Transportation identified intercity/intraprovincial and international trucking activity, focusing on overweight offenders, and classified it by truck type (axle configuration) and body style. A review of the degree to which weight limits were exceeded revealed that a large portion of overweight vehicles were within 10% of the prescribed limits. The information was used for highway planning, policy and enforcement purposes. Comparable studies were planned for the following years.
A paper describing a fatigue-based methodology proposed to assess the reduction in the service life of steel bridges due to heavy permit-trucks [Bruneau and Dicleli, 1994] was found. The methodology consists in generating variable amplitude stress range spectrum (VASRS) from weight and axle configuration of trucks. Frequency of occurrence of various stress ranges are determined and using Miner’s cumulative fatigue damage equation, the safe fatigue life-cycles can be determined as well as reduced fatigue life. The authors are also able to determine the allowable number of passages of a type of heavy permit-truck per month, for a specified percentage of reduction in fatigue life and a specified amount of traffic.

Recently, Harrison et al. [1998] conducted a study at two ports-of-entry (POE) on the Texas-Mexico border from 1994 through 1996. The study consisted of collecting truckload profiles, determining vehicle types and analyzing traffic counts at the Laredo and El Paso POE. Weigh-in-motion (WIM) devices were installed for this purpose. The findings from this truck traffic study show that five-axle tractor-semi-trailer (3S2) vehicles dominated traffic flows at both sites. Between 25% (El Paso) and 35% (Laredo) of the observed tandem-axle loads on loaded northbound trucks exceeded the U.S. legal load limit. Six-axle trucks (3 axle tractor with tridem-axle semi-trailer) were few in number but 80% (El Paso) and 87% (Laredo) of the tridem axles on the semi-trailers of northbound loaded trucks exceeded the U.S. limit. The experiences in this study confirm that WIM is relatively inexpensive, and recommend its implementation as part of the process of insuring load-limit compliance before vehicles travel on state and federal highway systems.

### 2.2.2 Permit Regulations and Procedures

In Texas, some researchers [Middleton et al., 1988] have evaluated the permit policy and fee structure. The study reports that, at the time of the research, bordering states to Texas had several differences in their permitting process. Differences exist in the maximum legal axle group weights and escort policies. The authors recommend an increase in permit fees, specifically for the category of super-heavy permits. Usually, the fee structure is based on the premise that each vehicle class should pay for actual usage or damage done to the highway infrastructure plus the cost of administering the permit system. An alternative fee schedule based on a weight-distance factor is recommended. The implementation of an automated routing scheme is recommended as soon as possible to improve pavement and bridge management strategies and reduce issuance time.

A paper from Fekpe [1997] addresses a procedure to evaluate infrastructure impacts, trucking productivity, and highway cost-allocation implications of alternative truck weight limits to develop regulatory and weight-control policies that are compatible with the existing infrastructure capabilities and enforcement options. The inputs include estimates of: a) probable weight distributions, b) changes in truck fleet mix, c) vehicle utilization or infrastructure usage, and d) definition of acceptable level of enforcement to achieve tolerable violation rates, are required. The procedure uses a weight-prediction methodology that resolves some major uncertainties associated with input variables required for assessing regulatory policies and their impacts in infrastructure management decisions.
During this survey, a paper describing the design of an electronic automated permit issuance system for over-dimensional and/or overweight vehicles with nondivisible loads [Nozick et al., 1998] was found. The design involves a GIS that is distributed over a number of computers connected by a local area network (LAN) in New York’ DOT. The system links to separate databases and facilitates data management and user interaction. The automated system was designed to replace a cumbersome manual system of data checking and route verification. Two principal subsystems can be identified – one to automate the permit submission and return process, and the second to automate the permit evaluation process. Within the sub-systems, the rules associated with the various restrictions on permits issued are encoded. According to the authors, the system can be transferred to other states or agencies.

### 2.2.3 Permit Evaluation Methodologies for Overloads

The effect of overloads on state-maintained highways has been the subject of study in the last decade. The objective of the permitting process for overloads is to prevent damage to pavement and bridges.

The analysis of super-heavy loads requires the determination of the induced (pavement and/or bridge component) stress under surface wheel loads coupled with an evaluation of the structural adequacy of the infrastructure to sustain the imposed stresses without developing damage.

James et al. [1986] evaluated the truck weight formula (1), a.k.a. as Bridge Formula B (BFB), mandated by the federal government and found that it is inadequate in several aspects enumerated in the paper. BFB limits the maximum allowable weight (W in pounds) of any group of axles under the vehicle as a function of the number of axles in a group (N) and extreme axle spacing of the group (L in feet). Eight restrictions are applied on single and tandem axles based on pavement damage criteria rather than on bridge stress criteria. The authors proposed a formula (2) to safely limit truck weights and allow increases in the arbitrary ceiling on overall vehicle weight without overstressing bridges, where L and W are defined as before.

\[
W = 500 \left( \frac{N}{N-1} \right) L + 12N + 36 \leq 80,000 \text{ lbs} \hspace{1cm} (1)
\]

\[
W = 1,000 \left( L + 34 \right) \quad \text{when } L \leq 56 \text{ ft} \hspace{1cm} (2a)
\]

\[
W = 1,000 \left( \frac{L}{2} + 62 \right) \quad \text{when } L > 56 \text{ ft} \hspace{1cm} (2b)
\]

This formula limits overstress ratios to 1.05 and 1.30 for HS20 and H15 design bridges. Whenever a transportation network can be identified that includes no H15 bridges, a more liberal formula (not examined here) can be applied. This proposed formula was demonstrated to work well for simple span girder bridges. One of the limitations of the proposed formulae is that the overstress ratio criteria is not documented nor justified by any bridge capacity behavior.
Later, James and Zhang [1991] demonstrated that the proposed bridge formula is also effective at limiting weights of vehicles on continuous, multiple-span bridges. The critical weights of various typical vehicle configurations are calculated for several two- and three-span bridge designs, including bridges designed by the service-load or load-factor design methods. The proposed formula allows removal or rising of the existing arbitrary 80,000 lb gross vehicle weight limit associated with the BFB. Steel bridges of medium span (around 150 ft. in span length) were expected to be most critical with respect to implementation of the proposed truck weight formula.

Osegueda et al. [1992, 1993] developed a Bridge Load Formulae (BLF) to evaluate the capacity of the bridges along the route. The BLF limits the allowable group weights of axles (GW) for a given span, as a function of the bridge’s span length(s) (L) and of the vehicle’s wheelbase (WB). If the allowable GW for the span length is less than that of the actual vehicle, the bridge should be avoided and an alternate route should be investigated. To demonstrate the feasibility of incorporating the developed BLF into a routing model, the researchers developed a prototype software written in FORTRAN, that routes vehicles using a highway network model of TxDOT’s Houston District and the Bridge Inspection and Appraisal Program (BRINSAP) database. The network model was created from drawings available at TxDOT, defining road segments as links and intersections as nodes. Bridges are attributed to the corresponding links on the network after mapping their geographic coordinates onto the maps. The software identified all segments of travel of a proposed route, which was not necessarily the minimized path length between two points. In addition, the corresponding bridges were identified and the bridge information was retrieved from BRINSAP. The developed BLF was not implemented, since BRINSAP has insufficient bridge span lengths for multi-span bridges.

Later, Osegueda et al. [1997, 1999] developed a geographic information system (GIS) to automate the routing of overweight vehicles in the Houston District of Texas. The GIS uses a network representation of highways and a relational database link to the corresponding bridge database (BRINSAP). The system automatically finds the shortest path between an origin-destination pair and any number of intermediate points, disabling from the network road segments with insufficient clearances and load-carrying capacity. The output consists of a map with the route found highlighted and a written report that includes a description of the route and the vehicle. The network was generated from digitized maps. Laborious preprocessing was required to verify network connectivity and minimal road information completeness and an exhaustive verification of bridge locations was made. The bridges were attributed to the corresponding road segments to create the relational database. In this project, the researchers incorporated two evaluation criteria to determine the feasibility of a route: a) Legal size and weight limits (Texas Administrative Code [1992]), and b) a Bridge Load Formulae developed by Keating et al [1994] (see section 3.2).

Fernando [1997] developed and evaluated a non-linear layered elastic pavement response model for super-heavy load analysis that predicts the induced stress under surface wheel loads. The predicted stresses are used with the Mohr-Coulomb failure criterion to evaluate the potential for pavement damage prior to the super-heavy load move, e.g. determine whether yielding of the material will take place under the induced stresses. The analysis
procedure was incorporated into a computer program called PALS. The inputs to the program include: a) the layer thicknesses along the route; b) cohesion and angle of friction of the layers; c) super-heavy wheel loads and load geometry; d) pavement surface condition, and e) non-linear stress-dependent material parameters. The program also includes analysis routines to evaluate the edge load condition and to compute the failure wheel load for a given pavement. The program assists the engineer to decide whether to allow the move or not.

Chen et al. [1996] implemented Fernando’s [1997] program to evaluate the potential pavement damage caused by a super-heavy load moved in Texas. Falling Weight Deflectomer (FWD) tests were performed on the pavement before and after the super-heavy load was moved. The FWD data and analyses show that the existing pavement structure is adequate for the planned super-heavy load move, and no significant distress due to the super-heavy load was observed after the move.

A paper by Chou et al. [1999] describes a quick method for evaluating overweight vehicle permits to travel in Tennessee roads to protect the public from bridge failures. The Tennessee Department of Transportation (TDOT) requires and issues travel permits for all vehicles with a gross weight over 150 kips. Due to the large demand of overload permit applications received, an empirical method was developed to efficiently identify any suspicious overweight vehicle requesting a permit, for further detailed analysis. The TDOT--Permit Section developed a “weight ratio” defined as the group axle gross weight to group interstate weight, to assess the effect of overweight trucks on the bridges. The federal bridge gross formula, as defined in equation (1), is a.k.a. the interstate weight.

Two allowable weight ratio curves (AWRC) were developed to relate the “weight ratio” to total vehicle gross weight.

One based on bridges designed for HS-20 trucks (interstate bridges)
\[
AWRC-I = 1.4 + 0.002333W - 0.0000133W^2
\]  
(3)
and the other for H-15 trucks (state bridges)
\[
AWRC-S = 1.25 + 0.001867W - 0.0000107W^2
\]  
(4)
where (W in kips) is the gross vehicle weight or actual highest group axle weight.

Two lower bound curves defined as the 95th percentile of the AWRC, represent a restriction region between the AWRC and itself.

The “weight ratio” is compared with the value computed with equation (3) when the overload vehicle is traveling on interstate routes, or compared with the value computed with equation (4) when the overload vehicle is traveling on state bridges. If the actual weight ratio falls outside the acceptance envelope, the permit application is further analyzed. If the weight ratio falls inside the acceptance envelope, posted bridges and size limitations are checked before final approval of the permit request. If the weight ratio falls inside the restriction region, a recommendation for speed reduction is issued with the permit, provided there are no posted bridges or size limitations along the proposed route.

The input to the method includes the route type, the number of axles, axle loads, and axle spacing.

A validation study, where detailed structural analyses were performed on typical Tennessee interstate and state bridges, shows that the methodology may be considered conservative. The AWRC were developed empirically for Tennessee, and may not be readily adopted by other states, unless a calibration exercise is thoroughly conducted.
CHAPTER 3
ROUTE SELECTION CRITERIA

3.1 Introduction

As mentioned before, several state agencies have been regulating and enforcing size and weight limits for commercial vehicles traveling through state-maintained highways, to prevent pavement and bridge facilities from being damaged. The truck size and weight regulations governing the physical and operating characteristics of vehicles are summarized in a set of documents for each state. There are inter-jurisdictional and regional differences. However, vehicles exceeding the legal limits and carrying indivisible loads may be required or desired to cross highway bridges, mainly for economical advantages. Therefore, the states accommodate special travel permits for these vehicles for a certain period. This chapter provides a brief discussion on the route selection criteria followed in the State of Texas based on legal limits and introduces an alternate bridge evaluation procedure developed for issuing overweight/oversize permits.

3.2 State of Texas

The Motor Carrier Division (MCD) of TxDOT is the agency that issues permits for overweight and oversize vehicles before moving through the state highways. Examples of overweight loads in Texas include mobile cranes, oil pressure vessels, steel-coil haulers, electric transformers for public utility companies, military hardware, industrial equipment, dragline components, heavy machinery, offshore pipe-laying equipment, rigs, tanks, mud pumps, bunk houses, road construction equipment, and forest management equipment. Other nondivisible loads may include single poles, girders, columns, wood or metal trusses and buildings or mobile homes.

The current permitting procedure followed by MCD is based on the rules and regulations for movement of oversize/overweight loads governed by the Texas Administrative Code (TAC) [TAC 2000]. These regulations serve as a screening process by limiting the overall dimensions and axle loads based on a gross axle weight criterion (which depends on the number of axles per axle group) as well as the maximum tire pressure per inch of tire width. If these limits are not exceeded, the axle configuration is considered sufficient to avoid damage to the pavement. If either criterion is exceeded, TxDOT's Design Division performs an analysis of the bridges along the vehicle's route to determine if a permit may still be issued.

The customary procedure for processing these requests is time consuming and costly. The process consists of:

a) manually establishing a tentative route, using a District Permit Map

b) identifying all the bridges on the route, and obtaining the information of the bridges to be crossed, and
c) revising clearances and analyzing the structural adequacy of the bridges for the overweight vehicle.

Alternate routes are investigated, as some bridge structures are found inadequate. As an effort of reducing the time to process the permits, it is becoming customary to re-use portions of routes already analyzed for greater loads. This approach may cause future infrastructure problems due to repeated overloads.

3.2.1 Legal Size and Weight Limits on Commercial Vehicles

An oversize/overweight permit must be requested in the state of Texas when the legal size and weight limits shown in Table 3.1 are exceeded. The legal size limits may vary depending on the time and/or type of movement. Occasionally, some vehicles exceeding certain dimensions above the legal sizes may require that the proposed route be physically inspected and or meet certain additional requirements, such as escort vehicles.

Table 3.1 Legal Size Limits in Texas (after [Texas Administrative Code, 2000])

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Legal size limits (ft-in)(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>8'-6&quot; (2591)</td>
</tr>
<tr>
<td>Height</td>
<td>14'-0&quot; (4267)</td>
</tr>
<tr>
<td>Length (single vehicle)</td>
<td>45'-0&quot; (13716)</td>
</tr>
</tbody>
</table>

The basis for maximum legal weight is the number of axles. The maximum weight of any group of two or more consecutive axles may be applied to inner axle groups such as the drive axles and the trailer or trailers, or the entire combination of axles from the steering axle of the power unit to the last trailing axle of the trailer. The maximum legal gross weight cannot exceed 80,000 pounds (357 kN). The TAC also regulates that the weight on any low-pressure tire should not exceed 650 pounds per inch (295 kg./25.4 mm) of tire width. This restriction is primarily for protecting the pavement. A different tire surface pressure applies to mobile cranes and oil field equipment. Table 3.2 summarizes the axle group weight limits allowed for issuing permits to vehicles that exceed the maximum legal weights.

Table 3.2 Legal Weight Limits in Texas (after [Texas Administrative Code, 2000])

<table>
<thead>
<tr>
<th>Number of Axles/Group</th>
<th>Maximum Allowable Axle Group Weight (Kips)(kN)*</th>
<th>Maximum Distance Between Extremes of any Group of Two or More Axles (Feet)</th>
<th>Legal Axle Group Weight (Kips)(kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.0 (111)</td>
<td>-</td>
<td>20 ( 89)</td>
</tr>
<tr>
<td>2</td>
<td>45.0 (200)</td>
<td>10</td>
<td>34 (152)</td>
</tr>
<tr>
<td>3</td>
<td>60.0 (267)</td>
<td>32</td>
<td>42 (187)</td>
</tr>
<tr>
<td>4</td>
<td>70.0 (312)</td>
<td>51</td>
<td>50 (223)</td>
</tr>
<tr>
<td>5</td>
<td>81.4 (363)</td>
<td>51</td>
<td>58 (259)</td>
</tr>
</tbody>
</table>

*NOTE: provided that the 650 lbs./inch (295 kg./25.4 mm) of tire width is not exceeded.
3.2.2  **Bridges Closed to Traffic and Load Posted Bridges**

When establishing a tentative or final route for a permit request, load zoned roads and bridges as well as roads and structures closed to traffic are identified along the proposed route through District Permit Maps.

The District Permit Maps contain detailed information on the operational status of a bridge, such as whether it is load posted, and additional information such as the actual load restriction present on the day of the inspection (e.g. 16,000 pounds) and the type of restricted load (e.g. gross weight, single axle loading or tandem loading) may be retrieved from a database.

3.2.3  **Alternative Bridge Load Formulae**

With the continuing increase in commerce and trade in Texas, the MCD continues to experience increases in the number of permits issued for overweight/oversize vehicles. The significant drawback of the current route evaluation procedure is that, it is time consuming and expensive to subcontract the engineering analysis of each bridge, particularly when a number of bridges must be crossed. An easier and less expensive method of analysis that does not require detailed engineering analysis has been developed by Keating et al [1994].

A set of Bridge Load Formulae (BLF) have been developed which determine the maximum allowable loads for the axles groups associated with a given vehicle. The maximum allowable axle group weight defined by Equation (5) is corrected by incorporating reduction factors that account for gage distance and number of tires per axle.

\[
GW_{rev} = \frac{GW}{n} \sum_{i=1}^{n} \frac{1}{R_i \cdot S_i}
\]  

(5)

where:

- \( GW_{rev} \) = Revised axle group weight, kN (kips);
- \( n \) = number of group axle combinations (same as maximum number of axles).
- Axles in groups should be adjacent (e.g. 12, 23, 34, 123, 234 and 1234);
- \( R_i \) = reduction factor accounting for gages wider than 1.8 m (6 ft.) as defined by

\[
R_i = \frac{1.8 + G}{2G} \quad (R_i = \frac{6 + G}{2G})
\]  

(6)

- \( G \) = axle gage, m (ft), measured from C.G. to C.G. of tire groups within the axle;
- \( S_i \) = reduction factor for each axle with more than four tires per axle;
  - 1.0 for axles with four tires or fewer;
  - 0.96 for axles with eight or more tires;
- \( GW \) = allowable axle group weight, kN (k), calculated from equations (7) or (8)
Equation (7) defines a “general” formula to limit the weight of any group of axles by the bridge design type and the group wheelbase; while equation (8) defines a bridge “specific” formula that also accounts for the span length of the bridge.

\[
GW = (a + b \cdot WB_{rev}) \cdot X \tag{7}
\]

\[
GW = w \cdot WB_{rev} \tag{8}
\]

\[
w = \left( \frac{aL^2 + bL + \frac{c}{L} + d}{WBL(2L - WBL)} \right) \cdot X \tag{9}
\]

where:

- \( WB_{rev} \) = revised wheelbase, m (ft.) as defined by Equation 10;
- \( X \) = design rating of the bridge (e.g. 5 for an H-15);
- \( w \) = allowable distributed load, kN/m (kip/ft.);

- \( a, b, c, d \) = regression constants (see Tables 3.3 and 3.4 below);
- \( L \) = individual bridge span length, m (ft.);
- \( WBL = WB_{rev} \) (revised wheelbase), m (ft.) when \( WB < L \); or \( L \) (individual span length), m (ft.) when \( WB \geq L \);

\[
WB_{rev} = \frac{WB}{\beta} \tag{10}
\]

where:

- \( WB \) = wheelbase length of axle group, m (ft.);
- \( \beta \) = correction factor for concentrated loadings;
  - 1.0 for continuous span bridges;
  - defined for simple span bridges as the lesser of Equations (11 or 12):

\[
\beta = 0.97 - \frac{D}{12.2} \leq 0.92 \quad \left( \beta = 0.97 - \frac{D}{40} \leq 0.92 \right) \tag{11}
\]

\[
\beta = 1.0 - \frac{GD}{21.3} \leq 0.92 \quad \left( \beta = 1.0 - \frac{GD}{70} \leq 0.92 \right) \tag{12}
\]

where:

- \( D \) = distance between the center of gravity and nearest axle, m (ft.);
- \( GD \) = greatest distance between any of two axles, m (ft.).
### Table 3.3. Constants for General Formula

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Impact</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>17.83 - 0.034X</td>
<td>1.973 - 0.0119X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.009 - 0.0077X)</td>
<td>(0.1265 - 0.0012X)</td>
</tr>
<tr>
<td>HX</td>
<td>10%</td>
<td>16.21 - 0.031X</td>
<td>1.804 - 0.0172X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.645 - 0.007X)</td>
<td>(0.1157 - 0.0011X)</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>12.81 - 0.027X</td>
<td>1.684 - 0.016X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.88 - 0.006X)</td>
<td>(0.108 - 0.001X)</td>
</tr>
<tr>
<td>HSX</td>
<td>0%</td>
<td>0.0</td>
<td>3.103 - 0.016X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0</td>
<td>(0.199 - 0.001X)</td>
</tr>
<tr>
<td>WB &lt; 11.6 m</td>
<td>10%</td>
<td>14.45 + 0.0013X</td>
<td>2.791 - 0.013X</td>
</tr>
<tr>
<td>(WB &lt; 38 ft.)</td>
<td></td>
<td>(3.249 + 0.0003X)</td>
<td>(0.179 - 0.0008X)</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>13.08 - 0.0623X</td>
<td>2.136 + 0.0062X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.94 - 0.014X)</td>
<td>(0.137 + 0.0004X)</td>
</tr>
<tr>
<td>HSX</td>
<td>0%</td>
<td>35.52 - 0.0342X</td>
<td>1.380 - 0.016X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7.985 - 0.0077X)</td>
<td>(0.0885 - 0.001X)</td>
</tr>
<tr>
<td>WB &gt; 11.6 m</td>
<td>10%</td>
<td>32.27 - 0.0756X</td>
<td>1.258 - 0.014X</td>
</tr>
<tr>
<td>(WB &gt; 38 ft.)</td>
<td></td>
<td>(7.255 - 0.017X)</td>
<td>(0.0807 - 0.0009X)</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>24.64 + 0.0356X</td>
<td>1.325 - 0.016X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.54 + 0.008X)</td>
<td>(0.085 - 0.001X)</td>
</tr>
</tbody>
</table>

### Table 3.4. Constants for Specific Formula

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>Impact</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>2.262 - 0.0204X</td>
<td>0.0</td>
<td>-459.1 - 1.376X</td>
<td>225.5 + 0.994X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.155 - 0.0014X)</td>
<td>0.0</td>
<td>(-1111 - 3.33X)</td>
<td>(166.3 + 0.733X)</td>
</tr>
<tr>
<td>HX</td>
<td>10%</td>
<td>2.320 - 0.0350X</td>
<td>0.0</td>
<td>-442.5 + 0.4835X</td>
<td>202.7 - 0.949X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.159 - 0.0024X)</td>
<td>0.0</td>
<td>(-1071 - 1.17X)</td>
<td>(149.5 + 0.7X)</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>1.883 - 0.0175X</td>
<td>0.0</td>
<td>-281.8 - 1.405X</td>
<td>143.4 - 1.36X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.129 - 0.0012X)</td>
<td>0.0</td>
<td>(-682 - 3.4X)</td>
<td>(105 + X)</td>
</tr>
<tr>
<td>HSX</td>
<td>0%</td>
<td>0.7588 - 0.0623X</td>
<td>126.3 - 2.85X</td>
<td>1771 - 52.89X</td>
<td>-835.1 + 24.63X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.052 - 0.0043X)</td>
<td>(28.4 - 0.64X)</td>
<td>(4287 - 128X)</td>
<td>(-616 + 18.17X)</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>0.861 - 0.0204X</td>
<td>59.16 + 0.22X</td>
<td>556.1 + 4.13X</td>
<td>-264.4 - 2.350X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.059 - 0.0014X)</td>
<td>(13.3 + 0.05X)</td>
<td>(1370 + 10X)</td>
<td>(-195 - 1.733X)</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>0.730</td>
<td>56.49 - 0.5916X</td>
<td>633.1 - 10.99X</td>
<td>-295.6 + 4.61X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.05</td>
<td>(12.7 - 0.133X)</td>
<td>(1532 - 26.6X)</td>
<td>(-218 + 3.4X)</td>
</tr>
</tbody>
</table>

AASHTO’s [1983] standard bridge design practices allow the incorporation of a dynamic loading effect by means of multiplying the live load moment by an impact factor. This impact factor should not exceed 30%. TxDOT uses a reduced impact factor to allow the issuance of an overload permit. The reduced impact factor value depends on the vehicle’s speed while crossing a bridge:
a) a 0% impact factor should be associated, if the vehicle is assigned an escort or its speed is restricted to less than 5 km/hr (3 mph);
b) an impact factor of 10% is recommended when the speed is restricted to approximate a smooth walking speed as a condition of issuance. In addition to this speed restriction, no stopping, starting, or gear changing of the pulling truck is allowed while the load is on the bridge;
c) if the speed of the vehicle cannot be controlled or monitored, a maximum impact factor of 30% should be associated.

According to Keating, the proposed formulae allow greater loads without engineering analysis, since the bridge type and the span length are taken into account. However, the formulation does not take into account any reduction in bridge service life due to accelerated deterioration rates from the permit vehicles.

3.2.4 Evaluation Procedure Using the Proposed Bridge Load Formulae

The bridge load formula (BLF) evaluation procedure is applied to all bridges that a given overweight vehicle must cross over. The vehicle and bridge information required to apply the formulation, as well as the overall steps towards the determination of the load-carrying capacity of a bridge are as follows.

The required vehicle information includes:
  a) total vehicle height (feet|inches);
  b) total vehicle width (feet|inches);
  c) total number of axles;
  d) Axle information
     1. location of each axle from previous axle (feet|inches). Steering axle is located at 0’00”;
     2. total weight on each axle (kips);
     3. gage between tire groups of each axle (feet|inches);
     4. number of tires on each axle, and;
     5. tire width in each axle (inches). Assumed the same for every tire in the axle.

An impact factor must also be selected, to appropriately use the corresponding regression constants in the “general” and bridge “specific” BLF.

The required bridge information includes:
  a) total number of spans in the bridge;
  b) total bridge length;
  c) length of the largest span;
  d) the bridge type (simple or continuous spans), and
  e) the operating rating code.

Once the required information is complete, the maximum allowable GW can be determined as follows:
First, from the vehicle description determine:

1. for each axle find
   a. the gage reduction factor;
   b. number of tires reduction factor.
2. the critical axle groups, and
   a. their corresponding combined reduction factors,
   b. their corresponding actual group weights,
   c. their corresponding wheelbase.
3. the location of the center of gravity C.G. of the entire vehicle;

\[
\text{COG} = \frac{\sum_{i=1}^{n} \text{weight}(i) \times \text{location}(i)}{\sum_{i=1}^{n} \text{weight}(i)}
\]  

(13)

4. parameters \( D \) and \( GD \) as defined above
   a. compute concentrated loading correction factor \( \beta \), if bridge has a single span*.
   Compute the revised wheelbase.

Then, using the bridge attributes:

1. if bridge type is continuous, set concentrated loading correction factor \( \beta \) to 1.0*.
   If bridge type cannot be determine set \( \beta \) to 1.0.
   Compute the revised wheelbase.
2. determine the design rating (\( X \)). The operating rating is coded as a three-digit integer. The first digit may be either a one (1) or a two (2).

   a. If the operating rating begins with a one (1), the rating corresponds to an H-type vehicle (two-axles) and the last two digits correspond to the design value.

   \[ X = (\text{operating rating} - 100) \]  

   (14)

   The appropriate regression constants for the HX formulae should be used.

   b. If the operating rating begins with a two (2), the rating corresponds to an HS-type vehicle (three-axles). The design rating is determined as:

   \[ X = \frac{\text{operating rating} - 200}{1.8} \]  

   (15)

   The appropriate regression constants for the HSX formulae should be used.

   c. If the operating rating begins with a different number, this indicates a different type of load restriction. For the most part these bridges will not be on the On-system roads, but if they are the BLF must NOT be evaluated.
3. depending on the number of spans, compute the allowable GW:
   a. if bridge has three or more spans use “general” bridge formulae (conservative).
   b. if bridge has one or two spans use the bridge “specific” formulae (less conservative).
      i. if bridge has a single span, use the total bridge length in the formula.
      ii. however, if the number of spans is two, the formula needs to be evaluated two times, one for each of the spans. The second span length is determined by subtracting the length of the largest span to the total bridge length.

After completing the calculations for the allowable GW, evaluate the revised GW using the corresponding combined reduction factors (gage and number of tires). GW_{rev} is now interpreted as the allowable GW for the specific vehicle and bridge rating. This value must be greater than the actual GW.

### 3.3 Evaluation for Route Adequacy

In general, the criteria to determine a route’s adequacy entails assessing the legality of the vehicle (dimensions, group axle weights and tire pressure) for a specific Jurisdiction or State, and evaluating the bridge infrastructure adequacy (clearances and load-carrying capacity) under the proposed BLF developed by Keating et al. [1994].

The following presents the route evaluation criteria from the infrastructure standpoint:

1. Prevent pavement damage:
   a. determine the maximum tire pressure exerted by the load through each tire and compare against the allowable limit set forth by the corresponding State or Jurisdiction; if actual pressure exceeds the limit, STOP route search and suggest partitioning the load or modify axle configuration or tire configuration (increase tire width, or number of tires).

2. Evaluate allowable bridge infrastructure adequacy:
   a. compare vehicle dimensions and axle group weights against the legal limits set forth in the corresponding State or Jurisdiction;
   b. propose a tentative route where all bridge clearances (vertical and horizontal, over and underneath) are met and avoid roads and bridges closed to traffic and/or load restricted;
   c. If axle group weights exceed corresponding Jurisdiction requirements, evaluate the load-carrying capacity of the bridges applying the proposed Bridge Load Formulae.
   d. If the load-carrying capacity of a bridge is insufficient, avoid the bridge and find an alternate route.

The aforementioned route adequacy evaluation process can be implemented in an automated routing system, considering that the required highway maps and bridge information and software are available.
CHAPTER 4
GIS COMPONENTS FOR ROUTING

4.1 Introduction

The automation of a route evaluation methodology for oversize/overweight vehicles is highly desirable to reduce the time of finding an adequate route, where all clearance and load-carrying limitations are safely met, and thus reduce the processing time to issue travel permits when the vehicles exceed regulatory requirements.

The desired features for an automated routing system include:
  a) a transportation network to model vehicular travel;
  b) access to road and bridge attributes;
  c) a software package with transportation analysis and data management capabilities; and
  d) an interface that enables the integration of the aforementioned, and enables user interaction to define vehicle and Origin-Destination information.

Due to the nature of the required information, the use of Geographic Information Systems technology seems appropriate to develop an automated routing system for overweight/oversize vehicles.

This chapter briefly discusses the different sources of information and software identified during a survey, and the final selections made for the development of the automated routing system.

4.2 Geographic Information Systems with Routing Capabilities

A number of definitions of geographic information systems (GIS) have arisen throughout the years. A common one is: “GIS are an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.” [ESRI, 1990].

A GIS integrates information systems, spatial analysis tools, modeling tools and graphics display capabilities to enable the solution of a variety of decision-making problems that involve complex spatial operations that would be very difficult, time consuming or impractical to solve otherwise. Typical applications of GIS include land registration, forestry, environmental planning, demography, and transportation studies.

A number of GIS software packages with capabilities suitable for the development of transportation applications are available in the market. Table 4.1 compares different GIS packages by enumerating some of their features.
Most GIS software packages include programmable features that allow the user to customize the application for specific needs accessing the built-in tools and models via their programming languages. Three of the leading GIS software packages with routing applications are ARCInfo, ARCView, and TransCAD.

### Table 4.1. GIS Software Packages for Transportation.

<table>
<thead>
<tr>
<th>GIS Package</th>
<th>Interface</th>
<th>Development Environment</th>
<th>Features / Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARC Network for ARC/Info® (ESRI)</td>
<td>Modular</td>
<td>Arc Macro Language</td>
<td>• Vehicle Routing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Transportation Analysis and Planning</td>
</tr>
<tr>
<td>Network Analyst for ARCView® (ESRI)</td>
<td>Extension</td>
<td>Avenue Scripts</td>
<td>• Find Best Route</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Find Closest Facility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Site Selection</td>
</tr>
<tr>
<td>TransCAD® (Caliper)</td>
<td>Integrated</td>
<td>(GISDK) GIS Developer’s Kit</td>
<td>• Network Analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Transportation Planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Vehicle Routing Planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Logistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Built-in Methods and Models</td>
</tr>
<tr>
<td>NETENGINE (ESRI)</td>
<td>Access through C, API, or via type library</td>
<td></td>
<td>• Path Finding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Facility Connection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Trace Network Topology</td>
</tr>
<tr>
<td>MGE Network® (Intergraph)</td>
<td>Components</td>
<td></td>
<td>• Network Configuration Creation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Routing, Allocation and Tracing</td>
</tr>
</tbody>
</table>

Source: Various vendor catalogs

ArcInfo and ArcView have set the standard for GIS functionality for a number of years. ArcInfo is a high-end GIS with tools for automation, modification, management, analysis, and display of geographic information. ArcView GIS is the most popular desktop mapping and GIS software. However, to build on core functionality, various extensions are required.

ARC NETWORK is used to model and analyze spatial networks in the ArcInfo environment such as vehicle routing, transportation analysis and planning, urban planning, retail marketing, school districting, bus routing, shipping and delivery optimization, and political redistricting.

ArcView’s Network Analyst enables to solve a variety of problems using geographic networks (i.e., streets, highways, rivers, pipelines, electric lines, etc.) such as finding the most efficient travel route, generating travel directions, finding the closest facility, or defining service areas based on travel time.
TransCAD is specifically designed for transportation applications. TransCAD combines GIS and transportation modeling capabilities in a single integrated platform, and its custom application development tool kit (GISDK) is easier to learn and implement, compared to the other leading packages. Of particular interest, are TransCAD’s “shortest path” routines, which generate the shortest, fastest, or least-costly route between any number of origins and any number of destinations, with any number of intermediate points, via network models.

TransCAD has been used in the past in a number of research projects for the development of specific transportation applications. A list of these are included in table 4.2.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Application topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banninga et al [1999]</td>
<td>Michigan’s statewide travel demand model</td>
</tr>
<tr>
<td>De Oliveira and Loureiro [1999]</td>
<td>GIS database/interface for urban traffic management in Brazil</td>
</tr>
<tr>
<td>Alam and Fekpe [1998]</td>
<td>Integration techniques to analyze freight-flow characteristics of I90-I94 corridor</td>
</tr>
<tr>
<td>Hartgen and Kim [1998]</td>
<td>Determine network access and local trade areas for commercial development at rural and small-town Interstate exits</td>
</tr>
<tr>
<td>Krishnan and Lancock [1998]</td>
<td>Distribution and assignment of freight flows</td>
</tr>
<tr>
<td>Leroux et al [1998]</td>
<td>Modeling and simulation for optimal route evaluation and computation of travel times for individual trips</td>
</tr>
</tbody>
</table>

Other GIS software packages are available, however, there are limitations as to the built-in tools and transportation analysis capabilities.

4.3 Required GIS Components for a Routing System.

To develop a GIS-based automated routing system that is capable of identifying and evaluating routes for special size and weight vehicles in the southern border of Texas, the following basic components are required:

1) A Road network model representing the On-system roads containing at least a classification of highways (e.g. Interstate highways, State highways, Farm to Market roads, etc.) and their corresponding designations. Other desired features include directions of travel and road mileage, preferably in database format;

2) A Bridge database with a comprehensive series of attributes such as bridge identification tags, geographic coordinates, number of spans, span lengths, design ratings;

3) A Route Evaluation model that accounts for avoidance of physical constraints and load-bearing criteria, and

4) A GIS software suitable for transportation modeling.

The sources of information should be readily available in widely used formats.
4.3.1 Road Maps

A transportation network model that accurately represents the actual highway system can be generated from a collection of digitized maps that contain the highways and access roads for the geographic region under consideration.

A vast number of digitized maps can be obtained from several sources. The available digitized maps for the Texas' highways have originated from two sources:
1) the Texas Department of Transportation,
2) the United States Geological Survey (USGS), and
3) the US Census Bureau.
These digitized maps are available in the public domain and have been modified by organizations and private companies to satisfy particular needs.

The TxDOT maps were developed to keep an accurate record of the actual roads in Texas. All geographic features are layered in 63 levels. The TxDOT County/Urban base maps contain greater road details such as interchanges, divided roads, frontage roads, exit ramps, etc. The symbols representing the location of bridges are also included in a specific layer. The maps are in Intergraph’s DGN format. Road designations are available as text annotation.

The USGS files do not contain this level of details. For example, complicated interchanges are modeled by a simple intersection. Since the routing is focused on identifying all potential bridges to be crossed by overweight vehicles, bridge locations at interchanges need to be accurate as a function of the path within the interchange.

The USGS files have the main advantage that databases do exist for them. However, these databases typically include very limited information. For example, some databases include functional classification of the roads but using definitions inconsistent with TxDOT’s road classification. The USGS files have the following disadvantages:
1) Divided highways may not include two separate roads
2) Actual details of interchanges and intersections are lacking or inaccurate
3) No details on the frontage roads, and no exit ramps
4) No indication of bridge locations.

The US Census Bureau makes available its TIGER files (Topologically Integrated Graphical Encoding and Referencing System), which contain extensive data regarding population makeup.

The conversion of digital data from existing formats is frequently employed, however, several difficulties may be encountered. A list of problems associated with TxDOT’s maps, are listed in section 5.2.1.
4.3.2 Road and Bridge Databases

In a similar fashion, a collection of information about the highway and bridge system, such as number of lanes, directions of travel, bridge locations and their geometric and structural characteristics, in database format, may be suitable to facilitate the access of detailed information that will complement any evaluation criteria that may be used.

During the survey, several road databases were found currently available. Most of these databases consist of attributes to digitized maps based on the USGS maps. Literally every company that sells GIS software provides digitized maps with a limited road database. Typically, these databases include the names of the road or highway and some sort of highway/urban/rural classification. At the time of this survey, no road database associated to TxDOT's digitized maps was available for Texas, containing the desired attribute information.

The TxDOT maintains a computerized file that contains a record for each bridge on public roadways in Texas. The database is maintained under the Bridge Inventory, Inspection, and Appraisal Program (a.k.a. BRINSAP). This bridge database complies with the National Bridge Inspection Standards, issued by the Federal Highway Administration. BRINSAP is available in MSAccess format, and consists of two tables: the On-system bridge table and the Off-system bridge table. These tables contain about 200 different attributes including the longitude and latitude coordinates, which are critical for proper mapping in a GIS application.

Based on previous experience, BRINSAP was found suitable for use in the development of a routing application, since all On-system bridges are contained.

Some of the bridge attributes, available in BRINSAP, that are required for use in the available bridge evaluation models include:

- Bridge structure number
- Minimum vertical clearance (Underneath and Overhead)
- Total horizontal clearance
- Load posting (operational status)
- Number of bridge spans
- Bridge type (simple or continuous)
- Design bridge rating (HX/HSX operating rating)
- Total bridge length
- Length of largest span

Other bridge attributes that may be useful when developing the routing application, in addition to the geographic coordinates, may include:

- Feature crossed
- Facility carried over (highway designation)
- Directions of travel
- Function of structure facility (overpass / underpass structure)
- Number of lanes on the structure
- Number of lanes under the structure
4.4 Selected Resources

Based on the available resources for building a GIS-based routing system, the final selections for the development of the automated routing system for overweight/oversize vehicles for the southern border region in Texas, include:

1) **TxDOT’s official digitized County/Urban maps** available from the Mapping Office of the Transportation Planning and Programming Division (TPP). The primary reason for selecting these drawings was the completeness and comprehensive amount of details, containing the geometric characteristics of overpasses, underpasses, interchanges and exit ramps needed to perform a comprehensive and detailed routing analysis through the On-system roads. **An associated road database is not available at this time.**

2) **TxDOT’s BRINSAP bridge database**. BRINSAP is the only bridge database available with sufficient bridge geometry data, including the geographic locations in world coordinates format. The database is available in MS Access format.

3) The current basic permitting rules and regulations for movement of oversize/overweight loads set forth by the Texas Administrative Code, including legal sizes and axle weight limits, may be incorporated as part of the route evaluation model. When the regulatory criteria is not met, then use the **Bridge Load Formulae** developed at TTI as an alternative.

4) **TransCAD® Transportation GIS software** was selected for its capabilities to handle numerous vehicle routing procedures.

In addition, a high performance computer is required to develop and run the application smoothly and quickly.
CHAPTER 5
GIS-BASED ROUTING APPLICATION DEVELOPMENT

5.1 Introduction

In an effort to facilitate the process of evaluating feasible routes for OW/OS vehicles, and to minimize time and manpower resources, without compromising safety nor efficiency, a GIS-based automated system has been devised to aid in the selection of routes, that integrates several components, and infrastructure evaluation methodologies. Previous chapters have addressed commercially available geographic data sets, GIS software with routing capabilities, and route evaluation criteria. This chapter describes the development of the routing application, including the problems encountered and solutions provided during the preparation of the network for routing. The chapter also addresses the integration of GIS software, maps, databases, and evaluation algorithms through a customized interface.

5.2 Network Preparation for Routing

Two critical factors need to be addressed when preparing a road network for routing [Osegueda, 1997]:

a) to have an accurate road network model that includes traffic flow directions, and

b) to accurately account for the correct bridge along a route at its correct location.

After this is accomplished, each bridge should be attributed to its corresponding overpass or underpass road segment for proper identification during route selection and evaluation.

The routing application requires two GIS layer systems. One system consists of a “line” layer representing the On-System highway roads for the specified geographic region and a “point” layer representing the corresponding locations of the On-System bridge structures. The conversion of the selected geographic data components (described in section 4.4) into geographic layer systems is described in the following paragraphs.

The On-System highway roads GIS layer was generated by importing the highway features contained in TxDOT’ official County/Urban digitized maps, into TransCAD. These maps contain all geographic features, organized and collected in several layers. The maps are developed using Intergraph Microstation software (DGN format). TransCAD’s add-in utility macro (“Import Intergraph DGN Files”) was used to select the appropriate layers containing the On-system roads, and automatically convert the corresponding drawing elements into a “line” GIS layer. The 1927 North American Datum (NAD27) coordinate system and the Texas DOT statewide mapping zone, were specified to account for proper spatial geo-reference. The layer system is referred as the “On-System County ROADS GIS”.

Since no database attributes are associated to these maps, such as highway designation or directions of travel, these are not present in the roads’ GIS.
In addition, TxDOT base maps are digitized, containing only drawing elements; therefore, the County ROADS GIS does not consist of a network model. A series of corrective measures are required to prepare the highway network for routing. These measures are addressed in section 5.2.2.

In a similar fashion, different “line” GIS layers may be generated for bridge symbols, railroads, streets and other geographic features represented by line segments, which can optionally be used for spatial reference.

TransCAD automatically maps world --latitude and longitude-- coordinates (in decimal-degree format) by generating a “point” GIS layer that represents locations on the surface of the earth. BRINSAP contains the geographic coordinates of each bridge record in degrees-minutes format. A conversion algorithm, implemented into a macro, is required to change world coordinates in degrees-minutes to decimal-degrees. BRINSAP’s native format is in MSAccess; TransCAD supports a number of database formats (e.g. dBase, comma-delimited and fixed-format text); therefore, it was decided to export BRINSAP’s entire On-system bridge table (BRGON) to dBase format, since this is a widely used format.

The newly exported bridge table required a few structure modifications to facilitate its use in TransCAD. Proper identification of BRINSAP field names, coordinate recognition and relational information from the ROADS GIS layer, was required. The preparation of the bridge database for routing is described in section 5.2.2.

After generating the “On-System County BRINSAP GIS” layer, the different County GIS layers (ROADS, BRINSAP, bridge symbols, streets, etc.) were super-imposed and the relative locations of the bridges to the other geographic features were compared, and resulted in the identification of a few problems with the bridge coordinates. A brief overview of the problems encountered and their corresponding solutions are addressed in the following sections.

5.2.1 Geographic Data and Database Problems

The problems identified with the geographic datasets and databases selected for the routing application, are classified into three global categories, which are summarized in the following paragraphs.

**Drawing Problems:**
The TxDOT drawing maps contain several problems associated with the connectivity of the highway segments including duplication of lines, and line disconnectivity at intersections (undershoots, overshoots and crossover) (see Figure 5.1). These problems were identified once the features were imported into TransCAD.

Furthermore, these map files contain errors in the content of the layers. For instance, occasional bridge symbols are missing, or misallocated within different layers in the County/Urban maps; a similar situation was encountered for a few road segments.
The presence of “centerlines” for divided highways also represents a traffic flow problem, since TransCAD may select the centerline as the “shortest path”. Moreover, since no road database is associated to these files, highway names and directions of travel for one-way roads are not available. Therefore, the “County ROADS GIS“ layer required significant amount of processing to convert it into a network model.

**Database Problems:**
When the different GIS layers are super-imposed in TransCAD, the “County BRINSAP GIS” bridge layer exhibits bridge-location problems, due to incorrect/offset geographic coordinates and/or missing coordinates (see Figure 5.2). BRINSAP was further explored for completeness of information, and as a result, occasional missing bridge attributes (e.g. span lengths, ratings, etc.) were observed for some records. These problems were carried over during the conversion to GIS format.

In addition, the BRINSAP database suffers modifications, in structure format only, during the conversion to dBase format. These modifications include truncated field names, and field-width resizing. Some cell-contents were truncated, and immediate identification of the header names was not possible.

Figure 5.3 depicts the On-system bridge table in the BRINSAP database, in native MSAccess format.
Figure 5.2. Problems with Bridge Coordinates: Original Location vs. Correct Location.

Figure 5.3. BRINSAP Database: On-System Bridge Table.
5.2.2 Corrective Measures

As mentioned above, several problems were encountered during the preparation of the network for routing. This section addresses the corrective measures applied accordingly, to prepare the highway and bridge GIS layers for routing analysis.

Preparation of Roads for routing
The ROADS GIS layer is not a network model itself; it contains several connectivity problems and missing highway attributes that impede proper routing analysis. Five customized macros were developed to address the correction of these problems. The sequence of application and a brief description of each macro are illustrated in Figure 5.4. These macros will semi-automatically allow the correction of connectivity problems, the assignation of missing attributes, and the definition of underpass/overpass intersections.

Several fields were added to be populated by specific attribute information such as:

a) the direction of travel under HEADING (e.g. NB, WB, etc.);  "tipo de via"

b) the highway designation under HIGHWAY_ID (e.g. IH0010);  "id de carretera"

c) the state enumeration under STATEFIPS (following the Federal Information Processing Standards, e.g. 48 for the State of Texas); and  "código de estado"

d) a “unique” road segment identification-number under CTYRDID. The later consists of an eleven-digit code that contains: the District number in the first two digits, the county number in three digits, and a unique six digit sequential number (e.g. 24-072-010000).  "código de sección de carretera"

After applying the Compare, Fixend, Assign_id, Assign_dir and Intersec macros, and deleting the centerlines for divided highways, the County ROADS GIS layer is considered ready for routing. However, a network model cannot be generated until the bridges are attributed to their corresponding road segment. Four relational fields were also added to the ROADS GIS (namely BRGOP1, BRGOP2, BRGUP1, and BRGUP2), where the corresponding bridge structure numbers will be placed (e.g. 270720255203032). Two fields are allocated for overpass bridges, and two for underpass bridges.

Preparation of BRINSAP for routing
To account for the proper identification of bridges during a route analysis, the location of each bridge needs to be verified and corrected, if necessary. Since BRINSAP contains geographic coordinates in degrees-minutes format, two fields are added to the BRINSAP GIS layer, LATITUDE1 and LONGITUDE1, where the converted coordinates to decimal degrees format, will be saved.

In addition, four relational fields are added to the BRINSAP GIS, namely CTYRDOP1, CTYRDOP2, CTYRDUP1, and CTYRDUP2, where the corresponding CTYRDID numbers will be attributed to each bridge record. Two fields are allocated for highway links that cross the bridges over them, and two for highway links that cross the bridges underneath them. During the conversion of BRINSAP to dBase format, some field names are truncated as the field width is also reduced compared to the original in MSAccess. A standardization of names and widths was made to avoid problems when accessing/retrieving bridge information for rapid evaluation of clearances and weight capacity. The sequence of these procedures is illustrated in Figure 5.5.
Figure 5.4. Preparation of ROADS GIS for Routing.

1. **Import**
   - Intergraph DGN Files macro
   - On-System County ROADS GIS map

2. **Compare**
   - Macro
   - Checks for repeated links and allows user to interactively remove them

3. **Fixend**
   - Macro
   - Corrects connectivity problems.

4. **Assign_id**
   - Macro
   - Used to interactively assign Highway_ID attribute to links

5. **Assign_dir**
   - Macro
   - Used to interactively assign traffic direction attributes to one-way roads and divided highways

6. **Intersec**
   - Macro
   - Used to interactively define Overpasses/Underpasses in intersections

7. **Delete “Centerlines”**

8. **Add fields (HWY_ID, HEADING, CTYRDID, STATEFIPS, BRGOP1, BRGOP2, BRGUP1, BRGUP2)**

9. **Add “bridge symbols” layer**

10. **Fill fields (CTYRDID, COUNTY_NO, STATEFIPS)**

11. **County ROADS GIS map, prepared for routing**

---

**RAW TEXT:**

5-6

- County/Urban digitized maps
- On-System County ROADS GIS map
- Import Intergraph DGN Files macro
- On-System County ROADS GIS map
- Compare macro
- Checks for repeated links and allows user to interactively remove them
- Fixend macro
- Corrects connectivity problems.
- Assign_id macro
- Used to interactively assign Highway_ID attribute to links
- Assign_dir macro
- Used to interactively assign traffic direction attributes to one-way roads and divided highways
- Intersec macro
- Used to interactively define Overpasses/Underpasses in intersections
- Delete “Centerlines”
- Add fields (HWY_ID, HEADING, CTYRDID, STATEFIPS, BRGOP1, BRGOP2, BRGUP1, BRGUP2)
- Add “bridge symbols” layer
- Fill fields (CTYRDID, COUNTY_NO, STATEFIPS)

**Figure 5.4. Preparation of ROADS GIS for Routing.**
Figure 5.5. Preparation of BRINSAP GIS for Routing.
The verification of each bridge location was accomplished by super-imposing the different County GIS layers (ROADS, BRINSAP, bridge symbols, streets, etc.) and comparing the relative location of the bridges to the other geographic features.
To appropriately locate a bridge record, the location description information in the BRINSAP database was cross-referenced and compared with the information in the County/Urban maps.

The bridge location information fields are listed in table 5.1 as follows:

**Table 5.1. BRINSAP Fields with Location Information.**

<table>
<thead>
<tr>
<th>BRINSAP field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F9LOCATION</td>
<td>Descriptive location information: w/respect to a point of reference</td>
</tr>
<tr>
<td>F6_1FEATXE</td>
<td>Feature crossed: creek, street, etc.</td>
</tr>
<tr>
<td>F7FACCARRD</td>
<td>Facility carried: traveled highway</td>
</tr>
<tr>
<td>F5_5RTDIR</td>
<td>Direction of travel</td>
</tr>
<tr>
<td>F5_1RTSTRF</td>
<td>Structure function: overpass or underpass</td>
</tr>
<tr>
<td>F11MILEPNT</td>
<td>Mile point</td>
</tr>
<tr>
<td>F28_1LANON</td>
<td>Number of lanes on the structure</td>
</tr>
<tr>
<td>F28_2LANUN</td>
<td>Number of lanes under the structure</td>
</tr>
</tbody>
</table>

The location of nine hundred and thirty-nine (939) bridges was verified for El Paso District. Table 5.2 shows the number of On-system bridges in each county of the District.

**Table 5.2. Number of On-system Bridges per County in El Paso District.**

<table>
<thead>
<tr>
<th>County name</th>
<th>County number</th>
<th>Number of bridges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewster</td>
<td>022</td>
<td>91</td>
</tr>
<tr>
<td>Culbertson</td>
<td>055</td>
<td>134</td>
</tr>
<tr>
<td>El Paso</td>
<td>072</td>
<td>390</td>
</tr>
<tr>
<td>Hudspeth</td>
<td>116</td>
<td>124</td>
</tr>
<tr>
<td>Jeff Davis</td>
<td>123</td>
<td>127</td>
</tr>
<tr>
<td>Presidio</td>
<td>189</td>
<td>73</td>
</tr>
</tbody>
</table>
5.2.3 **District Network Model**

Once the ROADS GIS and BRINSAP GIS have been prepared for routing, the last phase before creating a District network model consists of:

a) linking both layer by means of relational fields;

b) merging similar geographies into a single District-wide system; and

c) verifying/ensuring connectivity among the counties at their boundaries.

Both the ROADS and BRINSAP GIS tabular files have fields that were added, to share the same data for a common item, thus enabling the ability to access attribute data during the route search/evaluation process. Such common data includes a “unique” road-segment identification number (under the CTYRDID field in ROADS) and the “individual” bridge structure number (under the F0000_STRI in BRINSAP).

This common item in both GIS tables is the relational field that links them together. The bridge structure numbers were attributed to the corresponding road segment records using the customized macro *Brinsap2Roads*, specifically designed for this purpose (F0000_STRI to the BRGOP1….BRGUP2 fields in ROADS). In a parallel manner, the unique ID code of each road segment is attributed to the corresponding bridge record (CTYRDID to the CTYRDOP1…CTYRDU0P2 fields in BRINSAP).

After creating the relational ROADS-BRINSAP database for each County in El Paso District, the County geography systems for ROADS and BRINSAP were merged into single District GIS layers, respectively. The merge to a district-wide coverage was accomplished using customized macros (mergep and mergel) that semi-automatically merge “point” and “line” geographies, respectively. This resulted in a “**Final District ROADS GIS**” and a “**Final District BRINSAP GIS**” layer.

To ensure connectivity among the individual counties in the “**Final District ROADS GIS**”, the Fixend macro was employed. Then, a District Network Model was created using TransCAD’s built-in utility, from the ROADS GIS layer. This highway network model is used, in conjunction with the **Final District (ROADS and BRINSAP)** geographic layers, to solve the routing problem. The above procedures are depicted in Figure 5.6.

Figure 5.7 depicts the final El Paso District map created in TransCAD. The map contains three layers: ROADS (w/corresponding Endpoints), BRINSAP and Political County Boundaries. The right-hand side shows a view of the attribute information for the selected record, retrieved from the most commonly used bridge fields contained in BRINSAP.
Figure 5.6. Creation of Relational Database and District Network Model.
Figure 5.7. El Paso District Map and Bridge Information for Selected Record.
5.3 Routing Application Interface: Key Components

The previous sections describe the problems and corrective measures applied to the selected resources to develop the routing system. After making the corresponding preparations of the geographic data for routing, all GIS components and routing methodology are organized and arranged in a natural and logical sequence, to facilitate the proper execution of the routing application.

The geographic data is organized in a District GIS map, and the routing methodology is integrated in a Routing Program as illustrated in Figure 5.8.

The District GIS map requires two layers:
   a) the ROADS layer with its corresponding Endpoints layer, and
   b) the BRINSAP layer.
Optional layers may be included for spatial reference only, such as the “streets” and “bridge symbols” layers.

The Routing Program consists of an interface that allows:
   a) the selection of a highway network model (generated from the ROADS layer);
   b) the definition of the location of the path points in the map (using the Endpoints layer);
   c) the definition of legal limits for the corresponding Jurisdiction (e.g. Texas); and
   d) the definition of the vehicle description

   to search for an adequate route that meets clearance and load-carrying capacity restrictions.

This interface is encoded in a macro file (entitled OVR.rsc) that uses Caliper’s GISDK programming language [Caliper, 1996].

For practical purposes, the entire application is organized under a specific folder structure under the selected installation path. Each folder contains all files related to a specific GIS layer (e.g. ROADS, BRINSAP, etc.) or data description file (e.g. vehicle description or jurisdiction limits). For example, all files related to the ROADS GIS layer are located under (<installation path>/roads/xxx.xxx); vehicle description files are under (<installation path>/veh_lib/PGT.veh), etc.

The OVR program should always be located directly under the installation directory (e.g. C:/D24 or D:/Texas, etc.).
Figure 5.8. Overweight/Oversize Vehicle Routing Application: Key Components.
5.3.1 Main Toolbox

The entire routing evaluation process is executed from a customized toolbox that interfaces and integrates TransCAD’s shortest path algorithm and a few editing capabilities. The “Overweight/Oversize Vehicle Routing” toolbox (see Figure 5.9) includes several buttons and tool items logically arranged and grouped to facilitate the flow of execution.

![Figure 5.9. OVR Program: Main Toolbox.](image1)

Clicking the upper button of the toolbox, opens a dialog box that allows general project information definition (see Figure 5.10).

![Figure 5.10. OVR Program: Project Information Dialog Box.](image2)
The network file, the routing algorithm, the State or Jurisdiction file (from which the legal limits are to be retrieved for comparison), and an impact factor associated to the BLF (see Chapter 3), are selected using buttons, radio buttons, or scroll lists located on the left-hand side of the toolbox.

On the upper right-hand side, an arrangement of three buttons that allow vehicle information definition (entering, editing and saving data) are grouped together. Two dialog boxes are accessed when defining vehicle information. First, general descriptive information and overall height, width and total number of axles is defined in the “Initial Data” dialog box (see Figure 5.11).

![Figure 5.11. OVR Program: Initial Vehicle Data Dialog Box.](image)

This dialog box is followed by a series of dialog boxes that allow the definition of specific axle information for each axle in the vehicle (see Figure 5.12).

![Figure 5.12. OVR Program: Axle Information Dialog Box.](image)
In a similar fashion, buttons that enable/disable the selection of path points are grouped beneath the “Vehicle Data” group. These buttons allow the selection of the Origin and Destination points, by clicking directly over the endpoints of the line segments on the map. In addition, any number of intermediate points may also be selected.

The bottom-half of the OVR toolbox has two buttons and a panel. One button starts the route search, and the other opens the on-line help file. The panel displays the different files selected during a typical run.

The OVR macro resource file is an ordinary text file with extension rsc, containing the scripting GISDK code. This code must be compiled before running it. A resource file may be compiled using the buttons in the GISDK toolbox (see Caliper, 1996).

5.3.2 Steps to Solve a Routing Problem

When the OVR toolbox is launched, the program locates the different files required for proper execution, program variables are initialized, and the map is prepared for routing. The OVR program always identifies the current path of installation to facilitate the location of the different program files (e.g. the network file, the vehicle libraries, the help files or the output reports).

The solution to the routing problem for overweight/oversize vehicles consists of seven basic steps, using the customized toolbox:
1. Select a network model that corresponds to the geographic region in the map.
2. Select a jurisdiction under which the legal limits will be checked against (default is Texas).
3. Select a tire pressure (or use default) for the selected jurisdiction.
4. Select the desired impact factor (required to select the appropriate BLF factors).
5. Define the vehicle, providing overall size and axle configuration.
6. Define the location of the path points.
7. Start the route search and wait for the program to report the search results.

The adequacy of a proposed route is checked based on the criteria described in section 3.4. The default routing algorithm is the “Shortest Path” included in TransCAD.

5.3.3 Route Search Solution: Graphical Result and Written Report

When the routing macro ends the route searching process, two possible outcomes may be expected:
1. An adequate route was found meeting all constraints and load-carrying capacity, or
2. A route was NOT found for the specified vehicle and origin-destination locations.

After a successful search, the final route is highlighted on the map with a thick annotation line.
As the program identifies inadequate bridges along the proposed routes and disables their corresponding links from the network, those links are stored in different “sets” that are highlighted on the map with different colors. Each set has a different name and color associated indicating the specific constraint not satisfied.

When the routing macro finishes the route searching process, a final report is automatically generated under the `<installation directory>/reports` folder. NOTEPAD or WORDPAD launches automatically to view the output report on the screen.

The report consists of five main sections:
1. Executive Project Information
2. Vehicle Description
3. Jurisdiction Rules and Regulations
4. Route Description
5. List of road links disabled from the network and attributed bridges avoided due to different constraints:
   - Vertical clearance restriction
   - Horizontal width constraint
   - Load posting constraints
   - Missing information in BRINSAP database
   - Limited load-carrying capacity

Each section contains additional detailed information pertinent to the case under study, if necessary.

**5.4 Sample Run and Limitations**

This section presents an example of a simple route search for a hypothetical vehicle traveling in the El Paso District highway system. Points of origin and destination are randomly selected. Several default values are kept for simplicity of execution.

Vehicle Description

<table>
<thead>
<tr>
<th>Axle Dist.prev.axl(ft)</th>
<th>Weight/axl(kips)</th>
<th>No.Tires Gage(ft)</th>
<th>Tire_Width(in)</th>
<th>Tire_Pressure(lb/in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>00.000</td>
<td>14.000</td>
<td>2</td>
<td>06.500</td>
</tr>
<tr>
<td>02</td>
<td>16.000</td>
<td>23.000</td>
<td>4</td>
<td>06.500</td>
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<tr>
<td>03</td>
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<tr>
<td>11</td>
<td>05.250</td>
<td>34.000</td>
<td>8</td>
<td>06.500</td>
</tr>
</tbody>
</table>

End of Vehicle Description
Jurisdiction Rules and Regulations

Jurisdiction state name : Texas
Legal height (ft | in) : 14 | 06 --> Satisfied
Legal width (ft | in) : 08 | 06 --> NOT Satisfied
Legal Tire Pressure : 0650.000 lb/in --> Satisfied
Max. allow. group wt.:                         --> NOT Satisfied

Bridge Evaluation Criteria
Bridge Load Formula
Impact Factor: 10 %

End of Jurisdiction Rules and Regulations

Route Description

Geographic Coordinates (Degrees)               on Road Link(s)                Highway ID
Longitude     Latitude                (ID 1)             (ID 2)               (1)         (2)
Origin -105.200573 031.747104     24116010646   24116010645   US0062  FM1437
Destination -105.074824 031.745175     24116010652   24116010651   US0062  FM1576

Proposed Route:
Start            North  on  FM1437    13.20 Miles   (13.20 Miles).
Turn Right  East    on  FM2249      3.08 Miles   (16.28 Miles).
Turn Right  South on  FM1576    17.34 Miles   (33.62 Miles).

Total number of routes tested before final result = 2
End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance
Total number of bridges evaluated for vertical clearance = 3
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance

Links disabled and Bridges avoided due to limited horizontal width clearance
Total number of bridges evaluated for horizontal width = 3
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width

Links disabled and Bridges avoided due to load posting
Total number of bridges evaluated for load posting = 3
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity
Total number of bridges evaluated for load-carrying capacity = 2
CountyRDID      Hway  Heading          BridgeID
24116010652   US0062       --         241160037407009

Allow. GW(kips) Actual GW(kips) Axls/Grp  1st Grp Axle   BLF not met
153.914          170.000       005        004   General
Total number of bridges avoided due to BLF General = 1
Total number of bridges avoided due to BLF Specific = 0
End of links disabled and bridges avoided due to limited load-carrying capacity

5-18
Vehicle configuration and dimensions were compared against the jurisdiction legal limits, the result being that the width and axle group weights exceeded the maximums. A description of the location of the origin and destination points is included based on geographic coordinates, unique road link identification numbers, and highway designation of the intersecting streets. The program found a route after two trials. On the first trial route, a bridge with insufficient load-carrying capacity was encountered. The program reports avoiding such a bridge and disabling the corresponding road segment from the network. A second route was tested and all the criteria passed.

Figure 5.13 depicts the graphical solution for the sample case described above.

![Path Search: Graphical Solution](image)

The OVR routing application has a few limitations:
1) Only On-system jurisdiction roads and bridges are included. City streets and city bridges are under the Off-system jurisdiction.
2) Total vehicle length is not required as input, since turn radii is not available for turns.
3) Number of lanes are not available in the ROADS database.
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CHAPTER 6

CASE STUDIES

6.1 Introduction

This chapter describes three case studies, including an actual permit vehicle and two hypothetical cases, using the routing program developed for this project and described in Chapter 5. The case studies were evaluated under the Texas jurisdiction regulations, including the legal weight limits, specified under the Texas Administrative Code, and the Bridge Load Formula described in Chapter 4.

The first case study compares the results from the program with the authorized route of an actual travel permit request of a vehicle carrying a heavy load within the El Paso District. The second case examines a few routes for a hypothetical five-axle truck (3S2) that crosses the Mexico-US border on a daily basis. Tandem axle weights were attributed to the trailer, based on loads measured from vehicles crossing the southern border. Finally, a route evaluation analysis of a three-axle concrete-mix delivery truck was performed, since these vehicles are permitted to operate at a higher tandem axle load than conventional trucks and induce greater damage to pavements.

Copies of facsimile documents (courtesy of TxDOT’s MCD) as well as the routing reports generated by the program are found in Appendix A. Report formats slightly vary between case studies due to the continuous improvements made to the routing program.

6.2 Case Study 1: Overweight Vehicle in El Paso

The MCD provided UTEP with a permit request made to move an eleven-axle tractor-trailer hauling an injection-molding machine in El Paso, Texas. The load was 10 ft. wide, 13 ft. 6 in. high, with a gross vehicle weight (GVW) of 332 kips. (over 150 metric tons). The size and weight of the load exceed the legal limits. The original facsimile document is depicted in several figures in Appendix A of this report.

6.2.1 Vehicle Data.

Figure A1 (see Appendix A) shows a portion of the route inspection form, where a general description of the overweight vehicle is given along with a description of the actual route authorized for the move. A diagram of the load and transport vehicle is depicted on Figures A2 and A3, showing the dimensions and axle configuration of the vehicle and with two tables containing descriptive weight information. The diagrams have been reproduced in Figures 6.1 and 6.2 for clarity purposes.

Table information in Figure A2 is not very clear. After close examination of the table contents and deciphering most weight information, a few discrepancies were noticed in the vehicle configuration, as well as on the overall dimensions. Other information was not explicitly available or difficult to determine, such as the number of tires per axle. Several attempts were made to request MCD to resubmit the information, with no avail. The
requestor company [McGavick, 2000] was also contacted, however, the information was already off their records.

Figure 6.1 El Paso Overweight Permit Vehicle. Lateral View.

Weight discrepancies were adjusted to meet the total reported gross vehicle weight of 332,000 lbs. Gage distances and tire widths per axle are required for evaluation of bridge load-capacity using the BLF (see section 3.2.4).

The gage of the trailer section was determined from the information in the vehicle’s back view, considering that the gage is the distance from center of gravity (C.G.) to C.G. of the tire groups on each side of the axle (see Figure 6.2). The resulting gage (6’-6”) was assumed uniform throughout the entire vehicle, including the three tractor axles.

Figure 6.2 El Paso Overweight Permit Vehicle. Back View.

Considering the reported axle weights and tire loads, tire widths were determined assuming that the legal tire pressure limit of 650 lbs/in is met. After rounding off, the tractor’s steering and rear axle tire widths resulted in twelve (12) inches, while the trailer’s resulted in eight (8) inches. These tire widths were assumed uniform throughout each axle.
6.2.2 **Origin and Destination of Travel.**

Figures 6.3 and 6.4 depict the location of the points of origin and destination for the move of the overweight vehicle according to the MCD report. The path points were defined selecting the nearest endpoints to the intersections.

**Figure 6.3 Point of Origin. Loop 375 and Fonseca Intersection.**

**Figure 6.4 Point of Destination. Loop 375 and Zaragosa Intersection.**
6.2.3 Authorized Route by TxDOT’s MCD

The authorized route for the overweight move, described in the route inspection form (Figure A1), is graphically reproduced in Figure 6.5 with the highlighted line. This figure shows all bridge structures along the authorized route, pointing out overpass bridge structure (240720255204027), which is reported as avoided at the intersection of Loop 375 and Riverside Dr.

![Figure 6.5 Graphic Representation of Authorized Route for Overweight Vehicle Move.](image)

The route inspection form includes a list of attributes for bridge (240720255204025) as depicted in Figure A4 (in Appendix A) for unknown reason.

Figure 6.6 illustrates a detail of the intersection at Loop 375 and Riverside Rd. The route inspection form does not document the reason for avoiding this overpass.
Figure 6.6 Avoided Intersection in Authorized Route for Overweight Vehicle Move.

The following paragraphs briefly discuss the various scenarios considered to reproduce the authorized route, and the results reported by the routing program.

6.2.4 Scenarios and Results

The vehicle input to the routing program can be summarized as follows:

Model : Injection Moulding Machine  
Type : PGT Trucking, Inc.  
Nominal Capacity: 332 kip  
Height (ft | in) : 13 | 6  
Width (ft | in) : 10 | 0  
Number of Axles : 11  
Impact factor : **variable**  

<table>
<thead>
<tr>
<th>Axle</th>
<th>Dist.prev.axl(ft)</th>
<th>Weight/axl(kips)</th>
<th>No.Tires</th>
<th>Gage(ft)</th>
<th>Tire_Width(in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
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<td>12</td>
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<td>034.000</td>
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<tr>
<td>07</td>
<td>05.250</td>
<td>034.000</td>
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<td>08</td>
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<td>034.000</td>
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<td>05.250</td>
<td>034.000</td>
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<td>06.500</td>
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</tr>
</tbody>
</table>
The routing program requires the selection of an impact factor to account for the velocity of travel of the vehicle, according to the BLF methodology. Since the vehicle’s speed during the move was not provided by MCD, all three options (0, 10 and 30%) were investigated. After providing descriptive vehicle information, specifying the location of the origin-destination pair, and selecting the impact factor for each scenario, the program executed and generated reports describing the outcome. These reports are included in Appendix A. Each report is about two pages long. The reports can be identified by a four-character title, which describes the specific scenario considered, e.g. 10al.txt. The first two characters describe the impact factor used (10% in this case); the last two characters correspond to a suffix that is explained later in this chapter.

The vehicle’s width and group axle weights do not satisfy the jurisdiction’s legal limits; therefore, additional load-carrying capacity assessment is required when crossing overpass bridges along the proposed routes. First, all structures crossed over or underneath are verified against vertical and horizontal clearance. After finding a route that satisfies the clearance criteria, the load-carrying capacity on overpasses is evaluated.

When a 0% impact factor is selected, no solution is found (see report 00al.txt). On the first trial, going south-eastbound on Loop375, the program encounters the first four-span overpass structure (240720255204019), which spans over a waste way, and determines by the “General” BLF, that the allowable axle group weight is limited by 52% for axle group (2-3). The program avoids this bridge by disabling the road link from the network. The program continues evaluating bridges along the first route, alternating between road links close to the origin, and links close to the destination in an inward manner towards the middle of the proposed route. The program then reports that structure (240720255204046) located at the intersection of Loop 375 and Padres Dr. is also limited for the same axle group (2-3) as before by 48% and therefore, is disabled.

Since the possibilities of traveling in the south direction are exhausted, the program searches for alternate routes in the north-westbound direction towards US54 (not depicted in the figures of this report). Two paths are considered, and two bridge structures (230720016704083 and 230720016704081) are encountered, and also found limited in load carrying capacity. After four trials, alternate routes are no longer found. An impact factor of 0%, assumes that an escort should have been assigned to the vehicle, and its speed limit reduced to less than 3 mph. However, MCD’s route inspection form does not mention this.

When selecting a 10% impact factor, the same four routes inspected in the 0% scenario, are tested in this scenario. Again, no solution is found (see report 10al.txt). On the first trial, going south-eastbound on Loop375, structure (240720255204025) at Midway Dr., is found deficient in load-carrying capacity by 4% for axle group (2-3-4-5-6-7-8-9-10-11), according to the “General” BLF. However, structure (240720255204019) is not reported at all, meaning it is structurally feasible. Then, structure (240720255204046) is reported as limited by the same percentage as the previous structure and for the same axle group. In the last two alternate routes heading northwest towards US54, bridge structures (230720016704083) and (230720016704081) are also found limited by the same conditions. Afterwards, the program is unable to find a connecting route.
Similarly, no route is found when an impact factor of 30% is selected (see report 30al.txt). Again, four routes are tested and the same bridge structures avoided in the 0% scenario, are avoided for this scenario. However, this scenario differs from the 0% one, in that bridge (240720255204019) is limited in load capacity by 2% for axle group (4-5-6-7-8) and (240720255204046) is limited by approximately 1% of the actual axle group weight for (4-5-6-7-8-9).

Therefore, the routing program was not able to reproduce the authorized route (as described in the route inspection form) under the BLF methodology.

Examining the description of the authorized permit route (depicted in Figure 6.5), the ONLY overpass structure bypassed is (240720255204027) located at Riverside, without an explanation. However, the routing program reports that bridge structures (240720255204019 and 240720255204025) are insufficient and the map does not show any alternate lateral road to bypass these structures (see Figure 6.7).

To explain this discrepancy in the route solutions, several issues were revised/considered:
1) First, the location of the bridges was verified once again, as well as the assignment of the bridge numbers to the corresponding road segments. No problems were found.
2) Second, the original County/Urban file drawings were re-examined to determine whether there were road segments allocated in different layers other than the ones imported into TransCAD. No problems were found.
3) Third, from the standpoint of the load-carrying capacity, the traditional structural analysis could have determined that bridge structure (240720255204019) had sufficient load-carrying capacity for the permit vehicle, while the BLF methodology is determining otherwise. This could be occurring, since the “General” BLF is known to give conservative results and in addition, these formulae were determined for long-span bridges, not culverts or short-span structures. The values assumed for the axle configuration parameters (axle gage and tire width) missing in the inspection form, are unlikely to have a significant contribution on lowering the calculated allowable capacity.
4) A final possibility, yet remote, is that during the actual route inspection performed by TxDOT, the evaluation of some bridge spans could have been omitted.
A localized evaluation of each bridge span along the route, using the “Specific” BLF, is recommended. However, BRINSAP does not provide all bridge span lengths.

### 6.2.5 A Closer Look

A summary of attributes of all the bridges along the authorized route is tabulated in Table A1 in Appendix A. These attributes were retrieved from the bridge database BRINSAP. The selected attributes describe bridge location, physical characteristics and ratings. The bridges are presented from left to right, in the order in which they are encountered in the authorized permit route, starting from Fonseca St. (origin) to Zaragoza Rd. (destination). All bridges have three or four spans, which according to the BLF methodology, the load-carrying capacity is evaluated with the “General” formula. In addition, it is observed that all bridges are rated as HS20 for the inventory rating. However, the BLF evaluates load-capacity using the operational rating, since it represents the absolute maximum permissible load that the bridge can safely carry.

A systematic study was conducted to determine the load-capacity of all the bridges along the authorized route, and determine their adequacy. This was accomplished by removing inadequate bridges from their corresponding road segments (simulating their non-existence in the network) to skip their evaluation, and thus allow the evaluation of the remaining bridges. The initial set of scenarios described in the previous section, did not exclude any bridges from the network.

In the following set of scenarios, bridge (240720255204019) was excluded first. Afterwards, both (240720255204019) and (240720255204025) were excluded, and so on so forth. The reports for these scenarios are also included in Appendix A. The titles include a two-character suffix that corresponds to the last two digits of the bridge identification number, of the last bridge excluded from the network. For example, (3025.txt) is the report where a 30% impact factor was used, when bridge structures (240720255204019) and (240720255204025) were simultaneously excluded from the network. As stated previously, when no bridges were excluded, the title suffix describes that all bridges were included in the network (e.g. 00al.txt).

For each impact factor scenario, the exclusion of bridges from the network was stopped once a route was found. Table 6.1 summarizes the results from the routing program for the different impact factor scenarios and different number of bridges in the network.

| Impact factor | 0%   & 10%   & 30%   |
|---------------|-------|-------|-------|
| Bridges along authorized route | Including All bridges | excluding 019 | also excluding 025 |
| Any route found? | No after 4 trials | No after 4 trials | Yes after 3 trials |

Table 6.1 Route Solutions for Various Scenarios.
The following observations are drawn from the final reports on each impact factor scenario:

a) for a 0% impact factor, all bridge structures (240720255204019, 240720255204025, 240720255204027 and 240720255204046) are limited by approximately 50% under the General formula for axle group (2-3).

b) for a 10% impact factor, bridge (240720255204019) seems to have sufficient load capacity. However, bridges (240720255204025, 240720255204027 and 240720255204046) are limited by 4.3% under the General formula for axle group (2-3-4-5-6-7-8-9-10-11). This axle group fits within the 50 and 90 feet spans of these bridges.

c) for a 30% impact factor, bridge structures (240720255204025, 240720255204027 and 240720255204046) are limited by approximately 1% under the General formula for axle group (4-5-6-7-8-9). Structure 240720255204019 is limited by approximately 2%.

For the first two bridges (240720255204019 and 240720255204025), there are no exit ramps or alternate side roadways that can be used to bypass the structures. However, for the last two bridges, exit ramps, alternate roadways and entrance ramps do exist, therefore, the overloaded vehicle can bypass them by rerouting (see Figure 6.8).

Figure 6.8 Inadequate Overpass Bridge Avoided by Selecting Alternate Road.

The following route description is an excerpt from report 3025.txt (see Appendix A) pointing out the portions of the route where the overpass bridges are bypassed.

<table>
<thead>
<tr>
<th>Start</th>
<th>East on FR</th>
<th>0.00 (0.00 Miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continue</td>
<td>East on ON-RAMP</td>
<td>0.22 (0.23 Miles)</td>
</tr>
<tr>
<td>Continue</td>
<td>East on LOOP375</td>
<td>3.96 (4.19 Miles)</td>
</tr>
<tr>
<td>Continue</td>
<td>East on OFF-RAM</td>
<td>0.16 (4.35 miles) Bypassing</td>
</tr>
<tr>
<td>Continue</td>
<td>East on FR</td>
<td>0.01 (4.36 Miles) 240720255204027</td>
</tr>
<tr>
<td>Continue</td>
<td>East on ON-RAMP</td>
<td>0.13 (4.49 Miles) at Riverside Dr.</td>
</tr>
<tr>
<td>Continue</td>
<td>East on LOOP375</td>
<td>1.49 (5.98 Miles)</td>
</tr>
<tr>
<td>Continue</td>
<td>South on OFF-RAM</td>
<td>0.34 (6.32 Miles) Bypassing</td>
</tr>
<tr>
<td>Continue</td>
<td>South on FR</td>
<td>0.01 (6.33 miles) 240720255204046</td>
</tr>
<tr>
<td>Continue</td>
<td>South on ON-RAMP</td>
<td>0.36 (6.69 Miles) at Padres Dr.</td>
</tr>
<tr>
<td>Continue</td>
<td>South on LOOP375</td>
<td>0.76 (7.45 Miles)</td>
</tr>
<tr>
<td>Continue</td>
<td>South on OFF-RAM</td>
<td>0.07 (7.52 Miles)</td>
</tr>
<tr>
<td>Continue</td>
<td>East on FR</td>
<td>0.12 (7.64 Miles)</td>
</tr>
</tbody>
</table>
6.3 Case Study 2: Commercial Five-Axle Tractor-Trailer Truck

A second case study was conducted with a typical five-axle commercial vehicle type 3S2 (three axle tractor with a tandem semi-trailer). The purpose was to examine current truck routes in El Paso District when such a vehicle is loaded over the legal weight limits. A thorough literature and Internet survey was conducted to search for published and/or unpublished trailer-truck standards, specifically on axle configurations, finding scattered and non-comprehensive truck data. In addition, several attempts were made at local warehouses and truck terminals, to request permission to take measurements of the trailers stationed at the time, resulting in negative responses and no cooperation in most cases.

Eventually, axle configurations of four five-axle 3S2 trucks were field-collected. However, tandem axle weights were obtained from a series of charts, found in King and Lee’s [1997] report, which plot cumulative frequency distribution for tandem axle loads observed during different seasons between 1995 and 1996, at the Zaragoza P.O.E. in El Paso, Texas Figure 6.9 illustrates a typical chart from the report.

![Figure 6.9 Frequency Distribution for Tandem Loads: NB Trucks in El Paso, Texas (after King and Lee, 1997).](image)

The charts show curves for trucks with the number of axles ranging from three to six. The curves for five-axle tractor tandems and five-axle trailer tandem were selected one at a time. Then, by arbitrarily choosing the cumulative 95% number of vehicles surveyed and intersecting with the horizontal axis, the corresponding observed tandem loads were determined. A forty-nine (49) kip tractor-tandem load and a forty-seven (47) kip trailer-tandem load were determined. The loads were assumed evenly distributed between the two axles. The report shows several similar charts for different seasons, and it can be observed that the loads appear to remain constant throughout the different survey periods.
The report does not discuss steering (front) axle loads, since the load rarely exceeds the allowable single-axle limit. However, the front-steering axle weights were found in the technical data sheets of a few truck manufacturers on their corresponding websites. Two representative front-axle weights are reported: twelve (12) and twenty (20) thousand pounds respectively (see Figures A5a and A5b in Appendix A). Both weights comply with Texas legal weights for individual axles, however, only the twelve (12) thousand-axle weight was chosen for analysis. The above data was combined to complete the vehicle information of two hypothetical trailer-trucks for the case study (see Kenworth/Kenmex model and EPCC model in Figures A6 and A7 of Appendix A, respectively).

A separate set of axle configurations and tandem weights were found documented in a technical report by Sanchez-Ruiz and Lee [1996]. This information was not combined with the other field or Internet data (see WIM Calibration model in Figure A8 of Appendix A).

Finally, the EPCC vehicle model (Figure A7) was chosen for all the route scenarios.

Six typical truck routes in El Paso District were selected, based on a study by CSA, Inc. [1996]. The Zaragoza P.O.E. is the place where the tandem loads (reported by Sanchez-Ruiz and Lee [1996]) were measured, therefore is considered as the official point of origin. In addition, two different points of origin were chosen to account for different routes. If deemed necessary, intermediate stops were defined to reproduce the selected routes as close as possible.

An impact factor of 30% was used for all route scenarios assuming no travel speed limit. The first route was also analyzed in a seventh scenario using a 10% impact factor to compare any differences in the final route with the first impact factor scenario. Appendix A includes the routing reports generated by the program for the EPCC vehicle traveling through these routes. The reports can be identified by a title that includes the prefix “3S2_”, followed by the route scenario number (1-6) and ends with a two digit number representing the impact factor used (10 or 30).

The following table shows the different truck route scenarios. The origin and destination location descriptions, as well as the corresponding report titles are tabulated.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Report title</th>
<th>Origin</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3S2_1_30.txt</td>
<td>Zaragoza Intl. Bridge</td>
<td>Dona Ana County, NM</td>
</tr>
<tr>
<td>2</td>
<td>3S2_2_30.txt</td>
<td>Zaragoza Intl. Bridge</td>
<td>Reeves County, TX</td>
</tr>
<tr>
<td>3</td>
<td>3S2_3_30.txt</td>
<td>Bridge Of The Americas</td>
<td>Otero County, TX</td>
</tr>
<tr>
<td>4</td>
<td>3S2_4_30.txt</td>
<td>Zaragoza Intl. Bridge</td>
<td>Eddy County, NM</td>
</tr>
<tr>
<td>5</td>
<td>3S2_5_30.txt</td>
<td>Zaragoza Intl. Bridge</td>
<td>US54-Transmountain intersection</td>
</tr>
<tr>
<td>6</td>
<td>3S2_6_30.txt</td>
<td>IH10-US90 intersection</td>
<td>Terrel County, TX</td>
</tr>
<tr>
<td>7</td>
<td>3S2_1_10.txt</td>
<td>Zaragoza Intl. Bridge</td>
<td>Dona Ana County, NM</td>
</tr>
</tbody>
</table>
The “vehicle description” and “jurisdiction rules and regulations check” sections are only reported on the first route scenario, and are omitted on the remaining reports to avoid repetition of information and optimize report length.

It can be observed from the routing reports that when a 30% impact factor was used for the analysis, the final routes are determined on the first trial and no bridges are avoided. The only exception is for scenario 2, where the route was found after the second trial, since a bridge was avoided due to missing BRINSAP information in the first trial. When a 10% impact factor was used, the same solution as in scenario 1 was found.

The following figures 6.10 (a) through (f) depict the selected routes for the first six commercial vehicle scenarios. The figure for the last scenario is not shown since it is a replica of scenario 1.

![Scenario 1](image1.png)

a) Scenario 1.

![Scenario 2](image2.png)

b) Scenario 2.
c) Scenario 3.

d) Scenario 4.
e) Scenario 5.

f) Scenario 6.

Figure 6.10 Commercial 3S2 Vehicle Route Scenarios.
6.4 Case Study 3: Concrete-Mixer Delivery Truck

The last case study entails a concrete-mixer delivery truck. Several attempts were made to contact local concrete-mix delivery companies and request technical specification on their delivery vehicles with no avail. Eventually, a hypothetical vehicle was used for this case study. The descriptive axle attributes for the concrete mixer were determined from a combination of technical data acquired from manufacturer websites (see Appendix A). The overall height and width dimensions were assumed within the legal dimensions. This vehicle does not necessarily represent actual delivery trucks traveling in El Paso.

Two routes in El Paso were tested. The first route heading northbound starts at the intersection of Americas Ave. and North Loop (near the Zaragoza International Bridge). It takes IH-10 westbound then US-54 northbound and ends at the intersection with Transmountain Rd. (Loop 375).

The second route heading southbound starts at FM1905 (near Dona Ana County) and takes SH-20 and IH-10 to US-54 northbound and ends at the intersection with Transmountain Rd. (Loop 375).

Several intermediate stops were defined to “force” the vehicle to take the specified routes. Figures 6.11 (a) and (b) depict the route paths analyzed by the routing application.

In both cases, an impact factor of 30% was selected to use with the BLF, and resulted in finding routes with bridge structures without any restrictions (see routing reports in Appendix A under the titles Concrete Mixer 1 and 2).

![Route Diagrams](image)

a) Northbound Route.  
b) Southbound Route.

Figure 6.11 Concrete-Mixer Delivery Truck Routes.

6.5 Case Studies: Summary
Three case studies have been analyzed in this chapter utilizing the developed GIS routing system. The first case study compared the results of the GIS routing program with the actual authorized route for an overweight move in El Paso. The second and third studies used hypothetical vehicles traveling through typical truck routes in the District. The routing reports include a summary of the vehicle description, the final routes (if any), and any bridges avoided due to clearance or load-carrying capacity insufficiencies.

**It is not the purpose of these case studies nor this research, to validate the bridge load formulas (BLF) incorporated into the routing program, nor to validate any route permits issued by TxDOT’s MCD.**

The main purpose of this research is to demonstrate the feasibility of developing a GIS routing system in a border region and show how it can be applied in other locals.
CHAPTER 7
ROAD NETWORK RESTRICTIONS
(FEASIBILITY STUDY)

7.1 Introduction

A highway network model should account for real-time highway conditions, such as temporary road closures due to construction or utility works, physical restrictions due to different turn radii, legally prohibited turns, and changes in traffic flow directions, to determine solutions that are more realistic.

This chapter briefly presents the outcome of a feasibility study to account for two types of restrictions: prohibited turns and road segments restricted to traffic. A description on how to configure the road network to account for these restrictions based on TransCAD procedures is presented, as well as two examples.

7.2 Prohibited Turns

TransCAD [TransCAD, 1996] has the capability to automatically model turn delays or prohibit turns moving from one road link to another (specific link-to-link) by assigning penalty values. Turn penalties can be defined using a built-in tool (Turn toolbox) that creates/updates a turn penalty (TP) table (in dBase format) that stores the record identification numbers (ID’s) of the “FROM” and “TO” links, along with a penalty value to be applied when transitioning between the links. To prohibit a turn, the turn penalty value should be left blank.

However, if the road network needs to be regenerated, TransCAD may assign different record ID’s from the ones used to define the link-to-link turn prohibitions, thus preventing the routing application to properly identify them and account them as restrictions for routing purposes.

To avoid this problem, a feasibility study was made to research the possibility of defining link-to-link turn prohibitions using the CTYRDID link attribute, instead of the ID attribute. The CTYRDID number (as defined in section 5.2.2) is a unique attribute that does not change if the network is regenerated.

The in-house customized macro (ass_TP.rsc) was developed to facilitate the definition of turn penalties, by allowing the user to select the FROM-TO link pairs, and save their corresponding CTYRDID identification attribute, into a user-defined turn prohibition (UDTP) database (in dBase format). The macro permits the user to add turn prohibitions, scroll over the existing ones, and delete unwanted (e.g. temporary) ones.

An option was added to the OVR program, where the user chooses whether or not to incorporate specific turn restrictions in the route search. If they are to be included, the user
selects a UDTP table (previously generated using the *ass_TP* macro). The OVR program reads this UDTP table, and temporarily converts it into a TransCAD-compatible turn penalty table. The conversion is accomplished by retrieving the CTYRDID of the FROM and TO links for each record at a time, locating it in the ROADS layer and obtaining the corresponding ID number. These ID numbers are stored in a temporary TransCAD-compatible TP table with penalty values left blank. The OVR program then reads this temporary TP table to set the turn restrictions in the road network.

To demonstrate the effect of accounting for turn restrictions in route searches, two runs were executed using the same points of origin and destination. The first route was searched without considering the turn prohibition, and the second route considering the prohibition. The intersection is located in Jeff Davis County.

Figure 7.1 illustrates the route solution without the turn restriction, followed by the OVR program’s route description.

![Figure 7.1 Route Solution Without Considering the Prohibited Turn.](image)

**Proposed Route:**
Start West on 000078 0.14 Miles (0.14 Miles).
Total number of routes tested before final result = 1
End of Route Description ------------------------------------------

Figure 7.2 depicts the solution incorporating the turn restriction in the route analysis.
Figure 7.2 Route Solution Considering the Prohibited Turn.

Proposed Route:
Start West on 000078 0.33 Miles (0.33 Miles).
Total number of routes tested before final result = 1
End of Route Description

Comparing both route solutions and descriptions, the solution considering the turn restriction is different and longer than the one without the restriction.

UTEP surveyed within TxDOT for an existing database containing specific turn information for El Paso District. However, at the time of the survey, there was no database available. Therefore, UTEP decided to build a prototype UDTP database with a few prohibited turns, for feasibility-of-use purposes only. The developed TP table for El Paso District includes fifty-seven prohibited turns. These turns were visually identified at intersections where the angle between the intersecting roads is somewhat acute and the directions of travel of either road are bi-directional. Four (4) turn prohibitions were defined for Brewster County, ten (10) for Culberson, thirty-two (32) for El Paso, three (3) for Hudspeth County, eight (8) for Jeff Davis, and zero (0) for Presidio. The turn penalties where defined from the ROADS GIS layer.

Another type of turn restriction that can be implemented in TransCAD is prohibiting U-turns or backtracking. TransCAD provides the capability to automatically prohibit U-turns or backtracking in the network model if desired. However, this option is not fully implemented in the OVR macro.

The following figures compare route solutions when permitting and prohibiting backtracking at an intersection in Jeff Davis County.
Figure 7.3 shows the route solution originating at point 1, stopping at point 2, backtracking and ending at point 3.

Proposed Route:
Start  East on SH0118  8.45 Miles  (8.45 Miles).
Sharp Right  West on FM1837  3.24 Miles  (11.69 Miles).
Backtrack  East on FM1837  3.24 Miles  (14.93 Miles).  ← Permitted
Turn Right  South on SH0118  1.53 Miles  (16.45 Miles).

Figure 7.4 does not show a solution, since the U-turn or backtracking is prohibited at point 2.
7.3 Roads Closed to Traffic

TransCAD also has the capability of disabling/enabling links from a network to prevent/allow traveling through those specific links, both interactively and using Caliper’s GISDK programming commands [Caliper, 1996].

To facilitate the implementation of multiple link restrictions in the routing application, a database of road segments to be disabled from the network, should be created and maintained with current road conditions. UTEP found that TxDOT maintains a web site [TxDOT, 2000] that frequently posts reports to alert travelers about permit restrictions and current roadway conditions. The road reports can be accessed by roadway, by county, by condition or by District. At the time this feasibility study was made, no activity report was posted for El Paso District. However, by inspecting the type and format of the information provided in the web site for other districts, some insight was gained to develop a prototype database for El Paso District.

A procedure was devised to develop a user-defined database of road links restricted to traffic (refer to OVR’s On-line help). The database has to be semi-automatically updated using TransCAD’ built-in tools for single/multiple line feature selection and set creation, and the map containing the roads network on which the road links are to be closed.

Another option was added to the OVR program, to allow the user to choose whether to account for links included in a restricted links database, and disable them form the network. If the links are to be disabled, the user selects the restricted links table (e.g. C2T.dbf), the program automatically retrieves the links from the table, and stores them in a set entitled “Closed to traffic”. The program locates the links in the Roads layer using the CTYRDID tag (see section 5.2.2), and immediately disables them from the corresponding network model before the user initiates a route search.

To illustrate the effect of enabling/disabling traffic through a link, a sample database was developed, with a link to be restricted to traffic at the entrance ramp from Sunland Park Dr. to IH10 in El Paso County.

First, a route is searched to transport a vehicle from the intersection of Sundland Park Dr. and IH10 East entrance ramp (origin), to the intersection of Executive Center and US 85 (destination). The shortest path solution with the ramp opened to traffic is depicted in Figure 7.5.

Afterwards, the entrance ramp from Sunland Park Dr. to IH10 East is disabled from the network to model the closure to traffic (see Figure 7.6).

The route solution when the road link is disabled from the network, to represent the temporary road closure, is illustrated in Figure 7.7. This solution avoids the disabled road segment and takes a longer route to reach the same destination.
Figure 7.5 Route Solution with the Entrance Ramp Opened to Traffic.

Proposed Route:
Start West on SUNLAND 0.18 Miles (0.18 Miles).
Turn Left South on ON-RAMP 0.63 Miles (0.81 Miles).
Turn Left East on IH0010 2.28 Miles (3.09 Miles).
Turn Right South on OFF-RAM 0.18 Miles (3.27 Miles).
Continue West on EXECCTR 0.47 Miles (3.74 Miles).

Total number of routes tested before final result = 1

End of Route Description -----------------------------------------------
Figure 7.6 Entrance Ramp from Sunland Park Dr. to IH 10 Closed to Traffic.
Figure 7.7 Route Solution Considering the Entrance Ramp Closed to Traffic.

Proposed Route:
Start    South on MESHILL  0.01 Miles (0.01 Miles).
Turn Left  East on SUNLAND  1.16 Miles (1.17 Miles).
Turn Right South on SH0020  2.69 Miles (3.86 Miles). ← Mesa St.
Turn Right West on EXECCTR  1.10 Miles (4.97 Miles).

Total number of routes tested before final result = 1
End of Route Description ---------------------------------------------

This chapter demonstrated that both network restriction options are feasible for incorporation into routing analysis to model actual road conditions, and determine more realistic solutions. However, the current version of the routing application has a limitation when considering road links restricted to traffic. The road GIS system layer represents bi-directional road segments with a single line feature; also, this layer does not contain detailed information on the number of lanes per direction of travel. In the event that actual road conditions have individual lane closures in a certain direction, without having to detour the entire roadway section, the program will not differentiate between directions of travel nor number of lanes per directions of travel. Therefore, modeled conditions will not reflect actual ones.
CHAPTER 8

TRANSFERABILITY OF FRAMEWORK TO OTHER BORDER REGIONS
(Feasibility Study)

8.1 Introduction

Previous chapters have discussed the selection and integration of various components into a GIS that automates the selection and evaluation of routes for overweight/oversize vehicles for the On-system highway network in El Paso District.

Basic rules for the movement of overweight/oversize vehicles in Texas, and a rapid bridge load-capacity evaluation methodology were selected as the criteria to determine the feasibility of a route.

Digitized maps and a bridge database were selected to prepare the highway network for routing purposes. These geographic data sets could not be used in their native format; therefore, a conversion process was required. During the conversion of the data sets, a number of problems were identified, and a series of corrective measures were developed and conducted.

This chapter briefly addresses a feasibility study to implement the framework to other border regions. Differences in geographic data sources and network preparation are addressed. A sample run is included for a northern border region.

8.2 Data Sources: Differences in Network Preparation

A northern border region was selected to determine the feasibility of transferring the framework previously discussed to prepare a highway network for routing of overweight/oversize vehicles. Franklin County, in Watertown (Region 7), New York (see Figure 8.1), was selected among several candidates, for its small size, simplicity of its highway network, and availability of components to develop the routing GIS.

The GIS components secured to develop the network include:

1) Eastern U.S. Primary and Secondary roads in ArcView shape format [ESRI, 2000], from which the portion corresponding to Franklin, New York was extracted and converted into TransCAD’s GIS format. The Franklin roads layer does not have a road database associated to the line features, however, when generating the GIS files, several fields are included: a) the highway designation, and b) the state FIPS code. Directions of travel and heading are not available.

2) A portion of the Franklin county Bridge database (in MSAccess format) with a number of attributes similar to BRINSAP’s. However, field content and format differences were encountered when compared to BRINSAP. The database and companion manual were provided by the Map Information Unit of the NYSDOT [McElligot, et al 2000].
Figure 8.1 Northern Border Region: Franklin, New York, Region 7.

To enable the possibility of using these data sources with the OVR program, several format compatibility issues require attention. In addition, a rapid visual inspection of the contents of the geographic datasets was conducted, and it was concluded that most of the corrective measures described in section 5.2.2 would also have to be applied.

The ROADS GIS layer generated for Franklin, New York is not a network model; it also contains connectivity problems and missing highway attributes. Fields were added except for the STATEFIPS. The Fixend and Assign_id macros (see Figure 5.4) were used. Highway designations were added/completed based on map information consulted on various map search websites on the Internet. All roads were assumed bi-directional, since these are represented with single-line features (no divided highways). Similarly, overpass/underpass intersections were impossible to identify and define, since bridge symbols were not available. The deletion of centerlines was skipped.

The bridge database for Franklin, New York, consisted of ten tables among which most bridge attributes were contained, including geographic coordinates. The tables were exported to Excel format, where field headings were kept intact. This facilitated the identification of the fields with descriptive location information, including geographic coordinates, used to verify the bridge locations. In addition, those fields with attributes required for bridge evaluation based on the BLF, were also identified. The required fields were collected and organized in a separate file that was later exported into dBase format, for later incorporation into TransCAD. Fields with load posting information were not located in the database. Several attempts were made to contact NYSDOT to request the missing information, with no avail.
The Franklin bridge database contains the geographic coordinates of each bridge in degrees-minutes format. A difference between the BRINSAP database and this one, is that two fields are allocated to describe the coordinates in each direction, e.g. latitude (degrees), latitude (minutes), longitude (degrees), longitude (minutes). The conversion algorithm used for BRINSAP, to change world coordinates into decimal-degrees, was slightly modified to accommodate this difference in format. In addition, the header file used to rename and resize the database fields was also modified to accommodate for the various field format differences encountered. Some bridge information is also incomplete or erroneously entered.

Most of the procedure depicted in Figure 5.5, to prepare the bridge GIS layer, was followed without major deviations. To verify the location of the bridges, ROADS GIS layer and bridge GIS layer (also named BRINSAP for practical purposes) were super-imposed, and the descriptive information was cross-referenced with map information retrieved from map search websites on the Internet.

After preparing both GIS layers (ROADS and BRINSAP) for routing, the relational database was created, and finally a network model was generated for Franklin, New York. Figure 8.2 depicts the final Franklin New York map, along with the highway information attributed to the road segments.

![Franklin NY Map](image)

Figure 8.2 Franklin Routing Network and Highway Record Information.
The OVR macro was modified to: a) account for the different bridge database field names used in Franklin; b) to avoid checking for load posted bridges (since the information is not available); and c) the jurisdiction legal limits file was created for New York (see following section). Network restriction information (e.g. turn prohibitions and road segments closed to traffic) may also be defined for this border region as described in Chapter 6. The New York Department of Transportation (NYDOT) also maintains a website [NYDOT, 2001a] that reports State highway restriction information for commercial vehicles, including the interstate system. It does not include information on municipal roads.

8.3 Jurisdiction Legal Limits

New York, as well as Texas, has regulations for the movement of oversize/overweight vehicles. The following tables show the New York’s legal dimension limits (see Table 8.1) and the permissible gross weight of vehicles and combinations with pneumatic tires (see Table 8.2) for State highways and Qualifying Access highways.

Table 8.1 Legal Size Limits in New York State (after [NYDOT, 2001b])

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Legal Size Limits (ft-in)(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>8’-6” (2591)</td>
</tr>
<tr>
<td>Height</td>
<td>13’-6” (4115)</td>
</tr>
<tr>
<td>Length (single vehicle)</td>
<td>40’-0” (12192)</td>
</tr>
</tbody>
</table>

NOTE a: Limits apply for State highways and Designated highways.
NOTE b: Some exceptions apply.

Table 8.2 Legal Weight Limits in New York State (after [NYDOT, 2001b])

<table>
<thead>
<tr>
<th>Number of Axles/Group</th>
<th>Maximum Distance Between Extremes of any Group of Two or More Axles (Feet)</th>
<th>Maximum Legal Axle Group Weight (Kips)(kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>22.4 (100)</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8-10</td>
<td>40 (178)</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>34 (152)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ 1 (4.45)/ft. between extremes, cc. &lt; 71 (317)</td>
</tr>
</tbody>
</table>

NOTE a): Provided that 800 lbs./inch (363 kg./25.4 mm) of tire width or manufacturer’s tire rating is not exceeded.
NOTE b): Limits apply for State highways and Designated highways.
NOTE c): The overall gross weight on a group of two or more consecutive axles shall not exceed the weight produced by the application of the Bridge Formula B.
8.4 Sample Run

A simple hypothetical case is presented in this section to demonstrate the feasibility of transferring the framework previously discussed to prepare a highway network for routing of overweight/oversize vehicles.

![Feasibility Case in Northern Border Region](image)

**Figure 8.3 Feasibility Case in Northern Border Region.**

The following is a excerpt from the routing report for the case study tested in Franklin County, New York. The vehicle is a truck trailer with hypothetical axle weights, and the route includes an intermediate stop.
Project Information

Company : UTEP
Customer : NYSDOT
Permit Officer : CHMR
State/Province : New York
District/County : Franklin, Watertown
Origin : State Hwy 30, southern county limit
Destination : State Hwy 30, northern county limit
Comments : Feasibility case in northern border region

Network model file: E:\32FRAN~1\NETWORKS\FKYRDS.NET
Vehicle description file: E:\32FRAN~1\VEH_LIB\3T3VAN.VEH

Vehicle Description

Model : 3T3 Truck, Trailer
Type : Hypothetical
Nominal Capacity: 138.26 kip
Height (ft | in): 13 | 10
Width (ft | in): 8 | 7
Number of Axles: 6

<table>
<thead>
<tr>
<th>Axle</th>
<th>Dist.prev.axl(ft)</th>
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Vehicle's Maximum Wheel Base is 51.67 ft
Vehicle's Center of Gravity from the 1st axle is 31.71 ft

Jurisdiction Rules and Regulations

Jurisdiction state name: New York
Legal height (ft | in) : 13 | 06 --> NOT Satisfied
Legal width (ft | in) : 08 | 06 --> NOT Satisfied
Legal Tire Pressure : 0800.000 lb/in --> Satisfied
Max. allow. group wt.: (See below) --> NOT Satisfied

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Bridge Evaluation Criteria

Bridge Load Formula
Impact Factor: 10 %

End of Jurisdiction Rules and Regulations
Route Description

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Proposed Route:

Start            North  on STATE HWY 30                           10.22 Miles   (10.22 Miles).
Turn Right  East    on  BROAD ST                                    0.23 Miles   (10.46 Miles).
Turn Left    North  on COUNTY HWY 49                         0.29 Miles   (10.74 Miles).
Turn Right  East    on  STATE HWY 30                            0.20 Miles   (10.94 Miles).
Continue     East    on  STATE HWY 3                              5.09 Miles   (16.04 Miles).
Continue     North  on STATE HWY 30                           38.28 Miles   (54.31 Miles).
Turn Right  East    on  STATE HWY 99                            4.10 Miles   (58.41 Miles).
Turn Left    North  on COUNTY HWY 27                       12.38 Miles   (70.79 Miles).
Continue North  on COUNTY HWY 25                         6.38 Miles   (77.17 Miles).
Continue     North  on DUANE ST                                     1.25 Miles   (78.41 Miles).
Turn Right  East    on  HARRISON PL                              0.04 Miles   (78.46 Miles).
Continue     East    on US HWY 11                                  0.07 Miles   (78.52 Miles).
Turn Left    North  on STATE HWY 30                           0.39 Miles   (78.92 Miles).
Continue     East    on ELM ST                                      0.65 Miles   (79.57 Miles).
Continue     East    on JUNCTION RD                              1.63 Miles   (81.19 Miles).
Continue North  on US HWY 11                                  10.27 Miles   (91.46 Miles).
Turn Left    North  on STATE HWY 374                          4.48 Miles   (95.94 Miles).

Total number of routes tested before final result = 1
End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance
Total number of bridges evaluated for vertical clearance = 16
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance

Links disabled and Bridges avoided due to limited horizontal width clearance
Total number of bridges evaluated for horizontal width = 16
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width

Links disabled / Bridges avoided due to missing information in BRINSAP database
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity
Total number of bridges evaluated for load-carrying capacity = 16
No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

* End of Report

The routing application performed the route search, found an adequate route, highlighted the route in the map, and generated the corresponding report for the vehicle traveling through Franklin, New York. This case study proves that both the developed framework for preparing a network for routing, and the routing program slightly modified to account for minor map and database format differences, is feasible to implement in other border regions. However, the author recommends a revision or calibration of the regression factors in the BLF for bridges in other jurisdictions to ensure its general use and applicability.
CHAPTER 9

SUMMARY

9.1 Summary

The objective of this research was to develop an application to automate the selection of routes and the evaluation of the bridge infrastructure in the El Paso border region for vehicles exceeding legal size and weight limits, using GIS technology, to avoid inadequate structures with insufficiencies and protect them.

A literature search was conducted and the most relevant aspects of approximately twenty papers were briefly summarized in Chapter 2. The papers address topics that range from vehicle loads and structural safety, to permit regulations and procedures, to permit evaluation methodologies for overloads.

Chapter 3 specifically discussed the route selection criteria followed by the State of Texas. Legal size and axle-weight limits were addressed, as well as an alternative bridge load formula developed to rapidly assess the load-carrying capacity of bridges that is based on bridge attributes as well as vehicle characteristics.

To develop the proposed routing application, a survey of available GIS with routing capabilities, road maps, and road and bridge databases was made. Chapter 4 reports the final selections:

a) TxDOT’s official digitized County/Urban maps and
b) TxDOT’s BRINSAP bridge database.
c) The current basic permitting rules and regulations for movement of oversize/overweight loads set forth in the TAC were selected as part of the routing evaluation model.
d) The BLF was selected as an alternative to rapidly evaluate the load carrying capacity of bridges.
e) TransCAD Transportation GIS software was selected for its integrated routing capabilities.

Chapter 5 described the development of the routing application, including a framework to address the problems encountered and the solutions provided during the preparation of the network for routing. Two critical factors were addressed: a) the accuracy of the highway network model with directions of travel, and b) the correct location of each bridge for proper identification during the route selection and evaluation.

This chapter also addresses the integration of the routing capabilities of the GIS software, the extraction of the required geographic data from the selected maps and bridge database, and the evaluation algorithms, by means of a customized interface developed using GISDK programming language.

The routing application was developed and completed for the El Paso District in Texas.
To demonstrate the feasibility of the GIS routing application, three case studies were made and are described in Chapter 6. The first case study entailed an actual overweight vehicle permit request in El Paso, Texas. A detailed study of the route evaluation was presented. However, the purpose of the case study did not include the validation of the route permit issued by TxDOT’s MCD, nor the validation of the incorporated BLF. The other two hypothetical case studies involved commercial vehicles and concrete-mix delivery trucks that traveled through typical truck routes in El Paso District.

Chapter 7 reported a feasibility study to incorporate real-time highway conditions into the routing application. The chapter briefly described procedures to account for road closures and prohibited turns, along with a comparison of case studies with and without the highway network restrictions.

Chapter 8 addressed a feasibility study to transfer the framework developed in Chapter 5, to a northern border region. Franklin County in Watertown, New York was selected for this purpose. Differences in the network preparation of Franklin, New York, were briefly discussed, as well as regional jurisdiction size and weight limits. A simple case study was included.

The automated routing of vehicles exceeding legal size and weight limits, and traveling through border regions, has been integrated into a software application using GIS technology. The application was developed for the entire El Paso District in Texas. The various case studies demonstrated the feasibility of using such a system to (a) reduce the time it takes to find an adequate route and issue the permits for oversize/heavy vehicles, (b) to prevent the deterioration of bridges in border regions due to repetitive heavy loading, and (c) ultimately, to have a safer bridge infrastructure.
REFERENCES


APPENDIX A

CASE STUDIES: SUPPORTING DOCUMENTATION

OVERWEIGHT VEHICLE
(Facsimile courtesy of TxDOT - Motor Carrier Division)

Figure A1. Route Inspection Form Showing Authorized Route for Overweight Vehicle.

Figure A2. Original Sketch of Overweight Vehicle Configuration. Lateral View.
Figure A3. Original Sketch of Overweight Vehicle Configuration. Back View.

Figure A4. Descriptive Attributes for a Bridge along the Authorized Permit Route.
Overweight/Oversize Vehicle Routing Report
Routing Algorithm: Shortest Path Route

Network model file: C:\D24ELP\NETWORKS\D24.NET
Vehicle description file: C:\D24ELP\VEH_LIB\PTG2.VEH

Vehicle Description ---------------------------------------------------------
Model: Injection Moulding Machine
Type: PGT Trucking, Inc.
Nominal Capacity: 332 kip
Height (ft | in): 13 | 6
Width (ft | in): 10 | 0
Number of Axles: 11

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Vehicle's Maximum Wheel Base is = 069.25 ft
Vehicle's Center of Gravity from the 1st axle is = 044.21 ft
End of Vehicle Description --------------------------------------------------

Jurisdiction Rules and Regulations --------------------------
Jurisdiction state name: Texas
Legal height (ft | in) : 14 | 06 --> Satisfied
Legal width (ft | in) : 08 | 06 --> NOT Satisfied
Legal Tire Pressure : 0650.000 lb/in --> Satisfied
Max. allow. group wt. : (See below) --> NOT Satisfied

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<td>038.25</td>
<td>0227.000</td>
<td>0081.400</td>
</tr>
<tr>
<td>10</td>
<td>07</td>
<td>031.50</td>
<td>0238.000</td>
<td>0081.400</td>
</tr>
<tr>
<td>01</td>
<td>08</td>
<td>053.50</td>
<td>0230.000</td>
<td>0081.400</td>
</tr>
<tr>
<td>02</td>
<td>08</td>
<td>042.75</td>
<td>0250.000</td>
<td>0081.400</td>
</tr>
<tr>
<td>03</td>
<td>08</td>
<td>043.50</td>
<td>0261.000</td>
<td>0081.400</td>
</tr>
<tr>
<td>04</td>
<td>08</td>
<td>036.75</td>
<td>0272.000</td>
<td>0081.400</td>
</tr>
<tr>
<td>05</td>
<td>09</td>
<td>058.75</td>
<td>0264.000</td>
<td>0081.400</td>
</tr>
</tbody>
</table>

A-4
02 09 048.00 0284.000 0081.400
03 09 048.75 0295.000 0081.400
01 10 064.00 0298.000 0081.400
02 10 053.25 0318.000 0081.400
01 11 069.25 0332.000 0081.400

Bridge Evaluation Criteria
Bridge Load Formula
Impact Factor: 0 %

End of Jurisdiction Rules and Regulations

Route Description
Geographic Coordinates (Degrees) on Road Link(s) Highway ID
<table>
<thead>
<tr>
<th>Longitude</th>
<th>Latitude</th>
<th>ID 1</th>
<th>ID 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
<td>24072011472</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
<td>24072011205</td>
</tr>
</tbody>
</table>

Proposed Route:
No feasible route was found for specified path points
Possible reasons:
- Selected path points are not connected in selected network
- Prohibited U-turns or Backtracks
- See bridges avoided due to limited Vertical Clearance
- See bridges avoided due to limited Horizontal Width
- See bridges avoided due to Load Posting
- See bridges avoided due to missing BRINSAP Information
- See bridges avoided due to limited Load-carrying Capacity

Alternative(s):
- Modify vehicle configuration to redistribute load
- Temporarily strengthen week portions of proposed route.

Total number of routes tested before final result = 4

End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance
Total number of bridges evaluated for vertical clearance = 50
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance

Links disabled and Bridges avoided due to limited horizontal width clearance
Total number of bridges evaluated for horizontal width = 50
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width

Links disabled and Bridges avoided due to load posting
Total number of bridges evaluated for load posting = 31
End of links disabled and bridges avoided due to bridges posted for load

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
End of links disabled and bridges avoided due to missing info in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity

<table>
<thead>
<tr>
<th>County/ROID</th>
<th>Highway</th>
<th>Heading</th>
<th>BridgeID</th>
<th>Allow_GW(kips)</th>
<th>Actual_GW(kips)</th>
<th>Axls/Grp</th>
<th>1st_Grp_Axle</th>
<th>BLF not met</th>
</tr>
</thead>
<tbody>
<tr>
<td>240720111190</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204019</td>
<td>000021.884</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>240720111216</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204046</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010715</td>
<td>RAMP</td>
<td>West Bound</td>
<td>240720016704083</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010714</td>
<td>US0054</td>
<td>North Bound</td>
<td>240720016704081</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
</tbody>
</table>

Total number of bridge/spans avoided due to BLF General = 4
Total number of bridge/spans avoided due to BLF Specific = 0

End of links disabled and bridges avoided due to limited load-carrying capacity

*--------------------*  End of Report  *--------------------*

Time elapsed 00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report


Routing Algorithm : Shortest Path Route

Network model file: C:\D24ELP\NETWORKS\D24.NET
Vehicle description file: C:\D24ELP\VEH_LIB\PGT2.VEH

Vehicle Description ---------------------------------------------------------------

Impact Factor: 10 %

End of Jurisdiction Rules and Regulations --------

Route Description ----------------------------------------------------------------

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ID 1)</td>
<td>(ID 2)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:
No feasible route was found for specified path points
Possible reasons:
- Selected path points are not connected in selected network
- Prohibited U-turns or Backtracks
- See bridges avoided due to limited Vertical Clearance
- See bridges avoided due to limited Horizontal Width
- See bridges avoided due to Load Posting
- See bridges avoided due to missing BRINSAP Information
- See bridges avoided due to limited Load-carrying Capacity

Alternative(s):
- Modify vehicle configuration to redistribute load.
- Temporarily strengthen weak portions of proposed route.

Total number of routes tested before final result - 4
End of Route Description --------------------------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance ----------

Total number of bridges evaluated for vertical clearance - 50
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance ----
Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 50
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width -------

Links disabled and Bridges avoided due to load posting -------------------------
Total number of bridges evaluated for load posting = 31
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due bridges posted for load ---------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
Total number of bridges evaluated for load-carrying capacity = 4

<table>
<thead>
<tr>
<th>CountyROIID</th>
<th>Highway</th>
<th>Heading</th>
<th>BridgeID</th>
<th>Allow_GW(kips)</th>
<th>Actual_GW(kips)</th>
<th>Axls/Grp</th>
<th>1st_Grp_Axle</th>
<th>BLF not met</th>
</tr>
</thead>
<tbody>
<tr>
<td>24072011190</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204025</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072011216</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204046</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010715</td>
<td>RAMP</td>
<td>West Bound</td>
<td>240720016704083</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010714</td>
<td>US0054</td>
<td>North Bound</td>
<td>240720016704081</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
</tbody>
</table>

Total number of bridge/spans avoided due to BLF General = 4
Total number of bridge/spans avoided due to BLF Specific = 0
End of links disabled and bridges avoided due to limited load-carrying capacity

----------------------------------------------*  End of Report  *----------------------------------------------

Time elapsed  00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report
Report date: Mon Oct 23 19:17:15 2000

Routing Algorithm: Shortest Path Route

Network model file: \D24ELP\NETWORKS\D24.NET
Vehicle description file: \D24ELP\VEH_LIB\PGT2.VEH

Vehicle Description

Impact Factor: 30%

End of Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>(ID 1)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:
No feasible route was found for specified path points
Possible reasons:
- Selected path points are not connected in selected network
- or Prohibited U-turns or Backtracks
- or See bridges avoided due to limited Vertical Clearance
- or See bridges avoided due to limited Horizontal Width
- or See bridges avoided due to Load Posting
- or See bridges avoided due to missing BRINSAP Information
- or See bridges avoided due to limited Load-carrying Capacity

Alternative(s):
- Modify vehicle configuration to redistribute load.
- or Temporarily strengthen weak portions of proposed route.

Total number of routes tested before final result = 4
End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance

Total number of bridges evaluated for vertical clearance = 50
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance
Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 50
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width ------

Links disabled and Bridges avoided due to load posting ------------------------
Total number of bridges evaluated for load posting = 31
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due bridges posted for load ----------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
Total number of bridges evaluated for load-carrying capacity = 4

<table>
<thead>
<tr>
<th>CountyROIID</th>
<th>Highway</th>
<th>Heading</th>
<th>BridgeID</th>
<th>Allow_GW(kips)</th>
<th>Actual_GW(kips)</th>
<th>Axls/Grp</th>
<th>1st_Grp_Axle</th>
<th>BLF not met</th>
</tr>
</thead>
<tbody>
<tr>
<td>24072011190</td>
<td>LOOP375</td>
<td>East</td>
<td>240720255204019</td>
<td>000167.052</td>
<td>000170.000</td>
<td>05</td>
<td>04</td>
<td>General</td>
</tr>
<tr>
<td>24072011216</td>
<td>LOOP375</td>
<td>East</td>
<td>240720255204046</td>
<td>000202.054</td>
<td>000204.000</td>
<td>06</td>
<td>04</td>
<td>General</td>
</tr>
<tr>
<td>24072010715</td>
<td>RAMP</td>
<td>West</td>
<td>240720016704083</td>
<td>000202.054</td>
<td>000204.000</td>
<td>06</td>
<td>04</td>
<td>General</td>
</tr>
<tr>
<td>24072010714</td>
<td>US0054</td>
<td>North</td>
<td>240720016704081</td>
<td>000202.054</td>
<td>000204.000</td>
<td>06</td>
<td>04</td>
<td>General</td>
</tr>
</tbody>
</table>

Total number of bridge/spans avoided due to BLF General = 4
End of links disabled and bridges avoided due to limited load-carrying capacity

End of Report

Time elapsed 00 h 00 m 01 s
Table A1. Overpass Bridges Along Authorized Route. Attribute Summary.

<table>
<thead>
<tr>
<th>Bridge attribute</th>
<th>BRINSAP attribute field</th>
<th>240720255204019</th>
<th>240720255204025</th>
<th>240720255204027</th>
<th>240720255204046</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure Number</td>
<td>F0000_STRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility</td>
<td>F7FACCARRD</td>
<td>LOOP 375</td>
<td>LOOP 375 EB</td>
<td>LOOP 375 EB</td>
<td>LOOP 375 EB</td>
</tr>
<tr>
<td>Feature Intersected</td>
<td>F6_1FEATXE</td>
<td>Ascarate Wasteway</td>
<td>Midway Dr.</td>
<td>Riverside Dr.</td>
<td>Padres Dr.</td>
</tr>
<tr>
<td>Location</td>
<td>F9LOCATION</td>
<td>6.6 Mi. W FM 659</td>
<td>5 Mi. E Cordova Int. Br.</td>
<td>.5 Mi W FM 659</td>
<td>1.279 Mi. W Zaragoza</td>
</tr>
<tr>
<td>Roadway Width</td>
<td>F47TOTHRZC</td>
<td>42 Ft.</td>
<td>40 Ft.</td>
<td>40 Ft.</td>
<td>40 Ft.</td>
</tr>
<tr>
<td>Clearance Under</td>
<td>F54_2VTCUN</td>
<td>0 Ft. 0 in.</td>
<td>16 Ft. 5 in.</td>
<td>16 Ft. 0 in.</td>
<td>16 Ft. 09 in.</td>
</tr>
<tr>
<td>Operational Status</td>
<td>F41OPERSTA</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Bridge Type</td>
<td>F43_1MAIN</td>
<td>--</td>
<td>1131</td>
<td>1131</td>
<td>1131</td>
</tr>
<tr>
<td>No. of Spans</td>
<td>F46TOTNOSP</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total Length</td>
<td>F49STRLGTH</td>
<td>22 Ft.</td>
<td>190 Ft.</td>
<td>190 Ft.</td>
<td>190 Ft.</td>
</tr>
<tr>
<td>Length of largest span</td>
<td>F48MXSFLGT</td>
<td>5 Ft.</td>
<td>90 Ft.</td>
<td>90 Ft.</td>
<td>90 Ft.</td>
</tr>
<tr>
<td>Inventory Rating</td>
<td>F66INVRATE</td>
<td>(236) HS20.0</td>
<td>(236) HS20.0</td>
<td>(236) HS20.0</td>
<td>(236) HS20.0</td>
</tr>
<tr>
<td>Operational Rating</td>
<td>F64OPERRAT</td>
<td>(249) HS27.2</td>
<td>(249) HS27.2</td>
<td>(249) HS27.2</td>
<td>(249) HS27.2</td>
</tr>
</tbody>
</table>
Overweight/Oversize Vehicle Routing Report
Report date: Fri Jun 1 14:27:55 2001
Routing Algorithm: Shortest Path Route

Network model file: E:\__D24ELP\NETWORKS\D24_NET
Vehicle description file: E:\__D24ELP\VEH_LIB\FGT_VEH

Vehicle Description

Impact Factor: 0 %

End of Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>(ID 1)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:
No feasible route was found for specified path points
Possible reasons:
- Selected path points are not connected in selected network
- Or prohibited U-turns or Backtracks
- Or see bridges avoided due to limited Vertical Clearance
- Or see bridges avoided due to limited Horizontal Width
- Or see bridges avoided due to Load Posting
- Or see bridges avoided due to missing BRINSAP Information
- Or see bridges avoided due to limited Load-carrying Capacity

Alternative(s):
- Modify vehicle configuration to redistribute load.
- Or temporarily strengthen weak portions of proposed route.

Total number of routes tested before final result = 4
End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance

Total number of bridges evaluated for vertical clearance = 49
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance
Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 49
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width --------

Links disabled and Bridges avoided due to load posting -----------------------
Total number of bridges evaluated for load posting = 30
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load --------

Links disabled / Bridges avoided due to missing information in BRINSAP database
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity -------
Total number of bridge/spans evaluated for load-carrying capacity = 4
<table>
<thead>
<tr>
<th>CountyRID</th>
<th>Highway</th>
<th>Heading</th>
<th>BridgeID</th>
<th>Allow_GW(kips)</th>
<th>Actual_GW(kips)</th>
<th>Axls/Grp</th>
<th>1st_Grp_Axle</th>
<th>BLF not met</th>
</tr>
</thead>
<tbody>
<tr>
<td>24072011190</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204025</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>240720111216</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204046</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010715</td>
<td>RAMP</td>
<td>West Bound</td>
<td>240720016704083</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010714</td>
<td>US0054</td>
<td>North Bound</td>
<td>240720016704081</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
</tbody>
</table>
Total number of bridge/spans avoided due to BLF General = 4
Total number of bridge/spans avoided due to BLF Specific = 0
End of links disabled and bridges avoided due to limited load-carrying capacity

-----------------------------*    End of Report   *-------------------------------

Time elapsed 00 h 00 m 02 s
Overweight/Oversize Vehicle Routing Report


Routing Algorithm: Shortest Path Route

Network model file: C:\D24ELP\NETWORKS\D24.NET
Vehicle description file: C:\D24ELP\VEH_LIB\PGT2.VEH

Vehicle Description

- Impact Factor: 10%

End of Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longtude</td>
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<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:
No feasible route was found for specified path points
Possible reasons:
- Selected path points are not connected in selected network
- Prohibited U-turns or Backtracks
- See bridges avoided due to limited Vertical Clearance
- See bridges avoided due to limited Horizontal Width
- See bridges avoided due to Load Posting
- See bridges avoided due to missing BRINSAP Information
- See bridges avoided due to limited Load-carrying Capacity

Alternative(s):
- Modify vehicle configuration to redistribute load.
- Temporarily strengthen weak portions of proposed route.

Total number of routes tested before final result = 4

End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance

Total number of bridges evaluated for vertical clearance = 49
No links were disabled and no bridges were avoided due to limited vertical clearance

End of links disabled and bridges avoided due to limited vertical clearance
Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 49
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width -------

Links disabled and Bridges avoided due to load posting ------------------------------
Total number of bridges evaluated for load posting = 30
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load ----------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity -------
Total number of bridges evaluated for load-carrying capacity = 4
<table>
<thead>
<tr>
<th>CountyROID</th>
<th>Highway</th>
<th>Heading</th>
<th>BridgeID</th>
<th>Allow_GW(kips)</th>
<th>Actual_GW(kips)</th>
<th>Axls/Grp</th>
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<tr>
<td>24072011190</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204025</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072011216</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204046</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010715</td>
<td>RAMP</td>
<td>West Bound</td>
<td>240720016704083</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072010714</td>
<td>US0054</td>
<td>North Bound</td>
<td>240720016704081</td>
<td>000304.368</td>
<td>000318.000</td>
<td>10</td>
<td>02</td>
<td>General</td>
</tr>
</tbody>
</table>
Total number of bridge/spans avoided due to BLF General = 4
Total number of bridge/spans avoided due to BLF Specific = 0
End of links disabled and bridges avoided due to limited load-carrying capacity

-----------------------------* End of Report *-------------------------------
Time elapsed 00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report

Routing Algorithm : Shortest Path Route

Network model file: C:\D24ELP\NETWORKS\D24.NET
Vehicle description file: C:\D24ELP\VEH_LIB\PGT2.VEH

Vehicle Description -----------------------------------------------

Impact Factor: 30%

End of Jurisdiction Rules and Regulations -------

Route Description -----------------------------------------------

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>(ID 1)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:
No feasible route was found for specified path points
Possible reasons:
  - Selected path points are not connected in selected network
  - or Prohibited U-turns or Backtracks
  - or See bridges avoided due to limited Vertical Clearance
  - or See bridges avoided due to limited Horizontal Width
  - or See bridges avoided due to Load Posting
  - or See bridges avoided due to missing BRINSAP Information
  - or See bridges avoided due to limited Load-carrying Capacity

Alternative(s):
  - Modify vehicle configuration to redistribute load.
  - or Temporarily strengthen week portions of proposed route.

Total number of routes tested before final result = 4
End of Route Description -----------------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance --------
Total number of bridges evaluated for vertical clearance = 49
  - No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance ----
Links disabled and Bridges avoided due to limited horizontal width clearance ---
   Total number of bridges evaluated for horizontal width = 49
   No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width -------

Links disabled and Bridges avoided due to load posting ------------------------
   Total number of bridges evaluated for load posting = 30
   No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to load posting ---------------

Links disabled / Bridges avoided due to missing information in BRINSAP database
   Total number of bridges evaluated for missing bridge info = 0
   No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
   Total number of bridges evaluated for load-carrying capacity = 4
   
   CountyRoidID  Highway  Heading  BridgeID  Allow_GW(kips)  Actual_GW(kips)  Axls/Grp  1st_Grp_Axle  BLF not met
24072011190    LOOP375  East Bound 240720255204025  000202.054  000204.000      06            04           General
24072011216    LOOP375  East Bound 240720255204046  000202.054  000204.000      06            04           General
24072010715     RAMP    West Bound 240720016704083  000202.054  000204.000      06            04           General
24072010714     US0054  North Bound 240720016704081  000202.054  000204.000      06            04           General
   Total number of bridge/spans avoided due to BLF General = 4
   Total number of bridge/spans avoided due to BLF Specific = 0
   End of links disabled and bridges avoided due to limited load-carrying capacity

----------------------------*    End of Report    *-------------------------------

Time elapsed  00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report
Report date: Fri Jun 1 14:42:58 2001
Routing Algorithm: Shortest Path Route

Network model file: E:\D24ELP\NETWORKS\D24.NET
Vehicle description file: E:\D24ELP\VEH_LIB\PQT.VEH

Vehicle Description: 
Impact Factor: 0 %

End of Jurisdiction Rules and Regulations

Route Description:

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link[s]</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>(ID 1)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:
Start: East on FR 0.00 Miles (0.00 Miles).
Continue East on ON-RAMP 0.22 Miles (0.23 Miles).
Continue East on LOOP375 3.96 Miles (4.19 Miles).
Continue East on OFF-RAM 0.16 Miles (4.35 Miles).
Continue East on FR 0.01 Miles (4.36 Miles).
Continue East on ON-RAMP 0.13 Miles (4.49 Miles).
Continue East on LOOP375 1.49 Miles (5.98 Miles).
Continue South on OFF-RAM 0.34 Miles (6.32 Miles).
Continue South on FR 0.01 Miles (6.33 Miles).
Continue South on ON-RAMP 0.36 Miles (6.69 Miles).
Continue South on LOOP375 0.76 Miles (7.45 Miles).
Continue South on OFF-RAM 0.07 Miles (7.52 Miles).
Continue East on FR 0.12 Miles (7.64 Miles).

Total number of routes tested before final result = 3
End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance
Total number of bridges evaluated for vertical clearance = 3
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance

Links disabled and Bridges avoided due to limited horizontal width clearance
Total number of bridges evaluated for horizontal width = 3
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width ------

Links disabled and Bridges avoided due to load posting --------------------------
Total number of bridges evaluated for load posting = 3
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load -------

Links disabled / Bridges avoided due to missing information in BRINSAP database
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
Total number of bridge/spans evaluated for load-carrying capacity = 2

<table>
<thead>
<tr>
<th>CountyROID</th>
<th>Highway</th>
<th>Heading</th>
<th>BridgeID</th>
<th>Allow_GW(kips)</th>
<th>Actual_GW(kips)</th>
<th>Axls/Grp</th>
<th>1st_Grp_Axle</th>
<th>BLF not met</th>
</tr>
</thead>
<tbody>
<tr>
<td>24072011187</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204027</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
<tr>
<td>24072011216</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204046</td>
<td>000023.950</td>
<td>000046.000</td>
<td>02</td>
<td>02</td>
<td>General</td>
</tr>
</tbody>
</table>

Total number of bridge/spans avoided due to BLF General = 2
Total number of bridge/spans avoided due to BLF Specific = 0
End of links disabled and bridges avoided due to limited load-carrying capacity

-----------------------------* End of Report  *-----------------------------

Time elapsed 00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report
Routing Algorithm: Shortest Path Route
Network model file: C:\D24ELP\NETWORKS\D24.NET
Vehicle description file: C:\D24ELP\VEH_LIB\PGT2.VEH

Vehicle Description

Impact Factor: 10%

End of Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>(ID 1)</td>
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<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:
Start: East on FR 0.00 Miles (0.00 Miles).
Continue East on ON-RAMP 0.22 Miles (0.23 Miles).
Continue East on LOOP375 3.96 Miles (4.19 Miles).
Continue East on OFF-RAM 0.16 Miles (4.35 Miles).
Continue East on FR 0.01 Miles (4.36 Miles).
Continue East on ON-RAMP 0.13 Miles (4.49 Miles).
Continue East on LOOP375 1.14 Miles (5.98 Miles).
Continue South on OFF-RAM 0.34 Miles (6.32 Miles).
Continue South on FR 0.01 Miles (6.33 Miles).
Continue South on ON-RAMP 0.36 Miles (6.69 Miles).
Continue South on LOOP375 0.76 Miles (7.45 Miles).
Continue South on OFF-RAM 0.07 Miles (7.52 Miles).
Continue East on FR 0.12 Miles (7.64 Miles).

Alternative(s):
- Modify vehicle configuration to redistribute load.
- Temporarily strengthen weak portions of proposed route.

Total number of routes tested before final result = 3

End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance

Links disabled and Bridges avoided due to limited vertical clearance

End of links disabled and bridges avoided due to limited vertical clearance
Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 3
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width -------

Links disabled and Bridges avoided due to load posting -------------------------
Total number of bridges evaluated for load posting = 3
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load --------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity -------
Total number of bridges evaluated for load-carrying capacity = 2
County,RIDID    Highway   Heading   BridgeID   Allow_GW(kips)   Actual_GW(kips)   Axls/Grp   1st_Grp_Axle   BLF not met
24072011187   LOOP375   East Bound  240720255204027 000304.368        000318.000         10            02           General
24072011216   LOOP375   East Bound  240720255204046 000304.368        000318.000         10            02           General
Total number of bridge/spans avoided due to BLF General = 2
End of links disabled and bridges avoided due to limited load-carrying capacity

--------------------------* End of Report  *--------------------------

Time elapsed  00 h 00 m 02 s
Overweight/Oversize Vehicle Routing Report  

Routing Algorithm: Shortest Path Route

Network model file: C:\D24ELP\NETWORKS\D24.NET
Vehicle description file: C:\D24ELP\VEH_LIB\PGT2.VEH

Vehicle Description

Impact Factor: 30 %

End of Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>(ID 1)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.417689</td>
<td>031.752998</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.335461</td>
<td>031.674387</td>
</tr>
</tbody>
</table>

Proposed Route:

Start: East on FR 0.00 Miles  (0.00 Miles).
Continue East on ON-RAMP 0.22 Miles  (0.23 Miles).
Continue East on LOOP375 3.96 Miles  (4.19 Miles).
Continue East on OFF-RAM 0.16 Miles  (4.35 Miles).
Continue East on FR 0.01 Miles  (4.36 Miles).
Continue East on ON-RAMP 0.13 Miles  (4.49 Miles).
Continue East on LOOP375 1.49 Miles  (5.98 Miles).
Continue South on OFF-RAM 0.34 Miles  (6.32 Miles).
Continue South on FR 0.01 Miles  (6.33 Miles).
Continue South on ON-RAMP 0.36 Miles  (6.69 Miles).
Continue South on LOOP375 0.76 Miles  (7.45 Miles).
Continue South on OFF-RAM 0.07 Miles  (7.52 Miles).
Continue East on FR 0.12 Miles  (7.64 Miles).

Alternative(s):
- Modify vehicle configuration to redistribute load.
- Temporarily strengthen weak portions of proposed route.

Total number of routes tested before final result = 3

End of Route Description

Links disabled and Bridges avoided due to limited vertical clearance

Total number of bridges evaluated for vertical clearance = 3
No links were disabled and no bridges were avoided due to limited vertical clearance

End of links disabled and bridges avoided due to limited vertical clearance
Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 3
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width ------

Links disabled and Bridges avoided due to load posting -------------------------
Total number of bridges evaluated for load posting = 3
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load --------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity -------
Total number of bridges evaluated for load-carrying capacity = 3

<table>
<thead>
<tr>
<th>CountyRID</th>
<th>Highway</th>
<th>Heading</th>
<th>BridgeID</th>
<th>Allow_GW(kips)</th>
<th>Actual_GW(kips)</th>
<th>Axls/Grp</th>
<th>1st_Grp_Axle</th>
<th>BLF not met</th>
</tr>
</thead>
<tbody>
<tr>
<td>24072011187</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204027</td>
<td>000202.054</td>
<td>000204.000</td>
<td>06</td>
<td>04</td>
<td>General</td>
</tr>
<tr>
<td>240720111216</td>
<td>LOOP375</td>
<td>East Bound</td>
<td>240720255204046</td>
<td>000202.054</td>
<td>000204.000</td>
<td>06</td>
<td>04</td>
<td>General</td>
</tr>
</tbody>
</table>

Total number of bridge/spans avoided due to BLF General = 2
Total number of bridge/spans avoided due to BLF Specific = 0
End of links disabled and bridges avoided due to limited load-carrying capacity

---------------------------------* End of Report *---------------------------------

Time elapsed 00 h 00 m 01 s
--
COMMERCIAL FIVE-AXLE TRACTOR-TRAILER TRUCK

Figure A5a. Tractor Front-Steering Axle Weights.

Figure A5b. Tractor Front-Steering Axle Weights.
**Model:** Kenworth/Kenmex  
**Date:** July 22, 2000  
**Source:** Transportadora Ochoa  
**Location:** Camino a San Jose, Cd. Juarez, Chih. Mexico

- The reported vehicle dimensions correspond to ones measured at the site.  
- The axle weights reported do not correspond to the vehicle.  
  - Front-steering axle weight attributed based on technical data sheets from the Macktrucks Internet website (see Figure A5a)  
  - Axle Weights (2-5) attributed based on tandem-axle loads reported in King and Lee 1997 (evenly distributed over the two axles).

<table>
<thead>
<tr>
<th>Kenworth/Kenmex</th>
<th>Axle 1</th>
<th>Axle 2</th>
<th>Axle 3</th>
<th>Axle 4</th>
<th>Axle 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Tires</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Tire Width</td>
<td>10”</td>
<td>10”</td>
<td>10”</td>
<td>10”</td>
<td>10”</td>
</tr>
<tr>
<td>Tire Diameter</td>
<td>39”</td>
<td>39”</td>
<td>39”</td>
<td>39”</td>
<td>39”</td>
</tr>
<tr>
<td>Weight per Axle</td>
<td>12 kips</td>
<td>24.5 kips</td>
<td>24.5 kips</td>
<td>23.5 kips</td>
<td>23.5 kips</td>
</tr>
<tr>
<td>Distance from Previous Axle Gage</td>
<td>0’-0”</td>
<td>15’-10”</td>
<td>4’-4”</td>
<td>30’-10”</td>
<td>4’-3”</td>
</tr>
<tr>
<td>Maximum Width</td>
<td>8’-3”</td>
<td>6’-3”</td>
<td>6’-3”</td>
<td>6’-3”</td>
<td>6’-3”</td>
</tr>
<tr>
<td>Maximum Height</td>
<td>13’-2”</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Weight</td>
<td>116 kips</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure A6. Tractor-Trailer Descriptive Attributes. Kenworth/Kenmex Model.**
Model: <not available>
Date: July 12, 2000
Source: El Paso Community College, Mission del Paso Center
Location: 10700 Gateway East, El Paso Tx. USA 79927

- The reported vehicle dimensions correspond to the average of three vehicles measured at the site.
- The axle weights reported do not correspond to the vehicle.
  - Front-steering axle weight attributed based on technical data sheets from the Kenworth Internet website (see Figure A5a)
  - Axle Weights (2-5) attributed based on tandem axle loads reported in King and Lee 1997 (evenly distributed over the two axles).

**Figure A7. Tractor-Trailer Descriptive Attributes. EPCC Model.**
**Model:** TxDOT Lic. Plate 969-180  
**Date:** July 27, 2000  
**Source:** Sanchez-Ruiz and Lee [1996]  
**Location:** Laredo, Mexico

Vehicle dimensions not available.  
The axle weights reported correspond to known vehicle weights used to calibrate WIM devices.

**Figure A8. Tractor-Trailer Descriptive Attributes. WIM Calibration Model.**
Overweight/Oversize Vehicle Routing Report
Report date: Tue Sep 5 17:46:41 2000
Routing Algorithm: Shortest Path Route

District/County: D24-El Paso
Origin: Zaragoza International Bridge
Destination: Dona Ana County, NM

Vehicle description file: C:\D24ELP\VEH_LIB\EPCC.VEH
Vehicle Description

Model: 3S2 Truck, Trailer
Type: EPCC Driving School
Nominal Capacity: 116 kip
Height (ft | in): 13 | 6
Width (ft | in): 8 | 2
Number of Axles: 5

Axle  Dist.prev.axl(ft)  Weight/axl(kips)  No.Tires  Gage(ft)  Tire_Width(in)  Tire_Pressure(lb/in)
01 00.000  012.000  2  06.417   09.50  0631.579
02 08.750  024.500  4  06.080   09.50  0644.737
03 04.000  024.500  4  06.080   09.50  0644.737
04 27.667  023.500  4  06.500   09.50  0618.421
05 04.167  023.500  4  06.500   09.50  0618.421

Vehicle's Maximum Wheel Base is: 044.58 ft
Vehicle's Center of Gravity from the 1st axle is: 023.37 ft

Jurisdiction Rules and Regulations

Jurisdiction: Texas
Legal height (ft | in): 14 | 06 -> Satisfied
Legal width (ft | in): 08 | 06 -> Satisfied
Max. tire pressure: 0650.000 lb/in -> Satisfied
Max. allow. group wt. (See below) -> NOT Satisfied

First_grp_Axl Axles/group WheelBase(ft) Actual GW(kips) Allow. Legal GW(kips)
02 02 004.00  0049.000  0045.000
03 02 027.67  0048.000  0045.000
04 02 004.17  0047.000  0045.000
01 03 012.75  0061.000  0060.000
02 03 031.67  0072.500  0060.000
03 03 031.83  0071.500  0060.000
01 04 040.42  0084.500  0075.000
02 04 035.83  0096.000  0075.000
01 05 044.58  0108.000  0081.400
Bridge Evaluation Criteria

End of Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>Longitude</td>
<td>(ID 1)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.332892</td>
<td>031.672937</td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.287021</td>
<td>031.704985</td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.494656</td>
<td>031.759617</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.582115</td>
<td>032.000552</td>
</tr>
</tbody>
</table>

Turn Right  East on FR 0.00 Miles (0.00 Miles).
Continue East on ON-RAMP 0.13 Miles (1.49 Miles).
Continue East on LOOP375 0.35 Miles (1.85 Miles).
Continue East on OFF-RAM 0.15 Miles (2.00 Miles).
Continue East on FR 2.03 Miles (4.02 Miles).
Continue West on ON-RAMP 0.09 Miles (4.12 Miles).
Continue North on IH0010 8.65 Miles (12.77 Miles).
Continue West on OFF-RAM 0.11 Miles (12.87 Miles).
Continue West on FR 0.45 Miles (13.33 Miles).
Continue West on ON-RAMP 0.08 Miles (13.41 Miles).
Continue West on IH0010 0.30 Miles (13.70 Miles).
Continue West on OFF-RAM 0.08 Miles (13.70 Miles).
Continue West on FR 1.10 Miles (14.88 Miles).
Continue West on IH0010 8.82 Miles (23.70 Miles).
Continue West on OFF-RAM 0.37 Miles (24.06 Miles).
Continue West on US0085 0.07 Miles (24.14 Miles).
Continue West on ON-RAMP 0.08 Miles (24.22 Miles).
Continue North on IH0010 13.49 Miles (57.71 Miles).

Total number of routes tested before final result = 1
End of Route Description

Road Network restrictions [Database file(s) selected]
No link segments closed to traffic
No prohibited turns applied
End of road network restrictions

Links disabled and Bridges avoided due to limited vertical clearance
Total number of bridges evaluated for vertical clearance = 79
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance
Links disabled and Bridges avoided due to limited horizontal width clearance ---
  Total number of bridges evaluated for horizontal width = 79
  No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width -------

Links disabled and Bridges avoided due to load posting -------------------------
  Total number of bridges evaluated for load posting = 53
  No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due bridges posted for load ----------

Links disabled / Bridges avoided due to missing information in BRINSAP database
  Total number of bridges evaluated for missing bridge info = 0
  No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
  Total number of bridges evaluated for load-carrying capacity = 53
  No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

--------------------------------*  End of Report  *----------------------------------

Time elapsed  00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report
Report date: Tue Sep 5 17:59:40 2000
Routing Algorithm: Shortest Path Route
District/County: D24-El Paso
Origin: Zaragoza International Bridge
Destination: Reeves County, TX
Vehicle description file: C:\D24ELP\VEH_LIB\EPCC.VEH

Vehicle Description

End of Vehicle Description

Jurisdiction Rules and Regulations

Bridge Evaluation Criteria
Bridge Load Formula
Impact Factor: 30%

End of Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link[s]</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude Latitude</td>
<td>(ID 1)</td>
<td>(ID 2)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.332892</td>
<td>031.672937</td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.281021</td>
<td>031.698607</td>
</tr>
<tr>
<td>Destination</td>
<td>-104.068610</td>
<td>031.083245</td>
</tr>
</tbody>
</table>

Proposed Route:

Continue East on FR  1.36 Miles (1.36 Miles).
Continue East on ON-RAMP  0.13 Miles (1.49 Miles).
Continue East on LOOP375  0.35 Miles (1.85 Miles).
Continue East on OFF-RAM  0.15 Miles (2.00 Miles).
Continue East on FR  1.43 Miles (3.43 Miles).
Turn Right East on RAMP  0.17 Miles (3.60 Miles).
Turn Right South on FR  0.12 Miles (3.73 Miles).
Continue East on ON-RAMP  0.09 Miles (3.82 Miles).
Continue South on IH0010  8.25 Miles (12.08 Miles).
Continue South on OFF-RAM  0.03 Miles (12.11 Miles).
Continue South on FR  0.23 Miles (12.34 Miles).
Continue East on ON-RAMP  0.04 Miles (12.38 Miles).
Continue South on IH0010  55.86 Miles (68.24 Miles).
Continue East on OFF-RAM 0.07 Miles (68.31 Miles).
Continue East on FR 0.96 Miles (69.27 Miles).
Continue East on ON-RAMP 0.20 Miles (69.47 Miles).
Continue South on IH0010 83.64 Miles (153.11 Miles).
Continue East on OFF-RAM 0.17 Miles (153.28 Miles).
Continue East on FR 0.08 Miles (153.36 Miles).
Continue East on ON-RAMP 0.22 Miles (153.57 Miles).
Continue East on IH0010 1.81 Miles (155.38 Miles).

Total number of routes tested before final result = 2
End of Route Description -----------------------------------------------

Road Network restrictions [Database file(s) selected]----------------------
No link segments closed to traffic
No prohibited turns applied
End of road network restrictions----------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance ------
Total number of bridges evaluated for vertical clearance = 159
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance ----

Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 159
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width -------

Links disabled and Bridges avoided due to load posting -------------------
Total number of bridges evaluated for load posting = 124
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load -------

Links disabled / Bridges avoided due to missing information in BRINSAP database
County/ROID  Highway  Heading  BridgeID  Comment
24072012532  IH0010  East Bound  240720212104125  missing Vertical underclearance F54_2VTCUN
Total number of bridges avoided due to missing bridge info = 1
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
Total number of bridges evaluated for load-carrying capacity = 124
No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

Time elapsed 00 h 00 m 03 s

End of Report *--------------------------------------------------------

A-32
Overweight/Oversize Vehicle Routing Report
Report date: Tue Sep 5 18:15:44 2000
Routing Algorithm: Shortest Path Route
District/County: D24-El Paso
Origin: Bridge of the Americas
Destination: Otero County, NM

Vehicle description file: C:\D24ELP\VEH_LIB\EPCC.VEH
Vehicle Description ---------------------------------------------------------------

Jurisdiction Rules and Regulations ------------------------------------------------

Bridge Evaluation Criteria
   Bridge Load Formula
   Impact Factor: 30 %

End of Jurisdiction Rules and Regulations -------

Route Description ---------------------------------------------------------------

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees) on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude Latitude (ID 1) (ID 2) (ID 3) (ID 4)</td>
<td></td>
</tr>
<tr>
<td>Origin -106.450663 031.765632 24072010636</td>
<td>-----NA---- IH0110 --NA---</td>
</tr>
<tr>
<td>Intermediate -106.439073 031.830277 24072012834</td>
<td>24072010916 US0054 US0054</td>
</tr>
<tr>
<td>Intermediate -106.441064 031.904723 24072011084</td>
<td>24072011093 US0054 ON-RAMP</td>
</tr>
<tr>
<td>Destination -106.326207 032.001317 24072012530</td>
<td>-----NA---- US0054 --NA---</td>
</tr>
</tbody>
</table>

Proposed Route:
Start  North on IH0110  0.18 Miles (0.18 Miles).
Continue North on FR  0.10 Miles (0.28 Miles).
Continue North on ON-RAMP 0.04 Miles (0.31 Miles).
Turn Right East on IH0110 0.39 Miles (0.71 Miles).
Continue North on US0054 0.56 Miles (1.26 Miles).
Continue North on US0054 8.61 Miles (10.07 Miles).
Continue North on OFF-RAM 0.11 Miles (10.18 Miles).
Continue North on FR 3.51 Miles (13.69 Miles).
Continue East on US0054 6.10 Miles (19.79 Miles).

Total number of routes tested before final result = 1
End of Route Description ----------------------------------------------------------
Road Network restrictions [Database file(s) selected]---------------------------
No link segments closed to traffic
No prohibited turns applied
End of road network restrictions---------------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance -------
Total number of bridges evaluated for vertical clearance = 34
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance ----

Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 34
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width ------

Links disabled and Bridges avoided due to load posting ----------------------
Total number of bridges evaluated for load posting = 26
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to load posting for load ---------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
Total number of bridges evaluated for load-carrying capacity = 26
No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

--------------------------* End of Report *--------------------------
Time elapsed 00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report
Report date : Tue Sep  5 18:36:06 2000

Routing Algorithm       :  Shortest Path Route
District/County: D24-El Paso
Origin : Zaragoza International Bridge
Destination : Eddy County, NM

Vehicle description file: C:\D24ELP\VEH_LIB\EPCC.VEH

Route Description -------------------------------------------------------

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
<th>(ID 1)</th>
<th>(ID 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.332892 031.672937</td>
<td>24072011200</td>
<td>24072011201</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.267082 031.806470</td>
<td>24072013284</td>
<td>24072012771</td>
<td>US0180 FR</td>
</tr>
<tr>
<td>Destination</td>
<td>-104.531632 032.000034</td>
<td>24055010475</td>
<td>-----NA-----</td>
<td>US180/6 --NA--</td>
</tr>
</tbody>
</table>

Proposed Route:

Continue East on FR  1.36 Miles (1.36 Miles).
Continue East on ON-RAMP 0.13 Miles (1.49 Miles).
Continue East on LOOP375 0.35 Miles (1.85 Miles).
Continue East on OFF-RAMP 0.15 Miles (2.00 Miles).
Continue East on FR  9.17 Miles (11.17 Miles).
Turn Right East on US0180 3.45 Miles (14.62 Miles).
Continue East on US0062 78.51 Miles (93.33 Miles).
Continue East on US180/6 32.74 Miles (125.86 Miles).

Total number of routes tested before final result = 1

End of Route Description -------------------------------------------------------
Road Network restrictions [Database file(s) selected]---------------------------
No link segments closed to traffic
No prohibited turns applied
End of road network restrictions-------------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance ------
Total number of bridges evaluated for vertical clearance = 30
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance ----

Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 30
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width ------

Links disabled and Bridges avoided due to load posting ----------------------
Total number of bridges evaluated for load posting = 30
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to load posting for load ---------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity -------
Total number of bridges evaluated for load-carrying capacity = 30
No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

End of Report

Time elapsed 00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report
Report date: Thu Sep 7 18:09:10 2000
Routing Algorithm: Shortest Path Route

District/County: D24-El Paso
Origin: Zaragoza International Bridge
Destination: US 54 (Transmountain)

Vehicle description file: C:\D24ELP\VEH_LIB\EPCC.VEH
Vehicle Description: --------------------------------------------------------

Jurisdiction Rules and Regulations: ----------------------------------------

Bridge Evaluation Criteria
Bridge Load Formula
Impact Factor: 30%

End of Jurisdiction Rules and Regulations

Route Description: --------------------------------------------------------

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>In Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude Latitude (ID 1)</td>
<td>(ID 2) (1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.352892</td>
<td>031.672937</td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.267374</td>
<td>031.811011</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.440388</td>
<td>031.898809</td>
</tr>
</tbody>
</table>

Proposed Route:
- Turn Right East on FR 1.36 Miles (1.36 Miles).
- Continue East on ON-RAMP 0.13 Miles (1.49 Miles).
- Continue East on LOOP375 19.98 Miles (21.48 Miles).
- Continue West on OFF-RAMP 0.40 Miles (21.87 Miles).
- Continue West on FR 3.02 Miles (24.89 Miles).

Total number of routes tested before final result = 1

End of Route Description

Road Network restrictions: [Database file(s) selected]
- No link segments closed to traffic
- No prohibited turns applied

End of road network restrictions

A-37
Links disabled and Bridges avoided due to limited vertical clearance ----------
Total number of bridges evaluated for vertical clearance = 8
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance ----

Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 8
No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width ------

Links disabled and Bridges avoided due to load posting ------------------------
Total number of bridges evaluated for load posting = 8
No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due bridges posted for load ----------

Links disabled / Bridges avoided due to missing information in BRINSAP database
Total number of bridges evaluated for missing bridge info = 0
No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
Total number of bridges evaluated for load-carrying capacity = 8
No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

------------------------* End of Report *------------------------

Time elapsed 00 h 00 m 00 s
Overweight/Oversize Vehicle Routing Report

Report date: Thu Sep 7 18:18:04 2000

Routing Algorithm: Shortest Path Route

District/County: D24-El Paso
Origin: Intersection of IH 10 and US 90
Destination: Terrel County, TX

Vehicle description file: C:\D24ELP\VEH_LIB\EPCC.VEH
Vehicle Description -------------------------------------------------------------
.
End of Vehicle Description -----------------------------------------------------

Jurisdiction Rules and Regulations ---------------------------------------------
.

Bridge Evaluation Criteria
Bridge Load Formula
Impact Factor: 30 %

End of Jurisdiction Rules and Regulations -------

Route Description ----------------------------------------------------------------

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>ID 1</td>
</tr>
<tr>
<td>Origin</td>
<td>-104.830357</td>
<td>031.036255</td>
</tr>
<tr>
<td>Destination</td>
<td>-103.324970</td>
<td>030.588877</td>
</tr>
</tbody>
</table>

Proposed Route:
Start South on US0090 73.32 Miles (73.32 Miles).
Continue East on US67/90 34.46 Miles (107.78 Miles).
Continue North on US0067 19.63 Miles (127.41 Miles).

Total number of routes tested before final result = 1
End of Route Description -------------------------------------------------------

Road Network restrictions (Database file(s) selected)--------------------------
No link segments closed to traffic
No prohibited turns applied

End of road network restrictions-------------------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance -------
Total number of bridges evaluated for vertical clearance = 170
No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance ----
Links disabled and Bridges avoided due to limited horizontal width clearance ---
  Total number of bridges evaluated for horizontal width = 170
  No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width -------

Links disabled and Bridges avoided due to load posting ------------------------
  Total number of bridges evaluated for load posting = 168
  No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load ---------

Links disabled / Bridges avoided due to missing information in BRINSAP database
  Total number of bridges evaluated for missing bridge info = 0
  No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
  Total number of bridges evaluated for load-carrying capacity = 168
  No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

*-------------------------------*  End of Report  *-------------------------------*

Time elapsed  00 h 00 m 01 s
Overweight/Oversize Vehicle Routing Report
Report date : Thu Sep  7 18:51:00 2000
Routing Algorithm : Shortest Path Route

District/County: D24-El Paso
Origin : Zaragoza International Bridge
Destination : Dona Ana County, NM

Vehicle description file: C:\D24ELP\VEH_LIB\EPCC.VEH

Jurisdiction Rules and Regulations

Route Description

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees) on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>Longitude (ID 1)</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>Origin</td>
<td>-106.33289</td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.287021</td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.494656</td>
</tr>
<tr>
<td>Destination</td>
<td>-106.582115</td>
</tr>
</tbody>
</table>

Proposed Route:

<table>
<thead>
<tr>
<th>Turn Right</th>
<th>Distance (Miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East on FR</td>
<td>0.00 Miles (0.00 Miles).</td>
</tr>
<tr>
<td>Continue East on ON-RAMP</td>
<td>0.13 Miles (1.49 Miles).</td>
</tr>
<tr>
<td>Continue East on LOOP375</td>
<td>0.35 Miles (1.85 Miles).</td>
</tr>
<tr>
<td>Continue East on OFF-RAMP</td>
<td>0.15 Miles (2.00 Miles).</td>
</tr>
<tr>
<td>Continue East on FR</td>
<td>2.03 Miles (4.02 Miles).</td>
</tr>
<tr>
<td>Continue West on ON-RAMP</td>
<td>0.09 Miles (4.12 Miles).</td>
</tr>
<tr>
<td>Continue North on IH0010</td>
<td>8.65 Miles (12.77 Miles).</td>
</tr>
<tr>
<td>Continue West on OFF-RAMP</td>
<td>0.11 Miles (12.87 Miles).</td>
</tr>
<tr>
<td>Continue West on FR</td>
<td>0.45 Miles (13.33 Miles).</td>
</tr>
<tr>
<td>Continue West on ON-RAMP</td>
<td>0.08 Miles (13.41 Miles).</td>
</tr>
<tr>
<td>Continue West on IH0010</td>
<td>0.30 Miles (13.70 Miles).</td>
</tr>
<tr>
<td>Continue West on OFF-RAMP</td>
<td>0.08 Miles (13.78 Miles).</td>
</tr>
<tr>
<td>Continue West on FR</td>
<td>1.10 Miles (14.88 Miles).</td>
</tr>
<tr>
<td>Continue West on IH0010</td>
<td>8.82 Miles (23.70 Miles).</td>
</tr>
</tbody>
</table>
Continue West on OFF-RAM 0.37 Miles (24.06 Miles).
Continue West on US0085 0.07 Miles (24.14 Miles).
Continue West on ON-RAMP 0.08 Miles (24.22 Miles).
Continue North on IH0010 13.49 Miles (37.71 Miles).

Total number of routes tested before final result = 1
End of Route Description -----------------------------------------------

Road Network restrictions [Database file(s) selected]-----------------------
  No link segments closed to traffic
  No prohibited turns applied
End of road network restrictions------------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance ------
  Total number of bridges evaluated for vertical clearance = 79
  No links were disabled and no bridges were avoided due to limited vertical clearance
End of links disabled and bridges avoided due to limited vertical clearance

Links disabled and Bridges avoided due to limited horizontal width clearance ---
  Total number of bridges evaluated for horizontal width = 79
  No links were disabled and no bridges were avoided due to limited horizontal width
End of links disabled and bridges avoided due to limited horizontal width

Links disabled and Bridges avoided due to load posting --------------------
  Total number of bridges evaluated for load posting = 53
  No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to load posting

Links disabled / Bridges avoided due to missing information in BRINSAP database
  Total number of bridges evaluated for missing bridge info = 0
  No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity ------
  Total number of bridges evaluated for load-carrying capacity = 53
  No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

------------------------------------------ End of Report  *------------------------------------------
Time elapsed 00 h 00 m 03 s
CONCRETE MIXER DELIVERY TRUCK

Model: Bering HDMX / Kenworth W900S  
Date: July 20, 2000  
Source: http://www.beringtruck.com/literature/hdmxspec.pdf [Bering website]  

- Weights and dimensions correspond to Kenworth model W900S [Kenworth website].  
- Tire sizes correspond to Bering model HDMX [Bering website].

---

**Figure A9. Concrete-mixer Descriptive Attributes. Bering / Kenworth Model.**

<table>
<thead>
<tr>
<th>MIXER</th>
<th>Axle 1</th>
<th>Axle 2</th>
<th>Axle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Tires</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Tire Width</td>
<td>15.5”</td>
<td>11.5”</td>
<td>11.5”</td>
</tr>
<tr>
<td>Tire Diameter</td>
<td>42.7”</td>
<td>41”</td>
<td>41”</td>
</tr>
<tr>
<td>Weight per Axle</td>
<td>20 kips</td>
<td>29 kips</td>
<td>29 kips</td>
</tr>
<tr>
<td>Dist. from Previous Axle Gage</td>
<td>0’-0”</td>
<td>16’-4”</td>
<td>8’-8”</td>
</tr>
<tr>
<td></td>
<td>6’-5”</td>
<td>6’-1”</td>
<td>6’-1”</td>
</tr>
<tr>
<td>Total Width</td>
<td>8’-6”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Height</td>
<td>13’-6”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Weight</td>
<td>78 kips</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Concrete Mixer l.txt

Overweight/Oversize Vehicle Routing Report

Routing Algorithm: Shortest Path Route
Network model: C:\D24ELP\NETWORKS\D24.NET

Vehicle Description

Model: Mixer Truck
Type: Bering HDMX/Kenworth W900S
Nominal Capacity: 78 kip
Height (ft | in): 13 | 6
Width (ft | in): 8 | 6
Number of Axles: 3

Axle Dist.prev.axl(ft) Weight/axl(kips) No.Tires Gage(ft) Tire Width(in) Tire Pressure(lb/in)
01 00.000 020.000 2 06.417 15.50 0650.161
02 16.333 029.000 4 06.083 11.50 0630.435
03 08.667 029.000 4 06.083 11.50 0630.435

Vehicle's Maximum Wheel Base is = 025.00 ft
Vehicle's Center of Gravity from the 1st axle is = 015.37 ft

End of Vehicle Description

Jurisdiction Rules and Regulations

Jurisdiction: Texas
Legal height (ft | in): 14 | 06 --> Satisfied
Legal width (ft | in): 08 | 06 --> Satisfied
Max. tire pressure: 0650.000 lb/in --> Satisfied
Max. allow. group wt.: (See below) --> NOT Satisfied

End of Jurisdiction Rules and Regulations

Route Description

Geographic Coordinates (Degrees) on Road Link(s) Highway ID
Longitude Latitude (ID 1) (ID 2) (1) (2)
Origin -106.297595 031.686118 24072012694 24072011306 FR FM0076
Intermediate -106.319702 031.735748 24072011984 24072011985 IH0010 OFF-RAM
Intermediate -106.440559 031.782722 24072010783 24072010790 US0054 OFF-RA
Destination -106.440373 031.898081 24072011086 24072013198 FR FR
Proposed Route:

Start  East on FR  1.78 Miles  (1.78 Miles).
Continue West on ON-RAMP  0.09 Miles  (1.87 Miles).
Continue North on IH0010  8.65 Miles  (10.52 Miles).
Continue West on OFF-RAMP  0.11 Miles  (10.63 Miles).
Continue West on FR  0.45 Miles  (11.08 Miles).
Continue West on ON-RAMP  0.08 Miles  (11.16 Miles).
Continue West on IH0010  0.30 Miles  (11.46 Miles).
Continue West on OFF-RAMP  0.08 Miles  (11.54 Miles).
Continue West on FR  0.23 Miles  (11.76 Miles).
Continue West on ON-RAMP  0.07 Miles  (11.83 Miles).
Continue West on IH0010  0.57 Miles  (12.40 Miles).
Continue West on OFF-RAMP  0.30 Miles  (12.70 Miles).
Continue West on ON-RAMP  0.21 Miles  (12.91 Miles).
Turn Right North on US0054  5.90 Miles  (18.81 Miles).
Continue North on OFF-RAMP  0.24 Miles  (19.05 Miles).
Continue North on FR  2.07 Miles  (21.13 Miles).

Total number of routes tested before final result = 1
End of Route Description -----------------------------------
Concrete Mixer 2.txt

Overweight/Oversize Vehicle Routing Report  
Report date: Fri Sep 15 15:50:55 2000

Routing Algorithm: Shortest Path Route

Route Description -----------------------------------------------

<table>
<thead>
<tr>
<th>Geographic Coordinates (Degrees)</th>
<th>on Road Link(s)</th>
<th>Highway ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude Latitude (ID 1) (ID 2)</td>
<td>(1) (2)</td>
<td></td>
</tr>
<tr>
<td>Origin</td>
<td>-106.618402 031.999857 24072011149 NA NA FM1905 NA</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.51588 031.844029 240720101175 24072012664 IH0010 OFF-RAM</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.494399 031.759547 24072010281 24072010554 IH0010 OFF-RAM</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>-106.440415 031.814524 24072010870 24072010891 US0054 OFF-RAM</td>
<td></td>
</tr>
<tr>
<td>Destination</td>
<td>-106.440373 031.898081 24072011086 24072013198 FR FR</td>
<td></td>
</tr>
</tbody>
</table>

Proposed Route:
Start East on FM1905 0.76 Miles (0.76 Miles).
Turn Right South on SH0020 6.34 Miles (7.10 Miles).
Turn Left East on LOOP375 0.94 Miles (8.05 Miles).
Turn Right South on FR 0.21 Miles (8.26 Miles).
Continue South on ON-RAMP 0.12 Miles (8.37 Miles).
Continue South on IH0010 12.42 Miles (20.79 Miles).
Continue East on OFF-RAM 0.33 Miles (21.12 Miles).
Continue East on ON-RAMP 0.29 Miles (21.41 Miles).
Continue East on IH0010 2.25 Miles (23.66 Miles).
Continue East on OFF-RAM 0.40 Miles (24.06 Miles).
Turn Left North on FR 1.62 Miles (25.69 Miles).
Continue North on ON-RAMP 0.15 Miles (25.83 Miles).
Continue North on US0054 4.57 Miles (30.41 Miles).
Continue North on OFF-RAM 0.24 Miles (30.65 Miles).
Continue North on FR 2.07 Miles (32.72 Miles).

Total number of routes tested before final result = 1

End of Route Description -----------------------------------------------

Links disabled and Bridges avoided due to limited vertical clearance --------
Total number of bridges evaluated for vertical clearance = 60
No links were disabled and no bridges were avoided due to limited vertical clearance

End of links disabled and bridges avoided due to limited vertical clearance ----

Links disabled and Bridges avoided due to limited horizontal width clearance ---
Total number of bridges evaluated for horizontal width = 60
No links were disabled and no bridges were avoided due to limited horizontal width

End of links disabled and bridges avoided due to limited horizontal width ------
Links disabled and Bridges avoided due to load posting --------------------------
  Total number of bridges evaluated for load posting = 44
  No links were disabled and no bridges were avoided due to bridges posted for load
End of links disabled and bridges avoided due to bridges posted for load ---------

Links disabled / Bridges avoided due to missing information in BRINSAP database 
  Total number of bridges evaluated for missing bridge info = 0
  No links were disabled and no bridges were avoided due to missing info in BRINSAP
End of links disabled and bridges avoided due to missing information in BRINSAP

Links disabled and Bridges avoided due to limited load-carrying capacity -------
  Total number of bridges evaluated for load-carrying capacity = 44
  No links were disabled and no bridges were avoided due to limited load-carrying capacity
End of links disabled and bridges avoided due to limited load-carrying capacity

-----------------------------*  End of Report  *-------------------------------
Time elapsed  00 h 00 m 01 s