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ABSTRACT

The cost of aggregate transportation is an important factor in determining the competitive position of individual aggregate producers because the aggregates themselves have a relatively low unit value per ton. Transportation adds significantly to the buyer's total costs and can influence the buyer's preference for specific producers, provided the product quality remains comparable. In the 15 years since aggregate transportation costs were first published by this author, no new estimates have been publicly available. As the market prices for aggregates change, so does the relative significance of transportation costs. This report is an attempt to estimate the current transportation costs by simulating a typical truck operation, as well as by using changes in the producer price index and the consumer price index.

BACKGROUND

Construction aggregates—crushed stone, and sand and gravel—are relatively low unit value materials used in large quantities. In 2013, Illinois produced about 45 million metric tons of crushed stone, mostly limestone and dolomite, and 18 million metric tons of sand and gravel. The unit price at the point of production for crushed stone averaged about $10 per metric ton and that for sand and gravel averaged $7 per metric ton.

Because of the low unit value of aggregates, their transportation costs play an important role in determining the final cost to the consumer. The delivered cost of construction aggregates may account for up to 10% of the total project costs (Bush and Hayes 1995). A significant proportion of these costs are due to transportation costs, which can have a major influence on the competitive position of aggregate producers vying to be the suppliers.

Trucking is the predominant mode of aggregate transport, although trains and barges, as well as coastal and international shipping, are also used. When aggregates are not transported by trucks alone, the necessity of transloading material from trucks to other modes of transport, with the resulting cost increases, may provide trucking alone a competitive advantage over multimodal transportation. Cost estimates for barges and rail transport are not readily available, nor are these options universally available.

From the perspectives of pit or quarry operators as well as those in the transportation business, the ideal circumstances would be to be able to assess the markets in the context of all available modes of transportation to envision a geographic zone in which to operate with competitive advantage. The purpose of this study, however, is to provide cost estimates for the most predominant mode of transportation, leaving market positioning to the market participants.

Unlike the costs of the aggregates themselves, the transportation costs are neither reported nor systematically documented by any public or private agency. Transportation costs are proprietary information held closely by the service providers as well as contractors. In the past, individual consultants occasionally contributed articles in mining or trade journals providing case-by-case transportation cost information. In 1999, the Illinois State Geological Survey (ISGS), with the generous collaboration of one producer, was able to obtain company-specific data on the cost of aggregate transport by truck in Illinois and publish these data for the benefit of the public (Bhagwat 2000). The U.S. economy has undergone many changes in the past 15 years because of international terrorism, wars, and, most significantly, the 2008 financial and economic crisis. The construction industry suffered a severe setback resulting from the economic crisis. A factor contributing to the decline in demand for mined aggregates has been the growing use of recycled aggregates. State-by-state recycling data are not available; however, about 140 million metric tons of construction materials are recycled in the United States annually, or about 7% of the total aggregates mined and sold. Although substantial efforts and costs are involved in aggregate recycling, it reduces the cost of transporting aggregates from where they are mined. The post-2008 economic recovery has been slow and remains incomplete to date. The changing market conditions have highlighted the need for up-to-date information on transportation costs for aggregates. This is an attempt to provide such information. We focus on trucking because of the predominance of trucks as a means of aggregate transport in the United States.

APPROACHES TO TRANSPORT COST ASSESSMENT

The most direct and useful way to know the cost of transporting aggregates is to request quotes from providers of the services. The advantage of the direct approach is that all the market factors—local demand–supply, competition, and the capacity utilization factor and labor situation—are built into the quotes offered. At the same time, specific quotes need not necessarily reflect long-term or life-cycle sustainability

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for the provider of transport services. For broader geographic usefulness, however, a less direct approach to cost estimation adds a perspective on what to expect in the long run as well.

The broadest approach to transportation cost estimation is to develop a software model that allows the user to input specific values that affect costs, such as type and size of vehicle used, seasonal factors, modes of financing, contract duration, labor market conditions, and so forth. It also provides adaptability for various goods transported by truck. Software packages provide for the application of specific inputs and thus deliver accurate cost calculations that may be best suited for the sensitivity analysis desired for investment decisions. North Dakota State University developed one such model in 2003 (Berwick and Farooq 2003). One specific case calculated as an example by the authors of the North Dakota State University software model pertained to highway transport of grain over a distance of 100 mi (160.9 km) and indicated costs of about $0.055 per ton/mile. An approximation of the current (year 2014) costs can be obtained by adjusting for the increase in the consumer price index (CPI), which indicates a 30% increase. When the CPI is used, the cost estimate above would increase to $0.071 per ton/mile. Further adjustments would be necessary because several operational inputs have changed since 2003; for example, trucks have become more fuel efficient, but the diesel price has increased nearly fourfold. In the aggregate industry, trucks serve more limited geographic areas than do grain transporters. Serving construction projects close to the quarries or sand pits can be subject to considerations other than long-term average costs, such as competition among small local operators or road conditions that restrict the size of trucks used.

The American Transportation Research Institute (ATRI) provides an equally thorough and systematic approach to trucking cost estimation by publishing operational cost estimates for trucking. The ATRI also publishes revisions to its cost estimates periodically (Fender and Pierce 2012). The ATRI reports are based on input provided by truck operators nationwide in response to a questionnaire-based survey. The data cover a range of truck sizes and types as well as whether truckloads were full or partial. The carrier costs are presented on a per-mile as well as per-hour basis and are further broken down into subcategories of costs, such as labor-related costs, and various vehicle-related categories. About 60% of the trucks in the ATRI survey were five- or six-axle trucks. However, the report does not specify the average payload carried. Trucks in these categories vary in their carrying capacity, ranging up to 20 metric tons (Jakubicek 2014). The 2012 update also provides comparisons of how the costs in the subcategories developed over several previous years. Although the ATRI reports include all the goods and do not specifically refer to construction aggregates, their results, summarized below, are instructive:

- The 2011 average carrier cost per mile was $1.71.
- The 2011 average carrier cost per hour was $68.21.
- The 2011 shares of fuel and oil costs accounted for 35% of total costs, the driver-based costs accounted for 36% of total costs, and the remaining 29% of the costs were for repair and maintenance, insurance, capital, and others.
- Since 2008, the costs have reflected the impact of the severe economic recession, resulting in cost declines in 2009 and 2010 and indicating little cost increase in 2011 compared with 2008.

The ATRI cost estimates above would range from $0.085 to $0.114 per ton/mile for grain transported 100 miles, based on an estimated average payload of 15 to 20 metric tons.

In the aggregate business, it is common practice to pay a basic charge when a truck is provided for transport of materials from the quarry or the pit. An additional cost accrues depending on the transport distance.

Publications dedicated to the equipment used for highway and off-highway transportation of materials provide information more closely related to the minerals industry. Articles related to the owning and operating costs of large vehicles provide insights into ways to approach the trucking cost estimation for mineral aggregates. *Equipment World* (Jackson 2010) reported cost estimates for a Mack GU713 dump truck with the following cost breakdown:

- The 2010 owning and operating cost per mile was $2.28.
- The labor-related costs accounted for 61% of total owning and operating costs—significantly more than the ATRI estimate above.
- The fuel and oil cost accounted for 21%, significantly lower than the ATRI estimate.
- The results presented by *Equipment World* are similar to those of ATRI in that there is no breakdown between a basic charge and a charge per ton/mile.

Equipment World also provides some details on repair and maintenance expenses, such as expected miles per gallon and tire replacement, as well as capital-related expenses. The payload for the truck in this case is estimated to be 20 to 25 metric tons, which results in costs ranging from $0.091 to $0.114 per ton/mile.

The cost estimation approach by *Equipment World* combines the useful operational aspects with the simulation technique to calculate costs that the truck owner may be able to offer sustainably over the life of the truck.

TRUCK SIMULATION FOR ESTIMATION OF AGGREGATE TRANSPORT COSTS

The variety and models of trucks used in the transportation of aggregates is very large. Therefore, the actual costs will vary accordingly. As described earlier, software packages are available to accommodate the variety of vehicles, materials transported, and operational constraints. The purpose of this cost simulation effort is to arrive at approximate costs per ton of aggregates transported over a range of distances. To this end, we use the same dump truck used in the *Equipment World* estimate above (Truck Paper 2014), with the following specifications:

> 2015 model of Mack GU713 Granite Tri-Axle Dump, Mack MP8-455M HP engine, Allison 4500RDS 6-speed automatic transmission, Mack 20,000-lb front axle, 44,000-lb Mack rear axle and camelback suspension, 4.19 ratio, 11R24.5 rear tires, 16′ Tebco TCM AR steel body, electric tarp system, 20,000-lb nonsteerable lift axle. Price: $165,000 new.

Most aggregates are consumed close to the place of production, usually within 40 to 50 mi (64.4 to 80.5 km). Longer distance transport is possible depending on the competition, the desired quality of material and price offered, and the different modes of transportation accessible. Distance is an important factor determining the cost of transportation for two primary reasons: (1) the time needed for a round trip, and (2) the cost of fuel. For example, if the loading and unloading time remains unchanged at 15 minutes and the average truck travel speed is 40 mi/h (64.4 km/h), a 20-mi (32.2-km) round trip [total distance covered of 40 mi (64.4 km)] is completed in 1.25 h, whereas it will take 1.75 h if the transportation distance is 30 mi (48.3 km) but only .75 h for a distance of 10 mi (16.1 km). In a 12-h workday, the truck would make 9.6 roundtrips over 20-mi (32.2-km) deliveries, but about 7 over 30-mi (48.3-km) deliveries and 16 roundtrips over 10-mi (16.1-km) deliveries. The actual transportation cost data from 1999 (see Bush and Hayes 1995, p. 1) does show lower costs for shorter distances, but costs do not increase as quickly with distance as the roundtrip time would suggest because the average speed that can be maintained also increases with distance. Likewise, the fuel efficiency also increases with trip distance.

COST SIMULATION RESULTS

Table 1 presents the simulation input data. The basis for the simulation is a single truck owned by the service provider. The results of the simulation are presented in Figure 1. The simulation is conducted in intervals of 5 mi (8.1 km) beginning at a transport distance of 3 mi (4.8 km). Operating parameters usually remain similar within small distance intervals. The average truck speed is assumed to increase with the trip distance. Sketched into Figure 1 are also the current market prices for sand and gravel and for crushed stone to illustrate how the delivered cost of the material is influenced by the transportation costs. At the price of $7 per metric ton, free on board, for sand and gravel, the delivered price for sand doubles at a distance of about 23 mi (37 km). For the current crushed stone price of $10 per metric ton, free on board, the delivered price doubles in about 45 mi (72.4 km). In 1999, the data showed prices doubling at shorter distances. Since then, the market prices of stone and sand have risen faster than the cost of transportation. The number of aggregate producers has significantly declined in the last two decades. This has been due in part to pressures of urban sprawl and in part to consolidation to fewer but larger producers. The severe economic crisis of 2008 that resulted in a great decline in demand resulted in severe production cuts that contributed to price consolidation. At the same time, an overcapacity developed in the transportation sector, resulting in a slower growth in transportation rates and forcing some providers of transportation services to leave the market. As demand for aggregates picks up, the prices of aggregates and the cost of transportation may begin to rise more in unison than has been seen in the last decade.

The simulation algorithm is in Excel format and is easily used and adaptable to fit the specific conditions desired by the user. All calculations are performed with cell-specific directions, avoiding complex mathematical formulas. The Excel-based algorithm can be downloaded from http://isgs.illinois.edu/sites/isgs/files/files/publications/TruckCostSimulation.xlsx.

Table 1 Input data for the simulation

Transportation by truck	Amount
Manufacturer's suggested retail price ($)	165,000
Expected life (years)	10
Expected return on investment (%)	9
Depreciation	Straight line
Interest rate (%)	7
Miles/year	100,000
Operating days/year	250
Operating hours/day	12
Average load (metric tons)	24
Trip load time (hours)	0.25
Fuel use (miles/gallon)	6.2
Fuel price ($/gallon)	3.6
Driver wages ($/hour)	25
Benefits (fraction of wages)	0.33
Tire replacement	Once per year
Price/tire ($)	400
Number of tires	10
Lube, repair, etc. ($/month)	250
Insurance ($/month)	600

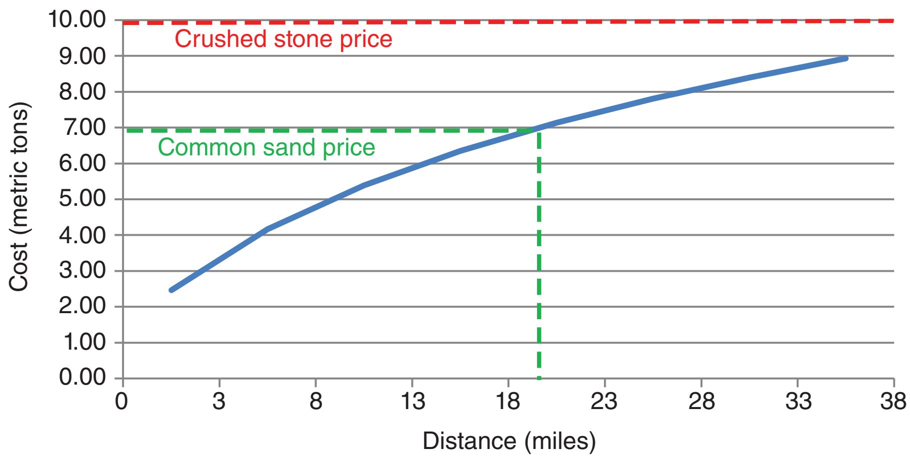

Figure 1 Simulated costs of aggregate transportation in 2014.

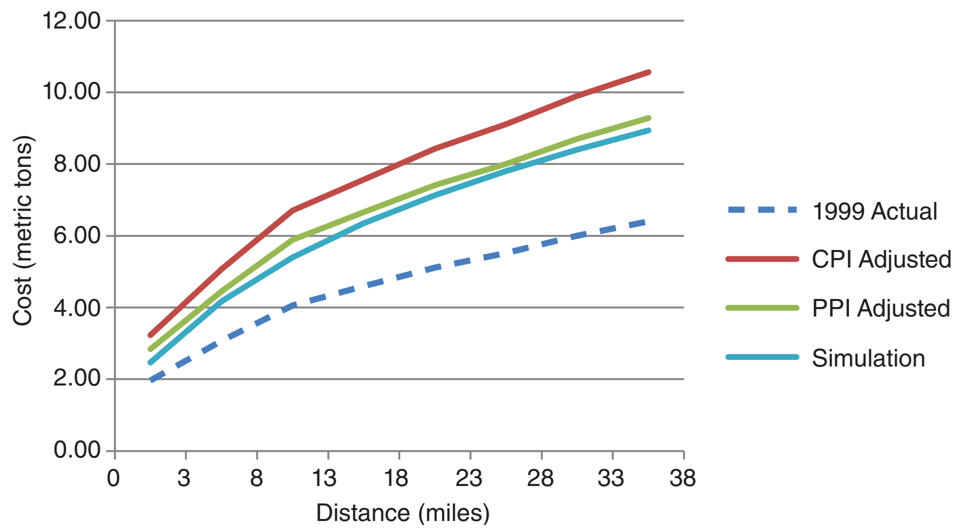

Figure 2 Comparison of 2014 costs of aggregate transportation by method of estimation. CPI, consumer price index; PPI, producer price index.

In Figure 2, the solid blue line represents the aggregate transport costs as estimated by the simulation. The dashed line in blue represents the actual 1999 costs reported in Bhagwat (2000, p. 1). The green line represents the escalation of the actual 1999 cost data using the producer price index (PPI). The PPI indicates how the manufacturing costs of equipment have developed over time. Finally, the red line uses the CPI to escalate the actual 1999 costs. The main observation emerging from the results in Figure 2 is that the cost estimates by simulation are almost identical to cost estimates arrived at simply by applying the PPI to the 1999 data. Why should one resort to simulation if the PPI gives equally accurate results? In part, it is because the CPI and PPI are based on baskets of selected goods and do not isolate the trucking industry, let alone the specific trucking sector involved in the transportation of construction aggregates.

The close alignment of simulated costs with the PPI-adjusted costs of 1999 indicates that the simulation approach is fundamentally sound. As a practical guide, however, it is important to note that the actual transportation costs in 2014 could be anywhere between the three projected curves in Figure 2. As noted earlier, the relative importance of transportation costs depends on the price of stone or sand at the quarry or the pit. Since 1999, the prices of aggregates have increased faster than the CPI. As a result, these materials can now be transported to more distant locations before the transportation costs equal the price of the transported materials. Consequently, this extends the market reach for the producers.

The slower increase in transportation costs in comparison with the prices of the aggregates themselves also contributes to holding the cost escalation of construction projects in check.

The recent explosive growth in demand for "frack sand" (i.e., sand used in hydraulic fracturing) and its high unit price further diminish the significance of transportation costs in that market. At the same time, the increased demand in transportation services caused by the demand in frack sand could exert an upward pressure on transportation cost rates in the future.

CONCLUSIONS

The results indicate that transportation cost estimates by truck simulation and based on price indices deliver valid and useful results. In particular, the use of the PPI resulted in values very similar to those in the simulation. Transportation costs have risen less rapidly over the past 15 years than the market prices of the aggregates themselves. As a result, the relative significance of transportation costs to the buyer of aggregates has slightly diminished. In other words, aggregates can be transported over longer distances before transportation costs equal the price of the aggregates themselves. It is estimated that in 2014, the transportation of crushed stone may have doubled its delivered cost about 45 mi (72.4 km) from the quarry, and that of sand and gravel may have doubled its cost about 23 mi (37 km) from the pit. Even though either cost estimation approach provides similar transportation cost estimates, the simulation approach is preferable because of its specificity. The results of this study also indicate that frequent cost simulations are useful because the market prices of aggregates can develop differently than the CPI or PPI might suggest.

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