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An Integrated Approach to Transportation Policy in BC

ASSESSING GREENHOUSE GAS REDUCTIONS OPPORTUNITIES IN FREIGHT TRANSPORTATION

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EXECUTIVE SUMMARY

Transportation services are central to movement of goods and people in modern economies. Their provision embodies many tradeoffs between: economic benefits, health effects, social and environmental impacts. Policies aimed at achieving deep greenhouse gas emission reductions from the transportation sector will invariably impact the balance of these benefits and dis-benefits of transportation. These impacts will arise both directly, as intended by the designers of the policy and indirectly, as a consequence of limited foresight, internal dynamics of the system and other drivers of how transportation services are delivered. Finally, it is important to remember that transportation facilitates transactions in the economy. The incentives in the economy and capacity of infrastructure to respond to changing patterns of demand are often a much stronger determinant of the evolution of this sector and its emissions.

It is tempting to ask which greenhouse gas emissions reduction policy is optimal. When the objective of a policy or program is to change matters marginally, one can assume that all other features remain unchanged and optimise for this specific objective. However, in the case of deep greenhouse gas emissions reductions this is not the case. Consequently, climate mitigation policies and programs cannot be *optimal*, unless one specific metric of impacts is used to reflect the myriad perspectives of stakeholders on the many aspects of this sector.

In this white paper our goal is to present an integrated assessment for the design of greenhouse gas emissions reduction policies. This involves:

- a framework for understanding the drivers of GHG emissions from the transportation sector;
- an approach for assessment of the intended and unintended impacts of policy proposals, reviewing more than a dozen BC initiatives;
- and, an evaluation methodology that explicitly reflects the challenges in realising the objectives of policy through program deployment and final outcomes.

We review iconic greenhouse gas emissions policies and programs, providing illustrations of their intended and unintended consequences. These illustrations highlight the importance of adopting an approach that can capture the full dynamics of this sector and the lifecycle impacts of policies and programs aimed at its modification.

Proposals such as low carbon fuel standards, mandated vehicle technologies, congestion fees, and investment in alternative transportation infrastructure all have complex intended and unintended consequences which need to be carefully assessed. The tools to conduct such analyses are already available to academia. A laudable goal is the translation of available knowledge into a toolkit suitable for design of policies and programs in this sector. Using this toolkit, rigorous and comprehensive analyses of transportation policy options can be performed. Both toolkit development and application can be accomplished through the Pacific Institute for Climate Solutions, with the promise of rapid turnaround on quantitative analyses of proposed new transportation strategies and policies.

CONTENTS

1 INTRODUCTION

1.1 Overview

This white paper examines the challenges of managing greenhouse gas emissions in the transportation sector in British Columbia, with a specific focus on emissions associated with freight movement. Three key areas are explored in detail:

- Drivers of greenhouse gas emissions in the transportation sector;
- Criteria for identifying effective greenhouse gas reduction policy solutions and desirable policy traits;
- Current and proposed greenhouse gas reduction polices, and associated risks and benefits.

1.2 Framing the Challenge

The overarching objective of government regulations should be the improvement of the welfare of its citizens, while ensuring that the welfare of those living beyond government jurisdiction is not adversely affected. In seeking long-term solutions for reducing the greenhouse gas emissions of transportation in British Columbia, we must focus on delivering the maximum benefits from transportation services while minimising any adverse socio-economic and environmental impacts. Current greenhouse gas emission patterns are a consequence of the technologies used to deliver transportation services as well as the pattern of demand for such services. Both will likely need to change in order to meet British Columbia's 2020 greenhouse gas emission reduction targets under the Climate Action Plan.

We have more than a century of experience with government policies and programs aimed at modifying key features of the transportation sector to increase safety and energy security, while lowering adverse environmental impacts. It is important to recognise that new policies aimed at greenhouse gas emissions alone can undo the benefits generated by earlier policies. Thus, in seeking to reduce greenhouse gas emissions we must understand the full benefits and costs of transportation services and the policy instruments available to modify these services. In this document we aim to outline an analysis approach that helps ensure that full costs and benefits are well understood.

1.3 Greenhouse Gas Emissions in British Columbia

The 2006 emissions inventory for British Columbia estimated annual emissions of 62.3 million tonnes of greenhouse gases ($MtCO_2e$), 8.6% of Canada's total [5]. Provincial emissions have grown 27.4% between 1990 and 2006, in large part due to emissions growth in the transportation sector (36% of BC's 2006 total [Figure 1]). Accordingly, greenhouse gas emissions reduction in the transportation sector will be a critical component of British Columbia's Climate Action Plan.

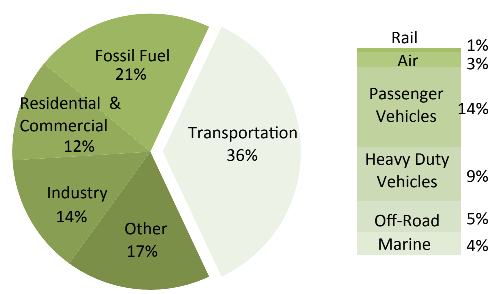

Figure 1 – Greenhouse Gas Emissions in BC, 2006 [5]

2 DRIVERS OF GREENHOUSE GAS EMISSIONS IN THE TRANSPORTATION SECTOR

Greenhouse gas emissions in the transportation sector are relatively straightforward to quantify based on fuel sales data. However, in order to reduce greenhouse gas emissions, we must understand not just emissions volumes, but the drivers of demand for the transportation services that generate these emissions. Relationships between transportation demand and our social, political, and economic systems are highly complex and uncertain. Further complicating these relationships are the long-time periods (i.e., the time to turn over the stock of vehicles) and large geographical scales (i.e., regional, provincial, or national) over which they operate. This section reviews these relationships within the context of British Columbia.

2.1 The Activity, Modal Share, Intensity and Fuel (ASIF) Framework

The Activity, Modal Share, Intensity, and Fuel (ASIF) framework developed by Schipper et. al. [9, 10] provides insight into drivers of greenhouse gas emission and the potential impact of policy decisions:

Activity: the total passenger[a] kilometres or tonne (freight) kilometres traveled;

Modal Share: the share of activity attributable to each mode *i* (eg. car, truck, rail, air, marine) [b];

Intensity: the amount of energy used per passenger or tonne (freight) kilometre by mode *i*;

Fuel: the greenhouse gas emissions per unit energy (eg. the carbon intensity of a fuel) for fuel type *j* used in transportation mode *i*.

Greenhouse gas emissions (G) are related to these four factors by the following equation:

$$\mathbf{G = A^*S_i^*I_i^*F_{i,j}} \quad \text{(see footnote [c] below)} \qquad (1)$$

Although there is likely interaction between factors, the relationship shows that greenhouse gas emissions increase as activity increases, as energy intensity increases and as the carbon intensity of fuel increases. It is somewhat less obvious that emissions increase as the structure of the overall vehicle fleet shifts to those vehicles with greater intensities. Thus, the overall intensity of the fleet is highly dependent on vehicle composition and the share of travel between the different modes.

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[a] Includes both motorized and non-motorized (walking and cycling) methods of transportation

[b] Modal share is also defined as Structure by Schipper et. al.. See Appendix A for definitions of the vehicle modes.

[c] More rigorously, S is a vector of the modal shares, I is the modal energy intensity of each mode i, and Fi,j, represents the sum of each of the fuels j in mode i

2.1.1 Trends in Activity, Modal Share, Intensity, and Fuel

Although greenhouse gas emissions are relatively easy to estimate on aggregate using fuel sales data, without understanding how the fuel is being used (A,S and I), informed actions cannot be taken to reduce emissions. This section examines trends in activity, modal share, intensity, and fuel in British Columbia between 1990 and 2005. High quality, detailed provincial data for most recent trends are unavailable. The analysis presented here is based on data published in Natural Resources Canada's "Energy Use Data Handbook, 1990 to 2005" and the associated Comprehensive Energy Use Database [1, 6]. Despite some limitations[d], these data provide a reasonable picture of greenhouse gas emission in British Columbia and the Territories (disaggregated data were not available).

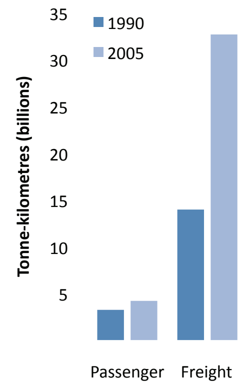

Figure 3 - Road Activity [1]

2.1.2 Activity and Modal Share

Total road activity, measured in tonne kilometres[e], increased dramatically (115%) between 1990 and 2005, with the greatest increase seen in the freight sector (134%) and a more modest increase in the passenger sector (30%) (see Figure 3). Detailed activity data at the provincial level were not provided for rail, marine, and air transportation. As a result, estimates were derived from other data sources. Although rail freight activity was estimated[f] to be more than double that of road, rail activity has grown more slowly between 1990 and 2005 (55% compared to 134%) and rail passenger activity has declined by 14%. In terms of total tonnage, marine activity has remained nearly unchanged between 1996 and 2005, but container traffic jumped 238% at the Port of Vancouver over the same period [11]. At Vancouver International Airport (YVR) both passenger and cargo traffic rose significantly (65% and 55% respectively) between 1992 and 2005 [12, 13]. Furthermore, although passenger activity at YVR has decreased in recent years, traffic at regional airports has shown stronger growth [14].

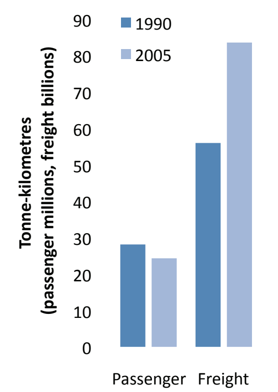

Figure 2 - Estimated[f] Rail Activity [1, 7]

Available provincial data describing changes in modal share between 1990 and 2005 show:

- light duty truck and SUV numbers grew by 92%, where as the number of small cars decreased and large car numbers remained essentially unchanged.
- a shift to smaller aircraft beginning in 1997 following airline industry changes including deregulation, signing of the Canada-United States Open Skies Agreement in 1995 and divestment of regional airports by Transport Canada [14, 15].

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[d] The data in the handbook and database are derived from numerous sources and models and include data for both BC and the Territories. There are some discrepancies with the data in the handbook and other sources such as Statistics Canada and Environment Canada. Despite these limitations the handbook provides a reasonable source of consistent data for a preliminary analysis.
[e] Although passenger kilometres are the more common unit of measure in the passenger sector, passenger kilometres were converted to tonne kilometres based on the assumption that the average person weighs 70kg to allow for comparison between the passenger and freight sectors.
[f] Rail activity was estimated using fuel consumption data to attribute activity at the national level to BC.

2.1.3 Intensity

Intensity data presented here are based on national level statistics[g]. Though individual vehicle intensity is somewhat dependent on operational, climatic and topographical factors, aggregate intensities are unlikely to be significantly different across the country. Intensities of all modes have decreased between 1990 and 2005 (see Figure 4 and Figure 5); freight sector decreases of approximately 16% and 37% were achieved by trucks and rail respectively. Similar trends were seen in the passenger sector, although it is important to note that passengers are inherently more energy intensive to transport than freight.

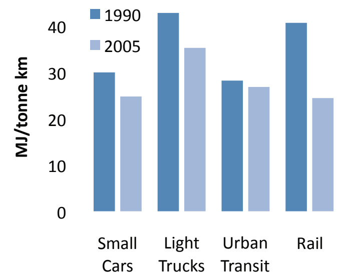

Figure 4 –Passenger Sector Intensities by Select Modes (zero emission modes including cycling and walking not shown) [6, 7]

The observed decreases in intensity result primarily from improvements in technical efficiency, increased capacity utilization[h] playing a role in some modes, notably air. In the passenger sector, increases in technical efficiency were seen across nearly all modes despite corresponding increases in engine power [16]. Critically, poor capacity utilization and operational inefficiencies have resulted in urban transit bus systems with per passenger intensities nearly equal to small cars (see Figure 4). Also notable are the significantly higher intensities of light and medium trucks in the freight sector (see Figure 5). This likely results from lower technical efficiency per tonne km than larger trucks, poor capacity utilization, and the performance penalty associated with operating in more congested urban environments.

In conclusion, although improvements in technical efficiency have played a significant role in decreasing intensities, congestion and infrastructure quality also impact intensity. However, there are insufficient data to draw a specific conclusion as to the magnitude of this impact.

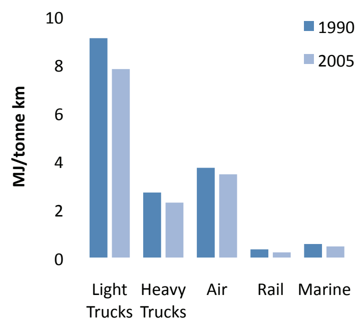

Figure 5 –Freight Sector Intensities by Select Modes [6]

2.1.4 Fuel

There has been little change in composition of fuels in the transportation sector between 1990 and 2005. Gasoline has remained the dominant fuel type in the on-road passenger sector (86%-93%). Diesel fuel makes up nearly all fuel consumed in the freight sector. However, there has been a shift to heavy fuel oil in the marine sector, which is likely to have a more significant impact on air quality than greenhouse gas emissions. Biofuels have yet to make significant inroads in either the freight or passenger markets, although several fleets including Translink have recently adopted biodiesel [17]. Although the overall carbon intensity of British Columbia's fuel mix has not changed as a result of fuel switching, the lifecycle emissions associated with fuel production have likely increased in recent years with the increasing contribution of Alberta's oilsands to Canada's fuel mix. Although these emissions are not generally attributed to the transport sector, they are driven by activity (and the resulting demand for additional fuel) in this sector.

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[g] Intensity data were not available at the provincial level

[h] The capacity actually used divided by the total available capacity; also known as a load factor.

2.1.5 Greenhouse Gas Emissions

As noted earlier, greenhouse gas emissions are the product of Activity, Modal Share, Intensity, and Fuel. Changes in these four factors have culminated in a 35% increase in emissions between 1995 and 2005[i] (see Figure 8 and Figure 9). Emissions rose substantially in the freight sector (55%) and more moderately in the passenger sector (19%); emissions are now split nearly equally between the two sectors. Substantial increases in emissions by light trucks in the passenger sector (88%) and increases across the board in the freight sector, with the exception of rail, drove up overall provincial transportation emissions (see Figure 7 and Figure 6). In aggregate, this was a result of increased activity and changes in modal share in both the passenger and freight sectors. Mitigating this increase were reduced intensities across all modes.

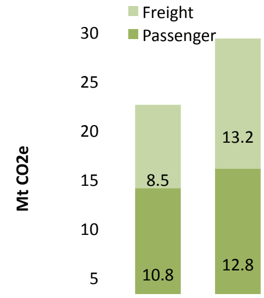

Figure 8 - Transportation Sector Greenhouse Gas Emissions [1]

2.2 Drivers of Activity, Modal Share, Intensity, and Fuel

Transportation greenhouse gas emissions have been increasing in British Columbia primarily due to increased activity and changes in modal share, although improved efficiency has offset this increase. Effective management of greenhouse gas emissions in the transportation sector requires understanding of the demand for these services and the social[j], economic, political, and technological drivers underlying this demand. In this section we review some of these drivers, providing the critical linkage between greenhouse gas emissions and policy options. The discussion is focused on those drivers with the greatest potential of affecting changein greenhouse gas emissions. It should be stressed that these drivers are highly interlinked, and although they have been disaggregated to a degree for the purpose of this discussion, those formulating policy must be aware of interaction between drivers.

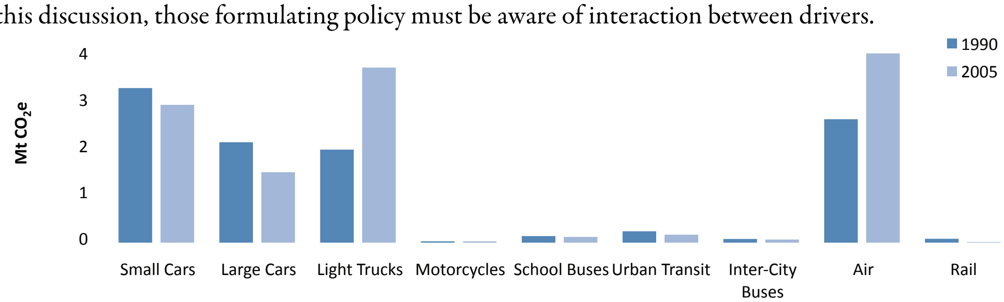

Figure 7 - Passenger Sector Greenhouse Gas Emissions (zero emission modes not shown) [1]

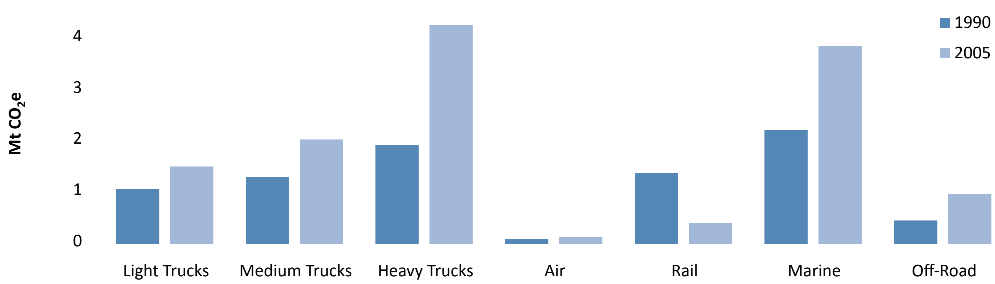

Figure 6 - Freight Sector Greenhouse Gas Emissions [1]

[i] Emissions by air and marine modes include only domestic activity

2.2.1 Economic Growth, Trade, and Population

Economic growth and population are key drivers of activity and emissions in the transportation sector (see Figure 9). British Columbia's gross domestic product (GDP) has nearly doubled between 1990 and 2004 and the link between GDP and activity, particularly in the freight sector, is clearly seen in Figure 9. However, correlation does not imply causation. Although traditionally linked, there is growing interest in the idea of *decoupling* the demand for transportation services from economic growth [18].

Despite being a useful macro level indicator, the relationship between GDP and activity provides little insight into decoupling these two variables because GDP encapsulates many factors [10, 19]. A recent review by McKinnon [20] that examined 12 possible drivers of decoupling in the United Kingdom revealed that although decoupling appeared to be taking place in the freight sector, much of it was the result of leakage; the shifting of emissions to other countries. In his analysis McKinnon cites three main drivers: increased penetration of foreign haulers, a modal shift from truck to rail, and a real increase in road freight rates. He further cites that the erosion of industrial activity to other countries, the corresponding growth in the domestic service sector, and diminishing rates of spatial concentration have had very significant impacts. Tapio [21] recently reviewed the issue of decoupling across 15 European countries and concluded that no decoupling had occurred in the freight sector but that there were some positive signs in the passenger sector. Activity in the passenger sector is strongly correlated to population (see Figure 9) as well as income and vehicle ownership [9]. However, others have argued that automobile dependence is more strongly related to urban form (see Section 2.2.2).

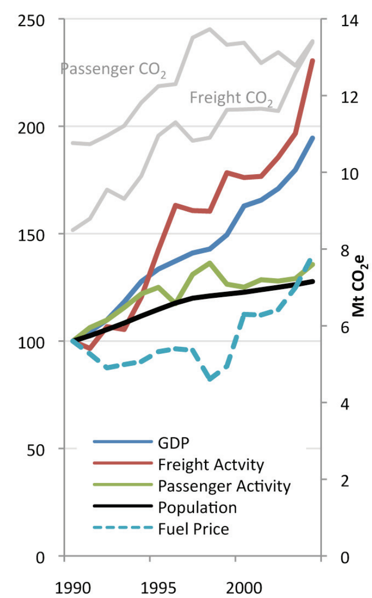

Figure 9 - Normalized Economic, Activity and Population Indicators (1990 = 100) and Greenhouse Gas Emissions for BC between 1990 and 2004 [1-3]

Over the last several decades a growing service sector has changed the face British Columbia's traditionally resource-based economy. The impact of this shift on dematerialization and the demand for transportation services is unclear. McKinnon [20] noted that dematerialization had little effect on decoupling economic and freight transportation growth in the United Kingdom and this is likely the case in British Columbia, although further analysis is required. However, unlike the United Kingdom, in British Columbia there has effectively been a modal shift from rail to trucking. Although there is unquestionably a complex interplay of factors at work, in aggregate, no decoupling of growth in the freight sector from growth in GDP is evident in British Columbia (see Figure 9). Promisingly, this is not the case in the passenger sector.

The recent growth of Asian economies, both as producers and consumers, is a significant driver of increased activity in British Columbia's freight sector [22]. The Port of Vancouver alone has

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[j] Including but not limited to population and demographics

experienced a 238% growth in container traffic between 1990 and 2005, and both the Ports of Vancouver and Prince Rupert are in the process of significant expansion [23]. Although the United States is still British Columbia's largest trading partner (by value), trade with China has nearly doubled between 1997 and 2007 (see Figure 10).

British Columbia's trading partners appear to have a direct impact on modal share in the freight sector. Evidence suggests that trade with Asia has driven growth in the rail sector, whereas trade with the United States has favoured trucking [24, 25]. Following the signing of the North American Free Trade Agreement (NAFTA) in 1993, trade with the United States grew significantly, as did activity in the freight sector (see Figure 9). While the rail industry was limited by its ability to adapt its infrastructure to take advantage of this change, the trucking industry, utilizing its greater flexibility, was able to respond to the new demand.

Several other factors have also conspired against rail in favour of trucking [24, 26]. British Columbia's changing economy has brought about a shift in exports from commodities (bulk goods) to value added goods [27, 28]. As the value of goods shipped increases, the percentage of the cost of the goods attributable to transport decreases. The result is less sensitivity to the cost of transportation and increasing willingness to pay for added services such as just-in-time delivery, which favours the more flexible and responsive trucking industry as well as air freight. Finally, increased United States-Canada border security has the potential to impact all modes of freight transport, although likely to differing degrees for each mode. To date cost impacts have been minimal [29], but there is some evidence of increased transportation costs as a result of new fees and delays. The long term cost impacts of border security remain uncertain.

2.2.2 Urban Form

As previously suggested, urban form has a significant impact on activity as well as modal share and intensity. The impact is often complex and difficult to quantify; nevertheless, numerous studies on the impact of urban form and activity have been conducted including several large studies by Kenworthy and Laube. Their review of more than 40 cities around the world shows that although wealth and the costs of purchasing and operating a vehicle are significant factors, urban form is the strongest driver of vehicle dependence and use [30, 31]. Estimates of this structurally enforced[k] vehicle use suggest that it makes up a significant fraction of overall vehicle use in urban environments [32, 33]. In addition, active transportation modes such as cycling and walking are particularly sensitive to urban form. These zero emission modes are often undervalued and may have significant potential to reduce emissions and improve health [34]. Increased density is widely associated with promotion of active transportation and reduction of energy and vehicle use.

In British Columbia structurally enforced travel such as commuting to and from work has changed little in the last decade. The average commuting distance has remained essentially unchanged at 6.5km between 1996 and 2006 [35]. However, over the same period there has been a modest reduction in the share of commuters using personal vehicles to get to work (81% to 79%) and a slight increase in those using public transportation (9% to 10%). Although British Columbia leads the country in terms of the number of employees commuting to work by bicycle – likely a result of the milder climate enjoyed by the majority of its residence - there has been little growth in this mode.

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[k] Travel required to meet certain vital functions in a society such as earning a salary and obtaining essential commodities.

2.2.3 Infrastructure

Infrastructure[1] is closely related to urban form and like urban form it impacts activity, modal share, and intensity. It has been well established that infrastructure development can increase vehicle ownership and use [9]. Further, the quantity and quality of road and rail infrastructure play critical roles in shaping modal share and, through their affect on congestion, also impact intensity. Poor infrastructure quality can increase intensity and reduce efficiency due to increased road-tire friction and increased accelaration and deceleration as a result of impediments to traffic flow. Finally, the process of constructing infrastructure generates substantial emission of greenhouse gases, in some cases negating any savings realized through more efficient operations.

Infrastructure congestion is an unavoidable characteristic of transportation systems; however, there are differing views on the necessity of mitigation congestion through the construction of additional infrastructure. Traditional thinking suggests that the impact of congestion is purely negative; increasing intensity and costs and reducing efficiency of the transportation system. Transport Canada recently released a report that estimated the annual cost of congestion in urban areas (mainly due to the value of lost time) was between $2.3 and $3.7 billion (2002 CND$) [36]. Conversely, it has also been argued that congestion is a critical feedback mechanism in the overall transportation system, shaping behaviour and regulating the demand for transportation services.

Investment and development of public transportation is widely recognized as a critical component of passenger sector greenhouse gas emissions reduction strategies. However, data presented in Section 2.1.3 raise concerns as to the level of emission reductions that can be achieved by public transportation, at least over the short-term. Nevertheless, in British Columbia (primarily in the Lower Mainland) significant investments are being made and modest increases in transit ridership have been observed [35]. There has been a general trend across a large number of Canadian cities of decreasing car use despite a growing number of commuters [37].

In the freight sector, public road infrastructure investments have likely had a significant impact on road-rail modal share in British Columbia, by offering an implicit "subsidy" to trucking. In both Canada and the United States, rail infrastructure is planned and owned by private companies, whereas road freight infrastructure is planned and funded by public agencies. In a recent review, Gorman [38] concludes that these disjoint planning processes have lead to suboptimal results and that United States truck freight could be reduced by 25% if intermodal rail infrastructure existed to support it, resulting in an 80% reduction in social costs. In Canada this decision making dichotomy initially played a different role. It was only after Canadian National Railway (CNR) was privatized in 1995 that it began expanding into the United States [25] and winning cross-border trade market share. Despite this initial success, many of the inefficiencies seen in the United States as a result of disjoint planning and funding processes likely exist in Canada, although further analysis is required.

2.2.4 Freight Logistics and Individual Choice

The decisions of individuals and organizations, themselves driven by many of the factors previously discussed, impact activity, modal share, intensity, and fuel both directly and indirectly. However, these decisions, even if optimal on the individual or organizational level, do not guarantee overall optimal

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[1] In this discussion infrastructure refers to both the transportation component of the built environment including roads, rail, marine ports, and airports as well as services such as public transportation.

results In his Nobel Prize winning work linking individual behaviour to macro-phenomena[m], Schelling [39] showed how reliance on individual preferences and decisions can lead to suboptimal results in aggregate. This finding suggests that high-level intervention, perhaps in the form of integrated planning, may be needed to realize optimal results across all scales.

Work by Richardson [40] suggests that factors that influence decisions differs between the passenger and freight sector. She finds that for passenger transport, physical, psychological and social needs are most important and that for freight transport, market forces and government policy dominate. This finding follows much of the discussion in the preceding sections. In the freight sector, market conditions are driving more timely and efficient delivery, such as just-in-time logistics - the economic benefits favour transporting over warehousing – which in turn can result in an undesirable modal share. However, better logistics across all modes, particularly truck and rail, has increased efficiency and reduced intensity. Despite these recent advancements a 2003 study in Germany revealed that there are still many opportunities to increase efficiency, particularly through improved information technology and Intelligent Transportation Systems (ITS) [41].

Although there is no doubt that passenger transport is influenced by both the variable (operating) costs and fixed (capital purchasing) costs, for example sunk cost logic[n], social factors also appear to be critical to the decisions of individuals. Recent work by Wilson [42] has shown that home renovation decisions made by British Columbian home owners are better explained by social norms than economic motives. Wilson further demonstrates that subsidies to individual home owners and on more efficient equipment leads to a free-rider problem and fails to convert the majority of home owners to more efficient alternatives. These findings likely extend to vehicle purchasing behaviour.

2.2.5 Technological Change

Technological change is a key driver of intensity and fuel and to a lesser degree activity and modal share. It has played a critical role in reducing intensity and emissions in British Columbia's transportation sector despite significant growth in activity. All modes of transportation have seen efficiency improvements over the last decade and had it not been for a preference for larger and more powerful vehicles in the passenger sector, emissions in that sector would likely have declined.

The future holds many promising technological solutions to reduce emissions in the transportation sector [43]; however, as many have acknowledged, technological solutions rarely deliver the savings that are promised. One of the many challenges faced by technological solutions is the rebound effect [44]. This effect occurs because higher efficiencies lower the costs of meeting demand for a given service, which in turn leads to consumers increasing their demand for that service. The net result is that a sizeable fraction of the emission reductions due to higher technical efficiencies are lost.

2.2.6 Fuel: Price and Lifecycle Emissions

There is no doubt that the price of fuel impacts activity (see Figure 9) and over the long term modal share. For example, high fuel prices create a preference for more efficient modes of transportation. However, in wealthy jurisdictions the fuel price elasticity of vehicle use tends to be low, particularly over the short term, meaning that a significant increase in price needs to occur before users begin curtailing activity [45]. In recent years, fuel prices have risen to historic highs in British Columbia and Canada, with a rapid decline in recent months. There is little question that higher fuel prices, whether

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[m] For example, how individual decisions related to employment and housing lead to patterns of regional development
[n] Sunk cost logic can be characterised by the following statement: "I paid for my car so I better use it"

produced by market forces or taxes, will reduce emissions, although the magnitude of this reduction is unclear [46].

As previously discussed, awareness of fuel and infrastructure lifecycle emissions is critical to truly achieving greenhouse gas emission reductions. Estimates have shown that only about 76% of emissions are actually associated with fuel combustion [47], with the remaining emissions associated with manufacturing (9%) and supplying fuel (15%). As discussed by Farrell et. al. [48], we are in the early stages of a transition away from conventional petroleum products. Our options include substitutes and unconventional sources. Enhanced oil recovery (EOR), heavy oil and tar sands, and coal liquefaction all have higher upstream energy costs and emissions. Biofuels have the potential to reduce lifecycle emissions but these reductions are highly dependent on feedstock, agricultural practices and conversion technologies. food-crop based ethanol has to date failed to realize lifecycle emission reductions because of emissions associated with its production [49]; in contrast, canola and soybean biodiesel have shown more promise [50].

2.2.7 Regulations

A variety of regulations impact greenhouse gas emissions in the transportation sector, including: fuel consumption regulations, air pollutant emissions regulations, and fuel standards. Fuel consumption regulations directly impact intensity. The latter two categories effect greenhouse gas emissions from vehicles both directly and indirectly. For example, emissions control devices required to meet air pollution regulations can increase vehicle fuel consumption. They may also reduce black carbon which has been shown to exacerbate global warming [51-54] and is associated with respiratory illness [55].

In aggregate, the light duty passenger vehicle fleet in North America has been required to meet Corporate Average Fuel Consumption (CAFE) regulations since the oil shock of the 1970s. However, CAFE has been largely unsuccessful in reducing overall fuel consumption because of a modal shift to larger vehicles. In 2004 the state of California attempted to introduce legislation to directly regulate greenhouse gas emissions; however the United States EPA overturned that legislation. British Columbia is currently considering similar legislation. In 2006 the Canadian government announced intentions to proceed with a renewable fuel standard, which is designed to reduce fuel lifecycle emissions. The provincial government has since expanded this mandate and requires that biodiesel make up 5% of provincial fuel supplies by 2010.

Non-road vehicles (such as construction, mining and agricultural equipment) were brought into the United States regulatory system in 2004. Trains and ships currently meet only basic pollutant emission standards in North America[56], although a new rule by the United States EPA requires that from 2012 onwards, rail and marine diesel engines must meet more stringent air pollution standards [57]. Canada does not currently regulate railway locomotive emissions, and marine engines are only required to meet a "visible smoke density test"[58].

In conclusion, while there is significant experience with regulating fuel efficiency (and thus greenhouse gas intensity) in the on-road, light-duty vehicle sector, there are no direct greenhouse gas regulations for the marine, rail, and air transportation sectors. Regulations that indirectly affect transportation greenhouse gas emissions (particularly fuel quality and pollutant emissions standards) may have important impacts, but the direction and magnitude of their impacts are highly uncertain.

2.2.8 Deragulation, Privatization and Competition

Deregulation and privatization, through the drive for greater economic efficiency, have impacted intensity and modal share. Increased competition has driven gains in operational efficiency in many modes but particularly within the air and rail sectors. Advanced technologies have reduced intensities and a modal shift to more appropriately sized vehicles and aircraft have improved capacity utilization. However, as will be discussed in Section 5.3.4, there are limits to the advantages of privatization and deregulation and a balance must be struck to achieve the best possible results.

3 EVALUATING POLICIES IN THE TRANSPORTATION SECTOR

In order to successfully reduce greenhouse gas emissions in the transportation sector, the drivers of emissions outlined in Section 2 must be addressed directly, or the relationship between the drivers and greenhouse gas emissions must be modified. Following the International Energy Agency [59], we group policy initiatives targeting transportation greenhouse gas emissions reductions into eight categories or "points of intervention", which may directly address individual emissions drivers, or target multiple drivers simultaneously.

1) **The costs of fuel**, which can be adjusted to (partially) reflect the estimated externality costs of greenhouse gas and other pollutant emissions associated with fuel use. Example: *fuel taxation based on carbon content.*
2) **Other variable costs of motor vehicle use**, where charges could be applied based on total vehicle distance travelled, time of use, and/or location of use. Examples: *distance-based vehicle insurance, bridge / freeway tolling, urban congestion charges, freight payload charges.*
3) **The conditions of road traffic flow,** which can be modified by addition of new transportation infrastructure, modification of the operational regime for existing infrastructure (signalling, etc), or use restrictions for infrastructure. Examples: *freeway expansion, high occupancy vehicle lanes, time of day restrictions on freight truck traffic, signal optimization.*
4) **Alternatives to conventional road transport**, which can include all modes of public and active transportation for personal travel, and non-road freight transportation modes including rail, marine, and air. These alternative modes typically offer less flexibility than conventional road transport, so policies encouraging alternatives include infrastructure building to expand service areas, addition of capacity to existing infrastructure, and incentives for use. Examples: *construction of freight intermodal facilities, upgrading of rail and short sea shipping infrastructure.*
5) **Technology Availability (vehicle / infrastructure supply),** which refers to the availability of vehicle, fuel, and infrastructure technologies that reduce greenhouse gas emissions. The primary point of intervention is through support of research and development of technologies. Example: *support for research of alternative fuel vehicles, pilot projects for truck stop / port electrification.*
6) **Vehicle fleet demand and characteristics**, which can be modified by regulating the allowable characteristics (fuel, weight, emissions, etc) of aggregate vehicle fleets, providing tax incentives / disincentives based on vehicle characteristics, providing incentives for retirement of high emitting vehicles, and permitting the use of new vehicle types (eg low speed electric cars). Additionally, fleet demand can be modified by policies linked to categories 3 and 4 above, which lower the marginal benefits of conventional vehicle use by providing compelling alternative transportation modes. Examples: *fleet average greenhouse gas emissions regulations, tax rebates for hybrid vehicles, development of urban freight pooling programs, scrapping programs for high emitting vehicles.*
7) **Urban form**, which broadly targets the shape, zoning, and density of communities, controls the availability of parking or alternative transportation, improves viability of active transportation (walking and cycling), and changes property taxation based on transportation provision. Examples: *promotion / zoning of multimodal industrial areas with linkages to road, rail, and marine transport, creation of pedestrian only zones.*

8) **Public knowledge / attitudes towards transportation**, which are influenced through educational campaigns, training and provision of information on transportation alternatives. Examples: *websites promoting and detailing transportation alternatives, freight industry association promotion of efficiency initiatives, driver efficiency training.*

Any given transportation policy does not act in isolation, but within the context of the broader political, economic, and social framework, as discussed in Section 2. Greenhouse gas emissions reduction policies targeting transportation are often composed of measures targeting multiple points of intervention and are implemented alongside a multitude of other policies put in place by all levels of government, from municipal to international.

3.1 Evaluation Framework

Recognizing the importance of looking beyond simple dollar per tonne ($/$CO_2$e) metrics and keeping lifecycle policy feasibility in mind, we present a comprehensive list of criteria for evaluating the viability of transportation greenhouse gas emissions reduction policy solutions. We take our outcome criteria from transportation policy assessment literature [40, 60, 61], with a focus on criteria relevant to freight transportation policy in British Columbia:

- **Air Quality** – the direct increase or decrease in transportation air pollution emissions[o].
- **Congestion** – the positive or negative impact on road traffic congestion.
- **Environmental Noise** - the direct increase or decrease in traffic-related environmental noise.
- **Economic Cost** – the direct costs of program implementation ($/tonne$CO_2$e for greenhouse gas emissions reduction policies). These are distinct from the indirect costs of the policy derived from policy benefits and disbenefits (discussed further below).
- **GHG Emissions** – the direct greenhouse gas emissions reductions (or increases) effected.
- **Traffic Safety** - the direct increase or decrease in the frequency and severity of traffic incidents.
- **Other** (Energy security, land / water use, food security, etc) – other outcomes that may be of concern for specific policies.

There are a variety of approaches to weighting the importance of each criterion for policy assessment purposes. Utility-based approaches to policy analysis calculate the external social cost (or benefit) of changes in each outcome criterion. Public health approaches assess the additional deaths or years of life lost caused or prevented by a given policy. Social / political priority weighting takes into account the prevalent normative weighting of each criterion. In his doctoral thesis research on integrated assessment of passenger transportation policy in the United Kingdom, Mazzi [61] provides the relative criteria weights for each of these three approaches (see Table 1). Note that direct economic costs are not included Table 1, as they would be weighted equally across all three approaches; the differentiating feature of each weighting approach is their method of assigning indirect costs and benefits to inherently non-monetary outcomes.

[o] These include criteria air contaminants such as ozone, carbon monoxide, oxides of nitrogen, and particulate matter.

Table 1 – Ranking of Outcome Criteria Rank for Transportation Policy Assessment (Mazzi, [61])

Criteria Weighting	Economic External Social Costs	Public Health	Political / Social Priorities
Primary	Congestion	Air Quality, Traffic Safety	Greenhouse Gas Emissions
Secondary	Air Quality, Traffic Safety	Environmental Noise	Congestion, Air Quality, Traffic Safety, Energy Security
Tertiary	Environmental Noise, Greenhouse Gas Emissions, Energy Security	Congestion, Energy Security, Greenhouse Gas Emissions	Environmental Noise
Not usually considered	Land / water use, food security		

Stakeholder groups lobbying for changes in transportation policy will often have widely divergent priorities with respect to the evaluation criteria listed, perhaps aligning with one of the weightings in Table 1, or perhaps with an entirely different relative weighting of concerns. In performing a practical policy analysis, the task is not to determine which relative criteria weight is "correct", but instead to acknowledge that policies should be evaluated against multiple sets of weightings. A robust policy design should perform well regardless of the criteria weights chosen.

Further to the outcome criteria described previously, it is also vital to consider the practical feasibility of transportation policies and programs throughout the policy lifecycle. Figure 11 (following page) provides a graphical overview of the policy lifecycle, showing the accrual of policy outcomes, both beneficial and not beneficial, and the "feasibility stages" of the policy implementation process, with factors that may inhibit policy and program implementation or effectiveness.

Factors impacting policy and program feasibility include:

- **Availability / Complementarity:** Is the policy and any underlying technology proven and economically deployed at a reasonable scale in other jurisdictions? Is it compatible with the path of development followed so far and does it lock in undesirable patterns that hinder future developments?
- **Political Acceptability:** Does the current government perceive the policy and any underlying technology positively and support the goals underlying the policy? As indicated by the "Electoral Horizon" in Figure 11, most transportation policies and programs will span electoral periods, and as such, may be subject to oversight by governments of different political compositions. A well-crafted policy should be robust across differing administrations.
- **Public Acceptability:** Does the electorate perceive the policy and any underlying technology positively and support the goals underlying the policy? Policies aimed at greenhouse gas mitigation may face public opposition due to perception that increased costs or personal compromise may be required.

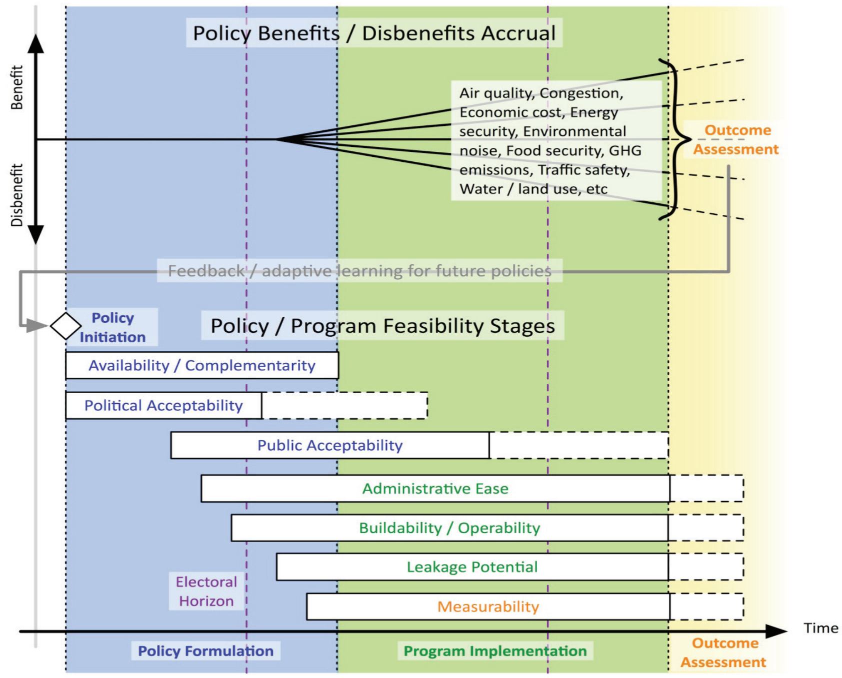


Figure 11 - Policy Lifecycle: Benefits / Disbenefits Accrual, and Feasibility Stages

- **Administrative Ease:** Are the policies and associated programs easily implementable given existing administrative and governance structures?
- **Buildability / Operability:** Is there sufficient capacity in the form of materials and labour to deploy and operate the technology or infrastructure programs underlying a given policy measure? It is important to recognize possible resource competition (such as skilled labour) with other economic sectors.
- **Leakage Potential:** Is the policy designed to use mechanisms that eliminate opportunities for consumers to meet their needs "across the border", outside the area of policy jurisdiction?
- **Measurability:** Are the outcomes of the policy and associated programs both measurable and attributable to the policy? In other words, will it be possible to derive a set of indicators to gauge policy effectiveness?

In promulgating and evaluating policies for greenhouse gas reduction potential, it is important to consider both initiatives expressly targeted at emissions reduction, and those with outcomes not defined in terms of emissions reductions. For instance, road expansion projects are often not evaluated in terms of greenhouse gas emissions impacts, but may have long term impacts on urban form, traffic flow, and public attitudes that undermine other projects targeted at transportation greenhouse gas emissions reduction. Additionally, due to the capital-intensive nature and long lifetime of transportation infrastructure and vehicles, past policies and programs may be locked in, creating a strongly path-dependant framework that new policies must function within. Thus, new transportation policies targeting greenhouse gas emissions reduction not only have to exist alongside a suite of other policies, but also alongside the persistent "ghosts" of past policies.

4 ASSESSMENT OF TRANSPORTATION POLICY INITIATIVES

Table 2 (following pages) groups major government freight transportation greenhouse gas reduction policy initiatives according to the eight categories discussed in Section 3. Examples are indicated for policies currently implemented in British Columbia. Following the evaluation framework elaborated above, the table shows the expected direct benefits (top left, in **bold**), indirect benefits (bottom right), direct dis-benefits (top left in **bold**), indirect dis-benefits (bottom right), and feasibility advantages (top left in **bold**), and feasibility disadvantages (bottom right) for each policy option.

It is important to draw attention to the potentially counterintuitive ratings for some policy options, which indicate both indirect benefits for a certain criteria, but also indirect dis-benefits for the same criteria (eg air quality indirect benefits and dis-benefits for new vehicle tailpipe emissions standards). This rating reflects that there may be pitfalls inherent in regulations designed to enforce a particular direct outcome (greenhouse gas emissions) without constraining other outcomes (eg air quality). For example, evidence has shown that greenhouse gas emissions reduction measures aimed at passenger vehicles in the United Kingdom resulted in a shift away from gasoline vehicles to diesel vehicles, reducing greenhouse gas emissions, but increasing particulate air pollution [8]. In the freight transportation context, it is conceivable that greenhouse gas emissions reduction policies could affect a modal shift from trucking to rail, but without constraints on rail air pollution emissions, could lead to degradation of local or regional air quality.

Table 2 – Assessment of Current Policy Initiatives Impacting Greenhouse Gas Emissions in British Columbia's Transportation Sector (following Mazzi [61])

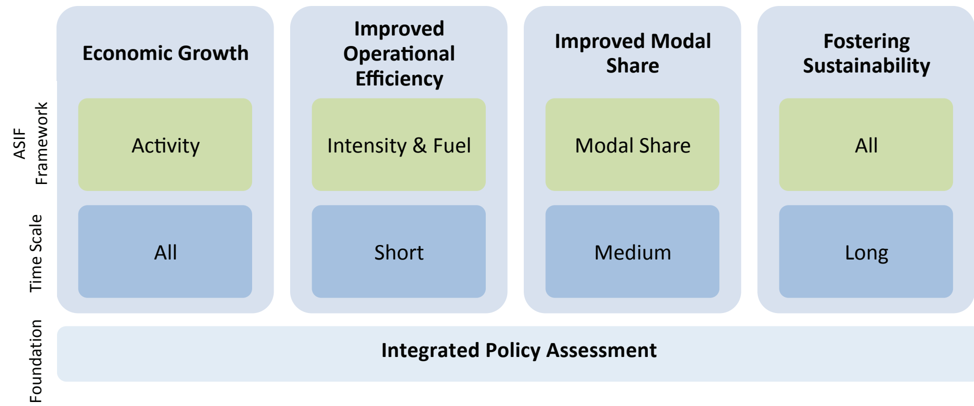
Legend: GHG – Greenhouse Gas Emissions, **C** – Congestion, **AQ** – Air Quality, **TS** – Traffic Safety, **EN** – Environmental Noise, **O** – Other, **AC** – Availability / Complementarity, **PA** – Political Acceptability, **AE** – Administrative Efficiency, **BO** – Buildability / Operability, **LP** – Leakage Potential, **M** – Measurability, **EE** – Economic Efficiency

Policy Category	Policy Description	British Columbia Example	Benefits	Disbenefits	Feasibility
Fuel Costs	upstream carbon tax	British Columbia 2008 transport / heating fuels carbon tax [62]	**GHG** / AQ, C	/ AQ, C	**AC, AE, EE** / PA, M
	Fuel tax	Fuel Excise Tax, Provincial Sales Tax [63]	**GHG** / GHG, C	/ AQ	**AC, AE, EE** / PA, M
	low carbon fuel standard (lifecycle CO_2)	Low-Carbon Fuel Standard [64]	**GHG** / AQ	/ AQ	/ AE, M
	Clean Fuels Tax Incentives	Clean Fuels Tax Incentives [65]	**GHG** / AQ	/ AQ	**AE** / M
Other Variable Costs	Bridge / road tolling	Gateway (twinned Port Mann Bridge); Golden Ears Bridge [66]	**C** / GHG AQ, N	/ GHG, AQ, TS	/ PA
	Charges on weight and distance driven;		**C** / GHG AQ, N	/ AQ	**M** / LP PA, AE
	Freight Cap and Trade		**GHG** / AQ, N,C	/ AQ,TS	/ AE, PA,LP
Traffic Flow Conditions	Highway infrastructure improvements	Kicking Horse Project; Sea-to-Sky Highway [67]	**C, TS** / GHG, AQ	/ GHG, AQ	**PA, AC** / BO,EE, M
	Urban road infrastructure improvements	Gateway Program; Border Infrastructure Program [67, 68]	**C, TS** / GHG, AQ	/ GHG, AQ	**PA, AC** / BO, EE, M
	Remote sensing / Intelligent Transportation	Green Lights Program; Weigh-in-Motion; [69]	**C, GHG** / AQ, TS	/	/ AC, M
Alternative Transportation	Rail infrastructure improvements	Roberts Bank Rail Corridor [70]	**C, TS** / GHG, AQ	/ GHG	/ BO
	Marine infrastructure improvements	Short Sea Shipping Project [71]	**C, TS** / EN GHG, AQ	/ AQ	/ BO
	Intermodal infrastructure improvements		**GHG** / EN TS, C, AQ	/ AQ	/ BO
	Capital stock replacement incentives	Increased Capital Cost Allowance Rate for Rail (federal) [72]	**GHG** / AQ, EN	/	**AE** / EE

	Legend: **GHG** – Greenhouse Gas Emissions, **C** – Congestion, **AQ** – Air Quality, **TS** – Traffic Safety, **EN** – Environmental Noise, **O** – Other, **AC** – Availability / Complementarity, **PA** – Political Acceptability, **AE** – Administrative Efficiency, **BO** – Buildability / Operability, **LP** – Leakage Potential, **M** – Measurability, **EE** – Economic Efficiency				
Policy Category	**Policy Description**	**British Columbia Example**	**Benefits**	**Disbenefits**	**Feasibility**
Technology Availability	Alternative fuels research funding	Hydrogen Highway; Innovative Clean Energy Fund [73, 74]	**GHG** / AQ, TS, EN	GHG	EE, M
	Vehicle efficiency research funding	ecoFREIGHT – Technology Fund (federal) [75]	**GHG** / AQ, TS, EN	GHG	EE, M
	Infrastructure research funding	ecoFREIGHT -Marine shore power (federal) [75]	**GHG** / AQ, TS, EN	GHG	EE, M
Vehicle Fleet Characteristics	Capital stock retirement / scrapping	Scrap-it Program [76]	**AQ, TS** / GHG, EN		AE, EE
	New Vehicle Tailpipe emissions standards	British Columbia Tailpipe Emissions Standards [77]	**GHG** / AQ, EN	AQ / C, TS , N	
	Low emissions vehicle tax incentives	Low Emissions Vehicle Tax Incentives [78]	**GHG** / AQ / C, TS, EN	AQ, EN, C	
	Existing Vehicle Emissions Retrofit regulations	British Columbia Diesel Refit program [79]	**AQ** / GHG		PA
	Vehicle efficiency retrofit incentives	GreenFleets BC – enviroTruck [80]	**GHG** / AQ, TS, EN	TS	AC,
	Emissions regulations enforcement	AirCare on Road; [81]	**AQ** / GHG, TS, EN		PA, AE,M
Urban Form	Broad regional planning frameworks	Metro Vancouver Liveable Region Strategic Plan; [82]	**GHG** / AQ, TS, EN	AQ / GHG, TS, EN	EE, M, / PA, AE, LP
	Tax incentives for multimodal industrial parks		**GHG** / C / AQ, TS, EN	C / TS, AQ, EN	EE, M
Public Knowledge / Attitudes	Awareness programs	Green Fleets BC - BioFleet, E3Fleet, Hybrid Experience; [80]	**GHG** / AQ, TS, EN		EE, M
	Driver training for efficiency	ecoENERGY for Fleets - Driver training (federal); [83]	**GHG** / C / AQ, TS, N		EE, M

5 EXPLORING FREIGHT TRANSPORTATION GREENHOUSE GAS EMISSION REDUCTIONS

This section explores options for achieving greenhouse gas reductions in British Columbia's freight transportation sector. It includes both existing policies that meet the criteria described in Section 3 and new policies and actions needed to achieve emission reductions. It is framed around four policy goals, which are aligned with the ASIF (activity, modal share, intensity, and fuel) framework described in Section 2.1 and that reflect the underlying drivers described in Section 2.2. Further, to ensure that unintended policy consequences are considered, an integrated policy assessment approach (as described in section 3) provides a foundation for assessment of all goals.



5.1 Economic Growth

As detailed in Section 2, economic growth is the single most significant driver of increased transportation activity (the distance and amount of freight moved). The increased activity induced by the growth in British Columbia's economy has steadily increased freight greenhouse gas emissions despite efficiency gains across all modes. Decoupling economic growth and the demand for freight transportation services is the "*holy grail of transport policy-making*" [20], but this decoupling is unlikely to occur in British Columbia in the near to medium term. This is due to the continuing economic importance of British Columbia's resource industries (which require movement of large volumes of freight) and the current policy focus on enhancing British Columbia's position as a Pacific Gateway for North American trade.

Given the uncertainty of decoupling economic growth and the demand for freight transportation services, reductions in greenhouse gas emissions in British Columbia's freight sector will likely depend on decreases in intensity, changes in modal share, and switching to lower carbon energy sources. Furthermore, policies that encourage wise investment in expanded transportation services and infrastructure will be critical to British Columbia's economic agenda. However, as British Columbia concurrently pursues both economic growth through expansion of the transportation infrastructure and reductions in transportation greenhouse gas emissions, it will be putting in place policies that are in direct opposition of one another. Provincial policy-makers will have to balance these competing policies such that emissions reductions through modal share, intensity, and fuel take effect at a rate greater than increases due to activity produced by economic growth. We discuss promising approaches to realizing this challenging task in the following sections.

5.2 Improved Operational Efficiency

A key first step in achieving greenhouse gas reductions in the freight transportation sector is the improvement in operational efficiency in existing transportation services. Given the policy context of greenhouse gas reduction, we define efficiency in terms of greenhouse gas emissions per unit of freight moved. Within a given mode, these efficiency improvements can be achieved through improvements in vehicle technology, improvements in modal traffic flow and improvements in operational behaviour. Across modes, greenhouse gas efficiency can also be improved through reduction in fuel carbon content.

5.2.1 Vehicle Technology

Penetration of existing vehicle efficiency technology is encouraged in British Columbia's passenger sector through the provision of a variety of sector-wide tax incentives and rebates (PST exemptions, federal ecoAuto rebate) for the purchase of new high-efficiency vehicles. Such sector-wide incentive programs are not currently offered in the freight sector, which instead is currently targeted with limited incentive programs (GreenFleetsBC enviroTruck, federal ecoFreight) with rigorous application procedures. The limited nature of these existing programs means that they can only provide efficiency incentives for a small percentage of the potential vehicle fleet in need of replacement or retrofit. The long service life and high mileage of freight vehicles relative to passenger vehicles means a larger emissions downside to freight companies purchasing vehicles that are not equipped with best-in-class technology, or avoiding vehicle efficiency retrofits.

Given the high capital cost sensitivity of the freight sector relative to the passenger sector [84], one policy approach is freight technology incentive programs with simplified application procedures. These incentive policies should be applied to all freight modes, as there is scope for vehicle efficiency improvements regardless of mode. Policies would likely have to be modally disaggregated due to the widely differing technology types across modes. However, in all cases, the focus of technology investment incentives should be on economic efficiency; incenting the largest greenhouse gas emissions reductions for a given pool of incentive funds, while keeping a view on avoiding unintended dis-benefits.

5.2.2 Modal Infrastructure

Modal infrastructure such as roads, rail lines, and marine docking facilities offer another area for greenhouse gas emissions efficiency improvements. Direct investments in expanding or "de-bottlenecking" infrastructure (eg. Gateway Program for roads, Roberts Bank Rail Corridor for rail) are typically undertaken to reduce congestion and improve safety, rather than reduce greenhouse gas emissions. As previously discussed, there is a significant possibility that such infrastructure investments may in fact increase greenhouse gas emissions, due to increased vehicle activity and emissions associated in infrastructure building. However, there exists considerable opportunity for improvement of modal greenhouse gas emissions efficiency through targeted infrastructure investment. Advanced paving technologies have the potential to reduce both vehicle greenhouse gas emissions through road surface improvements and pavement lifecycle greenhouse gas emissions through decreased input requirements. Similarly, rail infrastructure improvements such as grade separation, track twinning, and bridge replacement minimize congestion-related delays and allow operation at the most efficient speed. Finally, across all modes, intelligent transportation systems (ITS) solutions offer the prospect of interaction between infrastructure and vehicles to determine optimized traffic flow conditions in response to transportation demand or in response to public health concerns such as air pollution levels.

5.2.3 Operational Behaviour

Especially in road transportation where individual drivers have a high level of autonomy with respect to vehicle control, there is scope for efficiency improvements through modification of operational behaviour. The federal government currently offers the Smart Driver program for highway and urban fleets as part of its ecoFreight program. This voluntary program could be enhanced through the implementation of mandatory driver efficiency training as part of the licensing process for British Columbia's class 1 through 4 commercial driver's licenses. Further, there is growing industry support [85] for the implementation of speed limiting devices on trucks, with maximum speed recommendations ranging from 90 km/hr to 105 km/hr. Given their widely differing use profiles, differential speed limit settings for long haul trucks and urban logistics trucks may need to be considered.

5.2.4 Reduction in Fuel Carbon Content

Currently, freight transportation inputs in British Columbia are almost exclusively carbon-based, with diesel fuel predominating across all modes. As such, the Low Carbon Fuel Standard recently introduced in British Columbia will impact the fuel composition (and likely fuel price) for all modes, just as the British Columbia Carbon Tax will impact the fuel cost. Given the higher intensity of road transportation, these costs will be most strongly felt in the trucking mode. This should positively impact the competitiveness of other modes such as rail and marine, possibly resulting in mode switching (discussed further below).

In general, reduction in fuel carbon content should lead to an overall reduction in the carbon intensity of freight transportation, regardless of mode switching. However, there still exists significant uncertainty regarding the full lifecycle greenhouse gas emissions benefits associated with biofuels, which will likely provide a key source of low carbon fuel in the fuel mix. More tangible alternatives for greenhouse gas emissions reductions are offered by switching to conventional fuel sources with lower lifecycle carbon content, including natural gas and electricity. Unfortunately, the switching costs for these fuels are typically high, and are unlikely to be justified on the basis of greenhouse gas emission reductions alone. In some cases, especially in urban areas, the costs of fuel switching are justified by air quality improvements gains, as in the case of the Port of Los Angeles Clean Air Action Plan to replace diesel trucks with natural gas trucks [86]. Additionally, there are risks that switching to CNG could result in increased methane tailpipe emissions that would negate the effect of greenhouse gas emission reductions due to carbon content.

5.3 Improved Modal Share

As indicated in Section 2, growth in freight transportation volumes and an effective shift in modal share towards greater truck use has historically negated the impacts of improved modal operational efficiencies, leading to steadily rising greenhouse gas emissions. As such, a transportation policy suite focused on modal operational efficiency alone is unlikely to result in a net decrease of freight transportation emissions. Given the wide range of greenhouse gas emissions per unit of freight km offered by road, rail, marine, and air, there exists significant scope for greenhouse gas emission reductions through modal shifting to rail and marine. However, due to the inherent location inflexibility of these modes relative to road, shifts are most likely to be from pure road transportation to multimodal transportation, with the flexibility of road coupled with the efficiency of the other modes.

5.3.1 Levelling the Playing Field

In order to realize a freight transportation system in which modal shares reflect the most greenhouse gas-efficient means of transporting freight, policies should focus on "levelling the playing field" between modes. Currently, the infrastructure funding models between modes are vastly different, resulting in a significant public subsidy to road transport. Additionally, road infrastructure funding derived from fuel taxes is typically used to maintain and expand road infrastructure, rather than improve the linkages between modes. Tax treatment of road vehicles has historically been preferential, with higher annual depreciation rates than rail or marine. Conversely, regulation of vehicle emissions has historically been much stricter for road vehicles than for rail or marine, further delaying capital turnover to cleaner and more efficient vehicles in the latter transportation modes.

Achieving a level playing field would require a shift in transportation policy thinking away from a modally disaggregated approach to a multimodal systems approach. The ongoing federal - provincial Pacific Gateway program provides a starting point for this type of approach, as it relies on expansion of British Columbia's freight system across all modes to accommodate growth in freight traffic. Future funding decisions for freight transportation system infrastructure should be mode-agnostic, and based on costing that includes greenhouse gas emissions and other outcomes discussed previously as key decision variables. Additionally, road funding currently collected from the provincial fuel excise tax on road diesel fuel could be redirected into a freight infrastructure funding pool, along with excise tax revenue from rail diesel fuel and marine fuel. This funding pool could be used to fund the maintenance and upgrade of freight infrastructure regardless of mode, with funding decisions based in part on the projected potential to reduce system-wide greenhouse gas emissions. Eligible infrastructure would include intermodal facilities which could improve the interconnection between modes.

Levelling the modal playing field with respect to vehicle technology investment will require equity in terms of tax treatment of capital investments regardless of mode. A recent decision by the federal government to increase the allowed depreciation rate for rail vehicles to 30% brings the Canadian rail tax treatment in line with United States treatment, and closer to the 33% rate for marine vehicles and 30-40% rates for road vehicles. Any further changes in tax treatment should be considered in the context of the full multimodal transportation system to avoid preferential treatment of one mode over another. Further, in order to avoid unintended negative air pollution impacts associated with mode switching, it is important that vehicle emissions standards for criteria air pollutants be harmonized across all modes on an allowable emissions per tonne km basis. This could be achieved by adopting United States EPA emissions standards for all new and retrofitted heavy trucks [87], locomotives and marine engines [57].

5.3.2 Limitations of Intermodal Transportation

Even given a level playing field in which infrastructure funding, tax treatment, and vehicle emissions standards are harmonized across modes, opportunities for multimodal freight transportation are inherently limited on the provincial scale. External social cost studies of the full costs of road and intermodal transportation in Europe [60] indicate that intermodal transportation breaks even with road transportation at distances over 900km, roughly the distance from Vancouver to Calgary. This breakeven point is sensitive to train frequency in the intermodal system, with higher scheduled frequency resulting in a shorter break-even distance, down to 600km with 25 scheduled trains per week. However, a recent study of intermodal transportation in the United States [88] indicates that at short distances (400km), emissions associated with the operation of intermodal transfer facilities result in higher non-greenhouse gas air pollution emissions for intermodal transport than for trucking. Thus, despite the savings in greenhouse gas emissions, short-distance intermodal transport can result in increased freight travel time and increased air pollution emissions.

Given these results, shifting from single mode freight transportation (usually road) to intermodal transportation is unlikely to achieve net benefits for short transportation distances or on routes with infrequent intermodal schedules. One exception in British Columbia may be intermodal freight connections with international marine shipping terminals in Vancouver and Prince Rupert. CN Rail has recently constructed an intermodal facility in Prince George, British Columbia to facilitate container sorting, transloading, and modal transfer of containers arriving from or being sent directly to the Prince Rupert container shipping terminal [89]. A recent study [90] has indicated that Kamloops could host a similar inland intermodal terminal serving Vancouver's container ports, CN and CP Rail main lines, the Kelowna Pacific Railway shortline, and major highways including the TransCanada. For container freight traffic directly linked to marine container ports, these inland intermodal terminals offer the advantages of transfers to and from less congested road networks and removal of modal-transfer related air pollution emissions from dense urban areas.

5.3.3 Intermodal Transboundary Issues

As indicated, opportunities for freight modal shifting and intermodal transport may be limited within British Columbia due to the transportation distances involved, and the limitations of non-road transportation service frequency. However, east-west long haul freight transportation between British Columbia and Alberta (and points beyond) falls beyond the distances at which intermodal transportation based predominately on rail is expected to produce strong greenhouse gas emissions benefits, as well as full external social cost benefits. Similarly, north-south transportation, especially from states beyond Washington, Oregon and Montana, is also expected to fall beyond the intermodal break-even distances. Despite this, there currently exist large flows of long haul freight truck traffic across both the United States and Alberta borders, much of it terminating in the Lower Mainland. Given the truck inspection systems already in place for assessing the weight and safety of out-of-province trucks at borders, one possible policy to promote a move to intermodal rail-based transport would be a distance-based tolling applied to inbound and outbound trucks at border crossings. The tolls would depend on the distance between the load origin and destination to ensure that short-haul loads would not be unnecessarily penalized.

5.3.4 Urban Logistics

The rise of just-in-time logistics has resulted in significant duplication of road vehicle fleets, particularly in urban centres where a large number of competing freight pickup/delivery services and couriers cover the same service areas. As a result, route choices and vehicle loading is often sub-optimal, especially with respect to greenhouse gas and other pollutant emissions. Shared urban logistics systems have been proposed as a solution to this problem. These systems provide a “last mile” inter-modal solution, consolidating inbound freight from multiple modes and multiple carriers and optimizing delivery services, as well as working in reverse to pick up outbound freight. One policy approach to the development of an urban logistics service for a large city such as Vancouver would be the introduction of freight congestion charging on the majority of urban roads, with the possible exception of major truck routes between intermodal facilities. At the same time, tax incentives could be provided for shippers that consolidate their operations into designated logistics parks.

5.4 Fostering Sustainability

Fostering sustainability is about increasing welfare over the long term. It involves a wider discussion of our values and our social, economic, and political systems. Although such a discussion is beyond the scope of this paper, two key aspects that relate to transportation are particularly relevant: urban form and path dependence (development trajectory).

Urban form plays a critical role in reducing emissions in the transportation sector over the long term through increased active commuting (cycling and walking) and reductions in structurally enforced travel, such as commuting to and from work by private vehicle. However, affecting change in urban form is challenging. Influencing change through policy is often a long-term process and attribution of impact to policy grows more challenging as other factors evolve over time. These qualities also make it exceedingly difficult to predict the impact of policy aimed at changing urban form.

The link between urban form and infrastructure is strong and any investment in infrastructure must be supported by the underlying urban form; eg. public transportation in low density development is challenging at best. Although the influence of urban form is complicated, there is consensus that increased density is associated with lower private vehicle use and reduced energy use. In regards to both urban from and path dependence, it is critical to remember that both capacity and investment provide incentives. While expanding road infrastructure through projects such as the Gateway program may provide benefits over the short and medium term, it locks the province into a development path where the long-term benefits are less certain.

In addition, British Columbia will need to continue to work cooperatively with other jurisdictions and large market players to drive technological change in a direction that fosters sustainability. In conclusion, a greater emphasis on long- term goals that incorporate sustainability and that reflect current and desired development paths would assist in developing policies that increase welfare in the foreseeable future.

5.5 Integrated Policy

As indicated in Section 3.1, all policies evaluated for transportation greenhouse gas must also be evaluated with respect to other outcomes, including air quality, traffic safety, congestion, and noise. Additionally, it is important to review any possible roadblocks to policy feasibility to ensure that policies will be implementable in practice. Key recommendations for caution surrounding the policy options presented include:

1) **Technology Incentives** - Tying technology incentives for greenhouse gas reductions to accompanying reductions in other outcome variables, particularly air quality, traffic safety and noise. As such, technology funding for retrofitting trucks with low-rolling resistance tires or aerodynamic improvements appears to be a win-win, because fuel efficiency improvements will lead to decreases in other air emissions, noise will be reduced, and traffic safety is unlikely to be impacted. Conversely, using these incentives to fund so-called "long combination vehicles" may provide air quality and greenhouse gas improvements, but is also likely to impact traffic safety, especially on mountain roads. In all cases, the potential for free-riding and activity rebound associated with these improvements must be considered, as this may seriously affect the economic efficiency of the incentive programs. However, given the cost-sensitivity of commercial transportation relative to personal transportation, the magnitude or free-riding and rebound is likely to be of lesser importance.

2) **Emissions Regulations** - Ensuring that emissions regulations are applied to the entire freight sector and harmonized with a wider set of regulations in other jurisdictions. Previous experience in the passenger transportation sector has shown that efficiency / mileage regulations can cause dramatic negative modal shifting (and associated negative impacts to all outcome variables) if they are not broadly applied to the entire sector. Similarly, any regulations on either greenhouse gas emissions or other air pollutants applied in British Columbia must ensure that shifting cannot occur from a regulated mode to an unregulated mode. Further, to avoid leakage, regulations should be aligned with neighbouring jurisdictions, if possible. Applying regulation equivalent to the United States EPA emissions regulations will ensure that leakage through adjoining United States states is unlikely. Given the necessity of British Columbia or United States flow-through shipment of any Pacific freight bound for other parts of Canada, harmonization of emissions regulations with other Canadian jurisdictions is less likely to lead to major leakage, but would instead be administratively expedient, especially for rail transport.

3) **Modal Shifting** - Ensuring that efforts to effect modal shifting are focused not just on greenhouse gas emissions reductions, but all outcomes. As shown in Section 5.3.2, intermodal transport is not a better option in all cases, and may in fact have significant negative air quality, noise, and congestion impacts associated with modal switching operations. As such, intermodal transportation must be approached with careful analysis of full costs and benefits. Similarly to emissions regulations, measures to encourage the development of intermodal networks must ensure that shifting does not occur in the direction of modes that are less regulated with respect to non-greenhouse gas outcomes. Additionally, efforts to affect mode switching are inherently politically charged, because some modal shares will inherently be reduced as others gain. In this case, given the dramatic greenhouse gas efficiency advantage of rail and marine over road transportation, the desirable switch is likely away from trucking. Given the British Columbia Government's Climate Action Plan mandate, this is a necessary outcome, as operational efficiency (intensity improvement) alone is unlikely to effect absolute greenhouse gas reductions.

Each policy presented, and any new policies considered, will have unique outcome impacts and feasibility characteristics that make integrated assessment along the lines outlined in Section 3 vital to assessing risk and benefits of the full policy lifecycle.

6 TRANPORTATION POLICIES BEYOND THE FREIGHT SECTOR

The primary focus of analysis in this paper has been British Columbia's freight transportation sector. However, as discussed previously, passenger transportation accounts for half of all transportation greenhouse gas emissions. As such, it is vital that policy analysis and formulation efforts target both passenger and freight transportation, and develop policies that will span sectors whenever possible. Following from Section 5, we provide a brief review of five further policy approaches, ranging from specific vehicle technology mandates to a broad economic development focus

1) **Hybrid Vehicle Mandates / Incentives.** Hybrid vehicles are best used in stop-and-go traffic, and provide a positive lifecycle greenhouse gas benefit when driven in excess of 40,000 km/yr. As such, hybrids are perfectly suited to urban taxi service, but unlikely to produce greenhouse gas benefits under most personal vehicle use scenarios. A policy that requires all new urban taxis to employ hybrid technology is likely to realize greenhouse gas reductions, while current hybrid vehicle purchase incentive programs targeted at private vehicles are unlikely to do so. Given that hybrid technology is now widely deployed (more than 1 million hybrids sold in North America since 2001), there is little argument for the need to further subsidize technology development.
2) **Weight/ size-based vehicle insurance premiums.** Due to the low price elasticity of motor fuel, carbon taxation and other fuel levies may not be high enough to reduce the unnecessary use of large, high-emitting passenger vehicles. A growing body of evidence indicates that size and weight disparity in the passenger vehicle fleet results in increased injuries and fatalities for drivers of smaller vehicles. In recognition of the additional traffic accident injury risk associated with large (and high-emitting) vehicles, a size and weight-based vehicle insurance adder could be applied by the Insurance Corporation of British Columbia. Consideration of the additional injury risk they pose in accidents would raise annual insurance premiums for large passenger vehicles, likely reducing demand and overall vehicle fleet greenhouse gas emissions. Funds generated by the insurance adder could be directed to health care programs for vehicle accident injury victims.
3) **Urban Congestion / Parking Taxes.** In order to meet the public transit ridership goals advanced in the Provincial Transit Plan, significant investment in urban transit infrastructure and vehicles will be required. One funding policy approach would be the implementation of increased parking taxes in "congestion zones" in urban core areas. The funds from increased parking taxes could be used directly to enhance transit service to the congestion-zoned areas, as well as park and ride infrastructure for commuters to congestion zones who have limited access to suburban / extra-urban transit infrastructure. Reduced personal vehicle traffic on routes connected with congestions zones may reduce road congestion, improve air quality, and reduce the need for road infrastructure expansion. It is important to note that, in order to realize greenhouse gas savings, expanded transit systems would need to have sufficient capacity utilization to reduce system average per-passenger greenhouse gas emissions well below the levels for personal vehicles.
4) **Low Carbon Fuel Standard.** British Columbia has already implemented a Low Carbon Fuel Standard which requires fuel retailers to provide fuels adhering to a carbon intensity target that will decrease over time. In order for this policy to be effective at reducing greenhouse gas emissions associated with the full lifecycle of these fuels, it must take a full "well to wheels"

approach to determining fuel carbon content. This approach must include fuel co-products produced in refineries, because refiners may "shift" crude oil carbon content out of fuels regulated under the Low Carbon Fuel Standard into products that are not regulated by the standard. Similarly, biofuels must be assessed based on a lifecycle that includes indirect land use impacts (and associated greenhouse gas emissions) of fuel production. Without consideration of these factors, the Low Carbon Fuel Standard may fail to produce net greenhouse gas emission reductions.

5) **Support for higher value added domestic industries**. Though the British Columbia export economy has moved away from a pure resource focus in recent years, a large volume of our exports are still low value, high mass / volume commodities. Further development of value added industries in British Columbia could decrease greenhouse gas emissions associated with the long-distance transportation of commodities, while providing additional skilled employment in-province. Further, because manufactured products are more easily container-loaded, the opportunities for optimized intermodal travel are improved.

As previously stated, each policy presented here must be evaluated as a part of an integrated assessment along the lines outlined in Section 3, to assess the risks and benefits of the full policy lifecycle.

7 CONCLUSIONS & PATH FORWARD

In order to make progress towards meeting the province's 2020 Climate Action Plan goals, significant reductions must be realized in the transportation sector. In order to meet this challenge, additional policies directed at modifying transportation activity, modal share, intensity, and fuel use must be put in place. However, the complex interaction between these drivers of transportation greenhouse gas emissions necessitate rigorous analyses of new policy proposals. Analyses must focus not only on greenhouse gas reduction potential and economic efficiency, but also on all foreseeable benefits and disbenefits associated with such policies.

We have demonstrated that the individual building blocks required for integrated assessment of transportation policies are well developed. We face two challenges in translating this knowledge into tools and courses that can be delivered to the policy community in British Columbia:

- While the individual parts of the integrated assessment methodology for transportation policies in British Columbia are in hand, they need to be melded into a coherent decision-support platform designed for use by public and private sector policy analysts beyond the walls of academia.
- British Columbia-specific data to inform such an analysis framework are difficult to obtain, out of date, or have yet to be collected at the appropriate spatial, temporal and sub-sectoral resolution necessary for detailed analysis.

As such, one goal for further research is the translation of available knowledge into an integrated assessment toolkit suitable for design of policies and programs in the transportation sector. Following from this, a second goal is the rigorous analysis and ranking of greenhouse gas reduction policy options for the transportation sector. This exercise provides vital input for setting the provincial transportation policy agenda, but also allows testing and refinement of the integrated assessment toolkit that we propose. Both research goals can be accomplished through the Pacific Institute for Climate Solutions, with the promise of rapid turnaround on quantitative analysis of proposed new transportation strategies and policies.

7.1 An Example of the Proposed Approach

The path to completion of such a toolkit and supporting data is being tested through collaboration among UBC researchers, Translink and Giro Inc. The team's objective is to reflect the true objective of emission controls from public transit in program design. So far, we have translated the objective of minimising adverse health impacts from air pollution to mean "minimise emissions." However, the causal pathway to health impacts is inhalation of emissions, not the emissions themselves. Hence, if we can reduce emissions locally, where larger populations are outdoors or involved in physical activity, we can reduce adverse health impacts without incurring additional costs. The methodology for this project is being developed at UBC. The micro-data needed for high resolution emissions modelling are being collected by Translink. Giro Inc of Montreal, a leading logistics consulting company, will be incorporating the methodology in their user software packages and deploying it for Translink and 150 other large metropolitan areas in the world.

We propose the adoption of a similar approach to the challenge of greenhouse gas emission reductions from the transportation sector. The methodology can be supplied from academia, the data from the province and key stakeholders, and an appropriate partner organisation can port these into decision-support tools suitable for the appropriate user communities.

APPENDIX A – DEFINITION OF VEHICLE TYPES

Small car:A car weighing up to 1181 kg (2600 lb.) of gross vehicle weight. The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Large car: A car with a gross vehicle weight of 1182 kg (2601 lb.) or more. The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Light truck: A truck of up to 3855 kg (8500 lb.) of gross vehicle weight. The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight. This class of vehicles includes pickup trucks, minivans and sport utility vehicles.

Medium truck: A truck with a gross vehicle weight ranging from 3856 to 14,969 kg (8501 to 33,000 lb.). The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Heavy truck : A truck with a gross vehicle weight that is more than, or equal to, 14,970 kg (33,001 lb.). The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

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