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Assessing the Effects of Road Pricing on an Industry: The Grain Handling and Transportation System in Saskatchewan

by Eric K. Larson and James F. Nolan

This research evaluates the merits of road pricing scenarios affecting a single industry almost exclusively – grain movement on the rural road network in the west central region of the Canadian province of Saskatchewan. Policies in the Canadian grain handling and transportation industry have led to increased use of rural roads, accelerating road deterioration in the region. Using a simulated optimization framework to compare road pricing schemes, we find that a policy of differential road pricing based on known road maintenance costs generates the lowest total social costs. The differences between the simulated social costs in the pricing scenarios are surprisingly small.

INTRODUCTION

Policies in the rail transportation sector in Canada have been liberalized significantly over the past 25 years. In particular, changes to legislation have made it easier for the Class I railways to shed low-density, high-cost, grain-dependent branch lines from their Prairie networks. Concurrently, companies in the grain-handling sector in the past few years have closed many of the smaller elevators located on remote branch rail lines and replaced them with fewer but larger high-throughput terminals located on or near the railways' trunk lines. In western Canada by the late 1990s, the publicly supplied road network served as the primary feeder system for the movement of grain to the elevator system.

Grain farming and processing remains an integral part of the regional economy of the Canadian province of Saskatchewan (Schmitz and Furtan 2000). While there is comparatively little other road traffic on many roads in the province, increased grain movements have exacerbated the deterioration of much of the provincial roadbed at a time when there are severe constraints on public spending. Unfortunately, many roads in the region were not engineered to withstand heavy trucks, and compounding this problem is that many roads in Saskatchewan are already near the end of their useful life span. Extensive grain traffic on many Saskatchewan roads continues to compromise the diminished quality of the pavement surface and roadbed (Nolan 2003).

The discourse about how to refinance repairs to these roads has been going on now for almost a decade. Policy instruments such as fuel taxes, tolls or dedicated trucking routes have all been suggested as a means to allocate truck traffic, minimize the use of certain types of road, and raise rehabilitation funds (Saskatchewan Department of Highways and Transportation 2001). However, none of these suggested policy responses to increased grain movement on the Saskatchewan road network have yet to be implemented.

The model developed in this study is designed to assess the effects of road pricing policies on a major portion of a regional road network that serves an industrial use (grain movement) almost exclusively. To do this, representative and high-quality data from the late 1990s is used to calibrate and run a simulated optimization of grain truck routing in the important west central grain producing region of the province of Saskatchewan. For tractability and as an approximation to reality, it is also assumed that complete branch rail line abandonment has occurred in the study region. This means only high-throughput elevators on the main rail lines collect grain that is eventually transported by rail to ocean port for export. Under these conditions, farmers in the region are completely dependent on trucks to move grain from farms to these elevators.

Along with a base scenario of no road pricing, two other road pricing scenarios are developed. For comparative purposes, we evaluate a pricing scenario that should be easy to implement in reality – a policy of flat tolling for grain trucking across the region. However, a more interesting scenario examined is a differential road pricing scheme designed to reflect external or damage costs associated with road use based on road surface type. In fact, the road network in Saskatchewan consists of three distinct surface types, with some types more susceptible to damage from heavy loads than others. Each scenario studied generates different private costs (road charges, trucking charges, handling tariffs, and rail freight charges) and external costs (road damage). The resultant social costs of the hypothetical scenarios are compared to determine the magnitude of the welfare changes that would occur under each scenario.[1]

THE CANADIAN GRAIN HANDLING AND TRANSPORTATION SYSTEM

The past few years have seen massive restructuring in the grain -handling and transportation system (GHTS) in Canada. For example, from 1984 to 1995, grain transportation rates and rail line abandonment were regulated under the Western Grain Transportation Act (WGTA) and at that time, grain farmers paid anywhere from 30 to 50 % of their freight costs, with the federal government covering the remainder (Vercammen et al. 1996). This transportation subsidy was commonly referred to as the "Crow benefit."

The Canada Transportation Act (CTA), which took effect at the beginning of the 1995/96 crop year (August 1, 1995) changed the structure of freight rate regulation for grain (the Crow Benefit was removed and replaced with a set of specified rates), and also made it easier for the railways to divest themselves of inefficient branch lines. After this time, considerable branch line abandonment occurred relatively quickly across Saskatchewan as well as within the study region (Hemmes 2003). As argued by some stakeholders, this was a critical time because with the closure of smaller grain elevators and subsequent branch line abandonment, rural communities suffered disproportionately (SARM/SUMA 1998).

Not much has changed to the present with respect to line abandonment policy in subsequent modifications to the legislation. Essentially, a railway in Canada must make publicly available an up-to-date three-year plan regarding their networks, including the lines they wish to operate and those they wish to discontinue. The railway is allowed to amend its three-year plan, but the rail line in question must be listed in the plan for at least 60 days before the railway can take any action to abandon or sell the line (Law et al. 2004). In fact, there has been very little abandonment over the past few years and the process appears to be nearly complete.

Provincial governments in western Canada have concerns about the rural road system because even though the regulatory changes in rail that led to increased road use for grain movements occurred at the federal level, the provinces still have constitutional responsibility for highway maintenance. Saskatchewan has estimated that the rationalization of the grain collection system in the province increases road maintenance and repair costs by approximately C$90-$100 million annually (Government of Saskatchewan 2000).[2]

In 2000, the Canadian federal government implemented additional grain-handling system and regulatory reforms that have been active through the time frame of this study to the present (Government of Canada 2000). These include a revenue cap (replacing the long-standing rate cap on individual movements) applicable to grain transportation by rail, additional (but limited) federal funding for prairie roads, limitations on the branch line abandonment process, and the appointment of a third-party monitoring system for the regulatory framework. However, there is a broad consensus that these reforms have done nothing to slow the transition from a historical agricultural supply chain where grain moved from farm to elevator mostly via branch line rail, to the current supply chain where the same grain is now moved to elevators mostly via the regional road network (Saskatchewan Department of Highways and Transportation 2002).

LITERATURE REVIEW

An early study of the grain-handling system in western Canada was that of Karadininis (1985) who developed a cost minimization model for producer deliveries to examine the regional effects of varying freight rates. Heaps et al. (1992) built a detailed general simulation model of producer delivery in the Canadian grain-handling system and included transportation costs, but trucking pricing policies were not explicitly considered. Building on the work of Heaps et al. (1992), Khakbazan and Gray (1997) used grain-handling data to perform an analysis of railway incentives for branch line abandonment in Saskatchewan. Rees (1999) examined the effect of increased trucking due to both branch line rationalization and grain elevator consolidation. While Rees used differential road costs based on surface type to calculate external costs for road damage, his study did not account for the effects of charging the external costs as a road price or toll on road users.

As the basic issues surrounding rail line abandonment and links to rural road damage have implications in many North American jurisdictions, there are a number of related papers written describing potential effects on various U.S. jurisdictions. Among these, the papers of Babcock et al. (2003) and Casavant and Lenzi (1990) are most relevant to the current work. The latter was one of the first papers to pursue the basic link between rail line abandonment and road damage using explicit estimates of the cost of pavement erosion from increased traffic volumes on rural roads. And while similar in many respects to this research, the scope of rail line abandonment and increased road damage in the region studied in the Babcock et al. (2003) paper is broader than analyzed here. Covering much of the state of Kansas, these authors estimated road damage costs stemming from almost 1,800 miles of shortline rail abandonment to be nearly $60 million.

In the Canadian context, a set of papers from a 2003 conference in Manitoba addressed the broader issue of how the Canadian grain industry and its supporting transportation infrastructure has changed since extensive grain industry reforms (University of Manitoba 2003). The latter highlights the fact that Canadian grain transportation policy still generates considerable debate between government and industry. In sum, while a number of the listed studies assessed road damages stemming from the impacts of grain transportation reform, none of them sought specifically to assess the economic effects of a policy of road pricing for the growing grain trucking sector.

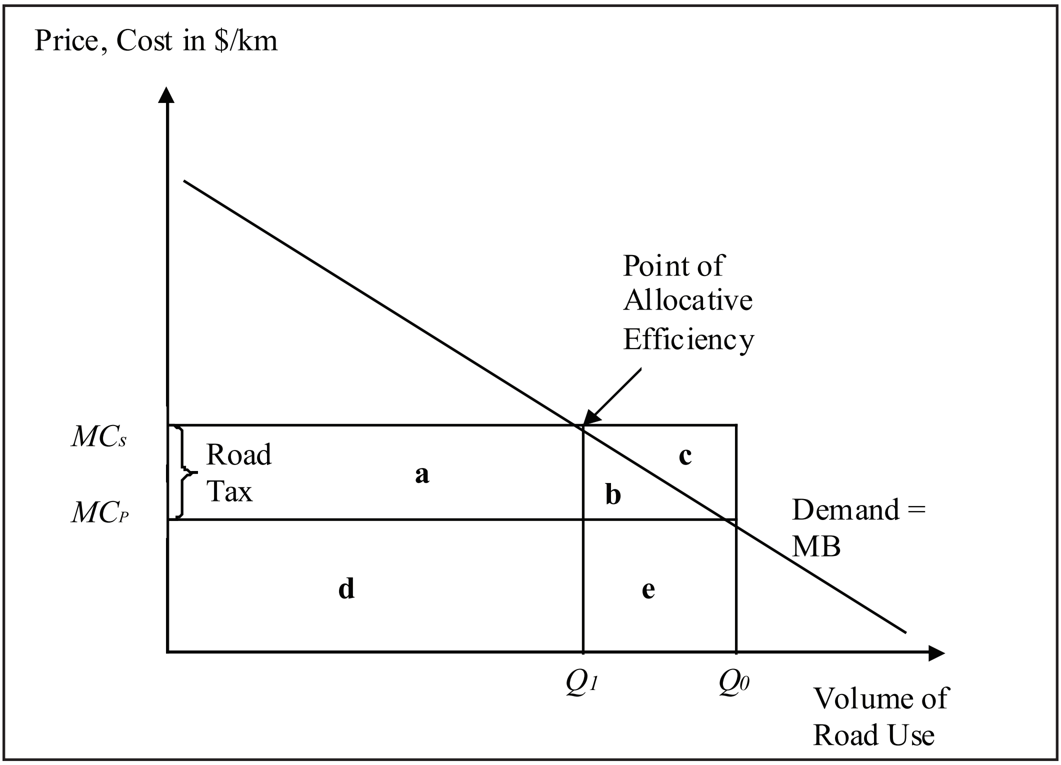
EXTERNALITIES AND PRICING

Over the past century, governments have supplied roads because they possess characteristics that justify some form of subsidy or intervention. These include a lack of excludability for users and the considerable external benefits provided by the use of the road. On the other hand, a major negative externality associated with the provision of public roads is the degradation of the road surface. Without a tax or toll designed to recoup the external costs of providing and maintaining the road, road users do not incorporate the social costs of providing or maintaining the road in their economic decision-making process. Tolls encourage road users to search for least-cost methods for using infrastructure.

Conceptually, excessive use of a public good occurs because appropriate price signals that would normally lead to allocative efficiency do not exist. On a typical public road, the marginal private cost paid by the road user is less than the marginal social cost, resulting in the overuse of the road network relative to the social optimum (Parkin and Bade 1991). Of course, it is well-known that taxes or tolls could be imposed to force the road user to face the full marginal social cost of road use, as shown in Figure 1.

The demand curve in Figure 1 is the demand for trucking services. It illustrates how consumers of trucking services value different levels of output. MC_P is the private marginal cost directly

Figure 1: Road Damage Externalities



incurred by truck users, and the quantity of road use is Q_0. The total private cost is the area "d" + "e." But consuming quantity Q_0 of road use incurs external costs – road damage in this case. MC_s is the marginal social cost that compensates for the negative externality of road repair together with the private marginal cost of trucking. The social cost at Q_0 is the area "a" + "b" + "c" + "d" + "e." The difference between the two cost curves captures the external cost, shown by the area "a" + "b" + "c." In this case, the optimal trucking traffic volume is Q_1, where the marginal social cost equals the marginal social benefit. For trucking and associated road damages, MC_s becomes the relevant marginal cost curve. Output Q_1 is allocatively efficient because a market output of more than Q_1 means that marginal social cost exceeds marginal benefit, whereas any point less than Q_1 results in marginal social cost less than marginal benefit. These cost concepts are the basis for the comparison of various road pricing schemes. The analysis is designed to generate and estimate these costs when trucking grain across the entire study region.

Delivery choice by farmers and subsequent trucking flows in the region are simulated in a spreadsheet using an optimization heuristic. The allocation of grain trucking movement is based on aggregate handling, road use, truck transportation, and rail shipping charges. In reality, other factors can also determine producer delivery decisions, such as company loyalty, special deals, and ownership, but for this study, it is assumed that relevant production costs are exogenous and therefore the focus need only be on those costs associated with grain handling and delivery.

For additional tractability, rail freight rates used in this study are capped from each delivery point to the West Coast at the Port of Vancouver. This means only transportation costs in the study region are relevant to individual decisions. As mentioned above, complete branch line abandonment in the region is assumed along with elevator consolidation on the main rail lines. This brings the number of grain elevators considered in the simulation close to current levels, especially considering the high-volume stations - but in reality there are slightly more elevators operating in the region than are included here. The simulated study region is served by nine high-volume elevators, and these are individually listed in Table 1. Considering the amount of road data and the number of possible transportation routings, only a limited number of trip origin centroids are developed, each based on an individual rural municipality (RM) in the study region.[3] Reducing the number of origins in this way may reduce the accuracy of predicted delivery patterns, but repeated simulations showed any errors generated in this manner did not affect the relative cost calculations between scenarios.

Table 1: Regulated Grain Rates to Vancouver

Elevator Station	Freight Rate to Vancouver (per ton/km)
Kindersley	$39.03
Luseland	$33.17
Cutknife	$34.45
Unity	$33.18
Lloydminster	$32.81
Dodsland	$33.82
Biggar	$34.78
Rosetown	$36.43
Dinsmore	$38.39
Mean	$35.12

Source: Canadian Transportation Agency, 2000

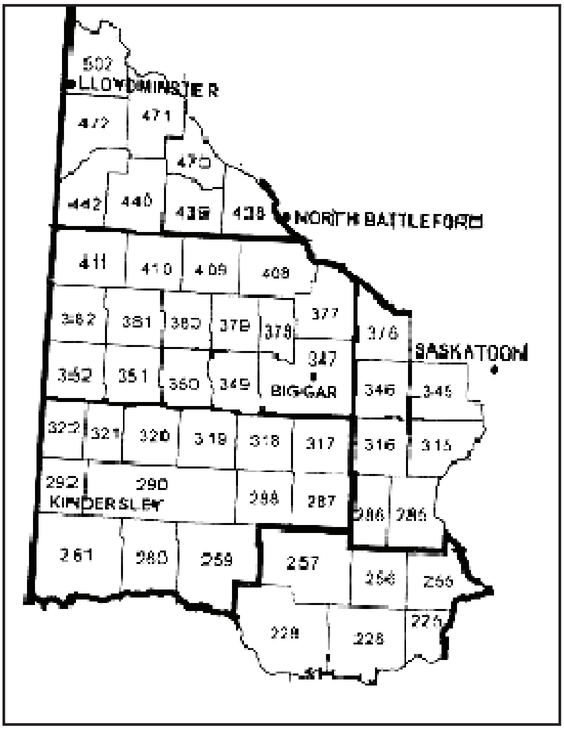
SIMULATING GRAIN MOVEMENT IN THE STUDY REGION

Figure 2 is a map of rural municipalities in the study region. The region is bordered by the North Saskatchewan River on the north, the South Saskatchewan River on the south and east, and by the Alberta-Saskatchewan border on the west. Since the region is partially bounded by rivers, movements in and out of the area can only occur across the few bridges in the region. It is assumed that farmers in the region will only deliver to elevators within the region. So in total, grain delivery patterns are limited to 49 rural municipalities (RM's) moving grain to nine high-throughput delivery points in the region.

Figure 3 illustrates both main (dark lines) and branch rail lines (lighter lines) in the study region, as well as highlighting (in darker print) the elevator stations that remain in the line abandonment simulation. Most of the branch lines in the region are located in the southernmost portion of the study area, so full branch rail line abandonment predominantly affects southern areas. Thus, rail line abandonment leads to increased grain truck movement in the southern region because producers have to travel farther north to find alternative delivery points.

The capacities of high-throughput elevator stations in the study region were obtained from the Canadian Grain Commission (1999). The model incorporates a grain storage capacity constraint because we want to analyze the situation where smaller elevators can no longer be used (i.e. full branch line abandonment and complete elevator consolidation). An elevator turnover rate of 10 is used in the analysis, meaning that each station can turnover its volume 10 times per year.[4] Elevator

Figure 2: The Study Region



companies are assumed to charge the same fixed handling rate per ton, so that all high-throughput elevators in the study region have the same costs in handling grain.[5]

To initialize the simulation, crop production data for the study region was drawn from two sources: the *1996 Census of Agriculture* compiled by Statistics Canada and *Agriculture Statistics 1997* compiled by the Saskatchewan Department of Agriculture and Food. Ten-year average yields per acre for seven crops (spring wheat, durum, oats, barley, canola, flax, and fall rye) for the rural municipalities in the study region were multiplied by the seeded acres contained in the census. It is assumed that approximately 75 % of yearly grain production will ultimately be exported through the western port of Vancouver.

Road users (i.e. grain trucks) in the simulation pay different charges on each road according to surface type. Saskatchewan Department of Highways and Transportation (1992) distinguishes between three road classifications in the province, based on physical construction (Figure 4);

1) Structural Pavement: ranging from a thin asphalt seal on a granular surface to a full depth asphalt concrete (approx. 40 % of the regional highway system).

2) Thin Membrane Pavement (TMP): thin asphalt mat approximately 25 to 50 mm thick placed directly on a prepared subgrade (approx. 40 % of the regional highway system).

3) Gravel: a layer of traffic gravel on a prepared subgrade (the remainder of the regional highway system).

Figure 3: Rail Lines in the Study Region

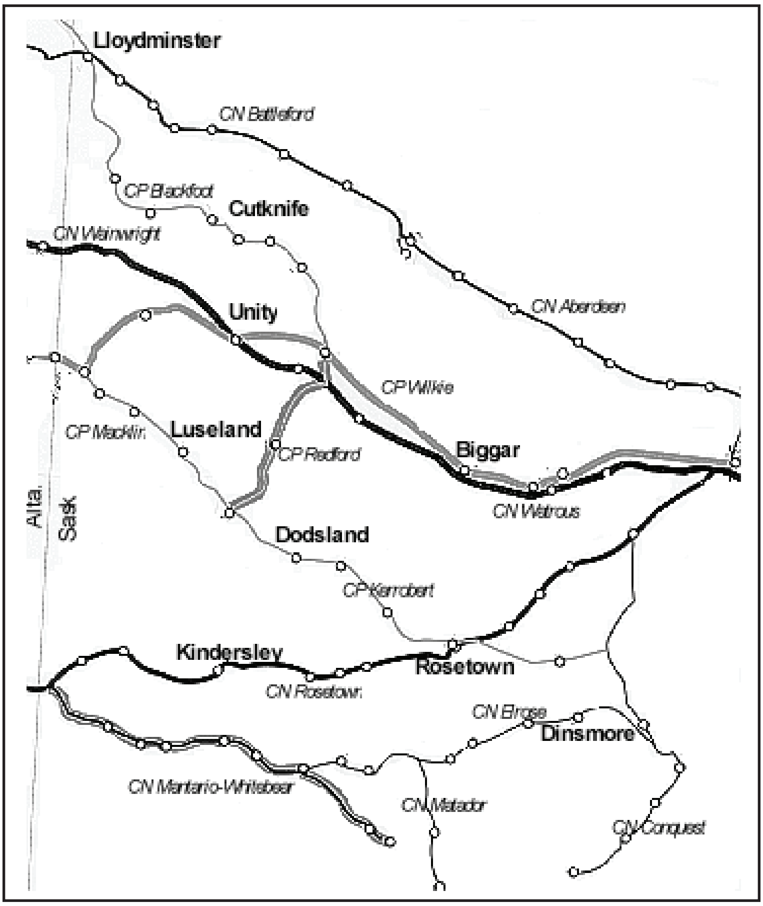
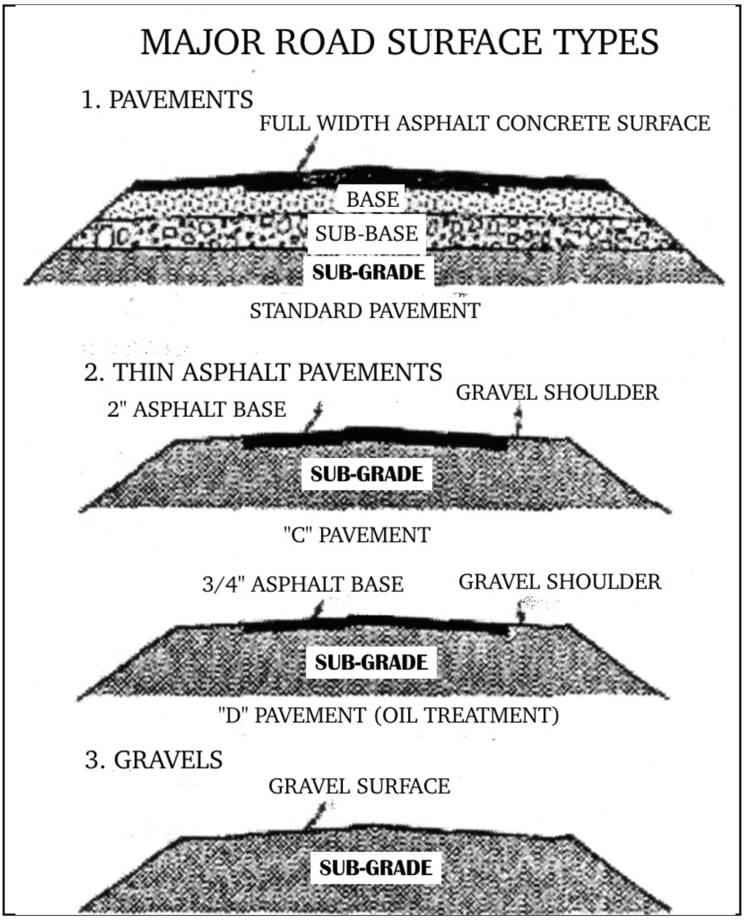


Figure 4: Major Road Surface Types in Saskatchewan



Source: Saskatchewan Department of Highways and Transportation, 1992.

Structural pavement roads were designed for heavy truck loads and high-traffic densities. Thin membrane pavements (or TMP) were originally adopted in the 1950s in Saskatchewan as a way of eliminating the dust and mud associated with gravel roads. However, TMP and gravel roads were never engineered nor intended to tolerate the large loads that are increasingly being used for grain movement (Saskatchewan Department of Highways and Transportation 1992).

Under this set of assumptions, total charges paid by producers to transport grain by truck to grain elevators in the study region are calculated based on the tonnage delivered, including road, trucking, and rail freight charges. Road mileage for routings was collected using the GIS software MapInfo,[6] while distances were computed for at most three alternative trip routings by road from each rural municipality to each delivery point. Critical to this analysis, mileage for each routing was further broken down by distance according to road type (i.e. gravel, thin membrane, or structurally paved).

The actual external costs of road damage incorporated into the simulation model are based on engineering estimates on a distance basis. The estimates of road damage from trucking in the province come from the 1999 Branchline Review (see Rees 1999). The actual road damage costs used are:

P-class (paved)	\$0.01325/ton-km
G-class (gravel)	\$0.0291/ton-km
T-class (thin membrane)	\$0.0873/ton-km

These costs are imposed on farmers as road charges in order to internalize external costs of road use in the region by grain trucks. A system of properly enforced differentiated road charges would encourage the utilization of structural pavement roads designed for heavier loads, while discouraging traffic on roads that were not designed for increased grain traffic associated with extensive branch line abandonment.

Road charges are not the only expense producers face when they deliver grain to high-throughput elevators. Producers utilize trucks to deliver their grain from the farm gate to the high-throughput elevators, and a cost of eight cents per ton kilometer is assumed in order to cover general trucking expenses.[7] A flat trucking rate does not take into consideration any cost differences between larger, multi-axle tractor-trailers versus the smaller, traditional farm truck, so this assumption means that all producers in the simulation use the same type (size) of truck and that any economies of scale from larger truck sizes is ignored.

As in reality, in the simulation once grain gets to the elevator system, it is moved over trunk rail lines to be exported via the Port of Vancouver. This movement is priced using capped or regulated rail freight rates. Average applicable freight rates were used to calculate producers' total final delivery expenses. The rates used in this study are similar to those currently charged, and are listed in Table 1.[8]

The road pricing scenarios considered in this paper represent two distinct ways to internalize the external costs associated with grain trucking within this region. Under each scenario, producers pay different road charges and subsequently adjust their elevator delivery decisions. Since the FOB price and production volume are parameters in the simulations, producers in this model are tasked only with optimizing the transportation (road and rail) and handling charges incurred in order to move their grain to port position.[9]

Incorporating available data and model assumptions, the rural municipality's objective function with respect to grain transportation and handling can be specified as (Larson 2002):

$$\text{(1)} \quad \text{Max } \prod = vP_w - vW_e - vW_f - vW_r - vW_t$$

$$\text{(2)} \quad \text{s.t. } W_e + W_f + W_t + W_r \leq P_w$$

where: $\prod$ = producer profit (from transportation)
P_w is the free-on-board (FOB) price of grain per ton
v is the volume of grain delivered
W_e is the elevator charge per ton
W_f is the freight charge per ton
W_t is the trucking charge per ton
W_r are the road charges per ton

and the constraint (2) means that producers in the RM will not transport grain if their handling and transportation costs exceed the FOB price. But this RM-level optimization problem is complicated by the presence of another capacity constraint at a system level – producers in an RM are assumed to deliver to their nearest delivery point, but only up to the level of elevator capacity at that delivery point in a given time period. The latter rule is incorporated so as to approximate actual grain allocation behavior in the region.

Due to the structure of the optimization problem, generating a solution to this optimization problem at the system level was accomplished using a heuristic. The first step of the heuristic computes the total road charges for each of three different delivery route options from each RM (origin) to all of the elevator stations (destinations). For each RM, the path to each elevator associated with the least total road cost (from the perspective of the producer) is selected as the optimal routing. Next, the model calculated the total charge (i.e. the sum of the minimized road charge, elevation charge, trucking charge, and freight to Vancouver) to deliver one ton of grain from each RM to each elevator station. A given rural municipality's production volume is delivered to the elevator that generates the minimum total charge per ton, subject to the capacity of the elevator. Production volume is multiplied by the total charge per ton to compute total delivery charges per RM.

If the RM's delivery of production exceeds a station's capacity, then delivery is allocated to the elevator station that has the next minimum total delivery charge. To limit any bias in the solution because of the sequential nature of the allocations, delivery in the simulation is conducted via a random ordering of RMs. As delivery order is randomized under the heuristic, a given model run will necessarily produce slightly different results than another run. Thus, the results reported here are generated from a sample of 1,000 different delivery patterns per scenario, with averages computed in order to construct the simulated data discussed in the next section.

RESULTS

The first scenario consists of no producer road charges (i.e. no road pricing) for grain trucking in the region, and thus serves as a "status quo" benchmark to compare against the road pricing scenarios. The second scenario implements differentiated road charges based on road surface type, using data on repair costs as a proxy for the trucking externality. The final scenario employs a flat road price per ton kilometer of grain trucking regardless of the surface type. Each scenario is discussed in turn, with emphasis on the cost totals in the respective data tables. Due to space considerations, a single table of relevant results for the first two scenarios is provided, along with a full set of tabulated results for the flat road pricing scenario. The complete set of tabulated results is available upon request from the authors.[10]

No Road Charge

Initially, grain transportation simulations were run without any assigned road charges. This implies producers in each RM deliver grain to elevators using the shortest route, searching for the lowest total grain handling charges subject to elevator capacity. The base case simulations are summarized in Tables 2 and 3.

Table 2 shows that the total private costs paid by producers to have grain delivered to elevators were approximately $125.4 million. Of this total, the rail freight rate was the largest portion at $87.2 million. The elevator tariff was the second largest producer expense at nearly $26.6 million, while direct trucking charges were the smallest of those included at around $11.6 million. In this base scenario, there are external costs in the form of road damage stemming from the unpriced trucking of grain. These costs are shown the middle column of Table 2. Table 3 shows that total external costs in this scenario were almost $7.7 million, with the overwhelming majority of the damage ($5.8 million) in the region attributable to the use of thin-membrane pavement (TMP) for grain movements.

In sum, total social costs for the base scenario are just over $133 million (Table 2). In this case, external costs from road damage comprise a small portion of social costs, about 6% of the total.

The quantity of road use demanded by producers is affected by the marginal private cost of road use. Without road pricing, producers in this model choose road use based on their marginal private cost. And because of road damage from trucking, the marginal cost to society of providing roads exceeds the marginal private costs to producers.

Table 2: Base Scenario (No Road Charge) – Social Costs

	Total Social Costs		
Delivery Point	**Total Private**	**Total External**	**Total Social**
Kindersley	$36,388,499	$2,593,742	$38,982,241
Luseland	$7,026,253	$609,595	$7,635,848
Cutknife	$3,070,078	$172,125	$3,242,203
Unity	$30,310,350	$1,560,774	$31,871,124
Lloydminster	$10,099,719	$362,494	$10,462,213
Dodsland	$1,699,236	$220,581	$1,919,817
Biggar	$7,351,531	$361,346	$7,712,877
Rosetown	$22,628,136	$1,033,893	$23,662,029
Dinsmore	$6,796,285	$767,370	$7,563,655
Total	**$125,370,089**	**$7,681,920**	**$133,052,009**

Table 3: Base Scenario (No Road Charges) – External Costs

	External Costs (Road Damage)			
Delivery Point	**Paved**	**TMP**	**Gravel**	**Total External**
Kindersley	$349,162	$2,104,496	$140,084	**$2,593,742**
Luseland	$9,609	$565,702	$34,284	**$609,595**
Cutknife	$15,883	$149,446	$6,796	**$172,125**
Unity	$276,790	$932,759	$351,224	**$1,560,774**
Lloydminster	$70,247	$191,304	$100,943	**$362,494**
Dodsland	$12,032	$182,355	$26,194	**$220,581**
Biggar	$38,541	$244,489	$78,316	**$361,346**
Rosetown	$264,166	$741,460	$28,268	**$1,033,893**
Dinsmore	$1,453	$733,959	$31,958	**$767,370**
Total	**$1,037,884**	**$5,845,970**	**$798,066**	**$7,681,920**

Differential Road Charges

Road pricing in this scenario is structured as follows. Movements on structural paved roads are charged 1.325 cents per ton kilometer, travel on gravel roads is charged 2.91 cents per ton kilometer, and travel on thin membrane roads is charged 8.73 cents per ton kilometer. The results of this scenario are presented in Table 4 below. Note again that in this case, the private costs shown are also the social costs because there are no external costs.

Under this road pricing scheme, total private costs in the study region are just under $132.6 million. This is an increase of about $7.2 million over the base scenario. In addition, rail freight charges decreased by about $400,000 compared to the base. We attribute this to the fact that more grain was delivered in the simulation to stations with lower rail freight charges, for example, delivering to Unity instead of Kindersley.

Table 4: Differential Road Charge Scenario – Private Costs

Station	Private Costs Rail Freight	Elevation Tariff	Trucking	Road Charges	Total Private
Kindersley	$23,473,347	$6,549,443	$4,236,890	$1,607,729	$35,867,409
Luseland	$4,903,083	$1,609,725	$619,745	$451,120	$7,583,673
Cutknife	$1,710,028	$540,557	$134,095	$76,779	$2,461,459
Unity	$23,196,385	$7,613,280	$4,198,731	$1,487,187	$36,495,583
Lloydminster	$6,787,410	$2,252,816	$1,005,295	$195,147	$10,240,667
Dodsland	$1,119,532	$360,488	$225,072	$116,055	$1,821,147
Biggar	$5,166,999	$1,617,844	$575,784	$211,013	$7,571,640
Rosetown	$15,851,108	$4,738,363	$2,116,113	$595,980	$23,301,563
Dinsmore	$4,616,557	$1,309,568	$529,411	$770,311	$7,225,848
Total	**$86,824,448**	**$26,592,084**	**$13,641,135**	**$5,511,322**	**$132,568,989**

Total road damage on structured pavement for this scenario increased by about $600,000 over the base scenario, while total gravel road damage increased by about $10,000. However, the most interesting finding within this scenario is that thin-membrane pavement damage decreased by over $2.7 million. Clearly, rational producers limit the use of costly TMP more than before since they incur the full costs of road damage. Overall, total road damage decreased by about $2.2 million over the base scenario.

The differentiated road pricing scenario fully internalizes the road damage from grain trucking and society is compensated for the full external costs of road damage by the producers. Thus, total net external costs are zero. The total social costs in this scenario are just under $500,000 less than the total social costs from the base scenario. This is a very small amount compared to the total social costs, less than 0.5 %.

Flat Road Charges

The final scenario tracks changes in the delivery patterns of producers if a non-discriminatory road price or toll was imposed on grain trucking in the study region. A flat road charge of three cents per ton-kilometer applicable to all road types was simulated.[11] The full set of results for this scenario is listed in Tables 5-7.

Total private costs generated by this scenario are found in Table 5. Under a policy of flat road pricing, producers spend approximately $130.9 million on total grain handling and transportation charges. This represents an increase of $5.5 million over the base scenario. In addition, total private costs are $1.7 million less than private costs under the differentiated road pricing scenario.

Rail freight charges were marginally less than the differentiated road charge scenario (by about $123,000), and measurably less (by about one half million) than the base scenario. Trucking charges decreased by about $870,000 compared to those under differentiated road charges, but they are approximately $1.2 million higher than the base scenario. Since trucking charges in each scenario are fixed on a per ton-kilometer basis, it is clear that producers in each RM traveled shorter distances to deliver their grain under the flat road charge scenario as compared to the differentiated road charge scenario.

Table 5: Flat Road Charge Scenario – Private Costs

	Private Costs				
Station	**Rail Freight**	**Elevation Tariff**	**Trucking**	**Road Charges**	**Total Private**
Kindersley	$22,470,159	$6,269,537	$3,789,559	$1,421,085	**$33,950,340**
Luseland	$5,008,034	$1,644,181	$591,517	$221,819	**$7,465,550**
Cutknife	$2,186,237	$691,092	$193,685	$72,632	**$3,143,645**
Unity	$23,046,008	$7,563,925	$3,919,535	$1,469,826	**$35,999,294**
Lloydminster	$7,101,876	$2,357,191	$887,231	$332,712	**$10,679,010**
Dodsland	$1,146,068	$369,032	$225,982	$84,743	**$1,825,825**
Biggar	$5,174,108	$1,620,070	$601,613	$225,605	**$7,621,397**
Rosetown	$15,873,692	$4,745,114	$2,005,409	$752,029	**$23,376,244**
Dinsmore	$4,695,429	$1,331,941	$557,705	$209,139	**$6,794,214**
Total	**$86,701,611**	**$26,592,084**	**$12,772,236**	**$4,789,588**	**$130,855,519**

Total road charges paid by producers in the final scenario were approximately $4.8 million, representing a decrease of over $721,000 compared to the differential road pricing scenario. Table 6 shows the breakdown of the road damage compared to the revenue generated by road charges. As with the base case scenario, thin-membrane pavement absorbed the majority of total road damage, with $5.5 million of a total of about $7.6 million, over $2.1 million greater than the differential road pricing scenario. As expected, under this scenario the total road charges paid by producers do not cover the full cost of road damage. Only those who delivered to one particular facility (Rosetown – note the negative sign) paid road charges in excess of the road damage they caused. The net balance is the total external cost for this scenario, over $2.8 million.

Table 6: Flat Road Charge Scenario – External Costs

	External Costs (Road Damage)					
Station	**Paved**	**TMP**	**Gravel**	**Total Road Damage**	**Road Repair Charges Paid**	**Total External**
Kindersley	$396,261	$2,062,355	$108,076	$2,566,692	-$1,421,085	$1,145,608
Luseland	$25,225	$537,139	$55,559	$617,923	-$221,819	$396,104
Cutknife	$15,709	$150,166	$6,820	$172,696	-$72,632	$100,064
Unity	$376,925	$1,067,753	$390,774	$1,835,453	-$1,469,826	$365,627
Lloydminster	$81,210	$216,150	$102,441	$399,801	-$332,712	$67,089
Dodsland	$5,639	$82,477	$53,815	$141,932	-$84,743	$57,188
Biggar	$40,707	$235,559	$83,736	$360,003	-$225,605	$134,398
Rosetown	$282,749	$435,433	$24,014	$742,195	-$752,029	-$9,833
Dinsmore	$6,602	$735,431	$45,692	$787,725	-$209,139	$578,586
Total	**$1,231,027**	**$5,522,464**	**$870,928**	**$7,624,419**	**-$4,789,588**	**$2,834,831**

Table 7 shows the total social costs for this scenario - the sum of the private costs and the external costs. Total social costs for the flat road pricing scenario were just under $133.7 million, about $1.1 million higher than the differential road pricing scenario. In turn, this scenario generates higher social costs than the non pricing scenario by about $640,000.

Table 7: Flat Road Charge Scenario – Social Costs

		Total Social Costs	
Station	**Total Private**	**Total External**	**Total Social**
Kindersley	$33,950,340	$1,145,608	$35,095,948
Luseland	$7,465,550	$396,104	$7,861,654
Cutknife	$3,143,645	$100,064	$3,243,709
Unity	$35,999,294	$365,627	$36,364,922
Lloydminster	$10,679,010	$67,089	$10,746,100
Dodsland	$1,825,825	$57,188	$1,883,013
Biggar	$7,621,397	$134,398	$7,755,794
Rosetown	$23,376,244	-$9,833	$23,366,410
Dinsmore	$6,794,214	$578,586	$7,372,800
Total	**$130,855,519**	**$2,834,831**	**$133,690,350**

DISCUSSION

Table 8 summarizes the key results of this simulation exercise. As expected, a policy of differential road pricing based on road damage in the study region leads to the lowest social costs and is therefore a Pareto improving economic policy over the status quo. However, differential road pricing does not perform considerably better than either the status quo (no road pricing) or a flat road price policy. A flat road charge is arguably the worst policy option for the study region under these conditions with respect to efficiency as it generates the highest social costs among the scenarios.

Table 8: Summary of Total Costs for the Scenarios – Private, External, Social

Scenario	**Total Private**	**Total External**	**Total Social**
No Charges	$125,370,089	$7,681,920	$133,052,009
Differential Charges	$132,568,989	$0	$132,568,989
Flat Charges	$130,855,519	$2,834,831	$133,690,350

Regardless of the policy implemented, the net savings in social costs from implementing road pricing policies for grain transportation in this region are marginal at best. The social cost savings are very small compared to the total handling and transportation charges in the system. To put this into perspective, based upon the data used here, the social cost savings from differentiated road pricing works out to less than 20 cents per ton, compared to total system costs of just over $50.00 per ton.

These results also appear to highlight another issue that has been little considered to date with respect to road pricing and its potential impact on industry. Road networks are fixed and in many cases cannot quickly be expanded in response to changes in transportation demand. In this example, this situation is compounded by the fact that grain farmers live where they work and are thus enormously constrained by their location with respect to the extant road network. Clearly, many farmers in the study region would have little choice but to use the same roads to deliver their grain by truck to an elevator, no matter what the road price. Thus for some industries in some areas, topography and connectivity of the supporting road network mean that there are inherent limitations to the potential efficiency gains possible through externality or road pricing.

This example is somewhat unique compared to other industries in terms of transportation and distribution logistics because many other industries can more readily relocate factories and warehouses if they need to improve transportation efficiency. Also, differential road pricing schemes in other jurisdictions may be based on congestion or time of day pricing as opposed to road maintenance considerations. But in those areas with serious impediments with respect to industrial location (for instance, in regions with either high land prices or low road densities), policymakers should exercise caution if a specific policy of externality pricing (especially one based on maintenance costs) is under consideration. If some industries in the region and their supply chains are characterized by diffuse production locations with delivery to a limited number of destinations, there may be very limited social welfare gains available over the unpriced status quo.

CONCLUSION

A simulated optimization model of road pricing over a regional transportation network in western Canada is developed to assess policy effects on the grain handling industry. Two plausible road pricing scenarios were examined. Neither road pricing scenario was found to produce a significant welfare improvement on the status quo.

The small difference in total cost among the scenarios is at least partially due to the dominance of both rail freight and elevation charges in total cost, staying mindful that these costs do not vary significantly across scenarios. But ultimately the topography of the road network in the study region, combined with the structure of the supply chain for the grain industry appears to limit potential efficiency gains available under externality (road damage) pricing. Therefore, any attempt to improve social welfare by using externality pricing in this region and for this industry is not likely to be worth the effort. This assessment is further validated when collection, monitoring, and policing costs associated with a road pricing policy are factored into the analysis.

Endnotes

1. For ease of exposition, the term “social” cost refers to full costing of the externality in question. We would like to point out that while there are other road use externalities that could be considered, the focus of this paper is on road damage. Thus, the pricing schemes discussed here do not account for other external costs of road use, such as pollution.

2. For the remainder of this paper, costs are listed in Canadian dollars.

3. The province of Saskatchewan is sub-divided into 238 “rural municipalities” or RM’s. As seen in Figure 2, the study region contains 49 RM’s. Similarly, the delivery points at the urban municipality level are used as an approximation for groups of elevators within close proximity. The total volume delivered within each scenario, based on averaged actual production data in the study region, was almost 2.5 million metric tons (Larson 2002).

4. This was the same rate used by the Rees (1999) study.

5. The model uses an elevation charge of $10.89/ton at each delivery point. More information on elevation charges is contained in Larson (2002).

6. Overlays were provided to the authors by Saskatchewan Department of Highways and Transportation.

7. This is the same cost used by Khakbazan and Gray (1997) in their study.

8. Even with regulatory changes on grain rates from a rate cap to a revenue cap, the actual rates applicable from points in the province have not changed much since 1999 (Canadian Wheat Board, personal communication).

9. In this model, the elasticity of travel demand relates only to the choice of road, and not to trip choice. Furthermore, the spatial distribution of supply and demand is not affected by variations in trucking cost. We would like to thank a referee for highlighting this point.

10. The simulation and data handling was done in Microsoft Excel using the Visual Basic macro programming language.

11. Although this particular scenario is similar to one examined in Khakbazan and Gray (1997), instead it is assumed here that a constraint exists on elevator capacity, along with complete branch line abandonment in the study region.

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