METHODOLOGY TO CHARACTERIZE AGRICULTURE-RELATED TRUCKING ON LOW-VOLUME RURAL ROADS TO SUPPORT ASSET MANAGEMENT

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ABSTRACT

This paper develops a methodology to characterize agriculture-related trucking on low-volume rural roads. The methodology considers truck trips from the field to intermediate storage facilities (field-to-storage) and from these facilities to market (storage-to-market). The methodology, which applies the transportation systems analysis approach, leverages knowledge from local producers through in-person interviews to qualitatively and quantitatively characterize the transportation supply and demand that generate truck flows. Flow characterization in terms of truck volumes and trip-making characteristics supports asset management decisions, such as maintenance timing and upgrade investments, in addition to providing information for forecasting future demand and infrastructure impacts.

The development and application of the methodology contributes in three ways. First, it characterizes truck flows from field-to-storage, a segment of the agricultural supply chain seldom considered by previous research. Second, it demonstrates the extent of information concerning road usage and impacts available from producers. Third, results from the application of the methodology to a study region in Manitoba reveal that: (a) smaller truck types are more commonly used for the shorter field-to-storage trips than storage-to-market trips; (b) actual distance traveled exceeds desired distance traveled, owing mainly to infrastructure-related regulatory constraints; and (c) trip length distributions for the storage-to-market segment exhibit a relationship between trip length and type of truck and commodity. The methodology is transferrable across jurisdictions and scalable for different geographic and temporal scopes. The specific results presented in this paper, however, may not be representative of conditions in other regions.
INTRODUCTION

This paper characterizes agriculture-related trucking on low-volume rural roads by applying a new methodology to collect data about the movement of agricultural commodities from the field to intermediate storage facilities (field-to-storage) and from these facilities to market (storage-to-market). Data collected through the methodology supports the management of rural road infrastructure assets.

Improved road infrastructure asset management and investment decision-making rely on more comprehensive information about the use and condition of these assets (1). For smaller road agencies, especially those in rural areas, it is difficult to commit resources for generating base data about road use (i.e., traffic volume) and condition given the mounting budgetary pressures of managing deteriorating infrastructure and growing infrastructure funding deficits (2, 3, 4). This difficulty exists despite recognition in Canada and the United States that effective rural transportation systems support rural economies and, in turn, the health of industries (such as agriculture) embedded in rural areas and the quality of life of rural citizens (5, 6).

In areas with intensive agriculture production, agriculture-related trucking is a critical aspect of rural road use. The transportation of agricultural products comprises an important component of commodity movements on rural roads. Historically, agriculture-related trucking has affected and been influenced by the economic activity of rural areas and the development of transportation systems serving these areas. In the past three decades in North America, this dynamic interrelationship has been influenced by the following (5, 7, 8, 9):

- increasing crop yields resulting in a larger volume of commodities being produced for a given area of land;
- changes in the types of crops being planted (e.g., in Manitoba, less land is used to grow wheat today than has historically been the case);
- a transition to fewer, but higher throughput grain handling facilities, operated by a smaller number of grain handling companies;
- increases in the size of farming operations and decreases in the number of farms;
- changes in truck regulations, which have enabled the use of larger, heavier, and more productive truck configurations on denser road networks; and
- mergers within the rail industry, rationalization of rail networks serving rural areas, and the introduction of shuttle train service for grain transportation.

In Canada, recent changes to the operation of the Canadian Wheat Board, concomitant adjustments in cross-border agricultural transportation, and possible expansion of grain transportation via northern rail and marine networks indicate that agriculture-related trucking will continue to play a dynamic role in rural economies.

These developments have placed increasing strain on rural road infrastructure, as larger and heavier trucks are used to haul products over longer distances (8). However, despite this, there are relatively few systematic data sources on which local governments can rely to support decisions concerning the operation and management of these roads, both currently and in the future. This paper aims to fill this data gap by developing a methodology to collect data that characterize agriculture-related trucking on low-volume rural roads.

Specifically, the objectives of this paper are as follows:

- to propose and develop a data collection methodology to characterize agriculture-related trucking on low-volume rural roads, including transportation from field-to-storage and storage-to-market;
to demonstrate the application of the data collection methodology, focusing on information obtained from producer surveys; and
• to present and interpret illustrative results obtained from the application of the methodology.

In pursuing these objectives, the intent is to provide pragmatic guidance for jurisdictions to better understand the current needs and impacts of agriculture-related trucking on low-volume roads through enhanced data collection. The data collected can help form the basis for more predictive demand models, though forecasting is not a specific objective of this research. The methodology focuses on truck trips generated by harvest activities and excludes other agriculture-related transportation such as the movement of seed, fertilizer, and implements of husbandry. Although the geographic scope of the analysis is limited to a particular region of Manitoba and Manitoba-specific characteristics are incorporated within the analysis, the methodology and insights are transferrable to other jurisdictions.

UNDERSTANDING IMPACTS OF AGRICULTURE-RELATED TRUCKING ON LOW-VOLUME ROADS

The changes in the agricultural industry that have intensified the impact of agriculture-related trucking on rural road infrastructure are well-documented. Quantifying and characterizing these impacts at a local scale, however, requires data that are difficult to obtain. Previous research has generally captured these impacts on the basis of data generated from demand models or stakeholder surveys (or a combination of both). Establishing estimates of truck traffic volumes and characteristics are the main targets of these efforts as they are closely related to infrastructure impacts (e.g., pavement and bridge design and maintenance).

Freight demand models estimate truck traffic volume (and/or commodity weight) based on the classical four-step demand modeling process, a direct demand modeling approach, or input-output models. These approaches provide estimates (in terms of trips or commodity weight) by establishing explanatory relationships between flow and a set of independent demand variables. Modeling freight demand—including agriculture-related demand—is a complex task because of the multidimensional nature of the freight demand unit, multifaceted interactions between different freight agents within the supply chain, and different values and transport costs associated with different types of freight \(^{(10)}\). Nevertheless, this approach has been successfully applied to characterize agriculture-related trucking, for example, at jurisdiction-wide \(^{(7, 11)}\) and more local scales \(^{(12)}\). Research adopting this approach, however, focuses on the storage-to-market segment of the supply chain rather than on the field-to-storage segment, which requires finer-grain knowledge of local transportation demand and supply characteristics.

Industry stakeholder surveys are a second data source which can be used to estimate truck traffic volumes and characteristics. These surveys, which are often integrated within demand models but may also be utilized independently, provide numeric inputs and an in-depth understanding of industry-specific transportation trends, issues, and anomalies which help interpret analytical results \(^{(13)}\). For example, Prozzi et al. \(^{(8)}\) assess the sustainability of rural road networks in Texas based in part on surveys of grain industry stakeholders (e.g., elevator and feed mill operators). Prentice et al. \(^{(14)}\) conduct an in-depth series of surveys of producers and other agriculture industry representatives in Manitoba. The results of these surveys not only provide a qualitative assessment of the suitability of the road network to serve agricultural demand, but also enable quantitative analysis of the impacts of agriculture-related trucking on these roads. As with demand models, however, this literature focuses on the storage-to-market...
segment and principally excludes the field-to-storage segment, which is also of interest to engineers charged with maintaining local road networks.

**METHODOLOGY FOR CHARACTERIZING AGRICULTURE-RELATED TRUCKING**

The data collection methodology applies the transportation system analysis approach to identify the data elements needed to characterize agriculture-related trucking and the relationships between them. This approach consists of three interrelated components: (a) the transportation system, \( T \), which encompasses transportation infrastructure supply, the vehicles that provide transportation service, and governing regulations; (b) the activity system, \( A \), which defines the demand for service; and (c) the flow system, \( F \), which characterizes travel, the resources it consumes and the services it provides. In the short term, \( T \) and \( A \) equilibrate to define \( F \). Over time, characteristics of \( F \) stimulate changes in \( T \) and \( A \), eventually creating a new equilibrium point for \( F \). These interrelationships are also influenced by exogenous factors, \( X \), such as the physical, political, or economic environments in which larger-scale trends occur.

Figure 1 depicts an adaptation of this approach, which provides the methodology for collecting data to characterize agriculture-related trucking on low-volume roads. The following paragraphs briefly describe the components of this methodology, referring specifically to the case discussed in this paper.

- **Understand exogenous factors, \( X \):** As described in the foregoing section, agriculture-related trucking (and agriculture-related transportation generally) has evolved considerably over the last three decades. The reasons for this evolution are complex and interrelated; however, a general understanding of these factors forms the starting point for the methodology.

- **Define the scope:** This step defines the geographic, temporal, and analytical scope of the data collection effort. Geographically, the survey may be constrained to the area influenced by a particular delivery point or may be as large as an entire jurisdiction (i.e., province or state). Temporally, the survey may cover activity associated with a particular season (e.g., spring seeding or autumn harvest), year, or may be repeated over several years to develop time series data. Consideration should also be given in this step to the key analytical questions that the survey is designed to answer. For the case discussed in this paper, the data collection effort focuses on truck trips generated during a particular harvest in a 36-mi.\(^2\) (93-km\(^2\)) land area. Five guiding questions, directed at acquiring data that support management of low-volume rural roads, helped shape the data elements on which the data collection methodology focuses: (a) What is the flow of agriculture-related trucking on local road systems, from field-to-storage and storage-to-market? (b) What are the key characteristics of this flow? (c) What explanatory demand variables influence this flow? (d) What aspects of transportation supply dictate actual flow and/or constrain desired flow? (e) What base case information might be needed to assess future impacts of ongoing industry trends?

- **Characterize transportation supply, \( T \):** This step involves developing an understanding of three main aspects of \( T \), namely, the road network serving the study region, the types of trucks used to transport agricultural commodities in this region, and the regulations that govern these movements. The next section describes the transportation system for the study region in more detail.
FIGURE 1 Methodology for characterizing agriculture-related trucking.

- Characterize transportation activity, $A$: This step involves understanding the system that generates the demand for agriculture-related trucking. Specifically, the following types of information should be gathered for the study region: land use, types of crops, location of storage facilities, and location of market destinations (e.g., grain elevators). The next section describes the activity system for the study region in more detail.
- Develop and test pilot survey: After defining the scope and gaining a basic understanding of the transportation and activity systems of the study region, preparation of a pilot survey begins. For the case discussed in this paper, the main goal of the survey is to collect information relevant to asset management that a producer would know by memory. Discussions with one producer helped refine the types of information that could be obtained within a relatively short in-person interview and which would be necessary for the purposes of the survey. Information collected about each farm operation includes the total cultivated area and the truck configurations used for hauling grain. Attaining information for the determination of truck flow from field-to-storage and storage-to-market is accomplished on a per field basis. Field-specific information includes the field area, crop type and yield from 2011, actual and desired routes from field-to-storage and storage-to-market locations, and truck configurations used to haul grain from each field.
- Conduct full survey: Full implementation of the survey involves in-person interviews with producers and follow-up phone conversations as necessary. For a large-scale application, web-based or paper surveys could be developed, provided that the farmer had access to relevant maps and other pertinent background information. For the case discussed in this paper, a total of 24 producers were interviewed between May and July of 2012 representing nearly all of the producers owning land in the study region.
- Characterize flow system, $F$: The last step in the methodology involves analyzing the survey data to help characterize $F$ and bring new insights about the infrastructure impacts of
agriculture-related trucking. These insights contribute to a better understanding of the broader exogenous factors. Specifically, flow is characterized in terms of truck volume (expressed in terms of vehicle distance traveled by road segment and truck type) and trip length.

APPLICATION OF THE METHODOLOGY

This section of the paper provides specific details and illustrative results about the application of the methodology in the study region and the types of insights that may be gained. Specifically, referring to the methodology in Figure 1, details are provided about the transportation (T) and activity (A) systems in the study region and the results and interpretation of the survey data, which help characterize truck flows (F).

Description of the Transportation and Activity Systems in the Study Region

Figure 2 shows a map of the study region and surrounding area. The study region is a 36-mi.\(^2\) (93-km\(^2\)) area located in an agriculture-intensive portion of southeast Manitoba, east of the Red River and Highway 75 (which connects to U.S. Interstate 29). The region primarily consists of cultivated land and no communities are present that generate other types of trips. The region totals 36 land sections according to the predominant division of land in the province. One section covers 640 acres (259 ha) and is separated from adjacent sections by roads at one-mile (1.6-km) intervals in both the north-south and east-west directions. The road network totals 84 mi. (135 km) and consists of 30 percent gravel surface, 51 percent dirt, and 19 percent asphalt. The majority of these roads—68 mi. (109 km)—are under municipal jurisdiction. Of the 16 mi. (26 km) of roads under provincial jurisdiction, about 6 mi. (10 km) (all paved) allow trucks up to the maximum provincial axle and gross vehicle weight limits (these are referred to as RTAC roads), while weight limits on the remaining 10 mi. (16 km) (some paved, some gravel) are restricted (these are referred to as Class B1 roads). Table 1 summarizes these limits for the six major truck configurations used to haul grain in the study region (categorized using the Federal Highway Administration 13-vehicle classification system).

<table>
<thead>
<tr>
<th>FHWA truck class</th>
<th>Tare (kg)</th>
<th>Maximum Gross Vehicle Weight (GVW) and Payload (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tractor</td>
<td>Trailer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5250</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>9800</td>
<td>-</td>
</tr>
<tr>
<td>6T</td>
<td>9800</td>
<td>2900</td>
</tr>
<tr>
<td>9</td>
<td>7620</td>
<td>4480</td>
</tr>
<tr>
<td>10</td>
<td>7940</td>
<td>5950</td>
</tr>
<tr>
<td>13</td>
<td>7940</td>
<td>9530</td>
</tr>
</tbody>
</table>

NOTE: 1 kg = 2.2 lb

Nearly 95 percent of the total 23,040 acres (9324 ha) in the region is used for grain production. The remaining five percent largely consists of waterways, drainage ditches, and farmyard space including land needed for livestock operations. A total of 26 producers own land in the study region; 24 were interviewed for this research. Of these producers, seven own up to
2000 acres (809 ha) of land, 12 own between 2000 and 4000 acres (809 and 1619 ha), and five own more than 4000 acres (1619 ha). Typically, a single producer does not own an entire section of land (this happens on only two occasions); rather, the division of sections into halves or quarters is common. The types of crops planted in this region in 2011 included (by area) canola (36 percent), soybeans (23 percent), oats (16 percent), spring wheat (13 percent), perennial rye grass (5 percent), winter wheat (3 percent), beans (3 percent), and corn (1 percent). For the study region, the 2011 harvest produced below average yields and dry conditions were prevalent during harvest time. During harvest, most producers hauled grain from the field to an intermediate storage facility either on their farmyard or on a field. Major nearby market delivery points included grain elevators, processing facilities (e.g., canola crushing and oat milling plants), and seed production facilities. The map in Figure 2 shows the locations of storage and delivery points relevant to the study region.

FIGURE 2 Study region.

Results and Interpretation of Truck Flow Characteristics

Analysis of data about the agriculture-related truck flows resulting from the 2011 harvest in the study region reveals insights about truck volumes (expressed as vehicle distance traveled by road
and vehicle type) and trip length for both the field-to-storage and storage-to-market segments. The data illustrates differences between actual travel and desired travel, which accounts for preferred routing if regulatory restrictions are removed but no change in vehicle ownership occurs.

As shown in Table 2, a total of 61,040 km (38,150 mi.) of travel resulted from the 2011 harvest in the study region. This estimate makes five major assumptions, namely that: (a) all trucks operate fully loaded in one direction and empty in the other; (b) none of the truck trips violate GVW limits on the roads under provincial jurisdiction; (c) truck trips on municipal roads adhere to Class B1 weight restrictions; (d) if more than one truck type is used by a specific producer in the field-to-storage segment, trips are evenly distributed between these truck types unless otherwise specified; and (e) if a single producer hauls a commodity to more than one market location, these trips are evenly distributed unless otherwise specified. These assumptions are reasonable given producers’ interest in maximizing productivity within legal bounds; however, there would be situations where the assumptions do not hold.

**TABLE 2 Actual and Desired Distance Traveled from Field-to-Storage and Storage-to-Market by Truck Class for 2011 Harvest**

<table>
<thead>
<tr>
<th>FHWA truck class</th>
<th>Vehicle-kilometers of travel (VKT)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field-to-storage</td>
<td>Storage-to-market</td>
</tr>
<tr>
<td></td>
<td>Actual</td>
<td>Desired</td>
</tr>
<tr>
<td>5</td>
<td>120</td>
<td>110</td>
</tr>
<tr>
<td>6</td>
<td>3920</td>
<td>3480</td>
</tr>
<tr>
<td>6T</td>
<td>360</td>
<td>340</td>
</tr>
<tr>
<td>9</td>
<td>2660</td>
<td>2390</td>
</tr>
<tr>
<td>10</td>
<td>3940</td>
<td>3130</td>
</tr>
<tr>
<td>13</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>C10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11,750</strong></td>
<td><strong>10,200</strong></td>
</tr>
</tbody>
</table>

**NOTE:** 1 km = 0.62 mi

- 6T denotes a class 6 truck pulling a pony trailer.
- C10 denotes a commercially-operated class 10 truck.
- C13 denotes a commercially-operated class 13 truck.

Specifically, the table reveals the following insights:

- Actual field-to-storage travel is about 20 percent of total travel generated by the 2011 harvest. However, because this travel occurs using smaller truck types, it accounts for 63 percent of the total number of truck trips.
- Field-to-storage travel is more likely to occur using smaller truck configurations, and almost never utilizes class 13 vehicles (eight-axle B-trains). Based on the sample data, commercial haulers are never used for this segment of the supply chain.
- Storage-to-market travel is dominated by articulated trucks (classes 9, 10, and 13), and approximately 15 percent of this travel is done using commercial haulers.
- For both the field-to-storage and storage-to-market segments, the desired routing is shorter than actual routing, indicating that from the producers’ perspective, the current transportation supply is at least partially imposing inefficiencies into their transportation decisions.

Further to this last point, Figures 3 and 4 illustrate the geographic differences between actual and desired truck flows for the field-to-storage and storage-to-market segments,
respectively. For the field-to-storage segment (Figure 3), these differences reveal that routing choices are based primarily on a preference to travel on gravel rather than dirt roads (Figure 2 shows roads by surface type). Trip distance does not play a large role in trip-making decisions at this scale. Further, though the intensity of truck travel on specific roads shifts somewhat, most of the individual road segments still accommodate some travel. This suggests that, from an asset management perspective, it is important to maintain roads even if they have extremely low truck volumes simply to provide basic access to the land.

For the storage-to-market segment (Figure 4), comparison of actual and desired routing indicates that trip distance is an important factor in trip-making decisions, but regulatory constraints sometimes increase route circuitry. A principal example of this is Highway 200 (the north-south road crossing through the study region), which would experience higher truck volumes under desirable conditions. However, because this road is subject to Class B1 weight limits, the majority of actual truck trips use Highway 75 (an RTAC road) as the alternative.
FIGURE 4 Two-way storage-to-market truck volume generated from 2011 harvest in study region: (a) actual and (b) desired.

An analysis of trip length distributions provides additional insights about truck flows from field-to-storage (Figure 5) and storage-to-market (Figure 6). Figure 7 breaks down storage-to-market trips by truck type. Findings from this analysis follow:

- Nearly 75 percent of field-to-storage trips (one-way) are 6 km (4 mi.) or less in length (Figure 5), indicating that this segment of the grain transportation supply chain is dominated by relatively short trips. None of these trips exceeds 25 km (16 mi.). Nearly all of these trips occur within a two-month timeframe (August and September).

- Storage-to-market trips (one-way) exhibit a (nearly) bimodal distribution (Figure 6), with peaks occurring at both the 30-km (19-mi.) and 60-km (38-mi.) ranges. None of these trips exceeds 130 km (81-mi.). The secondary peak in this distribution is mainly attributed to commodities other than spring and winter wheat, in particular canola and oats. For these commodities, producers can opt to haul to an elevator or directly to a processing facility. These facilities tend to be more widely dispersed than elevators and may also offer premium pricing opportunities. Thus, in the study region (and probably elsewhere as well), both distance and cost play a role in trip-making decisions, though the influence is commodity dependent. The trips are distributed seasonally as follows: 42 percent in winter (December to February), 22 percent in spring (March to May), 11 percent in summer (June to August), and 26 percent in autumn (September to November). This distribution partially reflects a preference to avoid weight restrictions placed on certain roads during spring thaw.
- The types of trucks used for storage-to-market trips (Figure 7) varies somewhat by trip length, with a general tendency to use larger trucks (classes 9, 10, and 13) for trips beyond roughly 40 km (25 mi.).

**FIGURE 5** One-way trip length distribution for field-to-storage trips for 2011 harvest.

NOTE: 1 km = 0.62 mi

**FIGURE 6** One-way trip length distribution for storage-to-market trips for 2011 harvest.

NOTE: 1 km = 0.62 mi

**Limitations**

The results reveal insights about agriculture-related trucking generated from the study region for the 2011 harvest. While these results are meaningful for this specific region, their direct applicability to other regions with different transportation and activity systems or other time periods is limited. The results represent responses from nearly all producers living in the study region and are thus of value to individuals responsible for asset management in this region. However, scaling the methodology to a larger geographic area would require careful consideration to ensure that the survey is statistically representative and that it captures a
meaningful sample size. Further, as the results are an estimate of current conditions and flows, extrapolation of these results into the future is not recommended. Nevertheless, they provide information essential to the development of more robust travel demand forecasting tools.

**FIGURE 7** One-way trip length distribution by truck class for storage-to-market trips for 2011 harvest.

NOTE: 1 km = 0.62 mi

**CONCLUSION**

This paper develops a methodology to characterize agriculture-related trucking from field-to-storage and storage-to-market. The methodology relies solely on data collected through producer surveys, thereby leveraging an extensive amount of industry intelligence. Adopting the transportation systems analysis approach, the methodology considers the influence of broad industry trends on agriculture-related trucking, the characteristics of transportation supply and demand, and their effect on local truck flows. Flows are principally expressed in terms of volumes (by road segment and truck type) and trip length. These flow characteristics provide fundamental inputs for asset management decisions, such as maintenance timing and upgrade investments. In addition, the flow characteristics provide base information that supports the development of demand forecasting models.

The development and application of the methodology contributes in three specific ways. First, because of its reliance on producer surveys, the methodology can be used to provide detailed characteristics on the field-to-storage segment of the supply chain in addition to the storage-to-market segment. This “first mile” of the agricultural supply chain is commonly overlooked by existing literature. Second, the application of the methodology reveals the extent of information available from producer surveys. Not only are producers able to provide qualitative comments on issues associated with agriculture-related trucking and road asset conditions, but the survey demonstrates that they are also able to quantify, on a field-by-field basis, specific details about truck trips, types, origin-destination patterns, commodities, and differences between actual and desired routes. These details are a rich resource to support asset management decisions concerning roads about which little quantitative information is known.
Potential exists for the results of these surveys to be used as a surrogate of total travel on roads serving agriculture-intensive areas. Finally, analysis of the data collected for the study region described in this paper provides insights about the impacts of industry trends on agriculture-related trucking. In particular, the results reveal that: (a) smaller truck types are more commonly used for the shorter field-to-storage trips than the storage-to-market trips; (b) actual distance traveled exceeds desired distance traveled, owing mainly to regulatory constraints related to the infrastructure; and (c) trip length distributions for the storage-to-market segment reveal a relationship between trip length and the type of truck and commodity being hauled. These findings generally confirm expectations.

The methodology developed in this paper is generic and can be applied to a range of geographic, temporal, and analytical scopes. However, actual implementation of the survey program for the case study presented involved extensive field work and in-person communication with individual producers. The scope of the case study made this approach possible; however, scalability to larger regions or broader timeframes would require development of on-line or paper survey forms. Based on experience gained from this research, relevant maps and background information should be incorporated as part of these surveys. Larger scale surveys would also provide improved insights about the influencing factors and characteristics of agriculture-related trucking and its impacts on local road assets.

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