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THE SASKATCHEWAN TRANSPORTATION MODEL AND ITS USE IN REGIONAL TRANSPORTATION PLANNING

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BACKGROUND

Introduction

Perhaps the most important issue facing road authorities in Saskatchewan is the rapidly changing grain handling and transportation network. Changes are placing an increased burden on the rural road network during an era of government restraint and debt management. Changing grain transportation is the driving force behind the recent formation of Regional Transportation Planning Councils (RTPC s). The Saskatchewan Transportation Model (STM) was developed in 1992 as a planning tool to help the Saskatchewan Department of Highways & Transportation (DHT) and RTPC s prepare for grain transportation rationalization.

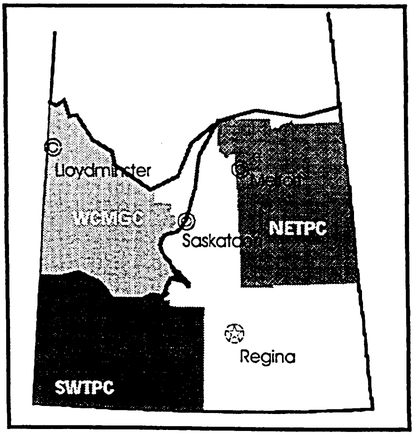
Regional Transportation Planning Councils (RTPC's)

In their 1994 report, the Transportation Policy Council, appointed by the provincial Minister of Highways & Transportation and comprised largely of municipal government leaders, identified an opportunity to move decision making to the local level. Stakeholders who have to live with the decisions must be given the opportunity to play a major role in determining their transportation system. They recommended to develop a process to permit elected representatives of municipal government to participate more effectively in transportation related decisions. This recommendation led directly to the formation of RTPC s.

The emerging regional (as opposed to local) nature of grain movement has created an even greater role for RTPC s. Saskatchewan rural municipalities (RM s) are relatively small geographical areas. Changes which occur outside an RM s boundaries can have significant social and economic consequences within that municipality.

The first RTPC formed on March 10, 1995 is the _Southwest_ Transportation Planning Council, Inc. (SWTPC). On February 24, 1997, potential members of the _Northeast_ Transportation Planning Committee (NETPC) agreed in principle to form an RTPC. The _West Central_ Municipal Government Committee (WCMGC), dealing with all types of government issues, formed a Transportation Subcommittee in February, 1995. This subcommittee is considered to be the equivalent of an RTPC. The map in Figure 1 shows the boundaries of these three organizations within Saskatchewan s grain producing area. Interest has been expressed in forming councils in other areas of the province.

Figure 1: RTPC Boundaries



Urban and rural municipal representatives of the RTPC s work cooperatively together, and with DHT, to decide the future needs and priorities for the Saskatchewan road network. However, the ultimate responsibility still lies with each jurisdiction for its portion of the overall network. This partnership in planning approach keeps with the long-standing spirit of Saskatchewan cooperatives.

Changes in Grain Transportation

Saskatchewan, often referred to as the Canadian grain basket , accounts for 55% of the nation s export grain industry. Agriculture in Saskatchewan, of which grain is the primary component, accounts for by far the largest percentage of the total economy of any province at about 12%. The great distance to ports means that grain transportation efficiencies are vital to Saskatchewan s economy in the global marketplace.

The grain industry has seen many changes over the last quarter century, and the industry is presently undergoing a massive rationalization. Abandonment of grain dependent branch lines, and consolidation of the grain elevator network are the key components of the rationalization.

Changes are occurring at a highly accelerated rate as a result of the August 1, 1995 elimination of the Western Grain Transportation Act (WGTA) and Crow Benefit rail freight rate subsidy, plus the new Canada Transportation Act (CTA), which provides a streamlined process for CN and CP to divest themselves of unprofitable branch lines. The following is a summary of changes affecting grain transportation.

Rail Branch Line Abandonment - The original 16,000 km rail system has been reduced to the present 5,700 km branch line system and likely will be shorter by the Year 2000. There is potential for a select few of the more viable branch lines to be saved by short line operators.

Grain Elevator Consolidation - The bottom line cause of increased grain traffic and resulting road damage is the increasing spatial distribution of grain delivery points. Consolidation would still be occurring to a large extent even without rail line abandonment, but the two issues do go hand in hand.

Older, smaller low throughput (LTP) wooden crib elevators, once commonplace to the prairie landscape, are being replaced by fewer, larger concrete high throughput (HTP) elevators[1]. The number of Saskatchewan elevators and delivery points have been steadily decreasing from 1,940 and 954 respectively in 1971, to 663 and 433 in 1996. With the accelerated rate of change, it s anticipated that there could be as few as 250 delivery points by the Year 2000, and less than 100 after the rationalization process settles down early in the 21st century.
HTP elevators provide added services, such as; grain cleaning, drying, blending, and agricultural information/resource centres. They are able to offer producers financial incentives to overcome higher trucking costs to attract greater volumes, due to multi-car loading incentives from the railways, inland processing advantages, and large economies of scale. It

[1] LTP s typically have a storage capacity of 2,500 - 6,000 tonnes and handle about 20K - 25K tonnes annually. HTP s have about 10K - 30K tonnes storage and handle 75K to 250K or more annually.

is questionable whether these incentives will still be offered once HTP elevators are the rule, and network rationalization is complete.

Larger Trucks - Longer hauls are more efficiently handled by larger (5+ axle) commercial trucks as opposed to 2 and 3-axle farm trucks. Once the grain is on a large commercial unit, the added cost to haul an incremental greater distance is small.

Inter-Elevator Transfers - describes the practice of moving grain from LTP to HTP elevators. In this case, LTP elevators act as satellite collection points for HTP elevators. Inter-elevator transfers are generally performed by truck, and can be even more damaging than if the satellite point didn t exist. Transfers often involve backhaul over producer haul routes, and are concentrated over short periods of time. This practice may be diminishing, as some major grain companies move to a best place first policy and procure grain directly off the farm.

Shift in Agricultural Activities - The loss of the $721 million/yr. Crow Rate Benefit, or two-thirds of the cost of moving export grain from elevator to port, is making other activities more attractive. Activities such as; domestic food processing of grains and oilseeds, livestock (primarily hogs), and specialty crops (potatoes, pulses, forage, etc.) are on the rise. These shifts will be most notable in central and eastern Saskatchewan, which are further from the port of Vancouver[2]. Some of these alternative activities are more damaging to roads than export grain is. Processing plants truck in raw materials from great distances, and truck out much of their product and bi-product. Specialty crops such as potatoes can be much higher yielding than grain.

Road Impacts

Saskatchewan has the most extensive rural road network in the country, with about 26,000 km of provincial highway and 160,000 km of rural road serving just over one million people. The system was developed with the intention of providing access to a close knit network of elevators and farm sites. Producers typically had no more than 10 to 15 km to haul to their nearest local elevator. This has resulted in a network of mostly low volume/low standard roads.

Thin membrane surfaces (TMS s), which are unique to Saskatchewan, are a thin (20 to 50 mm) asphalt mat placed directly on top of the subgrade. These surfaces were intended to provide a dust, mud, rock free

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[2] The majority of Saskatchewan s export grains are shipped through the west coast with the growing dependence on Asian markets. Only the southeast corner of the province has Thunder Bay as their primary port.

alternative to gravel surfaces, but are not designed to withstand large volumes of heavy truck traffic. There are 9,360 km of provincial and some municipal TMS roads in Saskatchewan. Some of these serve as major feeders to new HTP elevator sites. The result of this is inordinately high maintenance costs and/or costly upgrading.

Incremental municipal road costs are highly uneven. RM s adjacent to new HTP elevators are bearing the brunt of the cost with none of the economic benefits from these facilities. Saskatchewan s RM s are too small to absorb large budgetary increases.

There are traffic impacts to consider other than road surface structural impacts caused by increased truck traffic. More trucks on narrow (mostly gravel and TMS) rural roads is a safety concern. There is also an environmental concern with greater fuel emissions.

System Optimization Approach to Grain Transportation Planning

Ideally, stakeholders should be working toward improving overall system efficiency. There are four primary stakeholder groups (producers, railways, grain companies and government) and four cost elements (trucking, elevation, rail and road) to consider.

Trucking Costs - are of primary concern to producers. HTP elevators offset trucking costs with incentives to encourage longer hauls.

Elevation Efficiencies - are of primary concern to grain companies. Handing costs alone can be deceptive in that HTP elevators provide more services, and can attract larger volumes to help increase market share.

Rail Costs - are of primary concern to the rail companies. In Saskatchewan that generally refers to the Class 1 duopoly of CN and CP. In some regions of the province either company holds a complete monopoly on rail service. Short lines can potentially operate a viable branch line service at a lower cost than can CN or CP.

Road Costs - are the primary concern of municipal and provincial governments. Producers are also indirectly affected through higher taxes. Unlike the other cost elements, road costs are not strictly user pay, especially when it comes to regional heavy truck traffic. Costs incurred by another jurisdiction have no impact on an individual producer s decision regarding where to haul. Grain and rail companies feel that government money will always be available for changing infrastructure needs. If it was practical to implement a true user pay system, perhaps road impacts would be given their due consideration.

Stakeholders have separate and competing interests. Naturally, each will make decisions in their own best interest. In the end, it is the producers who pay the price, but they also have the ultimate power if they act collectively. It is questionable whether efficiencies realized by the rail and grain companies through system rationalization will be passed on in part or in their entirety to producers.

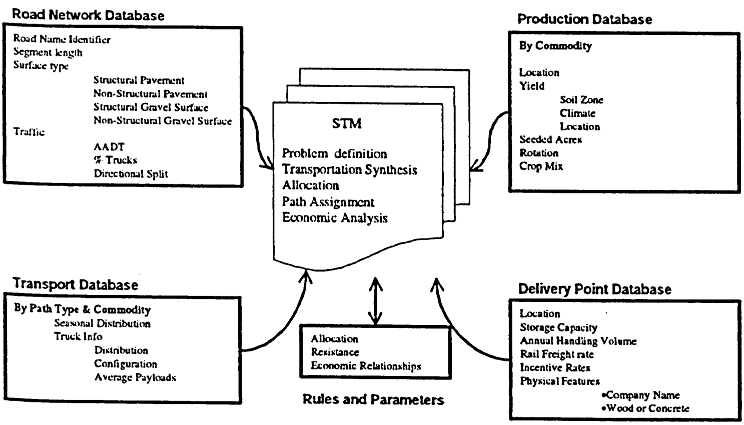
TRANSPORTATION MODELING

General Overview

In the early 90 s, DHT put together an initiative to develop a comprehensive transportation planning model called the Saskatchewan Transportation Model (STM). STM is essentially a set of GIS based analytical tools used primarily to quantify the costs associated with the structural changes occurring in the grain handling and transportation industry. This paper specifically makes reference to grain transportation modeling; however STM has been used to model other commodity traffic as well.

The model simulates origin to destination commodity traffic flow based on a given set of parameters or rules that determine routing. The commodity paths are stored in a database by path type, each path type is superimposed and accumulated for each road and highway link. The traffic modeling outputs can be passed on to economic cost models to estimate incremental system costs (road, elevation, rail, and trucking).

Figure 2: System Approach Used in Saskatchewan Transportation Model



Information Sources

The Saskatchewan Transportation Model incorporates several databases designed to represent origin and destination nodes, links for the rural municipal road and highway networks, characteristics of the transport system, and the rules and parameters that the model runs under.

Road Network Database- Provincial road network databases contain tabular information that includes road location identifiers, direction of travel, segment lengths, classification, surface type, and traffic volumes. The road network databases include both the provincial highway network and the rural municipal road networks.

Grain Production Database- The grain production database contains information specific in the calculation of crop volume. Grain production is calculated for each township location by crop type based on soil zone type, crop yields, crop rotations and mixes. Information is provided by Saskatchewan Crop Insurance, Prairie Farm Rehabilitation Administration, and Saskatchewan Agriculture and Food. Grain commodities include the seven major grains and oilseeds grown in Saskatchewan[3].

Delivery Point Database- Consists of elevator and agricultural processing information collected from the Canada Grains Commission and the Canadian Wheat Board. This information is supplemented by information provided by individual grain companies. The information includes delivery point locations, storage capacity, annual handling volume, rail freight rates, typical incentive rates, owner, and elevator type.

Transport Database- Consists of information that describes how and when the commodities are being hauled. The seasonality and mixture of truck types being used_varies for each commodity and path type.

Rules and Parameters

The rules and parameters determine O-D commodity allocation and the paths that are taken. Rules and parameters are tied to economic relationships such as path resistances, rail freight rates, trucking rates, and elevator incentives.

STM Modeling Components

Because of the scale and complexity of grain logistics, it is very difficult to simulate all the possible decisions that a producer will make in the delivery of grain. The approach used in the STM is to: 1) understand the major commodity movements, 2) research the physical constraints that limit commodity flows, and 3) develop the economic relationships that drive producer decision making.

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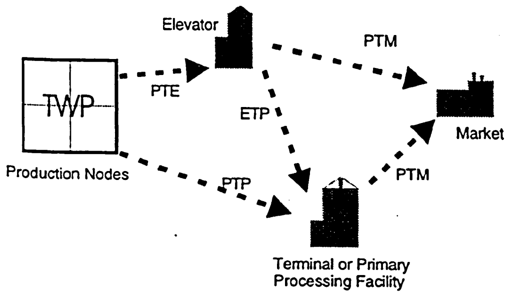
[3] Wheat, Oats, Durum, Barley, Rye, Canola, & Flax

To simplify our understanding of grain commodity movements it is necessary to break it into components that are easily modeled. It s assumed that each commodity is hauled from the farm to the elevator collection points (PTE). A portion of the deliveries may a transferred from the country elevator system to the larger terminals located on the mainline or even specialty processing facilities (ETP), with the majority remaining on site for rail delivery to port for export (PTM). In addition, some of each commodity is also hauled directly from the production nodes to the larger terminals or specialty processing facilities (PTP). The concentration of haul and the distribution of trucks varies seasonally for each haul type. Truck size tends to vary with length of haul and haul type.

Figure 3: Showing Grain Logistics.



Problem Definition

The systems approach to grain transportation requires a clear understanding of the level of rationalization in both rail and elevation networks, as well as policy changes that may be occurring in agriculture that affect production (quantity and location) and processing diversification.

Problem definition provides the framework for synthesizing grain logistics using the Saskatchewan Transportation Model. GIS software is used to setup the origin and destination locations and transportation network options that will be identified as possible scenarios. The expected outputs are scenario arrays defining the changes projected to occur regarding network consolidation, transportation economics, and commodity diversification.

Transportation Synthesis

The model combines the spatial analysis capabilities of GIS with the data manipulation sophistication of commercially available software packages such as spreadsheets and databases. A shortest path routing algorithm is used within GIS to determine a matrix of origin-destination path string combinations for four different path categories. The path strings are determined for producer to elevator (PTE), elevator to processor transfers (ETP), producer to processor (PTP), and processor to market hauls (PTM).

Allocation

Once a path string matrix is created, each commodity is allocated to the elevator using a linear programming algorithm. When the commodity is allocated to the elevator system based on production and handling constraints, an allocation matrix is used to assign commodity flows to the path string matrix. The allocation of grain from origin to destination is defined in the allocation matrix. Since the allocation table controls the volume of commodity on each path, the model has the flexibility to consider different alternatives by changing the allocation

The linear programming model used to determine the allocation matrix has an objective function that minimizes differential cost to the producer. The producer s cost is the difference between trucking cost and site cost.

H	=	T + (R I)
T	=	Trucking costs (distance based)
R	=	Rail Freight rates
I	=	Elevator incentives such as blending, elevation, storage, screening, unit car benefits.

The objective function is minimized with regards to production and elevator capacity constraints:

$$\text{Minimize } C = H_{ij} X_{ij} + H_{i+1\ j+1} X_{i+1\ j+1} + .$$

$$X_{ij} + X_{i+1\ j+1} + \ . \ \leq T_i$$

$$X_{ij} + X_{i+1\ j+1} + \ . \ \leq E_i$$

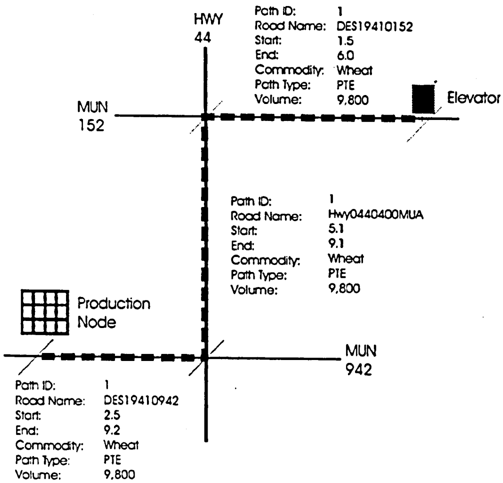
Where:

H	The Producers cost of transporting grain from the township (i) to elevator (j).
X	The tonnage hauled from township (i) to elevator (j)
T	The production constraint at township (i)
E	The capacity constraint at elevator (j)

Path Assignment

The *path string matrix* contains links to all road segments traveled for each path using a process called dynamic segmentation. The dynamically segmented road sections link to the road network databases by the road name identifier and by start and end kilometers. Through the allocation table, each path string is linked by path and commodity types to the production and transport databases

Figure 4: Origin-Destination Path string



Economic Analysis

Commodity traffic volumes generated by STM can be downloaded to a number of economic analysis models to determine road, rail, elevator, and trucking costs. Each of these models determine the total grain transportation systems cost.

Trucking Cost Model- The trucking cost model links vehicle-operating, labor, and administration costs to the truck distribution and segment haul lengths to estimate the cost of hauling grain for any given scenario. Vehicle operating costs per tonne-km for each truck configuration and surface type includes: capital depreciation, utilization, fuel, oil, maintenance, tire, insurance and registration.

Elevation Cost Model- The elevation cost model considers the average elevator operating costs and fixed costs for concrete and wooden elevators of different capacities. Operating costs include labor, maintenance, utilities, and marketing. Fixed costs include capital depreciation, taxes, and insurance.

Rail Cost Model- The rail cost model is used to estimate the annual cost of operating either a class1 or short-line operation. The model considers the average operating and fixed costs per tonne kilometer needed to operate a branch line. The operating costs considered are: labor, fuel and oil, track maintenance, engine maintenance, administration, and marketing. The fixed costs considered are: annualized cost of rail at salvage value, depreciated cost of locomotive, taxes, and insurance.

Road Cost Model- The road cost model is an experience-based model that estimates incremental costs of maintenance and capital upgrading due to modeled grain traffic on each road segment. Capital improvement decisions are based on the probability that a given existing road classification is suitable to carry the increased truck traffic. Maintenance costs are estimated using experience based cost functions. All costs are annualized over a 20 year period.

REGIONAL TRANSPORTATION STUDY RESULTS

DHT has recently performed STM traffic modeling and study analysis for the SWTPC and WCMGC.

Southwest Transportation Planning Council Study

Only producer to elevator (PTE) grain traffic was modeled for the existing and two future rail/elevator network scenarios. A systems optimization approach was taken; considering road, rail, elevation and trucking costs for the handling of the region s 2.44 million annual tonnes of export grain.

Scenarios

Delivery points for each of the following scenarios are shown in the traffic flow maps in Figure 5.

Scenario 1 - represents the highest predicted level of elevator consolidation. Seven delivery points would serve the region, including two located outside the region. These points are located on the CP main and non-grain dependent branch lines.

Scenario 2 - represents a modified version of the existing scenario, with 45 of the existing 65 delivery points plus the branch lines serving these points assumed open. Many of the 20 eliminated points are quite small and will be phased out shortly. This scenario provides a good benchmark with which to compare the two future scenarios.

Scenario 3 - represents a future scenario with a much lower level of consolidation than Scenario 1. There are 24 delivery points including the two outside the region.

Traffic Flow Maps

STM model accumulated grain traffic for the three southwest scenarios is shown in Figure x below. Note the much greater traffic volumes in Scenario 1, where grain is forced to move up to 150 km along N-S corridors from the Montana border to Swift Current and Gull Lake.

Figure 5: High Impact South West Road Sections Scenario 1

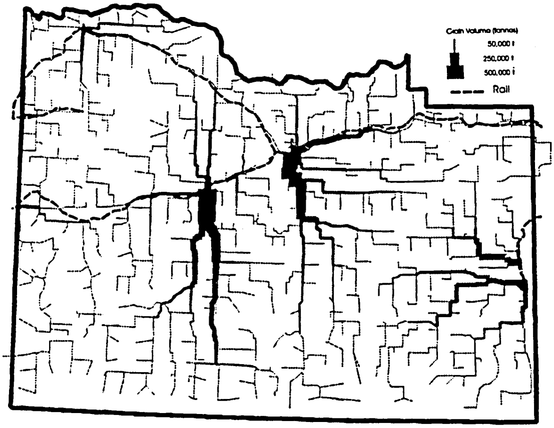


Figure 6: High Impact South West Road Sections Scenario 2

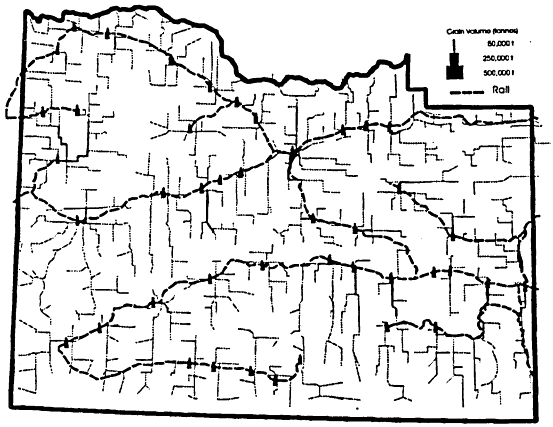
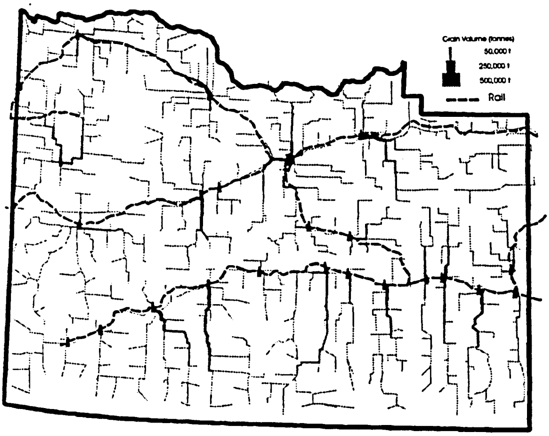


Figure 7: High Impact South West Road Sections Scenario 3



Systems Cost Analysis

Figure 8: Southwest Transportation Study Scenario Costs ($ million)

Scenario	1	2a	2b	3a	3b
Avg. Truck Haul (km)	66.8	24.6	24.6	32.6	32.6
Elevation	26.3	19.2	19.2	19.7	19.7
HTP Value Added	12.2	1.7	1.7	3.8	3.8
Net Elevation	14.1	17.5	17.5	15.9	15.9
Truck Cost	30.7	19.9	19.9	24.3	24.3
Rail Cost[4]	5.1	20.1	15.2	15.7	12.2
Subtotal	**49.9**	**57.5**	**52.6**	**55.9**	**52.4**
Road Impact Cost	14.3	8.6	8.6	11.6	11.6
Overall Net Cost	**64.2**	**66.1**	**61.2**	**67.5**	**64.0**

When road costs are not considered, Scenario 1 with the greatest level of consolidation appears most attractive. However, when road costs are added to the equation, a more moderate level of consolidation would appear prudent from an systems optimization perspective. Viable short lines have the potential to reduce operating costs in Scenarios 2b and 3b.

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[4] Rail costs for Scenarios 2a and 3a represent estimated Class 1 carrier costs. Rail costs for Scenarios 2b and 3b represent estimated short line operating costs.

Further Work

The results of this preliminary planning study have led to initiatives in; short line rail and alternative loading methods feasibility, traffic analysis for other commodities (oil), and developing a road management plan for the region.

West Central Municipal Government Comm. Transportation Plan

Unlike the earlier southwest study, the west central study was only concerned with road impacts related to three issues:

Grain Industry Changes - elevator consolidation, rail line abandonment and transfers to inland grain terminals.

Food Processing - This considers growing value added domestic processing activity in areas such as; canola crushing, malt barley processing and flour mills, and is tied to the abolishment of the Crow Rate subsidy.

Increased Irrigation and Expanding Lucky Lake Area Potato Industry - Potatoes are generally far more damaging to roads than is grain (much higher yields, 100% trucked, concentrated hauls).

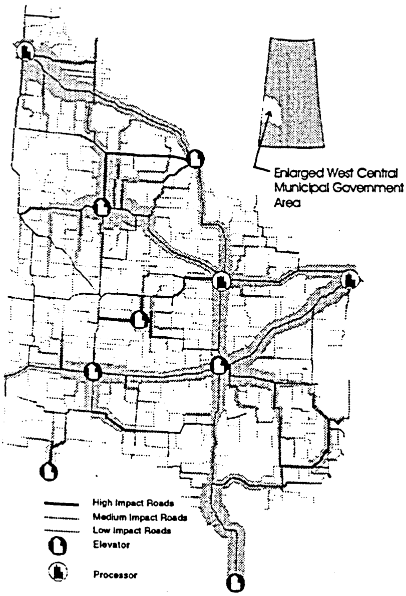
Although the scope of the project was to model as much agricultural traffic as practical, many activities of much lower order of magnitude could not be practically modeled.

Scenarios related specifically to grain elevator and food processing delivery points were developed for the Years 2000 and 2005. There was no existing scenario run to compare with the future scenarios.

The study s main objective was to determine which road sections are likely to be heavily affected by future developments related to the three stated issues. Figure 9 below provides an indication of which road sections are highly likely to require upgrading by the Year 2005, as predicted by STM traffic volumes and the road impact cost model[5].

[5] The present road impact cost model is used for macro cost analysis. It is not intended to be used to predict individual road performance.

Figure 9: High Impact West Central Road Sections (Year 2005)



This study was the testing ground for many of the enhanced STM processes described earlier, such as accumulating traffic for multiple commodities and path types, and applying seasonal distributions to traffic.

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