BENEFITS OF TRANSPORTATION

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1. Introduction

Undeniably, without transportation modern economies would be unsustainable. In decades past, transport infrastructure investment was justified purely on the bottom line or to serve the greater public policy of nation building. Externalities were not given thought because these were borne by society with the investment viewed as progress by the employment generated.

But, as the world became more crowded, coupled with catastrophic events, which were accentuated by the media, public opinion demands that any investment - public or private - meet a rigorous test that include previously ignored externalities. Determining impacts of externalities in many cases can be a highly subjective art.

In 2009, the Federal Full Cost Investigation (FCI) committee of Transport Canada commissioned an exploratory study to review available literature on the benefits of transportation and associated state-of-the-art evaluation methods. This paper is based on the study and begins with a theoretical foundation for discussion and definition of benefits, followed by a presentation of analytical toolkits used to justify (or not to) investment in a project. The traps and pitfalls of each methodology are discussed followed by a prediction of the future research directions and summary.

2. Conceptual Foundations

2.1 *The Problem of Defining Benefits*

The total benefit of transportation by definition is the area under the demand curve for transport. Transportation abounds with factors that complicate the textbook treatment of measuring costs and benefits because the sector is comprised of markets ranging from competitive to regulated, with both private and public provision of infrastructure.

Pre-existing actions may have significantly affected the market such that external factors are internalized or altered by other policies. Productive and allocative efficiency can be altered by ineffectual competition, irrational behavior, and imperfect information.

Greene and Jones (1997) state that if one only allowed transport by humans (walking and carrying) society would be back in the Stone Age. Thus when we set out to measure costs and benefits, analysts are faced with an important question. Compared to what?

2.2 *Role of Transport in the Rise of Industrialization*

Blum (1997) observes that the classic definition of transportation as a derived demand for goods and people movement is the logical starting point. Transportation benefits are linked to economic and social dimensions: goods (public-private), economic (markets), and geographic (spatial). The social dimension is defined in a *social transportation function* that contrasts the derived function for goods movement.

Hunter (1965) and Button (1993) claim there are positive linkages between transportation and economic development. The main benefit of the steam engine for transport was the lowering of shipping costs, expansion of domestic markets and resource exploitation to sustain the industrial complex. Each increment of transportation improvement was a pre-requisite for continued growth of national economies.

Fogel (1964) proposes that American 19th century economic expansion was possible without the railways. He suggests that natural waterways with canal expansion were sufficient to provide a transport system at comparable or lower costs than rail. Fogel's position is that economic development is seen as a complex process whereby transport *permits* the exploitation of resources, distant markets and talents of a country, but is not an absolute. Therefore, transport's role is releasing capital from one region so it can be utilized more productively elsewhere, although the necessary prior condition of suitable markets must exist.

2.3 *Theoretical Underpinnings*

Blum (1997) uses a competitive equilibrium (CE) definition of the benefits of transport arising from the exchange of commodities in markets having two distinct dimensions: market structure and spatial dimension. He expands the CE definition to include externalities from a supply and demand perspective. In figure 1, the demand curve D_1 is from an individual's perspective for a vaccine shot to prevent oneself from contracting the flu. Total consumption by individuals is Q_1 at price P_1.

True social demand is higher than private demand because social utility exceeds private utility; for instance spill-over effects may occur if the good offered is not completely private. In the case of the

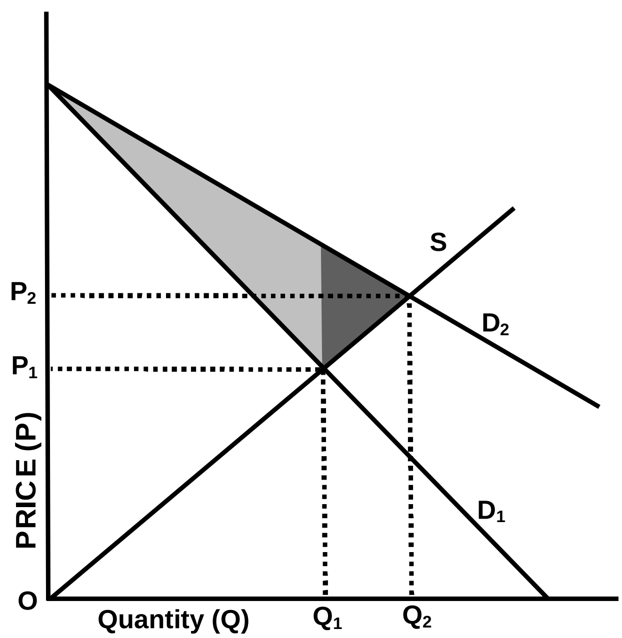


Figure 1: Supply-Demand Curve with Social Benefits

vaccine example, transport external benefits are present due to the vaccine itself and the transport to get it.

But, the shot also provides societal utility because it prevents others from contracting the disease by blocking the path of contamination. Consequently, actual demand should shift to a new equilibrium of D_2 with quantity consumed at Q_2 despite being at a higher price of P_2. The *societal external benefit* is given by the lightly shaded area, with loss of social utility given by the darker shaded area due to under consumption.

Prentice and Mazurek (2010) use a retail-production example in figure 2 to explain what happens in a market when a transport

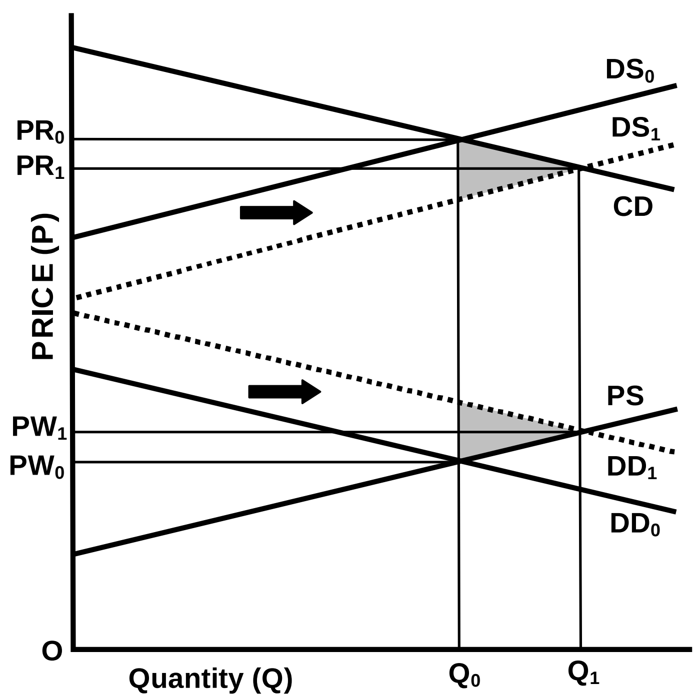


Figure 2: Retail-Production Example of Supply-Chain Effects from Transportation Improvement (Demand Side Changes)

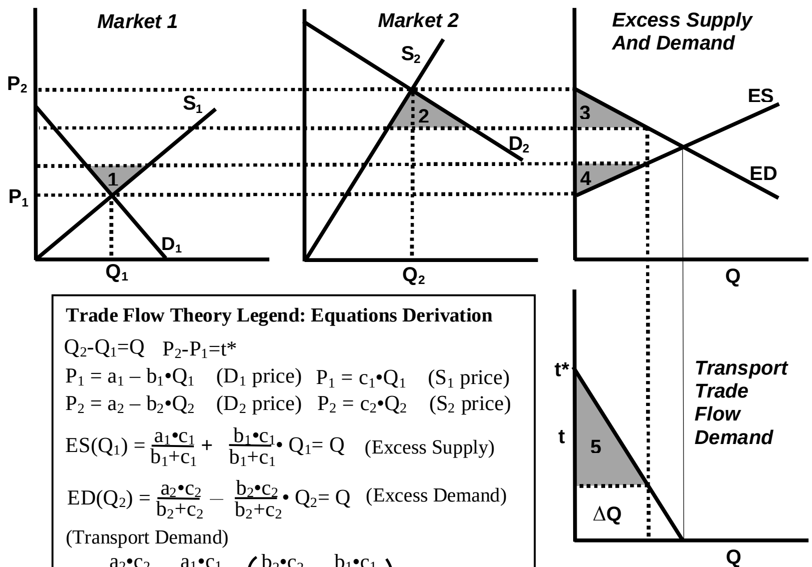
improvement occurs. The consumer demand curve (CD) defines the price-quantity curve for the retail consumer while the curve PS defines the price-quantity curve for the primary raw material supplier. Prior to the transportation improvement, the initial market equilibrium is at the product retail price of PR_0 at the derived supply quantity of DS_0. The wholesale price of raw material is PW_0 at the derived demand of DD_0.

After the transport improvement, the derived supply curve shifts from DS_0 to DS_1 to the new retail price of PR_1. If the primary supplier of the raw material is unaffected by the transport improvement, then the derived demand for raw material rises from DD_0 to DD_1 and increases the wholesale price to PW_1. The total quantity produced and consumed rises from Q_0 to Q_1.

Blum (1997) and Prentice and Prokop (2004) use trade theory to explain how transport overcomes spatially separated markets. Figure 3 shows trade flow between two markets with the context of two extremes: the absence of transaction costs and sufficiently high transaction costs that render the two regions autonomous. The transport reservation price is the maximum transaction (transportation) cost, represented by $t^* = P_2 - P_1$, that would reduce trade to zero.

Once transaction costs drop below t* trade begins to flow with producer surplus increasing in the first market more than consumer surplus falls; total wealth effects are positive and is represented by the shaded area number 1. In the second market, consumer surplus increases more than producer surplus falls, and the net increase is represented by shaded area 2.

For any given trade flow Q, the consumer surplus of demand is given by shaded area 3 with increase in producer surplus given by shaded area 4, and are identical to shaded areas 2 and 1 respectively. The *Transportation Consumer Surplus* (TCS) is the net increase in wealth contribution for the two markets and is represented by shaded area 5 and is the sum of excess supply and demand areas 3 and 4. The transportation demand and TCS curve equations are shown in the figure 3 legend for the mathematically adept.



Trade Flow Theory Legend: Equations Derivation

$Q_2 - Q_1 = Q \quad P_2 - P_1 = t^*$

$P_1 = a_1 - b_1 \bullet Q_1$ (D_1 price) $\quad P_1 = c_1 \bullet Q_1$ (S_1 price)

$P_2 = a_2 - b_2 \bullet Q_2$ (D_2 price) $\quad P_2 = c_2 \bullet Q_2$ (S_2 price)

$$ES(Q_1) = \frac{a_1 \bullet c_1}{b_1 + c_1} + \frac{b_1 \bullet c_1}{b_1 + c_1} \bullet Q_1 = Q$$ (Excess Supply)

$$ED(Q_2) = \frac{a_2 \bullet c_2}{b_2 + c_2} - \frac{b_2 \bullet c_2}{b_2 + c_2} \bullet Q_2 = Q$$ (Excess Demand)

(Transport Demand)

$$t = \frac{a_2 \bullet c_2}{b_2 + c_2} - \frac{a_1 \bullet c_1}{b_1 + c_1} - \left(\frac{b_2 \bullet c_2}{b_2 + c_2} + \frac{b_1 \bullet c_1}{b_1 + c_1} \right) \bullet Q$$

(Transport Consumer Surplus)

$$TCS = \frac{1}{2} \left(\frac{b_2 \bullet c_2}{b_2 + c_2} + \frac{b_1 \bullet c_1}{b_1 + c_1} \right) \bullet \Delta Q^2$$

Figure 3: Transport Consumer Surplus (TCS) from Trade Flow Theory

The previous figures depict the theoretical aspects of isolated transport investments. Figure 4 is taken from (1999 UN ESCAP) and demonstrates the role of transport in economic development within the socio-economic activity complex. Each increment of transportation improvement serves as a catalyst that promotes a feedback effect on the activities it supports. Reductions in input costs can lead to improved productivity, profits with the incentive to increase capital investment and output. This cycle of investment, spurred on by the initial transport improvement, provides the demand for the next round of transport improvements and so on.

What can be inferred from this diagram is that feedback mechanisms within a supply chain induce cycles of transport, industrial and social investments. In the broadest sense, growth effects from cyclical investment are captured at the aggregate level by GDP; determining the linkage mechanisms for cash flows within the network with precision is the challenge.

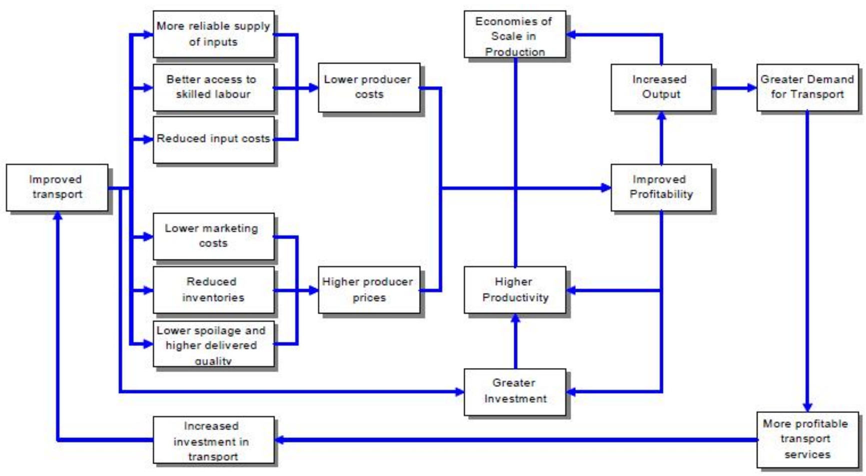


Figure 4: Economic Feedback Mechanisms from Transport Investments

3. Categories of Benefits

3.1 *Classification of Externalities*

Externalities occur when activities of one group affect the welfare of another. Button (1993) classifies the first as ***pecuniary*** or a calculable cost and cites the case of a garage owner that faces loss of business to a competitor further away when a new roadway opens.

Technological externalities appear in the utility function of a party without compensation. Button's example is when the after-mentioned new roadway blocks the view of a park for a resident (visual intrusion) and shadow prices are used to monetize these factors.

3.2 *Hierarchy of Benefits*

Prentice and Mazurek (2010) provide a hierarchical framework to classify benefits, they are:

Direct benefits of transportation can be defined as the services individuals and firms pay to receive, typically evidenced by transaction receipts. Direct benefits can be divided into those that serve a *derived demand versus primary demand*. Transportation resources consumed is willingness of the individual to pay to achieve a means to an end. All freight transportation serves a derived demand. If the cost of transport eliminates the ability to make a net gain, the shipment will not move.

Primary demand is carried out by individuals for the mere sake of travelling. A Sunday drive or a holiday cruise generally has the same origin and destination. The consumption of transport is for the enjoyment of the ride. The direct benefit, in the case of a primary demand, includes the entire consumer surplus.

Contingent (or mitigation) benefits target the prevention of damage, loss of life, cleanup costs, and other costs associated with natural or manmade disasters. An example of a mitigation benefit if an existing roadway is built to higher tolerances; say a 1 in 700 year flood versus a 1 in 100 year flood. If the road is repaired to its former state, it is not mitigation.

Incidental benefits, usually referred to as indirect, are gains that appear in the socio-industrial activity complex from the transport investment. Inventory costs, customer operations, size and costs, residential housing choice, and business location are typical examples of how transport infrastructure characteristics influence the immediate socio-economic complex.

Tertiary benefits (aka. Intangibles) are difficult to measure because they have no market price. Typically, intangible benefits appear in economic justification reports as numerically or subjectively ranked. Monetary value assigned to intangible benefits are based on best estimate or “gut feel” experience (shadow pricing).

4. Evaluation Methodologies

Three broad categories of analysis are used to evaluate investments, they are: *microeconomic, mesoeconomic and macroeconomic*. All use a variety of toolkits refined over several decades, but still retain shortcomings that are discussed in the section on traps and pitfalls.

Microeconomic evaluation generally relies on Benefit-Cost Analysis (BCA), or Cost-Benefit Analysis (CBA) as it is also known, to justify an investment and is the “workhorse” for analysts. BCA is based on the comparison of costs versus the anticipated benefits of an investment cash-flow for a specified time frame using a discount rate. An extension of BCA analysis is *Life Cycle Costing* (LCC) where by different infrastructure provision scenarios are run to determine the optimal return on investment.

Mesoeconomics lies between micro and macroeconomics by establishing links between the transport system and the immediate socio-economic complex. For industry, supply chain efficiency gains appear in inventory reduction, expedited production and cash turnover, lower warehouse costs and compressed customer response time. A more efficient, lean and responsive supply chain increases industrial capacity without expending additional resources. Incidental gains can be determined directly (working capital saved from inventory reductions) or estimated by the use of mathematical relationships such as elasticity functions.

Multi-Criteria Analysis (MCA) is a non-monetary method that uses weighted and/or numerical scaling in the absence of market prices for assessment. Multiple Account Evaluations (MAE) accrues sub-account costs and benefits to determine the impact on individual players. In a network, the objective is to maximize gains to the group as a whole without detrimental effects to any one player.

Macroeconomic studies utilize aggregate statistical inferences for assessing effects of large scale network investments ranging from civic to national economies. Airport economic impact studies attempt to demonstrate the ripple effect through the economy. Multipliers estimate indirect and tertiary job creation, and are often called the "egg on a plate" model.

5. Case Reviews

5.1 *Community Poverty Alleviation*

The role of transport in economic development is often debated on the premise that a prior demand must exist, but evidence from literature suggests that transport influences, and in certain cases invokes or enables desired activities to occur. The United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP 1999) examined the role of transport in poverty alleviation, projects were:

- Rural roads and Market improvement Project in Bangladesh,
- Least Developed village grant scheme in Indonesia,
- Dhading Development Project and Gorkha Development Project in Nepal,
- Aga Khan Rural Support Program in Pakistan, and
- Medium term Development Plan in the Philippines,

In all five cases, improvement in transport services played a pivotal role in increasing the standard of living in targeted communities. In two groups of villages in Bangladesh, agricultural output was 42 percent higher in the group with better transport, the difference attributed to the lower cost of fertilizer and market access.

> ***"More specifically, it has been recognized that the provision of a high quality transport system is a necessary precondition for the full participation of remote communities in the benefits of national development"***
>
> ***UN ESCAP 1999***

In Indonesia, a transport strategy was put in place that lowered costs of health care by high speed water and air access from outer islands to fully equipped urban centers. As the government's health budget was finite, it was not realistic to duplicate universal services on every island. Concentration of population in urban centers creates economies of scale that biases service provision to metropolitan areas. Regional health centers supported by rapid response transport proved to be the least cost, highly effective solution.

5.2 *Transportation Contribution to GDP Growth*

Green and Jones (1997) cite the rise in computing power over the past several decades that researchers have migrated to general equilibrium modeling (GEM) of networks to ascertain benefits. Fogel (1964) made an early attempt at such an approach to determine the social benefit of railroads versus canal networks in American from 1840 to 1890. The method estimates the resource cost of production in a time period with the initial and alternative transport systems in place to assess social savings.

Fogel calculated that American GDP growth was 4.7% higher with railroads over canal systems. This is in contrast to Williamson (1974) who calculated that GDP growth was in fact 12.8%. But Williamson's figure was for all transportation and distribution, including intermodal connectivity between canal and rail networks. What Williamson may have calculated was the incremental increase of structural and organizational changes in the entire socio-economic complex due to the presence of (competing) and complementary transport systems.

Nadiri and Mamuneas (1996) studied the contribution of highway capital to U.S. productivity and growth by using cost functions for 35 industrial groups. Causality tests suggest that aggregate highway capital can be considered an exogenous variable in the industry cost functions. Further, the authors made endogenous estimation of cost factors and independent estimate of demand for each industry – developing output and cost elasticities for each. Rates of return were calculated for highway investment by relating cost reduction estimates to opportunity costs of the roads to arrive at an aggregate measure of the social rate of return.

Table 1 shows that the rate of return was very significant during the 1950's and 1960's when the U.S. Interstate system was still in its infancy, but as the system matured, returns became comparable to private investment returns. Nadiri claims that highway investment was the second most significant contributor to U.S. productivity aside from the exogenous demand for goods and services.

Table 1: Annual Rate of Return (%) by Investment Type

Investment Class/Period	1950-59	1960-69	1970-79	1980-89
Total Highway Capital	35%	35%	16%	10%
Non-local Highway Capital	48%	47%	24%	16%
Private Capital	13%	14%	12%	11%

Source: Nadiri and Mamuneas (1996)

6. Traps and Pitfalls

Prentice and Mazurek (2010) identified the foremost problem in their research on the state of the art in methodologies for measuring transport benefits – the lack of a global standardized approach. There were notable differences between North America and Europe of what is included in a BCA.

In several European countries, tertiary issues such as community severance (a new road that cuts through a neighborhood), visual intrusion and access to essential services entered into the analysis by using MCA or MAE in addition to BCA. While the differing approaches are understandable from each society's valuation standpoint, it renders comparison of investments difficult.

BCA is best suited for isolated single projects that are not subject to network scaling effects. Agglomeration theory suggests that synergistic businesses will locate near infrastructure that offers the most expedient cost effective access to markets and productive capital. Transport improvements can induce structural and organizational change in the socio-economic complex.

Linkages in supply chain studies are also fraught with methodological errors. For example, inventory volumes are determined by carry costs and transport speed as a trade off against the risk of customer stock outs. Transport must be isolated from effects of other variables to assess benefit.

Macroeconomic studies rely on long run historical data to predict future results (as does BCA). This can be misleading if there are significant changes in technological, policy, societal and production factors that shift relationships during the analysis period.

Methodological errors such as double counting are more critical. Suppose a shipper has a volume discount with a carrier via a quarterly rebate. If the shipper places the rebate in the revenue side of a corporate ledger, it is double counted if the shipping charge already appears as a reduced amount in the cost column. Only when resources are conserved or overall wealth is increased are benefits realized.

7. Discussion

Quinet (1997) states that there is awareness that transportation prices send wrong signals to economic agents and leads to inefficient transport systems. Environmental valuation methods are still in the development stages and need to correctly combine economics, biology, ecology, chemistry and psychology. Despite this, several European nations have established taxes based on environmental damage.

Results by Fogel (1964) and Williams (1974) are similar to Nadiri and Mamuneas (1996) as wholly new technologies and systems are put in place. But, what is not clear is the endogenous (intermodality) relationships with rail and marine systems during this period. To what extent should the road network have been provided in relation to incumbent rail and marine networks? In other words, have we overbuilt the public road network? Are we today, in a sub-optimal unsustainable situation?

What the Nadiri and Mamuneas (1996) study alludes to is that at a given point in economic development, a country's growth potential is maximized for a given spatial and transport network. While the contemporary view may be that a high functioning transport system is an obvious *sine qua non* for fostering economic development, the opposing view is that further investment in expansion of existing transport systems (especially Europe, North America) are reaching marginal, or even negative returns.

8. Conclusion

The critical issue that the literature revealed was inconsistency in how benefits and costs are treated across jurisdictions, what is included and how it is measured. This largely stems from societal and cultural valuation of each item. The disconnection, however, does render benchmarking beyond generic measures on a global scale ambiguous.

Discourses among scholars in transport literature generally agree that external benefits of infrastructure and technology use are pecuniary in nature. As Quinet (1997) points out, revelations in benefits of transportation will not come from sector specific research, but rather the social and life sciences. GEM continues to evolve and previously elusive intangible externalities will become quantified, although this is a minor issue.

According to Greene and Jones (1997) the issue appears to be adequate accounting of public investment. At the heart of the matter is whether transport infrastructure, especially roads, should be a public good. Strapped by budget constraints, governments continue to evaluate the provision and regulation of highways as essential public goods. If a major public policy shift were to occur, fairness of the system would be an issue and understanding benefits is essential for establishing equity. Understanding and measuring benefits is where work remains to be done. Who pays for it is only half the equation.

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