Towards a Sustainable Transportation System

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Aryn Machell is a Professional Engineer at the City of Edmonton. He has five years experience developing strategic transportation policy, implementation plans, and progress measures for the City. Aryn has also developed, managed, and been a spokesperson for Transportation Demand Management initiatives, and he was an instructor of the City's Transportation Planning course through the Planning Academy for three years. Aryn has a Bachelor's degree in Civil Engineering from the University of Alberta, and is currently pursuing a Bachelor's degree in History, Art and Design from the same institution.

Introduction

While a city may be defined by its population, all it takes is a quick look at a map to recognize that its transportation system is a fundamental organizing principle behind its urban form. Transport is essential to the functioning of a city in all aspects of daily life and commerce. As a result, the planning, design, construction, and operation of the transportation system have a broad range of impacts on environmental sustainability, including: air, water, and soil quality; habitat and biodiversity; climate change; and arable land.

Sustainability is one of the strategic goals of the City's recently approved Transportation Master Plan, *The Way We Move*, where it is expressed as:

> *"Transportation decisions reflect an integrated approach to environmental, financial, and social impacts thereby creating sustainable, livable communities that minimize the need for new infrastructure and increase residents' quality of life."*

This goal recognizes that:

> *"The most effective way to minimize the transportation system's environmental impact is to reduce the scope and scale of that system so it is easier to make sustainable transportation mode choices."*

While the changes described in this paper can move Edmonton's transportation system towards environmental sustainability, they can also have positive impacts on the transportation system's financial and social sustainability, as further addressed in *The Way We Move*. For example, since automobiles are expensive, and 30% of the population isn't licensed to drive, providing a full range of convenient transportation options can improve social sustainability. Similarly, building a compact city makes more efficient use of infrastructure, which can reduce the financial burden of maintenance.

This paper is organized into four parts. The first part, *Impacts*, will describe how a transportation system influences environmental sustainability. The second part, *Closing the Gap*, will discuss the actions proposed by the City's current strategic plans to move towards a sustainable transportation system. The third part, *Examples from other Jurisdictions*, describes examples of actions taken by other jurisdictions to further encourage both compact development and a transportation mode shift. Finally, the fourth part, *The Future*, will discuss what a sustainable transportation system might look like within an urban setting.

Part I: Impacts

The environmental sustainability of the transportation system can be categorized into impacts related to three major areas: Manufacturing and Construction, Operating Energy, and Built Form. In this section, each of these categories is discussed, and an indication of the magnitude of Edmonton's impact is given.

MANUFACTURING & CONSTRUCTION

The transportation system is a built artefact. Aggregate, asphalt, concrete, and steel are required for the construction of infrastructure such as roads, bridges, and railways. Materials such as plastic, rubber, and metals are required for the manufacturing of everything from buses, trains, streetlights, and traffic signals, to cars, bicycles, and shoes as well. All of these materials require resource extraction and then processing and/or manufacturing which can pollute the air, water, and soil, destroy habitat, reduce biodiversity, and can contribute to climate change.

Additionally, all steps of the process – resource extraction, processing, and manufacturing or construction – require energy, which is referred to as the “embodied energy” of the final product. At present, this embodied energy is primarily derived either directly or indirectly from hydrocarbon fuels such as oil or coal. These fuels not only have extraction and processing impacts themselves, but also contribute to climate change through the emission of greenhouse gases.

The components of the transportation system must be disposed of once their condition has deteriorated beyond the point of functionality or safety. Materials such as concrete, asphalt, and steel are relatively non-toxic, and can be readily recycled or reused. However, manufactured products such as cars, shoes, or electronics frequently contain plastics, toxic chemicals, or heavy metals, and are rarely constructed in a manner that encourages recycling. As a result, disposal of these components of the transportation system can contribute to water and soil pollution.

How large is Edmonton’s impact? Over 570,000 automobiles were registered in Edmonton as of 2009. In addition, in 2008 Edmonton had nearly 10,000 lane-kilometres of road.

OPERATING ENERGY

In addition to the embodied energy of all of its components, the transportation system requires energy on an ongoing basis in order to operate. This operating energy can be in the form of hydrocarbon-derived fuels such as gasoline, diesel, and natural gas, or electricity generated by burning hydrocarbon-derived fuels such as coal, oil, or natural gas. Hydrocarbon-derived energy can have resource extraction and processing impacts including air, water, and soil pollution, habitat destruction, and reduction of biodiversity. The use of hydrocarbon-derived energy can contribute to climate change through greenhouse gas emissions. In addition, it can contribute to reduced air quality through other emissions such as particulate matter (e.g. PM_{10}) or chemical pollutants (e.g. NO_x).

Operating energy can also be electricity generated through ‘carbon neutral’ means such as wind turbines, solar cells, or hydroelectric dams. While these sources of electricity avoid many of the direct environmental impacts of hydrocarbon-derived energy, they too can negatively impact local biodiversity (e.g. habitat destruction, fragmentation, degradation, species extirpation, displacement). In addition, wind turbines, solar cells, and hydroelectric dams must all be manufactured or constructed, and as such have indirect environmental impacts.

How large is Edmonton’s impact? More than 95% of the energy currently used to operate Edmonton’s transportation system is either directly hydrocarbon-derived, such as gasoline or diesel for powering vehicles, or indirectly hydrocarbon-derived, such as the electricity used to power streetlights, traffic signals, or the LRT.

BUILT FORM

The transportation system requires land on which to build infrastructure, such as roads, sidewalks, railways, interchanges, bridges, and transit centres. However, transportation infrastructure also influences land use patterns. A new or expanded road can enable development to take place. Different roadway types, designs, and patterns influence land uses in different ways, as does the provision of additional transportation infrastructure such as sidewalks, bike paths, bus transit, and LRT. For example, wide, fast roadways can discourage compact, mixed use development. In contrast, narrow, slower roadways that are built in a grid pattern and are more attractive for pedestrians and cyclists can encourage compact, mixed use.

The transportation system has two main direct impacts on environmental sustainability related to land. First, urban development of natural areas and agricultural lands that support natural systems can destroy habitat and deplete arable lands and soils, further reducing local and regional biodiversity. Second, through the construction of impermeable surfaces such as roads and parking lots, as well as building roofs, the development of natural and agricultural lands can also increase runoff, affecting riparian systems and the water table, and can also intensify the urban heat island effect.

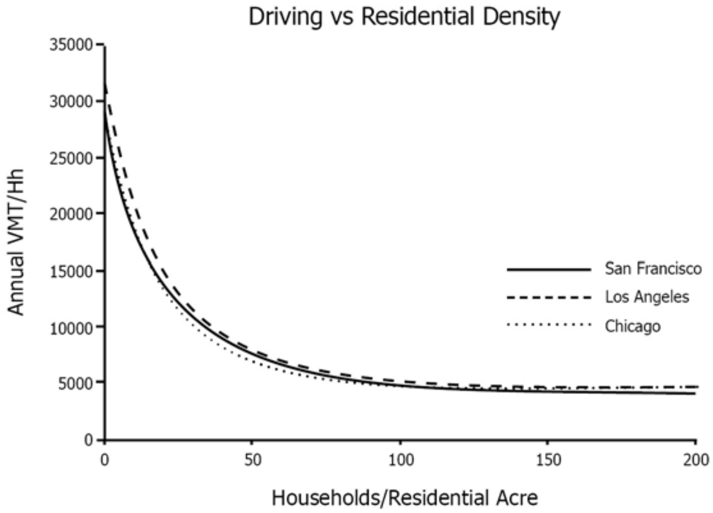
In addition to the direct impacts of land use, there is also a well-documented relationship between population density, automobile dependence, energy use, and automobile emissions. *An International Sourcebook of Automobile Dependence in Cities* [1] compared urban form, population, and travel behaviour data for 37 cities around the world between 1960 and 1990. It was found that

> *All indicators of motor vehicle ownership and use correlate strongly and negatively with urban density in all parts of the city, suggesting a strong link between reduced motor vehicle travel and higher urban densities. … As densities increase, all the indicators describing auto dependence decline in a strong and systematic way. … The data show that as auto dependence increases (higher car ownership, more car use, more roads and more parking), so too does energy use in private transportation, as well as overall transportation energy use per capita.*

More recently, such correlations have been referred to as 'location efficiency', and further investigations have found that:

> *Observed differences in density and transit can explain over 3:1 variations in vehicle miles driven per household for a constant level of income and household size.* [2]

This relationship is illustrated graphically in the following figure[3]:



In *Win-Win Emission Reduction Strategies*, the Victoria Transport Policy Institute (VTPI) described this relationship in more detail as a "cycle of automobile dependency", which included:

> *… > Automobile Oriented Transport Planning > Reduced Travel Options > Alternative Modes Stigmatized > Suburbanization and Degraded Cities > Automobile Oriented Land Use Planning > Generous Parking Supply > Dispersed Development Patterns > Increased Vehicle Ownership > …* [4]

So, not only is automobile dependence strongly correlated with low-density development, but automobile dependence is correlated with increased transportation energy use per capita. As has been described previously in the section *Operating Energy*, at present almost all energy used to operate Edmonton's transportation system is hydrocarbon-derived. Thus, built form can have a significant indirect influence on both air pollution and climate change through greenhouse gas emissions.

How large is Edmonton's impact? In 2009, Edmonton had a population of 782,439 and a developed land area of 42,491.2 hectares (424.912 km^2), for an average of 1840 persons per square kilometre. In contrast, Frankfurt, Germany is a city of approximately the same population as Edmonton, and has a population density of 2,687/km^2.

Part II : Closing the Gap

Most of the impacts that the transportation system has on the environment are not under the direct influence of the City of Edmonton. For example, regulating resource extraction, manufacturing, or vehicle emissions standards are not within the authority of municipal government. The City could work with other orders of government to consider stricter vehicle emissions standards, which would complement direct action on mode shift in reducing greenhouse gas emissions. Similarly, the preparation of a regulatory and legislative framework to enable future vehicle technologies and their supporting infrastructure could similarly have beneficial effects.

There are many City of Edmonton programs and services that improve the sustainability of its transportation system already in place. Recently, the City converted all traffic signals to LED bulbs, which has resulted in a significant reduction in energy use. Construction materials such as concrete and asphalt

are recycled at the end of their service life through the aggregate recycling program. Approximately 80% of winter road sand is recovered and reused. The City provides an on-line ride-matching service to promote carpooling, encourages commuting by transit through the ETS@Work transit pass subsidy program, and promotes walking and cycling.

However, the most significant shifts towards sustainability will come as the City implements its strategic plans. While *The Way We Move* was being developed, it was recognized that land use and transportation are inextricably linked, and that it was not enough to consider how sustainability might be achieved for the transportation system in isolation. Therefore development of *The Way We Move* was integrated with the development of the new Municipal Development Plan, *The Way We Grow*. Both *The Way We Grow* and *The Way We Move* align with the rest of the City's strategic plans, and together they will guide Edmonton towards the 30-year City Vision.

COMPACT CITY

Recently completed and approved by City Council, *The Way We Move* and *The Way We Grow* both recognize the importance of encouraging a compact, integrated development pattern through their shared strategic goal Transportation and Land Use Integration. As described in *The Way We Move*:

> *Transportation and land use are inextricably linked and impact Edmonton's environmental, financial and social sustainability. New approaches to land use planning and development will allow people to live closer to where they want to go and closer to the high quality transit service they need to get there. Designing complete communities - where citizens can work, live and access services, entertainment and recreation - reduces the need for automobile travel. Building communities around major transit infrastructure helps encourage transit use, develops a compact city, maximizes public infrastructure return on investment, and minimizes Edmonton's carbon and ecological footprint.*

By encouraging the development of more compact, attractive, mixed use neighbourhoods, Edmonton can affect the sustainability of its transportation system. Careful use of regulatory and advisory tools for land use, and the provision of transportation infrastructure such as urban-style, low-floor LRT through the City Council approved LRT Network Plan can enable the creation of compact, mixed use neighbourhoods. This is supported by the findings of *An International Sourcebook of Automobile Dependence in Cities*, which states:

> *[Rail Transit Systems] are, overall, the most important factor in the recovery of transit operating costs, seem to be the catalyst for compact sub-centre development and make a major contribution to sustainability on all indicators.* [1]

In addition, the strategic goal "Managing Growth" from *The Way We Grow* includes a policy to encourage a minimum of 25% of new housing units to be located in the Downtown and mature neighbourhoods. But a more compact, mixed use city isn't just about using less land. It is also about creating more attractive, walkable, livable communities centred around pedestrian-friendly transit. Thus, compact, mixed use neighbourhoods also support a transportation mode shift.

TRANSPORTATION MODE SHIFT

Changes in land-use patterns are only one element of the City's strategy to encourage sustainable transportation behaviour. *The Way Ahead*, the strategic plan for achieving the first ten years of the City

Vision, includes "Shift Edmonton's Transportation Modes" as one of its six goals. Transportation Mode Shift is also one of the goals of *The Way We Move*, and it recognizes that:

> *Encouraging fewer single occupant vehicle trips reduces the pressure on the roadway system and reduces the need for increased roadway investment. Moving more people in proportionately fewer vehicles adds to overall transportation system efficiency, minimizes environmental impacts and maximizes the effectiveness of financial investments in the transportation system. It also increases the efficiency of goods movement. Mode shift will be incremental. For example, more families could choose to own one automobile instead of two because they will be confident that other transportation modes will enable them to move conveniently throughout the city. Shifts in transportation modes will yield a significant benefit to personal and urban health and to environmental sustainability.*

Providing infrastructure is a key element of the strategic plan. *The Way We Move* recommends expansion of the LRT network to all sectors of the city through the City Council approved LRT Network Plan. Through the City's Active Transportation Policy, construction of missing links of sidewalk and shared use trails, as well as the implementation of an on-street network of cycling facilities are planned. Such investments in infrastructure to enable mode shift are supported by the findings of *An International Sourcebook of Automobile Dependence in Cities*, which states:

> *The existence of quality rail systems appears to be a crucial factor in understanding patterns of automobile dependence around the world. It is only in cities with good rail systems (regardless of whether they are in North America, Europe, or Asia), that automobile dependence is reduced. Cities with only bus systems constituting their transit systems are universally much higher in automobile dependence. … Rail transit systems, compared to all other motorized transportation, appear to have the best energy efficiency and greatest ability to attract people out of cars. … Non-motorized transportation is highly significant in both economic and environmental indicators in that walking and cycling contribute almost nothing to the cost picture for urban transportation compared to motorized modes and involve almost negligible environmental costs.* [1]

Transportation behaviour change can also be encouraged by developing, expanding, and improving programs and services such as bus transit, parking management, and transportation demand management.

As of the 2005 City of Edmonton Household Travel Survey, nearly 80% of trips on an average day were made by automobile. Both the historical trend and City's regional travel model predict an increase in driving as a mode share if we plan, design, build, and operate the transportation system the same way we have in the past. Through implementation of *The Way We Move* and *The Way We Grow* the City aims to reverse that trend and decrease the automobile mode share.

Part III : Examples from other Jurisdictions

Other jurisdictions around the world have taken further action to encourage a compact built form and a transportation mode shift. A number of the actions which have proven effective are discussed below.

It has been shown that increasing the number of households per area, coupled with improving transit availability and increasing attractiveness to active modes can lead to a significant reduction in automobile use[3]. Specifically, transit-oriented development can result in residents driving 10-30% less[4].

Direct influence on mode shift can be further achieved through aggressive Transportation Demand Management (TDM) strategies. TDM programs that rely on information and encouragement can achieve a reduction in vehicle travel of 5-15%; those that include financial incentives such as parking cash-out and pay-as-you-go insurance and registration fees can reduce vehicle travel by 10-30%[4]. Financial disincentives can also be effective at inducing mode shift. Road pricing and congestion pricing have been shown to reduce affected vehicle traffic by 10-20%; parking pricing can reduce vehicle trips by 10-30% [4].

Part IV : The Future

So, what could a sustainable transportation system look like in the long term? There is no one definition of what a sustainable transportation system, or indeed a sustainable city, would be. Nor is there a set timeframe in which it could be achieved; progress will depend on how quickly we move towards it through actions such as those described in parts II and III of this paper. The following scenario is one glimpse into a potential sustainable future.

A city with attractive, compact, mixed use neighbourhoods uses land, but it does so efficiently. Environmental and ecological impacts on habitat, biodiversity, and agricultural land can be further mitigated through careful integration with urban areas.

There are still cars. In fact, automobiles are uniquely useful tools for many types of trips. They are a good means of long-distance travel in a large and lightly settled country like Canada. They are convenient for carrying goods, both privately and commercially. They are often the most effective way of making complex, multi-destination trips.

In compact, attractively designed, mixed use neighbourhoods, a convenient, complete range of amenities, from groceries and retail shopping to sports, schools, and cultural centres can be incorporated. Thus, while neighbourhood streets provide access for automobiles, they are designed to encourage the use of active modes such as walking and cycling. Walking and cycling are natural choices for local trips in all seasons.

Transit knits neighbourhoods together, allowing for quick and convenient travel throughout the city. Through a combination of urban-style LRT, with stops at every neighbourhood centre along its route, and high quality bus service, transit service is easy and intuitive wherever you are. Alternatively, cycling facilities make medium-range trips convenient if you want to experience the joy of physical activity.

Goods and services are still the essential components of commerce, and they move efficiently through the city by rail and by road. Improvements in teleworking mean that some jobs require very little travel or commuting at all.

Of course, even this vision of a sustainable transportation system still requires infrastructure to be built and products to be manufactured. Manufacturing and construction processes can be redesigned to avoid pollution and their products can be designed for easy disassembly, reuse, and recycling.

Finally, the energy supplied to create and operate a sustainable transportation system comes from sustainable sources. This likely involves a number of different means of generating electricity; however it does not depend on expending non-renewable resources such as hydrocarbons.

Conclusion

So why is addressing the environmental sustainability of transportation important? Sustainable activities are those that can be maintained continuously without change. Unsustainable activities are those that cannot; that is, at some point, change will be imposed on them by the limits of the system. The opportunity available is to recognize unsustainable activities and undertake change voluntarily. The other face of opportunity is risk. Insofar as we have the opportunity to avoid further degradation to the natural environment and as a result maintain a higher quality of life, delay in action risks damage to Edmontonians' quality of life in the near and longer-term future.

To enable a sustainable transportation system, the City is changing how it plans, designs, builds, and operates. However, in the end, while the City can provide options for mobility, it is citizens who must make the choice.

References

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