Advocating for sustainable public and freight transportation

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DEVELOPING HIGHER SPEED ELECTRIC RAILWAYS ACROSS CANADA

Paper presented to the High Speed Rail Committee,

Transport Action Ontario

by

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DISCLAIMER FROM TRANSPORT ACTION ONTARIO

This report is intended as a backgrounder to foster discussion and it offers one possible long term vision on development of higher speed electrified railroads in Canada. It is the personal work of the author, who is a long-time member, director and colleague of TAO.

TAO welcomes submissions on all topics related to sustainable transportation. While we have long supported railway electrification, the details of how this is to be achieved as expressed in this report are the opinion of the author, and are not the official position of TAO.

EXECUTIVE SUMMARY

This paper on electrification of mainline railways, and the development of higher speed railways across Canada, was prepared for Transport Action Ontario (TAO) and for Transport Action Canada (TAC). It is intended to serve as a backgrounder and long term vision for use by advocates and supporters of railway electrification and higher speed railways in Ontario, and in other provinces and regions of Canada. As such, it can assist TAO and TAC members and others interested in working toward an electrified higher speed railway system for Canada

Over many years, there have been many studies and considerable research on the potential and costs of electrified higher speed passenger railways in Canada. Most have focused primarily on a higher speed Windsor-Quebec passenger railway corridor. This paper focuses on strategies to develop a mixed use electrified interprovincial medium speed railway (MSR) carrying passenger and freight traffic across Canada, operating initially at a maximum passenger speed of 250 km/hr and a maximum freight speed of 140 km/hr. This electrified railway is assumed to begin in central Canada, and be extended into a national MSR network, linked with a proposed high speed Windsor–Quebec City railway. Such a network could bind together a number of MSR corridors across the country and could eventually become an integrated transcontinental electrified MSR, or an even higher speed, passenger, and express freight railway.

Following (i) a brief introduction; the paper outlines: (ii) the technology of contemporary railway electrification; (iii) why it is important to Canada at this time; (iv) the significance of an interprovincial energy grid to transmit required electricity between regions and ensure a stable, economic and sustainable power supply for railway electrification and other purposes; (v) energy and performance benefits from electrification of some of Canada's mainline railways; (vi) social benefits of an electrified railway network; (vii) alternative strategies to make it happen; (viii) a proposal for a Federal Electric Railway Development Agency; (ix) an estimate of what a basic electrified MSR line might cost; (x) how it might be financed, and (xi) conclusions on why Canada should move forward now on this national initiative.

Currently, Canada has a web of sub-optimal railway infrastructure, with a small number of intensively used freight corridors in better condition. A few of these also carry a limited number of national and regional passenger trains, under contract between the major private freight railways (CN, CP) and VIA Rail, Canada's public national passenger operator, or with provincial commuter transit agencies, such as AMT in Quebec, and Metrolinx in Ontario. In western Canada, a private railway passenger tour operator, Rocky Mountaineer, has contracts with the two major private freight railways to carry its luxury tourist passenger trains through selected scenic western mountain regions, using existing freight routes. In many instances, however, diverse railway lines and many branch lines have been allowed to deteriorate because of the lack of a federal rail policy and because the private freight railways did not undertake necessary development and required technological improvements.

At the same time as many public highways face increasing traffic congestion, in part from increases in truck transports, some of which could be better carried on electrified railways, social and economic cohesion among regions has suffered, east–west connections and economic links

have been weakened, and VIA passengers have had to make do with less than first world levels of convenience, reliability, safety and speed on passenger corridors.

There are numerous economic, social and environmental benefits from constructing a mixed use electrified MSR, including: (i) Reduced travel time and increased productivity of freight and passenger transport (ii) Increased transport energy efficiency, as well as reduced total national energy consumption [of fossil fuels] by more than 11% (iii) Creating substantial new opportunities for high quality stable, skilled employment and related training in modern railway technologies on a long term basis. This is employment which cannot be rapidly transferred elsewhere, such as to countries with lower labour costs**;** (iv) Achieving near zero exhaust emissions from key components of railway motive power and some long haul trucking. These systems will be able to conserve increasingly scarce fossil fuels for more appropriate purposes. Such electrical energy will also be lower in cost over the longer term, as more sustainable energy is put in place. At the same time, this will offer a positive way to constructively address climate change; (v) Connect separated communities and regions; (vi) Provide new mobility options for people; (vii) Provide reductions in insurance, health care costs and emergency costs.

To bring about this dramatic transformation, a three step plan is proposed:

Step One: Undertake improvements in existing right of way (ROW) infrastructure by creative public investment well before electrification is either initiated or fully completed. These would benefit existing diesel passenger and freight operations in the short term by facilitating enhanced rail safety, frequency and service, higher operating speeds and reduced travel times. Where appropriate, construction would include new and straightened rail alignments and improved roadbeds through strategic public investment, including double, triple or quadruple tracking in selected locations, mainline railway switches or crossovers capable of safely handling higher train speeds, replacement of level crossings with appropriate grade separations, or more secure crossing barriers in intensive higher speed mixed use rail corridors, and the addition of security fencing on present and future medium speed railway ROWs.

Rebuilding station platforms level with the floors of passenger rolling stock is another important means to reduce delay, minimize dwell time, and improve travel time on selected VIA and/or regional commuter railway routes. In-cab signaling and higher tech communications with fail safe controls on locomotive dashboards are also essential to improve operating speeds and safety, and set the stage for the higher speed potential of future electrification.

Step Two: Electrify selected mixed use railway corridors which carry intensive high value traffic. It is proposed that mixed use higher speed electrified rail corridors begin in areas of highest regional population density and railway traffic density, and be designed to better serve at least four types of traffic demand. These would include: (i) Conventional fast freight, including selected Container on Flat Car (COFC) and Trailer on Flat Car (TOFC) operations, (ii) RORO (roll on-roll off trucking and related traffic), (iii) Faster regional, national and international passenger trains, (iv) Interregional commuter traffic in the vicinity of larger urban centers.

On some mixed use multiple track railway corridors, passenger traffic would eventually be able to move at speeds up to 250 km/hr., while time-sensitive freight traffic on appropriate rolling stock could move at speeds up to 140 km/hr. This would mean railway mixed use traffic would share three and four track railway right-of-way corridors while also sharing electricity supplies. Energy demands would be optimized to ensure that available electricity is used at the highest possible system efficiency, on available tracks, 24/7/365. In this way, higher energy system efficiency can ensure more rapid payback and ROI (return on investment) for this electrified national investment, while continuing to benefit both passenger and freight operations. This proposal assumes that adequate land already exists or can be acquired to widen or straighten ROWs where necessary to provide additional width and capability for increased track performance. In instances where this is not possible, more complex and/or costly alternatives may have to be considered and investigated. These may include selective bypassing or line relocation, duplexing, and/or more innovative track sharing.

Step 3: As the benefits of higher speed electric railways, including MSR operations are demonstrated, and demand for higher speed railways grows, investment could be stepped up in improved ROWs for MSRs, followed by the development of separate, designated passenger lines for HSRs (high speed railways) and/or VHSRs (very high speed railways). As an initial demonstration of HSR or VHSR capability for more Canadians to be able to experience, completion of a new high speed demonstration railway corridor between Montreal and Ottawa could be an important step.

Preliminary costs to electrify to an MSR standard are in the range of 8 - 16 $M/km. An initial transcontinental railway for Canada would have a double track length of at least 11000 km. and would cost in the range of about $100-125B. It is acknowledged that this investment would be phased over several decades including steps 1 and 2 discussed above.

There are organizational challenges in implementing an electrified multipurpose railway corridor as outlined in this vision. This will require a more interventionist, forward-looking Federal government. The two major private freight railway companies, which have shown no recent interest in such concepts, would also have to reconsider their policies and programs. Of the various alternatives outlined in this paper, one which could achieve this goal would be to negotiate a new partnership between the private freight railways, VIA and forward thinking federal and provincial governments. An important objective would be to establish a Federal government authority or agency as a public developer and operator of electrified high speed railway infrastructure in Canada. Such an entity would have public control of railway electricity supplies, distribution, and administration, as well as administration and control of either owned or leased selected electrified railway corridors and infrastructure.This could be done jointly between existing private railways, the Federal government and the respective provinces, and possibly one territory already served by railways.

In this plan, governments would play a key role in the planning and implementation of electrified railway networks. Only governments have the power, capacity and legal tools to rationally, equitably and democratically absorb or redistribute costs, benefits and savings from publically-funded changes in major railway transport infrastructure.

Railway rolling stock may be publicly, cooperatively, or privately owned and/or operated, as is the case in many countries. However, higher speed electrified railway infrastructure, similar to groundside and airside airport infrastructure and the safe control of airspace itself, should be owned and/or administered by government to ensure that: (i) all high speed passenger and freight trains, are kept safe, effective and efficient, and (ii) energy efficiency advantages from electrified railways are fully recaptured in the public interest to ensure rapid financial payback for this significant public investment.

Railways in the UK are one example, familiar to many Canadians, of railway infrastructure owned and administered by government(s), while the rolling stock running on it is owned and operated by a range of private or public companies. Similar cost shared arrangements have been worked out between public and private sectors in many countries within the EU, and in Switzerland.

Joint railway operations have also been established between Finland and Russia, in which both countries' national railways have jointly purchased MSR passenger trainsets from Alstom in France for "Allegro" service between St. Petersburg and Helsinki. During off peak hours, these same electrified railway lines carry public and private rail freight and overnight sleeper traffic between the two cities, as well as to Moscow and to other destinations, in both Russia and Finland.

In conclusion, mixed use MSR offers many benefits for Canada, with a capital cost that is certainly manageable for our country. With strong leadership from the Federal and Provincial governments, we can move onward into the 21st Century!

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In acknowledging the support received from a number of individuals who have read and commented on the paper, it is also important to recognize others who over the years, either through data shared from their own publications, or through their support of my earlier research efforts, helped set the stage for the electrified railway vision which is outlined here.

In particular, I wish to thank Glen T. Fisher, P. Eng. B. Com, Pres. CPRC, who in a meeting with me in 1978, patiently explained some of the challenges which were faced in trying to demonstrate to CP senior management at that time the potentials and advantages of electrifying all or part of CP’s railway corridor between Calgary, AB. and Vancouver BC to improve locomotive traction and energy efficiency. This research was relevant in developing a new longer, but non- electrified rail tunnel beneath the Rogers Pass. He also described research which had been undertaken in the early 1970’s to compare the performance of diesel vs electric traction and wheel slip over steep grades on Norway’s Bergen- Oslo electrified mainline (Illustration 4). This project had been a joint effort by CP and SP, in collaboration with NSB (Norwegian State Railway) early in the 1970’s. Reviewing G.T. Fisher’s 2007 paper to the RAC (Railway association of Canada) (see Bibliography, Item 3), confirmed my decision to develop this paper for TAO.

Special thanks are also due to Mrs. Betty Hewes, the first woman Chair of CN’s Board, who in 1985, together with Ron Lawless, at the time CN’s Western VP, were both very supportive of my efforts to initiate a pilot research demonstration study in anticipation of possible railway electrification in western Canada. Our Edmonton consultant team proposal, at that time, was designed to analyze the physical requirements and costs of grade separation or crossing protection, protective obstacle raising, signal and communication changes, and ROW infrastructure improvements. All of this was precedent to a possible 1200 km. electrified demonstration line linking Winnipeg, MB. with Edmonton, AB. Unfortunately, the proposal was less well received by senior management at Montreal’s CN HQ, and was not realized.

I would also, like to thank Ed Finn, a founder and recently retired executive editor of CCPA’s publication, Monitor, who in 2008 encouraged me to submit a short paper outlining the concept for an electrified higher speed railway across Canada. This article entitled *”Canada needs an electrified railway from coast to coast”,* was subsequently published in the Nov. 2009, CCPA Monitor. In 2014, the article was reprinted as one of a series selected by the Monitor in celebration of significant articles published during the previous 15 years in which Ed Finn was executive editor.

My sincere appreciation to Tony Turrittin, VP, TAO, and editor of its bi-monthly journal, who initially invited me to join TAO, encouraged me to write articles reporting on railway travels in Australia, France, Spain, and China and to write this paper.

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I. INTRODUCTION

Currently, Canada has a web of 19th and early 20th Century railway tracks and railway rights of way, much of which is underutilized. These include a relatively small number of well maintained conventional speed or slower speed mainline railway freight corridors. At the same time, on many frequently overloaded major highways as well as on urban and regional roads, a great deal of truck transport freight, which used to be carried by rail, increasingly languishes in severe road and highway congestion, producing wasteful environmental emissions, energy inefficiency, diminished transport productivity and large highway maintenance costs. With the higher cost of highway congestion, conventional highway systems are unable to overcome this congestion, nor handle this and/or other traffic increases safely and efficiently. Meanwhile, Canada has two major private Class I international freight railways, which competitively run profitable freight operations within North America, using a much smaller proportion of what used to be their once larger Canadian railway networks. At the same time however, these railways are unable to satisfactorily accommodate conventional passenger trains, nor are they safely and efficiently handling the rapid growth in certain types of freight, including air cargos, grain shipments, and hazardous and/or dangerous liquid cargos.

In many instances, the two national railways are operating sub-optimal services because they have not invested in longer term improvements in ROW infrastructure or rolling stock or intermodal infrastructure in a timely fashion. This problem has become particularly acute over the past thirty to forty years. These are improvements which would also have enabled these Class 1 railway operations to more safely achieve greater competitive system efficiencies. Problems which have become particularly acute include the need for infrastructure such as more double tracking, or longer and/or more accessible passing tracks on key single track lines, higher speed rail switches, greater sharing (joint use) of tracks through common corridors, joint efforts by rail operators to upgrade to more heavy duty roadbeds and related infrastructure in some corridors, improved level crossing protection and grade separation, and security fencing. The list goes on. It suggests that both railways have been unable to provide optimal service, either for themselves, their commercial clients, or for the general public wishing to travel safely and reliably on passenger railways.

In considering these issues, there are also significant institutional barriers or constraints to be overcome, which are not only problems for the railways but also for governments. These include divergences between Federal and Provincial constitutional responsibilities for inter provincial railway and highway transport - e.g. Railways (Federal); commuter and some industrial railways (Provincial); electricity generation for motive power (Provincial); highways (Provincial). There are also conflicts in priorities between large (Federal-Provincial) spending increases on cost–shared Trans Canada Highway (TCH) improvements and other highways, compared with spending for the very limited Federal Railway Grade Crossing Fund, financed by shared cost contributions by Municipal, (or Provincial), Federal, and private railways.

There are also a range of other issues such as railway property taxes, tax write-offs, and cost of services which fall differentially on private railway companies, public railway operations. trucking companies and various levels of government. A particularly serious contradiction is local or regional property taxation policies which incentivize some railways to prematurely close down one track of some of its double track lines to save on local or regional property taxes in the short term. This can and does result in serious system capacity losses and increased public costs over the longer term.

In the past few years, with the prospect of an economic and industrial recession continuing in parts of Ontario, Quebec, the Maritimes and in a number of other regions of Canada, including the elimination and reduction of quality jobs, and with little prospect of a substantive short term turnaround, new forms of long term public railway infrastructure investment are needed. Yet nothing has been expended in such an effort, either recently or over the past 40 years, except for spending on roads and highways. For example, in a recent year, typical annual Federal spending in the civil transport sector has indicated a ratio of 10:1 in favor of highways over railways, and 8:1 in favour of airports and air infrastructure over railways.

Railway electrification, concomitant with higher speed passenger and freight railway operations would: (1) provide rail passengers and many transport truck operators with more expeditious, energy efficient, comfortable, cleaner, quieter, and safer ways of traveling between cities and towns on faster passenger and freight trains, or commuting to work by electric railway more comfortably, safely and rapidly; (2) reduce traffic congestion on, and emissions from major urban highways, as well as from many existing mainline railways; (3) provide a new mobility option for truckers and others through RORO operations, substantially increasing productivity of private truck transport and other modes and substantially reduce travel time; (4) generate many hundreds of thousands of person years of skilled employment in both construction and new passenger and freight railway operations within Canada over many decades. (Many of these are skilled jobs which cannot be relocated to third world countries to reduce budgets for labour cost); (5) strengthen social and economic cohesion among Canada's regions and provinces; (6) reduce fossil fuel emissions from ground transport; and (7) shift dependence away from fossil fuel alternatives to near zero emission motive power options.

In recent years, there have been signs of increasing public interest of the potentials and benefits of railway electrification and higher speed rail operations. In Canada, possible reasons include:

(i) Increased Awareness of Other Countries: More Canadians have had opportunities to travel on higher quality conventional speed railways (CSRs), medium speed railways (MSRs), high speed railways (HSRs), and very high speed railways (VHSRs) in European countries such as France, Germany, Italy, Spain and the Nordic countries, as well as in China, Japan, and South Korea. Closer at hand, they have also seen or travelled on a nearby MSR within the US northeast. Through this "megalopolis", Amtrak's ACELA links Boston, Mass. and Washington, D.C. (Illustration 1). This MSR train, designed and built by Bombardier, currently travels 457 miles (731 km.) along the US Northeast Corridor in 6 hours 10 minutes, at a modest average speed of 126 km/h (79 mph). This includes dwell times in various state capitals, New York City (NYC), and other major centers, including Newark Airport. The corridor is referred to here as an MSR, because although Amtrak's Acela trains have the design capability to reach speeds of 250kph.(150 mph.), they do so only in limited locations and only with their integral "active tilt technology" in operation, given the many ROW limitations and sharper curved track sections on this route.

Illustration 1: AMTRAK'S ACELA near Saybrook, Conn. MSR designed and built by Bombardier. Design Speed 250 km/h.(150mph). Currently, the Acela covers the 731 km.(457mile) distance in 6.17 hours with up to 9 stops, including 5 state capitals, New York City, and Newark International Airport, Philadelphia,Pa., and New Haven,Conn.

Two AMTRAK Acelas passing near Philadelphia's 30th Street Station.

With only vague comprehension of why and how higher speed railway systems work and/or the operation of their rolling stock, there is an increasing public interest and questioning as to why superior, easily available, off the shelf higher speed railway technologies are not in place or not being planned and developed for Canada, given their adoption and obvious success elsewhere in the world over the past several decades.

(ii) Inconvenient Air Travel: Since 9/11/2001, passenger air travel has become increasingly less convenient, more costly, and slower in terms of total elapsed travel time door to door. In particular, this is the case for many shorter and medium distance flights, given the huge increase in airport security and resultant delays in passenger clearance and baggage handling. For example, some air transport trips (e.g. 350 - 400 miles (560 - 640 km.)), when all of the components of "total elapsed time" are included, take longer than the equivalent conventional driving time door to door. Many of these urban centers could also be connected from central city to central city in much less time if HSR or VHSR EMU trains, with new or improved ROWs were available.

(iii) Problems in Canada's Rail Capacity and Safety: In recent years, private freight railways have been increasing returns from more profitable higher value freight traffic, while inconveniencing and disadvantaging thousands of rail passengers from whom they derive less direct profit. In some instances, they have done this in order to maintain their market share for higher speed container freight. In other instances, major freight railways have been operating at slower than normal speeds in order to safely handle dangerous, but very profitable hazardous liquid cargos as a higher priority on some mixed use freight and passenger routes. Meanwhile, the railway industry has been unable to generate sufficient capital for appropriate rail system network upgrades, for safety improvements for essential rolling stock, or for more rapid replacement of unsafe or obsolete rolling stock which increasingly carry more dangerous cargos.

In many parts of Canada, a consequence has been more angry and frustrated railway passengers, and more frightened members of the general public who live close to major freight lines and fear possible catastrophic rail accidents, including tank car or chemical rail cargo explosions occurring in or near their communities. There are also many frustrated rail freight shippers, including many western grain farmers, who are fed up with increasing numbers of short line railways and branch line abandonments. This has forced many grain farmers to bear the additional cost of having to drive up to hundreds of additional kilometers further during and following each harvest season, despite rising fuel costs, simply to deliver their product to market. Also, grain elevators remain fewer and farther apart, and major freight railways or designated short line rail operators, may or may not be servicing all of these remaining elevators in a timely way.

(iv) Demographics: The demographics of Canada's population is changing rapidly as its population ages. As it does, increasing numbers of older Canadians are continuing to live their longer lives in communities where they may have long chosen to settle down and retire. Sometimes these are smaller communities located between larger centers whre real estate is less expensive. Many seniors have less affluence than they may have had in the past, and less continued ability to travel independently by automobile. Consequently, passenger trains and in particular higher speed or conventional speed regional passenger trains, linking major and minor urban centers can provide an important, affordable, comfortable, safer, and less stressful means to maintain family and social connections. They can also facilitate access to specialized health care services located usually in larger urban centers when older, and/or disabled persons are either unable, or less able, to drive.

(v) Congestion: As urban and regional traffic congestion on intercity highways intensifies, increased travel time and driving stress faced by more intercity drivers will increase the modal shift away from current drivers using the private auto mode, and encourage a shift to faster, safer, more comfortable and less stressful higher speed trains, if and where these become available.

II. WHAT IS RAILWAY ELECTRIFICATION?

Since the end of the age of steam in Canada in the early1960's, virtually all railway locomotives, with a few exceptions, have been diesel–electrics (DEs) rather than "pure" electrics. While both types use electric motors to drive their axles, diesel electrics must carry their own onboard electricity generating stations, together with the fuel required to power them, over long distances and/or over extended time periods (e.g. up to 19000 liters of fuel for most heavy duty DE mainline locomotives). Consequently DE locomotives are slower as well as heavier than electrics (typically 180-190 tonnes or more for newer high powered DEs, compared with 80 - 90 tonnes for high powered electrics). They cannot start, accelerate to speeds above 200kph., decelerate or stop as smoothly, are more complex and noisy to operate, are more costly to maintain and service, have a shorter working life, and are far less system efficient.

Electrics, on the other hand, have no power generators or fuel on board. Instead, they draw their electrical energy from overhead power lines called catenaries by means of retractable devices on top of locomotives called pantographs. These extend upward, hydraulically, from the roof of each electric locomotive or EMU. Raised pantographs slide along overhead catenaries, making contact and picking up or returning electricity to and from the nearest utility substation, as well as electricity to and from the regenerative braking systems on nearby electric trains as the respective trains speed along different tracks. This is how and why only electric locomotives with regenerative braking systems can produce and make use of recoverable electrical energy.

Railway traffic served by multipurpose mixed use electrified railway lines [as is now the case in many countries] includes:

(1) ***Conventional Speed Railway (CSR) Freight and Container Trains:*** These run at 120-130 km/h to a theoretical maximum speed of 148 km/h. on appropriately designed and maintained ROW and infrastructure. By regulation, conventional freight trains have been limited to <79 mph (< 130 km/h) in North America.

(2) Roll On Roll Off (RORO) Flat Car Trains**:** These are close connected freight trains capable of carrying truck transports at conventional railway (CSR) speeds, of a steady 125km/hr (75mph). Cargos include container trucks and/or other types of truck transports and trailers, loaded with a range of products. These can be carried together with their drivers, as well as long haul buses, and other vehicles such as RVs. In addition, all of this enhanced ground transport railway function can occur more quietly, with zero carbon emissions, where sustainable electricity (e.g. hydraulic, wind or solar electricity) rather than fossil fuels, is used to power railways. Thus, energy costs for such transport vehicles can be substantially reduced for long distance trips.

With added sleeping and modest dining facilities at the head of each train, electrified RORO trains can be capable of carrying 30-90 or more vehicles together with their drivers at steady speeds to 125 km/h. Many RORO trains have smaller wheels to provide a lower center of gravity, better catenary clearances, and easier loading and unloading of vehicles at termini. However, because their smaller wheels are speed limiting, maximum speeds of only 125 km/h (75 mph) are permitted for such rolling stock.

The economic rationale for carrying truck tractors with trailers on electric railways is as follows: If tractor units each weigh at least 8-10 tonnes, then for a train load of 40 tractor trailers, tractors alone can weigh 320-400 tonnes. However, a single powerful electric locomotive, usually with the pulling power of two heavy duty diesel electrics (DEs), weighs at least 80 tonnes, while two equivalent power DEs weigh at least 400 tonnes, including full loads of fuel. Subtracting the weight of a single 80 tonne electric locomotive from the weight of two DEs, results in 320 dead weight tonnes. This is roughly equal to 32 - 10 tonne truck transport tractors, which can be carried on a 34 car RORO train, without load penalty for their additional weight. At the same time, the single, powerful, electric locomotive uses approximately one fifth, the total system energy of two DEs; produces near zero emissions, provides better traction between rails and wheels, and generates up to 30db less noise at the rail property line than a single DE, and very much less than this if at least two DEs are used for equivalent power.(See Illustration 13, p.74)

While RORO technology may not provide sufficient short run profitability for investment by one or more private railways, which currently depend solely on DE power, it can provide very significant long term value and ROI if developed as an integral part of a program to electrify mixed use passenger and freight railways, financed by a partnership of private long term institutional investors and a public sector entity such as FERDA (See Section VIII).

(3) Conventional and Medium Speed Rail (CSR and MSR) Passenger and High Value Freight Express trains: On well-designed mixed railway traffic corridors, some CSR and all MSR trains are capable of operating safely at steady speeds to 220km/h (132mph) for passenger trains on double track systems. MSR trains can travel at speeds up to 255 km/h for both passenger trains and/or higher speed parcel post or express freight trains on four track electrified MSR segments. Within these mixed-use railway segments, however, there must be: total grade separation from roads and highways, sufficient passing tracks, higher speed switches, rebuilt ROWs with flatter curves, adequate track capacity (e.g. clearance widths) within station areas to safely handle higher speed trains with closer headways. Most important, all locomotive rolling stock and EMUs on higher speed systems would be be equipped with in-cab controls with ATC (Automatic Train Control) or Positive Train Control (PTC), or ERTMS (European Railway Train Management System) infrastructure to ensure safe operations and emergency shut-downs if driver response is unsatisfactory.This will also allow freight and passenger trains to run at speeds > 126 km./hr.
It is presumed that, once such improvements are in place, the regulatory speed limits for some freight movement of 130 kph might be increased to 140kph.

(4) ***Regional Commuter and Intercity Trains:*** These are capable of operating at speeds in the range of 100 - 160 km/h. within the regional railway commuter sheds of most major cities. Railway electrification may also increase the extent of such regional railway commuter sheds. For daily travel trips in urban regions of other countries, distances can be doubled from 80 to 160 km.

or more. For example, with the wider introduction of intercity TGVs and duplex TGVs capable of operating at speeds up to 320km/h throughout France and into neighbouring countries, regional daily travel distance to and from Paris (2 hours or less each way) now extends as far south as Lyon, as far west as Tours and Le Mans, as far east as Alsace, and as far north as Brussels, Belgium. Thus, many of these urban destinations are now accessible to Paris within the time limits of a business day.

The most important feature of high speed electric locomotive or EMU powered passenger trains is that they make it possible to transport overland, more rapidly than any other technology, larger numbers of people, (i.e. more than 1000 passengers/train, with 500 persons seated in each of two linked duplex trains). Such HS railways can also carry overnight mail or fast freight cargo in modified HSR rolling stock, including airfreight shipments between major airports, between large major cities and /or fast freight cargo to coastal port cities with ferry service, moving at MSR, or, in future HSR speeds. Such programmes have been running successfully for the past five years between Paris's Charles de Gaulle airport, London, Lyon, Marseille, Frankfurt, Madrid, Munich, Vienna, Barcelona, and Bratislava [by SNCF Cargo), in conjunction with Fedex and / or other fast freight cargo shipping partners.

All of the above four types of railway traffic share a common characteristic, namely they can all travel within common multitrack rail corridors or networks, although not all on the same tracks. These are known as a "mixed traffic rail corridors", often with the faster tracks in the center and the slower tracks on the outside. However, as railway speeds are increased substantially to HSR and/or VHSR speeds, such higher speed passenger trains must inevitably travel in their own ROWs. As speed differences between freight and passenger rolling stock and related safety issues become more critical, and as longer radii of curvature requirements (e.g. >7000 m.) call for increased separation of CSR and MSR from HSR and VHSR tracks, higher speed trains will inevitably require greater spatial separation.

***What do we mean by HSR or VHSR*?**

HSR and VHSR trains are high or very high speed EMU trains that can rapidly accelerate from zero to conventional speeds (i.e. up to 211 km/h. (132 mph.), run through medium speed ranges of 211- 248 km/h., and then accelerate further from designed MSR lines onto designated higher speed passenger railway (HSR or VHSR) tracks. On such ROWs, trains can safely operate at high scheduled speeds in the range of 248 – 374 km/h., with more recent top speeds as high as 480 km/hr. Such fast trains can also maintain such high speeds continuously and comfortably for long periods, provided that the railway infrastructure they are operating on, including communication and train control systems (e.g. ERTMS), tracks, roadbeds, catenaries and clearances are consistently safe, properly designed and well maintained, and their operating personnel are also well trained and certified.

Appropriately designed HSR infrastructure includes: heavy duty catenaries, and stronger electric cable support systems; continuous, heavy duty ribbon rail tracks; spring steel track ties; large radii of curvature ROWs and rail alignments on close spaced reinforced concrete ties or concrete slabs; high speed (HS) switches and crossovers; in–cab signals and communications with positive train control or ERTMS (i.e. which include automatic slow down and stopping, if an engineer fails to respond to signals appropriately); total grade separation of all railway crossings; and safety fencing securely enclosing high speed ROWs. Higher speed railway corridors must also run on well-designed viaducts or bridges, across rivers and stream valleys and through wider tunnels passing through hills and mountains to maintain the most direct routes and safe high speeds. On such infrastructure, HSR and VHSR trains can maintain their high speeds safely and comfortably, covering long distances with minimum travel times.

For example, if, in theory, two larger cities are 1600 km. (1000 miles) apart, then a non-stop HSR EMU running at 300 km/h. (187 mph.) or a similar VHSR EMU running at 380 km/h. (228 mph.) could cover this distance in 5.3 hours or 4.2 hours respectively. It is acknowledged that some slow down through some intermediate cities might be necessary. An MSR EMU or electrified train running at a steady speed of 250 km/h, non-stop, on a mixed use corridor, would require 6.4 hrs. to cover the same distance. By comparison, a conventional speed railway (CSR) train or EMU running at a steady speed of 208 km/h. (130 mph.) on a mixed use corridor would require at least 7.7 hours to cover the same distance, and a RORO freight train at 125 km/h (75mph.) would require 13.3 hours, roughly 3 times longer than the VHSR EMU. A contemporary CSR (e.g. VIA) passenger train, or typical conventional freight train, currently operating over the same distance at a typical average speed of 76.3 km/h (47.7 mph) would cover this 1600 km trip in close to 21 hours, non-stop.

[Note: As of the late 1980s, 47.7 mph or 76.3 km/h was cited as the average speed of all freight (and passenger) traffic in Canada, and there is little evidence that, in the interim, there has been much change. For example, in 1970 this author took a VIA rail transcontinental passenger train from Toronto’s Union Station to Winnipeg’s Main Street Station, a distance of approximately 2100 railway km. That journey required 31 hours, for an average speed of 67.7 km/h (40.6 mph) including numerous stops. Currently, the same VIA rail passenger trip over the same route requires 36 hours or more, for an average speed of 58.3 km/h (35mph) – hardly an improvement. Instead, there has been considerable reduction in service and an increase in travel time over the 45 year time interval, with a slower overall passenger train speed, ostensibly, to facilitate a slight improvement in convenient overnight stop times.]

III. WHY IS RAILWAY ELECTRIFICATION IMPORTANT NOW?

(a) Reduce Travel Time and Increase Productivity of Freight and Passenger Transport: For all types of rail transport, whether commuter, long and medium distance passenger rail, roll-on roll-off freight, container freight, grain, heavy metals, oil or lumber transport, railway electrification can improve mainline performance in terms of reduced travel and shipping times and improved productivity. For CSR, a 20%-30% reduction in travel time is achievable; for MSR and HSR, it can mean 50% less travel time; and for HSR and VHSR, a 60-70% reduction in travel time is achievable.

From the standpoint of travel time, comfort and safety, higher speed electric passenger trains are superior to jet planes for distances of less than 500 km. at CSR speeds (i.e. up to 132 km/h); for distances of less than 800 km. at MSR speeds (130-220 km/h.); for distances of less than 1200 km. at HSR speeds (220 - 300 km/h.); and for distances of less than 1600 km. at VHSR speeds (300-380 km/h.).

Also, regardless of their speed, sustainably powered electric passenger trains are capable of carrying more passengers per train, more comfortably, efficiently, quietly, and safely than any existing aircraft.

(b) Energy Consumption: Electrification of mainline railways has long been identified as an important means to reduce Canada's energy consumption. This is discussed in detail in Section V.

(c) Employment: With large increases in unemployment and under employment in higher skilled job sectors, and large questions as to whether traditional jobs in conventional industries including the transport and energy sectors are sustainable**,** electrification of Canada's mainline railways and more energy efficient higher speed ground transport can be key growth areas for sustainable, higher tech investment and employment early in the 21st Century.

Also important is the fact that the new types of jobs in the development of modern Canadian railway infrastructure cannot be simply picked up and moved to another country, where labour costs may be lower than in Canada, as has been the case with so many other industries in recent years. Railway electrification and the higher speed infrastructure it requires needs skilled teams, living, working and paying taxes in Canada, on an on-going basis. Their life challenges and career tasks will be to plan, design, build, contract, rebuild, renovate, operate, repair, maintain, secure, and administer fixed electric railway infrastructure and rolling stock, and to develop required sustainable energy to power modern ground transport systems long into the future.

This employment can be generated and sustained, not just within a single city, urban region , or within a limited number of regions, but in fact can be developed in at least 9 out of 10 of Canada's provinces, and eventually in at least one of its northern territories. Consequently, a very large number of Canadians have an important stake in the successful outcome of this longer term national infrastructure investment strategy.

(d) Green House Gas and Critical Air Contamination Reduction: If one accepts the notion that man-made climate change is real, that its destructive impact on the planet's microclimates and human environments is significant, and that climate change impacts will be increasingly devastating to human environments and to many species of animals and plant life, then rapidly reducing and eliminating unnecessary GHGs (greenhouse gases) including CO_2 emissions and CAC (critical air contaminant) emissions, which arise in part from fossil fuel powered ground transport such as diesel powered railways and diesel transport trucks, can provide an useful opportunity to reduce climate impacts on urban and regional environments.

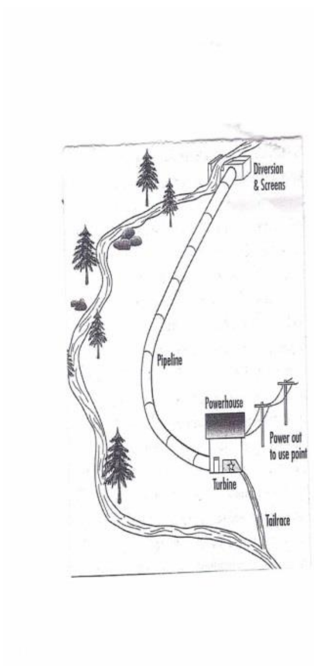
Fortunately, it is still possible to reduce many CO_2 and other emissions without drastic changes in lifestyle or reductions in the economic circumstances of most Canadians. In fact, strategies outlined here offer many positive opportunities for lifestyle enhancement. This includes cleaner, faster, quieter, safer, and more comfortable electrified ground transport than most Canadians have ever seen or experienced. This transformation can also be achieved with near zero carbon emissions from locomotives, or EMUs, and at a fraction of the energy system inputs which are being unsustainably expended for current DE powered railway and other ground transport systems.

Compared with the 7.4 M tonnes of CO_2/annum emitted by at least 80% of Canada's (DE) freight locomotive traffic [5], electric locomotives which use sustainable electricity produce near-zero emissions. This also applies to lesser quantities of critical air contaminants (CACs), such as NOX [NO_2 &NO_3 compounds], CO, PP, HC, SOX [SO_2&SO_3 compounds], and lead, which, together comprise the toxic exhaust content of most DEs, compared with near zero emission electrics. However, even large electric railway networks such as SNCF keep a few DEs on standby, in strategic locations, in case of power failures or outages in extreme emergencies. Thus, one uses the term near-zero.

(e) Use of Renewable Energy Another important consideration is the opportunity for Canada to use its unique, natural economic advantage in sustainable energy (e.g. hydroelectricity and smaller run of the river hydropower projects, tidal, or more precisely, multi-rotor hydrokinetic tidal or fast flow river turbines). These would be located substantially underwater, without the necessity of environmentally deleterious barrages or dams, within Canada's unique tidal estuaries or in some of its fast flowing rivers. Also important would be wind power and innovative off peak energy storage to ensure steady 24 hour electrical energy. This would mean not only being able to continue to export sustainable energy, but most important, to add value to lifestyles, mobility and economic potentials within many regions of Canada by comprehensively developing sustainable electricity together with electrified railways, which can use this energy efficiently.

Illustration (2) Run of the river power provided by small scale hydro-electric power stations, and Illustration (3) Multi-rotor hydro kinetic tidal turbine electric power generation.

Illustration(2) **Illustration (3)**



IV. THE IMPORTANCE OF MOVING ELECTRICITY BETWEEN TIME ZONES

Electricity from sustainable sources, such as hydraulic and wind powered electrical generation, are among the most environmentally safe forms of "high quality" energy available. Electricity transmission between major power grids is also the fastest way to move this form of energy most efficiently. Currently, at least 70% of Canada's total electricity is provided from hydraulic sources (e.g. hydroelectric and tidal power), and there is also considerable potential to increase such supplies (See Illustrations 2&3). By comparison, the United States, geographically less well endowed with hydropower, currently generates less than 7% of its electricity from such sources, and an additional 5% from solar and wind power. Consequently, the US depends heavily on much less energy efficient conventional fossil fuels, such as coal, gas and oil, as well as less safe, and less efficient nuclear power to generate its electricity with less motivation to electrify its railways.

The significance of high quality energy in the form of electricity is not only that it can power many complex machines and appliances, including computers, lighting, and HVAC systems, and can also power transport systems such as electric trains, subways, LRTs, streetcars, electric buses, movelators (i.e. electric powered ramps and/or moving sidewalks), elevators, as well as electric cars, and other battery powered small vehicles such as forklifts and golf carts. Also important is the fact that large quantities of electricity can also be shifted very long distances instantaneously. This is done simply by shifting blocks of electric power at power control centers in response to rapid changes in supply and/or demand requests at a nearby utility to or from others further away. Using modern transmission control technologies, some of BC's electricity is currently shifted south as far as San Diego, California; Manitoba Hydro regularly shifts electricity during the AC season all the way to Texas and buys some back during cold winter peaks; and Hydro Quebec continuously shifts and sells power south through northeastern US power grids to NYC and beyond throughout the year. This hydroelectricity export also helps power a medium speed electrified passenger railway EMU, AMTRAK's Acela, and other HS and regional commuter passenger trains within Boston - Washington electrified railway corridors.

While it is clear that most of Canada's hydro rich provinces have been able to export excess electricity to the US, less progress has been made with respect to developing a strong E-W inter-provincial electricity grid across Canada. While some may feel that a fundamental cultural change is needed within Canada to bring this about, such a grid would make it possible to easily shift electricity supply back and forth across the country in response to changing daily peak demands for electricity within various provinces in each of five and a half time zones, at least twice a day.

With four provinces (e.g. BC, MB, PQ, and NFLD) able to produce more than 92-97% of their own electrical energy needs from sustainable sources, such as hydroelectricity and wind, and at least another two able to produce a significant proportion of their electrical energy from hydrokinetic tidal, wind, or other hydraulic sources such as run of the river hydro, there is a timely case for establishing an east–west electricity grid. This would ensure that regions deficient in sustainable electricity might be strengthened, and sustainable energy surplus regions could become more stable, within their specific grid systems, by being linked east–west, as well as north - south.

In summary, there are at least three benefits in creating an E-W national electricity grid:

(1) Provides a secure supply of sustainable, stable, high quality electrical energy across Canada, regardless of changes in the world price or the supply of oil, synthetic oil or gas, or long term regional variations in the status of environmentally unsustainable non-renewables, such as tar sands, heavy oils, coal, shale gas, or nuclear energy and related safe, long term waste storage.

(2) Facilitates the potential shifting of sustainable electricity in response to changing daily or seasonal peak energy demands among and between Canada's 5 1/2 time zones. For example, as one time zone passes through its twice daily 3-4 hour peak demand, available electricity supply can be shifted east or west to an adjacent zone, which is arriving at its next demand peak.

(3) Provides a convenient, efficient means of supplying and distributing some of the electricity needs of higher speed railways, as electrification of mainline railways is developed and extended across the country.

Although, a national electrical energy grid can be important for the development of railway electrification, it is not a prerequisite, since electricity demand in the early stages of a basic electrified double track railway is relatively small (i.e. less than 50 MW /120 km). Therefore, some of this electrical energy can be provided by a number of smaller, run of the river type hydroelectric generating stations, or by networks of hydrokinetic turbines within major tidal regions, or fast river estuaries, and/or by wind power together with innovative, small scale energy storage infrastructure (e.g. pumped water reservoirs).

V. ENERGY AND PERFORMANCE BENEFITS FROM ELECTRIFICATION OF CANADA'S RAILWAYS

(1) Increase Transport Energy Efficiency: End–use or system efficiency for a railway power system is the ratio of total work done in propelling a railway locomotive and its load, relative to the energy content of the fuel source originally existing in the ground, and ultimately powering the locomotive's engine and axles. It is computed by multiplying the efficiency level of a particular component or step in a locomotive power system with the end use cumulative efficiency of all previous steps of energy process and extraction. For hydro powered locomotives and EMUs, system efficiency is 75 - 78% at the axles, and 50% for electrics powered by co-generation. This compares with about 23% for diesel–electrics (DEs) east of the Manitoba Ontario border, and an estimated 13% for DEs west of the ON-MB border [3]. This difference occurs because locomotives in western Canada use refined tar sands derived oil for their locomotive fuel needs. (See Tables 1-3.)

Table 1: Cumulative (End –Use) Efficiency of Hydro – Electrically Powered Locomotives

Step	Step Efficiency	End-Use Cumulative Efficiency
Water falling through turbine	95%	95%
Electric generator efficiency	97%	92%
Power transmission efficiency	92%	85%
Electric motor efficiency at axles	92%	78%

Table 2: Cumulative (End Use) Efficiency of Diesel Electric Powered Locomotives

Step	Step Efficiency	End-Use Cumulative Efficiency
Crude oil in the ground		100%
Crude oil at wellhead	86	86%
Crude oil at refinery	92%	79%
Refined diesel fuel	88%	70%
Transport to railway locomotive depots	98%	69%
Storage of fuel and pumping into loco.	99.5%	68%
Energy conversion by locomotive	35%	24%
DE motor efficiency at the axles	93%	23%

Table 3: Cumulative (End-Use) Efficiency of DE Powered Locomotives Using Tar Sands Derived Fuel

Step	Step Efficiency	End Use Cumulative Efficiency
Tar sands in the ground		100%
Tar Sands to initial processor in source region	92%	92%
Synthetic crude before refining (2bbl tar sands = 1bbl bitumen)	50%	46%
Refined DE loco fuel	88%	41%
Transport to loco. Depot	98%	40%
Fuel storage & pumping into DE loco. fuel tanks	*99.5%*	39.8%
Energy conversion by DE loco.	35%	13.9%
DE motor efficiency at axles	**93%**	**13%**

Source: Tables 1&2 in this series were first presented as Tables III & IV, in a Transport 2000 Ontario Newsletter article by the author, April 2009, p.6. Table 3, modified from Table 2, is presented here.

(2) Reduce Total National Energy Consumption: A 1974 report on energy efficiency to the Science Council of Canada by Dr. F.K Knelman [4] indicated that Canada could reduce total energy consumption by at least 11% by electrifying mainline railways. Most of this reduction in energy consumption would be in the form of more efficient use of fossil fuels for ground transport (e.g. diesel locomotive fuel). This report was written before the technology of electrical recovery from regenerative braking by electric locomotives was fully known, or the indicated efficiency savings may have been higher.

(3) Recover Energy Produced from Regnerative Braking: One of the most important features of current railway electrification for both conventional speed and higher speed trains is that regenerative braking now makes it possible to recover significant amounts of electricity from braking energy. This technology, available only on electric locomotives or EMUs, offers the potential for recapture of up to 70% of braking energy. This electricity can be used either on board the generating train or for assisting other electric locomotives or EMUs nearby which may require more energy for climbing grades or starting up on nearby tracks, or up to 30% of recaptured electricity can be sold back to the generating utility through the nearest electricity substation on the grid under circumstances in which electrified rail traffic is carefully coordinated and scheduled.

(4) Improve Adhesion and Traction Between Steel Wheels and Rail: Adhesion refers to the friction between steel wheels and steel rails on grades. For DEs, adhesion is 45% under good weather conditions, while for electrics, it is 35-40% under poor weather conditions but can be up to 55% under good weather,conditions. This data has been confirmed independently in tests conducted in 1971 on steep Norwegian electrified railway grades (>2% gradient). These were conducted on a 80 km. segment of the Oslo – Bergen railway between Voss and Finse, Norway, using ASEA Swedish electrics and CP type diesels.

Subsequent tests were conducted by Brown Boveri of Switzerland using similar electrics and diesels on a shorter distance of 24 km. over a steep gradient section (2.7% gradient between stations) on the Berne - Loetschberg - Simplon (BLS) Railway approaching the Loetschberg tunnel in Switzerland. These confirmed the Norwegian experience. (See Illustrations 4 & 5, for profiles of test areas in Norway and Switzerland) [6] These tests confirmed that better adhesion and traction of electric locomotives is an important feature of their improved performance over diesel – electrics. This advantage results in faster acceleration and deceleration, as well as smoother stopping and starting under severe grade and weather conditions. Consequently, it also ensures more comfortable sleep on overnight trains, as the starting and stopping of electric trains is almost imperceptible.

ILLUSTRATION 4: PROFILE OF TRACK IN TEST AREA. OSLO – BERGEN RAILWAY LINE, NORWAY, (Maximum Gradient >2%).

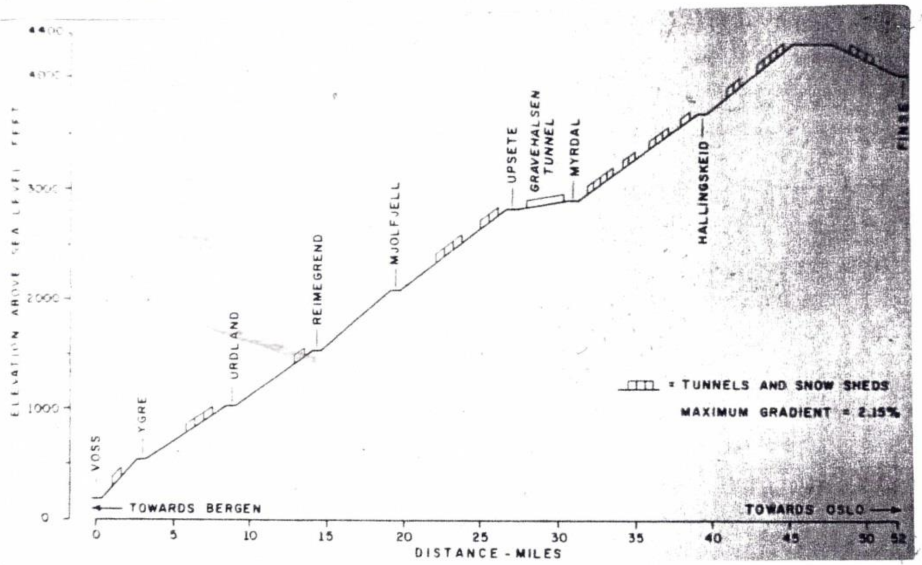
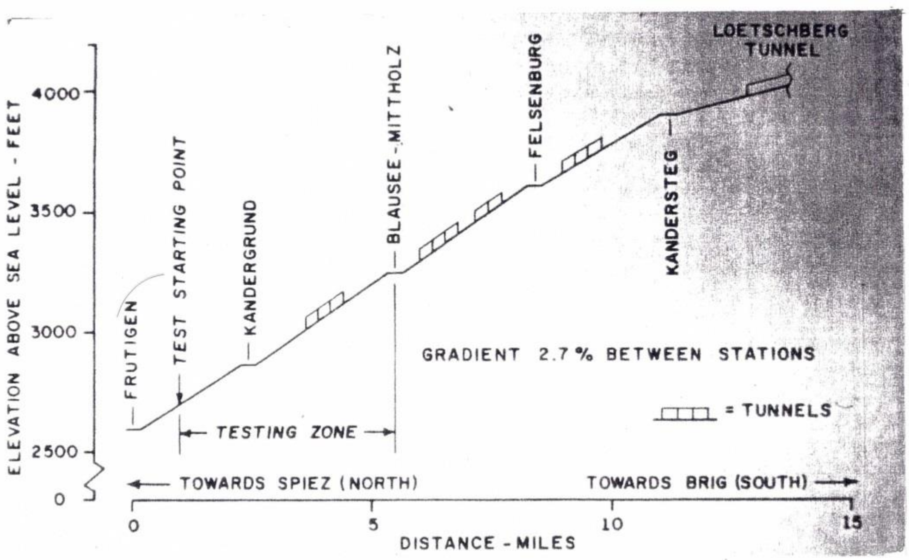


ILLUSTRATION 5: PROFILE OF TRACK IN TEST AREA, BERNE – LOETSCHBERG – SIMPLON (BLS) RAILWAY, SWITZERLAND, (Maximum Gradient >2.5%).



There are at least two reasons for the improved traction and adhesion advantage of electric locomotives and EMUs compared with the performance of diesel – electric locomotives and DMUs: (1) Diesel–electric locomotives and DMUs carry their own on board fuel supplies (19000 liters/loco on many DE machines), which can weigh close to 20 tonnes, compared with the normal 120 - 160 tonne weight of a medium performance DE locomotive with empty fuel tanks. Thus, as locomotive fuel is consumed, the effective weight of a locomotive over its axles and wheels changes (i.e.decreases), which may effectively reduce traction, depending on the quantity of fuel remaining. By contrast, electric locomotives carry no fuel and maintain constant weight over their drive wheels and axles, because electricity is supplied from overhead catenaries external to the locomotive or EMU. (2) The engineer or train controller of an electric locomotive has greater direct control of the electricity driving the wheels of the electric locomotive or EMU, and thus can more precisely control power to respective axle motors. By contrast, an engineer driving a diesel electric locomotive is controlling what is in effect a heavy mobile diesel electric power generating station, with less direct control over the electricity to the locomotive's axle motors or wheels. Thus, many diesel electric locomotives have a greater tendency for wheel slip with adhesion reduction on grades and in bad weather, due in part, to a tendency to" overpower" a locomotive's wheels. To address this problem, several DE manufacturers have introduced microprocessor control technologies in post 1990's locomotives to reduce wheel slip problems. It takes time, however, to transform entire DE fleets to respond to this particular performance problem, while newer, heavier, and more powerful DEs are still more complex to control with precision, even with the help of newer microprocessor technologies.

(5) Reduce Locomotive Noise: It has been estimated that noise levels of DE locomotives can be reduced up to 30db/locomotive at the rail property line by shifting to conventional electrics [7]. For HSR trains, noise level reduction compared with DEs may be only 20db (Alstom, 2010). However, idling noise for electrics can be totally eliminated, since they can be turned off and restarted instantly, thus saving energy, instead of having to idle as many DEs must do, either in colder weather and/or to sustain required braking energy in some situtions.

(6) Reduce the Lifetime Cost of Airbrake Maintenance: Airbrake maintenance is an ongoing cost of maintenance of freight railway rolling stock. With the introduction of electric locomotives with regenerative braking, the airbrakes of mainline freight cars are needed only in emergencies, or to hold a train in place when stopped on a mainline. Thus, airbrake maintenance costs can be reduced over rolling stock lifetimes [8].

(7) Eliminate Fuel and Oil Spills: Unlike electrics which have no fuel oil to leak, DEs, especially older rolling stock, inevitably tend to leak some oil onto roadbeds, into drainage ditches, creeks, streams, rivers, lakes and/or reservoirs, as well as into urban storm and sanitary sewer systems, where it can contaminate sewage treatment plants, or even some urban waterfront beaches. Such leakage becomes much more serious in the event of major railway accidents in which entire locomotives are overturned and up to 19000 liters of diesel fuel from each locomotive's ruptured tanks, can place natural environments at serious risk.

VI. SOCIAL BENEFITS OF A HIGHER SPEED TRANS-CANADA ELECTRIC RAILWAY

There are at least two important social benefits of a higher speed Canada-wide electric railway:

(1) Connect Separated Communities and Regions: Connect, link, or reconnect many disparate urban settlements, and regions, with greater comfort, safety, and speed than any ground transport system currently extant in Canada. Achieve this linkage with "no substantive urban community left behind". All urban communities would be served by faster and more energy efficient ground transport of one form or another, depending on their location and specific setting. In some instances, it might be electrified rail buses connecting seamlessly with higher speed electrified mainline passenger trains. In other situations, it may be long haul diesel buses riding on flat cars on RORO trains to achieve significant time distance advantage for some longer overland bus trips through regions with few intermediate railway or bus stops. A new national transport policy could make it possible for more of this to occur.

(2) New Mobility Options for People: Create new mobility options with the addition of higher speed trains (e.g.160 – 360 km/h.) which can (a) safely access many cities within a long railway corridor in a fraction of the elapsed time required by all other modes of ground transport; (b) provide faster mobility options, which can eventually operate at close to the current cruising speeds of turboprop aircraft; and (c) provide greater comfort, convenience, energy efficiency and safety for more passengers than any alternative mode of transport.

VII. ALTERNATIVE STRATEGIES TO MAKE IT HAPPEN

There are a number of alternative ways to bring about electrification of passenger and freight railways in Canada. All involve some degree of public sector initiative, investment, and/or control. Some have been tried in the past, and are still operating, with some improvements after more than a century. Others have been more successfully implemented elsewhere.

Alternative (1): Programs which Maintain the Status Quo

In Canada, two major private railway companies provide mainline freight service to many of the same regions in the eastern parts of the country, and each provides services to different regions in the west. To date, neither corporation has shown any interest in investing corporate resources to electrify existing freight tracks, even if there are longer term technical and economic advantages in increasing operating efficiencies. As private corporations, they appear to be primarily focused on improving their corporate bottom line in the short to medium term . It is acknowledged that mixed use railways do not operate on a level playing field with mixed use highways, either with respect to subsidized public investment, safety and security, maintenance and repairs, or other factors.

Electrification is a longer term strategy which neither private railway freight company appears to be willing to consider at this time unless some other entity (i.e. the public through its various levels of government) is prepared to put up the necessary capital and operating cost, at little or no cost or risk to the respective railway. However, the public, in general, would definitely question substantially subsidizing one or both freight railways, without governments either receiving an increased financial benefit from, interest in, or longer term ownership and control of fixed electrification or ROW assets, and improved performance of related public transport infrastructure. Given the magnitude of such public expenditures, no government which wishes to be reelected could embrace such alternatives, without significant new “rebalancing arrangements”.

Yet, some aspects of this policy alternative have continued to be employed to incentivize Canada’s private railways to continue to maintain their contractual obligation to provide continued access on their ROWs for basic VIA passenger traffic across the country, at the schedule discretion and control of the railways. VIA owns and operates a number of stations and a few segments of track, as well as most of its own passenger rolling stock. However, in general, the amount of publicly owned VIA track is relatively limited. Therefore, VIA must continue to contract with private railways. Railways have no clear obligation to ensure timely, automatic public right of use and/or priority on their ROW infrastructure, other than short term contractual agreements with VIA. Also, VIA has no long term governing Act or legislation which provides a permamnent commitment or contract strongly backed by the Parliament of Canada.

Because much of this privately owned ROW and track is now older, and a great deal is in less than ideal condition for conventional or higher speed electrified passenger railway operations, a typical expected railway response would be “If you want better track or infrastructure conditions to achieve faster speeds, safer operations, better schedules, then pay us more for the use and upgrading of our railway ROWs, operating services, rolling stock and/or maintenance equipment”. If government puts in more money for capital or operating costs, the railways are prepared to take the money. However, they may, or may not, deliver expected improvements in a timely fashion, unless public private contract arrangements are tightly and clearly defined, and carefully inspected, monitored and audited.

On some routes in which intercity passenger schedules at one time took close to 4 hours (e.g.3 hours, 59 minutes), travel times now routinely take 4 ½ - 5 hours. However, when public VIA trains are delayed, often through no fault of VIA, private railways which have control of rail traffic on their mixed use lines accept no responsibility for nor are mandated to provide compensation for significant delays or costs to VIA resulting from shortcomings in private freight railway operations.

Despite this undesirable situation, the Federal government has invested about $1B over the past half decade on improvements in the Windsor-Quebec rail corridor largely owned by the private freight railways.

Alternative 2: Introduce new legislation, i.e. a new Railway Act, possibly modelled in part on US Railway Transport legislation to bring DE powered VIA passenger rail service in Canada up to, at least, the level of basic DE passenger service currently provided by AMTRAK, as well as achieving other objectives for improvement of conventional speed railway passenger service.

Such proposed legislation would outline and set out procedures under which the Federal government would work with the Provinces to finance new services and operations of VIA Rail services. It would also clearly define the rights and obligations of both VIA Rail and the freight railways.

While this alternative may not facilitate development of electrified railways within higher speed railway corridors across Canada in the short term, it could go some distance, albeit very slowly, in setting the stage for future higher speed passenger railway improvements across the country. A key problem with going slowly is there would be little momentum built up to change public attitudes and perceptions about the advantages and potentials of electrified railways including CSRs, MSRs and HSRs.

Recently, a private member's bill was introduced in the House of Commons, known as the VIA Rail Canada Act, that established VIA's rights and obligations . TAO has provided input to this bill. It was a good first step and received support from all the opposition parties, but did not pass. Hopefully, a more committed future parliament will take up this cause once again and similar legislation will be passed.

Alternative 3: Phase out VIA as a "transcontinental" passenger railway system and use available VIA Rail's budget to develop a single new HSR line, linking Calgary and Edmonton or Windsor, London, the GTHA, the National Capital Region,Montreal. and Quebec City, through substantial public investment and control of a new publicly owned CSR or HSR corridor.

Although studies have been completed on HSR for the Calgary-Edmonton corridor, the most recent and detailed study was for the Windsor-Quebec City corridor.

This alternative has been detailed in a Federal – Provincial High Speed Railway study finally released in 2011. This study report which is currently posted on Transport Canada's website, is entitled **"Updated Feasibility Study of a High Speed Rail Service in the Quebec City – Windsor Corridor".** This study was conducted by EcoTrain, a group of international consulting firms led by DESSAU, and supported by DB International, KPMG, the MMM Group, and Wilbur Smith Associates.

The study evaluated 2 options: a 200km/h, diesel electric traction alternative [CSR], and a 300 km/h. electric traction alternative [HSR]. Both options considered stops at only 8 stations, namely Windsor, London, Toronto, Kingston, Ottawa, Montreal, Three Rivers, and Quebec City.

The study arrived at an estimated figure of $18.9B for the DE technology option, and a figure of $21.3B. for the HSR electric locomotive technology alternative. The figure for the Montreal-Ottawa-Toronto portion alone was $9.1B for the DE alternative and $11B for the electric traction option. In addition, only very narrow economic impact studies appear to have been undertaken.

[On the basis of similar DE technologies around the world, the proposed DE alternative would be permanently speed limited by its basic technology to <125mph or 200 km/h. while the top speed of the 300 km/h electric option could be increased significantly in the future from 300 to 380 km/h. with the use of currently available alternative electrified rolling stock, if the selected radii of curvature for ROWs were long enough (e.g. Bombardier's VHSR Zefiro Rome-Milan, Italy. Maximum design speed 380 km/h.,(See Illustration 12)]

The EcoTrain study concluded that the operating cost` for the Montreal – Ottawa- Toronto triangle alone would have a positive ROI but that the Toronto -Windsor and Montreal - Quebec City legs would be negative in terms of ROI. Here also, very limited economic impact analysis was provided for a decision to recommend that all Montreal-Toronto HSR passenger traffic be routed through Ottawa.

The study team also indicated that the development costs to the three governments, Canada, Ontario, and Quebec would be significant, with insufficient return on investment or other significant benefits to those contributing governments in improved environmental conditions, efficiency savings, etc.

The consultant team appear to have concluded that trying to work with one or both large private railway oligopolies, in a laissez faire economic world, represented a near impossible task. Thus, they stayed away from building upon the joint use of existing private freight railway infrastructure as much as possible, and by doing so, permanently removed passenger rail service from a number of St. Lawrence- Lakeshore communities, many of which already have the beginnings of a higher speed rail corridor. Instead, they appear to have concluded that to build higher speed railway tracks with substantial public dollars within the Quebec City- Windsor corridor, VIA, in its present form, must be eliminated as a passenger rail operator, and VIA service using mainline regional trains to smaller and intermediate size cities would have to be replaced with highway buses to provide ground transport feeding into the designated VIA bus-railway stations in eight major cities.

Thus, this proposed alternative would have resulted in the elimination of mainline interprovincial and regional passenger railway service to many communities on the south shore of the St Lawrence between Montreal and Riviere du Loup, and on through NB to Halifax; elimination of passenger railway services to at least five major historic St. Lawrence Valley-Lakeshore railway communities on the north shore between Montreal and Toronto; permanent loss of direct connection between Montreal and Toronto, and redirection of all higher speed passenger traffic between Montreal and Toronto along a more divergent route through Ottawa; elimination of HS passenger service to Smith Falls, Brockville, and Cornwall and elimination of (CSR) VIA, DE or DMU rail service to numerous smaller communities in southwest Ontario. These would include Chatham, Woodstock, Brantford, Aldershot (Hamilton) and Oakville. Daily railway service to the "northern railway corridor" communities of southwestern Ontario between London and Toronto would also disappear. Under this alternative, northern corridor centers in SW Ontario which would lose the potential of higher speed HSR, MSR or CSR VIA rail service, would include St. Marys, Stratford, Kitchener-Waterloo, Guelph, Georgetown, Brampton, Malton, as well as regional rail links to Pearson Airport.

In the 2011 EcoTrain report, these communities would be eliminated from continued VIA rail service, and would instead be provided with rail-bus services, in some cases feeding into one or more of the eight designated major HSR railway stations within Quebec or Ontario. Alternatively, although the EcoTrain study authors did not explicitly spell it out, expanded GO Rail (or bus services), would have to take up residual passenger demand, by picking up and feeding regional railway traffic, in a timely way, into 5 major Ontario based CSR or HSR (VIA) stations, while AMT, or others would have to do the same with the three CSR or HSR stops located within Quebec.

The EcoTrain team appears to have recognized the importance of developing new major public railway infrastructure with minimum direct subsidies to and /or interference from existing private freight railways. However, they appear to have overlooked or underestimated the importance of ensuring that if future CSR, HSR (or VHSR) corridors are to be successful, they must also link up with and be reinforced by international, national, regional, as well as intraregional railway passenger traffic. This is essential in order to build and sustain an effective, comprehensive passenger railway network. This is a basic function which VIA currently serves, albeit poorly at present. VIA continues to be important, potentially, if not actually, in providing basic railway service to many smaller and medium size Quebec and Ontario communities, as well as to numerous other urban centers across Canada. Consequently, this particular CSR/HSR study alternative, given the small number of cities (i.e. 8) and only one major International airport (Montreal Trudeau) which it can potentially serve, failed to attract significant support at any government level or among the general public.

Where this particular alternative also fell short was with respect to energy efficiency. In order to operate an energy efficient HSR [or VHSR] electrified passenger railway system, operators would have to run at least two trains (freight + passenger) per track direction per hour 24/7/365. For slower CSR DE trains operating on such a system, track capacity and schedules are more flexible since traffic demand would be determined by slower, more ubiquitous DE locomotives or other rolling stock on an initially non-electrified corridor, with no energy recovery. It would also be speed limited to < 200km/h. (125mph).

The only way energy efficiency might be better achieved on an electrified railway CSR or HSR system would be to run a number of electric powered CSR or HSR cargo trains overnight, as well as during daylight hours. These could carry either air cargo type containers or special high value express freight containers. This would make it possible to supplement lower levels of hourly HSR passenger traffic during daily low points in passenger traffic. In this respect, a stop at Trudeau airport in Montreal would be essential, as would possible air cargo links to other Southeastern Ontario international airports with significant multimodal air freight potentials such as Windsor, London, and Pearson airports. By comparison, within the EU, Paris[CDG-Roissy Airport], Frankfurt [Frankfurt-Main Airport]; Dusseldorf [Dusseldorf Airport], Amsterdam[Schiphol Airport] and Vienna[(Schwiechat Airport] are just a few of many large EU cities which have electrified CSR, MSR and/or HSR lines with major railway station stops situated either directly beneath their passenger - cargo terminals, or passing very close.

Alternatively, at certain low passenger travel periods or to take advantage of cheaper, available electricity and high quality underused ROWs and rolling stock, RORO and other slower, scheduled, frequent, conventional speed freight could be added to the rail traffic mix to move goods inter-provincially, around the clock. However, in this instance RORO or other slower speed CSR freight trains might compromise some higher quality railway infrastructure designed to serve higher speed passenger HSRs or other higher speed cargo trains within respective corridors. Consequently, the speeds of MSR, HSR trains running on some sections of mixed use railways might have to be modified.

Despite its many shortcomings, Alternative 3 was helpful in identifying some key issues with respect to a proposed publicly owned and controlled high speed electrified passenger railway within the Windsor – Quebec City corridor, and providing an update of some of essential capital costs. Recently, the Ontario government has announced a new study of High Speed Rail for the Toronto-Pearson Airport - Kitchener/Waterloo - London – Windsor corridor. However, since this study is just getting underway, no conclusions can be drawn as yet.

Alternative 4: Negotiate a new partnership between private freight railways and the Federal government, and establish a new Federal Railway Infrastructure Development Authority or similar agency as a public developer and operator of electrified high speed railway infrastructure in Canada. It is suggested that this agency have public control of electricity supplies, distribution, administration and operational control of selected electrified CSR, MSR, HSR and/or VHSR mainline railways.

This alternative assumes that it is possible for an interventionist, forward looking, Federal government acting in the public interest to negotiate, legislate and regulate change with regard to both capital construction and reconstruction in respect to selected existing private railway ROWs, as well as with respect to the ongoing operation and control of new and renewed electrified railways. The primary objective would be to produce a safer, more rational and efficient national electrified MSR, HSR and/or VHSR passenger system, as well as permitting the continuation of parallel, private freight railway systems which could continue to use conventional DE locomotives for their continuing operations. Such a parallel system network could also facilitate better existing freight services on older lines, while expanding newer electrified passenger services including RORO operations and higher speed multimodal shipments on electrified CSR, MSR, or even on some HSR tracks. Under this alternative, HSR and/or VHSR ROWs could be steadily pre-planned and gradually developed into separately designated higher speed passenger railway ROWs.

The concept of Alternative 4 is based on the premise that:

Only governments have the power, capacity and legal tools to rationally, equitably, and democratically absorb and redistribute costs, benefits and savings from publically-funded changes in major railway transport infrastructure. This includes ensuring maximum public safety, minimum travel times, mandated insurance reductions through the use of safer transport modes, fair treatment of private corporations as well as minimum environmental impacts and maximum public benefits with full disclosure and transparency.

One key reason for the need for public control, operation, administration of electrical energy, as well as railway infrastructure for new and rebuilt higher speed electric rail corridors, and for maintaining such operations under public control is to ensure that public safety is maintained as the first priority for higher speed electrified railway system operations, as has long been the case for safe aircraft operations in Canada.

Trains (i.e. rolling stock) under both public and private ownership and regulated control (e.g. AMTRAK, AMT, CN, CP, CSX, VIA, GO Rail, and NAR.) would all be able to access public, electrified, rail lines with properly qualified and publicly certified electric railway engineers in control of their trains. However, scheduling and safe operations of electrified lines would always be under public control to ensure highest priority for safety; that adequate railway capacity is available for both passenger and cargo requirements; and that through careful balancing of electrical energy supply and demand, energy efficiency is optimized. This requirement is essential to ensure rapid payback of capital financing to sustain the growth and development of the system.

Private railways would continue to own and operate their own yards, diesel powered secondary lines, as well as many non-electrified, slower, DE mainlines. However, all users of electrified higher speed mainlines, (e.g. CSRs, MSRs, HSRs, and VHSRs) would only move on and off such electrified lines under the control of a certified, national or regional public electric railway controller [engineer]. For example, NAV Canada's trained and certified air traffic controllers maintain safe jet and other high performance aircraft operations in the public interest in airports and airspace throughout Canada. They also coordinate with other (ICAO) regulated public air controllers of commercial and other aircraft moving to and from airspace throughout the world. Similarly, in Canada, higher speed electric trains would only move onto high speed electrified lines, under the direction of public controllers, trained and qualified to handle higher speed railway rolling stock, with no corporate private profit motive influencing either controllers or their managers. This type of higher speed electrified rail system control now operates successfully around the world, including the EU countries, Australia, China, Japan, South Korea, and Russia.

As stated in Chapter 1, under present constitutional conditions, the Government of Canada is responsible for administering the Railway Act and the Transportation Act, except where it is delegated to the provinces. Thus, the Federal Government has the central constitutional responsibility for leadership on this and related rail transport files.

VIII. PROPOSAL FOR A FEDERAL ELECTRIC RAILWAY DEVELOPMENT AGENCY (FERDA)

It is proposed that there be established an implementing authority, crown corporation or similar agency to take the lead in planning, coordinating, developing, contracting, operating, administering, and under the financial control of the Government of Canada, guaranteeing financing for the development of new electric railway initiatives. It is also proposed that this *Federal Electric Railway Development Agency (FERDA)* report directly to Parliament.

While this new entity would play a crucial role in moving electrification forward on an accelerated basis, it would also include consultation with, as well as participation by**:** (1) Provinces (2) railway companies (3) transport unions (4) First Nations (5) utilities (6) municipalities (7) other important interests including truck transport operators, consumers, ground transport insurers, as well as transport or pension fund investors.

Clearly, building a 21st Century railway system from an increasingly out-dated 19th and 20th C. railway network will require a coordinated national effort by all Canadians through their respective elected governments and democratically accountable institutions, working together in the public interest.

Financing of capital investment can be done from railway track and HS train user fees, ticket sales, freight charges, and energy efficiency saving paybacks, including sellbacks of braking energy at substations and other recoveries, as well as business taxes. It could also be based on a more efficient and productive national railway transport system, as well as from environmental savings associated with specific climate change reduction strategies. Financing could also be achieved in part by floating special bond issues, reminiscent of war savings bond campaigns during the early 1940s. This would be not unlike campaigning for contributions to finance "a new kind of war" waged to address the challenge of climate change. For this challenge, the issuance of "green bonds with guaranteed rates of return" could be an appropriate strategy. This has been done successfully before in North America. Since the 1950s and throughout the decades of the 20th Century, literally trillions of dollars have been spent in planning, building and maintaining the US Interstate Highway System jointly funded by gas taxes from both state and federal governments.

Another example might further illustrate what large scale public investments by national governments can achieve. In 2009, as the US government plowed more than $700B. into US bank bailouts to stabilize a shaky US and western banking system, with little provision for bailing out US homeowners impacted by a bank generated mortgage crisis, China invested at least $400 B. in mainline electrified railway development linking many of its hinterland regions. Its objectives were to (i) reduce total energy consumption for transport by 60%, (ii) stimulate employment during a major international [western originated] economic downturn and (iii) improve rail transport access and efficiency to less well served regions. China is currently completing 18,000 km. of its national higher speed electrified railway network, currently the largest HSR system in the world. [9]

If Canada, with a population approximately 1/45th the size of China's and with a much more mature, developed industrial economy, were to invest a significant proportion of its national infrastructure capital investment potential, say $90B, into a national railway electrification strategy, (i.e. $9 B /yr. over a period of 10-15 years), it could electrify most of its mainline railway infrastructure; substantially reduce railway locomotive and related truck transport's carbon footprint, and achieve a new mobility future, with near zero carbon emissions for selected mainline railways. This would positively impact more than 80% of Canadians who already live in larger urban communities across the country, many either along or near potential electric railway corridors, who could benefit directly and indirectly from the economic investment in such an energy efficient ground transport system.

Canada could also recover a significant part of its investment through energy efficiency savings in fuels which would not have to be be consumed for railway ground transport within Canada. Instead, these fuels could increasingly and more profitably [i.e. for Canada's balance of payments] be sold outside the country, as world demand for increasingly scarce fossil fuels and their by-products, continues to grow over the next several decades. The economy could also benefit from decreased health care costs through rail transport related accident avoidance, increased business activity, reduced stress as a result of significant travel time savings, and the stimulation of related transport investments, including feeder bus and other rail transit, which would strengthen mainline rail passenger service.

Implementation

(1) The plan could begin by implementing key aspects of NDR (the National Dream Renewed proposal), as outlined by TAO over the past several years, namely kick starting substantial incremental improvements in both railway passenger services and ROW improvements, with a strong focus on new railway legislation to make VIA operations competitive and comparable with the existing US AMTRAK system; improving railway and public safety; improving passenger security, comfort and satisfaction; and increasing research and development into higher speed railways, including improved cost / benefit analysis of HSR options with respect to ROI and social rate of return.

(2) Intensively improve existing CSR diesel powered railway corridors between Windsor and Quebec City. In the first stage, improve major grade separations on selected ROWs and add up to

two additional publicly owned tracks and new passing tracks within key station zones as well as other areas. In this way, as soon as the first railway lines are upgraded, ready and capable of operating at maximum CSR speeds (e.g. 200 km/h.), electrification of a public MSR system could begin and could be completed in step three. Initially, the railway corridor could be improved and electrified to a full MSR standard of operation (e.g. ultimately to a maximum operating design speed for passenger trains of 255km/h).

(3) The plan could continue with electrification of a (MSR) medium speed rail line between Montreal and Toronto, and Ottawa and Toronto. This would be followed by the extension of a medium speed (MSR) line from Montreal to Quebec City, and a similar extension or extensions southwest from Toronto to Windsor, and London to Sarnia. Once the Montreal – Toronto MSR system is operating efficiently or earlier, it is likely that public demand will increase for expanding the Quebec City – Windsor corridor development into a national MSR electric railway system .

As an initial demonstration of HSR or VHSR capability for all Canadians to be able to experience in Step 4, work could proceed earlier with a new high speed demonstration railway line between Montreal and Ottawa during Step 3. At 187 km., this intercity distance is short enough to be able to effectively demonstrate the potentials for faster railway operating speeds (e.g. scheduled speed range of 255 to 380 km/hr.), as well as the greater comfort and safety for intercity railway passengers on a demonstration HSR or VHSR railway ROW, served by appropriate rolling stock. This might include daily, half hourly train schedules which could cover the 187 km. (117 mi.) intercity distance in less than 35 minutes instead of the present two hours There could also be the possibility of at least one intermediate stop at Montreal Trudeau International Airport each hour. Such an interprovincial VHSR line could demonstrate that inter-city travel times within this corridor could be reduced dramatically, since the existing line currently depends on much slower DE locomotives to power VIA trains on ROWs currently limited to <79 mph. For an auto dependent public, such a demonstration could be important in helping to change public perceptions about comfortable, safe, economic, energy efficient travel on HSR and/or VHSR trains.

(4) Beyond an initial 1200 km. HSR corridor linking Windsor and Quebec City, electrification to MSR standards could proceed in further steps from Quebec City to Riviere du Loup, P.Q., Moncton, N.B., and Halifax, NS. (1206 km.); Toronto - Sudbury ON., (400km.); Sudbury and Thunder Bay (1260km.) Other stages could be simultaneously developed in 1200 - 1300 km corridor segments, as for example, Winnipeg, MB. and Edmonton, AB. (1314 km.); Winnipeg, MB. and Calgary, AB. (1259 km.); Edmonton, AB. and Vancouver, BC. (1214 km.); as well as Jasper, AB., to Prince Rupert, BC (1237 km.).

Note: 1200 -1300 km. distances have been assumed for analysis purposes in this paper, because these distance ranges have been demonstrated in electrified HS railway operations elsewhere as being practical outer limits for the location of major service centers for electrified CSR, MSR, as well as HSR and VHSR EMUs. These service centers are important because they can provide building infrastructure which is large enough to accommodate and service entire 8-10 car single, or duplex EMUs as complete units.

IX. WHAT MIGHT AN ELECTRIFIED HIGHER SPEED RAILWAY COST?

The estimated cost of an initial electrified railway corridor for Canada over a 15 – 30 year time period, could range from at least $100 to 130B., depending on the route(s) selected, design speed, staging, efficient planning and implementation strategy. (See Table 4 – Preliminary Cost of Electrification to an MSR Standard – Vancouver to Halifax.).

These cost estimates assume grade separation and/or secure protection of every rail crossing on MSR lines, secure fencing along all HS electrified railway ROWs and either rebuilding or improving selected rail lines to at least MSR operating standards. This would establish, as a minimum, electrified HS mixed use passenger and freight rail corridors with a maximum passenger railway design speed of 255 km/h. (153 mph.), and initial speeds of less than 140km/h for electric powered freight trains. In some locations, passenger trains or EMUs may have to use "tilt train technology" rolling stock as a means to reduce or defer the necessity of having to rebuild extensive lengths of curvilinear line within selected corridors, in the short term, while still maintaining up to 30% higher speeds.

Note: Not included are: the costs of developing a national electricity grid through five time zones. [The political barrier to establishing an east west electrical grid between various provinces must first be resolved between the federal government and the provinces]; electrification of some branch lines remote from transcontinental corridors which may also be electrified efficiently; electrification of commuter rail systems serving city suburbs but situated close to proposed national electrified mainline rail corridors; non electrified railway rolling stock; electrification of existing railway yards; special rolling stock for proposed RORO systems; the redesign and reconstruction of major existing stations; and the electrification of alternative HSR lines between Toronto and Windsor, Ontario. At least part of the latter recent figures can be obtained from data available in the aforementioned 2011 EcoTrain study report on the Quebec Windsor corridor.

TABLE 4: PRELIMINARY COSTS OF ELECTRIFICATION TO AN MSR STANDARD – VANCOUVER TO HALIFAX

REGION	**APPROX DIST. KM**	**EST.COST $B**	**EST.COST $M /KM.**
MOUNTAIN REGION			
(a) Vancouver – Edmonton	1214	15 – 20	12.4 – 16.5
(b)Vancouver – Calgary	1020	10 – 15	10 - 14.7
PLAINS REGION			
(a) Edmonton – Winnipeg	1314	10 – 15	7.6 – 11.4
(b) Calgary – Winnipeg	1259	10 – 20	11.9 – 15.9
LAURENTIAN SHIELD REGION			
Winnipeg – Sudbury	1704	20 -25	11.7 – 14.7
OTTAWA VALLEY REGION			
(ii) Sudbury – Montreal	616	6 – 8	9.7 – 13
GEORGIAN BAY REGION			
(i) Sudbury – Toronto	400	5 – 6	12.5 - 15
LAKESHORE REGION			
(i)Toronto – Montreal	533	6 – 8	10.2 – 13.6
LOWER ST. LAW. REGION			
Montreal – Quebec City	268	5 – 7	10.7 – 15.0
MARITIME REGION			
Quebec City – Halifax	1206	8 – 10	8.0 – 10.0
TOTALS Vancouver – Calgary – Winnipeg-Sudbury-Toronto-Montreal-Quebec City-Halifax	**6390 km Calgry 6639 km Edmtn**	**64 - 91 100 – 130***	

*Note: Transcon figures via Calgary do not fully account for the higher cost of tunneling and viaduct building through Rockies to develop a more direct electrified rail line linking Banff or Canmore with Kamloops, likely at elevations considerably lower than the existing 1885 CP rail corridor. A rough estimate that includes most of this tunneling would be $100 – 130B, ie $40B more than the base cost.

X. HOW MIGHT HIGH SPEED RAILWAY ELECTRIFICATION BE FUNDED?

Ensuring a reasonable return on investment (ROI) is essential, whether for public or private investment decisions. In 1999, for example, a world price of $38.00/ bbl. was the breakeven point for a reasonable ROI in an analysis of railway electrification within a 1200 km. mixed use railway corridor for western Canada. By 2009, the price of oil was $60-$80/ bbl., and by 2011 it rose to over $100/ bbl. and briefly higher by 2011. Even at the current $50.00/bbl.+, the ROI for railway electrification would still be positive.

In 2015, world oil prices suddenly fell to slightly less than $50.00/ bbl. However, there is serious question as to whether such low present world oil prices are sustainable, even over the short term, and how rapidly such oil prices will return to previous higher levels. It would appear that current world oil price levels will likely continue to increase steadily as time goes on, as easy oil continues to rapidly deplete everywhere.

Clearly, as a starting point for electrification of an initial railway mainline, it is important to select as a priority corridor railway ROWs which are already carrying large volumes of mixed use rail traffic 24/7/365. For this reason, a basic MSR mixed use corridor development is suggested as a strategy in order to ensure sufficient 24/7 passenger and freight traffic volumes to efficiently use available electricity and also achieve rapid ROI of electrified railway infrastructure.

Funding can come from a number of actions, for example:

(1) Shift some expenditure levels at senior levels of government: Gradually shift some current (Federal and Provincial) transport expenditures from highways to electrified railways and increase (Federal) expenditures for VIA electrified rolling stock and other essential electric railway infrastructure.

(2) Shift some public expenditures at local levels: This might include providing increased incentives to municipal and provincial spending programmes to shift investment priorities from more urban and regional roads to increased municipal or provincial cost shared contributions for level crossing improvements. This would cover more shared costs for increased numbers of essential grade separations, and/or improved crossing protections. It could also help to reduce urban and regional road congestion and improve public safety in such areas through more rapid improvement of urban and rural level crossings which currently obstruct or limit road circulation and rail operations along proposed higher speed railway corridors.

(3) Set User Fees and Trackage Charges that Reflect the Value of HS Railways*:* Increased use of the HS railways will be an attractive option to many sectors of the economy. Freight movers will appreciate the faster travel times, reduced operating costs, reduced maintenance costs and reduced insurance costs including some from avoided costs of fuel spills. It has been estimated that in Ontario and Quebec, at least 20% of current east west highway truck transport traffic could be diverted to RORO trains, if appropriate alternatives were available. Similarly, the traveling public will appreciate faster travel times, higher comfort levels and the lower risk of accidents travelling on higher speed passenger railways.

This can also be reflected in price differentials, including variations and price differences for train tickets, for different passenger users or more frequent use, and variable shipping rates for a wide variety of freight shipments and cargo transport These might be monetized not only on the basis of distance and/or reduced travel time, but also other criteria such as day of the week, month or season of the year, when specific travel or increased seasonal shipment pressures inevitably occur.

(4) ***Public capture of enhanced real estate values at major stations along electrified rail lines***: In the vicinity of major urban passenger and freight rail termini, there are major developments in locations such as Place Ville Marie at Montreal's Central Station and at Union Station in Toronto. In Montreal's downtown core, the existing complex represents a very large concentration of more than 433,000 sq. m. of offices with extensive underground shops, as well as the Place Bonaventure hotel and convention center complex, and numerous surrounding buildings. Much of this has been built atop Montreal's CN central station complex, between 1956 and the 1970's.

In Montreal, the concept of "emphateusis" has also been successfully used to finance a number of mixed public and private sector projects built over major transport routes (often at Metro stations). Under the concept of emphateutic leases, publicly owned lands are leased to a private developer for 34 years or more, after which the entire private building complex is written off by the private developer, and the building and land, with a transport station running continuously beneath it, reverts back to public (municipal) ownership. During the entire 34 year lease period, the underground Metro stations are maintained in public ownership and operation.

A second example, in Toronto, is the very large and intensive multilevel commercial office towers and shopping developments which have been concentrated on or within the City of Toronto's PATH system. This linear underground pedestrian shopping and office network concentrates and funnels literally hundreds of thousands of people/day through an extensive pedestrian network linking major private office building towers and their public lobbies, as well as major hotels, restaurants, shops and department stores. Most of this development begins at and beneath Toronto's City Hall, and extends more than a kilometer southward to and through Toronto's TTC Union Station stop. PATH also links with at least five other TTC subway stops beneath the city's central core. Also attached to this extensive multi building underground complex are a new feeder railway line, the UPExpress line to Toronto's Pearson Airport; Union Station itself, with its tracks carrying international, national, interprovincial, and interregional passenger trains; the TTC's under ground LRT loop running along the Toronto waterfront from a lower level to surface LRT; and several tracks of GO rail commuter train platforms at the same level as VIA's own tracks. All feed into and through Union Station's intense multilevel track and road network, past an adjacent regional GO bus terminal immediately located adjacent to GO Rail lines at Union Station. Also linked by a pedestrian network to this extensive complex are the CN Tower, Roger's Centre (domed stadium for baseball and football), the Air Canada Centre hockey/basketball complex, many major hotels, CBC's national English language HQ, VIA's Ontario offices, Toronto's large Metro Convention Center, Thomson Hall, the city's major concert venue, and Toronto's Four Seasons Opera and Ballet Theatre.

None of these myriad private office buildings and other private commercial facilities are currently paying the kind of corporate taxes, land rents and/or user fees which can begin to ensure even close to full cost recovery of new higher speed electrified regional commuter and/or interprovincial rail systems, and/or to help underwrite a significant part of the cost of electrification of VIA's transcontinental, international, interprovincial and regional rail network. However, there is now in place a critical mass of major buildings and related urban developments from which to begin to analyse the potential for substantial cost recoveries for needed capital and operating expenditures for a large electrified ground transport surface railway network serving central Toronto. To a significant degree, these large concentrations of mostly private developments, which continue to benefit enormously in appreciating real estate values from the public redevelopment of Union Station and other recent public sector led regional transport investments, could contribute significantly to the longer term capital and operating costs of required electrified local, regional and national surface rail transport.

While each of the major cities in Canada has similar urban concentrations around its existing major railway terminals, with the privatization of both Canadian railways, many urban redevelopment cost recovery opportunities may now appear less clear and/or more diffuse. Nevertheless, many opportunities exist to encourage and stimulate electric railway improvements including regional electrification closely linked to central city redevelopment. This can be done in part by both mandating and incentivizing private railways and other key real estate interests in major urban centers across Canada to contribute collectively through taxes, development charges, operating fees, and other measures to transform Canada's interprovincial rail networks as a major national asset which can help to catalyze a sustainable future for Canada's major cities and regions.

(5) Monetize public savings in insurance, health care and emergency service costs: These savings would result from substantially reduced accidents, injuries and liability claims arising from preventable accidents or mishaps at previously unprotected crossings and other unsecured rail properties. Through safer strategic grade separations and improved ROW design, security and maintenance savings would be inevitable. They can also be reflected in improved health and respiratory disease reduction in urban areas positively impacted by electrified railways, their reduced noise and air pollution arising from major shifts to sustainable electrified railway power and reduced dependence on fossil fuels.

XI. CONCLUSIONS

As cited in this report, this national vision of mixed use higher speed electric railways offers a long list of major benefits:

- Significant travel time and productivity enhancement for people and higher value cargo movement
- Improved mobility options for public travel
- Increased passenger comfort and convenience
- Improved linkages between urban settlements and regions
- Increased energy efficiency
- Ability to use renewable energy
- Thousands of new skilled jobs
- Increased public safety
- Public savings in insurance, health care and emergency service costs
- Reductions in GHG and CAC emissions

The capital cost of about $100B, spread over several decades, is readily achievable for the Canadian economy. Canada needs to move forward with this bold vision. To make this happen, increased government initiative and investment is mandatory. Onward into the 21st Century!

ACRONYMS, ABBREVIATIONS AND DEFINITIONS

AAR: American Association of Railroads

AC: Air Conditioning

ADIF: **A**dministrador **d**e **I**nfraestructuras **F**erroviarias, the Spanish National Railway agency responsible for designing, contracting, operating and administering all RENFE fixed assets, including buildings, stations, ROWs, bridges, tunnels, tracks, yards, etc.

ALSTOM: World class manufacturer of freight and passenger railway rolling stock, and in particular, design and manufacture of electric and DE, CSR products, as well as electric locomotives and train sets in MSR, HSR and VHSR speed classes. Alstom's Transport headquarters are located in France. The company also manufactures a wide range of leading edge electrical controls and operating systems for railway electrification and related infrastructure.

AMTRAK: US government owned agency charged with responsibility for managing and operating passenger services, trains, and infrastructure within the United States and in conjunction with Via Rail in Canada to selected cities in Canada, such as Montreal, Toronto, and Vancouver., In much of the US, Amtrak operates over railroad tracks owned and operated by private railway companies.

AVE: **A**lto **V**elocidade**s** **E**spanola – Marque for Spanish HSR trains operated by RENFE.

Axle: Steel shaft connecting (railway) wheels

BO – BO: refers to a double axle undercarriage, at either end of a DE or electric locomotive, or emu.

Bogie: An assembly of wheels, axles, brakes, and suspension systems which support locomotives, DMUs, EMUs, freight and passenger coaches, and other railway rolling stock.

BOMBARDIER: World class manufacturer of transportation equipment including jet and turboprop aircraft, ground transport railway rolling stock, including surface transport, subway cars, LRTs, passenger coaches, and a wide range of freight and HS passenger locomotives, EMUs and DMUs. With plants in many countries, Bombardier is headquartered in Quebec, Canada.

CAC: Critical Air Contaminants represent a significant volume of the toxic emissions (pollution) produced by all DE freight and passenger locomotives and DMUs. These toxic emissions include: NOX (NO2&NO3), SOX (SO2 & SO3), CO (Carbon Monoxide), PP (Particulates), HC (Hydrocarbons) and Lead

CAR-GO–RAIL: A passenger rail service, which began on some railways after the 1950's, allowing passenger's vehicles to be carried aboard the passenger train they are travelling on, with the empty vehicles pre-loaded on automobile cars, usually attached to the rear of the passenger train.

COFC: Container On a Flat Car

CN: Canadian National Railway Corporation

CNR: Canadian Northern Railway, (private corporation- predecessor of CN)

CPR: Canadian Pacific Railway Company**.** Canada's first railway.

CO – CO: refers to a *triple axle* undercarriage at both ends of a DE or electric locomotive.

CSR: Conventional Speed Railway. This refers to passenger trains capable of operating at speeds to a maximum of 220 kph. (132 mph.), and ROW infrastructure capable of safely handling railway traffic to that maximum speed.

Climate Change: A broad consensus among the UN, the EU, British, German, and Swedish governments that the concentration of GHGs in the atmosphere must be confined to a level that would prevent more than 2 degree Celcius [global] warming above pre-industrial levels. Preventing such increases by reducing GHGs, is seen as essential to avoid serious environmental catastrophe, through climate change, worldwide, within the next several decades.

DB: Deutsche Bahn Gruppe, the German (State) Railway Group. DB, is currently the EU's top freight carrier.

DE: Diesel – electric locomotive.

DMU: Diesel – electric Multiple Unit cars or trains operate with on-board diesel powered electricity generators powering electric motors located either directly above or on their driving axles. Such electric powered axles are usually found only on a limited number of coaches or cars within a train. Either the bogies in the first and last cars are powered (e.g. Alstom and Bombardier in France), or all have powered axles (e.g. Talbot built regional or commuter trains in the Netherlands), or trains may have a four axle power car within the middle of the train (UK). In the UK, Hungary, Czech Republic, and Slovakia, single coach railway vehicles, with at least two powered axles, are still seen on railway branch lines. In many cities, DMUs with several unpowered coaches are used for commuter trains, regional trains, or airport service trains linked with central business districts. Like DE locomotives, DMUs are unable to recover braking energy, while also, producing most of the deleterious environmental pollution of diesel trains.

DUPLEX: A double deck train, usually either a DMU or EMU which may be connected nose to nose. These are designed to handle a much larger volume of passengers than a conventional single level EMU or DMU, when connected with another similar train.(See also HSR Duplex EMUs).

EE: Energy efficiency

EMU: Electric Multiple Unit train. Some EMUs operate with powered axles on every bogie of their powered cars (M). These are often located at the front and back end of a train of up to 6 unpowered trailer units (T) (i.e. passenger coaches indicated as MTTTTTTM). On many of Siemens 8 car trains, the ICE3 operating in France and Germany, the Siemens VELARO in Spain, and the SAPSAN in Russia with up to 10 cars, the trains have electric motors in every second bogie giving them increased acceleration, higher speed capability, and improved braking energy recovery (e.g. max. design speeds to 350 km/h.)

ERTMS: An off the shelf interoperable **E**uropean **R**ailway **T**rain **M**anagement **S**ystem which when certified (e.g. in NA), facilitates prevention of collisions, overspeed derailments, movements through misaligned switches and the prevention of injuries to maintenenace workers operating within the limits of track authorities. It is also designed to bring a train to a safe stop, if an operator does not respond promptly to instruction signals.(See p.66, Trains, April 2011)

HSR Duplex EMUs such as those built by Alstom, in France, can carry 40% more passengers in their lighter, aluminum, double deck coaches, Two duplex EMUs connected nose to nose, as in China, France, or Japan can carry in excess of 1000 passengers in considerable comfort, and at speeds to 300 km/h. (Japan) 320 km/h. (France), 330 km/h. (Germany), and 350 km/h (China).

FRA: Federal Railway Administration [US]

Gal.: Gallon of fuel [US]

Grid: refers to electrical lines > 69kv, and distribution lines < 69 kv and > 110 volts.

GHG: Green house gases (See climate change)

HS: High speed

HSR: A high speed rail system which can maintain passenger railway speeds in a range > 255 km/h., and <320 km/h.

HSR Cargo : For over 10 years, SNCF has been running the French Post Office's distinctive yellow, high speed mail trains linking major French cities. These have used older model modified HSR passenger rolling stock, and SNCF infrastructure to provide faster mail and parcel post delivery during daily and nightly lacunas in passenger rail demand on TGVs. Recently, HSR cargo capability has been extended in conjunction with railway express and air cargo operators internationally. This includes both overnight air and HSR daily cargo express, including parcel post and express to and from Marseille, Lyon, CDG Airport (Paris), London, Frankfurt, Munich , Berlin, and cities as far east as Vienna, and Bratislava, Slovakia.

Hz: hertz refers to the number of cycles per second of (AC) alternating current passing through a circuit. (e.g. 60 Hz = 60 cycles per second.)

ICE: Inter City Express

ICV: Internal Combustion Vehicle

KV: kilovolt or 1000 volts

Loco; Loc. ; Locomotive:

MSR: Medium Speed Rail **-** a higher speed railway system which can maintain rail speeds up to and within the range of 132 – 150 mph (220- 250 km/h.).

MGT: Million Gross Tonnes of cargo transported, usually per unit of fuel, (e.g. MGT / gal or other unit of fuel consumption**)**

NAR: Northern Alberta Railway, owned by the Alberta Government and designated to be operated jointly by CN and CP.

NSB: Norwegian State Railway

ONR: Ontario Northland Railway, a provincially owned and operated railway and bus service connecting Toronto with selected northern settlements and urban centers within the province. In 2012, the Ontario government closed down the passenger railway function of ONR between Toronto and Cochrane replacing it with a bus service, as a money saving measure. Thus, ONR no longer has a direct rail passenger link between the GTHA and northern regions of the province.

PENDOLINO: Registered name for a tilt train technology developed and patented by FIAT. It enables railway rolling stock, including passenger coaches, EMUs, and DMUs, to better negotiate curvilinear routes by allowing the floors and sides of each passenger coach compartment to rise up to 8" tilting inward, in response to increased centripetal acceleration on tighter railway curves at higher speeds. This technology, now licensed for use on trains in many countries, makes it possible to reduce travel time on many curvilinear routes by 30% without the necessity of having to totally rebuild some older ROWs. The technology has the disadvantage of increasing vehicle weight per seat kilometer, thereby reducing energy efficiency.

POSITIVE TRAIN CONTROL: (See ERTMS)

RZD –Russian State Railway

RENFE: **Re**d **N**ational de los **F**errocarriles **E**spanoles. The routes of Spanish National Railway Company's (passenger, freight and commuter) trains . This public railway agency manages and operates all state owned and/or leased railway rolling stock. RENFE shares national headquarters facilities with ADIF, within a unique, low rise, institutional campus facility in northern Madrid.

RORO: abbrev. for Roll On Roll Off. In Austria and Germany referred to as Rollende Strassen, or Rolling Highway (eng. trans.) In many forms of this combined multimodal transport, truck transports together with their drivers, are carried on electric trains. The truck transports ride on specially designed close connected flatcars, while drivers ride at the front of the train, behind the locomotive, either in a café lounge car, with an adjacent sleeping car and/or day coach.

In this way, drivers who may have already reached their maximum allowable legal driving limit`of 11-12 hours within a driving day or night, can safely rest, eat, sleep, or relax, while an electric train moves them with their vehicles, up to a maximum additional distance of 600 - 1500 km. per 8-20 hour period. Countries which already participate in this type of electric railway based multimodal transport system include: Austria, France, Germany, Hungary, India, Italy, Luxembourg, Slovenia, Czech Republic, Slovakia, Switzerland and Turkey**.**

ROW: Right of Way

SIEMENS: One of the world's oldest manufacturers of electrical equipment. In 1883, the company developed and demonstrated the world's first electric train to carry public passengers at a trade fair. Currently, Siemens HSR/VHSR ICE–3 EMUs (Germany) include the VELARO (Spain) and the SAPSAN (Russia). An early version of the ICE-3 has also influenced the design of China's VHSR EMUs (e.g. China Railway's CRH 380) which are currently operating throughout China. Siemens high powered "Eurosprinter" series of freight and passenger locomotives are currently operating in many EU countries as are many components of the companies urban transit rolling stock, seen around the world. The company has developed some of the world's most advanced passenger and commuter trains, as well as a broad range of locomotives and EMUs. With plants around the world, Siemen's headquarters are in Germany.

SNCF: Societe **N**ationale des **C**hemins de Fer **F**rançais, The French National Railway, is headquartered in Paris, at Gare de Lyon. SNCF is currently Europe's largest and most innovative rail passenger, express mail and high speed cargo carrier.

SP: Southern Pacific Railway

TALGO: a light weight, passenger unit train designed to “passively” negotiate curves on curvilinear railway ROWs. Characterized by short length passenger coaches; connected at each end by a single shared bogie; with low mass per seat; low center of gravity; and a rear baggage car, or the latter may be replaced by an additional pusher locomotive at the train’s rear end. This reduces whip effect and improves motive power and stability. TALGOs may be powered by either electric or diesel locomotives, operating at one end or at both ends of a unit train. (See e.g. Amtrak’s North west Coast Limited linking Vancouver, BC. with Eugene, OR.)

TGV: Train a **G**rande **V**itesse. The TGV family of trains developed by Alstom for SNCF has been called “the world’s best known and most successful group of high speed trains” They have revolutionized rail travel in many parts of France, neighbouring countries, and also in the Far East (Jane’s Train Recognition Guide, 2005, p.204)

TILT TRAIN TECHNOLOGY: See Pendolino

TOFC: Trailer **o**n a **F**lat **C**ar

Undercarriage: Wheel, axle, brake, suspension, and motive power axle assemblies, suspended, or attached beneath a passenger coach, freight car, loco, or on a unit train such as an EMU or DMU..

X-2K EMU: With a max. design speed of 125 mph (200km/h.), Sweden’s flagship CSR EMU, (4400 hp.), reduced travel times from Stockholm - Goteborg, to three hours, and increased ridership by a factor of ten. The X-2K developed by Adtranz. (now Bombardier), in 1990 solved the problem of operating faster CSR trains on major routes with severe curves in Sweden, using active tilt train technology. In 1993, this train set a Swedish speed record of 148mph (238km/h) on a test run, although it was never designed as an operational MSR EMU. In that context, some of the research conclusions of the Green Train study, undertaken for Banverket in 2007 used the X-2K emu as a major data source. (Appendix VII). This data must be reviewed with caution, since this train has since been substantially redesigned and reengineered.

VHSR: Very High Speed Railways. These are usually EMU type trains running on very high performance high speed ROWs. Rolling stock such as EMUs have powered axles capable of high acceleration and maintaining sustained high speeds in the range of 300 - 380km/h. In 2007, SNCF and ALSTOM using a conventional TGV modified to VHSR standards achieved a world railway speed record of 574 km/h. (344 mph.), on SNCF’s Line de l’Est, a new HS line which is now an operational VHSR ROW situated between Paris and Strasbourg. Currently, in Italy, Bombardier’s Zefiro VHSR EMU maintains steady speeds up to 380 km/h. These trains, with a maximum design speed of 380 km/h, now operate on a newly engineered high speed route between Milan and Rome. In China, a 350 km/h. VHSR train currently links Beijing with Tianjin, and Shanghai, China’s largest commercial city. China’s capital is now also linked by VHSR, and/or HSR trains with Guangzhou, Sian, Harbin and a number of other major cities, including Hong Kong. All major intercity HSR or VHSR connections in China are designed to achieve max. 5 hour travel times, for distances up to 1400km.

Until 2009, SNCF had long held the highest scheduled start stop average speed for a scheduled HS route of 277.76 km /hr. In that year, China Railways (CR) introduced the world’s fastest scheduled train on Dec. 6, 2009. That CRH model averaged 310 km/hr.with a max. operating design speed of 347.2 km/hr. A year later in 2010, CR introduced its second generation CRH 380 which reached a maximum speed on a test run of 483.2 km/hr.(300mph) on a regularly scheduled route. (See p.26, Trains, April 2011)

VIA: VIA Rail, the Canadian government agency which administers and operates passenger trains, railway infrastructure and some limited passenger tracks, also leases services and track use from private freight railway companies, such as CN and CP.

VR: Finnish State Railway

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APPENDICES

APPENDIX 1: HSRs - KEY FEATURES OF RAILWAY INFRASTRUCTURE.

(a) ROWs, Roadbeds, Tracks and Signals.

(i) No level crossings on high speed railway lines.

(ii) HSRs will be able to handle steeper grades (> 2-2.5%), but will require wider radius curves (e.g. > 6000m. radius of curvature.) For VHSRs, (>7000 m. rad. of c.) will be required.

(iii) Heavy duty catenaries will be mandatory for rail lines with speeds above 250kph. (>150mph)

(iv) Higher Voltage Power Supplies will be required (i.e. 2-25kV 60 Hz power for heavier freight loads at speed, or to power VHSR (Very High Speed Railway) passenger trains.)

(v) ROWs will require: (.i) a very secure base and sub-base, including those on viaducts, and in tunnels; (.ii) reinforced concrete ties, with closer spacing on higher speed lines; (.iii) spring type steel rail anchors; (.iv) tamped stone road beds with surface stabilizers, fine mesh, or reinforced concrete ballast less track; (.v) continuous welded ribbon rail; (.vi) in – cab signals and communications. This will mean ROW signals which automatically transmit into approaching locomotive cab consoles, with automatic train shut down, if an train engineer (controller) fails to respond, promptly to key signals on the control console; (.vii) high speed turnouts (switches) as well as passing tracks, where required.

(b) Rolling Stock: HSR Key Features (i) Aerodynamically designed trains (rolling stock). (ii) Lower mass per seat km. (lighter weight trains and EMUs). (iii) In – cab signals with automatic train controls. (See **(a)**v(.vi) above). (iv) Regenerative braking which will allow recovery of up to 70 % of braking energy as electric trains or emus slow down or stop. Electricity recovered is used aboard the train, transmitted through the catenary to nearby rail traffic requiring power, or up to 30% can be "sold back", at the nearest substation. Consequently, where regenerative braking is available, schedule coordination, and timing are very important.

Illustration 6: RORO, Roll On Roll Off train, called Rollende Strassen or Rolling Highways by OBB, the Austrian State Railway. In the picture, two Siemens Eurosprinters heading a RORO train on a downgrade from the Loetschberg Tunnel on the BLS Railway, Switzerland

APPENDIX 2: WHAT IS ROLL ON – ROLL OFF (RORO): ITS CHARACTERISTICS AND POTENTIALS FOR CANADA.

In a number of countries, RORO (Roll On Roll Off) truck transport technologies have become an important means to move a significant amount of truck transport freight traffic with their drivers, with near zero carbon emissions, resulting in quieter, safer, less congested roads, highways, and urban areas. In Ontario, for example, a great deal of this traffic currently moves on congested 400 series highways and other major inter provincial and international routes. Instead, at least 20% of this traffic could be carried on close spaced flatcar unit trains on electrified railways. Some of these might also transport long haul interprovincial buses, and other owned or leased vehicles being moved between selected railway corridor points.

In this way, RORO trains could more than double the average daily travel distance of long haul truck transports across many regions of Canada. This would increase travel distance for a truck transport from a current maximum of 900 - 1000 km./day, up to an additional 1500 km./day, over a 24 hour travel trip. Consider a possible example: A New Brunswick trucker drives to PEI and picks up a load, then drives south to Moncton, NB. Here, tractor and rig are loaded onto a pre-reserved flat car, on a RORO unit train bound for Winnipeg, 2944 km. away. The driver might perhaps take a half day to drive to PEI, and another half day to get back to the rail head and onto a pre-reserved RORO train at Moncton. Regulations indicate that he cannot legally drive any further that day. The 2900 km.+ intercity trip distance, to Winnipeg alone would normally require at least 3 days of driving and at least two overnight rest stops for a single driver to safely cover by road. Instead, driving onto a RORO train, the single transport driver is assured that electrified railway technology will facilitate safely covering the distance to Winnipeg in approximately 26 hours, at an average overall speed of 112 km/ hr. which could also allow for at least 5-8 intermediate stops. Arriving rested and relaxed, the truck driver can then drive off to the shipper's final delivery destination, which may be hundreds of kilometers from the RORO arrival yard at the Winnipeg railhead.

While on board the RORO train, the driver sleeps in a sleeping car with showers, eats meals or takes coffee breaks in a cafe/lounge car, rolling along at (112 kph), an average speed faster than one could ever safely drive a heavy tractor trailer on a continuous basis. Along the way, other trucks might disembark with their loads at designated stops in or near various key towns and cities. These might include possible_stops in: Thunder Bay, Nipigon, Sault Ste. Marie, Sudbury, Toronto, Montreal, Quebec City or Riviere du Loup. [Note: The latter urban center is strategically important because it is the furthest downriver railway stop after Quebec City, where a truck transport bound for a north shore destination, arriving from the east or the west on the south shore can make a truck ferry connection to St. Simeon, and proceed along various north shore highways serving the Gulf of St. Lawrence region, 24 / 7 / 365].

On board a westbound train, the Maritime truck transport driver can negotiate pick–up arrangements for possible back haul loads. Thus, in less than a week a driver can have picked up and delivered multiple loads across the country, more expeditiously than the railways themselves, with less personal stress, risk of accident, wear and tear on the rig, zero fuel consumption while on board the train, lower noise impact on surrounding communities, near zero carbon emissions for that portion of travel aboard a RO-RO train, lower transport insurance costs, more efficient use of energy, and faster overall travel time (e.g, 29 vs 72 hrs). An intermodal container travelling on the same route could take up to 5 days for scheduled delivery of most high value cargo shipments in containers, exclusive of the additional time for pickup in PEI or delivery to remote, rural, or northern Manitoba or NW Ontario destinations.

Sustainable electric powered trains are also at least 5 times more energy efficient than truck transports. Thus, the increase in ground transport productivity by rail would be substantial. Unit train pre-reserved sections could be pre-loaded and/or post unloaded in 40 minutes or less, on simply designed yard tracks and loading areas without a need for elaborate, costly intermodal loading equipment. Entire 30 car unit train sections could then be connected or disconnected to or from longer 60, 90 or 120 car mainline unit train sections. These could be pulled off or on at major sidings beside higher speed freight mainlines, in less than 3-5 minutes, resulting in minimum delays in mainline operations.

APPENDIX 3: BASIC ASSUMPTIONS ABOUT RORO OPERATION

(1) A 25-30 car, close connected, unit train might be added to, or subtracted from, each 60 – 90 unit or greater, mainline RORO train (including service cars), in 3–5 min., approximately every 640 km.

(2) Each 25 – 30 car unit train could include its own dining/lounge car and sleeping car accommodation (service cars) sufficient to serve and accommodate up to 30 drivers.

(3) Entire RORO unit trains would be pre-loaded and/or unloaded, either before a mainline train arrives (or after it has departed), within 30 - 40 minutes.

(4) An automatic fail – safe vehicle anchor system would ensure safe, secure, vehicle lockdowns on close spaced flat cars .

(5) Pusher locomotives assembling some unit trains and preparing for mainline travel might remain attached at one end of their unit train, becoming either an automatic "slave unit" providing distributed power towards the rear, or in the middle of a train. In other instances, a newly serviced locomotive could provide fresh head end power at the front of a longer, multi-section, RORO train, if the lead end is being replaced at a specific stop.

(6) Crew changes would take place approximately every 4-5 hours, with crew replacements mainly corresponding with RORO stops. Attachment or disconnection of various sections to and from mainline trains should require no longer than a few minutes, including changing engineer – operators. When disconnection and/or attachment is complete, the new head end engineer and locomotive would take over, heading a 90+ unit RORO train, with distributed power.

(7) Truck transports would be expected to be at their respective loading centers, ready to roll onto their scheduled pre–reserved unit train space, at least 40-60 min., before their mainline train is scheduled to arrive on a nearby express track parallel to the railway's mainline.

(8) If buses are included, special rail bus units might be loaded on schedule at one end of a 25 – 30 car RORO unit train. By traveling part of their long haul trips on unit trains, long haul buses could provide all-weather, ground transport express service at faster average speeds (i.e. up to 125 km/ hr. by RORO train vs. a max. of 95 -100 km/hr. or less, under sole bus driver control, travelling on rural, two lane or four lane highways, through sparsely populated rural or remote areas.

Appropriate safe, long haul deluxe buses are currently available as standard off the shelf vehicles from world class highway bus manufacturers. Various models include: separate washrooms for men and women; serve yourself kitchenettes with water, non alcoholic drinks, a frig. with DIY sandwiches and cookies; at your seat audio visual entertainment; and plug ins for telephones and computers at one's seat; passenger controlled lights, blinds, and ventilation; high quality soundproofing, full HVAC, emergency security systems, and specially designed tilting seats for more comfortable sleep.

(9) Other transport cargoes which might be moved by RORO trains might also include: heavy construction equipment such as shovels, cranes, tractors and "cats" for contractors responding to

“just in time” construction contracts, or transcontinental environmental emergencies, such as earth quakes, regional floods or major firefighting events.

Lighting trucks, box vans, plows, emergency vehicles, firefighting equipment, mobile homes, or other camp accommodation, school buses on delivery from manufacturers, small aircraft or helicopters disassembled for shipment and/or aero engine components and assemblies, as well as cinema / film production operations. Many of these shipments must often be delivered rapidly over long distances in “ just in time” ground transport work orders.

Note: The only limitations on cargoes on some electrified mainlines or for RORO unit trains on such lines would be restrictions associated with (a) specified hazardous or dangerous cargoes: (b) extreme axle loadings running over axle load limited reinforced concrete railway ties or pads; and (c) loads in which extra width or heights of cargo may pose a risk to side or vertical clearance restrictions on some electrified lines.

(10) Central railway controllers would at all times be in direct communication with train crews, service personnel and/or on board bus operators. In emergencies, controllers would be able to order all or part of a train “off line” at secure siding locations, where regional security or health and safety personnel could rapidly provide emergency response.

APPENDIX 4: THREE ISSUES IN CONSIDERING MSR (220 - 255kph) AS A STARTING POINT FOR HSR OPERATIONS

Issue 1: Catenaries: A light economic catenary for 2-25 kV 60Hz power systems can move a wide range and mix of trains at up to 250km/h.(150 mph). Up to this maximum speed, catenaries require only this light framework and support structure [11] as shown in Illustration 7: Catenary design for up to Medium Speed Railway (MSR).Max. design speed 250 Km/h.(150 mph.)

However, at speeds above 255km/h., catenaries require heavier, more complex and more costly cable support structures. Such systems would be over designed, if they were primarily serving only trains operating at speeds of MSR or lower.

It is estimated that initially mixed use electrified railway corridors would carry 50-75% freight or cargoes of various types, operating at < 150km/h.; 10-15 % would be passenger trains operating at under 250kph, and up to 20% would be commuter trains. Most electrified commuter trains would operate on separate tracks, in speed ranges of < 132-160kph. Few commuter trains could operate at maximum speeds >250kph.

Illustration 7: Catenary Design Medium Speed Railway (MSR). Max. speed, 250 Km/h.)

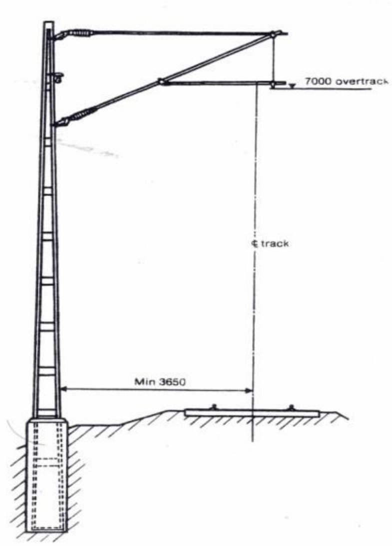

Figure
Typical Steel Pole with Single (Line) Cantilever

44
45

Issue 2: Separate vs. Mixed Use ROWs

Even if and where a heavier HSR or VHSR catenary is justified in selected, interconnecting track locations, it is likely that HSR or VHSR trains will only be able to operate safely and efficiently at their full higher speeds on separately designated ROWs.

However, where HSR systems are established, they will require separate ROWs, as outlined in Issue 1. In some regions, there may initially be insufficient high speed rail passenger traffic (24/7/365) to economically justify totally independent, energy efficient, sustainable, electrical systems. Under such conditions it may be appropriate to locate CSR, MSR and HSR railway lines close enough to one another, so that their energy supplies and regenerative braking energy “sell backs” at utility substations can be coordinated and interactively shared for maximum mutual advantage by various types and speeds of electrified rail traffic.

Issue 3: Sharing More than Electricity Supplies.

If a mixed use line such as outlined in Issue 1 is the best way to maintain a wide range of rail traffic for up to 4-6 trains/hour running within the same 2-4 track corridors in the same direction, then the higher cost of either a high speed central track or a separate high speed railway corridor located to one side of an existing CSR or MSR mainline may be feasible and practical. In this way, some of the cost of electronic signaling, train controls, improved station platforms, grade separations, fencing, security, HS switches and crossovers, flattened curves and reduced super elevations might also be shared between faster and slower railway traffic.

In corridors, where sufficient CSR and MSR traffic expansion has already occurred, then new higher speed lines, with their additional cost of heavier catenary support structures, total grade separations, bridges, viaducts and tunnels, as well as stations, platforms, station parking, and security fencing, could all be shared between CSR, MSR, HSR, and/or VHSR traffic, although HSRs and VHSRs will likely operate on separate ROWs.

APPENDIX 5: THE CASE FOR PUBLIC CONTROL OF ELECTRIFIED RAILWAY RIGHT OF WAYS AND RELATED INFRASTRUCTURE

Public ownership and control of electrified railway rights of way and fixed infrastructure, is essential for the following reasons:

(i) It will facilitate increased competitiveness in schedules and travel time, equipment used, and services offered by both private freight railways, as well as by electrified publicly owned passenger rail and public, private, or third sector (co-op) RORO rail systems, versus other less energy efficient ground and air transport alternatives.

(ii) It can facilitate effective coordination of electricity supply and demand from a wide variety of sources and will ensure that sustainable energy is available, when and as required, and that if braking energy is recovered through normal railway operations, it will either be reused locally or expeditiously "sold back" at the nearest utility substation.

(iii) It will provide greater assurance and accountability for public safety, security, and reliability, as well as transparency with respect to transport energy efficiency and reduction of fuel emissions. Evidence also indicates that states with histories of efficient publicly owned railways also have extensive histories of safe, minimum accident performance, in particular, those with substantial CSR, MSR, and/or HSR operations such as Austria, Belgium, France, Japan, Germany, Italy, Netherlands, Spain and Sweden.

(iv) It can ensure reasonable access by all users of electrified lines who will all be able to take advantage of faster performance, lower cost, higher efficiency, and sustainable sources of energy for motive power. It will also assure users that, subject to the regenerative braking technology of the rolling stock which railways are using, they will obtain the benefits of the safest, lowest cost, most energy efficient electric railway infrastructure.

If current forms of public private partnership are insufficient, what is a possible alternative?

If private railways are not prepared to bear any of the cost of electrifying their own lines without total off-book guarantees by governments, or other essentially risk free arrangements to their private corporations, then they must relinquish some of their historic private corporate prerogatives. These may include ownership or control of certain existing mainlines, or portions thereof, in favor of being able to continue the right to use these same mainlines, improved to a faster, safer, higher standard by others, and maintained under permanent public operational control and administration. Such improved electrified lines would also be subject to new operational standards of public safety, security, on-time schedules, and other relevant performance criteria. These would be essential to ensure that national and regional goals of mobility, health, public safety, energy efficiency, economy, fossil fuel reductions, etc., are achieved in a timely way.

APPENDIX 6: SOME REASONS WHY MAINLINE RAILWAY ELECTRIFICATION HAS NOT YET BEGUN IN CANADA

During the first energy crisis in Canada in the early 1970's, a minority Federal Liberal government was in power . The NDP, which held the balance of power keeping that government in office, insisted on a number of wide ranging measures to improve Canada's energy efficiency position. [It is important to recall that the late Tommy Douglas was the NDP Federal energy critic in Federal Parliament at the time]. One of those measures included a study of the possibility of electrifying major railway mainlines across Canada. In 1974, the Federal government had also received a Science Council report [12] recommending among other things railway electrification of Canada's mainline railways as a means to reduce national energy consumption [primarily fossil fuel consumption] by at least 11%.

Perhaps as a result, the Federal Minister of Transport received approval for a study of Railway Electrification in Canada [13]. This study carried out under the guidance of the Federal MOT and the two major railways through the aegis of the RAC (Railway Advisory Committee)_of MOT, was delegated to be undertaken by the Canadian Institute for Guided Ground Transport (CIGGT), located at Queen's University, Kingston, ON. It was hoped by many transport planners, government officials, politicians and NGOs at the time that CIGGT would set out accurate realistic assumptions and conditions which would help to get Canada's railways moving along a path toward mainline electrification, if not immediately, then at least as a longer term strategy with substantial results by the year 2000, if not earlier. Alas, this did not happen. It was becoming clear to some at the time, and in retrospect, after nearly 40 years, it is now clear why it did not happen.

An important reason was that the selected study team made the erroneous assumption that all newly electrified rail lines in Canada, post 2000, would obtain their electricity primarily from thermal sources (e.g. Ontario Hydro from nuclear and thermal (coal fired) stations in the east, and Calgary Power from coal fired thermal stations in that province). As a result of this assumption, the study team concluded that since the energy system efficiency of thermally generated electricity (28%) differed little from the system efficiency of diesel locomotive generated electricity (23-25%), energy efficiency would make little difference in the equation of diesel vs. electric motive power. Therefore, Canadians would have to wait some years (circa 2004 was projected at the time) before differentials between rising market prices of diesel fuel and the price of centralized electricity production would provide sufficient economic incentive to electrify Canada's railways. The notion that four or five of Canada's provinces, several of which were already major hydro electricity producers, had large quantities of relatively inexpensive, or undeveloped "exportable hydro-electric power", deliverable at an electric axle motor efficiency of 75-78% appears to have been beyond the appreciation of the CIGGT team. The following bit of history may further illustrate this point.

After the CIGGT study was completed in 1976, it was presented to its major clients in Ottawa. In 1977, it was presented in summary form, to an invited seminar at the Centre for Transportation Studies, University of Manitoba. [14] The author of this present TAO paper, was at that time, a Ph.D. graduate student in the Faculty of Engineering at the U. of Man, and was an invited audience member at that presentation. During the Q&A session, he raised the following question? "Why did the study team assume that all or most energy supplies for railway electrification would derive essentially from thermal or nuclear power sources, when in fact, Canada is a net exporter of hydroelectric energy from provinces such as B.C., Manitoba, Quebec, and NFLD, and 75 % of all Canadian electricity production in 1977, was [and in 2010, 65% still is], hydro-electricity?

The CIGGT team response was, from this author's recollection, as follows: "… each stage of railway electrification would have to generate its own electricity supplies. In Canada, hydro sources would mostly be fully developed and allocated by that time (post 2000). Therefore, the study team assumed that thermal energy would be the only practical, available new source of energy." The great tragedy in that response is not just that CIGGT made an erroneous assumption with very long term negative consequences for railway electrification, but that it gave important clients of the study, (i.e. Canada's major railways and government) license to go to sleep for more than thirty years, while modest, but important prerequisite steps to electrification, such as double tracking, grade separation, roadbed rebuilding, curve realignment, safer in–cab signaling and communications, all went on the back burner.

Meanwhile, the EU countries, with France and Germany leading the way, Australia, China, India, Japan, Russia, even South Korea, moved ahead steadily with expansion of railway electrification, while Canada continued to take its backward technological cues from the US and its agencies. Compared with Canada, the US is a country with little natural advantage in sustainable (hydroelectric) power and therefore little incentive to electrify its own railway systems, even if it could have done so long ago, since it has been so wedded to fossil fuel DE technologies, and so dominated by fossil fuel industries over the past century.

Public Investment in Electrified Railways

For more than 80 years, little progress has been made through public or private railway initiatives in advancing the progress of railway electrification in Canada, with the exception of the Mount Royal tunnel line in Montreal (1918), and the construction of a 79 mile single track coal railway branch line from Tumbler Ridge to Anzac BC by the BC railway, a provincial crown corporation (1983). Subsequently, the entire electrified BC branch line railway was closed down. [Both of these examples are further dealt with in Appendix 7]. At the same time, relatively little has been done either by the major freight railways and/or other public transport agencies, in terms of improved crossing protection or elimination of crossings and replacement with grade separations. Also, little progress has occurred with respect to widening sharp curves and reducing super elevation of such curves to facilitate an increase in average operating speeds without necessitating "tilting technologies" or other interventions on extensive curvilinear sections of track. Nor has there been much progress on rebuilding obsolete key infrastructure such as old bridges, viaducts, railway rights of way, or increasing other clearances to better facilitate electrification, and also permit safe increases in operating speeds, and higher railway freight loads.

To date, the two national railways, both private since the 1990's, have refused to proceed with any railway electrification unless there are substantial public subsidies, either in the form of "off book loan guarantees", or other undefined public/private partnership arrangements [15]. [In some circles, these types of PPP's have been described as a "privatize the profits and socialize the risks or losses approach" in the financing of investment for public infrastructure.**]**

This description may not be far off, because over 100 years ago, when Mackenzie and Mann were building their extensive multiline railway empire with large public land and other government subsidies and loan guarantees, their entire empire of five or six regional, national and international railways crashed in massive bankruptcy and foreclosure, when national and international economic conditions changed rapidly at the time of the First World War. In addition, in 1912, Mann, with a great deal of important information essential to the future of his companies either in his head or in his briefcase, went down with the Titanic on the way back to Canada from a railway finance negotiating meeting in London, England. As a consequence, and to recover at least some of its large investments in and/or loan guarantees to these companies, the Government of Canada was forced to step in, take over, and reorganize the company's extensive regional, trans-continental, and international railway assets in Canada's national interest. This was how CNR (Canadian Northern Railway) with its various subsidiaries, was reborn as CN, a publicly owned major railway network in 1918. This new national railway, grew very effectively, under the leadership and management of Sir Henry Thornton, especially before the Great Depression, and remained a dynamic and productive publicly owned railway system for over 75 years. This also included CN's many essential national and international roles through several wars, and a number of other major national crises [16]

APPENDIX 7: RAILWAY ELECTRIFICATION UNDER WINTER CONDITIONS; SEVEN CASES FROM CANADA, NORWAY, SWEDEN, AND RUSSIA

It is sometimes argued that weather in Canada is too cold to operate electric trains. The following seven examples indicate why this is not so, although more research may be needed on certain aspects of MSR, HSR and VHSR train and EMU design and operation in far northern regions.

Case I. The MalmBanen: Narvik, Norway, to Kiruna, Svappavarra, and Lulea, Sweden.

Norway and Sweden have been linked in their far northern regions by an electrified freight and passenger railway for over 90 years. At latitude 68 degrees north, this industrial rail line originally connected only one iron ore mine near Kiruna, Sweden, with the port of Narvik, Norway. From here, shipments of iron ore were transported to central Europe by ship through much of the 20th Century. In recent years, this railway, now called the Malmbanen and providing both passenger and freight service, has been expanded to over 335 miles (540 km). It now extends from Narvik, on the north Atlantic coast of Norway to Lulea, Sweden, on the NW coast of the Gulf of Bothnia. This line, which now services several mines at Malmberget, Svappavarra, as well as Kiruna, Sweden, handles some of the heaviest ore shipments in Europe. In 2001, the railway received 9 new twin section electric locomotives at over 360 tonnes/pair. Together, each pair generates 16,470 hp or 10,800 kW continuous. Built by Adtranz, (now Bombardier), these are among the largest and most powerful electric locomotives in the world. Although relatively slow, with a maximum speed of 80km/h, they pull huge loads of ore on a mixed passenger and freight rail line located mostly within the Arctic Circle [17].

Case II: Montreal, Quebec

To develop new suburban lands on the north side of Montreal Island, the Canadian Northern Railway Company, one of several private rail companies begun by Mackenzie and Mann early in the 20thCentury, had, in the pre-World War I years, planned and built a double track 3 mile railway tunnel under Mount Royal mountain in Montreal. In part, the purpose of this tunnel was to develop and service a new "Model City" situated at the north end of the new tunnel, which was later named the Town of Mount Royal (TMR). This new modern, early 20th Century planned urban municipality began with a clean, quiet, electrified railway bisecting the town, but with the electrified railway line sufficiently depressed in cut, to facilitate efficient layout of the town's streets, major roads and other infrastructure services. Thus, there were no protrusions, steep slopes, or steeply graded overpasses which might hamper easy surface road and utility circulation, either within the town itself, or within the town center, in winter.

With no stops located within the tunnel itself, travel time to Montreal's central station from the TMR station, or from Portal Heights station, at the northern mouth of the tunnel was only 10-15 minutes, and is now much faster with new infrastructure and rolling stock. [See Illustration 8]. This initial electrified line was first inaugurated in 1918. In the early 1980's, the initial line of 2.4 kV DC was increased to 3kV DC, as electrification of this double track line was steadily extended northwestward across both the Island of Montreal and its adjacent Jesus Island, toward the Two Mountains area.

In the 1990's, the electrified line was rebuilt again with a 25kV 60Hz AC power supply and with new rolling stock designed and built in Canada. The Bombardier built regional passenger commuter trains, have design speeds of 120km/h.(75mph) [18]. Cars are heated and air conditioned, and with no delays on entering the internal track network of Montreal's Central Station, the trip from Portal Heights now takes 6 minutes to cover the five kms.

AMT. the Montreal region commuter rail operator, has been rapidly expanding regional commuter rolling stock in response to increasing public demand for additional capacity on electrified commuter lines within the Montreal region. With Montreal and the Province of Quebec's strong industrial and technical leadership in snow removal and other aspects of winter transport technology, winter weather has never been more than a routine challenge for electrified trains in the Montreal area. It should be remembered that the Bombardier Company itself, began with Armand Bombardier's invention of the snowmobile in the early 20^{th} Century and the Sicard Company's development of innovative heavy duty urban snow blowing machines, developed in the province of Quebec within the same era.

Illustration 8: Bombardier's Quebec built regional electric commuter train coaches, with a design speed of 125km/h. (75mph) with two alternative door heights.

Case III: The USSR, and Russia; An Electrified Trans-Siberian Railway.

Within a forty year period after the Russian revolution of 1917, the former Soviet Union developed, extended, and electrified much of the railway line connecting Moscow with Irkutsk, extending eventually more than 7500 kilometers to Khabarovsk, in the far eastern region of the country. More recently, the Russian State Railway (RDZ) electrified the last 500-600 km. section of the Trans-Siberian Railway, linking Khabarovsk southward to the strategic Pacific port of Vladivostok. Also completed in the late 20^{th} Century by the former USSR government, was a new

”short cut “ stretch of electrified railway across Siberia, north of Irkutsk and Lake Baikal, called the BAM (i.e. the Baikal – Amur line).

These new and older electrified mixed use railway lines, through many time zones across Siberia, have operated successfully in all kinds of severe winter weather, in war time, peace time, through mountain tunnels, across frozen steppes and taiga, under myriad extreme weather conditions for almost 90 years.

Case IV: The Leningrad now St. Petersburg – Moscow Express.

On its 645 km. electrified railway line between Leningrad, (recently renamed St. Petersburg, its pre-revolutionary name) and Moscow, Russian State Railways (RZD) have, from the late 1970’s until recently, depended on a streamlined aluminum chassis, Russian designed electric locomotive to pull its long trains. These 200km/hr. CSR trains, designated ER200, often carried 816 passengers. It covered the intercity distance in as little as 3.5 hours non-stop. Like slower trains on the Trans-Siberian route, this important rail route faced challenging winter conditions in maintaining its 160-200 km/h. express schedules. Much slower schedules have been long maintained for local trains with infrequent stops, and for overnight intercity sleepers on this route.

Case V: The 2009 St Petersburg –Moscow HSR Express, SAPSAN

From the mid 2000’s to 2009, SIEMENS Transportation, the German rolling stock manufacturer, conducted extreme cold weather tests on a modified version of its ICE-3 type high speed EMU (Design speed: 300-350 km/h). In Spain, Siemens called its ICE-3 train, now running on the AVE line between Madrid and Barcelona, the” Velaro”. The objective of Siemen’s research for the Russian State Railway contract, was to develop an HSR EMU, based on its Velaro design which would stand up to the rigours of extreme cold weather railway operating conditions, and maintain, all-weather, high speeds throughout the year.[19]

Tests were completed on these HSRs, and in the initial test period they were running at up to 281 km/h. (169 mph), on an improved, mostly straight, double track electrified mainline. It appears that these new HSR EMUs, which Russian Railways (RDZ) now call the SAPSAN (Peregrine Falcon), are dramatically changing the efficiency and performance of passenger railway transport between these two cities [20]. An important implication is an emerging shift in modal split between air and HSR travel for this medium haul air and ground transport route, which currently has a door to door total elapsed time of over 5 hours by commercial jet air transport, and a total elapsed time of less than 4 1/2 hours by SAPSAN, including a number of stops. All of this, without even reaching the manufacturer’s basic design speed. Non-stop time between the two cities is currently 3:40 hours or approximately 172km./hr.(103mph),with a significant shift to passenger rail from aircraft occurring as a result of a new safer, faster, more efficient and comfortable HSR EMU. (See Illustration 9). When and if this train is able to hit its max. design speed (e.g. 350km/h,) SAPSAN will be able to cover this interciry distance in two hours or less.

Key questions, which remain, are how effectively Siemens has addressed longer term issues of HS operation under sustained extreme cold weather,over many years, and more important, how effective Russian Railways will be in improving and/or rebuilding sections of its railway ROW between Russia’s two most important cities, to accommodate the HSR design capability of Siemens modified ICE-3. As of 2014, Russian railways still had not completed the necessary ROW and infrastructure improvements required to enable SAPSAN to achieve its basic design speed of 300 km/h (186mph) or its maximum design speed of 350 km/h (210 mph), speeds which are now common in western Europe. Although, no railway has solved all of the problems of cold weather HSR train operations, a number of these issues are identified and further discussed in Case VII.

Illustration 9: Siemens designed and built, SAPSAN for Russian Railways linking Moscow and St. Petersburg, (i) at speed in winter.

Below, (ii) SAPSAN at speed in spring.

Case VI: BC RAIL's Tumbler Ridge – Anzac Electrified Branch Line .

In the late 1970's, BC RAIL, a provincial crown corporation at that time, was faced with the challenging task of establishing a new 80 mile freight rail link across the northern Rockies from an open pit coal mine at Tumbler Ridge, BC. on the east side of the mountainous Continental Divide to a rail junction on the west side of this region. This would connect with BC Rail's north –south mainline at Anzac, BC. The BC N-S Rail line links Anzac to Prince George, BC., where BC rail interchanges with CN's historic east–west freight and passenger mainline. As part of the privatizing efforts of a subsequent BC government, this public railway asset was subsequently acquired by the already privatized CN railway. From Anzac, coal trains moved onto CN's historic, E-W trans-continental rail line, linking Prince George, with tidewater coal loading facilities at Prince Rupert, BC., from where the coal was shipped to Asia.

Given the heavy snow and avalanches in this region of the northern Rockies, it was determined that the best route across the Continental Divide was through long railway tunnels, and over bridges and viaducts running directly through and under the mountains, with a few steeper grades and sharp curves, rather than snaking circuitously through river valleys and around the mountains. However, long tunnels make no sense if they necessitate using 6 - 8 or more diesel – electric DE locomotives to move each heavy coal train along this line, together with more complex and expensive tunnel ventilation systems which would be required.

Consequently, the line was electrified with a 50 KV 60Hz AC power, with the power distribution line carried along the catenary, avoiding the cost of a separate, parallel power distribution line. 50KV was a less common system, but on paper appeared more energy efficient. The single track branch line railway used 4 - 180 tonne heavy duty EMD GF6C2 electric locomotives, 2 pulling and 2 pushing, for each train.(Illustration 10, p.67. [This is several thousand HP more, and twice the weight of twin electrics currently used on the Malmbanen in Norway and Sweden].

For the subsequent 17 years, from 1983, this BC coal railway demonstrated that electrified rail lines might be a practical way to provide conventional speed power for heavy freight, under more extreme winter weather conditions in northwestern Canada. The project had also been developed and made rapidly operational from 1980-83, through the mechanism of a provincial crown railway, with mandated powers for public infrastructure development.

Unfortunately, this "electrification test case" ended in premature demise of railway electrification in this Canadian region. The company which developed the mines at the Quintette and Bull-Moose sites, near Tumbler Ridge, did not undertake a long term feasibility analysis nor did they provide accurate technical information and disclosure to governments and/or to the BC Provincial Railway during the energy rush of the late 1970's. By the late 1990's, it was clear that the line would not receive sufficient coal traffic to pay for its required electricity, notwithstanding the low BC hydro price for 50 KV power provided to the original line. With no other traffic sharing the line's energy, with the company's poor management and inadequate market research, and lack of careful oversight by government(s), the mines were closed by the early 2000's. The catenary was removed and 6 locomotives were scrapped. In 2004, the remaining initial locomotive, No. 6001, was acquired by benefactors and donated to a transport and forestry museum in Prince George, BC. It is unfortunate that the electric locomotives were designed for 50 KV, instead of 25 KV operation, since they could have been more readily reused together with much of their infrastructure.

Illustration 10 : Locomotive No. 6001; the first GE 4000 HP 50 KV Electric locomotive of the seven which operated for 17 years, on the Tumbler Ridge –Anzac branch line (1983 – 2000). It is now exhibited in a railway museum in Prince George, BC.

Case VII: High Speed Train Operation in Winter Climate: A study in winter–related problems and solutions applied in Sweden, Norway, and Finland.

Summary of a report by Lennart Kloow and Mattias Jenstav, on a research project Green Train (Grona Taget) undertaken for the Swedish National Railway Administration (Banverket). 62pp.(2006) [21]

Summary Abstract

- There are many unresolved problems with switches, brakes, and ballast pickup.
- Many [problems] are independent of speed and others are dependent on train speed.
- Lack of experience and knowledge about HS (> 200kph.) train speeds in winter poses a number of specific problems which are identified.

(1) Pieces of ice, frozen gravel, pieces of frozen roadbed, are swept up into the underside of railway rolling stock by high speed air turbulence. Based on Swedish Railway's experience with its X-2 (MSR) train, this can cause havoc with pipes, hydraulic assemblies, and other sensitive components if they are not properly protected. [RENFE, Spain's National Train Operator, indicated, in a 2008 personal interview, that for similar reasons, it had decided to not increase HSR train speeds beyond 300km/h. e.g. on Renfe's Madrid – Barcelona line as well as on other HSR lines). The 350 km/h. speed was Siemens design limit for its Velaro trains [22] (see Illustration 11). In the Swedish study, [which focused on much slower X-2 (MSR)

EMUs introduced in 1990 by ADTRANZ, (now Bombardier)], snow and ice built up and lodged in the undercarriage of bogies, brakes, suspension, and tilt control systems. The study identified the need for costly redesign, of undercarriage assemblies on X-2 rolling stock.

(2) Ice on tracks and in some switches under certain weather conditions can also pose risks to braking, power drive and shock absorber systems. [Many of the same problems occur in both DE and electric trains, although electrics generally have a much better all-weather traction and HS performance record.]

The key problem is speed. Faster trains traveling at or above 200 kph. experience weather problems associated with snow and ice buildup in crucial bogie and brake systems. Solutions presented include: de-icing procedures and technologies, much like jet aircraft before take-off in winter; selective heating and/or automatic de-icing of critical systems and surfaces; seasonal reduction in speeds to 160 km/h. Other measures were also identified to overcome such problems.

The report also extensively reviewed literature from Japan National Railways on HSR cold weather operations within JNR's northern regions (e.g. Hokkaido), and cited useful examples.

Illustration 11: RENFE's 300km/h.(187mph.) Siemens designed VELARO emu currently operating on the Barcelona–Madrid, and Zaragosa–Madrid-Valencia AVE and other lines.

APPENDIX 8: KEY TECHNICAL FEATURES OF ELECTRIFIED RAIL SYSTEMS

(i) Regenerative Braking

One of the most important and impressive features of railway electrification, for both conventional speed railway (CSR), medium speed railway (MSR), high speed railway (HSR), and very high speed railway (VHSR) systems is the opportunity which electrified trains provide for recapture and productive reuse of significant amounts of braking energy which is transformed into useful electricity through the technology of "regenerative braking". This technology is only available on electric locomotives or EMUs.

In simple terms, this means that as electric trains are braking and slowing down, instead of simply generating friction and heat from their brake systems, power brake systems become electricity generators and 70 – 80 % of this energy can be recaptured for reuse, either aboard the train itself to power HVAC (heating, ventilating, or air conditioning) systems, on board communications or controls, or can be fed to nearby trains through the catenary and its network of overhead power distribution lines. Alternatively, up to 30% of regenerated braking electricity can be sold back to the electricity generating utility through the nearest sub-station from the generating train. Thus, at the instant trains are accelerating and require more power, they can either use electricity generated from the braking of another nearby train, or its excess braking energy can be sold back for reuse.

As an example of this efficiency process, in the year 2007, in Spain, RENFE, the state railway agency, which also runs commuter rail services in five Spanish cities, was able to recover in the order of 180M kwh. of electricity through regenerative braking, solely from its commuter train fleet [23]. In future years, through sustained annual energy efficiency measures, RENFE/ADIF (the state administrator for railway infrastructure) expect to achieve greater savings in electrical energy through a variety of innovative measures.

(ii) Headways

Headways are the safe spacing between trains running on the same line in the same direction. Such spacing can be measured in distance and/or travel time. Adequate headways ensure that if a problem occurs along a railway line, following trains will have sufficient time and distance to react and stop safely.

Assuming 1 train every 2 minutes on a subway or metro system @ at speeds ranging between 50 – 80 km/h., and maximum capacity of 800 passengers / train, then line capacity would be 30 x 800 = 24000 passengers per lane / hour, depending also on interstation distances and dwell times.

Considering another example, in Japan, the JNR (Japan National Railway) allows for 6 min headways on its 250-300 km/h. Shinkansen (HSR) lines. At an average of 800 - 1600 persons / train (single or duplex vehicles), and up to 10 trains per hour, this system could carry in the order of 8000 – 16000 persons per track direction per hour.

These examples assume similar types of rail traffic such as short commuter lines or longer distance high speed passenger trains. However, if some passenger trains operating in the 160–180 km/h speed range are required to operate in systems of "mixed traffic" with some freights operating in the 80-120 km/h speed range, and some commuter trains in the 90–140 km/h speed range, provision must be made for faster trains to pass slower ones at speed. This can be done by means of strategically located high speed passing tracks of sufficient number and length. In this way, a double track line might become a triple track line or a quadruple track network in a selected section of corridor with faster trains operating on designated higher speed tracks.(See also Appendix VIII, Item (v))

In situations where commuter rail traffic converges with other mainline traffic, more tracks may be required within selected sections of rail corridor. Trains would come to be differentiated by their specific tracks, typical average speeds, and frequency of stops. Meanwhile, all electric powered trains regardless of their type or speed would continue to share the same electricity supplies including catenary networks, substations and long distance power transmission lines. In this way, it is possible to power an entire electric railway network, including commuter trains, intercity mainline passenger trains, conventional freight trains and new forms of RORO traffic, all running on their respective tracks at different speeds, while sharing electricity from sustainable sources.

(iii) In –Cab Signaling

For more than eighty years, electric signaling systems on North American railways have depended upon signals and signal controls which were external to the cab of the railway locomotive. That is, they were electric signals posted automatically on overhead or line side signal structures indicating by their arrangements of coloured lights that the line ahead was clear (green), that an engineer could proceed slowly with caution (yellow) or must stop and not proceed further (red). Electric signals have also been controlled by electric circuits running in part through the rails themselves. Track circuits have also controlled warning signals at crossing gates, including bells and other devices to control vehicular and other traffic crossing railway lines.

These types of train control systems are called CTCs or Centralized Train Controls, operated usually from a central dispatch office of a national or regional railway control center. At such a center, it is possible to observe the progress of all of the traffic on a particular railway network, as each individual train makes its way along the system. Lights on a large CTC control panel indicate the status of signals along the way, as each train proceeds either with a clear signal, with caution, or is signaled to stop.

A serious limitation of CTC control systems is that they are external to the locomotive and/or the train controllers cab. Under severe weather conditions with a single driver alone in a locomotive cab, a line side or overhead signal may either be missed or seen too late to react promptly, if a train is moving very fast, the line ahead is not clear, and/or extreme inclement weather makes it difficult to clearly see external signals. This can be particularly problematic on single track lines with inadequate sidings or passing tracks, where two trains may be approaching from opposite directions, and one train must stop and/or pull off onto a siding in a timely way.

Therefore, in mixed use rail corridors or even single purpose railway lines, at higher speeds in – cab signal indicators are essential for safe operation. What this means is a set of lights on the engineers dashboard control panel which indicate whether the zone the train is about to pass through has a green, yellow or red signal. The panel will also indicate the recommended speed for that particular zone, as well as speed and conditions for subsequent zones. Most contemporary in - cab control systems also have a means to automatically control a train and bring it to a stop, should a stop signal have been missed or ignored by an engineer. For higher speed trains, such as MSR, HSR, and VHSR systems, such safety controls in a controllers cab are essential to maintain the kind of fail - safe operations and accident free performance which is now the norm for higher speed railways around the world.

(iv) Grade Separation and Security Fencing

At close headways (e.g. closer than 2 trains / hour) on double track lines, full grade separations are essential. They are also mandatory on any medium to high speed rail lines. This means that there can be no level crossings anywhere on such corridors. All level crossings must be closed, and relocated or replaced either by underpasses or overpasses or by secure hydraulic devices.

At short intervals (e.g. farm roads), these may take the form of a single vehicle road bridge or underpass large enough to accommodate a single vehicle, pedestrians, animals, etc. At longer intervals, full scale road or highway bridges or underpasses are required to accommodate multiple lanes of motor traffic.

At all types of grade separation as well as along electrified mainlines, full security fencing is required to adequately ensure prevention from intrusion onto railways by unauthorized persons or by animals or wildlife.

(v) High Speed Switches and Passing Tracks

An essential requirement for safe operation of a mix of train operations on double track, triple track, or quadruple track rail networks, is a means to facilitate faster trains passing slower ones at speed, without the necessity of either train having to alter its normal operating speed and with no risk or compromise to safe railway operation. The availability of passing tracks of adequate length and high speed switches or crossovers in appropriate locations can facilitate such passing arrangements in a safe, secure manner. Such high speed passing arrangements are essential in ensuring safe operation of electrified HS lines.

(vi) Road beds, Sleepers and Track Anchors

Roadbeds must be secure and stable to support higher speed trains, however a double track rail line is much narrower than a conventional 4 lane highway (14m. vs. 45m.). Consequently, less land will be required and there will also be no requirement for land for major road interchanges every 1 – 5 miles or less, as is the case for most major multilane highways.

Creosoted wooden ties no longer have the reliability, environmental safety, security and stability of reinforced concrete ties. Nor are they able to ensure the kind of secure, tight anchoring of every tie, which is essential to ensure a safe, smooth ride at a wider range of higher speeds and train loadings. This means not only the ability of mainline railways to carry heavy loads when required, such as coal, ore, and/or grain, but to also carry higher speed passenger and freight trains (e.g. COFC's, TOFC's), with less wear and tear on rolling stock and infrastructure. Most important is that there be little movement of ties (i.e. sleepers, rails, or tie anchors), as HS passenger trains pass over them. Curved sections of mainline track and their ties, take a severe pounding not only from heavy freight cargoes, but from multiple DE powered mainline freight locomotives (e.g. up to four locomotives @ 140 -190 tonnes each, plus up to 20 tonnes of fuel in each locomotive's tanks). Therefore, rail and roadbed systems must be tighter and more secure than conventional rails set on wooden sleepers with their less reliable tie plates and looser steel spike anchors.

There is at least one aspect of wooden ties which makes them superior to reinforced concrete sleepers, and that is their ability to tolerate extreme axle loadings by ultra-heavy freight cars, as well as heavy DE locomotives with very high axle loads. Since axle loading is the most critical indicator of loading on rail ties, it is essential that strict regulation be enforced with regard to loading on new reinforced concrete rail ties or sleepers. For example, if close spaced ties are designed to carry maximum axle loads of 25–30 tonnes, and they are continually overloaded with heavy locomotives and freight loads with much higher tonnages per axle (i.e. 35 – 40 tonnes and up), new overloaded r.c. (reinforced concrete) sleepers will more rapidly crack and breakdown. This can be prevented by ensuring that heavier loads are at least supported by sufficient unit train bogies with increased axle arrangements (e.g. cars with 6 or 8 wheel bogies) as well as larger bogie configurations for DEs (e.g. CO– CO or 6 axle bogies), or BO-BO-BO (6 axle locomotives), instead of (BO – BO or 4 axles) for heavier DE locomotives. It can also be addressed by ensuring that new higher speed track corridors with r.c. sleepers on mixed rail traffic roadbeds have their sleepers placed closer together or that new lines are built beside or close to older lines of wooden tie rail tracks which can continue to be used for by-passing heavier freight shipments and/or much higher axle load DE locomotives around some line segments.

(vii) Railway Curves: Radii of Curvature, Super Elevation, TALGO Trains, and Tilt Train Technologies

Over the past 150 years, as train speeds have steadily increased and as the height of car loadings has risen, super elevation of the outer rail track on curves has been increased to ease the stress of heavy rail traffic negotiating curves at speed. The faster trains travel and the heavier they are loaded, the harder their wheel flanges press upon the outside rails of sections of curved track. If the radii of curvature of tracks is too short, at higher speeds centrifugal forces can become critical, or at best more difficult to control.

To overcome this problem for higher speed passenger railway traffic, several alternative measures have been developed over the past sixty years to enable passenger trains to handle extreme curvilinear routes, particularly in mountainous regions**.** The first was a patented passive technology devised by a Spanish engineer in the late 1940's - early1950's.

Called **TALGO** trains, they involved three basic principles of "passive intervention": (1) make passenger coaches shorter and lighter; (2) place the greatest mass of each coach as close to the floor as possible, and place the normally heavier baggage coach at the tail end of the train to reduce whip effects; and (3) at end of each coach locate only a single axle bogie with its two wheels centered beneath the connection or link between the coaches, thereby linking the coaches permanently as a unit train. This technology allowed lighter weight passenger trains, initially pulled by diesel electrics and subsequently by electrics, to literally snake through extremely curvilinear, mountain railway routes at 30% faster speeds.

In the 1960's, a second solution, developed in Italy, involved the introduction of "active tilting technology". These **PENDOLINO** trains as they are called, were first developed by the FIAT company. This patented technology permits significantly greater increases in average train speed through extreme curvilinear railway routes without the necessity of having to rebuild an entire mainline railway ROW over the short term.

FIAT's special patented active tilt mechanism, installed on each coach, is designed to tilt inward, displacing the side and floor of each coach upward as much as 20 cm. (8") in response to changes in the centripetal acceleration of the train as it moves around a curved section of track. This allows trains to more comfortably negotiate curves at higher speeds. In this way, trains achieve (1) up to 30% faster travel times; (2) less stress on passengers and service personnel especially when eating or serving meals; (3) safer and more comfortable rides; and (4) less wear and tear on railway infrastructure on mixed use railway lines [24] .

Active tilt mechanisms do have at least one disadvantage, in so far as they add significantly to the weight of a coach, thereby reducing the relative energy efficiency of a train. Nevertheless, many countries have introduced passenger rolling stock which incorporates this technology. These include: Australia, Canada, the Czech Republic, Finland, Japan, Norway, Portugal, Sweden, Slovenia, Spain, Switzerland, UK, and the US.

Although active tilt technology trains represent faster than conventional speed train operations (e.g. up to 255km/h compared with 160 km/h or less), for mixed rail traffic conditions to safely accommodate higher speeds, the concept of mixed use electrified rail lines, and tilting technologies must be totally reconsidered in the case of higher speeds. Instead, new purpose built HSR (e.g. 280 - 320 km/h and / or VHSR (e.g. 300 – 380 km/h)) ROWs must be planned, designed, and built appropriately with the correct radii of curvature and super elevation of track for such speeds.

For these higher speeds, rebuilding of railway infrastructure and ROWs, with longer radii of curvature track (e.g. > 7000 meter radii of curvature for speeds > 350km/hr.) are essential. Also new low mass per seat EMUs can be introduced which can eliminate MSR locomotive hauled trains in favor of lighter HSR or VHSR EMUs, with powered axles over the length of the train (e.g. Siemens ICE – 3 Velaro, up to 330 km/h. (Illustration 11); the current French TGV HSR single level and duplex EMUs are routinely capable of 320 km/h.(197mph), or Bombardier's (single level) Zefiro VHSR EMU, with a design speed to 380 km/h max. (228mph). This EMU currently provides high speed service between Rome and Milan.

Illustration 12: The ZEFIRO, a VHSR EMU built by Bombardier for a new Italian VHSR line linking Rome and Milan. This train has a maximum design speed of 380 km/h.(228mph)

(viii) Energy Efficiency

The most important aspect of energy efficiency and a key measure of comparative cost- benefit of electric locomotives operating on electrified lines and diesel-electric locomotives operating on non-electrified DE systems, is the extent to which electric trains are able to use the electricity available to their axles most efficiently and on a continuous basis. In this respect, diesel – electrics can never perform at the system efficiency levels of pure electrics as long as rail traffic on electrified lines is able to efficiently use available electricity, 24 / 7 / 365, or close to this level.

Consequently, electrified railways and their traffic flows must be organized so that electricity supply and demand is as close to a continual state of balance as possible, around the clock and throughout the year. The following example may illustrate:

Case I:

A diesel electric (DE) locomotive operates at a system efficiency of 14 – 23% [24] (See Table 2) (i.e. only 23% of the total potential energy of the locomotive as a power system is ultimately powering the axles of the locomotive). These system efficiency figures are constant for DE powered trains in eastern Canada, but operate at even lower values (est. 13%) west of the Manitoba-Ontario border, when depending on tar sands derived fuel. These figures hold consistantly, regardless of the number of trains per unit time traveling on a particular line, since each DE carries its own diesel –electric generating station and fuel supply on board, making it independent of the number of trains on a particular railway track.

Case II:

An electric locomotive is capable of operating at much higher system efficiency (e.g.. 75-78%) [25] Table 1) (i.e.78% of the potential electrical energy generated by a fixed power station is available nearby to power the axles of the electric locomotive). However system efficiencies are not constant, but depend on ensuring a continuous balance between electricity supply and demand, and also ensuring that this balance is scheduled, monitored and sustained 24/7/365. In this way, no electricity potential need be "wasted" or lost either through overhead catenaries or at electrical substations due to rail traffic flows and 24 hour traffic loads having been inefficiently planned, carelessly scheduled, or poorly coordinated.

Let us consider a more specific example:

Assume that a 1200 km. double track electrified line is fully utilized in terms of traffic volume and that supply and demand for electricity is in continual balance. Then the system should be able to run at least three passenger or freight trains/hour in each direction over its entire length, [assuming reasonable lengths of train and weight of cargoes] i.e.72 trains/track/24 hour day or 144 trains/day, on both tracks, at CSR or slightly higher speeds. All of these trains, would use only 500 MW of sustainable electricity (e.g. hydroelectric power, hydrokinetic tidal power, wind power with off peak energy storage, etc.) over the entire rail line, or approx. 50 MW/120 km. of electrified railway corridor. By comparison, a DE fossil fuel dependent double track railway system would require at least 1500-2000 MW of fossil fuel generated electrical energy to power the same total traffic loads over the above 1200 km. corridor.

Clearly, the notion of energy system efficiency and carefully coordinated traffic planning is central in designing a successful electrified railway in which available electricity is efficiently used.

Traffic on a line need not be all long distance or short distance passenger trains, fast freight trains, commuter trains, or RORO truck transport trains. Instead, there must be a carefully programmed, scheduled and balanced flow of electrified railway traffic, running on a corridor 24/7/365, in order to ensure efficient use of available electrical energy (at reasonable cost), and also ensure efficient use of available railway infrastructure.

In terms of the physical economy of rail transport, a single well designed electric locomotive can outperform a DE locomotive by a factor of at least 3:1 [26]. The following example further illustrates comparative DE and electric locomotive productivity.

A single, high performance, diesel electric freight locomotive (e.g. GMC, SD75 - 4300 hp. (3200kw. Weight: 178 tonnes Design speed 70 mph. (113km/h.), currently seen on many CN lines in Canada, can pull at least 500 ton miles of cargo/gal of fuel. By comparison, a single electric locomotive (e.g. Siemens Transportation Services, Eurosprinter model – 8575 hp. (6400kw). Weight 86 tonnes Design Speed 142 mph (230km/h.), currently seen on both passenger and freight railways across Austria, Germany, Hungary, Italy, Poland, Slovenia and Switzerland, can pull in excess of 1600 ton miles of cargo/gal of fuel (in electrical energy equivalent) and at faster speeds than the NA locomotives [27]. (Illustration 13)

(ix) Traction Efficiency

Another aspect of performance efficiency in comparing DEs with electric locomotives has to do with the comparative traction efficiency (wheel on rail friction) of DEs vs electrics. The evidence is clear that electrics can outperform diesels in terms of their ability to pull, push, start, accelerate, move more smoothly, decelerate and stop more precisely, under virtually all weather conditions.

The improved traction efficiency of electric locomotives facilitates faster running times, better stops and starts for loading and unloading, improved acceleration and deceleration, reduced wear and tear on railway infrastructure, reduced wear on wheel flanges and brake systems, and improved night and day comfort levels for both passengers and train crews on faster passenger and freight rolling stock.

Illustration 13: Comparison of Two CN GMC DE freight locomotives, (4300 HP each). Design speed: 113 km/h. (70mph.) on a mixed use CSR line, Copetown, Ontario. –vs- a single Siemens ”Eurosprinter” electric locomotive, (8575 HP). Design speed: 230 km/h. (142mph), capable of multiple working on both passenger and freight operations, including RORO on CSR, and fast passenger trains, shown on an CSR line, near Innsbruck, Austria.

APPENDIX 9: SOME IMPORTANT ISSUES FACING CURRENT DE AND COMMUTER ELECTRIC RAILWAY OPERATORS

(1) Slower acceleration and less smooth traction for starting, acceleration and braking under all weather conditions on diesel-electric powered railways and commuter lines.

(2) Lack of common elevation above the rails, between passenger coach floors and station platform heights. This problem, carried forward from the age of steam, increases time delays in boarding or disembarking from stopped passenger trains in rural and suburban locations. In Montreal, the AMT (Agence Metropolitaine de Transport), possibly as an interim strategy, has introduced 2 sets of doors on its recently acquired EMUs, in order to address the problem of extreme variations in platform heights between Montreal's Central Station. One set is located toward the middle of the coach, flush with the rail coach floor and for higher Central Station platforms. Conventional doors and steps exist at the ends of each coach for use in suburban stations, where one must climb down many steps to ground level platforms.[28] (Illustration 8,). However, the additional safety risk, time loss in efficiency, as well as the loss of seating space within each coach, resulting from this compromise is significant, A passenger or commuter rail line with up to 15 stops, having an extra 2 minutes per stop to allow passengers time to line up and climb up or down the coach steps can mean an extra 30 min. per travel trip, while an additional 3 min. per stop can mean up to an additional 45 minutes per travel trip, measured from the end of a commuter line to the train's final destination.

(3) Difficulty in stopping DE passenger trains or DMUs, at precisely the same place within a station area (as is done in many stations in Europe or Asia in which electric trains or EMUs are widely used), makes it more difficult to direct passengers (with their luggage) to wait at a designated location along a station platform in advance of their train's arrival and departure. This can sometime result in many minutes of unnecessary delay at station stops, as boarding passengers run back and forth with their luggage along crowded platforms trying to locate the correct entry point for their particular coach and seat.

(4) Railway grade crossings which are not safely protected with fences and crossing gates, or which have insufficient grade separations at important level crossings, increase the risk of accidents. In recent decades, this has been an important factor in bringing about major reductions in maximum allowable operating speeds for both DEs and electrics in Canada, Australia, Asia, and the US. In instances in which railway lines could otherwise easily handle intercity express trains at speeds of 211 – 237 km/h., with the use of tilting technologies, train operators have been ordered by transport safety regulators to not exceed 144 -160 km/h., due to serious potential accident risks at many unprotected or inadequately protected level crossings.[29]

(5) Insufficient fencing and other security measures along rail ROWs increases the incidence of wildlife, domestic animals, and humans getting onto active rail lines and being accidently killed or injured.

Since at least 3 of these points apply to DEs, as well as electric trains, these issues can be addressed, before electrification is introduced. This would improve operating speeds and safety for both cargo and passenger traffic, regardless of when electrification is implemented.

TABLE 5: Distance and Non Stop Travel Times between Major Urban Centers in Canada Under Four Assumptions of Speed (e.g. CSR, MSR, HSR and VHSR)

CITY 1 & PROVINCE	CITY 2 & PROVINCE	DIST (KMS)	TRAVEL CSR.	TIME MSR	(HRS) HSR	VHSR
HALIFAX, N.S.	MONTREAL, PQ.	1280	8.00	5.00	4.25	3.8
HALIFAX, N.S.	MONCTON, NB.	225	1.40	0.88	0.75	NA
HALIFAX, N.S.	FREDERICTON,	471	2.94	1.85	1.57	0.80
FREDERICTON, N.B.	QUEBEC, P.Q.	579	3.67	2.27	1.93	NA
MONCTON, N.B.	BATHURST, N.B.	200	1.35	0.79	0.67	NA
BATHURST, N.B.	RIMOUSKI, P.Q.	175	1.59	1.09	0.75.	NA
RIMOUSKI, P.Q.	RIV. DU LOUP	100	0.63	0.39	NA	NA
RIMOUSKI, P.Q.	MONTREAL, P.Q.	600	3.75	2.35	2.00	NA
RIVIERE DU LOUP, PQ	QUEBEC, P.Q.	180	1.13	0.71	0,60	NA
RIVIERE DU LOUP, PQ	MONTREAL, P.Q.	500	3.13	1.96	1.67	NA
MONTREAL, P.Q.	OTTAWA, ON.	203	1.37	0.80	0.68	0.56
MONTREAL, P.Q.	KINGSTON, ON.	272	1.70	1.07	0.96	NA
MONTREAL P.Q.	TORONTO, ON.	590	3.69	2.31	1.97	1.64
MONTREAL, P.Q.	HAMILTON, ON.	640	4.00	2.51	2.13	1.78
OTTAWA, ON.	TORONTO, ON.	399	2.49	1.56	1.33	1.11
OTTAWA, ON.	HAMILTON, ON.	450	2.81	1.76	1.50	1.25
OTTAWA, ON.	SUDBURY, ON.	460	2.86	1.80	1.53	NA
SUDBURY, ON.	SLT.STE.MARIE	302	1.89	1.18	1.00	NA
HAMILTON, ON.	SUDBURY, ON.	438	2.74	1.72	1.46	NA
OTTAWA, ON.	QUEBEC, PQ. .	482	3.01	1.89	1.61	1.34
TORONTO, ON.	SUDBURY, ON.	400	2.50	1.57	1.33	NA

NIAGARA FALLS,	SUDBURY, ON. .	495	3.09	1.94	1.65	NA
NIAGARA FALLS, ON.	WINDSOR, ON. .	365	2.28	1.43	1.22	NA
MONTREAL, PQ.	QUEBEC CITY	263	1.64	1./03	0.88	NA
KINGSTON, ON.	TORONTO, ON.	318	1.99	1.25	1.06	NA
KINGSTON, ON.	LONDON, ON.	400	2.50	1.57	1.33	NA
KINGSTON, ON.	OTTAWA, ON.	82	0.51	0.32	NA	NA
TORONTO, ON.	WINDSOR,ON.	360	2.25	1.41	1.20	1.00
WINDSOR, ON.	QUEBEC, PQ.	1184	7.40	4.64	3.95	3.29
WINDSOR, ON.	RIV. DU LOUP	1356	8.47	5.31	4.52	NA
SLT. STE MARIE, .	THUNDER BAY	705	4.41	2.76	2.35	NA
THUNDER BAY, .	WINNIPEG,MB.	697	4.36	2.73	2.32	NA
TORONTO, ON.	K-WATERLOO	105	0.66	0.41	0.35	NA
TORONTO, ON.	LONDON, ON.	185	1.16	0.73	0.62	NA
TORONTO, ON.	THUNDER BAY	1407	8.79	5.52	4.69	NA
TORONTO, ON.	SUDBURY, ON.	400	2.50	1.57	1.33	NA
SUDBURY, ON.	THUNDER BAY	1007	6.29	4.00	3.36	NA
THUNDER BAY	WINNIPEG, MB	695	4.28	2.69	2.28	NA
MONTREAL, P.Q.	WINNIPEG, MB	2391	14.94	9.38	7.97	6.65
WINNIPEG, MB.	REGINA, SK.	578	3.67	2.27	1.93	1.61
SUDBURY, ON.	WINNIPEG, MB.	1704	10.65	6.68	5.68	4.73
WINNIPEG, MB.	CALGARY, AB.	1259	7.87	6.35	4.20	3.50
WINNIPEG, MB.	MELVILLE, SK.	448	2.79	1.75	NA	NA
WINNIPEG, MB.	SASKAON, SK.	783	4.89	3.07	2.61	2.18
WINNIPEG, MB.	EDMONTON , AB.	1314	8.21	5.15	4.38	3.65
TORONTO, ON.	WINNIPEG, MB.	2104	13.15	8.25	7.01	5.84
MELVILLE, SK.	SASKATOON, SK.	335	2.09	1.31	NA	NA

SASKATOON, SK.	EDMONTON, AB.	531	3.32	2.28	1.77	1.45
REGINA, SK.	SASKATOON, SK.	259	1.62	1.02	0.86	NA
EEGINA, SK.	SWIFT CURRENT	166	1.04	0.65	NA	NA
SWIFT CURRENT , SK.	MEDICINE HAT AB.	219	1.37	0.86	NA	NA
MEDICINE HAT, AB.	CALGARY, AB.	299	1.87	1.17	1.00	NA
REGINA, SK.	CALGARY, AB.	770	4.87	3.02	2.57	2.14
EDMONTON, AB.	JASPER,AB.	364	2.38	1.45	1.24	NA
JASPER, AB.	KAMLOOPS, B.C.	452	2.82	1.77	1.51	NA
KAMLOOPS, B.C.	VANCOUVER, .	400	2.50	1.57	1.33	NA
CALGARY, AB.	EDMONTON, AB.	309	1.93	1.21	1.03	0.80
CALGARY, AB.	KAMLOOPS, B.C.	478	2.99	1.88	1.59	NA
.CALGARY, AB..	VANCOUVER, .	1080	6.96	4.24	3.60	3.00
EDMONTON , AB	KAMLOOPS, B.C.	823	5.14	3.23	2.74	NA
EDMONTON , AB.	VANCOUVER,	1223	7.64	4.80	4.08	3.40
EDMONTON , AB.	PRINCE RUPERT	1462	9.14	5.73	4.87	NA
JASPER , AB.	PRINCE RUPERT	1091	6.82	4.28	3.64	NA
JASPER , AB.	PRINCE GEORGE	386	2.41	1.51	1.29	NA
PRINCE GEORGE ,BC.	PRINCE RUPERT	706	4.41	2.77	2.35	NA
PRINCE GEORGE, BC.	KITWANGA, B.C.	483	3.01	1.89	1.61	NA
KITWANGA, B.C.	PRINCE RUPERT	243	1.52	0.95	0.81	NA
EDMONTON, AB.	KITWANGA, B.C.	1219	7.62	4.78	4.06	NA
EDMONTON, AB.	PRINCE GEORGE	757	4.73	2.97	2.52	NA

NA : Not available or not applicable in these sections.

TABLE 6:
SELECTED CITIES IN WHICH ELECTRIC TRAINS LINK CENTRAL AREAS WITH THEIR AIRPORT TERMINALS.

CITY	STATE	AIRPORT	APROX DIST.KMS.	TIME MINS.	SYSTEM TYPE
Amsterdam	Holland	Schiphol	15	17	2
Atlanta	Georgia	Hartsfield-Jacksn	15-20	20-25	1
Barcelona	Spain	El Prat	18	20	2
Brisbane	Australia	Brisbane Interntl	<10	15	1
Cologne	Germany	Cologne, Bonn	8	10	2
Frankfurt	Germany	Rhein-Main	25	11, 25	3, 2
Kowloon, HK	China	Chek Lap Kok	20	20	3
London	England	Heathrw/ Gatwik	23, 40	25, 40	1, 2
Madrid	Spain	Barajas	8,10	12, 15	1
Mexico City	Mexico	Mexico Interntl	8	20, 25	1
NYC/Newark	New Jersey	Newark Interntl	15	30	2, 3
Oslo	Norway	Gardermoen	46	25	2, 3
Paris	France	Chas. De Gaulle	40	30	1
San Francisco	California	SF Internl	15	20	3
Singapore	Singapore	Changhi	10	20 – 25	1
Stockholm	Sweden	Arlanda	42	15	3
Tokyo	Japan	Narita	80	36	3
Wash., DC.	USA	Reagan Interntl	5	15	1
Vienna	Austria	Schwiechat	30	30,15	1, 3
Vancouver	Canada	Vanc. Interntl	12	26	3
Zurich	Switzerland				4, 2, 3

SYSTEM TYPE LEGEND
(1) Full Subway Train – FST
(2) Electrified Rail Passenger Train ERPT
(3) Custom Designed High Speed Passenger Train – HSPT
(4) LTR or Tram