Transportation Infrastructure and Regional Development in Northern Manitoba:

Realities and Prospects

by

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Abstract

The relationship between transportation and economic development is well documented. Two requirements indispensable to this relationship are access (ability to reach a place) and connectivity (relationship of the place to others). The interaction of people and markets via transportation infrastructure facilitates trade and increased social interaction; all vital for development.

This thesis examines the nature of access and connectivity of the multi-modal transport network (i.e. road, rail, water and air modes) of Northern Manitoba, a study area characterized by many small communities distributed in a vast area, with some having no year-round overland access, forcing them to rely on the seasonally constructed winter road system.

Models of the four modal networks (graph theory) are used to analyze the transportation network's structure, accessibility and connectivity for specific points in time with a view to understand network change. Recommendations are offered that would facilitate the integration of transportation planning.

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1.0 Introduction

To reiterate a cardinal rule: transport is a fundamental process of movement, influencing societies, countries, communities and individuals: with it, progress ensues; without it, societies stagnate. Movement allows for connectivity; for example, of people who wish to interact at a social level, of buyers and sellers in the marketplace and for the day-to-day satisfaction of one's basic needs while functioning in a modern economic system. Transport figures prominently in the literature pertaining to economic fundamentals, growth and development theory, since this connectivity, the ability to move people or goods from one spatial point to another, underpins both social and economic relations. The general importance of transport and connectivity is widely appreciated, but it is in the manner of how the transformative effects of transport are harnessed to derive its economic benefits where differences in opinion, approaches and outcomes arise in the literature.

In the field of economic geography, the role of transport in processes of regional economic development is well documented, although the exact manner by which this occurs is debatable. Transport is widely regarded in the economic, geographic and planning literature as affecting basic relationships such as supply and demand, extents of markets, and the somewhat more difficult concepts of economic potential, or opportunity, afforded by connectivity and access. Hoyle (1973: 9) characterizes the relationship between transport and development as follows:

> The interaction between the level and pattern of transport resources and the average level of living in a population of an area is a critical factor affecting economic and social progress, and must be taken into account at all stages of national and regional development planning…even in the remote and least developed of

inhabited regions, transport in some form is a fundamental part of the daily rhythm of life.

Thus, at the core of the relationship between transport and development, primacy is given to the need for movement, both of goods and people, to achieve increased levels of economic activity. It is the physical, enabling infrastructure, which allows for the accessibility of place and connectivity of markets and people.

In the Province of Manitoba, specifically in the northern extents of the jurisdiction, the land transportation network (i.e. road and rail) exhibits a largely north-south spatial orientation and relationship. In addition, there are numerous communities in the northern region which do not have year-round road access, are accessible only by rail, or are heavily dependent on air access. The widely varying degrees of access accompanying this state of affairs pose significant hurdles, or even barriers, to connectivity, and therefore, by extension, to the potential for economic development.

Each of the four major modes operating in the region (road, rail, water and air) has its own characteristics that are reflected in passenger and freight movement, underlying economic structures, specialized enabling infrastructure, and relative comparative advantages over other modes for specific applications.

The Provincial Government has articulated policy and has undertaken major transportation planning initiatives that, if or when fully implemented, will substantially increase the breadth of the road transport network, providing year-round overland access and connectivity to many remote communities. None of these is explicitly related to the development of an industry or productive activity; rather each is being planned under the heading of transportation equity, accessibility, connection with south and the desire to not solely rely on winter roads and aviation for sustaining remote communities. In turn, improved access may induce industrial development (as the public infrastructure may play a permissive role). The potential future change in the network may be examined empirically to offer insight into the access and connectivity. The networks in the other modes (rail, water and air), must be examined as well, although future network configurations and plans for expansion or significant alteration are not readily attainable (as they are often commercially confidential until public announcement). Undoubtedly, however, comparison of the historical and current networks will provide some insight.

1.2 Objective of Research

Access and connectivity are fundamental preconditions for economic development. Geographic techniques can be used to create representative models of spatial transport networks to quantitatively describe, measure and analyze specific aspects of the transportation network structure and connectivity. With that in mind, the objectives of this research can be summarized as:

1. To selectively review the literature pertaining to the relationship between transportation and economic development.
2. To survey the relative benefits and disbenefits of the four major modes of transportation.
3. To succinctly describe the current state of the multi-modal transportation network in the study area of northern Manitoba.
4. To undertake an applied analysis of the multi-modal transportation network, using graph theory techniques (for historical, current and future networks).

5. On the basis of the results of the applied analysis, to interpret the results and suggest implications for integrated multi-modal transportation planning.

Upon placing the above in context, it is evident that this thesis explores the following two overarching questions:

1. How may the future transportation network affect the accessibility and connectivity in the study area (in relation to the past and the present)?
2. How may investments in particular modal infrastructure influence the ease of movement of people and goods, and how may the four modes relate to each other, if at all (i.e. degree of multi-modal integration)?

Answers to the above are expected to follow from the testing and analysis of the following research statement:

> The modelled transportation infrastructure expansion will produce greater degrees of access and connectivity than the existing (2010) transportation infrastructure present in the study area of Northern Manitoba.[1]

Implicit in this assertion is the proposition that greater levels of transportation access and connectivity will promote increased opportunities for regional economic development.

Before any conclusions can be drawn, it is necessary to begin with fundamentals, namely the importance of transport in the entire development / social well-being nexus. To

[1] This future modelled transport infrastructure is based on published documentation pertaining specifically to the East Side Lake Winnipeg and the Manitoba-Nunavut Road. Although all four modes (road, rail, marine and air) are modelled and investigated (Chapter 5), only the road mode has current available documentation regarding future network expansion.

that end, the relationship between transport and development needs to be established in a broad theoretical setting.

1.3 General Organization

Chapter Two undertakes a literature review focusing on the relationship between transport and development that draws on selections from the disciplines of geography and economics. The review is structured in a two-fold fashion. First, the general relationship between transport and economic development is reviewed and focus is given to the common, fundamentally recognized economic principles which transport directly affects. These include the division of labour and economic specialization, supply and demand relationships and the extents of markets. Secondly, the literature review turns to particular topics informing the role of transport in economic development.

Chapter Three provides a comparative overview of the major attributes of the four major transport modes (road, rail, water and air). Appreciating the comparative strengths and weaknesses of the four modes, including the infrastructure requirements for their use and the means of conveyance (i.e. units of carriage) and the required infrastructure for operation (i.e. the linkage (or way), and the node (or terminal)) is crucial. Indeed, that appreciation extends to the fundamental economic and spatial relationships of modal operation, and the relative strengths and weaknesses of a given mode vis-a-vis other modes. This chapter provides a review of the four modes structured along the lines of a basic two-part rubric in each instance. First, a general discussion on the modal requirements is provided. Secondly, an overview discussion concerning the basic economic and spatial considerations that influence modal operation and geographic distribution is outlined.

Chapter Four begins to set the stage for the modelling and analysis in subsequent chapters by defining and examining aspects of the study area in Northern Manitoba. The current transport network is described by mode and salient aspects are reviewed.

Chapter Five details the methodology and application used for the analytical component of this study. A brief introduction to graph theory is provided, which leads to an explanation and discussion of the associated indices used in the analysis to ascertain the connectivity of the multi-modal northern transport network and the accessibility of the nodes within it.

Chapters Six through Nine are devoted to the modelling and analysis of each of the four modes: road, rail, water and air, respectively. A common framework is employed for each modal investigation (where feasible), which requires the examination of a current network, an historical network, a referential comparator network and a future network. The road and air modes enjoy the most comprehensive coverage on account of their historic, current and future breadth. Conversely, the examinations of the water and rail modes are more succinct as both modes exhibit a lesser degree of historic and likely future expansionary network activity.

Chapters Ten and Eleven offer a review on the topics of climate change and sustainability respectively. The issue of climate change is reviewed and potential impacts on the transport infrastructure within the study area are highlighted. The discussion on sustainability explores two sub-topics, those of community sustainability and environmental sustainability, as any discussion of transport infrastructure development must address these factors.

Lastly, Chapter Twelve will take stock of the results of the discussion and analysis contained herein, and draw conclusions based upon the results derived from the analysis. These conclusions, in turn, inform recommendations aimed at furthering transportation planning in this remote region, planning vital for its ongoing development.

2.0 Literature Review: Relationship between Transport and Development

The basic movement of people and goods has been a primary factor in the historic development of economies, nations and civilizations. This chapter will focus on three relationships upon which transport may be shown to exert significant influence. These relationships are elementary, but nonetheless fundamental to understanding the dynamic between transport and economic development. Although the transport – economic development relationship is generally acknowledged, fully understanding the nature of the relationship remains a constant challenge for those in this field. Transport, and its supporting infrastructure, allows for the production factors (typically private) in a region to increase their productivity. In “proper combination” with other factors such as labour and capital, transport has been noted as being the driver for regional economic development (Rietveld and Nijkamp, 1992: 1).

Milne (1963) acknowledges that the function of transport is not as straightforward as it may first appear and that understanding the problems associated with simple movement are some of the most difficult for the field of economics. Similarly, the underlying motivation for the existence of transport has been noted to be the need to overcome the physical distance between producers-consumers, buyers-sellers, or other entities that demand interaction, but understanding the way that these interactions affect locational decisions are complex (McCarty and Lindberg, 1966). That is to say, while the importance of transport’s function in positively affecting economic development is widely accepted, it is in the details of how the mechanics of transport actually exert this transformative power where the uncertainty arises. Rather perversely, as will be discussed further in the review, transport can be seen to negatively affect a local economy. The relationship between infrastructure and regional development is one that has long been studied and remains today a point of interest for researchers and scholars (Nijkamp, 1986; Straszheim, 1972). This is all the more necessary because the use of transport in development schemes has at times been motivated (to varying degrees) by considerations other than rational economic decision-making and a desire for optimal use of capital and resources.[2]

Transport's ability to affect this transformative economic change is generally acknowledged in the fields of transportation and economic geography and planning. Authors such as MacKinnon *et al.* (2008: 10) note that the association between the quality of transport and its required infrastructure, and the level of economic development is "clear and widely accepted", and that in economically developed areas, the connections of the transport, the geographical reach of the modes, generally render fewer locations inaccessible. MacKinnon adds a cautionary note to that association by asserting that while the contrasts between transport in developing and advanced economies can be made, "explaining how they occur is a far more demanding task".

Strazheim (1972: 212) contends that it is this "possibility", or potential for transport to affect regional development that has "long enticed regional economists", and this is clearly demonstrated in the central role of transport in locational theories (of the firm, household location and so on) and the role of comparative advantage in trade theory. This "possibility" that transport is perceived to embody is confirmed in many instances by history, inspiring many to make it a primary factor in planning for economic development of cities, regions and

[2] These considerations may be held to be those of regional, transport or economic development policy. Although this subject matter is not the focus of this inquiry, several of the authors reviewed in the literature selection explicitly discuss the policy aspect, such as: Button (1982), Hilling (1996) and Nijkamp (1986).

nations. Abramovitz (1955: 173), in his sketching of a common framework for analysing the effect of railroads on economic development, asserted that in some cases (such as Western Europe, the United States and several British dominions) these “possibilities” were “dramatically realized”. Likewise, Jackman (1935) in his review of railway development in Canada notes that the role of transportation facilities is paramount in the development of every country, and in the case of Canada, not only allowed for the initial settling of the territory, but its subsequent advancement.

The transformative impact of transport on economies extends beyond merely the theoretical, as it has practical importance (Hoyle, 1973). One must not solely view transport as a series of economic choices and relationships at play in a spatial context. There exist many practical aspects not directly economic such as those bearing on social functions (allowing for the separation of work and residence, to say nothing of social interconnections and for satisfaction and enjoyment) and strategic importance and functions (such as national defence or for political gain)(Senior and White, 1983; Milne, 1963; Troxel, 1955).

When thinking about transport in general, then, one is cautioned to avoid narrowly focusing on the theoretical economic relationships, or the spatial relationships observed or identified. Clearly, there exist other influencing factors motivating the need for transport, investment in transport infrastructure or policy related to transport in a jurisdiction. The degree to which these other factors influence actions in the marketplace, capital investment or policy setting, need to be appreciated in order to provide a balanced analysis. For instance, the use of transport for political ends is widely acknowledged in the literature (White and Senior, 1983; Hilling, 1996; Gauthier, 1970; Jackman, 1935).[3]

The literature reviewed may be generally situated within the fields of economic and transport geographies. An overview of the salient features of the two is beneficial. McCarty and Lindberg (1966: 6) describe the purpose of economic geography, in general, as the study of the locations of activities which have an economic character and note that it is used to explain the location of economic phenomena. This approach allows one to investigate economic processes in relation to a spatial point of reference. Chisholm (1970: 183), in a review of pricing policies, argues that a reason that transportation is central to the literature on the subject of locational theory and analysis is that it has long been recognized as a primary factor in determining geographic patterns.

An economic geographic perspective as described above can be contrasted with the more traditional economic approach to transport study, which as Button (1982) notes, the main tool used is rooted in standard microeconomic theory with the focus on the economic problems of moving goods and people. Troxel (1955) provides an understanding of the transport process from an economic perspective: it is an integrative process, connecting people and things in one spatial location with other people and places. Transport is predicated on relationships which have a spatial orientation. It is in the identification and interpretation of these economic relationships in a spatial context at a given point in time when an economic geographic approach can be particularly informative.

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[3] It should be noted that the road and rail modes differ in that, in the North American context, highways are typically government owned (although various arrangements for building, financing and operations exist), whereas rail is typically privately owned (although government concessions, such as preferential financing arrangements, or land transactions have historically aided the private capital investment).

As mentioned, Troxel (1955) characterizes the economic meaning of transport as an integrative process, integrating people and things in one spatial place with those in one or more other spatial places. Through this integration, relationship, or connection between spatial locations is achieved, the result of a transportation process linking the two points, along a route or link, typically employing some form of transport technology. White and Senior (1983: 1) note that transport, which is a derived demand, creates “utilities of space” and is economically motivated. Spatially, there will be areas of surplus and deficits (of commodities or services) and the volume of supply and demand will affect the pricing of a desired exchange, and there will be a cost to physically transport the good between two points to satisfy the transaction.

Taaffe and Gauthier (1973: 1), major figures in the geographic field of spatial analysis, characterize three general concerns or interests of the transport geographer. First, they are concerned with linkages and flows which form a given network; secondly, they focus on the centres (or nodes) which connect these linkages; and thirdly, they assess the totality or summation of these linkages and centres which form relationships in the systems or networks (and in particular the emergent hierarchical structures which may be identifiable in these networks, such as hinterlands).[4] The transport geographer is concerned with the organization of an area, in particular attempting to understand and explain the processes which have produced the spatial structures under investigation.

[4] A discussion on linkages, flows, nodes, and so on, will be undertaken in Chapter 5 of the thesis which reviews the graph theory approach (the methodology section). Therein the usage of this terminology will be defined for the purposes of the analysis.

Hoyle (1973: 9) draws a distinction between the approach of the economist and the economic or transport geographer. He contends that the economist is largely concerned with the assessment of demand and the pricing, or costs of overcoming distance. However, from a geographer's perspective, the viewpoint on the subject shifts slightly, from a stress on costs and prices to a concern for how transport affects the spatial location, or distribution of activities, both social and economic. That stated, Hoyle does note that geographers and economists are both concerned with the impact that transport, and improvement in transport facilities, can have on development, and that both disciplines have attempted to assess this relationship.

White and Senior (1983) describe the importance and interest of transport for geographers as being of a three-fold nature. First, the basic human nature of the activity, which has a definitive spatial component, is of interest. Secondly, as a movement in space, it produces variations and influences both economic and social activities. Thirdly, a geographic approach is suited to the analysis and understanding of the technological role that evolving transport systems play over time in the influence of the spatial factors aforementioned. For them, analysis of transport may provide a basic means to help explain spatial patterns, especially when multimodal transport facilities are viewed or analysed through a systems approach. It is the spatial movement which is of particular importance, as transport is a derived demand; that is to say, for reasons other than pure pleasure, transport is purposive, as it typically incurs a cost (which may be monetary, time, or energy expenditure). It has been noted that in recent decades the fields of economic and transport geographies have diverged from one another, in spite of the "manifold connections between them on the ground" (MacKinnon *et al.*, 2008).

Transport, at one and the same time, is multidimensional. That is, it has a physical dimension (the movement from point A to point B), a technological dimension (the mode used) an economic dimension (the cost associated with movement) and lastly it may be appropriately viewed in a spatial dimension (where does the transport occur). Herein lies the crux of the approach of transport geography: it is not bound to any set of approaches or tools prescribed by academic tradition. The geographer may look at the economic, social or political aspects of the study area in an integrated fashion, although he does not investigate all of these aspects, only the ones that have a spatial expression (Taaffe and Gauthier, 1973).

2.1 Fundamental Principles of the Relationship between Transport and Economic Development

It stands to reason that the core relationships which require or necessitate linkages, centres and networks require understanding and explanation. For it is an understanding of these economic phenomena and relationships which produce the need for transport at any scale, be they local, regional, national or international. Troxel (1955) describes the evolution of linkages, centres, networks and dominant points within these systems as a legacy-product of the historical transport relationships and technical forms of transport and other influencing considerations such as those which were politically or militarily motivated. The role of historical population settlement as a result of transportation is notable, and the subsequent location of population centres on road and railway lines is well documented. It is important to recognize that past decisions regarding transport routes and technologies to some degree influence the existing levels and layout of transport networks (White and Senior, 1983). Wilson (1970) notes the various means in which improved transportation is expected to exert a positive influence: namely in the form of political unity, social cohesion, economic growth, specialization, price stability and the more difficult to measure factor of attitudinal change. Conversely, it is noted (as was remarked earlier in this chapter) that transport can exert a negative effect on the aforementioned factors as well.

A review of the three fundamental relationships will allow for better understanding of how transport, and in particular freight transport, provides opportunities for realizing greater efficiencies through the division of labour and the geographical or spatial separation of productive processes. Transport is crucial to overcoming the distance that is incidental to the division of labour (Button, 1982).

2.1.1 Division of Labour and Economic Specialization

The first relationship is that of the division of labour and economic specialization. The historical formation of dominant centres of influence within networks may often be attributable to the historical role of transportation and the particular method of transport employed during the formative period. The development and harnessing of subsequent advances in transport technology over time have certainly changed the method by which the transport occurs. Yet, since the primary function of transport is to facilitate movement on the Earth, which has resources and people located heterogeneously upon it, the outcomes have all trended towards improved accessibility and connectivity. Indeed, twentieth-century advances in transport technologies and the accompanying legal, transactional and financial supporting systems, have so revolutionized the former (through the increase in speed and lowering of costs), as to lead some to claim (prematurely) “the death of distance”. It is noted that this has not necessarily reduced the total amount of transport consumed; rather it has transformed the way in which it is used, which is constantly changing (Rietveld and Vickerman, 2004).

Button (1982) provides three main reasons for maintaining that transport is a key influence on the relationship between the division of labour and economic specialization. First, as the earth’s surface is heterogeneous in nature, intuitively this requires movement to satisfy wants and needs (demand), be it personal, industrial, commercial, etc., from other spatially separated locations. Secondly, modern, industrial societies rely on a high-level of specialized production, which requires a diverse array of inputs from various sources and, in turn, an extensive marketplace for finished products. Thirdly, transport allows for the exploitation, or capitalization of economies of scale.

Milne (1963) argues that the economic activity of any society can follow one of two conflicting principles. First, the society can follow the principle of self-sufficiency, or secondly, it can follow the principle of the division of labour which leads to specialization. An economy can be based on the production of a limited number of products, goods or services for itself, or, it can produce a limited number of products, goods or services and supplement the remaining need, or demand, through a process of exchange with an external society or economy. White and Senior (1983) reiterate the fundamental importance of the division of labour, and note that classical economists since Adam Smith have argued that a primary element in the process of economic development is the division of labour and for a limited number of specialized economic activities to be undertaken. The conceptual relationship between capitalizing on an economy's division of labour, and using improvements in transport to overcome distance and extend the range of markets was recognized by Smith two centuries ago (Button, 1982). No economy will be encouraged to specialize through the division of labour if there is not an accessible market of sufficient size to produce the demand required to sustain a particular producer and its output or supply.

The basic division of labour may assume one of two forms. In the first place, there is the simple division of labour (which is also referred to as horizontal specialization) by which labour indeed specializes its production, seeing the production of the particular product through from raw inputs to final finished good, ready for the marketplace. In the second place, a more complex division of labour is implemented (which is also referred to as vertical specialization) by which multiple actors perform specialized and discrete productive tasks on certain elements of the overall productive process of a good (Milne, 1963). The upshot of this from a transport perspective is that, in the case of the former, raw inputs are required to be brought to a location to undergo a productive process, and the finished product requires transport to its final marketplace destination.

Conversely, in the case of the latter, the productive process is performed at multiple spatial locations by various actors, which likely requires transport of the product multiple times through the phases of production, before ultimately being transported in its finished form to the destination market. This is seen in many contemporary productive processes whereby a product may be assembled in several locations around a nation or the world prior to movement to final market. Similarly, multiple actors providing inputs in a productive process, also give rise to the spatial phenomenon of agglomeration of production, where the various actors are located adjacent to each other.

As this occurs, intuitively, some form of transport is thus required to overcome or bridge the distance separating the areas which are specializing in a limited number of productive activities. One can appreciate this general premise applies to the four illustrative scales previously referred to: the local, the regional, the national and the international. Transport is the means by which producers, economies, or areas with surplus can interact with those of deficit in a spatial context.

Jackman (1935), in his extensive work analyzing the role of the railway in the formative development of Canada, notes that, in general, transportation facilities are likely the single most important capital component and that they not only affect the initial stages of a country's development, but persist in exerting significant influence. To illustrate this point, he describes the manner by which the railway in Canada typifies the ability of the rail mode of transport to span the vast territory comprising the nascent country, thereby connecting areas of surplus with areas which presented markets for the goods. The obvious example is the movement of western agricultural products to central Canada in response to the demand exerted by the locus of population in that general region (including its transhipment role to overseas markets). Jackman further notes that it is the exchange of these commodities, and in particular the more effective the means of exchange (such as the efficiency of modal movement), that creates the opportunity for capital accumulation.

A discussion of the division of labour and economic specialization would be remiss were it not to mention an influencing factor in an economy's pursuit of competitive advantage, a factor which White and Senior (1983) term areal specialization. This is an intuitive premise, for physical geographic characteristics (such as topography, climate and weather, vegetational cover and so forth) endemic to a place will likely influence the nature of the productive activities in which the place may engage. This applies more to primary activities such as resource harvesting and processing and less to modern manufacturing which may occur within a production plant not necessarily tied to physical geography of place (such as is the case with microprocessor manufacturing).[5]

Transport allows for the division of labour and therefore specialization of economies. It has been noted as being a "critical success factor" for the competitiveness of regional economies and therefore, missing, or inadequate, transport linkages translate into a reduction in the potential productivity of a regional or national economy (Rietveld and Nijkamp, 1992: 1). Locations relatively disadvantaged in the marketplace are those that are inaccessible, have an inadequate supply of transport to satisfy the demand, or are served by transport which as a component of total cost is overly high for the particular output. A major force in the encouragement or development of specialized economies is available transport which is supportive for the physical movement of the productive good, besides being appropriately priced as a cost factor of the product, to say nothing of being efficient and regular in the physical transport of goods from point A to point B. As an example of failing in these

[5] For a detailed investigation of this phenomenon see Todd (1990).

characteristics, it is not feasible to transport low-value aggregate by air, since this is typically the most costly mode.[6]

2.1.2 Supply and Demand

The economic specialization of activity, which is spatially distributed, therefore leads to a situation in the marketplace where trade is required to satisfy wants in one location with surplus product from another. Since transport is both a derived demand and varies temporally, this feature is implicit in discussion of other factors, remaining the core principle underpinning economic analysis of transport (Button, 1982). The temporal fluctuation may be attributable to factors such as consumer demand, business cycles, seasonality of production, market influences, and the nature of the product. This temporality and fluctuating nature of demand on transport may be illustrated by the movement of agricultural products from producer to market following harvest in the autumn or the movement of consumer goods to retailers in advance of the Christmas season.

McCarty and Lindberg (1966: 168) describe the provision of transport to satisfy the demand of one economy with supply of a good or product from another economy as illustrative of the principle of complementarity. This, they note is "a direct result of the territorial specialization of production". Complementarity may be viewed as the symbiotic relationship between two economies in the satisfaction of their supply – demand requirements. As conceptually developed by Ullman, complementarity is related to two other

[6] A review of the modes (road, rail, water and air) will be provided in Chapter 3 of the thesis, and the benefits / disbenefits of the modal capabilities and characteristics will be provided.

principles: transferability and intervening opportunity, both of which are further discussed below.

This principle of complementarity is predicated on the specialization of production in the respective economies. The production of a good and its subsequent need to be transported to its intended market does not just occur by happenstance, for ultimately all economic production is based on the "delicate relationship of supply-price-demand" (Chisholm, 1970: 137). Transport connects producer and consumer, buyer and seller, importer and exporter, etc., and is not driven purely because a relationship exemplifying the notion of complementarity exists. The consumer, buyer or importer typically has three options to procure a wanted commodity or good: he can purchase a similar good from another seller; he can choose to purchase another good; or he can produce the good himself. Lowe and Moryadas (1975: 10) note that economic differentiation between two locations alone does not produce the need for movement or transport, but it is demand driven (the satisfaction of demand in one location with the available supply of another). This is the basis of what they term specific complementarity.

McCarty and Lindberg (1966) further identify two concepts, which relate the notion of complementarity with the three general options available in the marketplace. The first concept is that of transferability. The cost of the product in question must allow it to be offered at a low enough price to induce the buyers to either not produce the good themselves or not choose to forego obtaining it. In this instance the higher the cost of transport, the lower the likelihood of purchase. Lowe and Moryadas (1975) assert that the transferability of a good is largely based on the real cost of transfer.[7]

The second concept is that of intervening opportunity. If complementarity exists, and the price is favourable, and moreover there exists another source of a similar product, the alternative source may be favoured over the original source (as the price may be lower). Likewise, specific complementarity is not sufficient in and of itself to generate movement, if there is a similar product located closer to the point of demand, or is more easily accessible, even if of inferior quality to the first source, and thus may be preferable because of lower prices. This is referred to as an intervening opportunity and is a negative concept, as it will prevent movement based on specific complementarity (Lowe and Moryadas, 1975). These two concepts are incorporated into the notion of distance decay, which holds that at increasing distances there will be a decline in interactions.

By the late twentieth century, the real cost of transporting goods had been declining for 150 years (Chisholm, 1970: 152). Three main reasons accounting for this are: the shift to more efficient methods of transport (i.e. from horse to rail or truck), technical improvements in the manner of transport (i.e. single horse cart to 100+ car trains with double-stacked shipping containers), and shifts in the value of goods transported (i.e. towards higher unit values, utilizing improved methods). These three factors have allowed for the lowering of transport costs, which takes into consideration and reflects the size of the transport gap (i.e. the distance required to travel) and the means of bridging the gap (i.e. the mode utilized and

[7] Real cost of transfer is akin to total cost of transport (the combination of the fixed and variable costs), that is it includes the price of the transportation, insurance, and other associated charges required to facilitate the transport of a good from one destination to another.

its efficiency) (Milne, 1963). The reduction in general transport costs has therefore furthered the economic extent of markets, an extreme illustration of which is the massive importation of consumer goods to the North American marketplace from East Asian locations in the globalized economy.[8]

The provision of new transport infrastructure, or investments in existing infrastructure improvement, influence both the factors of production and consumption in that a reduction in transport costs may stimulate one of two effects. The first effect is that either exported goods become cheaper, or conversely, imported goods become cheaper (due to the reduction in the cost of transport as a proportion of the final cost of the product at the market).[9] If the cost of exported goods becomes cheaper, this will lead to an expansion of total production (as, theoretically, demand will increase), which will allow for the development of economies of scale and ultimately result in an overall increase in production and employment. This effect is predicated on the notion of complementarity of markets introduced above.

At the same time, the cost of imported goods may become less, which may affect the local production of goods (as they are partially or wholly substituted with imports), which would lead to diseconomies of scale and ultimately a decrease in production and employment (Rietveld and Nijkamp, 1992). Hilling (1996) describes an upshot of transport investment as the potential for an increase in the range of products or commodities which can be moved, together with increased volumes of the same products. Reiterating the notion of

[8] It should be noted that low transport costs are not the only factor influencing the globalized supply-chain. Other major factors influence the final market price of goods at the point of consumption in North America, one of which is the cost of labour and manufacturing as a component of overall price in other export jurisdictions.
[9] Banister and Berechman (2000) argue that transport cost, as a proportion of total cost, is relatively small. Other costs, such as those associated with skilled labour, site of production or manufacturing, amongst others may be more important than transport costs.

diseconomies, the improved transport may allow for the importing of outside goods, which may create a disadvantage for the local economy.

Furthermore, Rietveld and Nijkamp (1992: 4) note that improvements in transportation infrastructure should allow for a regional economy to better use its private production factors (i.e. labour and capital), for the improved levels of transport derived from the improved infrastructure will require lower levels of capital and labour to reach the same levels of production. According to this premise, at the same level of labour and capital input, an economy should be able to increase its production or output, thus accruing benefits. Banister and Berechman (2000: 36), in explaining their conceptual approach to modelling and measuring the impact of transport infrastructure investment and economic development, note that "the most fundamental outcome of an investment in transportation infrastructure is the changes in the relative prices of accessibility of various locations". The price of accessibility will influence the supply and demand characteristics, but as previously mentioned, any analysis of transport, infrastructure and development must also consider the nature of the extant local economy and the various decision-makers active within it.

In their discussion of the historical development of specialization, agglomeration and spatial economies, Lowe and Moryadas (1975: 3) point to the consequences of society's (and the economy's) development from a simple food-gathering economy, to one predicated on sedentary agriculture, to an industrial and now the contemporary post-industrial state. In the context of the latter, they note that the division of labour and specialization of economies are extreme. The amount of interaction between spatial economies has led to the increase and need for movement, which has given rise to multiple modes at one's disposal. Contemporary production, by means of a "multiplicity of minutely specialized economies", has two consequences. First, there is an increasing role for agglomeration economies, and secondly, the importance of internal (to the firm) scale economies increases.[10]

2.1.3 Extents of Markets and Distance

In reality, there are no modern economies which can operate on a model of self-sufficiency. Interactions between several economies must occur to satisfy their particular wants and needs, which require goods or products to be moved between economies and the exploitation of any major economies of scale (Button, 1982). Therefore, economies are dependent on inter-regional relationships and transactions (to varying degrees) and, as Milne (1963: 21) notes, this interdependency create economies which are at the same time complex and delicate in their operation. The movement, or transport required, to create or sustain these inter-regional economies may vary in spatial separation; for instance, agricultural products from a rural area into a major urban area or the international trade of primary commodities or value-added finished goods between nations on different continents.

The division of labour and the specialization it produces have a practical limit, referred to as the extent of the market, which is argued to play a major role in the function of transport. The extent of the market is the volume of demand for the good and it is directly affected by the provision of transport (as this factors into the final market-price of the good),

[10] Lowe and Moryadas (1975: 4) refer to agglomerations as meaning "both the origins and the destinations of massive amounts of movement, or alternatively, they represent the basic elements in spatial interaction". This concept is typically used to describe groupings of certain activities, production processes or services in close proximity to reduce the overall distance required to be travelled and to capture economies of scale. Economies of scale refer to "the differences in the unit cost of production due solely to the differences in aggregate volume of output".

since transport allows the product to be moved to the location of the demand, overcoming the divide between the economies. The smaller the divide or gap between producer and consumer, the more efficient will be the use of transport to bridge the gap, and that in turn will produce a greater market extent (Milne, 1963; White and Senior, 1983). If a major component of a product's final market price is the cost of transport, lengthening the distance transported (for the same cost) or improving transport times or efficiency (reducing the proportion of transport cost to final market cost by economies of scale, methods of shipment, transport technologies, etc.) will allow the extent of the market to be furthered. In the market-place, similar goods may be transported drastically different lengths to a particular location, but due to other inputs in the productive process such as cost of labour, raw materials, tariffs and so on, the market price may be comparable.

The above-mentioned gap may be viewed as a physical separation (distance) to be overcome or in the sense of economic distance. Economic distance looks beyond merely the spatial distance between two given points, and instead is concerned with the cost of transport. Following this logic, economic distance represents the cost of both physically overcoming the producer-consumer gap and the other costs associated with doing so (Milne, 1963). Lowe and Moryadas (1975) describe economic distance in a similar light, that is as a cost, which reflects the amount of energy required to facilitate movement or transport.

Although improved transport systems allow for specialization of economies, alter the supply and demand relationship and extend the accessibility of markets, the literature does draw a clear distinction between the experience of developed nations and that of developing nations. One is cautioned against drawing inappropriate parallels or interpretations between the two contexts as there are significant differences between them.[11] As previously noted, it is generally accepted that improved transport systems will benefit an economy, but in those which are developed, the effect of further improvements is largely unclear, as opposed to those in earlier stages of economic development, for there is a diminishing return on investment (MacKinnon *et al.*, 2008).[12]

In the context of the remote communities within the study area which have sporadic or no overland transport accessibility, there exists a unique situation which is not readily addressed in the literature, this is the relationship between "developing" regions and the "developed" regions within an advanced nation and economy. The discussion of this relationship, and the literature informing the issue, then becomes a hybrid between the two. This lends itself to two parallel, yet very different public policy debates within one political jurisdiction. In terms of transportation, in the southern developed areas there is discussion of modal shift from automobiles to public transit, transportation demand management schemes, and other ways to increase capacity of transportation infrastructure without the increase of additional physical capacity, while at the same time in the northern undeveloped reaches, there is discussion of providing a singular gravel road into a remote community, currently inaccessible by overland transport.

[11] As this thesis is focused on Manitoba, this review and subsequent work will be focused on the literature and information pertaining to economically developed nations.
[12] MacKinnon *et al.* (2008: 20) argue that, in general, a national economy will benefit from a "good transport system". The relationship or question which is "far more ambiguous" is centred on the function or utility of further investment in transport infrastructure in the context of existing high-capacity networks. Their review of the literature leads them to suggest, "the scope for substantial impacts on the economy is relatively limited in such cases, compared to earlier stages of development", in part due to the fact that the provision of additional capacity often leads to inducing additional traffic.

2.2 Perspectives on the Role of Transport and Economic Development

Within the literature on transport and economic development, there are several major perspectives on how the fundamental economic relationships operate. This section will review two of these differences in perspective, deemed especially cogent, and comment on how they are treated in the literature. To begin, the supply-led and demand-led dichotomy will be examined. This has been referred to as the chicken and egg problem, obsessed with establishing which comes first, development or transport (Hilling, 1996). Simply stated, is the availability of transport a prerequisite for economic development, or does the economic development necessitate the need for transport?

2.2.1 Supply and Demand-led Perspectives on Transport and Development

At the outset of this section, it should be noted that much of the writing on the supply and demand-led dichotomy is contained within literature which provide retrospective analyses of transport and economic development in developing countries. Although as aforementioned, this literature review is primarily concerned with the context of developed nations (as the focus of the larger study will be on contemporary Manitoba), the fundamental perspectives on transport and the mechanisms by which it may, or may not, stimulate economic development remain, I will argue, salient. If one were focused on the interaction and effect of transport development in an urban area or region, the drawing of parallels and inference from that body of literature may be inappropriate. Hoyle (1973) notes that in modern or advanced economies, transport planning is to a large degree focused on applying new economic development strategies via a renewal or modification of an existing transport system. Conversely, in developing countries, transport is often viewed as a means to produce rapid economic development. According to that logic, for a study dealing with an area in which there is a dearth of formalized roads, minimal or sporadic opportunity for intercommunity connection and minimal to no overland access to major markets, it is plausible to argue that the differences in perspectives on the fundamentals of transport, while not necessarily conceptually transferable, nevertheless may heighten one's understanding of the basic role that transport plays in spurring development in areas previously regarded as remote or only partially accessible.[13]

Hilling (1996), who is focused on the developing world, posits the dichotomy as one between supply and demand models. In the former case, the supply-led approach typically holds that transport leads to the widening of markets, increased production and positive economic effects. This is a view held by development planners. By their lights, the building of a railroad or the construction or upgrade of a highway will provide the opportunity or possibility for economic development to occur in an area, for its installation allows for market extension, the division of labour and economic specialization, and encourages lower shipping costs and so on.

Conversely, the demand-led approach holds that the provision of transport is in response to demand, and that this demand may be categorized in two major ways; respectively styled revealed and latent. Intuitively, revealed demand is that which exists, the movement of goods currently undertaken; on the other hand, the latent demand (or prior dynamism) refers to that which may exist but is unable to be undertaken owing to an existing

[13] As will be elaborated in Chapter 4, it is conceded that no communities in the study area are completely inaccessible. Yet they are all severely handicapped in terms of economic distance, namely the pricing structure of moving goods and people to and from a community. It is in situations where there is sporadic or limited overland access, rendering aviation as the primary mode of transport (which is also the costliest), that any economic development is likely to be thwarted, unless heavily subsidized.

lack of capacity of the infrastructure or unavailability of transport services.[14] The supply-led approach figured prominently in the classical growth theories (Hilling, 1996). In this instance, it is held that the investment in transport infrastructure will allow the latent or revealed demand to be fully expressed through the increase in productive activities, and when aggregated will move the economy towards the stage of economic "take-off" associated with classical theories of development.

Wilson (1973: 226) concludes that the success of an investment in transportation is dependent on the existence of this prior dynamism, which typically signals an area (be it a region or nation) where opportunities are being actively sought and exploited at the same time. It is situations such as these where investment in transport will likely be of immediate benefit. In contrast, areas characterized by no growth or development are not expected to benefit from the provision of increased accessibility through transport infrastructure. In other words, transport investment "cannot be expected to accomplish much". He further notes that it is much more difficult to initiate economic growth than it is to facilitate the expansion of that which is under way, for the former likely requires investment in a host of factors in addition to transport, including the vital human capital.

In a discussion focused on the economics of transport in the context of the developing world, Button (1982: 248) notes that transport may be seen to have four functions. First, it is an important input factor of production, allowing for the satisfaction of demand with supply and movement of people between spatial areas. This is particularly important for the rural

[14] Conventional transportation systems' engineering and planning is typically focused on revealed demand. Transport infrastructure capacity is ascertained, demands are projected (for normal and growth scenarios) and investments are made in the facilities in response to the estimated demands (i.e. highway expansion, addition of rail sidings, etc.)

agricultural areas as it enlarges the market for their products and may bring the producers into a monetary economy. Secondly, transport can alter production factor costs, as when reduced stocks of inventory are required to be kept at the ready. Thirdly, transport allows for increased mobility of labour, ideally to areas where it is most needed. Fourthly, transport improves the wellbeing of individuals in society, the upshot of improved access to social services.

Rietveld (1989) describes this dichotomy as either a passive or an active strategy towards infrastructure investment. In the passive context, infrastructure follows private investment (i.e. provision of increased roadway capacity due to increasing industrial production in a particular area). However, in the active context, infrastructure leads private development. This is the case when a government uses transportation infrastructure as a tool of regional development, which as Reitveld cautions, can have disappointing results if the private sector fails to respond to the proffered incentive. A simplistic example of this is if a jurisdiction provides transport access and municipal servicing to a “greenfield” parcel of land in an attempt to induce industrial or commercial development and the private developers fail to build at the location, firmly unconvinced of its merits.

At the very least, the literature concedes that transport may act as a *sine qua non* for economic development; that is to say, it is an indispensable component in the overall equation, although its relative importance may remain debatable. Thus it is safe to assume that economic development needs transport, to a greater or lesser degree.

2.2.2 Positive, Permissive or Negative Effects of Transport on Development

Within the literature, it is allowed that the role of transport may produce one of three effects on an economy: positive, permissive or negative. Hilling (1996) describes the three possible relationships between transport and development that were articulated earlier by Gauthier. In the first instance, there may be a positive relationship, whereby transport is directly responsible for the expansion of economic activity. This occurs, for example, when a rail line or road is put through a particular region, and an industry or firm establishes itself there on account of the access provided by the transportation infrastructure. If the access were not available, the decision to locate in that region would not have occurred.[15] In this instance, transport plays an important role in the process of capital formation with the expansion of directly productive activities (as opposed to social capital) being the positive result of the improved transport opportunities. The roads in Northern Manitoba to the communities of Snow Lake and Lynn Lake are illustrative of this impact on the mining sector. If there were no roads (or railways), mining would not be feasible and its expansion unthinkable.

Secondly, there may be a permissive effect whereby transport does not stimulate economic growth in and of itself, but it does not inhibit growth (where other stimulating factors are present). A classic example of this is the role of the railways in the development of the United States and the notion that economic development would have occurred

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[15] The provision of transport infrastructure in this case could be facilitated by the governing authority of the jurisdiction or by the private concern itself. In the former case, this provides an illustration of the role of larger transport policy in the development of regions as the decision by a governing authority to provide access may not be made on purely rational economic terms. A hybrid situation can arise too, wherein an understanding between business and government may lead to concessions – such as the government providing the access while a business agrees to locate in that region.

regardless of the railways being laid, in that the inland waterways would have been able to carry much of the burgeoning demand for transport. This view argues that the railways followed development, as opposed to leading it in that the transportation mode did not directly produce the economic activity or the subsequent increases in economic growth (Gauthier, 1970).

Thirdly, there may be a negative effect. In other words, the transport investment does not realize or produce the returns which would have been gained by directing investment to another productive activity. Evidently this is a misuse of capital, for the investment in transport did not produce the anticipated returns. It would have been more beneficial to society to steer the investment to another sector of the economy, since the investment (or overinvestment) in transportation reduces the potential growth in productive activities and leads to an absolute economic decline. Vividly exemplifying this phenomenon is the proposed, but to date not constructed, “bridge to nowhere” in Alaska. In the early 2000s the Gravina Island Bridge was proposed to be built to connect the town of Ketchikan with Gravina Island, the site of the international airport and a small number of residents. The proposed bridge, which was to replace an existing ferry service at a cost of nearly $400 million, quickly became a contentious political issue. The project’s detractors (including political representatives and taxpayers) claimed that it was a misuse of public funds (which could be better spent elsewhere on the transportation system or in other State programs or projects). In short, they condemned it as a prime example of “porkbarrel politics” (State of Alaska, 2011).

Having undertaken the above review of the fundamental principles of the relationship between transport and economic development, and secondly, the perspectives in the literature on the role of transport in the processes of economic development, the discussion will now turn to the four modes of transportation (road, rail, water and air), furnishing an investigation of their collective core functions and a detailed review of each, with a view to understanding the benefits and disbenefits of each.

3.0 Transportation Modes

Transport, as a function, moves people or commodities from one place to another, where they may prefer to be, or where their relative value is greater (Faulks, 1974). As a process, and function, transport is necessarily related to the land, since even the sea and air modes interface with it at a port, and it has a spatial context (Troxel, 1955). To facilitate this movement, modern transport systems have generally consolidated around four transport modes which operate in three physical realms or environments: on land, on water, or in the air.[16] Over the course of the history of transport development, there have been periods when a particular mode, transport technology or source of motive power has been favoured and the others correspondingly neglected. Through the development of transport technology, and especially in the aftermath of the Industrial Revolution with the harnessing of steam and subsequent rise in mechanization of transport, great advances have been made.[17]

As the forms of transport and their enabling technologies have developed over the course of history, so have their impacts on the spatial location of settlements, economies and human interaction. Primitive human motion has given way to harnessing the motive and carrying-capacity benefits of draught animals. In time, this was superseded by mechanical forms of motive power operating in a variety of mediums, no longer restricted to the earth's surface; and this progression has wielded great transformative effects on civilizations, economies and the wellbeing of mankind.

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[16] This thesis will focus on transport of people and freight by road, rail, water and air modes. No treatment will be given to other modes such as pipeline or telecommunication, which appear in some literature when discussing transport modes, such as CITT (2008), Delaney and Woellner (1974), Faulks (1965), McCarty and Lindberg (1966).

[17] The development of transport technology and its implications for several fundamental properties of transport, spatial and economic relationships, include increases in speed, carrying capacity and reduction of costs. This in turn has extended markets, influenced the specialization of regional economies, and has underpinned the process of economic globalization. These issues have been remarked on elsewhere in the thesis.

The importance of transport, the development of its technology and facilities and its impact on the growth and advancement of nations and the way in which they are spatially organized are all factors that have been recognized by many authors, especially some of the celebrities of social science.[18] The development of transport facilities[19] has been noted to be likely the most important and vital element in the development of a country (Jackman, 1935), and the fundamental importance of transport in the processes of economic growth and development "has never been seriously questioned" (Button, 1982: 245), although debate exists of how the actual mechanics of growth and development are effected.[20] Some authors, such as Milne (1964: 24), suggest that, although a broad connection between developments in transport and economic development may be made, it is not possible to simplify or reduce the relationship by means of concluding a cause and effect relationship. Rather, it may be more appropriate to view the relationship between historical developments and advancement in the industrial arena on the one hand, and transport on the other, as having interacted through time to the benefit of both sectors – by "mutual association". From an economic point of view, transport may perform an integrating role; that is, serving to bring together persons or things that operate from two distinct, spatially separate locations. This integration permits materials to be brought together, distributed to appropriate users while, at the same time, conspiring to

[18] Two of these celebrities are Adam Smith (1982) and Alfred Marshall (1959). Both of their classic treatises pertaining to the fundamentals of economics and the mechanics of trade and development do not explicitly pay much attention to the specifics of transport, and its role. One can infer how transport does, however, facilitate the achievement of economic growth and development by providing a mechanism for the undertaking the division of labour, affecting the rents of land, industrial organization, production, specialization, trade, supply and demand, and so forth.

[19] This thesis will use the term "transport facilities" in reference to the infrastructure which enables or allows transport to occur. These facilities are the roads and highways, rail lines, seaports and airports and their various structures which support the use of the dominant technologies; these are currently the automobile or truck, trains, ships and aircraft.

[20] An illustration of this debate includes the "chicken and egg" paradox, the crux of which is whether transport drives economic development or visa versa (Button (1982), Hilling (1996), and Gauthier (1970)).

differentiate places according to economic or political significance (Troxel, 1955). These issues were touched upon in previous sections of the thesis.

Today, the major modes employed in the movement of both passengers and freight are road transport and rail transport (on land), water transport and air transport. Each of these four modes may be used to transport both people and freight. While this is theoretically true, in practice there exist economic and feasibility issues which impose practical limits upon the use of a particular mode for particular purposes. This may be largely attributable to the economic and spatial implications of the modes, which are often dependent on factors such as distance, market value of the product or the time in transit, constituent matter of product (i.e. unitization, bulk, packaged, a person), carrying capacity of modal equipment, cost structure of modal transport and so forth. Thus, factors such as distance, time, cost and requirements for transport (i.e. a basic level of protection or comfort for passengers or cargo securement and unitization requirements for freight) readily dictate the modes that are used for the transport of a particular object. Consequently, this has led to the development of general conventions pertaining to what (passenger or freight) travels by which mode.

It is critical to appreciate the comparative strengths and weaknesses of the four modes, including their differences with respect to infrastructure requirements for their use and the means of conveyance (i.e. units of carriage) and the required infrastructure for operation (i.e. the linkage (or way), to say nothing of the attention to the node (or terminal)). That appreciation, in turn, extends to an understanding of the fundamental economic and spatial relationships of modal operation. It requires a thorough understanding of the functions of transport at the outset.

3.1 Functions of Transport

The physical act of transport occurs for at least one of three reasons, regardless of mode, technology, or overall objective of the exercise, be it to move people, freight or both. These three overarching reasons may be better described as functions; inspired, respectively, by economic, social and political considerations. The three functions may at the same time be independent of one another, exhibiting a mutual exclusiveness, or conversely, the motivating distinctions may be blurred and appear to overlap in their primary purposes. An overview of each of them follows.

3.1.1 The Economic Function

The economic function of transport may be summarized in three points (Button, 1982). They relate to familiar notions. The first is that due to an unequal distribution of resources around the world, no one area is in a position to satisfy its own needs in their entirety. Resources and goods need to be moved between spatially separated locations in order to achieve the satisfaction of demand with an adequate level of supply. Secondly, building upon the first point, the development of modern societies and economic markets requires specialization of production, and that, in turn, necessitates the enlargement of markets. Thirdly, transport allows for the full implementation of economies of scale, permitting economies to focus on producing a relatively narrow range of goods to fulfil the requirements of domestic demand while using the surplus to obtain goods imported to satisfy demand for the remaining products not otherwise available in the domestic economy.

The above three economic functions are influenced by the major geographic reality that resources, people, markets and so forth are separated in their locations on the Earth. As noted above, this spatial distance between source and production, manufacturer and consumer is often referred to as a gap. The gap may be specified as one of time and distance (Milne, 1964). Transport allows for this gap or spatial separation to be overcome, providing linkages for human interaction, transport of raw inputs to processing and distribution of final products to markets and end consumers. The degree to which an economy can indulge in specialization within a given territorial entity is limited by the extent of the market that is available. Only through transport can this market be readily expanded.

3.1.2 The Social Function

The history of mankind is intimately related to the development of transport. Transport is currently, as it was historically, used by individuals, communities and nations for social purposes. In liberal-democratic societies, social forces exert much influence on transport, particularly as it concerns public policy and investment choices. Troxel (1955) suggests that in the “real world” social purposes as an influencing force in transport often transcend economic purposes.[21] While transport provides for the interaction and exchange of peoples, ideas, cultures and so forth (Button, 1982), it also brings about travel for pleasure, reduces isolation and enhances the individual's ability to access services (e.g. medical and education); to say nothing of expanding opportunities for recreational pursuits and making possible virtually any degree of concentration or dispersion of population which is chosen (impacting the spatial evolution of the city) (Delaney and Woellner, 1974).

Particularly in the context of developed nations, transport has allowed for the spatial separation of work and domiciliary functions, and this can be traced in the transportation-land use relationship exhibited in many North American cities. As transport has developed, so too has the spatial configuration of cities, typically in an expansionary fashion. The grid structure and relative compactness of the nineteenth-century city, which gradually extended outwards from the typical centrally-located commercial business district, may be directly correlated to historical mass-transit facilities (such as street cars and subways), and in more recent times, access to high-volume roadways (in the case of exurban communities).

3.1.3 The Political Function

It is a truism that political processes have exerted influences on transport systems. This political influence may be thought of in three senses. The first is political influence

[21] The social influence on transport has likely risen in the light of shifting paradigms in the political, engineering and planning of transport investment in infrastructure, networks and policy in the twentieth century. The allied professions have shifted from a technocratic or top-down perspective, to, at least in principle, a process where consultative processes and community or social participation in the decision-making and design process has become the norm. Contemporary transport planning / design processes will typically include a front-end consultation component, which may be undertaken because it is " industry best practice" or a legislated requirement to do so (i.e. provincial environmental assessment legislation / regulations, and federal legislation which compel the "duty to consult" First Nations). Public opposition to preliminary plans and designs may result in a range of reaction from slight project alteration, inclusion of robust mitigation measures to complete project cancellation. Social pressures may influence transport development by way of pockets of individual opposition (i.e. NIMBY - "not in my backyard"), organized lobby and interest groups, etc. (i.e. environmental groups) voicing opinion on general grounds (i.e. no development in an area) or specific grounds (i.e. potential project impact on one species or group of people).

exerted by the governing structure (in liberal-democratic systems) or the ruling class (in a variety of authoritarian contexts). This political influence or pressure is exerted in a downward fashion. Illustrations of this may be when a government constructs a transport facility for the tangible purpose of exploiting resources, extending market reach, or under the guise of promoting regional or national unity, providing equitable access, or other political or policy aims.[22] Secondly, political influence may be exerted from below, by a community or by individuals. This may occur on a range of scales from the community or region, to provincial or territorial. In this instance a segment of the population is demanding the establishment of a transport facility, which elected officials or decision-makers may provide.[23] Thirdly, transport has allowed for representative forms of government to develop, as typically representatives are sent on behalf of their constituents to a central house of government to act as interlocutors on their behalf in legislative and representative governance processes (Delaney and Woellner, 1974). Without effective means of transport, this legislating role would be downright impossible.[24]

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[22] In the study area, the Town and Port of Churchill are representative of these aims. Federal and Provincial government efforts (and financial expenditures) created the grain handling port and the connecting railway (which opened for traffic in September 1929 and the Port accepted its first shipment of grain in 1931 (see Manitoba, 1969 and Greig *et al*., 1983). Manitoba (1969: 176) asserts, in a review of the route to the north, that the "transportation history of Manitoba has been dominated by the demand for an alternative to the politically compelled east – west flow whether by way of a competitive railway to the United States border or by way of a railway to the [Hudson] Bay".

[23] Requests for transportation infrastructure from communities are exemplified in virtually any planning process undertaken in the study area. Consultations undertaken for regional planning exercises (e.g. the East Side Lake Winnipeg planning process (ESRA, 2009a)), political exercises (e.g. the *Northern Development Strategy* (Manitoba, 2005), or the *2020 Manitoba Strategic Vision* (MIT, 2009)) or for functional engineering / route planning studies (i.e. the Manitoba Nunavut Road (NK-SNC, 2007)) all feature communities' desire for transportation access.

[24] In the study area, a functional, as opposed to legislative role of transport in the administration of government can be seen in the examples of Thompson and Flin Flon as regional centres. Thompson is the seat of the Provincial court in the area (and the travelling court is referred to as the Thompson circuit); health services are based out of the Thompson General Hospital and it is the seat of the Burntwood Regional Health Authority; and a hub for other governmental departments' regional systems. Likewise, Flin Flon is the seat of a Provincial court circuit, health care is focused on the Flin Flon General Hospital and it is the seat of the NOR-MAN Regional Health Authority.

Political rationales have been used to justify colonizing territories and for nation-building. Again, these ends would be bound to fail without adequate transport facilities. On the African continent, for example, modern transport was introduced and used by the colonial European rulers to access and exploit natural resources while at the same time facilitating a degree of control over the colonial territory.[25] Resources, population and economies are typically dispersed or scattered within the political borders of a country or other areal jurisdiction. Transport has historically played a role to permit movement intra-jurisdictionally, to effectively defend borders, as well as to provide political cohesion. Hilling (1996), in his survey of transport development on the African continent, notes that in contrast to the railways in metropolitan countries, which permitted the widening of markets and development of the export sector, many of the railways were "constructed for non-economic reasons and provided the inland penetration as a by-product of the need to demonstrate the effective political control required to justify colonial claims to territory". Having modern transport networks and infrastructure may be seen as indicative of one's power or strength as a nation (Button, 1982).

A major factor influencing transport has been governments' use of it in the defence of a country, in the act of war, or to maintain control of an annexed or conquered area.[26] Troxel (1955), notes that some patterns of transport relations have been constructed in their entirety to serve military purposes.[27] In the United States, in the 1920's, the War Department began

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[25] Transport as a means of control may be thought of in two terms. The first is control as in subjugation, the ability to deploy armed forces, etc. The British first introduced the railway into India with this purpose in mind, for example. Control may also be thought of in terms of commercial control, such as using transport to grow one segment of the economy, often with a focus on the export of one or two primary commodities or products. Railway investment in the Prairies worked to this end.

[26] Taylor (2002) provides a review of the practical and strategic use of the Churchill area for research and military purposes in the twentieth century (both Canadian and United States' purposes).

[27] In his survey of the development of railways and waterways in Germany, Moulton (1926) notes that both waterways and railways in that country were developed, to some degree, to serve military ends. It is argued that

the process of nominating and selecting candidate roads for inclusion in the Federal Aid System, which was largely done under the guise of national defence (as a predecessor to the Interstate system). Under this scheme, the federal government paid one-half of the cost of improvements on designated routes. In 1923, approximately 169,000 miles (approximately 272,000 km) had been designated, and by 1940 there were approximately 235,000 miles (approximately 378,000 km) in this category (Vance, 1986).

It has been noted that political intrusion as an influencing factor is not necessarily a negative phenomenon. For social objectives to be given attention in the face of overwhelming economic pressures in support of specialization and furthering the extents of markets, intrusion may be necessary or required (Vance, 1986). The degree to which this intrusion occurs and its effects are well documented.[28] Much government intrusion has been justified on the ground of transport cost and its impact on society. Cost, indeed, can be viewed as the common denominator of all transport systems, as the next section will elucidate.

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in a practical sense, during a period of conflict, the railways exhibit more favourable characteristics in the carrying of supplies, munitions, etc., in that the speed of transit was greater and the ability to repair destroyed facilities (i.e. rails) was easier than the waterway (i.e. repairing a destroyed set of locks). Therefore the railway could likely be put back into service in a shorter period of time. Furthermore, the use of canals would require transhipment at the destination, they were subject to a period of seasonal icing and they provided relatively slow service in comparison with the railroad.

[28] Government intrusion into transportation is largely effected through mechanisms such as legislation, regulation and the apportionment of funding. Historical and contemporary aspects of this are dealt with extensively by Button (1982), Troxel (1955), Jackman (1935), and Vance (1986) and any typical text on the economics of transport will devote content to the issue of government involvement. Although now slightly dated, Bonsar (1984) provides an introduction to the general arguments for and against the intrusion of the Canadian state into the operation, delivery and servicing of transportation services; and furthermore speaks to the nature of this intrusion according to each of the major modes. It is noted that prior to the late 1960's, economists did not pay great amounts of attention to the economic regulation of transportation, but that in the 1970's it began to be more readily examined and questioned.

3.2 Common Elements of Transport Economics / Cost

Prior to examining the specific characteristics of the four modes, a review of several of the commonly identified economic or cost elements in the literature is beneficial (and will allow later discussions to focus on the mode in question – as opposed to generally applied characteristics). The nature of product, distance to be traversed and the speed at which this is desired, will all act to affect the mode chosen and the corresponding cost of the service. The consumer or user of transport services will assess and weigh the advantages and disadvantages of the available modes of transport available (to suit his or her particular need) and, in theory, will choose the mode (or combination of modes) which will minimize the total costs of production (Milne, 1963).

Despite the diversity of choice and service, there are eight commonly identifiable economic, or costing, characteristics which are applicable to a discussion of all modes. The eight characteristics of transport or transfer costs have been identified by Hoover (1948: 17-26), and are summarized in Table 1, and further discussed with examples below.

Table 1 - Summary of Common Elements of Transport Costs		
Common Element		**Notable Features or Characteristics**
1	Cost vs. Rate on Shipment	• Cost of transport and rate (or price charged) are not necessarily the same, some will pay more "real costs" than others. • Some rates may disproportionately distribute costs of overhead, capital, etc. (internal subsidization). • Cannot necessarily use rate to assign a disbenefit to a particular mode.
2	Cost Dependence on Route	• Intuitively, a longer distance will incur a greater price charged, but this is not always the case. • Concept of economic distance,[29] that is choice of easiest route (i.e. ease of transport, topography, climate, direction of transport) may supersede linear distance in importance of costing.
3	Network Density & Circuity	• Increased density allows for increased options for points of production, transfer, or route. • Density of network and interconnectedness of nodes (i.e. circuity) depends on volume (demand) of a mode. • Cost of transport is affected by volume.
4	Relation of Cost to Length of Movement	• Transport costs (in all modes) generally increases at a slower rate than in proportion to distance (as terminal cost and other expenses are not related to distance). • Costs tend to "taper off" with distance (particularly in the case of water transport). • Modes with relatively low terminal costs and high line-costs (i.e. road transport) have an advantage with shorter transfers, modes with high terminal costs and low line-costs (i.e. air, rail, water), will have an advantage with longer transfers.
5	Relation of Cost / Rate to Direction of Movement	• A differential in transport cost will typically exist depending on the direction of movement (i.e. depending on backhaul opportunities).
6	Structure of Rates	• Classes of freight rates (such as zonal charging, commodity rates, and others) will often exhibit a cost curve which resembles a step, rather than a linear curve or straight line relationship of cost / distance. • If multiple lines serve the same node, regardless of lengths of lines from origin, a balancing effect on the cost will bring them closer to parity.
7	Size / Volume of Shipment	• Larger shipments typically reduce transport costs (in all modes). • This is partly attributable to the averaging out of economic factors such as overhead and handling expenses. • Large shippers tend to receive more concessions from transport providers than smaller shippers (i.e. in terms of rates, flexibility in scheduling, etc.).
8	Relative Transportability of Transported Goods	• In many cases, a mode may be used to transport a variety of goods and commodities. • Transport costs may reflect the relative ease by which the service provider can handle the goods in transit (e.g. amount of time and labour required to handle a container, relative to handling a sensitive bulk grain). • Stowage factors of differing cargoes

Source: after Hoover (1948).

[29] Hoover's (1948) usage of the term economic distance in this instance varies from the usage of Milne (1963) and Lowe and Moryadas (1975) previously described. Hoover uses the term to represent a cost element that is focused on the relative ease of transport over a given distance, as opposed to expressly focused on linear distance. This may be seen as a slight variation of another common usage of economic distance, which relates to the distance a cargo may be transported and the cost of that transport service as a proportion of the cargo's value (a rudimentary example being freight rates for luxury goods transported expeditiously in an aircraft and low value bulk commodities transported over the course of several weeks in a vessel).

For the first element, cost vs. rate on shipment, Hoover (1948: 17) states that "the costs of performing a transfer service are one thing, and the charges that a shipper or consignee has to pay to have those services performed are another". Actual charges for service will be influenced by a multitude of parameters, including those such as minimum profit margins for the carrier, covering of overhead and operational costs and others. There are other less obvious (but still economically rational) reasons for rate variance, such as attempting to secure work in a tight market by undercutting typical prices in the marketplace, lowering real prices on the basis of a secured volume of future shipments, carrying a shipment in lieu of an empty backhaul or movement to reposition equipment, amongst others. There are also industries for which keeping low inventories on hand is preferable to warehousing, and the cost of an expedited shipment by aircraft is warranted over a lower cost of transport. These considerations are especially cogent for some Just-in-Time models of manufacturing, highly perishable foodstuffs, and retail products with particular time sensitivities (i.e. high-value, cutting-edge fashion accessories).

For the second element, cost dependence on routes, Hoover elucidates this principle with a discussion of the distance wherein it is not measured as a straight line but rather along the most economic route. He offers illustrations of physical and climatic factors which may influence the cost of transport and the need for varying degrees of engineering improvement to allow for transport's required and enabling infrastructure. In the first feature noted in Table 1for this element, the imperfect relationship between distance travelled and costs, is one of fundamental importance to economic and transport geographers. The notion that choice of easiest route may supersede linear distance may be exemplified in the choice of "tapping into" the jetstream rather than abiding by the great circle route in aircraft travel. Moreover, by utilizing the jetstream, operational efficiencies are gained.

For the third element, network density and circuity, Hoover (1948: 18) uses the example of the "relatively coarse" network of American railroads being supplemented by the "much finer network" of intercity road transport by truck and the myriad potential routing options this provides. He particularly is interested in points of production, and with denser transport networks available, there is a lowering of "roundabout transfers" and more points within the network may be feasibly considered for locations of production. Transport costs are generally affected by volume, the upshot of the carrier's ability to distribute the costs of capital, overhead and operations over a larger number of units.

Regarding the fourth element, relation of cost to length of movement, Hoover (1948: 19) notes that costs of transport "increase less rapidly than in proportion to distance" and this is largely attributable to the fact that "terminal costs and some other expenses are independent of the length of haul". On the basis of theoretical modelling exercises undertaken by Cullinane and Khanna (1999), carriage costs applying to a container vessel on a trans-Atlantic voyage of 4000 miles (6,440 kilometres) with a carrying capacity of 200 TEU[30] (a small coastal feeder ship) is approximately $400 USD per TEU, while the same voyage on a vessel with a carrying capacity of 6,000 TEU (a post panamax class ocean vessel) will incur a cost of approximately $100 USD per TEU. The economies of scale in this illustration are evident in the reduction of cost per TEU as the capacity of the vessel and the distance travelled increase.

[30] TEU is the "twenty foot equivalent unit", the baseline unit of measurement for marine container capacity.

The fifth element is the relation of cost / rate to direction of movement, which is dependent on backhaul opportunities. Should none be available, a differential cost may be applied. If there is a dominant direction of freight flows, shippers may be able to avail themselves of favourable transport service prices when they are shipping against the dominant flow, for as Hoover (1948: 22) notes, it "costs little more to run with a load than empty". Likewise, for the shipper seeking to transport goods in the dominant direction, the inability to secure backhaul traffic will be incorporated in the one-way price.

On the topic of the sixth element, structure of rates, Hoover uses the illustration of rate schedules formed on the basis of grouping points of origin and destination into blocks or zones as opposed to the specific destination. CITT (2008: 3-24) noted that group rates "applied to one or more commodities from a manufacturing or source area to a consuming area, rather than to a specific destination". The underlying rationale of this type of price structure is to avoid price discrimination on the basis of location. A variety of formulae and combinations of charges are used by Canadian railways, depending on commodity, location and distance.

In terms of the seventh element, the size / volume of shipment, Hoover (1948: 23) notes that "all elements of transfer costs per pound are reduced when shipments are larger". The economies of scale are accrued by the seller or buyer, in that there are lessened product handling and overhead expense and reductions in freight rate are typically provided for shipments of greater size / quantity. In general, the larger the load (i.e. more TEU) and the longer the distance travelled, the less the per unit (TEU) costs will be.

The eighth and last element noted by Hoover is that of the relative transportability of the good. In this instance it stands to reason that bulk liquid, aggregates, containers or secure break-bulk goods will require less specialized handling than will fragile, dangerous goods or bulky, perishable or irregularly shaped freight. Consequently, they will be carried at more favourable freight rates.

3.3 Road Transport

Road transport today is undoubtedly the most prevalent mode in terms of route / network extent, and Hilling (1996) notes that it exhibits a "universality" which no other mode matches. Faulks (1965) contends that its primacy is based on its ability to facilitate "door-to-door" service and the flexibility of the mode's use is a primary feature. Roads, the indispensable operating medium for highway vehicular transport, are composed of various types, and degrees of sophistication, some of which border on ubiquitous distribution around the world.[31] They embrace, at one extreme, unimproved dirt tracks which have by default become the way of choice between two points for travel by foot or horse-cart, upwards in sophistication to the modern, limited-access expressway (which may be on, above or below-grade) made of the latest bituminous or concrete pavements.[32]

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[31] An element of the aforementioned flexibility of the road mode lies in the fact that it does not necessarily even require a road to operate on. For the purposes of this thesis, a road is defined as having the minimum characteristics as defined by the World Bank's "basic access road" criteria (Lebo and Schilling, 2001). This road is rudimentarily engineered to accommodate vehicular travel (motorized access as distinct from non-motorized access) and incorporates basic road design principles. The cross-section will vary according to terrain (i.e. flat, mountainous, rolling), but will incorporate the following basic design elements. The road surface will be approximately 3.0 metres in width, with a crowning, or camber of 5-8% grade to allow water runoff. Minimum horizontal curve radius should be 12 metres. It will be made of in situ materials, and if assessed to be weak (according to specified engineering parameters) it will be improved with gravel. Side drainage will be provided as will culverts and bridges where required; local hydrological characteristics should be ascertained and the roadway structure should be situated at least 50 centimetres above flood levels. The entire cross-section will vary between 3.5 and 5.0 metres (depending on the ability to provide sloped ditches). In rolling and mountainous regions, maximum vertical gradients should be kept to 12–15%. If shoulders are unable to be provided, periodic passing areas must be provided at intermittent points.

[32] Automobiles and trucks can operate (albeit not to their full potential) on unimproved soils, sands, etc. The role of improved, basic access roads (from existing paths or tracks) in permitting improved use of road transport units of carriage in developing nations is well documented in the technical literature of lending institutions such as the World Bank. See Lebo and Schelling (2001).

For the purposes of this investigation, road transport will represent the transport of people or goods via a wheeled vehicle.[33] This typically occurs in the vehicular form of an automobile or bus for passenger transport and any number of configurations of van or truck in the case of freight transport. Throughout this discussion, road transport for passengers and freight will be noted as being distinct, and the pre-eminent focus will be on the discussion of the freight implications.

3.2.1 Modal Requirements

3.2.1.1 Unit of Carriage

At its most simple level, road transport uses a wheeled vehicle which moves upon and along a linkage, or way, which (as previously defined) may be constituted of natural soil or of a variety of improved structures (e.g. surface treatments or pavement types).[34] As the level of improvement increases, supporting civil infrastructure, such as bridges, culverts and tunnels allow for the way to horizontally and vertically deviate from the existing terrain and traverse natural features such as rivers, mountains and urban agglomerations with little effect on vehicle performance (i.e. speed, and safety). The unit of carriage for passenger transport may include vehicles such as the automobile, truck (as in the instance of military troop

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[33] The term "vehicle" is used in the context described by Faulks (1965: 5), which is a unit of carriage used in land conveyance. By extension, this thesis will use the term "rolling stock" in reference to both the power unit (engine) and the unit of carriage (car) for rail transport, "vessel" for water transport (for example, container ship, laker and barge) and "aircraft" for air transport.

[34] Although the engineering properties and techniques for the construction of roads have evolved through history, the basic design characteristics have remained quite similar. The roads of the Romans were thoughtfully constructed and included a cleared right-of way in forested areas, and the road itself exhibited a curved, or cambered running surface of gravel or cobbles, which was supported by a substructure of progressively larger stones or aggregate. In the early 1800's, John McAdam took the basic properties of the Roman road and developed a road-building system which bore his name. The major aspects of the "macadimized road" were similar to the Roman; that is, the necessity of a cambered running course and the importance of drainage. McAdam's contribution focused on the road building materials, setting strict standards for sizing of aggregate, not using large stones to underpin wet areas, and the components of the road bed admixture (i.e. no clay, earth, chalk or other material which could be affected by frost). McAdam was convinced it was not the physical thickness of the road, but its constituent materials, which provided its structural properties to handle loading, and the necessity to pack the road surface to make it impermeable was the key to maintaining its strength (SEMP, 2007).

transport), bus, etc. The choice of the unit of carriage for passenger transport is largely differentiated between private and fare-paying transport functions. In the case of private passenger transport, an individual may use an automobile, light truck or motorcycle – it is largely a choice based on preference and requirements for carrying capacity (i.e. luggage and personal effects, or, indeed, mixed usage, whereby personal mobility is combined with freight haulage). In the case of fare-paying passenger transport, this may be delivered by for-hire taxicabs, publicly provided mass transport, intercity buses or coaches, and so on. The vehicle employed by the transport provider will be based on economic factors of operation, which will be influenced by such operational elements as demand for service (i.e. number of passengers), routing configurations (i.e. distance or number of stops), and business considerations such as revenue per kilometre, capital and maintenance costs of particular vehicles, fuel consumption, and freight capacity amongst others (e.g. Greyhound buses combining passenger transport with freight and parcel carriage).[35]

The unit of carriage for freight transport in the road mode can assume a number of forms, which may differ across regions, provinces / states, countries and globally. Reasons for this variety may include historical legacies (i.e. in the manufacture of trucks, transport technologies, industry standards), availability of particular vehicles, local regulation and legislation pertaining to safety, environmental and engineering (i.e. weights and dimensions) properties, and so on. Suffice to say, the commercial motor-carrier industry exhibits differences when Canada is compared with Europe, in the developed world, and likewise when compared with West Africa, in the developing world, both in terms of vehicle

[35] Depending on the level of freight to be moved on a particular route, if the storage area on the underside of the passenger bus is used in its entirety (for travellers' effects and parcels), a short trailer often referred to as a pup trailer, will be hauled behind the bus (with parcel freight only). In Canada, these pup trailers can be seen operating on the trans-Canada mainlines, and on some Manitoba routes, especially in the lead-up to the Christmas season where an increase in parcel service is used.

appearance and the limits imposed on their operation by governing authorities (i.e. allowable weights, configuration of carrying units and maximum dimensions).

In Canada, commercial motor vehicles are largely under the jurisdiction of the Provinces and Territories (except in the case of extraprovincial trucking which is within the Federal purview), and approvals for licensing, vehicle and equipment configurations, weights and dimensions, speed limits, carriage of dangerous goods, etc., are dictated by the jurisdiction in question. To ensure a degree of uniformity in the industry, jurisdictions are signatories to agreements such as the National Safety Code, which attempts to maintain a like-regulatory regime (CITT, 2008).

Commercial motor vehicles used in road transport in Canada have many different combinations of power unit and carrying body; too many to address here. However, a simplistic division may be made between those which primarily operate in urban contexts, such as delivery vans and trucks, and those which operate on the highways and traverse long distances, such as cross-country hauliers. Depending on the above-noted distinction, there will be differences in the form and characteristics of the power unit, and depending on the application, the unit of carriage (i.e. trailer, chassis for containers, other specialized equipment types) and the configuration (i.e. straight truck, tractor-trailer, and multiple configurational permutations such as number and length of trailers being pulled) employed will vary. The trailers, much like in the rail mode, will be either multipurpose (i.e. standard trailer of 53 feet in length) or specialized (i.e. tanks for specific liquids, configurations for carrying automobiles, logs, grains, etc., or flatbeds accommodating an array of dimensional loads).

3.2.1.2 The Linkage (or Way)

Regardless of the type of road transport vehicle used, the underlying purpose[36] or the object of carriage (e.g. passenger or freight), a characteristic of road transport is that both the passengers and freight utilize the same way – there is joint-use of the enabling infrastructure.[37] The degree to which the linkage requires improvement from its original state (i.e. existent soil or natural path) to an improved state (i.e. improved roadway with drainage) is based on many factors. Some of these factors have been identified by Delaney and Woellner (1974) and include: the nature of the soil and its durability under a variety of weather conditions, the properties of the foundation materials locally available, natural obstructions (i.e. horizontal alignment), variation in level (i.e. vertical alignment), travel speed desired, dust mitigation, volume, continuity and composition of vehicular traffic and safety.

Roadways may be classified, which typically is done to differentiate the design or engineering characteristics that a particular roadway will exhibit, and therefore what size or mass of vehicles may safely use it. A general example used in developed transport networks in an advanced-country context is based on the hierarchical order of local roads or streets,

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[36] The "underlying purpose" may be one of two. First, as transport, in an economic sense, is a derived demand, that is to say, transport does not occur without a purpose, and that purpose is to meet the demands set by supply and exchange mechanisms of the economy. Secondly, travel by individuals is often undertaken to achieve a social or utility end (i.e. travel to the workplace, to fulfil the demands of one's lifestyle such as shopping), but there is also an aspect which is more difficult to analyse, predict and account for, and that is travel for the sake of travel (e.g. a Sunday drive) (Button, 1982).

[37] The same holds true for rail, water and air transport. Joint-use in road transport may be limited in some regards, such as with the assignment of designated commercial truck routes through municipal or urban centres, or designated urban routes for the transport of dangerous or toxic materials. At the provincial level of road authority, the highway classification which regulates the axle or gross vehicle weight-loading which may be applied to a particular segment of highway, is a reflection of the strength of the infrastructure (roadway, bridges, culverts, etc.) and its associated engineering properties.

arterial roads, expressways or freeways.[38] This is a standard approach, and with some variations is typically used in urban North American cities and municipalities.

Moving up one level of authority or jurisdiction to the provincial level, in the Province of Manitoba, for example, three weight classes are used on the provincial highway network. Each class of highway has a corresponding specific axle loading and gross vehicle weight limit which is specified in regulations. RTAC[39] highways are also known as Provincial Trunk Highways (PTH) and have a numerical designation (i.e. on the provincial highway map) between 1 and 110. These highways are rated to a 62,500 kg gross vehicle weight. Below RTAC are the Class A-1 Highways and these are rated to a 56,500 kg gross vehicle weight. Lastly, the Class B-1 highway is any Provincial Road which has a numerical designation greater than 110 and is rated to a gross vehicle weight of 47,630 kg (MIT, 2010a).[40]

3.2.1.3 The Node (Terminal)

The concept of the node (or terminal) in road transport is open to a range of interpretations. Thus a terminal may represent an origin and destination (i.e. in the sense of a node at the ends of a given linkage). As such, its identification may lead to infinite possibilities. In the context of passenger transport, the terminal could be one's place of

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[38] Some classifications may include "parkway" which literally may be a road that traverses a natural area. Depending on the jurisdiction, this roadway may be off-limit to commercial traffic (as in the case of the National Capital Commission parkways in the Ottawa region).

[39] RTAC is the Roads and Transportation Association of Canada, now called TAC, the pre-eminent transportation technical and policy industry association in Canada (consisting of both governmental and private industry members). This association publishes the recommended technical standards and best practices to which the road transport industry designs its highway infrastructure.

[40] Furthermore, segments of Provincial Highway which meet specified criteria may be classified as part of the National Highway System (NHS), which has three classifications: core, feeder or northern and remote routes. This allows the Provincial authority to access cost-sharing funding for improvements to highway infrastructure (COMT, 2009).

dwelling as the point of origin, and a commercial centre as the destination. In the context of commercial passenger transport, the terminal could be bus depot 1 in City A and bus depot 2 in City B. In the context of freight transport, the origin could be the loading dock of a manufacturer and the destination could be the receiving door of a retailer.

It is obvious that the infrastructure requirements at the nodes, both origin and destination, will be peculiar to the specific application (i.e. passenger or freight), and the facility design will typically be built to accommodate the type of vehicle(s) which will use it (i.e. automobile, truck, etc.). Likewise, depending on the circumstances, the terminal could be of no direct cost to the transport provider or, conversely, costs may be incurred for its use (i.e. fees for use of common terminal or direct capital expenditure on private facilities).

3.2.2 Economic Considerations

This section will treat the economic consideration of passengers and freight transport by road separately. Broadly, passenger transport by road may occur privately for the individual, as in the case of one using his vehicle or in a for-hire or fare-paying relationship. In Canada, commercial passenger transport by intercity bus is under the authority of the provinces and therefore is subject to a variety of operational and economic regulatory regimes that practically cover the gamut from virtual "free-market" environments of near complete deregulation to various regimes of increasingly regulated or state-subsidized models.[41] As Canada is a large jurisdiction and, granted that in the West and North, it

[41] The contrast between regulation and deregulation is that the proponents of deregulation argue that entry into the intercity bus service market will be based on demand and that factors such as innovation, finding efficiencies and the impact of competition will determine the shape of service delivery. The role of government is to ensure safety. Advocates of forms of regulatory oversight contend that deregulation causes service providers to cease operation on low-density routes. A review of the deregulated provincial structures in Canada (namely, Alberta, Ontario, New Brunswick and Newfoundland) suggests that there has not been significant cessation of services (COMT, 2010a: 4).

exhibits relatively diffuse and separated locations of urban populations, the various regulatory models pose operational concerns to the bus service providers (COMT, 2010a).

At the municipal or urban level, public transport services, in the road mode, may be provided typically by buses, of various sizes, capacities and styles. Funding for this service is seen as a public good and is typically furnished in some combination of farebox revenue and municipal, provincial / territorial and federal subsidies which is applied to both operational and capital requirements. In Canada, for the year 2007-2008 it is estimated that the breakdown of net operating revenues (a measure of transit investment which focuses on government contribution by removing the contribution from the farebox) was as follows: municipalities contributed 62.7%; provincial governments 29%; and the federal government 20% (COMT, 2010b).[42]

In the instance of road transport of freight, companies may maintain and operate a fleet of vehicles for their own transport needs, especially if specialized vehicles or equipment are needed (in the case of private carriers). Alternatively, they may fulfil their transport needs through contracting their requirements to a service provider (as is the case with for-hire carriers). Concerning for-hire carriers, a distinction is drawn between common carriers, who offer services to any potential customers, and contract carriers, who restrict their operation on the basis of geography, commodity, etc. (CITT, 2008). In the freight sector, numbers of service providers have developed which facilitate transport services without actually physically moving anything. These are the third-party or non-carrier operators, such as

[42] In 2008 total provincial operating contributions to public transit were $859 million; in Manitoba the comparable figure was $26.1 million (COMT, 2010b).

logistics providers, freight forwarders and freight brokers who work to consolidate loads, load-match and handle paperwork for shippers.[43]

Glaeser and Kohlhase (2003: 10) note that in the United States, road transport by truck in the period following World War II has been a “major factor” in the transportation industry. This claim is justified in the comparing of the magnitude of total spending on transportation in the United States and the shift from rail to road transport as a percentage of this totality. In 1947, more than 50% of the United States’ total transportation spending was rail-based; in 2003, road-transport (trucking) assumed more than 77% of total spending. They further note that the ton-miles (where one ton-mile represents the movement of a ton load over one mile) transported by rail far surpass those carried by road, but since road transport is, on average, more than ten times more expensive than rail per ton-mile, it assumes a greater total share of spending.[44]

In the Canadian context, the impact of freight movement by road transport on the economy is equally telling. CITT (2008) states that trucks account for over 50% of freight shipments (based on revenue) and 30% based on weight, and that 75% of manufactured goods (by value) is moved by road transport.

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[43] Logistics providers are akin to consultants who work with a client shipper to assess their transport requirements and to develop a plan and contract the services required to execute the carriage. Freight forwarders are companies (typically not carriers) who will consolidate less than truckload (LTL) quantities from multiple shippers to form truckloads that are contracted to carriers. Freight forwarders will typically arrange pick up of the LTL and handle the documentation requirements of the shipments (e.g. collect three LTL shipments in Winnipeg, consolidate the load to make a full truckload and contract a carrier to transport to Toronto). Freight brokers’ (typically not carriers) services generally revolve around matching trucks to loads and vice versa (CITT, 2008).

[44] It is of interest to note that when manufacturers, distributors or shippers in general use their own fleets for provision of road transport services, the value of this service (if it were provided by an external party) is not counted or reflected in the United States statistical records. The implication of this omission is that data used in the analysis may underestimate the importance of the sector (Glaeser and Kohlhase, 2003).

3.2.2.1 Costs of Infrastructure

As the road transport sector does not build its required infrastructure for operation, the costs are for the most part variable, although in as much as trucks pay taxes (such as fuel tax), they are indirectly contributing to the fixed costs of road provision. The costs include various taxes, licensing and registration fees, and fees for use (i.e. toll roads, special permits for movement, etc.).

3.2.2.2 Cost of Usage

The cost of usage for the transport of passengers for private road transport is a function of cost elements accruing to the carrier, including those of the vehicle, insurance, driver licensing and registration, fuel, maintenance and upkeep, etc. In the case of fare-paying passenger transport, the cost incurred is the fare set by the service provider, which incorporates the cost and a profit margin.[45]

The cost of usage for commercial freight purposes is the price for services set by the provider, which will vary according to many factors, including type of load, weight and dimension of load, origin and destination, and scheduling constraints, amongst others. In their investigation of long-term pricing of transport services in the United States, Glaeser and Kohlhase (2003) concluded that, based on their evidence ranging between 1947 and 1999, while the cost of shipping by other modes in general exhibited a decreasing trend in cost,

[45] For instance, in the current passenger rail and road transport contexts in Canada, there exist a range of operating models. In the commercial intercity bus sector, these vary from a purely commercial, free-market structure (i.e. operating and fare structure are unregulated by any level of government intervention) to those with forms of economic regulation (such as “monopoly” positions granted to certain carriers in a jurisdiction, with stipulations put on route, schedule and fare adjustments and the imperative to cross-subsidize unprofitable routes, applied by the public regulator in turn for a closed market) to a provincially run service (e.g. the crown corporation - Saskatchewan Transportation Company). In the rail sector, carriers such as VIA Rail receive public operating subsidies while the Ontario Northland service operates at arms’ length from the provincial government but is subsidized in years of shortfall. For a full discussion on the current state of the intercity bus service regulatory regime in the Canadian provinces see COMT, 2010a.

shipping costs for trucks remained virtually constant. They point to several factors accounting for this phenomenon, including the regulation of the trucking industry in the United States up to 1985 and rising fuel prices. Their analysis points to deregulation of the industry as being responsible for technological changes which have driven down the costs (cents per ton-mile) since that time; a trend sufficient to offset rising fuel prices.

Delaney and Woellner (1974) note that the extensive use of road transport is an indication that the relatively low cost of operation and other benefits offset the cost of movement by other modes. To substantiate this claim they offer seven positive qualities of the road transport mode:

1. The ability to provide door-to-door service and the limited need for specialized terminals;
2. The speed of the overall journey (which may not require transloading);
3. Vehicles are owned by persons and companies which may allow for more effective production and distribution schedules, gains in operational efficiencies, etc.;
4. Service and fuel are readily available;
5. Vehicles are relatively easy to operate in a safe manner and do not required specialized training and skill;
6. Fixed linkages are commonly held (i.e. by the public) and are not typically specific-use in nature and the costs and maintenance are not specifically attributed to one user; and
7. Mass production of vehicles has resulted in a relatively low capital start-up cost.

3.2.3 Spatial Considerations

As mentioned at the outset, road transport is the most ubiquitous form of transport and the roadways upon which this movement occurs can vary in construction, network configuration, density and form. Two spatial considerations will be commented upon: first, the nature of the network or system on which the road mode operates; and, second, some aspects of the speed of operation.

3.2.3.1 Network or System

Two levels of highway network will be discussed to illustrate the spatial breadth of the system in the Canadian context: the federal National Highway System (NHS) and the highway system in the Province of Manitoba. At the national level, the NHS (as of January 2009) comprised over 38,000 kilometres of highway.[46] On this system, in 2007, there were an estimated 125 billion vehicle-kilometres travelled, with commercial trucks accounting for 19.1 billion kilometres. Between 2007 and 2009, the NHS system received $8.8 billion of cost-shared investment for its maintenance and improvement (COMT, 2009).

In Manitoba, the provincial highway network is composed of approximately 19,000 kilometres.[47] This network has a capital value estimated to be $5.6 billion. Supporting the highways themselves are 1,250 bridges and 1,150 large culverts, with a capital value of $2.3 billion. A distinct feature of the road transport system in Manitoba is the existence of the significant seasonal winter road network located in the northeast and northern regions of the province. This 2,200-kilometre network seasonally links 23 remote communities, which have

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[46] Of the 38,038 kilometres on the NHS in 2009, 27,624.5 kilometres were designated core routes, leaving 4,495.8 kilometres regarded as feeder and 5,917.4 kilometres as northern and remote. Of this northern and remote designation, a total of 2,792 kilometres was unpaved.

[47] Of the 19,000 kilometres in the Provincial Highway System in 2009, 8,300 kilometres were structural pavement, 4,700 kilometres were asphalt surface semi-pavement, and 6,000 kilometres were gravel.

approximately 30,000 residents. The network is typically operational for six to eight weeks per year and requires approximately $9 million per season to build and operate (MIT, 2009).

3.2.3.2 Speed

The speed of road transport is in theory only limited by the technology and engineering of the vehicle (based on the source and efficiency of the motive power), the counteracting forces of natural physics (i.e. resistance of various forms of friction) and the properties of the linkage (i.e. unimproved track or a improved roadway structure with a relative slight deviation in gradient). Practically, the speed of operation is only limited by law (i.e. posted speed limit, use of designated truck routes) and operational factors, such as roadway conditions (i.e. snow, rain, fog) and issues of network mobility (i.e. urban congestion, roadway closure for maintenance or construction). In North America (and elsewhere in the developed world), limits are placed upon commercial drivers as to the number of hours they may operate the vehicle (and other operating regulations are contained in the *National Safety Code*) (CITT, 2008).

3.2.4 Benefits and Disbenefits of Road Transport

The major benefit of road transport may be summed up in the term “flexibility”. Flexibility may be thought of in the sense of the ability of the mode to be used in a variety of environmental conditions: it is not strictly limited to its enabling infrastructure and it can provide “door-to-door” service. All other modes almost always require road transport at the origin or destination of the travel.[48] Road transport acts in a critical supporting capacity for

[48] For instance, the use of intermodal containers (i.e. rail / vessel) requires handling or drayage at the point of origin (i.e. loading the container and transporting it to the rail terminal) and at the destination it requires drayage from the port or rail yard to the end location (i.e. it will require unpacking of container and subsequent return to

rail, water and air transport, as it acts as a feeder network to support the consolidation and distribution of people and freight for the other modes (Faulks, 1974).

Road transport cannot necessarily compete against the other three modes in the aspects of volumes moved, speed or distance of movement, but a major benefit is convenience. This convenience is paramount to the owner of the private automobile which facilitates the transport of passengers essentially upon demand. A synopsis of the general benefits and disbenefits of road transport is provided in Table 2.

Table 2 - General Benefits and Disbenefits of Road Transport

Benefits	Disbenefits
• Relative flexibility • Relatively low cost (vehicles and operation), especially for short hauls • Door-to-door service • Does not require specialized infrastructure • Many service providers	• Relatively low carrying capacity • Regulations affect operation (i.e. hours of service, weights and dimensions) • Relatively poor ability to transport bulk cargo • Poor cost efficiencies in long-distance carriage

3.3 Rail Transport

Rail transport, as it has emerged in the period since the Industrial Revolution, has played a significant role in the development of economies and nations. In the emerging of Canada as a unified nation, the railways have been regarded as instruments of economic and social development (CITT, 2008) and, what is more, this role continued long after the country's infancy. Through the subsequent stages of national growth and economic advancement, the railway, as a means of conveyance and communication (i.e. linkage and expansion of markets, peoples, social welfare, etc. over a larger territory), has been critical (Jackman, 1935). The development of the railways and the competing enterprises and

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the rail yard or port). It should be noted that port transhipment without land drayage occurs. Port transhipment from barge to sea-going vessels occurs in New Orleans, LA and Mobile, AL (in the case of grains); in Rotterdam, Netherlands from bulk vessel to barge / river vessels (in the case of iron ore and coal); and on the Pearl estuary, containers are loaded onto barges and transhipped at Hong Kong onto ocean container vessels.

companies which strove for dominance and growth in fits and starts in the late 1800's and early 1900's is a fascinating study in corporate and syndicate-run business and industry-political relations and is well recounted in the literature (Jackman, 1935; Vance, 1986).[49]

Rail transport has markedly different characteristics from the other three modes, with the primary point of differentiation being its relative inflexibility. The rail mode operates on a fixed linkage, with specialized equipment, and there is no alternative for its operation if unforeseen circumstances arise (i.e. accidents or derailment, and blocked or damaged trackage). In addition, due to this feature, railways are run on reasonably strict operational schedules, as in many circumstances there is two-way traffic operating on a single track of rail with sidings for pullout. Conversely, the broad benefits of rail transport are its ability to move large amounts of freight with significant mechanical efficiency over long distances. This review will stress the transport of freight in the rail mode, rather than the movement of passengers.[50]

3.3.1 Modal Requirements

3.3.1.1 Unit of Carriage

The unit of carriage in the rail transport mode is the rolling stock, which comprises the power unit (the engine) and the units of carriage (the cars, chassis for containerization, passenger cars and specialty units such as tank cars). Three classes of units of carriage may

[49] The two Class 1 railroads operating in Canada remain major forces in the national economy and on the equity markets. For example, CN in 2007 posted revenues of $7.9 billion, while CP posted revenues of $4.6 billion. (CN, 2010; CP, 2010).

[50] Passenger transport in North America has returned to the public and political agenda as witnessed by recent funding announcements for high-speed rail projects in the United States (*New York Times*, 2009), discussions of a link between Edmonton and Calgary, Alberta (Van Horne, 2004) and the expansion of the regional commuter network in the Greater Toronto Area. This review of the rail mode is couched in the assumption that rural and remote passenger service, alone, is inadequate to stimulate investment in rail routes. That is to say, industrial usage will drive (and has historically driven) the investment in railways in this area (i.e. Port of Churchill and branch lines accessing locations of mining: Flin Flon, Thompson, Lynn Lake in Manitoba). Consequently, usage of the railway for transport of passengers can follow (but will never be the primary factor of importance).

be identified, according to intended use: 1) those accommodating passengers only; 2) those accommodating goods only; and 3) those which accommodate both passengers and goods, the so-called mixed freight trains, wherein each is made up of cars adapted for carrying a range of goods, commodities, and in some cases, people (Delaney and Woellner, 1974).

For freight transport by rail in North America several major types of units of carriage can be identified. Each is purpose-built for the efficient and safe carriage of certain types of materials and products (somewhat similar to the above-mentioned road transport), and all units of carriage are, in general, rated for maximum weights of around 100 tonnes. Briefly, the standard boxcar (with a sliding door) is suitable for manufactured products, wood pulp, newsprint, etc. Two styles of hopper car predominate, one for grains, potash and fertilizers, and the other for sands, gravels and coal. These are top-loaded into compartments, and product is discharged from the bottom. Open gondola cars can accommodate cargo such as steel products, ores, coal and sulphur, and these are typically loaded and emptied from the open top (or in some cases side discharged), and may be covered with hard-tops or tarpaulins if required. Tank cars vary according to the liquid and its pressure and their capacity can range from 13,500 US gallons to 33,800 US gallons. There are a variety of other specialized units of carriage, including centrebeam cars (for finished wood products), log cars (for raw timber), gondolas for aggregates, flat cars, cars dedicated to the carrying of containers (both marine and domestic sizes), and those for vehicles amongst others (CITT, 2008; CP, 2010; CN, 2010).

3.3.1.2 The Linkage (Way)

Rail transport requires trackage, which typically consists of the steel rails, in turn, supported by crossties (or sleepers) that are made usually of wood or concrete, and which sit atop a bed of ballast, typically of crushed rock. These three fundamental components of trackage are the means whereby the linkage maintains its alignment and stability and it is the engineering properties associated with the strength and spacing of the steel rail,[51] spacing of the sleepers[52] and type and depth of the ballast which determine the railway's loading characteristics, the type of motive power required and the speed at which the unit may travel (Delaney and Woellner, 1974).[53] On the Hudson Bay line, the presence of subsurface ice structures such as permafrost, and other associated terrestrial phenomena, such as muskeg, have consistently provided recurring challenges to line operation, particularly between Gillam and Churchill.[54]

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[51] The spacing of the steel rail, measured from the inside faces, represents the rail gauge. Standard gauge in North America is 4'8½" (1.435 metres). One is cautioned not to confuse the gauge of the railway (standardized width between rails) with the loading gauge of the rails. Currently on the CN system, the main lines are rated to 286,000 pounds while the secondary lines are rated at either 268,000 or 263,000 pounds (CN, 2010); that is, the allowable axle loading on the rail (a function of the strength of the trackage) and the allowable dimensions along the way (the dynamic envelope). The importance of the dynamic envelope cannot be overstated as tunnels, overpasses, etc., are constructed to a standard. When a revolution, such as the double-stacked container train, is embraced, this may require significant alterations to the way to accommodate the increase in height. Delaney and Woellner (1974) caution as to the need for transport planners to exercise a degree of foresight in this regard and Levinson (2006) provides an account of the challenges that had to be overcome in agreeing on a standardized dimension for the shipping container and the effects on the marine, rail and road transport providers.

[52] Hilling (1996) notes that there may exist between 1,300 and 2,200 sleepers per kilometre of track. The number is determined by the engineering requirements needed to attain the desired system performance (i.e. number of trains, speed, sleeper material and longevity, etc.).

[53] It should be noted that although the track gauge of 1.435 metres is now the world standard, in the twentieth century there were, and in some cases still are, a variety of gauges in use. Hilling (1996) notes that there are nearly 40 different gauges which range from 0.330 metres to 1.670 metres, with perhaps 12 in fairly common use around the world.

[54] Churchill Task Force (1995: 5) notes that at the time of their investigation, it was estimated that there were 2,100 sinkholes (areas of settlement of the grade due to melting permafrost), and as a result safety and regulatory requirements were in force which limited the operating speed on the line to 30-40 miles per hour, as well as restrictions on the types of cars that could be used (due to their flexibility properties).

More so than in road transport, rail transport is constrained by the ability of the unit of carriage to operate on vertical gradients and horizontal curvatures, regardless of available capital or construction resources. The rolling stock has functional limits on its operation (whereas a truck on a roadway is in many senses more flexible).[55]

Another major feature of the linkage required for rail transport is a system of signals, which control and regulate movements of rolling stock on particular segments of track, collectively comprising the entire network. As many railways operate units travelling in two directions on single tracks, the use of sidings and signals allow for the safe passage of units, or the overtaking of units in the same direction.[56] Due to the extensive requirements incidental to building, operating and maintaining the rail linkage, a large proportion of capital is expended on its upkeep and this overhead constitutes a high proportion of total rail transport operating costs (Faulks, 1965).

One distinct feature of the linkage in rail is that rail companies have exclusive right to its use.[57] In the light of this, and the historically heavy economic / government regulation in this mode, there are complex rules and regulations surrounding actions such as

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[55] On the Hudson Bay line, the critical parameters of the horizontal and vertical alignments are not so much a factor of traversing existing topography (as was a factor in the route of the lines to the Pacific coast through the Western Cordillera) as they are of episodic bends and twisting of the rail alignment due to the permafrost, sinkholes, etc., as described above, which can require emergency stabilization and maintenance to permit passage.

[56] A Canadian example of this is the operation of VIA Rail passenger service in a mixed-environment with CN freight service in Western Canada. Freight receives priority; therefore the passenger train spends significant amounts of time idle on sidings waiting for authorization to proceed. Hilling (1996) provides a simple but telling illustration of the two-way directional use of a single tracks in mining operations in Mauritania and the placement of passing loops (sidings) and the scheduling / operational parameters which allow the trains to pass each other at specific points at specified times along a 650-kilometre journey.

[57] The origins of this exclusive use may take various forms. In the case of private companies, they may have secured the right of way and financed the entire building of infrastructure, or conversely, the state may have historically secured the right of way and companies have operated within it and following deregulation purchased it all from the state (i.e. Canadian National Railway after 1996), or in the case of state-run enterprises, the right of way and infrastructure are public assets (e.g. in France and other European countries), amongst other arrangements. It should be noted that since the privatization of railways in the UK (following the passage of the *Railways Act* in 1993), one-state owned company may own the track, but it enters into agreements which may allow several concessions (Train Operating Companies) to operate on the same lines (may be both passenger carriers and, separately, freight operators).

interswitching, competitive line rates, joint track usage and running rates, which fall under various Acts and associated regulations in Canada. Private ownership, therefore, granting complete control of a given system to a company allows it to “enforce a strict code of operational discipline” (Faulk, 1965: 2).

In Canada, national passenger rail service is operated by VIA Rail, which was established by the federal government in 1977 and receives annual operating subsidization. VIA Rail operates on CN trackage. Prior to the formation of VIA Rail, both CN and CP operated their own passenger services (CITT, 2008).

3.3.1.3 The Node (Terminal)

Similar to the case of road transport, the node, or terminal required in rail transport, will differ depending on whether the usage is passenger or freight. Passenger terminals will vary in size and degree of functions. In large Canadian cities there are examples of major passenger rail stations (such as in Montreal, Toronto and Winnipeg) which in their size and architectural ornamentation provide an illustration of the wealth and importance of the railroads in the economic and developmental history of the country in the late nineteenth and early twentieth centuries. At the other end of the spectrum, a terminal may be a flag stop along a rail line, and this may have no significant amenities other than its defined location (e.g. on the Hudson Bay Railway).

In the case of freight transport, nodes will vary in their design, layout and size and function. Marshalling yards are used by the rail companies to assemble and disassemble units of carriage to form a complete train destined for a particular location (such as in the case of the CN Symington Yard and the CP Winnipeg Weston Yard). The terminal acts in two ways:

as a point of collection of goods to be placed on a train, or as a distributive point where goods are taken from an inbound train and dispersed to their final destinations such as through placement on a different train onto a branch line, or by transfer to another mode (i.e. truck delivery). The intermodal terminal is a dedicated facility where containers (the 40-foot marine shipping container or the 53-foot domestic intermodal container) are loaded and unloaded from the train and placed on chassis for truck distribution. Physically, they can occur as an adjunct function at marshalling yards or at stand-alone sites where this activity occurs.

3.3.2 Economic Considerations

As the capital and operating expenses of the rail mode are relatively high, it stands to reason that the rolling stock must be kept moving to the greatest degree possible to generate revenue. The productive performance[58] of the railways is key not only to their individual success but that of the larger industry, in part due to the fact that since 1945, railways in most countries have experienced a declining proportion of market share as the use of road transport has significantly increased (Oum *et al*., 1999). Despite their loss of market share in haulage as a whole, railways have dramatically improved their productivity in the course of the twentieth century.

[58] Oum *et al*. (1999: 10) describe the concept of productivity as it applies to the rail mode, and its variation between firms and over time. It is a function of elements such as differences in efficiency, economies of scale, in network characteristics, and other performance-affecting "exogenous factors". Among the latter are average length of haul, traffic composition, market size, quality of service, weather conditions and technological change. Note that there are some similarities between these factors affecting productivity and the common elements of transport costs as suggested in Table 1.

3.3.3 Spatial Considerations

3.3.3.1 Network or System

The length of trackage within the control of the Class 1[59] railways is constantly changing, the result of mergers and acquisitions, and the abandonment of spurs and feeder lines. For the purpose of illustration, currently CN has 20,421 miles (32,864 kilometres)[60] of trackage in its North American network which spans eight provinces and 16 states, and CP has 13,200 miles (21,243 kilometres), similarly distributed across the two countries (CN, 2010: CP, 2010).

3.3.3.2 Speed

The speed at which rail transport operates is comparable to that of road. There is the limit on speed from the engineering and operational characteristics of the linkage (i.e. the trackage, capacity of the line, physical obstructions or operational delay, maintenance schedules, etc.) and the rolling stock (i.e. displacement of the engine unit, number and type of units of carriage, etc.). Operationally, the rolling stock will typically not maintain the high speeds that technically it is capable of, due to the signalling and management of traffic on the lines (i.e. maintaining safe headways and inter-train distances). The railways monitor the performance of their rail systems, using the average speed of units hauling certain types of cargo as an indicator. As an illustration, for the period between June and November 2010, on the CP network, bulk trains averaged a speed of 20.1 miles per hour, intermodal trains 28.8

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[59] There exist four classes of railway and their distinction is based upon annual revenue. Class 1 railways currently have gross annual revenues of more than $250 million. In Canada this includes CN, CP and VIA Rail. Class 2 railways have average gross revenues (of Canadian operation) greater than $500,000. Classes 3 and 4 have average gross revenues of less than $500,000 (CITT, 2008). In the United States, Class 1 railways are those which had 2009 operating revenue of $378.8 million or more (of which there were seven, including CP and CP), and this threshold number (and those for Class 2 and 3 railways) changes every year (typically increasing) (AAR, 2010a).

[60] Note that the railroads still operate using the mile of the imperial system as the measure of distance, as opposed to the kilometre of the metric system.

miles per hour and carload trains 19.6 miles per hour. Cumulatively, all trains on the system maintained an average speed of 22.0 miles per hour (35.4 kilometres per hour). For the same period in 2009, the average speed on the CP network was 25.1 miles per hour (40.4 kilometres per hour) (CP, 2010).[61]

3.3.4 Benefits and Disbenefits of Rail Transport

The major benefit of rail transport is its ability to move relatively large volumes of freight for long distances. Although the speed of travel will vary over the course of the journey, the operation of rail on private infrastructure allows for complete control of scheduling and traffic, allowing the service to run on controlled schedules, twenty-four hours a day. Although not the main focus of this discussion, the mechanical efficiency of the rail mode is significant.[62]

Disbenefits of the rail mode include a high initial capital cost of rolling stock and supporting infrastructure. The massive amounts of capital required are cost-prohibitive to all but the most well-backed business ventures (such as large-volume mining projects) for new builds and adequately long timeframes are required for return on investment. The use of dedicated infrastructure poses both benefits (control of scheduling) and disbenefits (need for consolidation services at origin and distribution at destination). A synopsis of the general benefits and disbenefits of rail transport is provided in Table 3.

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[61] Bulk trains are largely composed of units of carriage such as the hopper and gondola cars. Intermodal trains are largely composed of chassis for carrying containerized traffic. Carload trains are largely composed of boxcars, and specialized units (such as automobile carriers, log cars, etc.) which carry break-bulk materials.

[62] The mechanical efficiency of the rail mode is often touted by the industry, especially on environmental grounds. For example, the American Association of Railways asserts that one gallon of fuel can move one ton of freight by rail an average of 480 miles, and points to the comparative efficiency and lower emissions of the rail mode vis-à-vis the road mode. Means of creating these efficiencies include procuring new locomotives, implementing locomotive monitoring systems, training engineers, reducing idling, integrating new componentry and design, amongst others (AAR, 2010b).

Table 3 - General Benefits and Disbenefits of Rail Transport	
Benefits	**Disbenefits**
• Relatively large carrying capacity • Private infrastructure (control of network and scheduling) • Efficient operation for all but short hauls • Long distance transport is cost-efficient • Ability to transport bulk cargo and containers • Operates in own right of way (independent of road traffic), thus avoiding gridlock problems	• High cost to maintain infrastructure (linkage and nodes) • Confined to operation on specialized infrastructure • May require road transport at origin / destination for transhipping to water mode[63] • Limited number of service providers (two major in Canada), potentially limiting competitive pricing • Complex regulatory regime (i.e. Railway Revenue Cap, interswitching and others)

3.4 Water Transport

For purposes of this discussion, water transport will focus on freight applications,[64] particularly in large bodies of water.[65] In Canada, several major types of international services (i.e. global) and domestic services exist (i.e. on the east and west coasts, the St. Lawrence Seaway system, and the Mackenzie River in the north) (CITT, 2008).

Through time, as transport modal technology has been developed and improved, it is often overtaken by another mode, usually on the basis of service amenities. First and foremost among these amenity considerations is time, although that is almost matched with flexibility of service, general proximity to destination, etc. Such is the case for water transport for passengers. In the majority of cases, other than for pleasure (i.e. cruise ships),

[63] Road transport may not always be required at the origin or destination. For instance, bulk coal can be discharged directly from a ship to railcar, and oil / fuel can be pumped form a tankship to railcar without a road intermediary.

[64] As noted in the Introduction (page 2), this thesis focuses on the northern and remote areas, particularly Northern Manitoba or Northern Canada. In these regions, formal inland waterways or canals do not presently exist (not to the exclusion of the historic use of York Boats and other vessels engaged in the fur trade). As in some United States or European examples (such as the Erie and Manchester Ship Canals respectively), the inland waterway played a pivotal role in the transition of transport and the economic development of the area (see Moulton, 1926). Water transport will be used in reference to vessels, ships, and barges.

[65] This section will focus on "large bodies" of water, as distinct from inland water transport on lakes, in channels or canals, etc., as for the most part the latter are insignificant in the Canadian context. For instance in Manitoba, other than northern ferries (operated by the Province), and limited commercial barge charter-service, there is no longer any scheduled commercial passenger or freight service on the system of rivers (i.e. Red or Assiniboine) and lakes (i.e. Winnipeg). It should be noted that there does exist a commercial fisheries industry. In 1965, the last mixed passenger / freight vessel (the S.S. Keenora) was retired and one company, Marine Transport Limited, was operating a fleet of three tugs and several bulk oil carriers, equipment barges, bulk cement carriers and one general merchandise freight vessel, the M.S. Joe Simpson (Manitoba, 1969).

for long-distance travel the aircraft has supplanted the ship as the mode of choice (Delaney and Woellner, 1974).

3.4.1 Modal Requirements

3.4.1.1 Unit of Carriage

The unit of carriage in the marine transport mode is the vessel, which may vary in size, shape, function and source of motive power. Types of vessels include dry bulk vessels, which carry cargoes such as oil, iron ore, coal, or grain, container vessels, refrigerated vessels, those which transport bulk fuels and chemicals (in a liquid or highly pressurized state) such as tankers, chemical and gas carriers (i.e. "liquid bulk" vessels), and there are a variety of specialized vessels.

Focusing on container ships, there are several generations of ships, corresponding with capacity classes, which are identifiable and presented in Table 4. The various "panamax" designations developed as the Panama Canal was (and remains) a crucial piece of civil infrastructure in the operation of global trade and commerce, therefore its dimensions became a de facto international standard. With the widening of the Panama Canal, a new class of ships will emerge based on the new dimensional characteristics and it should be noted that there exist vessels in operation which far surpass the capacity of the post-panamax plus class.[66]

[66] According to the A.P. Moeller – Maersk Group, their PS-Class vessels, including the "Emma Maersk", can carry 11,000 TEU, which is approximately equivalent to a train 71 kilometres in length (Maersk, 2010). Furthermore, super post-panamax vessels of 12,000 to 14,000 TEU are currently in service.

Table 4 - Generations and Capacities of Container Ships		
Generation	**Capacity**	**Class**
First	Less than 1,000 TEU	---
Second	2,000 TEU	---
Third	2,000 to 3,000 TEU	---
Fourth	4,000 TEU	panamax
Fifth	5,000 TEU	post-panamax
Sixth	5,000 to 6,000 TEU	post-panamax plus

Source: After CITT (2008).

The trend to larger ships (specifically in the context of container transport) is a result of the general commercially-realized principles of economies of scale. The larger the vessel and the carrying capacity, the "costs at sea" per tonne or TEU decrease (Cullinane and Khanna, 1999). In terms of the carriage of bulk goods, specifically tankers, there has been a similar trend towards an increase in vessel size, as the advantages of economies of scale were known, but similar to the issue with container ships, the adoption of larger classes of tanker was tempered by the fact that operational constraints thwarted their widespread adoption (i.e. need to expensively retrofit ports to allow passage of larger tankers) (Conway's, 1992). Whereas in the late twentieth century, larger tankers were classed either as VLCC (very large crude carriers – 200,000 to 299,999 dwt)[67] and ULCC (ultra large crude carriers – above 300,000 dwt), there are vessels which are in the 400,000 to 550,000 dwt capacity range. Dry bulk carriers, dedicated to coal and iron ore, also now exceed 400,000 dwt.

Cullinane and Khanna, in an appraisal of the major container lines, identified five reasons for the exhibited trend. These were:

1. Gaining competitive advantage (through ship economies of scale) and forcing competitors to react;
2. Larger alliances (of companies) have made bigger ships operationally viable;

[67] Dwt refers to deadweight tonnes.

3. Industry's expectation of future growth in container volume, cargoes utilizing containerization and of container penetration inland;
4. Developments and improvements in port infrastructure (in particular increased depths and bigger cranes) have facilitated use; and
5. When turning over of capital stock, companies are assessing the sizes of replacement vessels and choosing to retire smaller vessels and purchase new stock of larger classes (Cullinane and Khanna, 1999: 186).

3.4.1.2 The Linkage (Way)

The linkage required in water transport is any navigable water which is sufficiently deep to accommodate the draft of the particular class of vessel. In practice, port entrances, channels, sand banks, and other obstructions in coastal and port areas require artificial improvement. This may take the form of dredging, channelization and the construction of locks, etc. Due to the various natural states of the marine transport environment, and their susceptibility to the vagaries and relative unpredictability of the weather, sea conditions, and so forth, the vessels which operate in this medium must be designed to maintain seaworthiness in variable operating conditions. Accordingly, there is a difference between vessels which can ply the oceans, those which are used in the Great Lakes system and those used in Arctic environments. The first conforms to stricter requirements than the second, while the third must fulfil the strictest requirements of all. Differences of building specifications, licensing and insurance ratings affect the practical ability (and in turn the costs of construction and operation) of vessels to operate in certain states of the marine environment. Furthermore, all ship operators are aware that navigational aids are required to approach land from the high seas. These may take the form of lights, markers, buoys and other forms of signalization (Delaney and Woellner, 1974), and their costs are in part passed on to the ship operators resorting to them.

3.4.1.3 The Node (Terminal)

The nodes for water transport are located on land, typically as ports, which have the infrastructure and required equipment to move the freight cargo (containers, bulk, and other forms) from the vessel onto another form of transport (typically road or rail, but can include transhipping to other varieties of water transport)[68] for a subsequent leg of the journey or final distribution. There are four necessary features of port facilities: first, a favourable location; secondly, a haven possessing sufficient shelter from natural elements when the vessel is using the terminal (i.e. breakwaters, inland location accessed by channel); thirdly, sufficient depth of water for the vessel (at all phases of the tide) in the channel and harbor; and fourthly, facilities to effect the transfer of freight (and passengers) from sea to land and vice versa (Delaney and Woellner, 1974).[69] Depending on the situation of the terminal relative to the sea or waterway, services such as tug and pilotage may be mandatory, and impose additional costs on ship operators.

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[68] There are many container transhipment ports which focus on vessel-to-vessel movements of containers rather than to a foreland / hinterland transhipment by other mode. This type of transhipment can be for both international movements as well as for hub to and from coastal ports inland. For example, in China's Pearl River basin, this vessel-to-vessel transhipment takes place midstream and this is noted to be primarily to avoid fees associated with the use of land terminals (USDOT, 2008)

[69] As an illustration, the Northern Manitoba Port of Churchill has four loading berths (panamax-class) with dockside depths of 8.5 metres, capable of accommodating a maximum vessel size of 225 metres LOA (length overall), and has a variety of dockside grain and cargo handling and storage capabilities (Port of Churchill, 2010).

3.4.2 Economic Considerations

3.4.2.1 Cost of Infrastructure

As water transport operates in a natural environment (save for the required operating infrastructure such as navigational and communications aids), the cost of infrastructure is incurred at the terminals. The terminals may be owned and operated under various business models and corporate structures, such as those with state backing, wholly private ownership or a combination of the two.

3.4.2.2 Cost of Usage

Bulk freight transportation by water may be split into two markets. First, services may be acquired on the spot (or tramp) market. In this instance, a service provider will operate for a customer on the basis of a short-term contract, a charter, or a specified number of trips or moved quantity between two points. This market is known to be highly volatile in its pricing (CITT, 2008). Secondly, a time-charter market exists, where typically long-term contracts are entered into, usually when there is a longer-term source of product (such as bulk commodities). Under this arrangement, vessels may or may not be contracted with a crew (CITT, 2008). In contrast, for scheduled services – liner shipping – traditionally much of the transport occurred under “conference rates”.[70]

The terminals (and the authorities of the harbours and ports hosting the terminals) will generate revenues by charging the vessel a number of fees for various services rendered

[70] Shipping conferences are groups of ship owners and operators that offer service in a particular zone. Other service providers are referred to as “non-conference lines” and they compete on the basis of cost against the conferences. It should be noted that the European Commission officially ended the exemption formerly provided to conferences in 2006, with an implementation date of October 2008. This effectively abolished the conference system (which had been in existence since the 1870’s in various forms) with the end goal of fostering competitiveness by removing the market distortion of price-fixing and competition limiting practices (EU, 2006).

while docked, some of which have been mentioned.[71] Similarly, the users of canal and lock systems will be assessed a variety of fees.

3.4.3 Spatial Considerations

3.4.3.1 Network or System

Terminals are located throughout the world. In the global system of containerized transport, it is interesting to note that the shipping companies which offer scheduled services, that is the liner companies, categorize the routes and ports of call similar to a railroad or bus schedule. There is a variety of options on a given route (eastbound and westbound on the main North Atlantic and North Pacific trades), and typical days of transit applied for a given movement. The various shipping companies have their routes available to the transport and logistics community so that inland staging and coordination of goods and transport to terminals can be facilitated to meet the departure scheduled for a particular vessel.

An area of increasing interest for nations and the shipping community is the use of ice-bound waters, such as in the arctic or circumpolar regions. Nations such as the Russian Federation have advanced operational networks of ports and appropriate equipment (i.e. ice breakers) to utilize these routes (i.e. the Northern Sea Route) on a commercial basis.[72]

3.4.3.2 Speed

The speed of transport by water will vary according to a number of factors, including operational considerations such as running speed, which may be reduced during times of

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[71] CITT (2008) notes that charges may include combinations of the following: anchorage (charge per vessel to moor awaiting cargo or berth space); harbour charges (charge against vessel based on Gross Registered Ton (GRT) on each harbour entry (cover port costs of dredging, breakwaters, personnel); berthage (charges assessed on basis of vessel size and are levied in 12 hour increments); wharfage (levied on basis of weight / measurement of cargo); and handling and other ancillary charges.

[72] For a detailed discussion of the technical and geopolitical issues surrounding contemporary and future use of arctic and circumpolar waters for marine trade, see Arctic Council (2009).

economic recession to save on fuel consumption (slow-steaming),[73] tonnage, and natural considerations, such as weather, sea conditions, current flows, presence of obstructions).

3.4.4 Benefits and Disbenefits of Water Transport

The major benefit of water transport is its large carrying capacity, applicable to both containerized and bulk freight. The capability for flexible operation on the seas is a benefit, since areas of inclement weather or potential danger or hostilities (e.g. pirates) may be circumnavigated. If there are problems at a given terminal (e.g. labour unrest), in some cases a secondary terminal may be accessed (and the inland transportation may get the product to its final destination using an alternative route).

Conversely, the major disbenefits of the water mode are the relative length of time required to transport goods and the need to have transhipment occur at terminals for subsequent inland distribution. The several points of transfer, and the multiple actors that are involved in the overall transport function, present multiple opportunities for the system to fail or break down. Although sea-going vessels are equipped with sophisticated navigational and communications equipment and advanced mechanical systems and hull design, they are still susceptible to the vagaries of the weather and natural hazards such as shifting sandbars. A list of general benefits and disbenefits is presented in Table 5.

[73] Slow steaming has been shown to reduce consumption of fuel, a 1 to 2 knot reduction in speed from the normal 20-22 knots may provide a 5% savings in fuel, but there may exist several operational considerations in doing so, including timing issues with accessing berthage at a port of call and efficiency issues related to incomplete combustion of fuel, potentially leading to an array of mechanical system issues and a possible increase in NOx emissions (*Fairplay Solutions*, 2010).

Table 5 - General Benefits and Disbenefits of Water Transport	
Benefits	**Disbenefits**
• Large carrying capacity, providing the ability to transport bulk cargo and containers in large volumes • Linkage between nodes is cost free (other than required navigational and communications equipment) – although not risk free (i.e. pirates, natural hazards such as icebergs and sandbars) • Relatively flexible (i.e. can change course mid-journey, take alternative routes to destination)	• Susceptibility to extreme weather, especially in polar environments • Usually requires further transport at origin / destination (either truck or rail for consolidation and distribution respectively)[74] • Relatively costly nodal infrastructure • Requires time, not appropriate for certain time-sensitive cargoes

3.5 Air Transport

Air transport has had a major impact on the ability to move passengers and freight around the world. Equally, it has been noted as having a major impact on the process of economic globalization (Button, 1999; O'Rourke and Williamson, 1999), and in turn, has been supported by improvements in technologies and investment in infrastructure which have resulted in a space / time collapse (Rodrigue, 1999). Rodrigue (1999) further argues that other than in the rail mode, there will likely not be significant gains made in the speed of transport[75], but they are likely to become more efficient and less costly. Thus, although not necessarily moving faster, two factors are identified as affecting this time / space collapse, namely, economies of scale and the considerable expansion of transport infrastructure.

3.5.1 Modal Requirements

3.5.1.1 Unit of Carriage

The unit of carriage is the aircraft, which may come in a wide spectrum of forms. Three general configurations of aircraft are used for passenger and freight movement: first,

[74] Note that many bulk carriers (including liquid) discharge directly into the user's premises (e.g. oil refinery, steel mill) after loading at a source of the bulk product (i.e. oilfield, mine).
[75] Rodrigue (1999: 255) notes that travel time by Boeing 747 over the North Atlantic in 1999 was roughly the same as what was required in the mid-1970's, when that aircraft was originally put into service and supersonic aircraft such as the Concorde were found to be economically and environmentally unsound.

passenger; secondly, freight; and thirdly, those which combine both passengers and freight. With aircraft used in the transport of passenger and mixed-freight, there exists a range of levels of comfort for the traveller, extending from luxury to rudimentary, as in the case of military troop and freight transport (e.g. a jumpseat or bench in a cargo hold).

One aspect of air transport which differentiates it from the other three modes is that its cost generally precludes the usage of it for general or bulk freight. Typically, freight transport by air relies on high-value or time-sensitive cargo. Freight transport by aircraft has, to some degree, adopted the practices of water transport and embraced the use of standardized forms of unitization. The difference is that aircraft containers are often designed according to particular dimensional properties of an aircraft's cargo hold, in an effort to maximize usable space. The use of containers protects the cargoes inside (often small packages), allows for a measure of security and safety for the cargo[76], and allows ease of movement in, out, and within the aircraft, on the tarmac and within the terminal. Micco and Serebrisky (2006) point to the development of the wide-bodied aircraft in the 1970's as instituting a change in the unit of carriage which re-shaped the sector. The increased space on these aircraft led to the ability to transport significantly more freight and passengers, which opened up an air cargo market. As further developments in aircraft technology and design came about, which allowed for increased cargo payloads, this eventually led to the introduction of all-cargo airlines into the market. Table 6 illustrates a select range of aircraft currently operating in the study area.

[76] Safety in the sense of protecting the cargo from the elements, from damage due to falling off a pallet, being struck by machinery, etc. A level of quality assurance can be obtained if the container is sealed with a lockable tab.

Table 6 - Select Aircraft Operating in Study Area					
Aircraft	**Speed (mph)**	**Range (mi)**	**Passengers (max)**	**Cargo (lbs)**	**Operator(s)**
ATR42-300	285	500	42	10,000	Calm Air
Beech 99	230	900	14	2,400	Perimeter
Cessna Caravan 208	214	928	9	---	Northway Aviation
Cessna Grand Caravan	214	1,368	9	3,000	Northway Aviation
Dash 8	290	900	37	8,000	Perimeter
Fairchild Metroliner	293	683	19	5,000	Bearskin Airlines
Merlin	300	1,700	6	700	Perimeter
Metro Cargo	300	1,100	3	3,000	Perimeter
Metro II	300	1,100	14	2,700	Perimeter
Metro III	300	1,700	19	4,000	Perimeter
Hawker 800	500	2,700	8	---	Perimeter
Saab 340B	300	1,076	34	3,300	Calm Air, Bearskin Airlines

Source: Airline operator and aircraft manufacturer information.

3.5.1.2 The Linkage (Way)

The linkage for transport by aircraft is the sky. Similar to transport by water, although this linkage may appear to be open and in a natural state with a virtually unlimited capacity, in reality it is a highly ordered and structured operating medium, and the ability of the infrastructure on the ground applies capacity constraints on the system.

The skies are heavily regulated through international agreements, typically determined in a bilateral relationship between two countries. The basic elements of these agreements are commonly referred to as the five freedoms.[77] These basic principles which are incorporated into bilateral agreements between countries have their genesis in the Chicago Convention in 1944, where the first two freedoms were approved. In short (CITT, 2008), the first freedom allows a carrier licensed in one nation to fly over another nation's territory without landing. The second freedom allows for a technical stop; namely aircraft which require fuel or mechanical repair may stop in the territory of a signatory nation

[77] CITT (2008: 5-5) notes that in effect there are seven freedoms (numbers 6 and 7) aspired to by the aviation industry, but not generally accepted as elements in bilateral trade. The sixth freedom is a combination of the third and fourth; that is, a carrier transports revenue traffic (between two nations) over its base nation, while the seventh freedom is a form of cabotage; the carrier transports revenue traffic between two points within a foreign nation.

(without boarding or alighting revenue traffic). The third freedom allows for the carriage of revenue traffic from the carrier's base nation to the territory of the signatory nation. The fourth freedom allows for the reverse of the third freedom; that is, a carrier can carry revenue traffic back from the signatory nation, to its base nation. Lastly, the fifth freedom allows a carrier, based in one country, to carry revenue traffic from a second country to a point in a third country (if all nations are signatories). Needless to say, there are those in this sector who advocate for the relaxation of this form of regulation, and the adoption of "open skies" in the global air transport market, and they have succeeded in the European Union, for instance.

3.5.1.3 The Node (Terminal)

In its basic form, the node is the site with the required infrastructure and services to permit safe operation of the aircraft and facilitate take-off and landing functions (landing ground) as well as on-ground support (i.e. fuelling, freight / baggage movement, passenger functions, etc.) and roadway networks to facilitate the movement of people and cargo to and from the airfield, according to the size and scope of the facility. Button (1999) notes that an airport may serve a dual function, serving both domestic and international airlines. With increased traffic, airports face both scheduling strains on operations and constraints on technical capacity (forcing operational efficiencies to be found, in order to avoid adding an expensive runway).

In Canada, there are approximately 1,800 aerodromes, of which 631 are certified.[78] Twenty-six airports are part of the national airports systems (NAS),[79] including Winnipeg,

[78] Aerodrome is the technical term used by Transport Canada to designate registered facilities where landings and takeoff occur.

Toronto, and Montreal, together with airports at provincial / territorial capitals, and facilities maintaining passenger levels above 200,000 annually for three consecutive years. These facilities handle approximately 95% of air travellers in Canada (Transport Canada, 2011a). In Manitoba, the Department of Infrastructure and Transportation in 2009 operated 24 northern airports. In the fiscal year 2009-2010, these northern airports accounted for 53,521 aircraft movements, carrying 186,056 passengers and 12,417 tonnes of freight in total (MIT, 2010b).

3.5.2 Economic Considerations

3.5.2.1 Cost of Infrastructure

In general terms, the cost of infrastructure in the air mode is related to the terminals and their associated infrastructure. There are a variety of ownership and operational models for airports in Canada (i.e. for small private airfields), but the majority of significant airports are categorized under the Federal Government's National Airport Policy and must subscribe to its model of operation and defined roles and responsibilities.[80]

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[79] In Manitoba, under the four categories of the Federal National Airports Policy (NAP), airports are classified as follows: NAS airports: Winnipeg; Regional and Local airports: Brandon, Dauphin, Flin Flon, Gillam, Lynn Lake, The Pas, Thompson; Small airports: St. Andrews; Remote airports: Churchill, Norway House; Arctic airports: none (Transport Canada, 2011a).

[80] In Canada, the Federal Government, beginning in the mid-1990's has undertaken a program to divest itself of airport ownership to the local Canadian airport authorities (CAA). Under the guise of the aforementioned National Airports Policy, the Federal roles and responsibilities for the nation's airports are laid out for all classes of airport: those comprising the National Airports System, the Regional and Local, the Small and the Arctic. In essence, for the 26 NAS airports, the Federal Government is the landlord and leases the property to the CAA (i.e. charges rent); additionally it sets national standards for safety, operation, security, etc. The local CAA operates under a not-for-profit corporate structure, with a board of directors, and is responsible for revenue generation, infrastructure maintenance, upgrades and new construction. The smaller, non-NAS airports, can access the Airports Capital Assistance Program (ACAP) for infrastructure improvement projects.

3.5.2.2 Cost of Usage

The airlines which operate aircraft are assessed a variety of fees for use of airport infrastructure and services (i.e. cargo, airside support activities such as refuelling and de-icing, emergency response, etc.) and, in Canada, are assessed charges by NAV Canada.[81] In some instances all services are provided by the airport on a cost-recovery basis, while in others, airlines contract the required services and they are provided solely to that specific carrier at a particular airport, including ticketing and baggage-handling services. There are companies which have private aprons and facilities on airport grounds. For example, United Parcel Service has its own apron and facilities for the firm's all-freight aircraft at the J.A. Richardson Airport in Winnipeg. In Canada, the operation of aircraft is a federal responsibility; therefore the standards and licensing requirements are national in nature.

All-freight carriers enjoy an advantage over their passenger-carrying counterparts in that their business operations are not necessarily tied to airports with costly fees on account of them serving as prime locations for business or general travellers. Freight firms can operate from less busy terminals and schedule movements for off-peak hours in an attempt to lessen the user-fees associated with their use of a terminal facility. Moreover, they can compare and choose between similar terminals in different jurisdictions, opting for those with the least onerous economic and industry regulations (Micco and Serebrisky, 2006). There are also cases of low-cost or discount passenger airlines operating under the same principle, such as Southwest in the United States, Porter in Central Canada using Toronto Island as opposed

[81] NAV Canada is responsible for providing civil aviation services in Canadian airspace. Service is provided on a cost-recovery basis and includes all manner of air navigation services, including air traffic control, flight information, aeronautical information, weather briefings, airport advisory services and electronic aids to navigation. The entity operates under the *Civil Air Navigation Services Commercialization Act* (the ANS Act) (NAV Canada, 2010).

to Pearson International, Easyjet and Ryanair in Europe using Stansted and Luton in Greater London as opposed to Heathrow or Gatwick.

3.5.3 Spatial Considerations

In the Canadian air transport sector, three types of service providers may be identified: regional carriers,[82] national carriers, and international carriers (CITT, 2008). The air transport industry often operates its networks as hub and spoke systems. In this configuration, it is similar to the other modes, where the larger carriers will provide transport, (typically longer-distance journeys using larger capacity aircraft) from a limited number of locations. Smaller independent or affiliated regional carriers will provide the consolidation and dispersion of passengers and freight at the hubs (typically shorter-distance journeys using smaller capacity aircraft). In Canada, the illustration of Air Canada is relevant. The regional service, Jazz, which often uses smaller turbo-prop aircraft, will bring passengers to a hub, such as Montreal or Vancouver, where they will board a larger Air Canada jet aircraft for transcontinental or trans-oceanic flights.

3.5.4 General Benefits and Disbenefits of Air Transport

A list of general benefits and disbenefits is presented in Table 7. The major benefit of air transport is its ability to provide both passenger and freight service over vast distances at high speeds. This has redefined both passenger and freight transport. Faulks (1965: 10) suggests that the water and air modes share several general characteristics. These include:

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[82] Regional carriers often act as the “spokes” in the hub and spoke system. In Manitoba, the regional carriers which serve the North (such as Calm Air, Bearskin, Perimeter, and others) not only provide intercity transport intraprovincially (e.g. Thompson to Winnipeg), but in effect allow for freight and passengers to be transloaded onto national carriers for transport and subsequent distribution across Canada or internationally.

1. The fact that both operate national and international routes (for both passenger and freight);[83]
2. The linkage (or way) is natural, thus operation may be somewhat flexible;
3. Both require extensive navigational aids to facilitate transport (although the linkage is natural);
4. Both require specialized nodes (terminals) which are often sophisticated and expensive, but typically are not owned by the operator of the transport service;
5. Both are operated (to varying degrees by international agreements and governance arrangements;[84] and
6. There exists a sizeable charter market for services in both modes.

Table 7 - General Benefits and Disbenefits of Air Transport

Benefits	Disbenefits
• Speed / time, most appropriate for high-value, time-sensitive cargoes (i.e. express service) • Long distance transport of passengers and freight • Linkage between nodes is cost free (other than required navigational and communications equipment) • Varying units of carriage allow for flexibility of use and cost • Flexibility of route: can change path for emergency, to avoid weather phenomena, or to escape on-ground issues at destination, etc.	• Relatively low carrying capacity: not well suited to bulk or dimensional cargoes • Relatively costly • Requires specialized nodal infrastructure (i.e. runway, navigational and communication equipment) • Regulated environment (for safety, and in context of international trade, economically) • Susceptible to weather (particularly related to take-off and landing)

[83] Note that the same could be said of the other modes (e.g. railways and intercity bus service from Canada to the United States).
[84] These international agreements and governance structures include, in the water transport mode, collective pricing arrangements as per conference agreements, liability arrangements such as the Hague-Visby Rules and the Hamburg Rules, Special Drawing Rate (SDR) for member countries of the International Monetary Fund (IMF), etc. In the air transport mode, corporate alliances are formed between carriers, and international member organizations such as the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA). The international air transport context is heavily regulated, with an obvious example being the "five freedoms" of air rights which are bilaterally negotiated between countries (CITT, 2008).

3.6 Summary of Modal Comparison

Given the above review of the four major modes, it has been clearly shown that certain factors will likely influence, if not govern, the choice of mode used, depending on several major characteristics, which may be categorized as modal requirements, economic and spatial considerations. The four modes have been reviewed to gauge how their inherent characteristics may accrue both benefits and disbenefits to the consumer of transport services, provided particular geographical and cargo circumstances are taken into account.

The road, rail, water and air modes of transport all differ in terms of their units of carriage, the linkage and the nodes required for operation. Likewise, there are distinct differences in the economic considerations of their respective uses, both in terms of the costs of infrastructure and the costs of usage. The nature (i.e. passenger or freight) and the composition (i.e. bulk, break-bulk or containerized) of the entity requiring transport must be viewed against the spatial considerations of distance and time, as ultimately this relationship will affect the cost of the transport service.

When assessing the modal implications from a transport planning perspective, one must be aware of the benefits and disbenefits of the mode not just from the viewpoint of operational characteristics, but also in terms of the broader infrastructure required to enable use of the mode and the costs associated with it. This dynamic will differ according to specific scenarios. Comprehensive planning is required for all modes as the infrastructure incident to the linkages typically requires a significant period of time to move through the design, environmental licensing and construction phases. The water and air modes may be thought of as spatially less intrusive, since their infrastructure is relegated to a defined site (as opposed to a 1,000-kilometre road or rail line). A summary of the elements reviewed in this chapter is provided in Table 8.

With the review of the literature on the relationship between transport and development and the survey of the transportation modes providing a foundation, the remainder of this thesis will focus on the study area within the Province of Manitoba and the spatial analysis of its transport networks.

Table 8 - Summary of Transport Modes: A Comparative Survey of Strengths and Weaknesses (specifically freight transport)

		Road	Rail	Water	Air
1	**Infrastructure**				
	Unit of Carriage	• Commercial motor vehicle (various configurations of power unit and carrying unit)	• Rolling stock (engines and rail cars – various functions)	• Vessel (various sizes / functions – e.g. container ship, laker, barge)	• Aircraft (various sizes / functions)
	• Cost (comparative)	• Relatively low investment	• Very high investment	• Very high investment	• Very high investment
	• Strength of service (capacity)	• Finished goods, small package, variable highway and local distance, drayage • Up to 35 tonnes per unit	• Up to 10,000 tonnes per unit train	• Bulk and containerized • Up to120,000 gross tonnes per container ship; in excess of 400,000 DWT for bulkers	• Up to 125 tonnes
	• Illustration of bulk grain	• 1 truck = 22 tonnes	• 1 train = 454 trucks	• 1 laker = 3 trains or 1,362 trucks	• *NA*
	• Bulk handling capability	• Fair	• Excellent	• Excellent	• Poor
	• Package handling capability	• Excellent	• Excellent (containerized loads) • Fair (others – due to handling procedures)	• Excellent (containerized loads) • Excellent (bulk) • Fair (others such as break-bulk)	• Excellent (unitized) • Fair (other – break-bulk) • Poor (bulk)
	Linkage (Way)	• Roads, highways	• Trackage	• Oceans, lakes, river systems, canals	• None (lanes in the sky)
		• Built and maintained by governments	• Built and maintained by companies (in North America)	• Built and maintained under various models (i.e. canals and port approaches)	• *NA*
	Node (Terminal)	• Sole (private) and common-use terminals and yards • Cost recovery through freight rates	• Terminals (built and maintained by railways) • Cost recovery through freight rates	• Ports (built and maintained by private companies and governments) • Cost recovery through user fees	• Airports, runways (built and maintained by private companies and governments) • Cost recovery through user fees
2	**Economic Considerations**				
	Cost of Infrastructure	• Indirect	• Direct	• Direct	• Direct
	• Capital cost (comparative)	• Low	• Very High	• Very High	• Very high
	• Requirements	• Highways and roads, terminals	• Rolling stock (engine and cars), terminals, tracks, signals, etc.	• Vessels, containers, cranes, bulk conveyors, storage, ports, etc.	• Aircraft, terminal, runway, navigational – communication, equipment, security, etc.
	Cost of Use				
	• Operating cost	• Driver, fuel, maintenance, user fees, tolls, etc.	• Engineer, crew, fuel, maintenance, etc.	• Captain, crew, fuel, maintenance, user fees (ports and other), etc.	• Pilot, crew, fuel, maintenance, user fees at airports, etc.
3	**Spatial Considerations**				
	Network or System				
	• Strength of service (distance)	• Short distance	• Long distance	• Long distance	• Long distance
	• Flexibility (comparative)	• Very flexible	• Not very flexible	• Not very flexible	• Some flexibility
	Speed	• Time sensitive and scheduled	• Scheduled	• Non-time sensitive	• Time sensitive

Sources: CITT, 2008; Delaney and Woellner, 1974; and Faulks, 1965.

4.0 The Transport Network and its Development in Northern Manitoba

4.1 Study Area

The focus of this study is on the existing and future road network in Northern Manitoba. The study is limited to the area of Manitoba contained within boundaries which may be defined as from approximately $53^0$00' N on the western border (with Saskatchewan), extending in an approximate straight line in the south-easterly direction to $51^0$50' N on the eastern border (with Ontario) and extending northwards to the border (with Nunavut / Hudson Bay). The study area is depicted in Figure 1. This area is deemed suitable, for north of this arbitrary line of demarcation the transport network (both road and rail) largely assumes a north-south orientation, and exhibits limited interconnection amongst its links. The outcome is a low-density spinal network. In addition, it is north of this line that the seasonal winter road network is built on an annual basis, providing overland access to the communities on the East Side of Lake Winnipeg (north of Hollow Water and Provincial Road 304). Lastly, this line of demarcation roughly approximates the "North" region used by Statistics Canada and the Manitoba Bureau of Statistics for purposes of data collection.

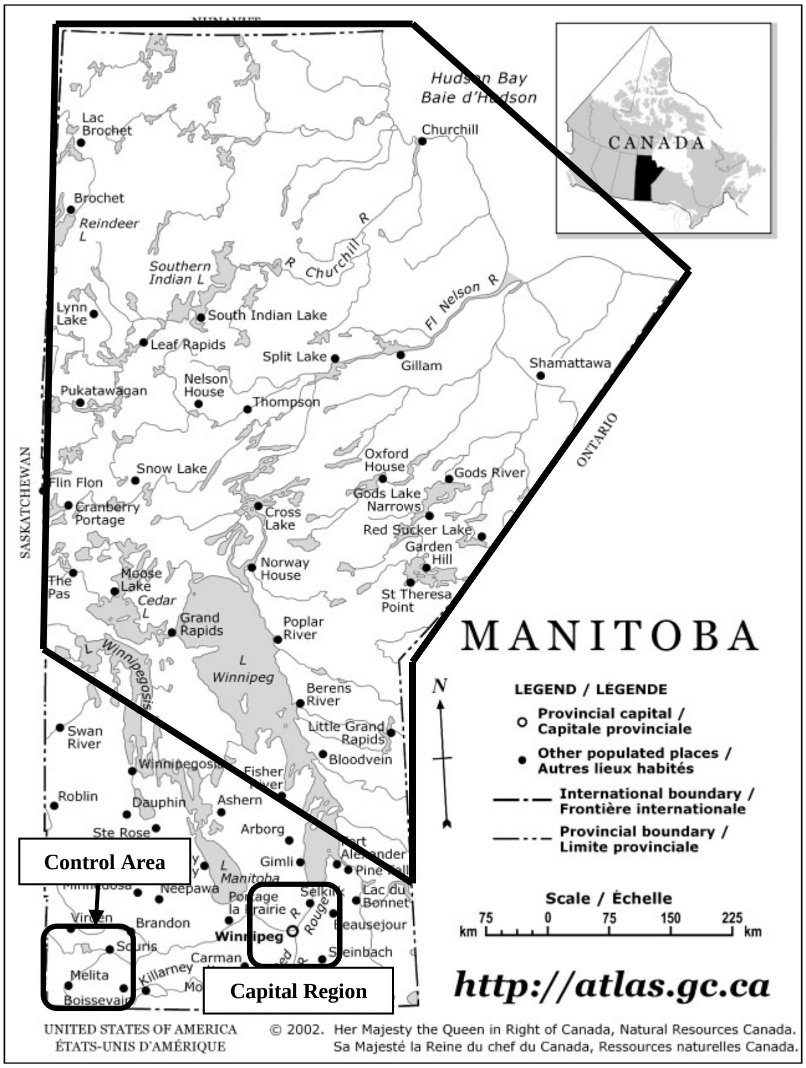

Figure 1 - Study Area [85]

4.2 Overview of Current Transport System in Study Area

4.2.1 Road Transport System

The current road transport system in the study area embraces three classifications of roadway: Provincial Trunk Highways (PTH), Provincial Roads (PR) and those on the winter road system. There are approximately 1,115 kilometres of PTH, which are all two-laned paved roadways; 1,373 kilometres of PR roadway (462 kilometres of which are paved or

[85] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

asphalt-treated and 911 kilometres which are gravel); 114 kilometres which are classified as other or unknown condition; leaving 2,200 kilometres of winter roads.

In the study area the traffic using the road network varies by roadway. Using the typical engineering / planning measure of Annual Average Daily Traffic (AADT)[86], the number of vehicles on an average day during the year using select roadways on the system is provided in Table 9 and Figure 2 for illustration.

Table 9 - Traffic Levels on Select Roadway Links in Study Area

	Road	Segment	Veh. count AADT
1	PTH 6	Jct. of PTH 6 and 60 (immediately south of Grand Rapids	690
2	PTH 6	Immediately south of Thompson	2,170
3	PR 280	Immediately east of Gillam	290
4	PR 391	East of Lynn Lake	110
5	PTH 10	South of Flin Flon	1,550

Source: UMTIG, 2011

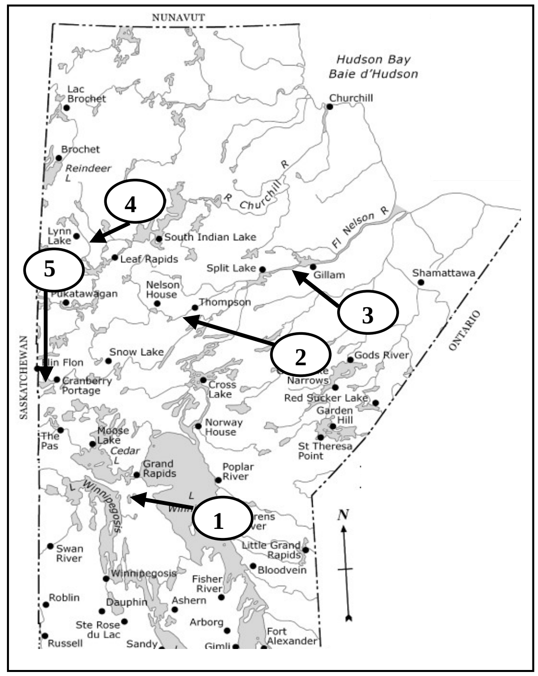

Figure 2- Traffic Levels – Map of Referenced Locations[87]

4.2.1.1 General Development of Road Transport Networks

In the prairie provinces and northern territories, roads and road networks are constructed in one of three fashions. First, a private entity may construct a road, typically to provide access to a business asset such as a mill or mine site, such as the 600-kilometre privately built and operated ice road (although open to the public) from Tibbitt to Contwoyto

[86] AADT is defined as the number of vehicles passing a given point on an average day of the year, as estimated using data collected over an entire year, according to a particular methodology (UMTIG, 2011).
[87] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

in the Northwest Territories, or a natural asset such as a resort, forestry area, or a location of staked mineral resources. These are often all-weather roads, as they are primarily used for commercial purposes with a limited lifespan, such as when built to access a construction site. Additionally, the roads are typically in remote areas, where sourcing of building products (e.g. aggregates) in a relatively close proximity is critical to project cost suppression. As noted above, there are examples of private roads in the Northwest Territories which are usually associated with capital-intensive oil, gas or mining operations. In Manitoba, prior to 1971, there were private operators providing winter overland services on a combination of frozen lake, river and winter road to the northern extents of the province and into north-western Ontario, the notable company being the Sigfusson Northern Transportation Company (Foster, 1996).[88]

Secondly, the governing authority, such as a province or territorial government, constructs the road transport facility. Currently in Canada, a Province or Territory will typically contract the physical construction of the infrastructure to private sector companies via the form of a bid-tender process. Depending on the project, the initial planning and design phases may be undertaken internally, or they too may be contracted to external engineering service providers. Some jurisdictions also contract external providers to perform ongoing transport infrastructure maintenance operations (such as road clean-up and snow-clearing activities), while others continue to provide this service. The process of contracting some planning and design aspects, and all the construction activity to third-party providers, is currently the standard approach used in Manitoba by the Department of

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[88] The significance of the year 1969 as the historical benchmark is that a comprehensive study of the Northern Manitoba transportation system (multi-modal) was undertaken as part of the *Royal Commission Inquiry into Northern Transportation* (Manitoba, 1969). This report includes detailed information and maps, providing a comprehensive snapshot at the time of the state of the transportation system, and the attendant economic and social factors.

Infrastructure and Transportation, for both the highway network (PTH and PR) and the seasonal road network.

A third situation, albeit not currently used in Manitoba, is a partnership approach, which may assume one of several financial and legal contractual relationships.[89] In this instance a variety of project responsibilities may exist between the parties. For example, the governing authority may construct the roads, but the private entity provides maintenance services, or the governing authority may contract the private entity to manage the construction and maintenance operations, amongst myriad other relationships. The rationale for this approach arises in situations where the governing authority does not have the in-house capacity to undertake the project or in circumstances where it may be more cost-effective to put the project, or components thereof, to a competitive bid process or where there is a motivation to reassign project risk (such as for complex designs, time-sensitive project scheduling, or due to an authority's lack of experience, resources or available manpower).

4.2.1.2 Seasonal and All-Weather Roads

A clarifying distinction between seasonal and all-weather roads is required. Seasonal roads in Manitoba may be referred to with interchangeable terminology such as winter roads, ice roads, and so on, all of which incorporate a core notion; namely, they are not permanent in nature. Approximately 2,200 kilometres of winter roads were constructed in 2008-2009 by

[89] Manitoba's *Vision 2020* recommends that the Department "explore the option of private-public partnerships in order to enhance the development of new transportation infrastructure, particularly for those communities not now serviced by an all-weather road" (MTGS, 2005: 14). An example of this type of partnership is the Government of the Northwest Territories' 2007 signing of a concession agreement with the Deh Cho Bridge Corporation to design, construct, finance and operate (DCFO) an approximately 1-kilometre-long cablestay bridge across the Mackenzie River, replacing a seasonal ferry service and ice crossing (Government of the Northwest Territories, 2011).

the Province of Manitoba, at a cost of approximately $9 million. This network provides temporary overland access to 23 communities and approximately 30,000 residents. As this network is directly affected by the vagaries of the weather, it is typically officially open for six-to-eight weeks per year (MIT, 2010).[90] The length of the seasonal road network is down considerably from its network length in 1969 when it equalled approximately 4,000 kilometres, and slightly more than the network length of 1,600 kilometres in 1978 (Adam, 1978).[91] Seasonal roads follow the same route year over year, and traverse both overland and ice surfaces. In Manitoba, construction of seasonal roads was begun in the 1940's by private-sector concerns, but this activity was taken over by the Province of Manitoba in 1971 (Foster, 1996).

Conversely, all-weather roads (AWR) are permanent roads which are under the authority of the Province. They are constructed and maintained according to Departmental engineering standards. Where river crossings exist, permanent crossing structures are provided. The major benefits of the all-weather roads are their reliability. The commercial vehicle industry and the public can be confident that the roads will be of a certain standard, having the ability to safely accommodate both commercial movements and private vehicles on the entire network. This reliability aspect includes factors such as the geometry of the road dressing, its engineering properties, such as loading, structural integrity, curvature

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[90] It should be noted that the current seasonal road network in Manitoba is constructed to facilitate basic access to the communities it serves. The network is not created to any alignment standards and vehicles with a gross vehicle weight exceeding 7 tonnes (approximately 15,500 pounds) are recommended to travel at speeds no greater than 15 km/hr when on sections of ice and maintain a separation distance of 1 kilometre (MIT, 2011).

[91] As a point of comparison, the Northwest Territories in 2007 maintained 1,425 kilometres of publicly constructed winter roads and there were numerous privately constructed and maintained winter roads which accessed the public highway network. These were primarily to service the oil and gas industries and mining resupply activities. The longest private winter road was from Tibbett to Contwoyto, a distance of 570 kilometres (Government of Northwest Territories, 2007).

sightlines, etc., and the fact that it will be maintained to a minimum level (i.e. snow clearing, grading of running course, signage, etc.).

4.2.1.3 Road Access and Regional Economic Development in Rural and Northern Contexts

As remarked upon earlier, the literature generally supports the notion that transport is a necessary requirement for economic development and this is further verified when one examines the general economic development or growth theory. In the light of the above, governments, whether nations or sub-national authorities, have historically used, and continue to use and espouse, the notion that transport access and economic and social development are closely interrelated. This stance often forms the basis for policy and programs to support the development of transport infrastructure in instances where traditional cost-benefit ratio analyses do not indicate a net benefit for a particular project. Broader public policy goals such as transportation equity, the right to access, and reliable, basic connectivity to existing networks as are available in other areas of a particular jurisdiction (i.e. a province) may be cited as motivating and decision-making factors for the expenditure of public funds on these transportation projects.[92]

In the context of this study within the Province of Manitoba, there certainly exists a motivation or desire, as expressed in numerous policy and planning documents, for providing reliable, all-weather road access to remote reaches and locations of the province. As

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[92] Transportation equity may be defined as the "fairness with which impacts (benefits and / or costs) are distributed" (Litman, 2011). The right to access, or "equitable access", as articulated in Manitoba's *Vision 2020* (MTGS, 2005), embodies the aforementioned definition of transportation equity. The public consultative process of *Vision 2020* determined that this concept was of importance to Manitobans and it formed a point of contrast between north and south conceptions of the transportation network (i.e. the south, due to its accessibility and connectivity, was perceived to have greater opportunity than the north, where accessibility and connectivity is often limited). Litman (2011: 6) notes that in the practice of transportation planning and decision-making, "there is no standard way to determine how much weight to give a particular equity objective", and planning decisions should "reflect community needs and values".

expressed in more recent publications, the aspirations for these remote regions of the province are first and foremost for the creation of social and economic betterment for the residents, followed by local economic and resource development opportunities. Just two of such representative documents, albeit perceived to be significant, are *The Northern Development Strategy* and *Vision 2020*. Each is briefly discussed, with weight being placed on what it has to say about the provision of all-weather road transportation access.

The 2005 *Northern Development Strategy* is "the Manitoba Government's long-term plan to develop the human and natural resources of Northern Manitoba. The strategy creates opportunities for social and economic changes to benefit all Northern Manitoba" (Manitoba, 2005). The strategy, which remains current as a policy platform for government, was developed by five Members of the Legislative Assembly for the Province of Manitoba. It outlines five priority areas: transportation, health, employment and training, housing, and, lastly, economic development. It is a high-level document which makes several statements on the priority area, followed by listing select points of action and investment that the government had made to date. It is inherently a political document as opposed to a technical planning document, therefore concept elaboration and specifics are sparse.

In the context of transportation, the *Northern Development Strategy* describes the terrain of Northern Manitoba as often posing a barrier to movement and notes that "about 33,000" people in the northern reaches of the province have "no all-weather access roads" and furthermore the current winter road system is becoming "more fragile with global warming". When the operational duration of the winter road system is abbreviated, typically goods are flown into the remote communities, often at greatly increased costs.[93] The *Strategy* acknowledges that reliance on the winter-roads (and air transport) “drives up the cost of living in many communities and compromises health care, employment and training”.

Vision 2020 is a more comprehensive document and was the result of a planning process which was aimed both at informing the citizens of Manitoba of the challenges affecting transportation infrastructure and at encouraging them to participate in the debate as to the long-term solutions – which were to be both visionary and capable of implementation. Focusing on northern transportation, the idea of equitable access was identified as a high priority through the consultative process. Furthermore, it was noted that:

> Most Manitobans consider the ability to access essential services through basic mobility, as well as access for daily activities and social interactions, to be *fundamental rights* [emphasis added]. Residents living in 39 remote northern communities, however, continue to lack year-round ground transportation. Whether travelling to work, to school, to access health care, or to attain social services, these Manitobans are often faced with long journeys and in some cases need to rely on unreliable road, rail, ferry or air services. Inclement weather further complicates the situation and poses another set of challenges to overcome (MTGS, 2005).

In terms of the road network, a priority issue recommended by the Steering Committee was that the Province seek to realign the winter roads and create permanent roads, and implement a plan to install permanent bridge and culvert structures at water

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[93] Although slightly dated, the 2003 *Northern Food Prices Report* examines the cost structure of supplying food to northern communities and the differential between those with road access and those which are fly-in. The analysis presents cost data for the North West Company as a telling illustration. The freight costs, as percentages of total sales costs, vary between stores with road access and those that are fly-in. The average freight cost for road stores (for all types of food products) is noted as being 3.3%, ranging from 2.6% (frozen) to 8.3% (beverages). In contrast, for the fly-in remote stores the average freight cost is 12.5%, ranging from 11.8% (meats) to 27.9% (dairy) (Manitoba, 2003: 8).

crossings to lengthen the usability of the seasonal road network. Related to the all-weather road network was the question of how to fund this endeavour. On this point the Steering Committee recommended that the Department investigate options for private-public partnerships in the provision of new transportation infrastructure. Lastly, on the issue of economic development, it was recommended that the Department establish a tripartite funding relationship with the federal government and First Nations to commence the construction of an all-weather road network on the East Side of Lake Winnipeg and to other remote communities.

4.3 Rail Transport

The current rail transport system in the study area operates in two forms. There is the Hudson Bay Railway which runs from The Pas (connection onto CN trackage) to Churchill (627 miles / 1,010 kilometres), and the Keewatin Railway Company, which runs from Sherritt Junction to Pukatawagan (185 miles / 251 kilometres on the Sherridon subdivision which continues northwards to Lynn Lake) as illustrated in Figure 3.

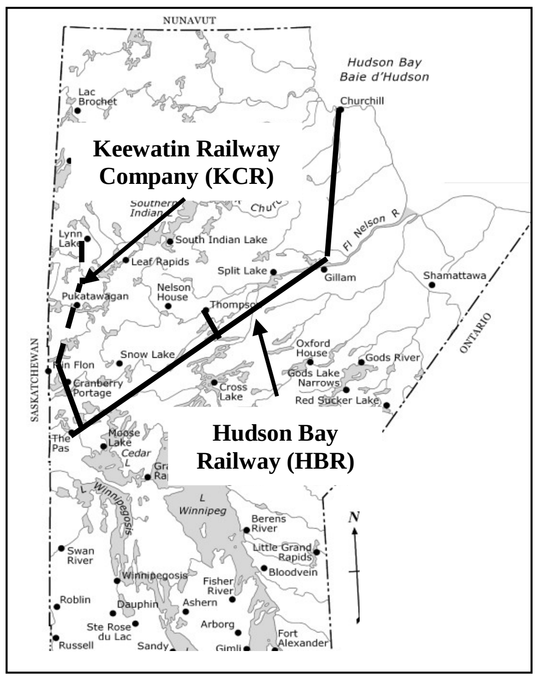

Figure 3- Rail Transport Network[94]

[94] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

4.3.1 Hudson Bay Railway

The Hudson Bay Railway (HBR) provides the singular form of overland access to the Town and Port of Churchill at its northern terminus. The HBR reached Churchill in April 1929 and became fully operational when the port facilities were completed in 1931. In 1951, the line became part of the CN system and in 1979, VIA Rail assumed the passenger operations (Greig *et al.*, 1983).

Currently, freight moved on this line includes perishables, automobiles, construction materials, heavy and dimensional equipment, hazardous materials, kraft paper, concentrates, containers, fertilizer, wheat and other grain products. Major private sector users of the line include Hudson Bay Mining and Smelting (now HudBay Minerals), Tolko Manitoba, Gardewine North, Imperial Oil, Petro Canada, Sittco Energy and the Canadian Wheat Board (OmniTRAX, 2011). Passenger service is operated by VIA Rail over the HBR trackage and connects Winnipeg with Churchill, and serves points in between (including the Keewatin Railway Company at The Pas). The passenger schedule is provided in Table 10.

Table 10 - Passenger Schedule - Hudson Bay Line

Train	Origin – Destination	Frequency	Duration
693	Winnipeg – Churchill	Tuesday Sunday	44 hours (1 day, 20 hrs)
692	Churchill – Winnipeg	Thursday Saturday	45 hours (1 day, 21 hrs)

Source: VIA Rail Canada, 2011.

Historically, the largest commodity by tonnage exported from the Port of Churchill has been grain products (e.g. by the Canadian Wheat Board) which arrives at the port by way of the HBR. Other sources of tonnage include supplies for industrial development and the annual resupply of communities of the Kivalliq Region of Nunavut under contract by the

Government of Nunavut according to its “Sealift” program (the majority of this tonnage moved under this program for the Territory as a whole, originates from the greater Montreal region) (Government of Nunavut, 2011).

4.3.2 Keewatin Railway Company

The Keewatin Railway Company (KRC) began operation in 2006 following the purchase of the line from OmniTRAX, the owner of the Hudson Bay Railway. The KRC is a First Nations’ railway, which was supported by the Federal and Provincial Governments, and is operated by three First Nations in the area: the Tataskeweyak Cree Nation, the Mathias Colomb Cree Nation and the War Lake First Nation. The Railway operates two scheduled mixed passenger and freight trains as summarized in Table 11.

Table 11 - Passenger Schedule - Keewatin Railway Company

Train	Origin – Destination	Frequency	Duration
290	Pukatawagan – The Pas	Tuesday Friday	7 hrs, 30 mins
291	The Pas – Pukatawagan	Monday Thursday	8 hrs, 45 mins

Source: VIA Rail Canada, 2011.

4.4 Water Transport

The current water transport system may be categorized in two ways: international or export / import oriented and intraprovincial. The first pertains solely to the Port of Churchill, the deep sea port located within the study area. The second category refers to the water transport operating within the province, which today takes the form of ferry services, as no schedule passenger or freight transport service exist. Each will be briefly surveyed in turn.

4.4.1 The Port of Churchill

The Port of Churchill is Manitoba's only deep-sea port. As noted in section 3.4, the port currently has four berths and can accommodate Panamax-class vessels (i.e. grain, general cargo and tanker ships) with lengths of up to 225 metres (length overall) to a depth of 11.5 metres. Dockside, the grain elevator has a storage capacity of 140,000 MT. There are two cranes, indoor and outdoor storage areas, a petroleum terminal with a 50-million-litre capacity, and six miles of rail trackage available for marshalling activities. The infrastructure can currently unload in excess 100 rail cars per day of grain and can load 1,200 MT per hour onto vessels. Currently there are three tugs available for towing and harbor entry / egress (Port of Churchill, 2010).

The predominant commercial activity at the port since its commission in 1931 has been the handling of grain and other agricultural products (typically for export), although mining and forest products have been exported as well. Inbound traffic has consisted of ore, minerals, steel, building materials, fertilizer and petroleum products which have been transported on the Hudson Bay line for subsequent distribution to southern markets. Between 1997 and 2010, total annual exports from the port have ranged from approximately 300,000 tonnes to slightly above 700,000 tonnes, the vast majority being Canadian Wheat Board (CWB) grains (wheat and durum) with the occasional shipment of non-CWB products (such as feed peas, alfalfa, flax seed, canary seed, canola and linola) (Port of Churchill, 2010).

4.4.2 Intraprovincial Water Transport

The Province of Manitoba operates ferry services at eight locations within the study area (as illustrated in Figure 13), specifically:

1. South Indian Lake
2. Split Lake
3. York Landing
4. Seafalls
5. Norway House
6. Islandview
7. Bloodvein
8. Matheson Island

In 2009-2010, the eight operating locations conveyed a total of 91,481 vehicles and 208,193 passenger movements (MIT, 2010).

4.5 Air Transport

The current air transport system in the study area is composed of private operators using airport facilities which may fall under one of two jurisdictions, either Federal or Provincial authority. The Province of Manitoba oversees the operation of twenty-two northern airports in the study area,[95] while a further five airports fall under the National

[95] The 22 airports within the bailiwick of the Province are: Berens River, Bloodvein, Brochet, Cross Lake, Gods Lake Narrows, Gods River, Ilford, Island Lake, Lac Brochet, Little Grand Rapids, Norway House, Oxford House, Pikwitonei, Poplar River, Pukatawagan, Red Sucker Lake, St. Theresa Point, Shamattawa, South Indian Lake, Tadoule Lake, Thicket Portage and York Landing. Two additional airports are currently under consideration for the communities of Wasagamack and Pauingassi (MIT, 2010b).

Airports Policy (NAP) – regional / local category and two under the remote category.[96] The dimensions of the runways, the surface type and airside facilities vary by location (e.g. 2900' x 75' crushed rock runway at Berens River to the 4000' x 100' crushed rock at Island Lake and the 9,200' asphalt surface at Churchill). The variation is largely attributable to the terrain and topography adjacent to the communities and also historical factors.[97] The dimensions of the runways dictate the type of aircraft which may access the given community.[98]

Passenger and cargo levels at the provincially-overseen facilities vary significantly from year to year, to some degree influenced by the length of operation of the winter-road system. Figure 4 illustrates the total passenger, freight traffic and aircraft movements for the twenty-two airports for the time period from 1990 until 2009-10 (MIT, 2010b).

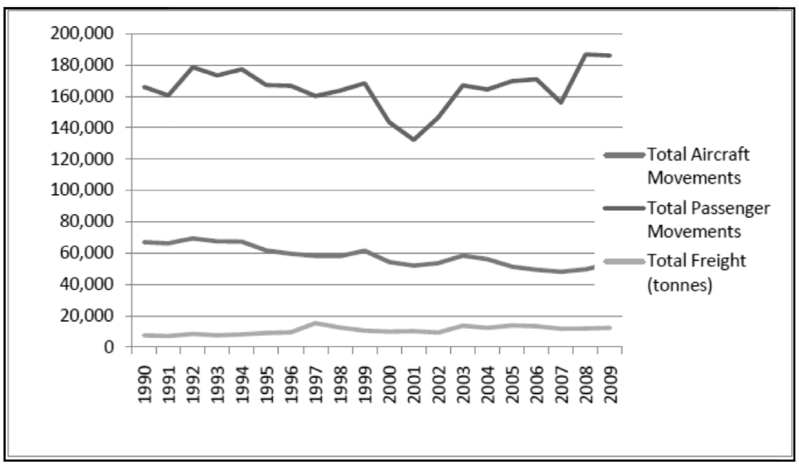

Figure 4 - Summary of Air Transport Activity (1990-2009)

[96] The five NAP – regional / local airports in the study area are Flin Flon, Gillam, Lynn Lake, The Pas and Thompson while the two airports under the auspices of the remote category are Norway House and Churchill. Regional / local airports meet the criteria of: scheduled passenger traffic of less than 200,000 a year for three years; they are not the national / provincial / territorial capital; they are not classified as arctic or remote. However, they do enjoy a current form of federal financial involvement and have scheduled passenger traffic. Remote airports are defined by the criteria that the air transport service is the only reliable, year-round mode for the community and that the community is reliant on the air mode to facilitate the majority of its traveller and cargo traffic in and out (Transport Canada, 2011a).

[97] An example is the role of the United States Air Force in the aviation infrastructure in Churchill beginning post World War II and ending in 1968 (Taylor, 2002).

[98] See Table 6 for a select illustration of the range of aircraft currently operating in the study area.

This chapter has provided a synopsis of the existing transport network in the study area and has discussed some of the factors influencing its development to the present. The following chapters will turn to an applied analysis of this transport network by mode.

5.0 Applied Analysis of Spatial Transport Network

In an attempt to understand the above relationship, various spatial analysis techniques in the field of geography have been developed which allow researchers to examine, quantitatively compare and produce a visual representation of a study area for investigation; ultimately with the aim of testing a research hypothesis through the construction of models (of varying complexity). One of these techniques is graph theory.

The application of this technique in economic geography was *en vogue* in the 1960's, and although in many respects it has been superseded by more complex and involved analysis techniques which use computers, its simplicity and fundamental logic still lend themselves to application for the rudimentary spatial analysis of transportation networks. It is especially germane for the comparison of a network over time, before or after expansion or contraction, and provides a common framework for the analysis of two or more networks.[99] Indicative of this lasting relevance is a pioneering study of Garrison, which has echoes in contemporary studies. Garrison's (1960) study of a portion of the United States' Interstate Highway System applied the typical graph-theory indices to analyse the network. In addition, he presented a comparison across modes: highway and railroad. Fifty years later, Derrible and Kennedy (2010) used graph theory application to analyse and compare 33 metro systems around the world and characterize them according to their network properties, specifically noting the characteristics of regional accessibility, local coverage and regional coverage. Lowe and Moryadas (1975: 79) note that graph theory is not really a theory in the proper

[99] Instructive texts which address both theory and application (especially in the context of transport) include Haggett and Chorley (1969), Taaffe and Gauthier (1973), Lowe and Moryadas (1975), and Tinkler (1977).

sense of the term, rather it is branch of combinatorial topology and it is “a powerful, versatile language which allows us to disentangle the basic structures of transportation networks”.

Graph theory, and its associated methodological technique, is reductionist in nature, for it allows researchers to describe complex systems and structures through a simplified abstraction. In rudimentary cases or applications, it uses relatively noncomplex mathematical methods, although more involved computations and analysis may be undertaken from the basic definition of the network(s). These techniques allow for the relatively easy development of numerical models and the subsequent empirical analysis and comparison of networks over time, against one another, and so forth. Kansky (1963) notes that the fundamental concepts of graph theory allow for the recognition of “relations between seemingly non-correlated elements” of transportation networks.

5.1 Methodology

5.1.1 Graphs as Symbolic Representations of Spatial Phenomena

Graph theory uses the reductionist technique of representing network structure, or topology, in the form of a graph, which represents the basic spatial structure of a given network. The simplification of the information visually allows for a degree of focus on important structural characteristics under investigation, while the use of matrices for the computation and analytical investigations provides a straight-forward and logical approach to modelling network, or networks, for a variety of investigative purposes.

The reduction or shedding of information inherent in the graph technique does confer, as Haggett and Chorley (1969: 7) note, “certain penalties and benefits”. The penalties, or disbenefits, include the loss of information (an inherent property of any model), while the benefits include a greater degree of abstraction, relative ease of data handling and comparison and flexibility (Haggett and Chorley, 1969). Tinkler (1977: 5) stresses the distinction between the use of graphs by mathematicians and geographers. For the latter, the graph often is representative of existing places and connections, whereas for mathematics it is usually an abstract representation of nodes and links. Thus the geographer is producing a "map of some reality", which the mathematician may term the "embedding" of a graph on another space. This can lead to some methodological issues which have been accounted for in the use of planar and non-planar graphs (a fundamental distinction).[100]

As related above, Garrison (in Berry and Marble, 1960: 242), in his seminal analysis of the Interstate Highway System in the south-eastern United States, identified five general properties that make graphs appropriate for the measurement of transportation systems:

1. A network has a finite number of places (i.e. nodes);
2. Each route (edge connecting vertices) is a set consisting of two places, that is it originates and terminates at a node;
3. Each route joins two different places;
4. At most, only one route may join a pair of places; and
5. No distinction is made between start and end of route, that is they are assumed to flow two-ways.

From this foundation, a multitude of possibilities arise, as we shall see.

[100] Planar graphs are those in which all edges intersect at a vertex (that is they are "embedded" in the plane). Conversely, non-planar graphs cannot be drawn as a plane graph without a crossing of edges (Tinkler, 1977: 6). Further explanation of this is provided on page 107.

5.1.2 Topological Networks, Nodes, Linkages and Subgraphs

The topological, or representative network, seeks to portray a complex system in an elementary or somewhat facile form (in terms of informational content), consisting of points and lines (Taaffe and Gauthier, 1973). In so doing, the topological network is not concerned with representing the true nature of the transportation network and its constituent parts, but rather one which is abstracted and which conveys only the major features. Elements, such as relative position of two nodes or perhaps relative distance, are conveyed in a topological network.[101] The topological network, as a model (and models in general), allows for the elimination of "real world complexities, enabling greater comprehension". Moreover, it allows for data manipulation and the testing of relationships, permits generalizations which may lead to a better understanding of the subject matter and subsequent inferences and scientific predictions, and, last but not least, provides a common language and methodological construct which may be widely applied (Lowe and Moryadas, 1975).

Taaffe and Gauthier (1973: 101) note that, on the basis of a topological network, the use of graph-theoretical techniques is forthcoming with two types of measurements. The first type embraces indices which describe the geometrical pattern of the transportation network in an aggregate form; this will be the alpha, gamma, beta indices described below. The second type consists of a set of numbers which measure or situate an individual network element, such as a particular vertex or node, in relation to the entire network. They will be expressed in the matrices used to calculate and rank nodal connectivity, as described below.

[101] Relative distance is meant in the general sense of proximal location of vertices in relation to one another. Therefore, in reality, vertex 'x' is farther away from vertex 'y' than vertex 'z', and therefore in the topological representation of the graph, this relationship of relative spatial distance is likewise represented in the length of the edges connecting the three vertices.

The topological representation of a transportation network may assume either the planar form or the non-planar form. The distinction is as follows: planar graphs are used to topologically represent land-based transport modes such as highways or railroads, as there are distinct routes which are used and the intersection of two vertices will always occur at a node. The non-planar graph is used when representing the air mode, or conceivably the water mode, as there are no necessarily determined routes (in the abstraction) for an aircraft to use to connect two nodes. As a visual representation, multiple routes may cross, but in actuality there is no relationship between them.

Vertices (or nodes)[102] are the locations where any form of interaction originates or terminates, and enjoy specific coordinates in geographic space (Lowe and Moryadas, 1975). Taaffe and Gauthier (1973) view vertices as cities that are connected by linkages, and a vertex will exhibit characteristics based upon its relative accessibility. Vertices may be ranked in a hierarchical fashion, according to defined criteria groups, and they may be analyzed, compared and contrasted by means of various mathematical operations and structural identification techniques. For this study vertices represent either a population centre (of any form) or the intersection of two edges.[103]

Edges (or linkages)[104] connect vertices and permit movement. For this study they are the physical, permanent all-weather roadways on the ground. Edges are fundamentally related to vertices, as transport is not needed, nor typically provided from an origin point to

[102] For consistency, this chapter will henceforth use the term vertices, whereas in much of the literature the term node is used.
[103] An example of such a hierarchy is nodal accessibility, which places in rank order the vertices (nodes) according to their accessibility, for instance as determined by creating a connectivity matrix (Taaffe and Gauthier, 1973). Edges (routes) may be hierarchically examined by way of applying a Strahler stream ordering, the same principle as applied in hydrographical studies (Lowe and Moryadas, 1975).
[104] Hereafter, this chapter will use the term edge, whereas in much of the literature the term linkage is used.

destination nowhere, such as a dead end. It may be taken for granted that an origin and a destination are required, as is a reason for the transport to occur. Edges may be relatively straight-line in orientation (i.e. to incur minimum cost), or they may bend to avoid natural or manmade features (i.e. rivers, mountains, cities).

5.1.3 Network Characteristics: Measures of Connectivity and Accessibility

The interaction and connectivity a transport network provides are critical to both the economic and social development and sustainability of an inhabited place. By extension, the larger the region in which it is situated, the more significant this becomes. This chapter will use the term accessibility as defined in the straightforward manner by Lowe and Moryadas (1975: 7). Thus, access is "…the ease with which a specific location can be reached from a given point." Taaffe and Gauthier (1973) note that a fundamental concern of network analysis is the relative accessibility of a vertex in relation to the network in which it is embedded. This relative accessibility of a vertex, or its "reachability", be it modal specific or at an aggregate level, may dictate its hierarchical or spatial position as a gateway or hub in a larger system (e.g. Chicago or Winnipeg on the national railway systems). As a transportation network evolves over time, the relative position of a vertex may change in relation to the network, and thus its accessibility may be affected.

In an abstracted network (i.e. one represented by edges and vertices), connectivity represents the degree of connection between all vertices and "is probably the most important structural property of the network" (Taaffe and Gauthier, 1973: 101). This degree of connection, when taken as a whole, represents the connectivity of that network and provides an index to the relative simplicity or complexity of the network structure (Lowe and Moryadas, 1975). Taaffe and Gauthier (1973: 101) note that expansion or intensification of linkages between two given vertices is directly related to the demand to move people and goods, thus the degree of connectivity of the "transport network is an indicator of the complexity of the spatial order that it imposes on the region it serves". Rather more to the point, connectivity has direct connotations for economic development – a truism recognized by Kansky (1963) – in that its enhancement progresses in tandem with increasing levels of economic development. Garrison's (1960) study highlighted the salience of this relationship for an entire American region, and one, significantly, that included remote rural parts not unlike the remote characteristics of the study area of this thesis. Another relatively remote area subject to similar analysis, the Zhujiang Delta in Southern China, also vividly displays the consistency occurring between measures of network expansion and rapid economic development (Loo, 1999).

As noted by Haggett and Chorley (1969: 32), the indices of network structure commonly used in graph theory (and applied in this paper) are in their most basic form based on three network elements:

1. The number of vertices;
2. The number of edges; and
3. The number of subgraphs (non-connecting or separately defined subsystems).

Several standard graph-theory indices are used which incorporate the aforementioned three network elements in their calculation. This study uses four standard indices for evaluating and comparing the connectivity of a transportation network. These are the cyclomatic number and the alpha, beta and gamma indices. In addition, a rudimentary connectivity matrix provides an indication of the direct connectivity between pairs of vertices. These indices are more fully discussed below.

5.1.3.1 Cyclomatic Number

The cyclomatic number uses the number of edges (E), vertices (V) and loops or circuits (G) in a given network. The values for this indicator will range from 0 to (2V-5) for a planar graph. As Lowe and Moryadas (1975: 89) assert, well-connected networks are those which exhibit numbers of loops. Developing networks tend to exhibit subgraphs – reflecting a lack of interconnectedness – while more developed networks have fewer of these, since their situation is one of multiple connections and their corollary of multiple network loops.

$$\text{Cyclomatic Number} = E - V + G \qquad \text{[EQ. 1]}$$

5.1.3.2 Alpha

The alpha index (α), or redundancy index, expresses a ratio between the existing (or observed) number of circuits in a network and the maximum number which may theoretically exist in that network. Alpha values range from 0 to 1, with a value of 0 indicating that the network is branching (exhibits no circuitry) and that removal of any one edge would split the network into two (i.e. subgraphs). Conversely, a value of 1 indicates a completely connected network, where any additional edges would result in duplication of connectivity (Haggett and Chorley, 1969).

The alpha index, as specified in Equation 2, is for planar graphs.

$$\alpha = \left(\frac{E - V + G}{2V - 5}\right)100 \qquad \text{[EQ. 2]}$$

The alpha index, as specified in Equation 3, is for the non-planar graph (air transport).

$$\alpha = \left(\frac{E - V + G}{\frac{V(V-1)}{2} - (V-1)} \right) 100 \qquad \text{[EQ. 3]}$$

5.1.3.3 Beta

The beta index (β) is the simplest descriptor of network complexity. It relates the number of linkages to the number of vertices in a ratio, with lower values indicating simple topological structure and higher values representing more complex structures. In other words, it is a simplistic measure of linkage intensity (Lowe and Moryadas, 1975). Beta values from 0 to 1 indicate networks which are disconnected (i.e. possess no circuits) while values (for planar graphs) between 1 and 3 indicate increasing levels of circuitry. Planar graphs have a maximum value of 3, while non-planar graphs may have an infinite range of values (Haggett and Chorley, 1969). As higher β values are indicative of more complex network structure, the index value is typically higher for developed countries than for underdeveloped ones (and this holds true for regions within a country). Moreover, for a given country, the index value will increase over time as new network edges are constructed (Lowe and Moryadas, 1975). The beta index used for both planar and non-planar analyses is illustrated in Equation 4.

$$\beta = E / V \qquad \text{[EQ. 4]}$$

5.1.3.4 Gamma

The gamma index (γ) provides a measure of the actual number of edges in a network relative to the maximum possible number of edges. Planar graphs have a range of values between 0 and 1 and the calculated number may be expressed as a percentage. Similar to the β index, the γ index has a direct correlation with levels of economic development. Accessibility in developed countries (or regions) is typically greater than in underdeveloped ones, for there exist multiple or alternative ways to access a given vertex (Lowe and Moryadas, 1975).

The gamma index, as specified in Equation 5, is for planar graphs.

$$\gamma = \frac{E}{3(V-2)} \qquad \text{[EQ. 5]}$$

The gamma index, as specified in Equation 6, is for the non-planar graph (air transport).

$$\gamma = \frac{E}{V(V-1)} \qquad \text{[EQ. 6]}$$

5.2 Structural Analyses of Networks

The above network indices reflect the network at an aggregate level, that is, as a contiguous system. Another aspect of the graph-theoretic technique examines the individual vertices. As modelled, networks may be examined for changes over time that occur as a result of network modification and expansion. The use of matrices for analyses allows the researcher to understand the effect on an individual point in the given network. This study will use one matrix, the simple connectivity matrix, to examine the properties of the four networks. This matrix establishes the degree of a vertex.

5.2.1 Simple Connectivity Matrix

The simple connectivity matrix uses the abstracted topological network and translates it into matrix format, thus allowing for several calculations to be undertaken. By convention, the x-axis (horizontal row) is the origin vertex, and the y-axis (vertical column) is the destination vertex. The simple connectivity matrix then represents the direct connection of a given vertex to one or others. It is a rudimentary illustration of the presence or absence of connectivity, for it is only expressing the existence of direct connectivity or no connectivity between two or more vertices in the network (Taaffe and Gauthier, 1973).

5.2.2 Degree of a Vertex

Building upon the simple connectivity matrix described above, the "most primitive" measurement of accessibility is found from within the matrix. By simply summing the rows, the direct connectivity from the vertex in question to all other vertices in the network is ascertained. The higher the value for a vertex, the greater its accessibility vis-à-vis the entire network. Vertices can then be ranked to illustrate their relative, direct accessibility, which is termed the degree of a vertex. It must be noted that this has "serious limitations" as a measurement, since it does not account for indirect or multi-step connections (Taaffe and Gauthier, 1973).[105] In view of this shortcoming, further use of matrices in analyzing the networks has not been undertaken. As there exist no or few multiple-step routes within all the subject networks, other than the existing 2010 control network, it is believed that calculating

[105] Indirect connections, or multistep connections, represent the total number of ways to get to a specific vertex from any other vertex in the network, that is, determining how many combination of paths exist between vertex *i* and vertex *j*. By using sets of matrices which power the simple binary connectivity matrix (i.e. C, C^1, C^2, $C^3 \ldots C^n$), one can determine there are x number of different pathways to reach *i* from *j* or vice versa.

measures of indirect connectivity and the accessibility matrix are largely uninformative and an unneeded endeavour, for the effort required to do so would largely outweigh the relevance of the information obtained. Since the structure of all the networks, other than the existing Southern Manitoba 2010 control, is largely linear with minimal circuitry, one can conclude, as have Lowe and Moryadas (1975), that matrix manipulation in order to infer multistep connections is not a fruitful exercise.

With the methodology outlined, it is now appropriate to examine its specific application to Northern Manitoba transportation networks.

5.3 Analyses of Modal Networks

To model and analyze the four modal transport networks, the same approach was used for each, although due to data / operational limitations, the creation of the four networks for all four modes proved impractical. Each analysis focuses on the modal network within the study area, specifically investigating the given transport network at three specified points in time:

1. Existing 2010 network:
2. Historical 1969 network; and
3. Future 2035 network.

In addition, to allow for a referential point of comparison, a model is created of a southern area:

4. Existing 2010 Control network

For the investigation of each mode, using the above-noted four models, three distinct sets of analysis are undertaken (where appropriate):

1. Comparative-static analysis: existing 2010 network against the historical 1969 network;
2. Cross-sectional analysis: existing 2010 network against the existing 2010 control network; and
3. Existing-Future state analysis: existing 2010 network against the future 2035 network.

To begin, the comparative-static analysis is presented for each mode, which compares the existing 2010 network with the historical 1969 network for the study area. This will illustrate the extent of system development in the forty-year timeframe (1969-2010). Secondly, the cross-sectional analysis is presented, which compares the existing 2010 network with a contemporary representative network in the more developed southerly region, termed, as noted, the existing 2010 control network. This will illustrate the extent of relative difference in measures of network connectivity and accessibility between the northern, remote study area and its more integrated southerly counterpart. With the above two analyses to set the context, attention turns to an existing-future state analysis that compares the existing 2010 network with the future 2035 network. This illustrates and suggests the extent of relative difference in measures of network connectivity and accessibility for a point 25 years into the future.

For clarification, the relationship between the network indices, models and analyses is conceptually illustrated in Figure 5.

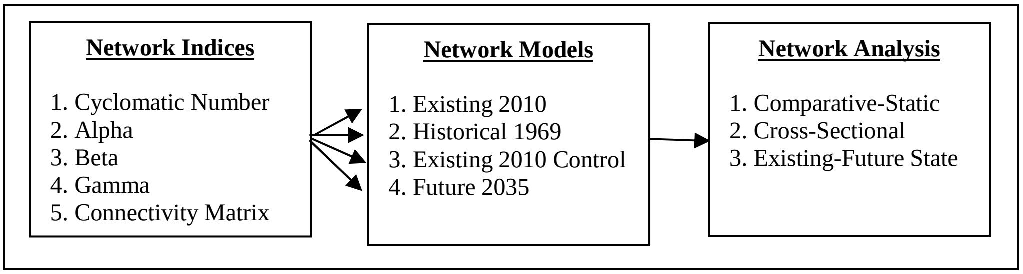

Figure 5 - Ideal Relationship between Network Indices, Models and Analysis

In the analysis of each mode, this relationship does not always hold true, for all four network models are not used for all modes and therefore the three network analyses, which require the four models, are not carried out in each case. The exceptions will be noted in due course. As befits its key role, the road mode is the first to receive attention.

6.0 Analysis of Road Transport System

To model the four road networks, typical conventions used in the literature pertaining to graph theory were employed. In the analyses, vertices represent one of two circumstances. First, they may represent geographical places with a population base, such as a town, village, hamlet, or First Nations reserve. Secondly, they may represent junctions between two edges, such as in the intersection of two roads.

Two points of clarification need to be mentioned at the outset. First, in several instances on the west, north and south limits of the study area, edges are denoted with arrows. This is to indicate that a vertex or terminus to the particular edge does not exist in the subject region because it continues beyond the study area boundary (i.e. into either Saskatchewan, Nunavut or Southern Manitoba). To maintain conceptual and methodological continuity amongst the four models, none of the edges indicated with an arrow of continuance is accounted for in the modelling. This is a major abstraction inherent in the model, for it is readily apparent that the study area connects with Saskatchewan at several points (i.e. west of The Pas and Flin Flon) and to the southern road transport network (e.g. south of Roblin and Grand Rapids, amongst others). To maintain consistency, these connections are excluded in all instances.[106]

The second point of clarification is that the southern limit of the study area was chosen on the basis of the general density of the road network found below that line of

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[106] This is an illustration of the abstractive nature of modelling, for invariably there is some degree of disconnect between the real world and the modelled environment. Although this particular action may reduce the overall length of the reported network, and remove several edges from the computations, the fact that it is commonly done for all modelled networks is an extenuating circumstance.

demarcation.[107] The grounds for this decision were set out at the beginning of Chapter 4. South of the study limit, there are more road interconnections (of various roadway classifications) and therefore route options for transport between vertices. As the focus is on remote transport, the inclusion of the network below this point would not only render the analysis of the model more complex from a computational and representative purpose), but would also cloud the primary object of the study through the inclusion of vertices and edges which exhibit and form a more complex network.

6.1 Existing 2010 Road Transport Network

The model of the existing 2010 road transport network is illustrated in Figure 6.[108] As depicted, it consists of 21 edges and represents approximately 1,975 kilometres of road network and 21 vertices (representing 16 geographically-named locations and 5 highway intersections). A detailed overview of the topological structure and detailed breakdown of the edges and vertices contained in the model of the existing network is provided in Appendix A.

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[107] The northern study region, as depicted in Figure 1, is approximately 250,000 square kilometres in area, within which the existing 2010 network has approximately 2,219 kilometres of road, producing a density of approximately 0.0079 km / km^2 Conversely, the southern existing 2010 control network, as depicted in Figure 8, is approximately 10,000 square kilometres in area, within which there are 1,119 kilometres of road, producing a density of 0.1119 km / km2, suggesting that the southern 2010 control region is approximately 14 times "more dense" than the northern study region.

[108] The current 2010 network is based on the current Manitoba Official Highway Map (Manitoba, 2010).

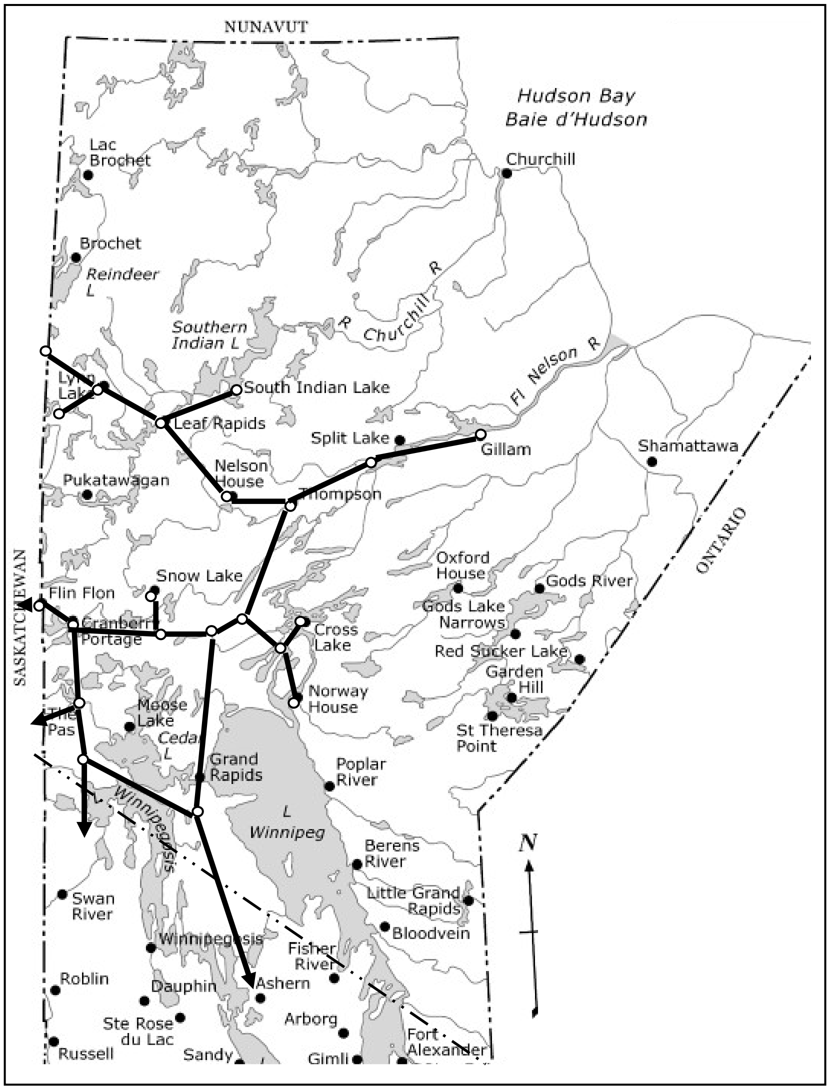

Figure 6 - Existing 2010 Road Transport Network[109]

6.2 Historical 1969 Road Transport Network

The model of the historical 1969-road transport network is illustrated in Figure 7.[110]

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[109] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*
[110] The historical 1969 network is based on Manitoba (1969: 202). This was chosen as the historical benchmark year due to the comprehensive information contained within the *Royal Commission Inquiry Into Northern Transportation*.

This model has 10 edges representing approximately 839 kilometres of road network and 13 vertices (representing 11 geographically-named locations and 2 highway intersections). A detailed overview of the topological structure and detailed breakdown of the edges and vertices contained in the model of the historical 1969 network is provided in Appendix B.

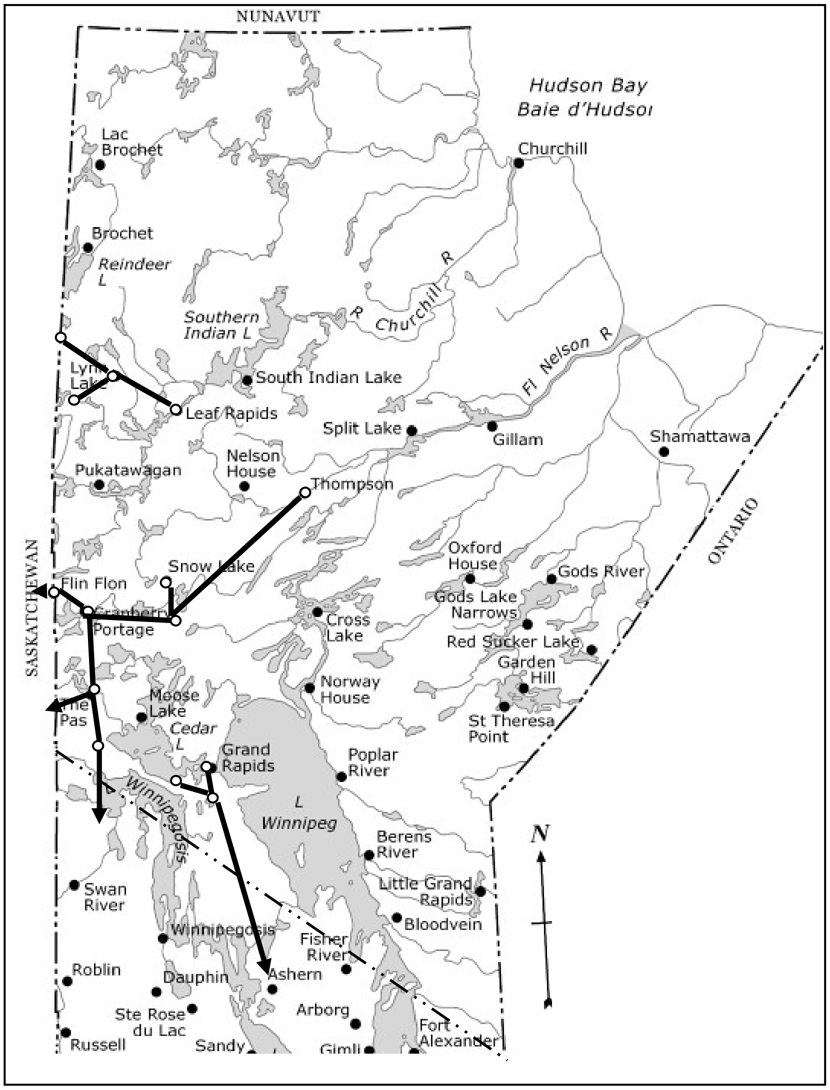

Figure 7 - Historical 1969 Road Transport Network[111]

[111] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

6.3 Existing 2010 Control Road Network

The model of the existing 2010 control road transport network is illustrated in

Figure 8. This model has 85 edges representing approximately 1,119 kilometres of road network and 58 vertices (representing 23 geographically-named locations and 35 highway intersections). The existing 2010 control network is located in the southwest corner of the Province of Manitoba. It encompasses the area bounded to the west by the Manitoba-Saskatchewan border, to the south by the Manitoba-North Dakota border, to the east by PTH 10 and to the north by PTH 1 (the Trans-Canada Highway). This quadrant is approximately 100 kilometres by 100 kilometres (10,000 km^2), which is approximately 1/25th the size of the northern study area. An overview of the topological structure and detailed breakdown of the edges and vertices contained in the model of the existing network is provided in Appendix C.

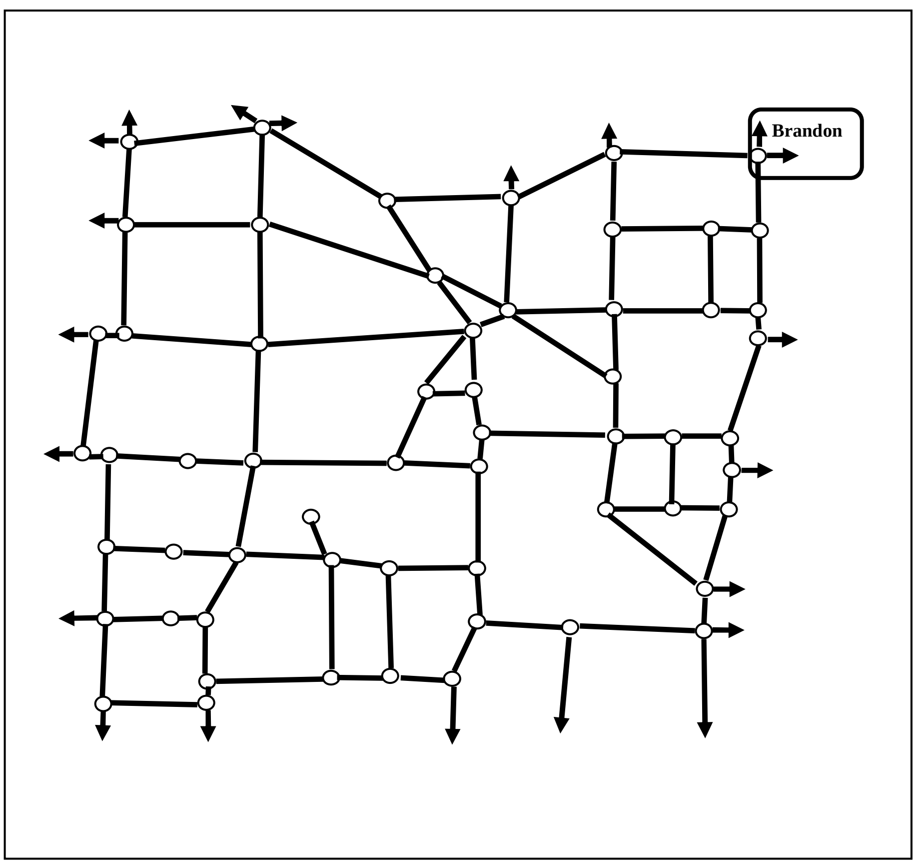

Figure 8 - Existing 2010 Control Road Transport Network[112]

6.4 Future 2035 Road Transport Network

The model of the future 2035 road transport network is illustrated in Figure 9. The future 2035 network is based on Manitoba (2010), ESRA (2009a and 2009b). This model has 37 edges representing approximately 3,208 kilometres of road network and 38 vertices (representing 25 geographically-named locations and 13 highway intersections or major water crossings). Details of the future 2035 network are provided in Appendix D.

[112] *Base map removed due to copyright, please follow link*. Source: Manitoba (2010), http://www.gov.mb.ca/mit/map/pdf/map1.pdf

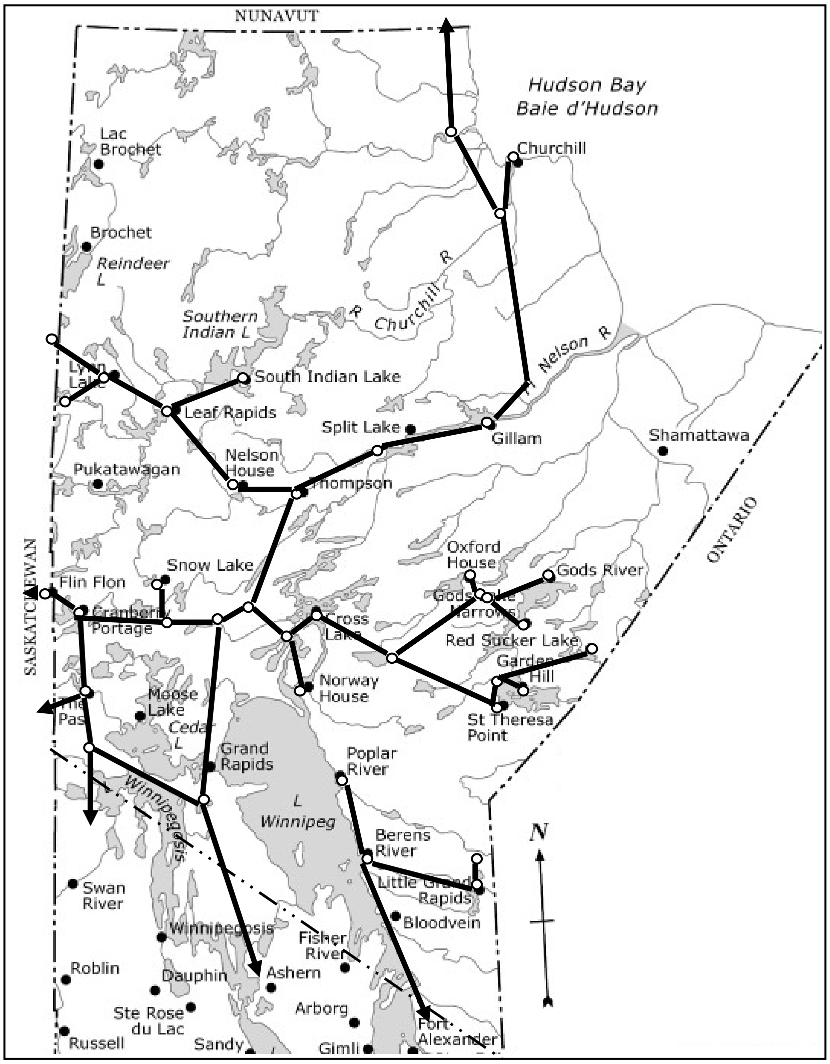

Figure 9 - Future 2035 Road Transport Network[113]

6.4.1 Alignment of Future 2035 Road Transport Network

The future network is separated into two distinct long-term projects, or initiatives, which are currently in varying stages of planning / engineering study processes. The first is the Manitoba-Nunavut Road project and the second is the East Side Lake Winnipeg Road project, with the latter noted as having both a northern and southern component. Each is briefly described below.

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[113] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Manitoba-Nunavut Road

The Manitoba - Nunavut Road (MB-NU Road), with its preferred eastern alternative, will commence at Sundance, Manitoba (east of Gillam at the terminus of PR 290), and will proceed northwards for 180 kilometres, generally following the Hudson Bay Railway to the crossing of the Churchill River. The first all-weather road will split at the crossing of the Churchill River (which has a channel width of 326 metres), with one leg proceeding northeast 110 kilometres to the Town of Churchill, while the other proceeds northwards for 90 kilometres to the second major river crossing at the Seal River (channel width 460 metres). North of the Seal River crossing, the road will proceed for 400 kilometres to Arviat, Nunavut, an additional 230 kilometres to Tikirarjuag and another 90 kilometres to Rankin Inlet. With the preferred eastern alternative identified by the planning study, business case and further detailed engineering and planning assessments are currently underway. The initial estimate (in 2006) of the cost of the 1,100-kilometre road was $1.2 billion (NK-SNC, 2007). The road alignment indicated in Figure 9 portrays the recommended eastern alternative of the Manitoba-Nunavut road.

East Side Lake Winnipeg Road

The East Side Lake Winnipeg Road is in the early phase of construction and its implementation is overseen by a “stand alone entity” (autonomous body), the East Side Road Authority. The alignment portrayed in Figure 9 for the northern section of this project (i.e. proceeding eastwards from Cross Lake to the Island Lake and Northern Cree communities) has been recommended through a comprehensive planning study process (ESRA, 2009a). The southern route alignment, portrayed in Figure 9 is based on the recommended road works of the East Side Transportation Initiative (ESTI), a strategic initiative “to provide improved, safe and more reliable transportation service between all of the communities on the east side of Lake Winnipeg and the rest of the province.” The two primary objectives of this ESTI are the completion of the long-term, East Side Large Area Transportation Network Study and the construction of an all-weather road from PR 304 to Berens River, which is currently underway. This will see the existing Rice River Road upgraded north of the Hollow Water First Nation, an upgrade that will extend beside Lake Winnipeg for approximately 85 kilometres to the Bloodvein First Nation. Thereafter, it will continue northeast for approximately 71 kilometres to the Berens River First Nation (ESRA, 2009b). The continuance of all-weather road linkage from Berens River northwards to the Poplar River (i.e. by 2035) and eastward to the First Nation communities of Little Grand Rapids and Pauingassi is a strong likelihood, probably incorporating some of the current overland seasonal road alignment. Furthermore, it is likely to be included in the future East Side Large Area Transportation Network Study.

6.5 Results of Road Transport Network Analyses

As noted in the introduction, three analyses were undertaken to examine the road transport network. To reiterate briefly, they were, first a

> <u>Comparative-static analysis</u>, comparing the existing 2010 network against the historical 1969 network;
>
> <u>Cross-sectional analysis</u> in which the existing 2010 network is contrasted with the current 2010 southern network; and,

Existing-future state analysis wherein the existing 2010 network is compared against a future 2035 network.

6.5.1 *Network Characteristics*

A summary of the properties of the four road networks is presented in Table 12.

Table 12 - Summary of Modelled Properties - Road Transport Networks

Network Property	Existing 2010 Network	Historical 1969 Network	Existing 2010 Control Network	Future 2035 Network
Edges	23	10	85	37
Vertices	21	13	58	38
Network loops (G)	1	0	28	1
Total network length (approx.)	1,975 km	839 km	1,119 km	3,208 km

The results of the three network analyses - the comparative static analysis, the cross-sectional analysis and the existing-future state analysis - are summarized in Table 13.

Table 13 - Summary of Network Analyses - Road Transport Network		
1. Comparative-Static Analysis		
Measure	**Existing 2010 Network**	**Historical 1969 Network**
Cyclomatic Number	3	0
Alpha (α)	8%	0%
Beta (β)	1.1	0.8
Gamma (γ)	40%	30%
2. Cross-Sectional Analysis		
Measure	**Existing 2010 Network**	**Existing 2010 Control Network**
Cyclomatic Number	3	55
Alpha (α)	8%	50%
Beta (β)	1.1	1.5
Gamma (γ)	40%	51%
3. Existing-Future State Analysis		
Measure	**Existing 2010 Network**	**Future 2035 Network**
Cyclomatic Number	3	0
Alpha (α)	8%	0%
Beta (β)	1.1	1.0
Gamma (γ)	40%	34%

6.5.2 Structural Analysis

Complementing these quantitative results are data pertaining to the structure of each network. They are summarized, using a simple connectivity matrix (see Table 14). This indicates the number of direct connections between a particular vertex and others in the network.

Table 14 - Summary of Simple Connectivity Matrices (Degree of a Node)							
1. Existing 2010 Network		**2. Historic 1969 Network**		**3. Existing 2010 Control Network**		**4. Future 2035 Network**	
Direct Conn.	No. of Nodes	Direct Conn.	No. of Nodes	Direct Conn.	No. of Nodes	Direct Conn.	No. of Nodes
5	0	5	0	5	2	5	0
4	0	4	0	4	9	4	0
3	8	3	3	3	28	3	12
2	5	2	1	2	18	2	11
1	8	1	9	1	1	1	15

With the above information, it now becomes opportune to discuss their implications.

6.6 Discussion of Results

6.6.1 Network Characteristics (Table 12)

Upon examining the network characteristics, inferred from Table 12, the extent to which the existing 2010 control network exhibits looping or circuitry is evident. This conforms to expectations, as the presence of multiple loops is a defining characteristic of a mature or well-developed transportation network. The structure of the network, visible in Figure 8, clearly is an example. This network circuitry leads to a higher degree of connectivity, which, as discussed above, is required for economic development. In this particular instance, the road network corresponds to the lattice network of sections and ranges that were laid out in the early survey, thus it conforms to a broad lattice pattern (vertical and horizontal).

Conversely, in the existing 2010 network, historical 1969 and future 2035 networks, all naturally applying to Northern Manitoba, the minimal looping exhibited is indicative of a transportation network which is relatively vulnerable to severing. If one segment of critical highway is closed, a sector is either rendered inaccessible, or, depending on location within the network, it may only be accessed after a lengthy detour.

6.6.2 Comparative Static Analysis (Table 13)

The results of this analysis all indicate that the current 2010 network exhibits greater connectivity than that which obtained in 1969, and this is readily apparent from the configurations as presented in Figure 6 and Figure 7. The beta measures for each are relatively close in magnitude (1.1 for the existing 2010 and 0.8 for the historical 1969), suggesting that despite an addition of 1,380 route kilometres to the network over forty years, the average number of edges connecting each vertex remains approximately 1. The existing 2010 network was calculated to exhibit 8% connectivity in its alpha measure, while due to the absences of any network loops, the historical 1969 network is 0% connected. For the existing 2010 network, the gamma measure of 40% connectivity is contrasted with the historical 1969 network's 30% connectivity. As the gamma indicator is a measure of the ratio of actual number of edges to the maximum possible number of edges, the results in both circumstances are suggestive of relatively unconnected networks. The structural analysis presented in Table 14 indicates that the current 2010 network has 5 more vertices with 3 or greater direct connections than the historical 1969 network, while the number of terminal vertices, that is those having only one direct connection, remain relatively equal (8 and 9 respectively).

6.6.3 Cross-Sectional Analysis (Table 13)

The cross-sectional analysis compares two existing networks at the same point in time, but as the comparison is between a northern or remote network and a relatively dense and well-established one, the results reflect this obvious contrast. A major indicator of difference is the cyclomatic number, which for the existing 2010 network is 3, but for the existing 2010 control network is considerably greater, at 55. This is due to the network circuitry or loops in the control network, and this is reinforced by the alpha index, which indicates that 50% of the total possible number of circuits are present in that network. Furthermore, the beta measure indicates that there are 1.5 edges for each vertex, which is one-half of the approximate maximum theoretical limit of 3. The structural analysis (Table 14) provides a further basis for comparison between the lack of connectivity exhibited in the existing 2010 network and the high connectivity incident to the existing 2010 control network. In the control network, 67% of the nodes have three or more edges connecting them, in marked contrast to the 38% applying to the existing network.

6.6.4 Existing – Future State Analysis (Table 13)

The results of this analysis, the comparison between the existing 2010 network and the future 2035 network, is of particular interest to this study.[114] The results are relatively close in their values for the four measures. With the addition of approximately 989 kilometres of all-weather road to the network in the future 2035 network, the form of the network gains no circuitry and remains linear. As presented, 17 vertices are added to the network, but all remain primitive in their connectivity, and many remain terminal in the network. With the situation pertaining to the roads established, it is now appropriate to regard the position of the railways.

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[114] This is of interest as the development of the future 2035 network will require significant mobilization and expenditures of public resources. In the context of the analysis undertaken in this thesis, the degree to which the increase in network length and spatial reach of the network corresponds with any notable change in the graph-theoretic indices will be insightful. As the road transport mode is of greatest concern to the potential economic development within the study region, measures of connectivity between current and future networks are important to this prospect.

7.0 Analysis of Rail Transport System

Three rail networks were modelled and analyzed. In the rail transport analyses, vertices represent one of two circumstances. On the one hand, they may represent geographical places with a population base, such as a town, village, hamlet or First Nations reserve. On the other, they may represent junctions between two edges, such as in the intersection of the rail mainline and a spur.

Note that on the west limit of the study area, the edge is denoted with an arrow (towards Saskatchewan). Moving south from The Pas, The Hudson Bay Railway's CN extension crosses into Saskatchewan and connects with the CN mainline at Hudson Bay in that province. Moving southeast, the CN mainline crosses back into Manitoba (approximately 20 kilometres northwest of Roblin), at a point on the provincial border, approximately 300 kilometres directly south of its northern exit point.

7.1 Existing 2010 Rail Transport Network

The model of the existing 2010 rail transport network is illustrated in Figure 10. As depicted, it consists of 15 edges and represents approximately 1,220 kilometres of rail network and 16 vertices. A detailed overview of both the topological structure and the edges and vertices contained in the model of the existing network is provided in Appendix E.

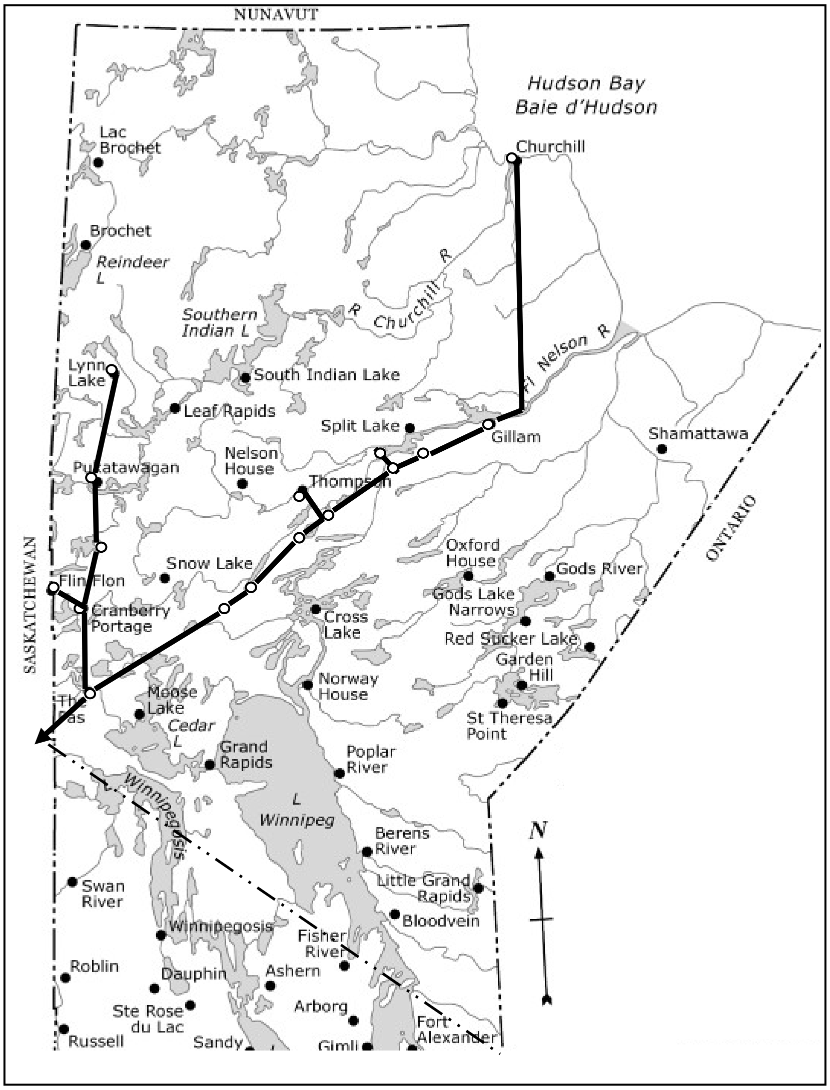

Figure 10 - Existing 2010 Rail Transport Network[115]

7.2 Historical 1969 Rail Transport Network

The model of the historical 1969 rail transport network is illustrated in Figure 11.[116] This model has 16 edges representing approximately 1,300 kilometres of rail network and 17 vertices. Consistent with the previous entry, a detailed overview of the topological structure

[115] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

[116] The historical 1969 network is based on Manitoba (1969: 202). As remarked above, 1969 was chosen as the historical benchmark year owing to the comprehensive information pertaining to that era which is available through the *Royal Commission Inquiry Into Northern Transportation*.

together with a breakdown of the edges and vertices contained in the model of the historical 1969 rail transport network is provided in Appendix F.

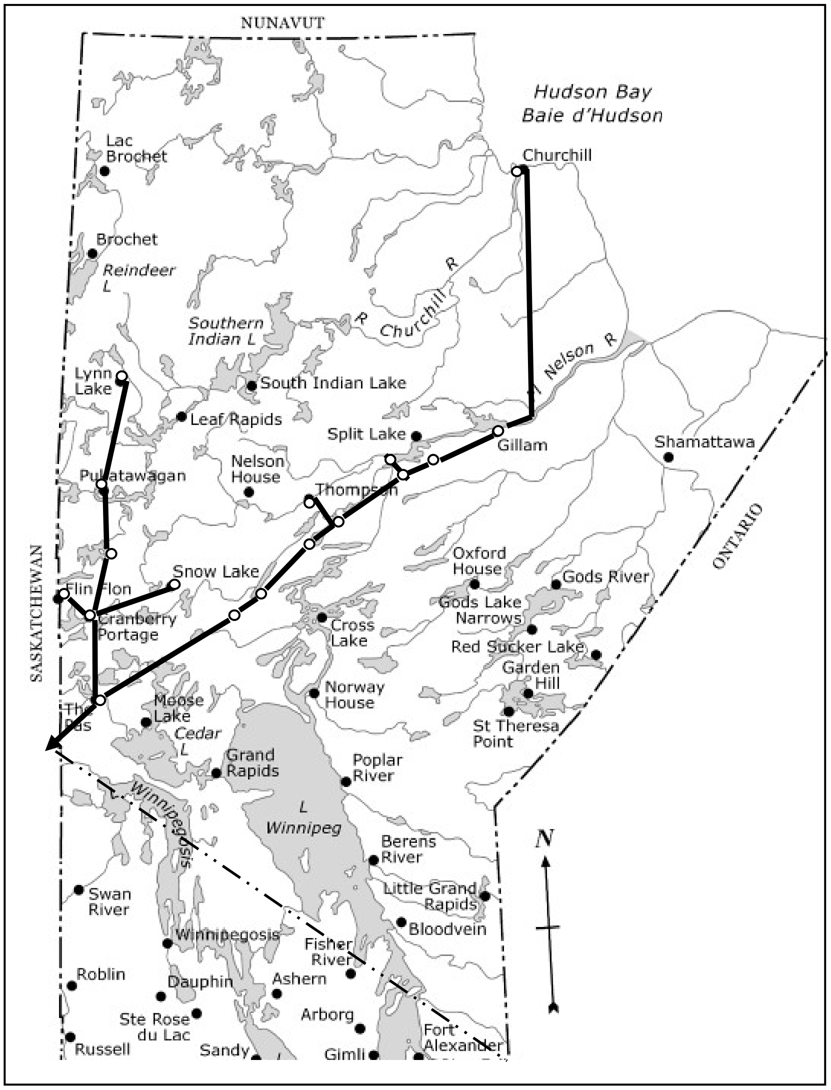

Figure 11 - Historical 1969 Rail Transport Network[117]

7.3 Existing 2010 Control Rail Transport Network

The model of the existing 2010 control rail transport network is illustrated in Figure 12.

[117] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

This model has 25 edges and 26 vertices and represents approximately 405 kilometres of rail network. Details of the topological structure and of the relevant edges and vertices contained in the model of the existing network are provided in Appendix G.

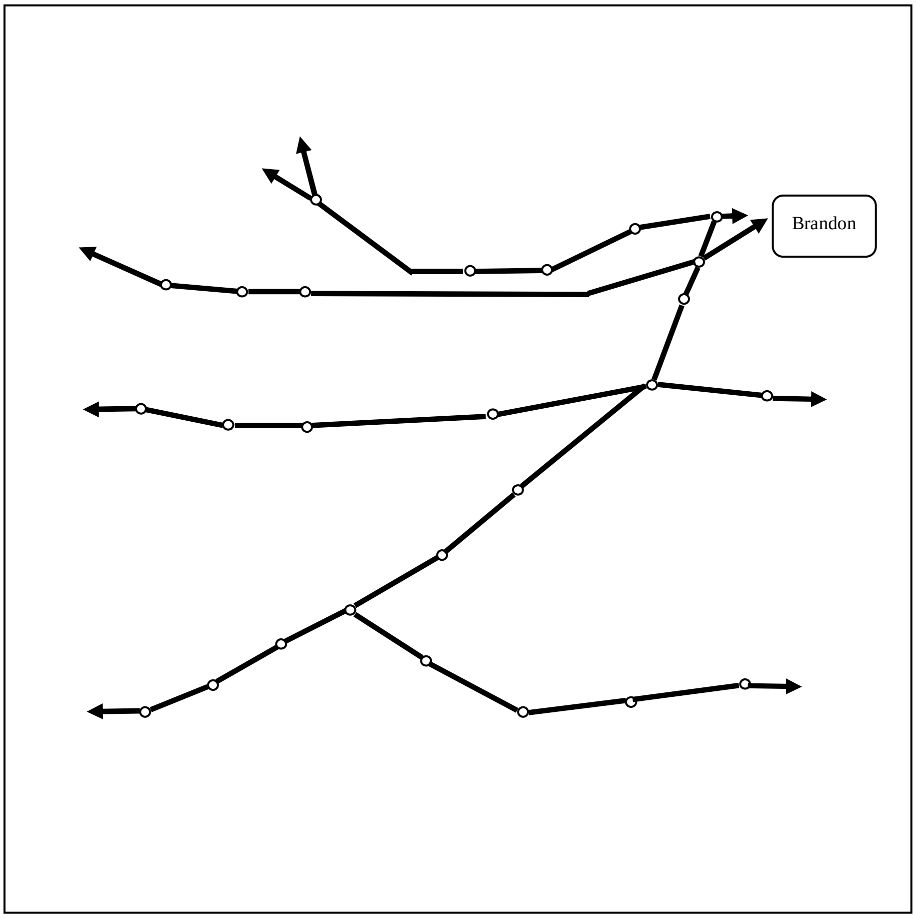

Figure 12 - Existing 2010 Control Rail Transport Network[118]

7.4 Future 2035 Rail Transport Network

No future 2035 rail transport network was created for analysis as there currently does not exist any speculative or published plans or strategies for network expansion. Activity on the rail transport network currently consists of capital upgrade and maintenance of the

118 *Base map removed due to copyright, please follow link*. Source: Manitoba (2010), http://www.gov.mb.ca/mit/map/pdf/map1.pdf

existing Hudson Bay Railway mainline (i.e. ballast stabilization, tie replacement, etc.). If a major expansion of rail system capacity were to occur at a future point, it would in all likelihood lead to infrastructure expansion following one of two general courses.

In the first place, a major capital upgrade to the existing railway could occur. This would likely entail strengthening the bridge and culvert structures and widening or raising (or both) the dynamic envelope of the right of way.[119] This may allow for new uses of the railway, such as moving oversize / overdimensional loads for industrial purposes (e.g. facilities / plants built in modular units for mining, refining, etc.) or for accommodating double-stacked containers in intermodal traffic. The ability to handle these types of loads may theoretically change the economics of the rail line at points along the line and at its terminals, promoting improved cost-efficiencies.

In the second place, a new mine or area of significant primary resource extraction or processing could warrant the building of a spur line to a point adjacent to the line or, as described above, a program of significant capital upgrade.

The above two scenarios could occur in reverse as well, that is the ceasing of operation followed by regulatory, then physical abandonment of a rail line or spur line. This could be precipitated by the closure of a major industry or in the event that the capital costs of line operation outweigh the revenue traffic generated or subsidies provided (i.e. by government) to maintain solvency (see discussion in Section 7.6.1).

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[119] The dynamic envelope is the area (e.g. specific height and width) that a typical train is provided along the entire course of the way. This means that all overhead wires or structures (i.e. telephone poles, bridge trusses, or natural features such as rock cuts or large trees) on all sides are a specified distance removed from the path of the train. This allows the train to carry loads which may be oversized or overweight (in comparison with normal traffic) along a given section of trackage (i.e. large, angular industrial equipment which may be secured to a typical flat car although is significantly larger (height and width) than a standard rail car).

7.5 Results of Rail Network Analyses

Two analyses were undertaken to examine the rail transport network:

1. Comparative-static analysis: existing 2010 network against the historical 1969 network; and
2. Cross-sectional analysis: existing 2010 network against the current 2010 control network.

7.5.1 Network Characteristics

A summary of the properties of the three rail networks is presented in Table 15.

Table 15 - Summary of Modelled Properties – Rail Transport Networks

Network Property	Existing 2010 Network	Historical 1969 Network	Existing 2010 Control Network
Edges	14	15	25
Vertices	16	16	26
Network loops (G)	0	0	0

The results of the two network analyses - the comparative static analysis and the cross-sectional analysis - are summarized in Table 16.

Table 16 - Summary of Network Analyses - Rail Transport Network		
1. Comparative-Static Analysis		
Measure	**Existing 2010 Network**	**Historical 1969 Network**
Cyclomatic Number	0	0
Alpha (α)	0%	0%
Beta (β)	0.9	0.9
Gamma (γ)	33%	36%
2. Cross-Sectional Analysis		
Measure	**Existing 2010 Network**	**Existing 2010 Control Network**
Cyclomatic Number	0	0
Alpha (α)	0%	0%
Beta (β)	0.9	1.0
Gamma (γ)	33%	35%

7.5.2 Structural Analysis

The structural analysis of each network using a simple connectivity matrix is provided in Table 17. This indicates the number of direct connections between a particular vertex and others in the network.

Table 17 - Summary of Simple Connectivity Matrices (Degree of a Node)					
1. Existing 2010 Network		**2. Historic 1969 Network**		**3. Existing 2010 Control Network**	
Direct Conn.	No. of Nodes	Direct Conn.	No. of Nodes	Direct Conn.	No. of Nodes
5	0	5	0	5	0
4	0	4	0	4	0
3	4	3	5	3	4
2	7	2	6	2	15
1	5	1	6	1	7

7.6 Discussion of Results

7.6.1 Network Characteristics (Table 15)

Upon examining the network characteristics, inferred from Table 15, the existing 2010 network and the historical 1969 network appear to be nearly identical. This is to be expected as the difference between the two networks is one spur line. In the historical 1969 model, there is a spur approximately 80 kilometres in length which runs from Optic Lake to Chisel Lake (in the vicinity of the community of Snow Lake). This spur was abandoned by CN, the upshot of the loss of (mining) traffic, as noted above.

None of the three networks exhibits any looping, which is be somewhat expected for the two northern rail networks and a southern prairie network, thus the cyclomatic number in all cases is zero. The northern networks, and the southern control network to a greater degree, exhibit a structural pattern which may be termed “mildly dendritic”. In other words, the feeder or branch lines concentrate and connect into the mainline(s).[120]

The southern control network exhibits a far greater density,[121] which again is to be expected given that the historical and present-day function of the rail lines in the south is greatly different from that applying in the north. Rather than delivering grain to tidewater - the prime motivation for the Hudson Bay Railway - the southern network largely serves a feeder function for prairie agricultural products, with the objective of moving commodities from local point of collection (i.e. the grain elevator) to the point of distribution. Both, of

[120] This is akin to the dendritic patterns and stream-ordering used in hydrology or fluvial geography (such as applied in Strahler diagrams).

[121] The northern study region, as depicted in Figure 1, is approximately 250,000 square kilometres in area, within which the existing 2010 rail transport network (depicted in Figure 10) has approximately 1,120 kilometres of railway, producing a density of approximately 0.0045 km / km^2 Conversely, the southern 2010 control network, as depicted in Figure 12, is approximately 10,000 square kilometres in area, within which there is approximately 405 kilometres of railway, producing a density of 0.041 km / km^2, suggesting that the southern 2010 control region is approximately 9 times “more dense” than the northern study region (and as McCombe (2011) recounts, in past years, prior to the mass closure of branch lines on the Prairies, it was denser still).

course, necessitate long-distance haulage, ultimately often accessing ports (Vancouver, Prince Rupert, Thunder Bay or Churchill) for onward sea carriage.

7.6.3 Comparative-Static Analysis (Table 16)

The comparative-static analysis does not provide much comparative insight, and this is to be expected as the existing 2010 network and the historical 1969 network are virtually identical save for the one edge representing the now abandoned Optic Lake to Chisel Lake spur. Both networks exhibit alpha indicators of zero, which is reflective of the branching structure of the networks and that any severing of the network will result in the creation of subgraphs. The beta indicators are similar at 0.9, which is indicative of their elementary structure that exhibits no network circuity. Lastly, the gamma indicator for each is very similar (33% and 36% respectively), again indicative of the theoretically underdeveloped network. Approximately one-third of the possible total theoretical nodal connectivity is present.

7.6.4 Cross-Sectional Analysis (Table 16)

The cross-sectional analysis, comparing the existing 2010 rail transport network with the existing 2010 control network, likewise does not indicate any great dissimilarity between network properties even thought the density of the existing 2010 control network is greater (and it exhibits network properties very similar to the historical 1969 network as well). The major difference between networks is the number of edges and nodes, where the existing

2010 control network has approximately double the number of both for a system which is approximately one-third the size in length.[122]

[122] The existing 2010 network is composed of 14 edges and 16 vertices within a network of 1,220 kilometres (average length of each edge is 76 kilometres). Conversely, the existing 2010 control network comprises 25 edges and 26 vertices within a network of 405 kilometres (average length of each edge is 16 kilometres). This points to the role of the networks, in the north it is largely destination oriented; that is, moving people and goods long distances to nodes such as Thompson and Churchill, while in the south (existing 2010 control network) the network was designed, as remarked above, for collection and feeder purposes (i.e. agricultural products and the elevator system).

8.0 Water Transport

The analysis of the water transport network is cursory, as the current state of activity within the study area is minimal, and the historic activity level, although slightly higher, proved marginal to the activity, stature and complexity of the networks of the other modes.

Through time the Port of Churchill has exhibited ebbs and flows in the amount of seaborne traffic in and out of the Port, but as topologically represented in the model, it stands alone as a vertex. As further described below, there has been some marine activity (i.e. scheduled freight and passenger service) on Lake Winnipeg over the years, but today this activity has all but ceased. The ferry services which are operational at several points through the province (and are operated by the Manitoba Government) provide access and connectivity for the road transport network. The ferries connect two road segments in lieu of a structure crossing reasonably wide rivers (i.e. north of Norway House on PTH 373), and across narrowing of larger water bodies (i.e. adjacent to the Bloodvein Bay on Lake Winnipeg or between Split Lake and York Landing northeast of Thompson).[123]

Granted this lack of inland water transport activity in the study area, no control network is modelled. Furthermore, since no known plans exist (speculative or published) for any new service and network expansion, no future network is presented in this thesis. On the basis of the above, the water transport analysis is simplistic, being confined to the existing 2010 network and the historical 1969 network. As no real network existed, or exists, a graph theory analysis is not undertaken.

[123] The ferry services in Manitoba are operated by the Northern Aviation and Marine Operations branch of the Manitoba Department of Infrastructure and Transportation.

8.1 Existing 2010 Water Transport Network

The model of the existing 2010 water transport network is illustrated in Figure 13.

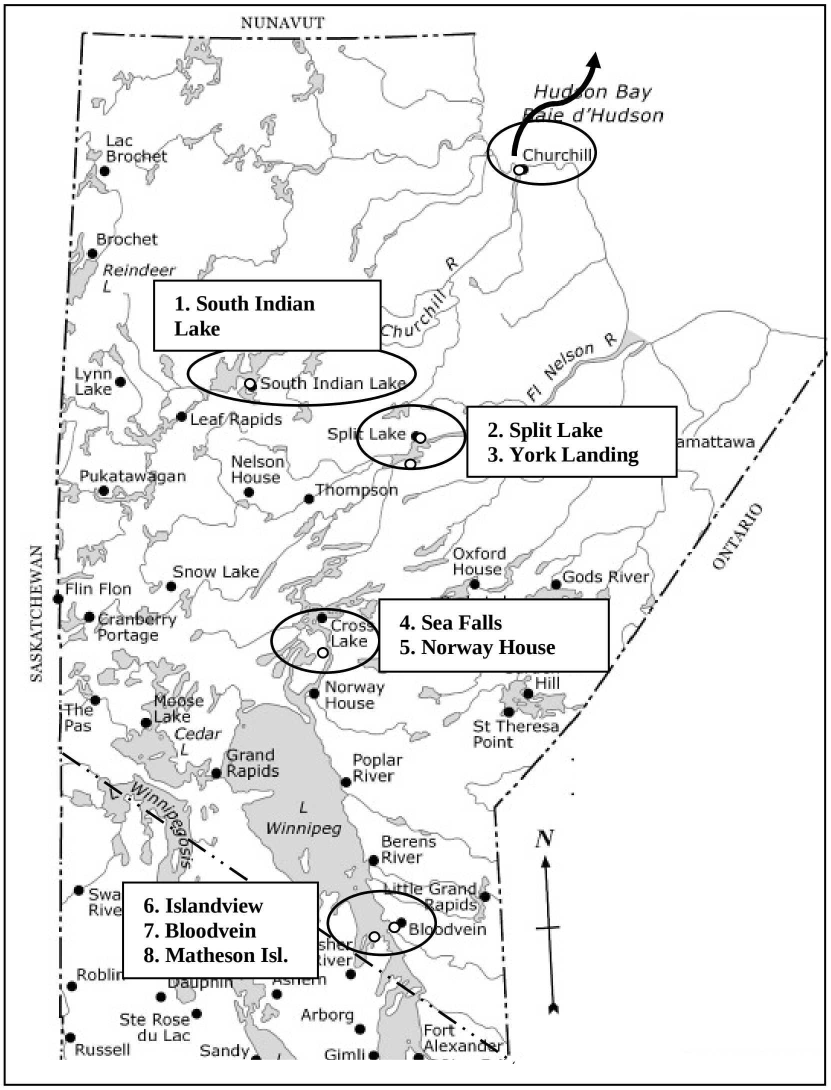

Figure 13 - Existing 2010 Water Transport Network[124]

The water transport activity in the existing 2010 water transport network may be categorized in two ways: international commercial activity based solely on the Port of Churchill and intraprovincial movement via the ferry services provided by the Province of

[124] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Manitoba. This applies to the remaining eight locations noted in Figure 13. Details pertaining to the vertices contained in the model of the existing network are provided in Appendix H.

8.2 Historical 1969 Water Transport Network

The model of the historical 1969 water transport network is illustrated in Figure 14. Details pertaining to the vertices contained in the model of the historical network are provided in Appendix I.

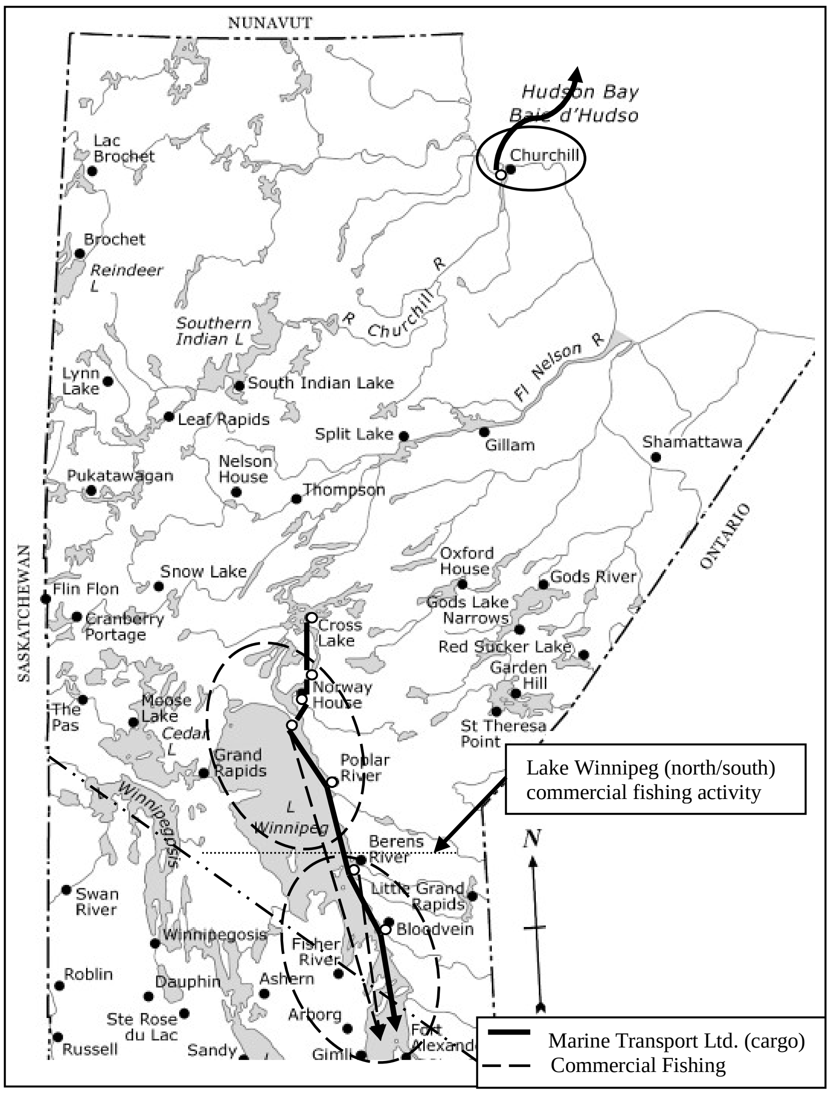

Figure 14 - Historical 1969 Water Transport Network[125]

[125] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

The water transport activity depicted in this model is more substantive than in the existing 2010 model and is denoted as two-fold. First, there is commercial freight activity, undertaken by Marine Transport Limited. At the time, this company transported freight from Winnipeg, Selkirk and Gimli in the south to points in the study area along the eastern (e.g. Bloodvein, Berens River and Poplar River) and northern shores (Warrens Point) of Lake Winnipeg and into the Playgreen Lake / Nelson River region (e.g. Norway House and Cross Lake). The flow of goods northwards consisted predominately of general and refrigerated freight, building materials, gasoline and oil products, gravel and coal while a small amount of southbound backhaul was reported, composed largely of timber and pulp products (Manitoba, 1969).

Secondly, a substantial commercial fishery operated in this period on Lake Winnipeg. As depicted in Figure 14, it is separated into activity occurring north of Berens River and activity occurring south of Berens River.[126] Both the cargo and commercial transport activity exhibit a general north-south orientation, with freight largely moving northwards, while fish catches moved predominately southwards to the central marketplaces.

Appraisal of water transport completes the investigation of the surface modes. Therefore, it is now opportune to consider the air mode.

[126] This delineation of north and south commercial activity was presented in Manitoba (1969: 293-294). It was used as a largely arbitrary means to categorize the communities which received northbound commercial freight service and to categorize the general origin of the southbound commercial fish freight traffic.

9.0 Air Transport

The analysis of the air transport network is somewhat cursory, although more informative than the water transport mode. A reasonable snapshot of the current 2010 air transport network was developed from open source commercial route information and a detailed account of the historical 1969 network has been developed based on the *Royal Commission Inquiry into Northern Transportation* (Manitoba, 1969). Following the convention applied in the above analysis, an existing 2010 air transport control network was unable to be developed as only one southern Manitoba location (Brandon) has scheduled service (from Winnipeg). Similarly, a future network is elusive and therefore ignored. The nature of air transport services and the required infrastructure to operate them (i.e. one needs a unit of carriage, and two terminals (i.e. runways), which can be water, grass, gravel or asphalt, at origin and destination) render this mode highly flexible in terms of adjustments to scheduled services, both in respect of the patterns of operation and the nodes serviced. New companies can enter the market at will and with relative ease.

9.1 Existing 2010 Air Transport Network

The model of the existing 2010 air transport network is illustrated in Figure 15. As depicted, it consists of 40 edges and 25 vertices. The network was developed on the basis of an open-sourced scan of the *scheduled service* within the study area.[127] It is important to note that many of the scheduled carriers, as well as many for-hire operators, will provide charter

[127] The carriers providing scheduled air service in the study area were ascertained to include: Bearskin Airlines, Perimeter Air, Calm Air, Northway Aviation, Missinippi Airways and Kivalliq Air.

services to virtually any location in the study area.[128] Therefore, the model may be seen as having some limitations as to its comprehensiveness. A detailed overview both of the topological structure and of the edges and vertices contained in the model of the existing network is provided in Appendix J.

[128] A first principles estimation of the passenger and cargo payload capacities of both the scheduled carriers and the charter carriers was undertaken based on the licenced commercial aircraft as per the Transport Canada Civil Aircraft Register (Transport Canada, 2011b). The payload of the aircraft and the number of craft within a given company's current registered (under the commercial designation) fleet was used to determine the approximate cargo payload capacity (through use of manufacturer and industry sources). As noted above, scheduled carriers in the study area were ascertained to include: Bearskin Airlines, Perimeter Air, Calm Air, Northway Aviation, Missinippi Airways and Kivalliq / Keewatin Air. The prominent Manitoba-registered charter air service providers, which do, or could reasonably provide service in the study area included: Keystone Air Service (Winnipeg), Sky North Air (Winnipeg), Fast Air (Winnipeg), Gillam Air Service (Gillam), Kississing, Amik Aviation (Little Grand Rapids), Gogal Air Services (Snow Lake), Adventure Air (Lac du Bonnet), Interlake Aviation (Stony Mountain) and Lynn Lake Air Service. The total number of aircraft for scheduled carriers is estimated to be 62, with a total passenger capacity of 1,640 and a cargo payload capacity of an estimated 195,660 pounds. For the charter carriers, the total number of aircraft is estimated to be 69, with a total passenger capacity of 512 and a cargo payload capacity of an estimated 118,660 pounds. The analysis points to the differentiation of aircraft between the classes of carrier, with larger, more powerful aircraft models (therefore typically more expensive) being used by the scheduled providers, while the fleets of the charter carriers tended to be smaller aircraft models. It should be noted that several of the carriers in both classes have aircraft that exclusively provide medical support services, and when registered as such, these were removed from the data set. This analysis, based on open-source data should be taken to be an estimate (based on a number of data assumptions) and therefore only a suggestion of a "magnitude of scale" comparison.

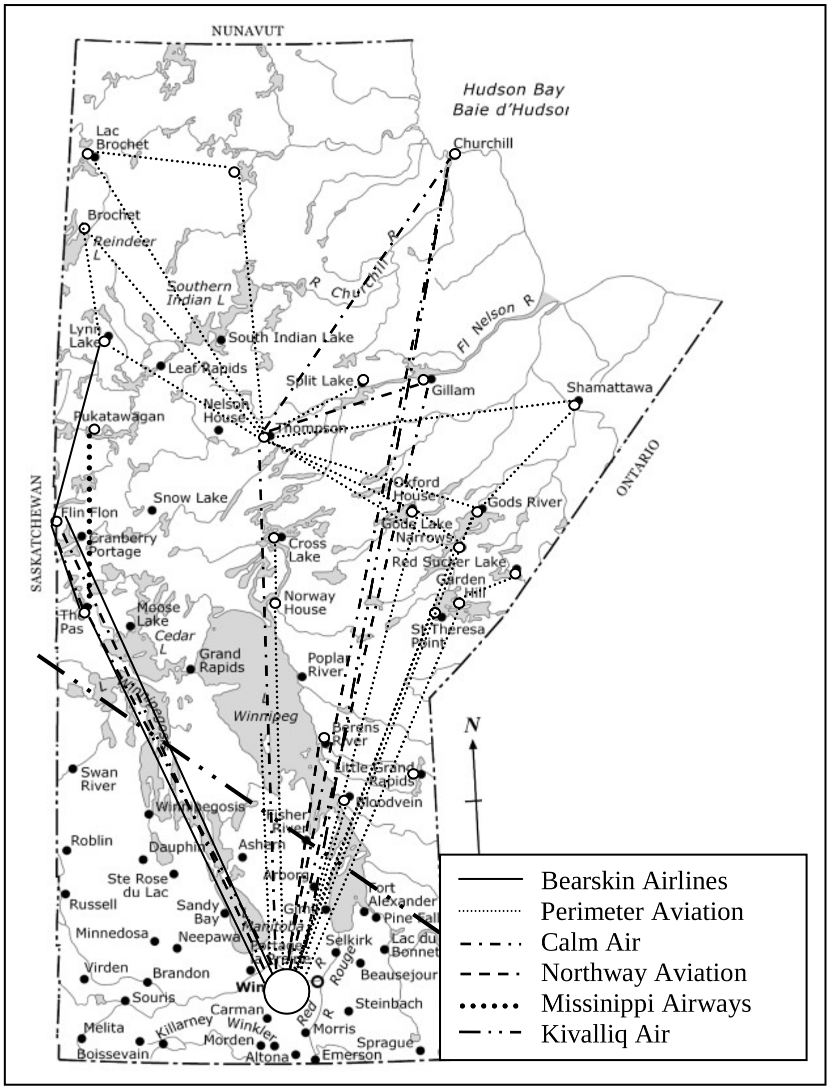

Figure 15 - Existing 2010 Air Transport Network[129]

9.2 Historical 1969 Air Transport Network

The model of the historical 1969 air transport network is illustrated in Figure 16. As depicted, it consists of 44 edges and 28 vertices. As noted in the section introduction, the network was developed on the basis of information contained within the *Royal Commission Inquiry into Northern Transportation* (Manitoba, 1969). This source provided a comprehensive account of the situation at that point in time, although since the data were

[129] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

aggregated into class 1through class 3 routes,[130] it proved impossible to determine whether those data represented both scheduled and charter air services. Moreover, the summary figure depicting the air transport system is extremely difficult to follow (e.g. very cluttered visually),[131] further compounding the issue of interpretation. Therefore, the model presented is of a reasonable quality, but cannot claim to be as specific, or instill the same degree of confidence as, for instance, the road transport network. A detailed overview of the topological structure and of the edges and vertices contained in the model of the existing network is provided in Appendix K.

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[130] Class 1 routes denote scheduled public air carriers (passenger and / or freight) serving designated points , Class 2 routes denote carriers that offer transport on a route pattern "with some degree of regularity", while Class 3 routes offer services from a designated base of operations to a designated area or specific point(s) (Manitoba, 1969).

[131] If a strict interpretation of the nature of Class 1 routes was used, the historical 1969 air transport route would reduce to just three route pairings: Winnipeg –Flin Flon, Winnipeg-The Pas, and Winnipeg-Thompson.

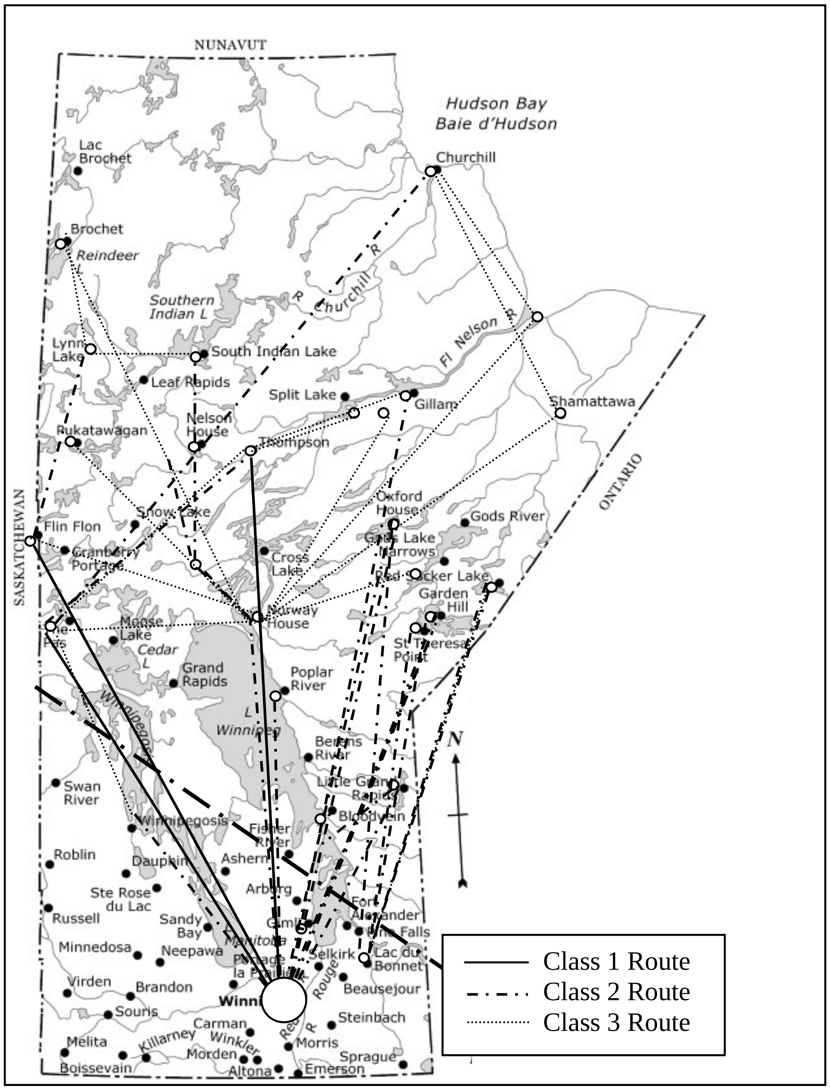

Figure 16 - Historical 1969 Air Transport Network[132]

9.3 Results of Air Transport Network Analyses

Granted the nature of the available models, one analysis only was undertaken to examine the air transport network:

<u>Comparative-static analysis</u>: existing 2010 network against the historical 1969 network.

[132] Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

On the basis of this analysis of the two networks, and mindful of some of the data limitations pertaining to the historical 1969 network as described above, the results should be regarded as patchy at best.

9.3.1 Network Characteristics

A summary of the properties of the two air transport networks is presented in Table 18.

Table 18 - Summary of Modelled Properties – Air Transport Networks

Network Property	**Existing 2010 Network**	**Historical 1969 Network**
Edges	14	44
Vertices	16	28
Network loops (G)	*na*	*na*

The results of the single network analysis - the comparative static analysis - is summarized in Table 19. Note that due to the nature of air transport (e.g. no fixed path such as road or rail – although lanes in the sky do exist), non-planar calculations are used.

Table 19 - Summary of Analysis – Air Transport Network

1. Comparative-Static Analysis

Measure	**Existing 2010 Network**	**Historical 1969 Network**
Cyclomatic Number	*na*	*na*
Alpha (α)	0%	4.6%
Beta (β)	0.9	1.6
Gamma (γ)	6%	6%

9.3.2 Structural Analysis

The structural analysis of the two networks, using a simple connectivity matrix, is provided in Table 20. This indicates the number of direct connections between a particular vertex and others in the network.

Table 20 - Summary of Simple Connectivity Matrices (Degree of a Node)			
1. Existing 2010 Network		**2. Historic 1969 Network**	
Direct Conn.	No. of Nodes	Direct Conn.	No. of Nodes
18	1	12	1
11	1	10	1
---	---	6	1
5	2	5	2
4	3	4	2
3	3	3	5
2	7	2	8
1	8	1	8

9.4 Discussion of Results

9.4.1 Network Characteristics (Table 18)

Examining the network characteristics, as modelled, the historical 1969 network exhibits approximately three times more edges and twice as many nodes as the existing 2010 network. Regardless of the data issues, there are thus obvious discernible differences in the structure of the air transport networks.

One major shift has been in the use of hubs. In the historical 1969 network, the regional northern hub was Norway House. In the existing 2010 network, that has shifted to Thompson. In addition, in the historical 1969 network, the structural relationship between the communities on the east side of the province and southern points was more diffuse (i.e. oriented to the southern points of Winnipeg, St. Andrews, Gimli, etc.). In 2010, the majority of service is operated out of the Winnipeg airport, although one carrier (Northway Aviation) still operates from the St. Andrews Airport, located just north of the City of Winnipeg.

9.4.2 Comparative-Static Analysis (Table 19)

The results of this analysis suggest that both the existing 2010 and historical 1969 air transport networks are relatively minimally connected (in terms of 6% gamma indices – the number of actual connections to total maximum). This is to be expected due to the hub and spoke network structure exhibited in both instances and is typical of larger air transport networks such as those at the national level. No further inference of a credible nature can be made on the basis of this comparative-static analysis by virtue of the data limitations noted in the preamble of Section 9.2.

With the analyses of the modal transportation networks, one now has an appreciation of the structural characteristics of the modelled networks, and the degree to which they have changed, for specific points in time. Prior to drawing conclusions for transport planning, the following section will briefly discuss two topic areas which one would be remiss to not address in a study of this nature; namely, the potential longer-term effects of climate change and factors relating to sustainability of community and the environment. Together, they bring to bear longer-term effects on the transportation networks.

10.0 Implications of Climate Change

The spectre of climate change over time, and its potential influence on the transportation infrastructure and the mobility of inhabitants and economic activities in the study area, is a phenomenon that cannot be overlooked. As shown in this thesis, the transportation networks of the surface modes exhibit network characteristics that point to their fragility, the upshot of their lack of circuitry and their linearity of form. This reality leads to a situation in which there often is no mitigation or backup plan if a transportation linkage is rendered unusable (e.g. road washout, inability to maintain winter-road integrity, train derailment, structural collapse of infrastructure, etc.). In general, the surface modes (road and rail) lack redundancy in their respective systems.[133] Conversely, some expected effects of climate change may prove to be somewhat beneficial to transport (e.g. altered patterns and thickness of ice in Hudson Bay permitting expanded marine transport).

This discussion will not focus on the empirical modelling, prognostication, academic and scientific debates over the rate of change, temperature fluctuations and speculated impacts based on fifty-year extrapolations and the like. Rather, this chapter will focus on the probable implications for transportation infrastructure and systems that arise from the effects of generalized broad changes in climate. For the more northern areas of the study region, a main consideration will be the impact on the permafrost, with a secondary consideration being the ice in Hudson Bay. This is justified because all but one of the communities in the

[133] NRTEE (2009) notes that the lack of system redundancy is a major point of differentiation between southern and northern infrastructure systems in Canada. The vulnerability posed to communities if a single component of critical infrastructure is imperilled, compromised or fails, and where there exist no other options, can lead to service interruptions, lost productivity and inability to meet basic needs. That stated, in the study area, if land based transport networks (road or rail) are severed in all cases air transport may be employed for critical movements (at a cost premium).

study area are inland, and the exception, Churchill, is actually situated on the Bay. Furthermore, as discussed in the thesis, the Port of Churchill, in its terminal position on the rail network acts as a gateway, that is, an exchange point for handling imports or exports.

In addressing this subject, the chapter will be divided into two parts. First, the biophysical effects of climate change that may be applicable to the study area will be briefly reviewed and situated with examples. Secondly, there will be speculation on broader implications. This discussion will revolve around two areas: the internal implications for intraprovincial movement (e.g. within northern communities and their relationship to the south) and the implication for inter-territorial or international transport (e.g. focused on the Port of Churchill and marine transport through the Canadian Arctic and beyond).

10.1 Biophysical Change

In a rudimentary form of conceptualization, the relationship between climate change and transportation infrastructure may be as follows: changes in elements of the weather in turn may produce weather-related hazards or dependencies. These may exert influence on three areas of transportation: infrastructure, operations and demand (Mills and Andrey, 2002: 78). This relationship is illustrated in Table 21.

Table 21 - Relationship between Weather, Hazards / Dependencies and the Sensitivities of Transport		
General Weather Elements	**Weather-related hazards / Dependences**	**Sensitivity of Transport**
- Precipitation (snow, hail, rain, etc.) - Temperature - Wind (speed, direction) - Humidity - Sky conditions (sunshine, fog, UV, etc.)	- Freeze-thaw cycles - Ice and snow cover - Permafrost - Reduced visibility - Riverine and coastal flooding	**1. <u>Infrastructure</u>** - planning - design -construction - maintenance **2. <u>Operations</u>** - efficiency - mobility - safety **3. <u>Demand</u>** - location - timing - mode(s)

Source: after Mills and Andrey (2002: 78)

In the study area the weather element with the most bearing on the transportation network is temperature.[134] A long-term increase in average temperature is likely, to some extent, to affect two biophysical phenomena directly related to freezing – the permafrost[135] and sea ice.

A discontinuous band of permafrost is present across the northern reaches of the study area and it becomes continuous closer to the coastline of Hudson Bay. Permafrost influences the engineering and geotechnical properties of soil and other earth materials, and

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[134] ACIA (2009) notes that in the Arctic Region, manifestations or trends of climate change on the physical system (which may directly impact this study region) may include: rising temperatures, increasing precipitation, rising river flows, thawing permafrost, declining snow cover, retreating summer ice and rising sea level. ACIA further notes that general effects on society of the foregoing may include: expanding of marine shipping, increasing access to resources (i.e. oil and gas, minerals), enhanced marine fishery activity and disrupted transport on land (i.e. disturbed all-weather roads, unreliable winter roads).

[135] Permafrost – in general, refers to "earth materials that remain below 0^oC for two consecutive summers". According to this definition, permafrost covers more than half of the Canadian landmass and may be characterized in two ways: continuous (in northern areas where it may be several hundred metres thick) and discontinuous (on the more southerly fringes of its extent, where it may only be several metres thick). In the study area, the southern fringe of the discontinuous zone (isolated) begins approximately at the northern end of Lake Winnipeg, and extends north becoming more prevalent until it may be classified as continuous (in a band roughly parallel to Hudson Bay)(Furgal and Prowse, 2001: 61).

other geophysical properties (e.g. hydrological, the formation of bogs and muskeg). Long term effects of thawing may include increased infiltration of water downwards, greater groundwater storage, lower spring runoff, differential settlement and ponding, and potential draining of lakes and wetlands (Furgal and Prowse, 2007).

Related to the thawing of permafrost, suggested effects on infrastructure are increasing disruption of land-based transportation, including pipelines, and the lessening of the period available for use of seasonal road networks that traverse frozen lakes and rivers. The thawing may also affect other land-based infrastructure such as runways and rail lines. This may necessitate the use of more robust engineering design and construction techniques moving forward, which would increase the cost of infrastructure creation and longer-term maintenance (ACIA, 2009).

The potential effect on the winter-road network in Manitoba is telling, as in recent years quite a range of variability has been experienced in terms of days of operation. Between 1990 and 1997, the network on the East Side of Lake Winnipeg was operational for an average of between 50 and 55 days per year. In 1998 the network was operational for a mere 22 days, followed by 51 days in 1999, 20 days in 2000, and 59 days in 2001 and 25 days in 2002 (Kuryk, 2003: 20).[136]

The effect of a general rising temperature is forecast to affect the sea ice.[137] On the Manitoban coastline of Hudson Bay, the water typically freezes up by the end of December and begins to clear of ice in July, with the distribution and thickness of ice, year over year,

[136] The implications of this variability are immense. As previously discussed, many of the communities on the East Side of Lake Winnipeg have no other overland access. In 1998, winter roads to 12 communities failed, which required the Provincial Government to organize an expensive alternative of flying supplies into the communities. Approximately 10 million litres of fuel and 1 million kilograms of foodstuffs were airlifted in 1998 (Kuryk, 2003: 23).

[137] This commentary is generally focused on Hudson Bay and the broader implications northwards along the coast of Nunavut and the North West Passage to the West.

being quite variable (Furgal and Prowse, 2007). ACIA (2009) notes that a reduction in sea ice is likely to increase the prevalence of marine transport and access to resources in the affected area. There would be both positive and negative repercussions to this from a marine transport perspective. The positive may be a lengthening of the shipping season at the Port of Churchill; the negative may include more hazardous ice floes present in the shipping lanes, which could mean higher insurance rates.

10.2 Potential Implications

Of the many effects that climate change process and its biophysical manifestation may bear on the transport system in the study area, the broad implications on economic development can be expressed in terms of intraprovincial transport and, or interprovincial / international transport.

Intraprovincial movement on the existing overland network may continue to be compromised, in terms of both reliability of the current 2,200-kilometre seasonal winter road network, and the existing road and rail infrastructure (particularly between Gillam and Churchill). The freeze-thaw cycles and changes to the discontinuous permafrost will further impact the overland network and require significant capital upgrade to maintain it in a state acceptable for operation. All-weather roads will provide a greater degree of reliability, access and connectivity to communities than the current seasonal-winter roads. A far greater challenge would be maintaining operation on the railway, depending on the actual rate of change in the subsurface ice structures. This may become a barrier to private investment activity in the region, and from the public perspective, will incur great expense when periodic emergency resupply of severed communities is required by air.

Conversely, interprovincial or international transport may be a beneficiary in some aspects. Yet dire consequences cannot altogether ruled out. On the positive front, the potential lengthening of the marine shipping season in the North may suffice to open new opportunities for further international export or import activities and for the annual resupply for Nunavut. This prospect, though, is critically linked to the supporting infrastructure of the Hudson Bay Railway and any potential future seasonal or all-weather road to Churchill from the south. Thus if the supporting network is imperilled to any further degree, resort will be had to alternative, southern transport networks and supply-chains (centred on Montreal), in spite of the greater distances involved. In the final analysis, the consistent travel times for goods in a well-established supply-chain will prevail over the greater degree of commercial risk obtaining from usage of the Churchill supply-chain.

In sum, potential climate change implications are, at one in the same time, a threat and opportunity to the transport network in the study area. The threats come in the form of the potential of extensive damage to infrastructure from acute biophysical occurrences (e.g. the rapid appearance of a sinkhole which warps a rail line) and the more chronic issue of variable lengths of annual freeze periods, the latter affecting the reliability of the winter road system and the rate of deterioration of pavements and structures due to heaving, frost-jacking and other engineering and geotechnical issues. From a public policy perspective, this above-noted variability can be viewed as an opportunity, as it has forced the provincial and federal levels of government to address the long-standing issue of the reliability of these transportation networks. The outcome, practically, has been the upgrade of the winter-roads to all-weather standard, and on the Hudson Bay rail line, a significant cost-shared program of capital rehabilitation began in 2007 at a cost of $60 million (i.e. ballast and ties).

A discussion of potential factors of climate change would not be complete without addressing the broader concept of sustainability. As this thesis has suggested, the transport network in the study area lacks resiliency, and may prove to be less reliable in the future. This reality will have effects on both community sustainability (beyond economic development) and environmental sustainability (as potential transport infrastructure projects may be pursued, such as the all-weather road network, or there may be an increase in traffic on existing networks, such as with an increase of trade flows through the Port of Churchill). The next chapter briefly introduces the element of sustainability from a community and environmental perspective.

11.0 Sustainability

The topic of sustainability and sustainable development is vast, and the term itself is fraught with ambiguity and a range of meanings and interpretations (Robinson, 2004). Discussions of sustainability have, in the span of several decades, become almost a prerequisite element of any discussion on transport. This applies to both southern and northern Manitoba as well, although the focus may shift between the two. Of the myriad aspects possible for investigation, this discussion will briefly examine the implications in the study area of two components of sustainability, the community and the environment, and more specifically, how transport in the area may affect each.[138]

11.1 Community Sustainability

There may be three ways in which the communities may be categorized according to their access to transport, which, as this thesis has argued, has bearing on their sustainability. The community in question may exhibit one of the following properties:

1. It has year-round surface transport (road, rail or both);
2. It has episodic surface transport (winter road); and
3. It relies entirely on air transport.

The particular categorization of the community and the transport modes that provide access have far ranging implications for community sustainability.[139] As noted in Chapter 3, the factors particular to the use of each mode, according to specific intent and use, vary

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[138] This discussion will not specifically wade into other aspects of broader sustainability, such as social, cultural, and so forth as the focus of this thesis is on transport and economic development (as opposed to aspects of socio-cultural relationships).

[139] For example, IUS (2009: 31) notes that Churchill is sometimes referred to as the "accessible arctic", a result of its well-established rail and marine facilities and the frequency of air transport (although lacking road access). It further suggests that in spite of its arctic location, its relative accessibility (vis-a-vis other communities in the region) affects the costs of goods. Even though these are more expensive than in Winnipeg, they are generally lower than prices applying in neighbouring communities in the north.

greatly, and ultimately affect the cost structure of that mode's use. Thus, although one can use the air mode to transport a person or cargo from point A to B, it will be faster than overland transport (by road or rail), but will come at an expense premium and has limitations of weight, dimension and form of unitization. This extends to start-up economic development initiatives as well. A business in a remote community, if its markets lie outside that community, must factor in relatively costly air transport into the business model and end cost. Furthermore, many potential business opportunities will be completely unfeasible with air-only transport. Among these would be harvesting or intermediate finishing of primary commodities, manufacturing of larger / heavier items and any processes or applications requiring input of liquids or bulk material. This same general relationship also applies to foodstuffs, which is an important issue for northern residents as was evidenced in the 2003 *Northern Food Prices Report*, which solely focused on the communities within the study area. Freight costs, reflecting the accessibility of the various modes, strongly influence the end price of products "on-the-shelf" within the community (Manitoba, 2003).[140]

Moving from a framework of categorization based on transportation to one that follows on the work of Randall and Ironside (1996), another informative system of general classification can be applied. This, too, is an attempt to understand the communities in the

[140] The end price includes more than simply moving the item into the community, but also typically includes a percentage mark-up to account for the higher costs of doing general business in a remote community (i.e. higher costs of construction, maintenance, equipment repair, heating fuels, etc.). Manitoba (2003: 8) states clearly that:

> However, it is important to note that there is a direct relationship between road access to a community and lower cost for nutritious [i.e. perishable] foods. In communities that have all-weather road access, the freight costs, the costs of doing business and therefore food prices are relatively competitive with southern food retailers. In addition, all-weather road access allows residents to drive to nearby centres that offer even lower process and sales.

study area, but one based simply on their predominant economic function or characteristic.[141] Accordingly, communities fall into one of the following categories:

1. Resource-based communities;[142]
2. Administrative / transportation hub communities;
3. First Nation communities; and
4. Hybrid of the above.

In the study area, examples of resource-based communities include Snow Lake, Lynn Lake, Fox Mine (mining) and Gillam (hydro). For their part, administrative / transportation hub communities are absent from the region in pure form, but continue to exist in hybrid form when combined with resource-based activities, such as Flin Flon and Thompson (mining and administrative / transportation hub), The Pas (forestry and administrative / transportation hub) and Thompson (mining and administrative / transportation hub). First Nation communities, such as Nelson House, Pukatawagan, Little Grand Rapids, amongst many others, also figure prominently.

The utility of the above schema is that transportation will affect the community in slightly different ways, depending on its overarching classification. As transport is a fundamental aspect of community sustainability in the study area, a select review of what the

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[141] This grouping is a modification of that suggested by Jones and Rosenburg (1992).
[142] Randall and Ironside (1996: 26) note that there is an "intimate relationship" between communities based on industrial specialization and employment stability. This is particularly true when the communities' resource operation is particularly susceptible to national or international trends in business, commodity price fluctuations, etc. The authors note that a stereotypical defining feature of these resource-dependent communities is the "existence of an imbalanced labour and industry profile", where employment in the industry far outweighs employment in other activities.

terminology of sustainable development and community is instructive. This may suggest ways in which transport can play an integral role in the sustainability of a given community.

Three core elements embodied in the concept of a sustainable community, are the environmental, the social and the economic. Newton *et al.* (2002: 285), in their development of a community-based sustainability vision for Churchill, review the elements of a sustainable community as defined by Roseland (1992) and articulate a vision where a sustainable environment “recognizes that growth occurs within limits and is restricted by carrying capacity of the environment, and uses materials in continuous cycles”. Secondly, with regard to the social, it “values cultural diversity”, exhibits transparent decision-making processes (which incorporate community perspective), and “encourages fair distribution of benefits among all members (including the disadvantaged)”. Lastly, the economic component envisions a “local economy that is stable and diversified, relies on local strengths and resources, and encourages local initiatives”.

The Institute for Urban Studies (IUS, 2009: 9), in its *Sustainable Churchill Discussion Paper,* notes that commonly cited dimensions of a sustainable community were found to include minimized energy consumption and the use of renewable energy, compact development minimizing the consumption of land, a reduced need for transportation, preserved agricultural lands and habitats, minimized waste stream and conservation of water and preservation of biological diversity.

Newton *et al.* (2002), focusing their commentary on Arctic and Subarctic communities (notably Churchill), concede that the development of sustainable communities is difficult, citing the challenges posed by isolation, high unemployment and susceptibility to climate change. Discussions of community sustainability cannot be divorced from the discussions of economic development. To reduce unemployment, to bring productive activity to regions and from a broader social perspective, to provide longer-term skills training, experience and increased levels of disposable income to residents all require economic activity. Put bluntly, the absence of economic activity will create or maintain relationships of dependency, a situation which does not allow for individual and community decision-making, self-determination or relative autonomy.[143]

As discussed in the literature review in Chapter 2, transport access and connectivity is a fundamental requirement of economic development. There can be no growth in sustainable economic activity in areas of absolute isolation and for those with reduced or expensive forms of access, this will pose a formidable obstacle to the start-up of economic activity. For communities that are accessible only by air, there will likely be no prospect of any economic activity other than that which may be able to be sustained within a closed community.

In their identification of transportation-related factors of a sustainable Churchill (25 years on the horizon), Newton *et al.* (2002: 285) found that the community felt that the long-term viability of the sector will require an "active port" and a "coordinated effort by the rail and airline sectors". A fundamental aspect of the active port was noted to be increase in

[143] A reinforcing factor, tied to productive activity and autonomy, is the ability of remote communities to retain their young adults, who may leave the community in search of economic and other opportunities. Demographic and employment trends in Manitoba's North Region, the delineation of which almost exactly matches the study area of this thesis, suggest there may be some initial merit to this view. According to the 2006 Census, the Northern Region reported a 16.4% unemployment rate, contrasted with the Manitoba rate of 5.5% (Winnipeg Region 5.2%). Furthermore the age distribution profile of the north is relatively young: 31.4% of population is 0-14 years (19.6% for Manitoba), while the next demographic brackets suggest relative parity: 15-24 years, 16.7% (14.1% for Manitoba) and for 25-54, 38.9% (41.3% for Manitoba). This may suggest that teens and young adults readily leave the communities of the Northern Region for a variety of reasons, possibly school, social, work prospects and other opportunities (MBS, 2008: 8).

tonnage, which today, as it has been over the past century, is a preoccupation of the various incarnations of port operator, marketing agencies, transport companies and provincial government. It was noted that an integrated rail and port approach would be required to drive movements and increase the longer-term profitability of the multi-modal system. The airport and the aviation sector were noted by the community as being an activity that has sustainable development implications, specifically as a hub for servicing of the Far North.

Likewise, IUS (2010) found that transport is indispensable to Churchill's development prospects and that it is in and of itself a generator of economic input. The IUS' research and "visioning" work with community stakeholders found, similar to Newton *et al.*, that vision principles pertaining to economic sustainability included transportation and a need for diversification of economic activities. The Port of Churchill was remarked as being a potential driver of further economic activity for the community and the proposed Manitoba-Nunavut all-weather road was cited.

An element of community sustainability at play in the study area is the relationship between the First Nations' communities and the Crown. The relationship between these communities and the Provincial and Federal Governments influences decision-making and infrastructure projects, rendering them unduly complex, as there are multiple parties with potentially varying perspectives and requirements, legal authority and funding capabilities. As a result, projects usually require lengthy preparatory and planning phases. If the structure of the administration of the current reservation system were to drastically change, or cease, in the time horizon between 2010 and 2035, this would certainly alter much of the grounds upon which conceptual transportation route-planning and economic projections have been made to date.

In sum, there will undoubtedly be a degree of tension within a community between advocates for development (i.e. transportation, economic, natural resource / mineral extraction, etc.) and those that oppose it, on a variety of grounds. At the very least, it is the easing of such tension where a broad-based planning process can help to articulate a vision for future decision-making. In summary, as Newton *et al.* (2002: 289) maintain:

> The North is endowed with rich resources and only partially exploited possibilites. There is a clear need to identify opportunities and promote local economic, environmental, and social development to reduce poverty, improve education, and strengthen cultural identity in local northern residents. A mobilization of resources and broad cooperation among stakeholders is essential to meet the multiple challenges in the North.

Harnessing these possibilities, specifically through transport development, is more likely when close attention is paid to the issue of environmental sustainability.

11.2 Environmental Sustainability

It is a prerequisite of infrastructure projects in this era to undergo some degree of institutionalized scrutiny and a process of regulatory approval, prior to construction. This may range from the more succinct screening and construction mitigation plan in the case of an upgrade to an existing structure to a fulsome, in depth, multi-year environmental impact assessment and licensing process in the case of a new bridge, hydroelectric facility or mine.

The key to the environmental aspect of sustainable communities is, through a reasonably comprehensive planning process, to fully unearth, disclose and discuss the likely primary and secondary effects of a particular project, not only on the biophysical environment, but on the socio-cultural environment as well. This planning approach and documented process is required to obtain project licensing for infrastructure projects which, depending on the location, type and political / governmental jurisdiction, may be Federal or Provincial in nature.

For ongoing transportation activity in the community of Churchill, Newton *et al.* (2002) note that this planning is crucial, as on the one hand residents would like to see increased economic activity based around the port and rail, which would increase vessel traffic in the harbour, and may require dredging or other large-scale infrastructure upgrade or replacement). On the other, there is a will to capitalize on the area's tourism features related to wildlife, such as the whales in the river estuary.

No transportation development or activity is absolutely benign, and communities, governments and the planners and designers of transport infrastructure fully appreciate this fact. They are compelled, in any event, to consider and mitigate deleterious effects of their new projects.

The final chapter will draw the findings of all other chapters of this study together, presenting broad conclusions and suggestions for those preparing future plans or policies for transportation infrastructure development

12.0 Conclusions and Implications for Transportation Planning

On the basis of the modelling and analyses untaken for the individual four modes, this chapter will draw broader conclusions that have practical implications. Specifically, it will permit the formulation of recommendations germane to integrated, multi-modal transportation planning.

12.1 Road Transport

The results of the analyses undertaken on the four road networks are slightly alarming, implying that on the basis of network connectivity alone, the future 2035 network expansion does not greatly alter the fundamental measures or indicators of connectivity as calculated using a graph-theory approach. Broadly, if economic development is tied to the connectivity and relative accessibility of a vertex in a transportation network, then the future network expansion will provide only basic access. From this positive perspective, this basic access will move from reliance on seasonal winter roads to being anchored on an all-weather road pattern which is accessible for use year round, thus rendering it more reliable. This outcome, of course, is an important factor for the establishment of any productive activity, since the would-be investor must be confident that he can get his product, resource, or good to a market.

If not on purely economic grounds, the construction of a future 2035 network, and the basic, reliable, all-year access implicit in permanent all-weather roads, will allow for the supply of the subject communities with sundry goods from the south or northern regional hubs (i.e. foodstuffs, building supplies, etc.) and will at the very least play a permissive role in the transportation / economic development relationship. Put otherwise, if not directly affecting the increase in productive activity upon construction, the road network's very existence may allow for future endeavours as the economies of transporting goods and services may become less burdensome (i.e. in the case of mineral or primary product extraction).

Additionally, the road network will likely be championed as playing a quasi-political role; that is to say, achieving a public-policy aim of providing equitable transportation access to northern residents. However, it will be difficult to quantify aspects of socio-cultural enhancement or economic development afforded by this new mobility.

12.2 Rail Transport

The results of the analyses for the rail transport networks are not particularly helpful. This is attributable in large part to the relative stagnant network evolution in the study area over the course of forty years, during which no new routes opened but an 80 kilometre-spur was abandoned. The nature of rail transport's high construction and maintenance costs and the structure of its operation (likely privately built, financed and operated) require a catalyst for development (e.g. construction, commissioning and ongoing operation of a new mine site). Dedicated passenger rail services would be unable to provide the necessary economic rationale for this level of investment, for the population densities in the subject region are far too low and the length of system required too long (in kilometres of trackage) to justify any investment of serious proportions. Certainly, passenger rail transport services could be a secondary use of a primarily commercial freight line in a new network development scenario if population centres were to exist along the commercial line.

The above provisos notwithstanding, several prospects for the Hudson Bay mainline exist which may precipitate significant upgrade (beyond routine or focused capital improvements), expanded use of existing infrastructure or even network expansion. A central element in this proposition is the future use of the Port of Churchill at its northern terminus. With the predominant historical user of the Port being the Canadian Wheat Board, and its future in peril, the amount of grain shipped through the Port may decrease dramatically, conceivably ceasing altogether. Port diversification is required, and to accomplish this task, capital upgrade will be required for its new uses. Prospects for diversification may include containerized traffic, mining-related traffic and becoming a gateway for continental industrial movements (i.e. off-shore manufactured industrial equipment / facilities entering the North American continent via the Port and HBR). Additionally, an enhanced resupply function for the communities of the high arctic using short-sea shipping / barging based out of Churchill would be feasible (much of this activity currently is based out of Montreal).

One of the shortcomings of rail transport in the study area from a network perspective is the route adopted by the permanent way. This certainly poses a time-distance impediment from a passenger travel perspective, as well as in the case of transporting some cargo (i.e. fresh foodstuffs), since the duration of the journey between Winnipeg and Churchill is nearly 45 hours one way (VIA Rail Canada, 2011). As the historical and current route necessitates travelling northwest into Saskatchewan on the CN system (at approximately 51°50'), re-entering Manitoba (at approximately 53°50') and accessing the Hudson Bay Railway at The Pas, the time and distance is substantially greater than if there were a route within Manitoba (i.e. north from Winnipeg through the Interlake Region or on the west side of Lake Manitoba).

The structure of the network, its remoteness, northern topographic issues (e.g. discontinuous permafrost) and the vast distances entailed in its links, have always posed, and will continue to pose, challenges and risks for the operators of the railway and port and those businesses that may seek to use them. Any new reinvigoration of the port will likely require significant capital upgrades, by virtue of the sheer scale of the undertaking.

Despite the challenges, rail transport is aptly suited to serve the development needs of a future industrializing north. Hydro-electric dam development, recommissioned or new mine site developments, or the emergence of a heavy-haul corridor could all draw on the modal capabilities of rail transport and the existing route. Depending on the economics of a particular project, the building of a new spur to access locations adjacent to the main line may be warranted.

The future use of rail transport for passenger services will likely remain as it is today. Due to the transit time, passenger travel from Winnipeg to Churchill is largely tourist in nature, while those accessing the mode at The Pas or Thompson have more reasonable trip durations.

12.3 Water Transport

The intraprovincial water transport services are largely “connective” in nature. They function as mobile pieces of infrastructure, providing water crossings where the economics of constructing an engineered structure such as a bridge or causeway is prohibitive, or, in the instance of the Split Lake – York Landing service, where connecting the two First Nations communities is a multimodal enterprise: Split Lake has road access and across the Nelson River, York Factory has rail access via a winter road. Emerging scheduled passenger or freight service (i.e. on Lake Winnipeg) is highly unlikely. The ability of road transport to access the communities on the north shore of the area (i.e. Cross Lake and Norway House) and the relative small populations (and thus demand) on the east shore (i.e. Berens River, Poplar River) which are currently on the winter road network and are slated to be connected on the future East Side Lake Winnipeg all-weather road network and have air transport access to boot, could not support a scheduled, commercial water-based service.

The Port of Churchill, which was designed and has long been operating as a grain exporting hub, with minimal levels of import traffic, has the opportunity, indeed will be compelled to diversify its operations to remain viable. This is certainly the case in a post-Canadian Wheat Board scenario. Because of the location of the port relative to any hinterland market, any new uses will need to be planned in conjunction with the railway (as the only means of overland access). Since the current owner / operator of the port also owns the Hudson Bay Railway (OmniTRAX), this required level of integrated planning should not pose an issue.

12.4 Air Transport

Air transport offers the most extensive reach to the communities in the study area, both historically and currently. An obvious influencing factor for this outcome is the flexibility offered by the mode; namely its time-distance advantage and its ability, depending on aircraft, to use water, gravel, grass, dirt, etc. as a runway. Air transport's role in the study area will likely not diminish to any great degree, although the general network of the operations may shift as economics dictate. Passenger service will likely increase moderately as population growth is generally steady in the north and major civil infrastructure and commercial developments in remote areas are ongoing or in the works (i.e. hydroelectric dams, mining activities), which necessitate the conveyance of staff.

With the future extension of the road network, the transport of general freight can be expected to shift from the air to the road, except in the case of highly time sensitive or valuable cargo. Although long distances may have to be traversed, the modal shift could be expected to lower the freight cost of products, which, in theory, should lower the retail price to some degree. Additionally, the ability to provision communities on a year-round basis will flatten out the spikes in demand / scarcity or unavailability currently experienced using the winter road and air systems, which also affects retail prices. Future economics of air transport and the aircraft in use by operators may put pressure on the airport owner / operators / administrators such as the Federal and Provincial governments to expand runways to accommodate new generations of larger aircraft or those with differing power sources (i.e. shift from propeller to jet).

12.5 Conclusions

Upon revisiting the research statement: “the modelled transportation infrastructure expansion will produce greater degrees of access and connectivity than the current 2010 transportation in the study area of northern Manitoba”, and the hypothesis that greater levels of transportation access and connectivity will promote increased opportunity for regional economic development, on the basis of the analyses undertaken, several conclusions can be made.

First, in real terms, the future 2035 road network will produce greater levels of access and connectivity than the existing 2010 network. Although to be sure, the spinal structure of the network will remain vulnerable as it will lack any circuitry or redundancy, and any unforeseen problems on any given link will sever the network.

Secondly, because of the absence of any planning documentation or any known network expansion plans for the air, rail and water modes, and thus models and analyses which lack a degree of confidence, no specific conclusions can be drawn based on the hypothesis. It is likely that the air transport network will change over time due to its relative flexibility of operation while the rail network and water networks will likely remain largely as they are now. Rail expansion, in particular, will require an economically significant project to warrant network expansion.

Thirdly, potential opportunities for significant levels of increased economic activity may be present with the current multimodal network provided by the Port of Churchill, the Hudson Bay Railway and portions of the Provincial highway system. Similar to above, significant upgrade to the railway and port will require a bona fide project of a given magnitude to warrant the sizeable investment of capital required to diversify use.

Fourthly, more detailed study is required on the potential for increased economic development which may result from any one of the potential network expansions discussed in this thesis. This would require not only an investigation of the transportation implications but also the business-case scenario which new transportation infrastructure or services would impact.

Fifthly, other than the expansion of the road network, any significant expansion of the networks of the other modes will require private investment, which may lever state funds in any event and thus will not assume a supply-led approach to infrastructure or transportation service provision. This investment will be forthcoming only under the demand-led scenario;

that is to say, with an attendant value proposition and very favourable, solid cost-benefit scenario to justify the capital outlay.

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Appendix A Existing 2010 Road Transport Network

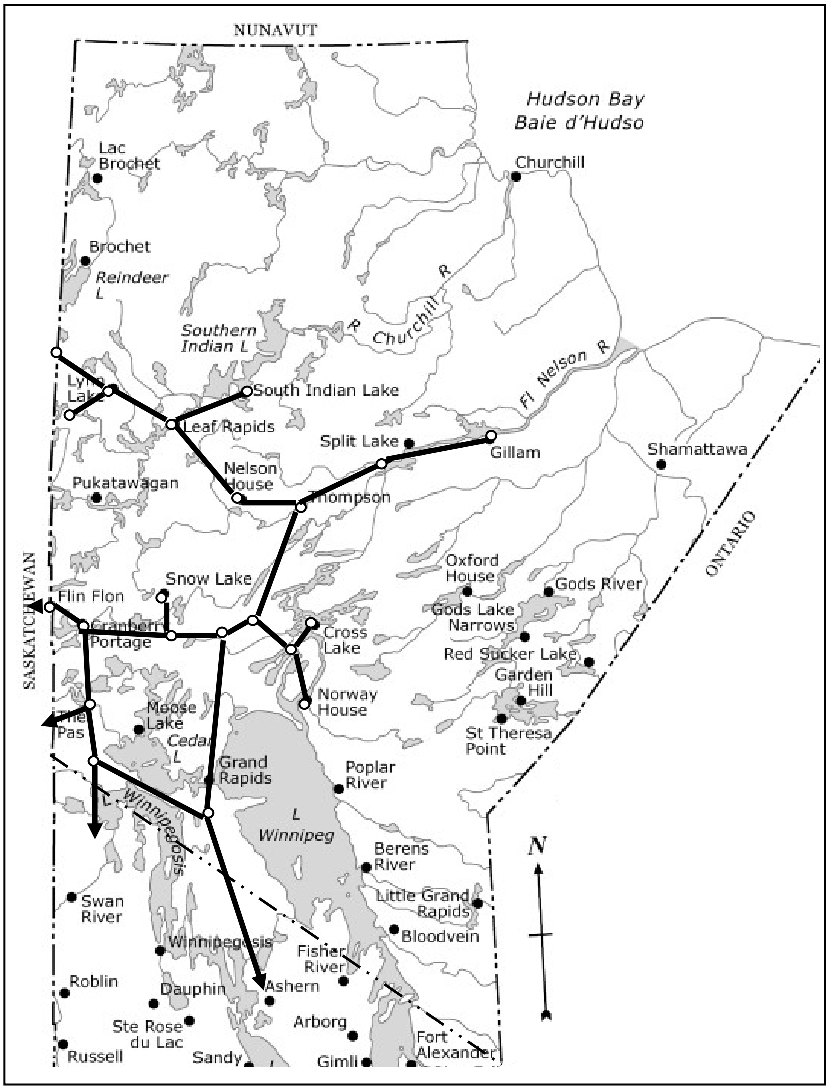

Figure A-1: Existing 2010 Road Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix A Existing 2010 Road Transport Network

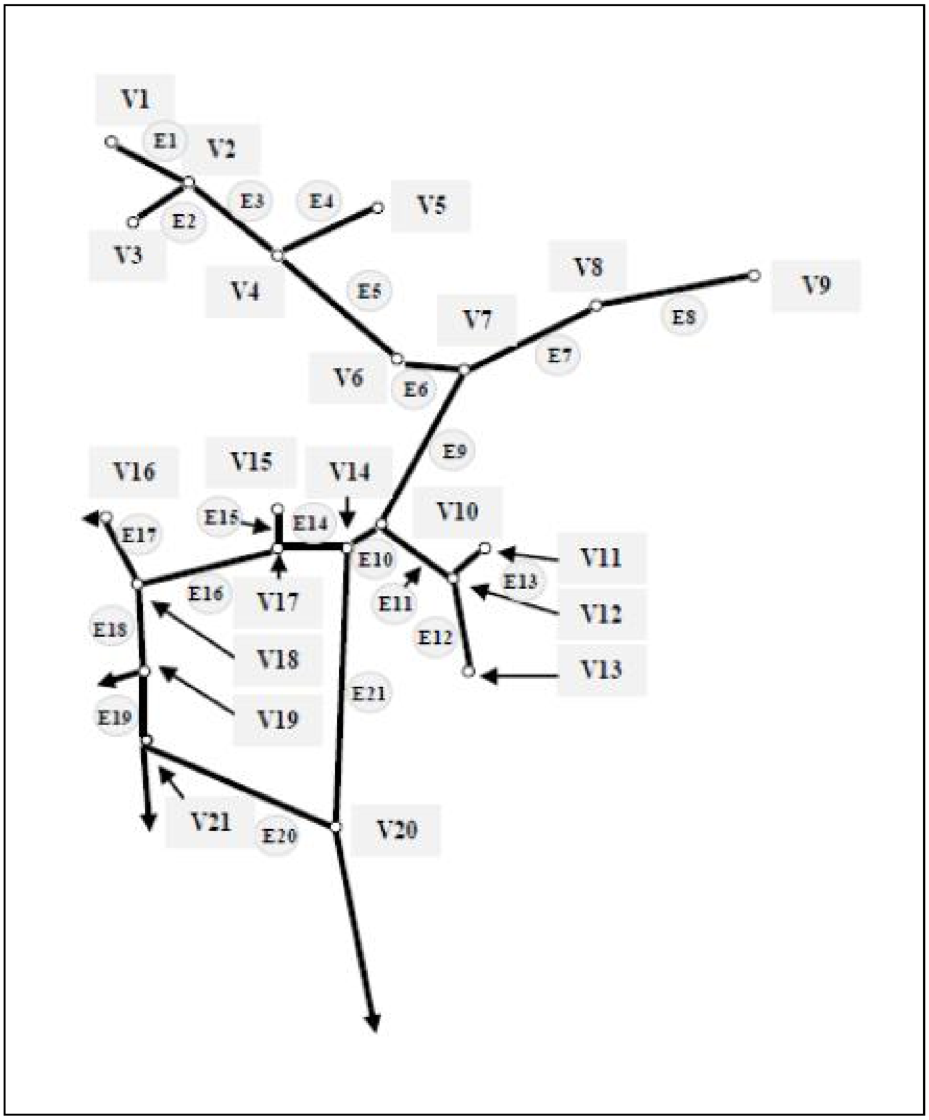

Figure A-2 – Existing 2010 Road Transport Network: Detail of Vertices and Edges

Appendix A Existing 2010 Road Transport Network

Table A-1 – Summary of Edges on Existing 2010 Road Transport Network			
Edge	**Name**	**Surface Type**	**Approx. length**
1	PR 394	Gravel	98 km
2	PR 396	Paved	45km
3	PR 391	Paved	105 km
4	PR 493	Gravel	92 km
5	PR 391	Paved / Gravel	144 km
6	PR 391	Paved / Gravel	70 km
7	PR 280	Gravel	126 km
8	PR 280	Gravel	164 km
9	PTH 6	Paved	122 km
10	PTH 6	Paved	30 km
11	PR 373	Paved / Gravel	96 km
12	PR 373	Paved / Gravel	77 km
13	PR 374	Paved / Gravel	37 km
14	PTH 39	Paved	63 km
15	PR 392	Paved	35 km
16	PTH 39	Paved	100 km
17	PTH 10	Paved	65 km
18	PTH 10	Paved	75 km
19	PTH 10	Paved	74 km
20	PTH 60	Paved	152 km
21	PTH 6	Paved	205 km
Total Approximate Length of Network			**1,975 km**
PR – Provincial Road PTH – Provincial Trunk Highway			

Appendix A Existing 2010 Road Transport Network

Table A-2 - Summary of Vertices on Existing 2010 Road Transport Network	
Vertex	**Place Name**
1	Kinoosao (SK)
2	Lynn Lake
3	Fox Mine
4	Leaf Rapids
5	South Indian Lake
6	Nelson House
7	Thompson
8	Split Lake / York Landing
9	Gillam
10	Intersection of PTH 6 & PR 373
11	Cross Lake
12	Intersection of PR 373 & PR 374
13	Norway House
14	Intersection of PTH 6 & PTH 39 ("Ponton")
15	Snow Lake
16	Flin Flon
17	Intersection of PTH 39 & PR 392
18	Intersection of PTH 10 & PTH 39 ("Simonhouse")
19	The Pas
20	Intersection of PTH 60 & PTH 6 (34 km south of Grand Rapids)
21	Intersection of PTH 60 & PH 10
PR – Provincial Road PTH – Provincial Trunk Highway	

Appendix B Historical 1969 Road Transport Network

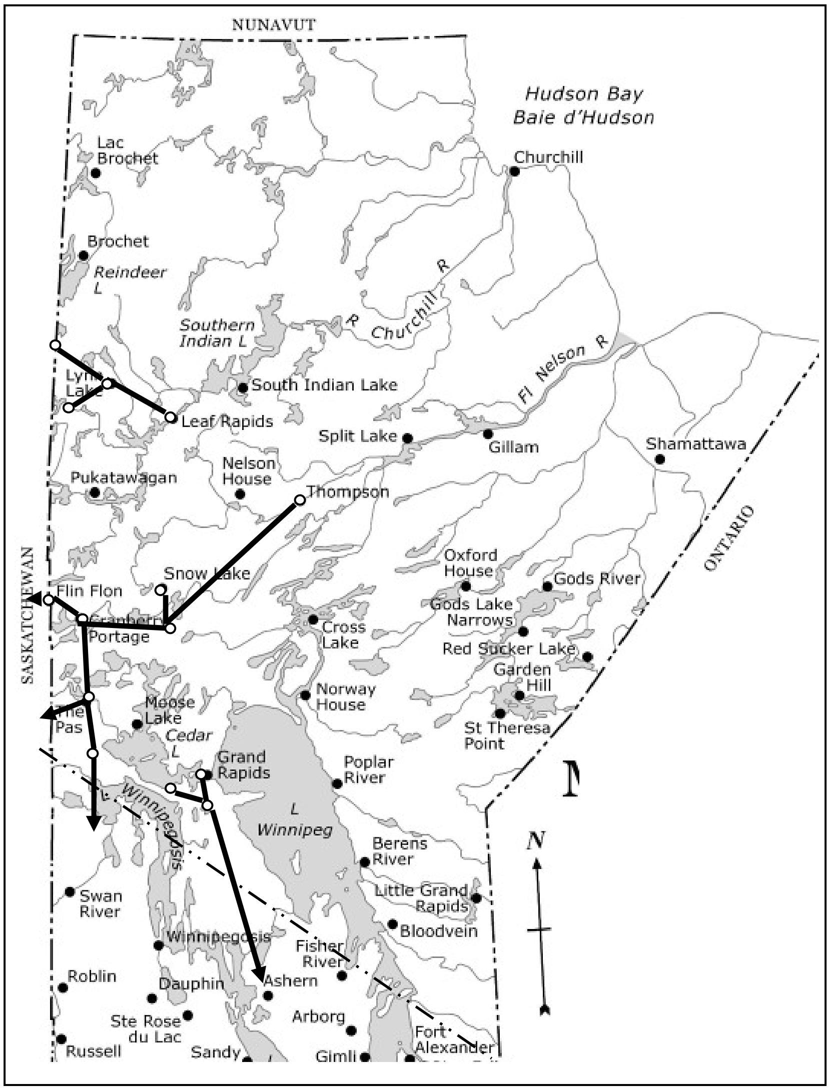

Figure B-1: Historical 1969 Road Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix B Historical 1969 Road Transport Network

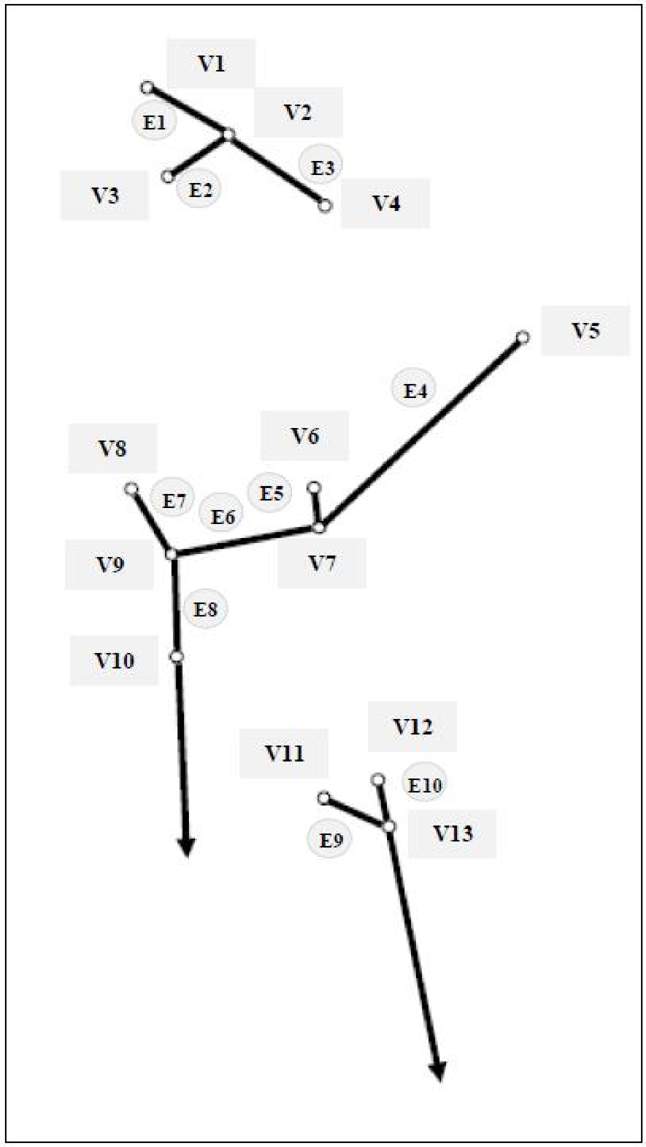

Figure B-2 - Historical 1969 Road Transport Network: Detail of Vertices and Edges

Appendix B Historical 1969 Road Transport Network

Table B-1 – Summary of Edges on Historical 1969 Road Transport Network			
Edge	**Name**	**Surface Type**	**Approx. length**
1	PR 394	Gravel	94 km
2	PR 399 (Now PR 396)	Gravel	45 km
3	PR 399 (Now PR 391)	Gravel	105 km
4	PR391 (Now PTH 39 and PTH 6)	Gravel	220 km
5	PR 392	Gravel	34 km
6	PR 391 (Now PTH 39)	Gravel	101 km
	PTH 10	Paved	67 km
8	PTH 10	Paved	74 km
9	PR 327 (now PR 327 & PTH 60)	Gravel	64 km
10	PTH 6	Gravel	35 km
Total Approximate Length of Network			**839 km**
PR – Provincial Road PTH – Provincial Trunk Highway			

Appendix B Historical 1969 Road Transport Network

Table B-2 - Summary of Vertices on Historical 1969 Road Transport Network	
Vertex	**Place Name**
1	Kinoosao (SK)
2	Lynn Lake
3	Fox Mine
4	Leaf Rapids
5	Thompson
6	Snow Lake
7	Junction of PR 392 and PR 391
8	Flin Flon
9	Intersection of PTH 10 & PR 391 (“Simonhouse”)
10	The Pas
11	Easterville
12	Grand Rapids
13	Junction of PTH 6 and PR 327

Appendix C Existing 2010 Control Road Transport Network

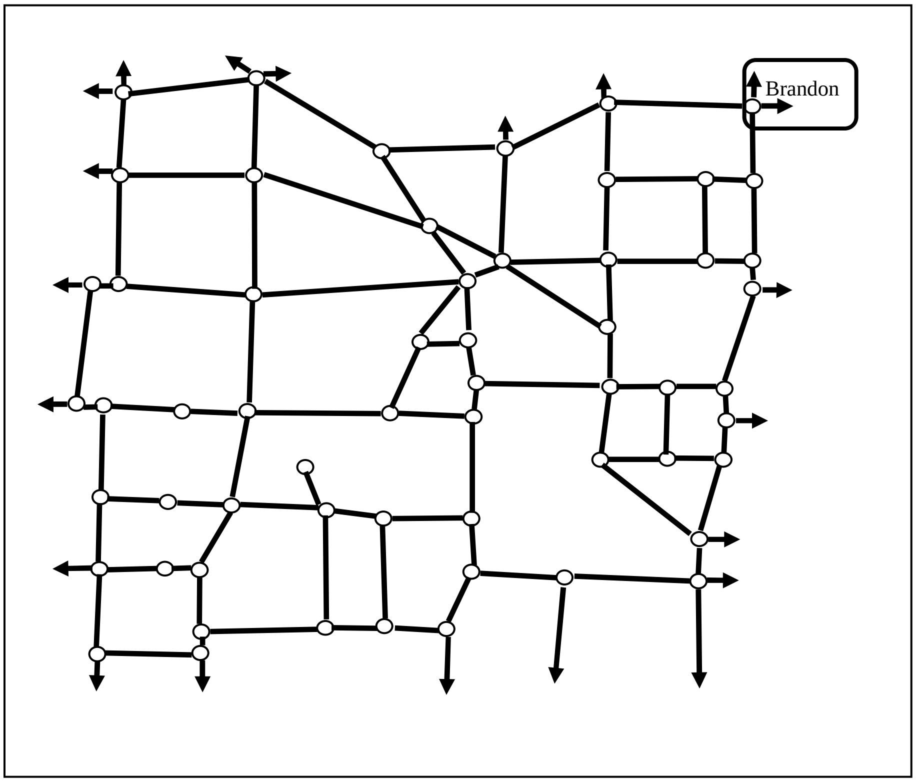

Figure C-1 - Existing 2010 Control Road Transport Network: Overview

Base map removed due to copyright, please follow link. Source: Manitoba (2010), http://www.gov.mb.ca/mit/map/pdf/map1.pdf

Appendix C Existing 2010 Control Road Transport Network

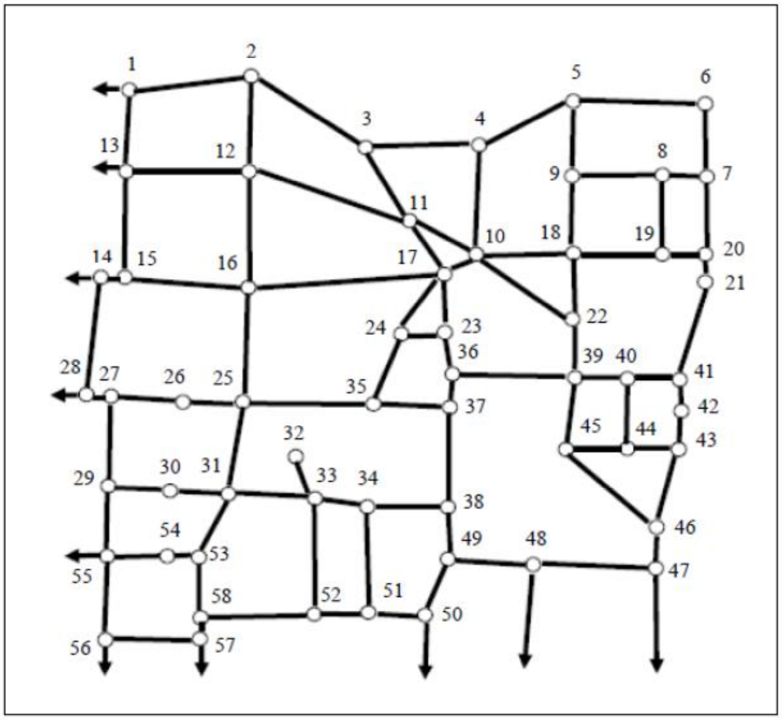

Figure C-2(a) – Existing 2010 Control Road Network: Detail of Vertices

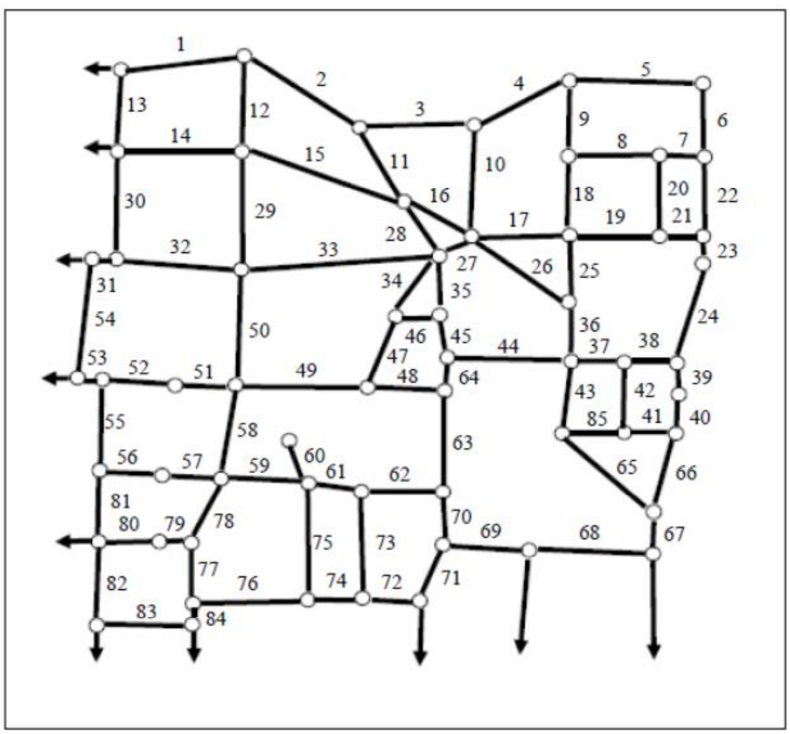

Figure C-2(b) – Existing 2010 Control Road Network: Detail of Edges

Appendix C Existing 2010 Control Road Transport Network

Table C-1 – Summary of Edges on Existing 2010 Control Road Network			
Edge	**Name**	**Surface Type**	**Approx. length**
1	PR 257	Paved	25 km
2	PTH 1	Paved	19 km
3	PTH 1	Paved	18 km
4	PTH 1	Paved	16 km
5	PTH 1 / PR 459	Paved	18 km
6	PTH 10	Paved	12 km
7	PR 349	Gravel	7 km
8	PR 349	Gravel	17 km
9	PR 250	Paved	12 km
10	PTH 21	Paved	18 km
11	PR 543	Paved / gravel	15 km
12	PTH 83	Paved	16 km
13	PR 256	Paved	15 km
14	PR 255	Gravel	25 km
15	PR 255	Gravel	25 km
16	PR 543	Gravel	10 km
17	PTH 2	Paved	14 km
18	PR 250	Paved	12 km
19	PTH 2	Paved	17 km
20	PR 348	Gravel	12 km
21	PTH 2	Paved	5 km
22	PTH 10	Paved	12 km
23	PTH 10	Paved	5 km
24	PTH 10	Paved	18 km
25	PTH 22	Paved	10 km
26	PR 347	Gravel	20 km
27	PTH 2	Paved	8 km
28	PR 543	Gravel	10 km
29	PTH 83	Paved	18 km
30	PR 256	Paved	18 km
31	PTH 2	Paved	4 km
32	PTH 2	Paved	36 km
33	PTH 2	Paved	32 km
34	PR 254	Gravel	10 km
35	PTH 21	Paved	10 km
36	PTH 22	Paved	10 km
37	PTH 23	Paved	8 km
38	PTH 23	Paved	8 km
39	PTH 10	Paved	5 km
40	PTH 10	Paved	6 km
41	PR 343	Gravel	8 km
42	PR 444	Gravel	11 km
43	PR 448	Gravel	11 km
44	PTH 23	Paved	21 km
45	PTH 21	Paved	8 km
46	PR 541	Gravel	10 km
47	PR 541	Gravel	10 km
48	PR 345	Paved	12 km
49	PR 345	Paved	20 km
50	PTH 83	Paved	18 km
51	PR 345	Paved	10 km
52	PTH 2	Paved	14 km
53	PTH 2	Paved	2 km
54	PR 256	Paved	32 km
55	PR 256	Paved	18 km
56	PR 445	Paved	10 km
57	PR 445	Paved	6 km
58	PTH 83	Paved	16 km
59	PTH 3	Paved	12 km
60	PR 452	Paved	8 km
61	PTH 3	Paved	8 km
62	PTH 3	Paved	14 km
63	PTH 21	Paved	16 km
64	PTH 21	Paved	5 km
65	PR 448	Gravel	18 km
66	PTH 10	Paved	8 km
67	PTH 10	Paved	6 km
68	PTH 3	Paved	20 km
69	PTH 3	Paved	14 km
70	PTH 21	Paved	8 km
71	PTH 21	Paved	11 km
72	PR 251	Paved	10 km
73	PR 254	Gravel	15 km
74	PR 251	Paved	10 km
75	PR 452	Paved	16 km
76	PR 251	Paved	18 km
77	PTH 83	Paved	10 km
78	PTH 83	Paved	13 km
79	PTH 3	Paved	6 km
80	PTH 3	Paved	10 km
81	PR 256	Paved	10 km
82	PR 256	Paved	13 km
83	PR 251	Paved	16 km
84	PTH 83	Paved	3 km
85	PR 343	Gravel	8 km
Total Approximate Length of Network			**1,119 km**

PR – Provincial Road
PTH – Provincial Trunk Highway

Appendix C Existing 2010 Control Road Transport Network

Table C-2 - Summary of Vertices on Existing 2010 Control Road Network

Vertex	Place Name
1	Intersection of PR 256 & PR 257
2	Virden
3	Intersection of PTH 1 & PR 254
4	Griswold
5	Intersection of PTH 1 & PR 250
6	Brandon
7	Intersection of PTH 10 and PR 349
8	Intersection of PR 349 & PR 348
9	Intersection of PR 250 & PR 349
10	Intersection of PTH 21 & PTH 2
11	Intersection of PR 255 & 543
12	Scarth
13	Cromer
14	Sinclair
15	Intersection of PTH 2 & PR 256
16	Pipestone
17	Delau
18	Souris
19	Intersection of PR 348 & PTH 2
20	Intersection of PTH 2 & PTH 10 (n)
21	Intersection of PTH 2 & PTH 10 (s)
22	Intersection of PTH 22 & PR 347
23	Intersection of PTH 21 & PR 541
24	Grande-Clairiere
25	Intersection of PTH 83 & PR 345
26	Broomhill
27	Intersection of PR 345 & PR 256
28	Tilston
29	Intersection of PR 256 & PR 445
30	Intersection of PR 445 & PR 252
31	Melita
32	Napinka
33	Intersection of PTH 3 & PR 452
34	Medora
35	Lauder
36	Intersection of PTH 21 & PTH 23
37	Intersection of PTH 21 & PR 345
38	Intersection of PTH 21 & PTH 3
39	Elgin
40	Fairfax
41	Intersection of PTH 10 & PTH 23
42	Minto
43	Intersection of PTH 10 & PR 343
44	Intersection of PR 343 & PR 444
45	Intersection of PR 343 & PR 448
46	Boissevain
47	Intersection of PTH 10 & PTH 3
48	Intersection PTH 3 & PR 450
49	Deloraine
50	Intersection of PTH 21 & PR 251
51	Intersection of PR 254 & 251
52	Waskada
53	Intersection of TH 83 & PTH 3
54	Intersection of PTH 3 & PR 252
55	Pierson
56	Intersection of PR 256 & 251
57	Intersection of PTH 83 & PR 251 (s)
58	Intersection of PTH 83 & PR 251 (n)

<u>Appendix D</u> <u>Future 2035 Road Transport Network</u>

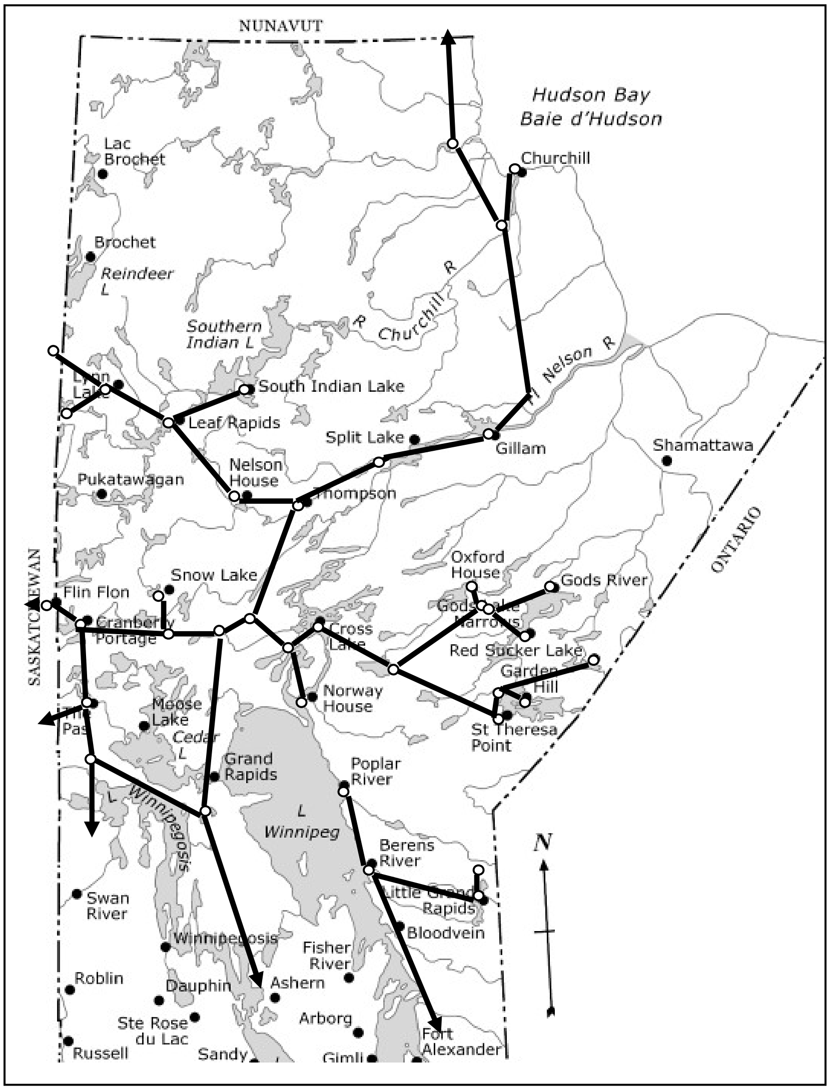

Figure D-1 – Future 2035 Road Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix D Future 2035 Road Transport Network

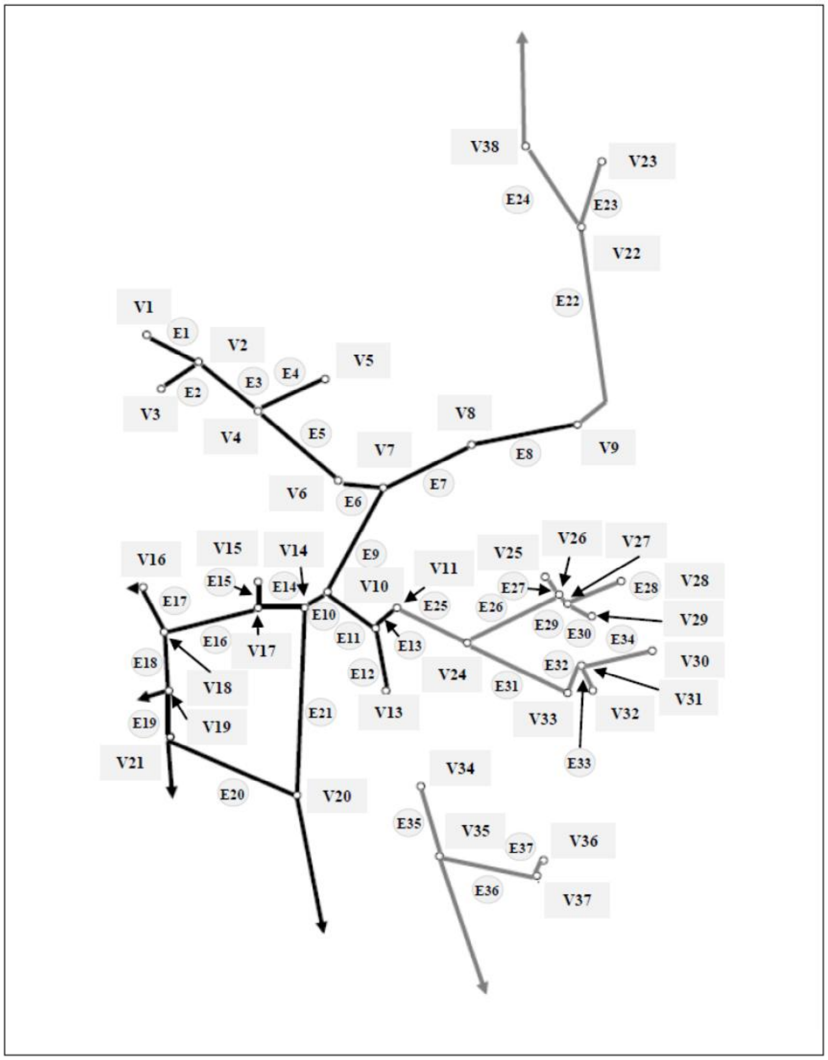

Figure D-2 – Future 2035 Road Transport Network: Detail of Vertices and Edges

Appendix D Future 2035 Road Transport Network

Table D-1 – Summary of Edges on Future 2035 Road Network			
Edge	**Name**	**Surface Type**	**Approx. length**
1	PR 394	Gravel	98 km
2	PR 396	Paved	45km
3	PR 391	Paved	105 km
4	PR 493	Gravel	92 km
5	PR 391	Paved / Gravel	144 km
6	PR 391	Paved / Gravel	70 km
7	PR 280	Gravel	126 km
8	PR 280	Gravel	164 km
9	PTH 6	Paved	122 km
10	PTH 6	Paved	30 km
11	PR 373	Paved / Gravel	96 km
12	PR 373	Paved / Gravel	77 km
13	PR 374	Paved / Gravel	37 km
14	PTH 39	Paved	63 km
15	PR 392	Paved	35 km
16	PTH 39	Paved	100 km
17	PTH 10	Paved	65 km
18	PTH 10	Paved	75 km
19	PTH 10	Paved	74 km
20	PTH 10	Paved	75 km
21	PTH 6	Paved	210 km
22	*MB - NU*	Gravel	180 km
23	*MB – NU*	Gravel	110 km
24	*MB – NU*	Gravel	120 km
25	*ESLW (n)*	Gravel	70 km
26	*ESLW (n)*	Gravel	100 km
27	*ESLW (n)*	Gravel	10 km
28	*ESLW (n)*	Gravel	55 km
29	*ESLW (n)*	Gravel	30 km
30	*ESLW (n)*	Gravel	30 km
31	*ESLW (n)*	Gravel	150 km
32	*ESLW (n)*	Gravel	40 km
33	*ESLW (n)*	Gravel	25 km
34	*ESLW (n)*	Gravel	65 km
35	*ESLW (s)*	Gravel	175 km
36	*ESLW (s)*	Gravel	130 km
37	*ESLW (s)*	Gravel	15 km
Total Approximate Length of Network			**3,208 km**

PR – Provincial Road
PTH – Provincial Trunk Highway
MB – NU – Manitoba – Nunavut Road
ESLW – East Side Lake Winnipeg Road

Table D-2 – Summary of Vertices on Future 2035 Road Network	
Vertex	**Place Name**
Existing Road Network	
1	Kinoosao (SK)
2	Lynn Lake
3	Fox Mine
4	Leaf Rapids
5	South Indian Lake
6	Nelson House
7	Thompson
8	Split Lake / York Landing
9	Gillam
10	Intersection of PTH 6 & PR 373
11	Cross Lake
12	Intersection of PR 373 & PR 374
13	Norway House
14	Intersection of PTH 6 & PTH 39 ("Ponton")
15	Snow Lake
16	Flin Flon
17	Intersection of PTH 39 & PR 392
18	Intersection of PTH 10 & PTH 39 ("Simonhouse")
19	The Pas
20	Intersection of PTH 60 & PTH 6 (34 km south of Grand Rapids)
21	Intersection of PTH 60 & PTH 10
22	Crossing of Churchill River
23	Churchill
24	Intersection
25	Oxford House
26	Intersection
27	Intersection
28	Gods River
29	Gods Lake Narrows
30	Red Sucker Lake
31	Intersection
32	Island Lake / Garden Hill
33	Wasagamack / St. Theresa Point
34	Poplar River
35	Berens River
36	Pauingassi
37	Little Grand Rapids
38	Crossing of Seal River

Appendix E **Existing 2010 Rail Transport Network**

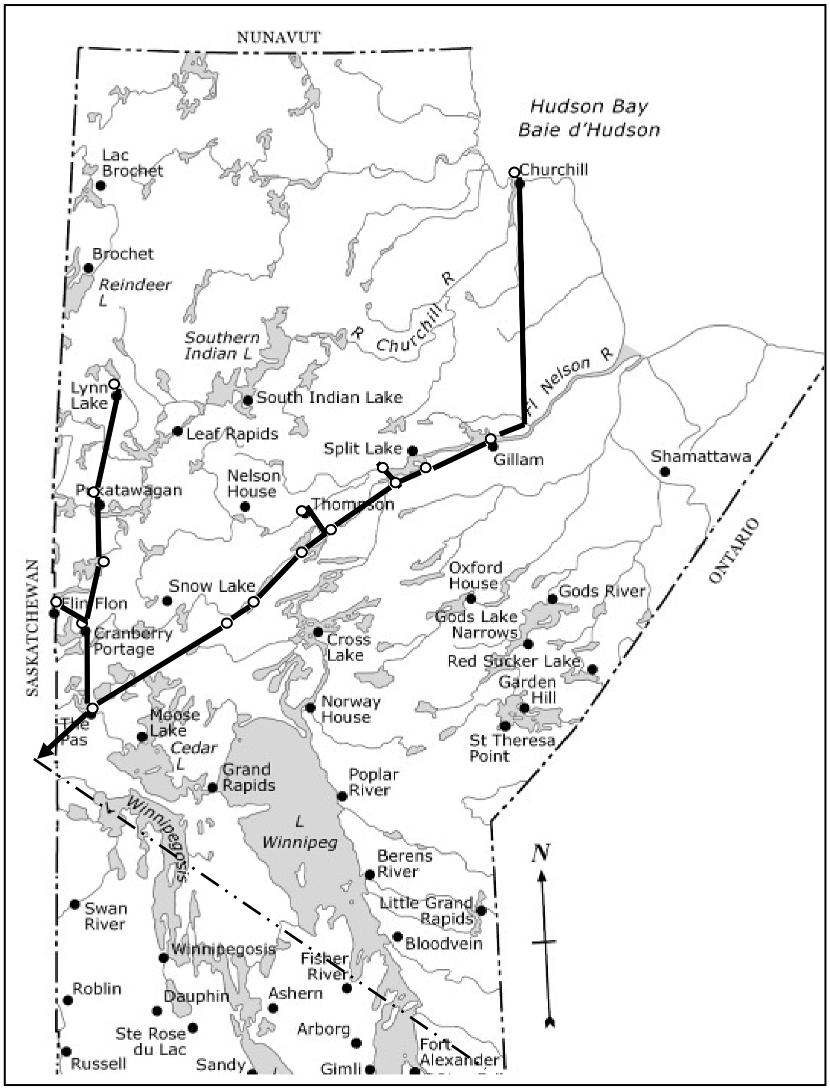

Figure E-1 – Existing 2010 Rail Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix E Existing 2010 Rail Transport Network

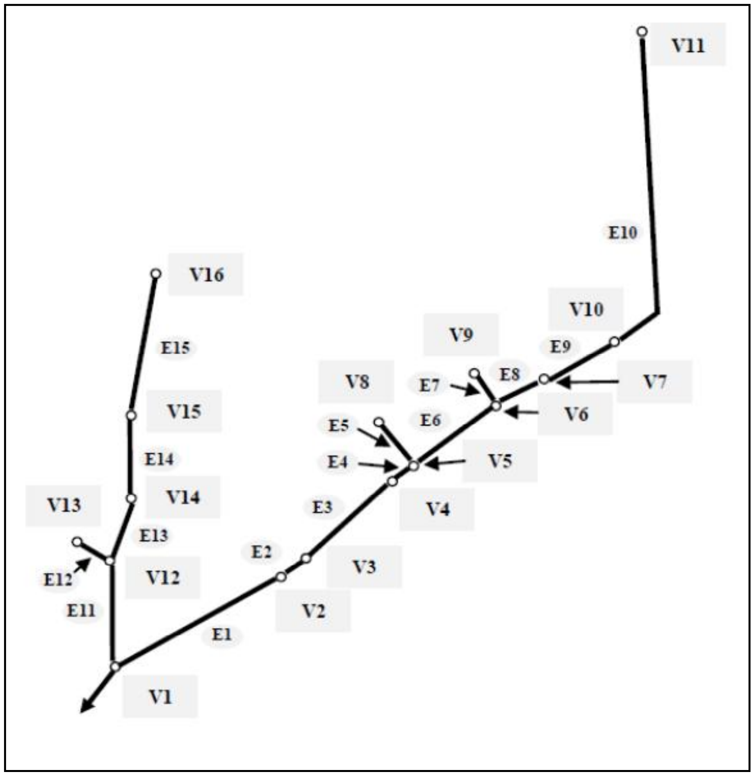

Figure E-2 – Existing 2010 Rail Transport Network: Detail of Vertices and Edges

Appendix E Existing 2010 Rail Transport Network

Table E-1(a) – Summary of Edges on Existing 2010 Rail Transport Network			
Edge	**Vertices Pair**		**Length (approx).**
1	The Pas (1)	Wekusko (2)	120 km
2	Wekusko (2)	Wabowden (3)	85 km
3	Wabowden (3)	Thicket Portage (4)	80 km
4	Thicket Portage (4)	Thompson Jct. (5)	20 km
5	Thompson Jct. (5)	Thompson (8)	45 km
6	Thompson Jct. (5)	Pit Siding (6)	88 km
7	Pit Siding (6)	Kelsey (9)	22 km
8	Pit Siding (6)	Split Lake / Ilford (7)	35 km
9	Split Lake / Ilford (7)	Gillam (10)	65 km
10	Gillam (10)	Churchill (11)	285 km
11	The Pas (1)	Sherritt Jct. (12)	80 km
12	Sherritt Jct. (12)	Flin Flon (13)	45 km
13	Sherritt Jct. (12)	Sherridon (14)	60 km
14	Sherridon (14)	Pukatawagan (15)	75 km
15	Pukatawagan (15)	Lynn Lake (16)	115 km
		Total length of network (approx.)	**1,220 km**

Table E-1(b) - Summary of Vertices on Existing 2010 Rail Network	
Vertex	**Place Name**
1	The Pas
2	Wekusko (at junction of PTH 6 / 391)
3	Wabowden
4	Thicket Portage
5	Thompson Jct.
6	Pit Siding
7	Split Lake / Ilford
8	Thompson
9	Kelsey
10	Gillam
11	Churchill
12	Sherritt Jct.
13	Flin Flon
14	Sherridon
15	Pukatawagan
16	Lynn Lake

Appendix F Historical 1969 Rail Transport Network

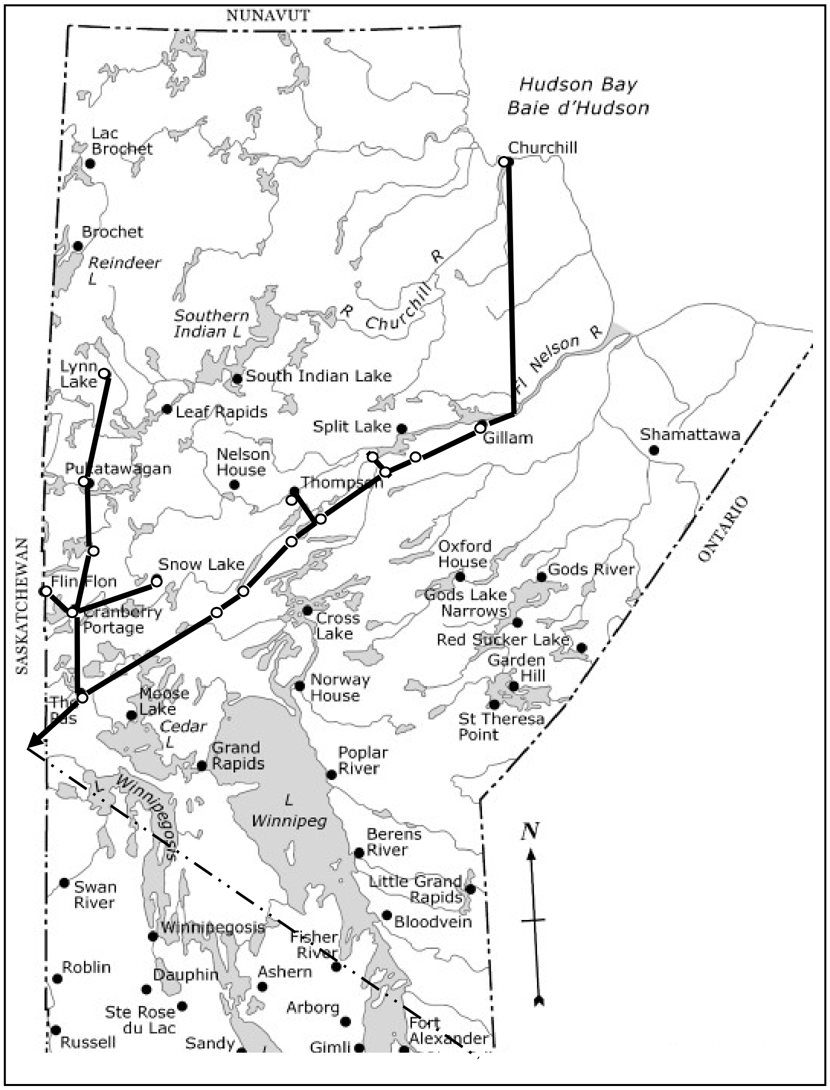

Figure F-1 - Historical 1969 Rail Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix F Historical 1969 Rail Transport Network

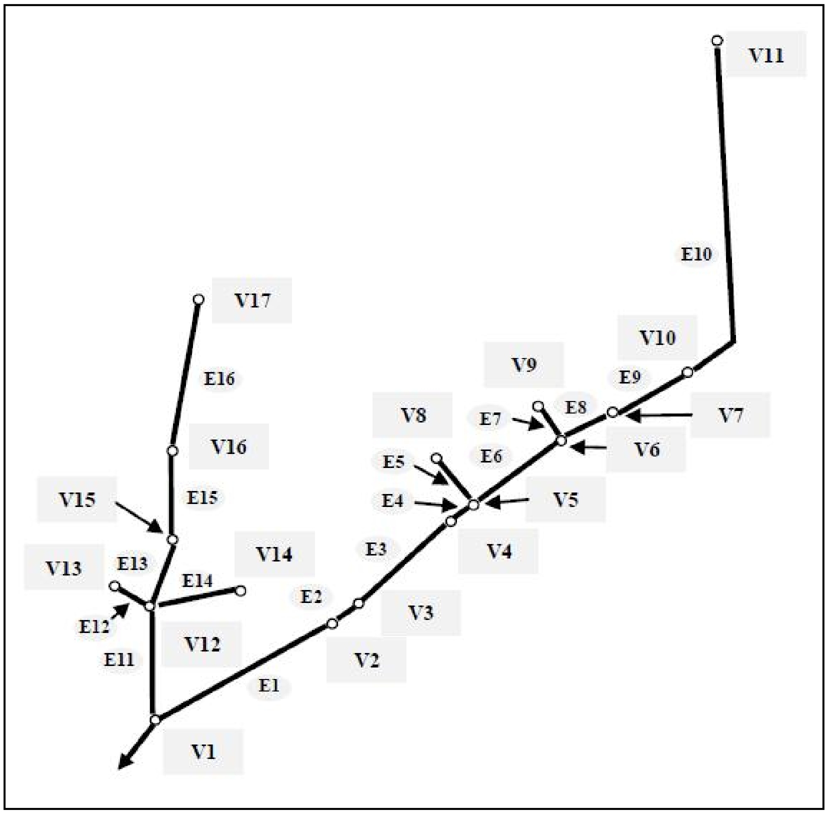

Figure F-2 - Historical 1969 Rail Transport Network: Detail of Vertices and Edges

Appendix F Historical 1969 Rail Transport Network

Table F-1(a) – Summary of Edges on Historical 1969 Rail Transport Network			
Edge	**Vertices Pair**		**Length (approx).**
1	The Pas (1)	Wekusko (2)	120 km
2	Wekusko (2)	Wabowden (3)	85 km
3	Wabowden (3)	Thicket Portage (4)	80 km
4	Thicket Portage (4)	Thompson Jct. (5)	20 km
5	Thompson Jct. (5)	Thompson (8)	45 km
6	Thompson Jct. (5)	Pit Siding (6)	88 km
7	Pit Siding (6)	Kelsey (9)	22 km
8	Pit Siding (6)	Split Lake / Ilford (7)	35 km
9	Split Lake / Ilford (7)	Gillam (10)	65 km
10	Gillam (10)	Churchill (11)	285 km
11	The Pas (1)	Sherritt Jct. (12)	80 km
12	Sherritt Jct. (12)	Flin Flon (13)	45 km
13	Sherritt Jct. (12)	Sherridon (14)	60 km
14	Sherritt Jct. (12)	Snow Lake (14)	80 km
15	Sherridon (15)	Pukatawagan (16)	75 km
16	Pukatawagan (16)	Lynn Lake (17)	115 km
		Total length of network (approx.)	**1,300 km**

Table F-1(b) - Summary of Vertices on Existing 2010 Rail Network	
Vertex	**Place Name**
1	The Pas
2	Wekusko (at junction of PTH 6 / 391)
3	Wabowden
4	Thicket Portage
5	Thompson Jct.
6	Pit Siding
7	Split Lake / Ilford
8	Thompson
9	Kelsey
10	Gillam
11	Churchill
12	Sherritt Jct.
13	Flin Flon
14	Snow Lake
15	Sherridon
16	Pukatawagan
17	Lynn Lake

Appendix G Existing 2010 Control Rail Transport Network

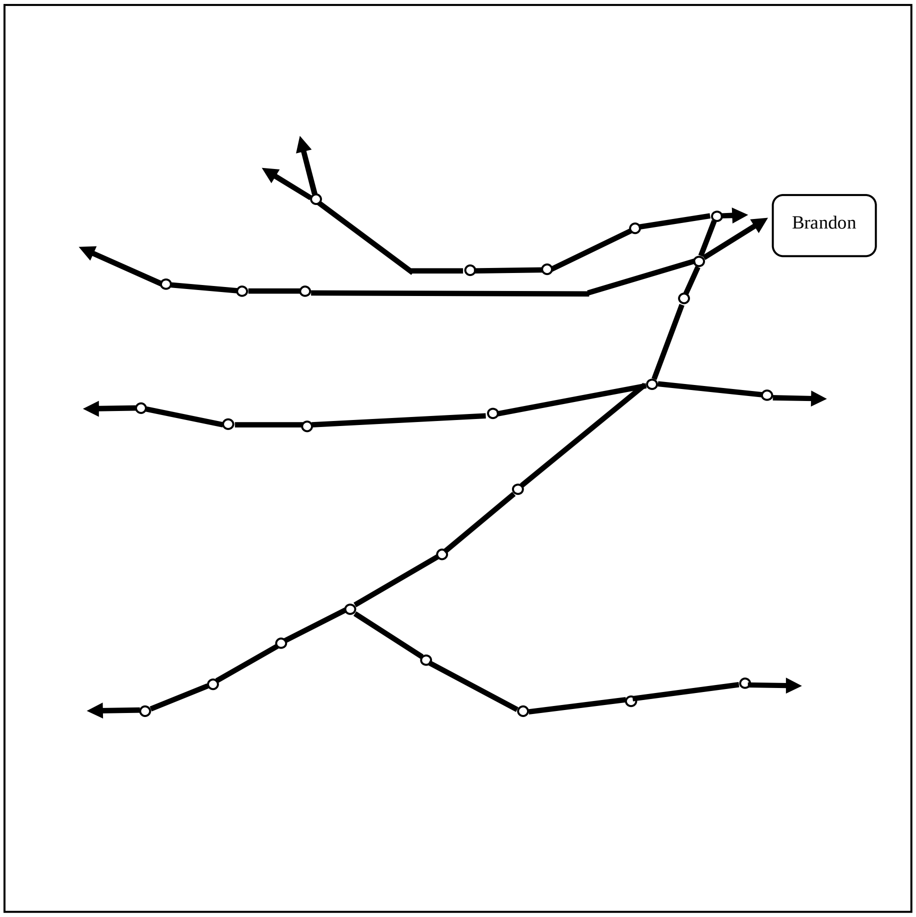

Figure G-1 – Existing 2010 Control Rail Transport Network: Overview

Base map removed due to copyright, please follow link. Source: Manitoba (2010), http://www.gov.mb.ca/mit/map/pdf/map1.pdf

Appendix G Existing 2010 Control Rail Transport Network

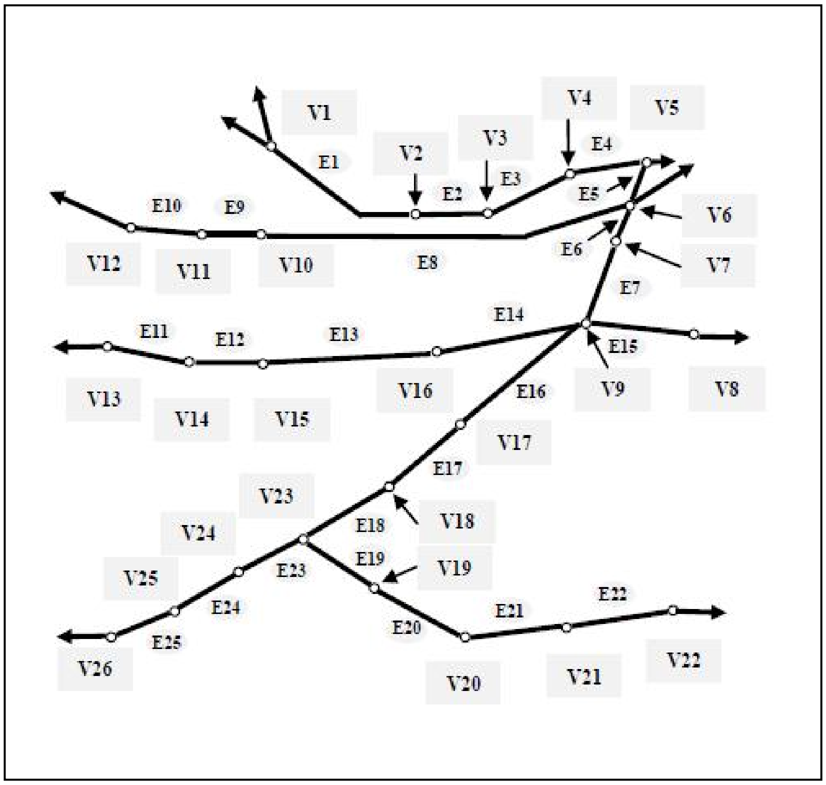

Figure G-2 – Existing 2010 Control Rail Transport Network: Detail of Vertices and Edges

Appendix G Existing 2010 Control Rail Transport Network

Table G-1 – Summary of Edges on Existing 2010 Control Rail Network			
Edge	**Vertices Pair**		**Approx. length**
1	Virden (1)	Oak Lake (2)	25 km
2	Oak Lake (2)	Griswold (3)	12 km
3	Griswold (3)	Alexander (4)	15 km
4	Alexander (4)	Kemnay (5)	12 km
5	Kemnay (5)	Jct. of CN and CPR lines (6)	6 km
6	Jct. of CN and CPR lines (6)	Beresford (7)	6 km
7	Beresford (7)	Souris (9)	12 km
8	Jct. of CN and CPR lines (6)	Scarth (10)	50 km
9	Scarth (10)	Woodnorth (11)	10 km
10	Woodnorth (11)	Cromer (12)	10 km
11	Sinclair (13)	Reston (14)	15 km
12	Reston (14)	Pipestone (15)	10 km
13	Pipestone (15)	Deleau (16)	30 km
14	Deleau (16)	Souris (9)	22 km
15	Souris (9)	Carroll (8)	22 km
16	Souris (9)	Hartney (17)	25 km
17	Hartney (17)	Lauder (18)	15 km
18	Lauder (18)	Napinka (23)	15 km
19	Napinka (23)	Medora (19)	15 km
20	Medora (19)	Deloraine (20)	18 km
21	Deloraine (20)	Whitewater (21)	15 km
22	Whitewater (21)	Boissevain (22)	15 km
23	Napinka (23)	Melita (24)	10 km
24	Melita (24)	Elva (25)	10 km
25	Elva (25)	Pierson (26)	10 km
		Total length of network (approx.)	**405 km**

Appendix G Existing 2010 Control Rail Transport Network

Table G-2 - Summary of Vertices on Existing 2010 Control Rail Network	
Vertex	**Place Name**
1	Virden
2	Oak Lake
3	Griswold
4	Alexander
5	Kemnay
6	Jct. of CN and CPR lines
7	Beresford
8	Carroll
9	Souris
10	Scarth
11	Woodnorth
12	Cromer
13	Sinclair
14	Reston
15	Pipestone
16	Deleau
17	Hartney
18	Lauder
19	Medora
20	Deloraine
21	Whitewater
22	Boissevain
23	Napinka
24	Melita
25	Elva
26	Pierson

Appendix H Existing 2010 Water Transport Network

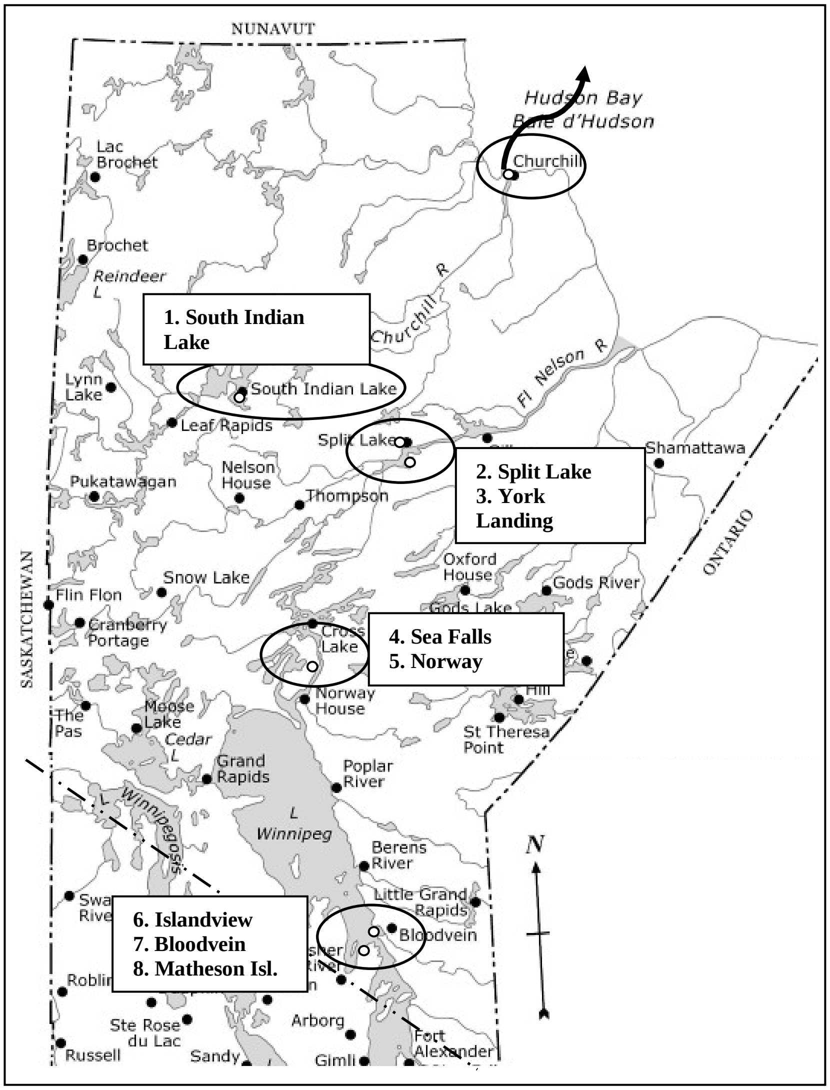

Figure H-1 – Existing 2010 Water Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix H **Existing 2010 Water Transport Network**

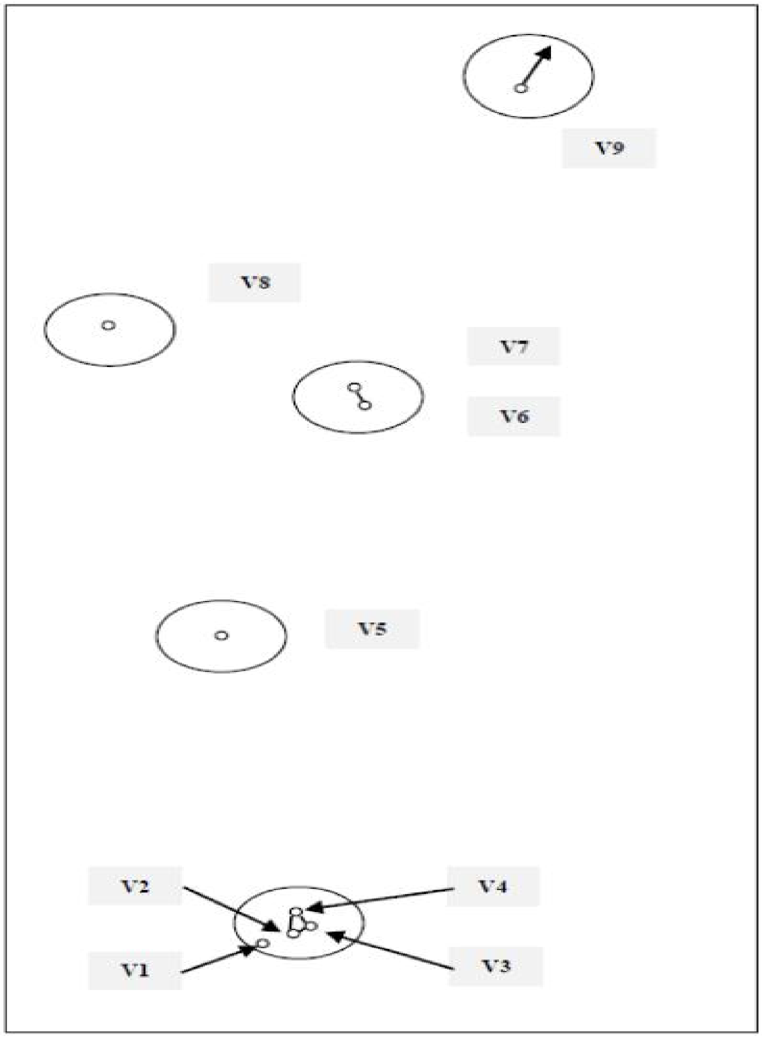

Figure H-2- Existing 2010 Water Transport Network: Detail of Vertices and Edges

Table H-1-- Summary of Vertices on Historical 1969 Water Network	
Vertex	**Place Name**
1	Matheson Island
2	Island View
3	Bloodvein
4	Princess Harbour
5	Sea Falls – Norway House
6	York Landing
7	Split Lake
8	South Indian Lake
9	Port of Churchill

Appendix I Historical 1969 Water Transport Network

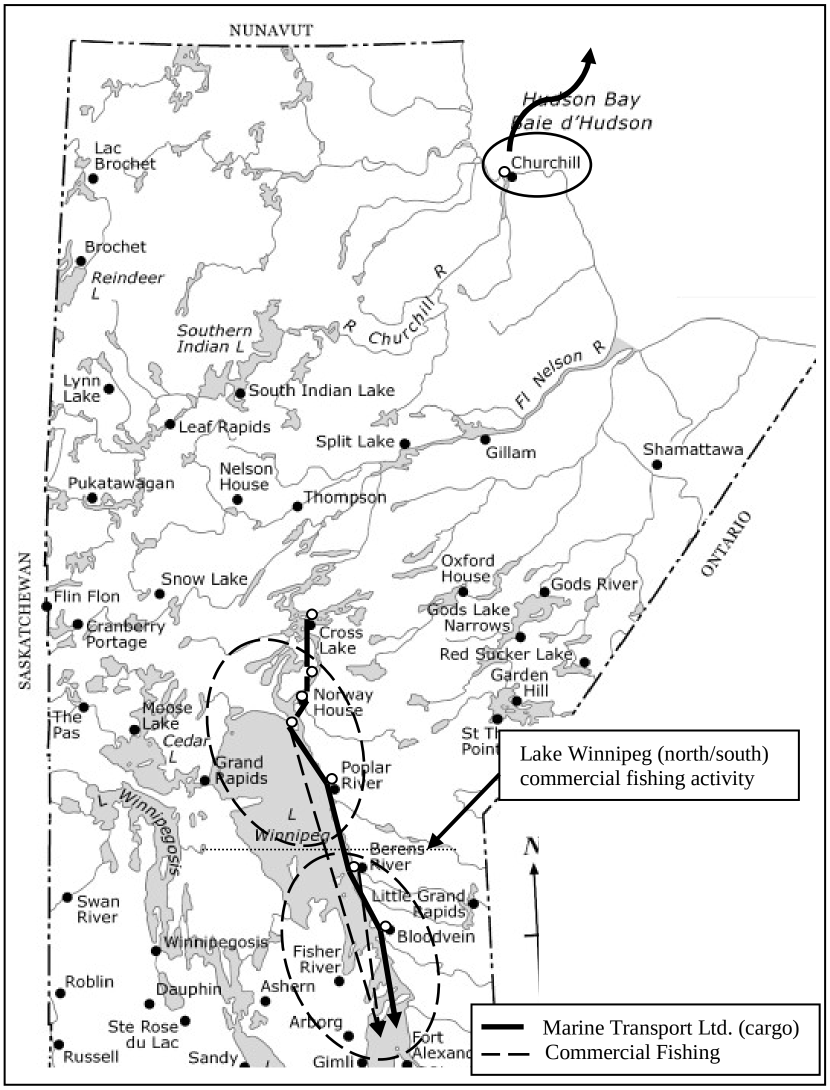

Figure I-1 – Historical 1969 Water Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix I Historical 1969 Water Transport Network

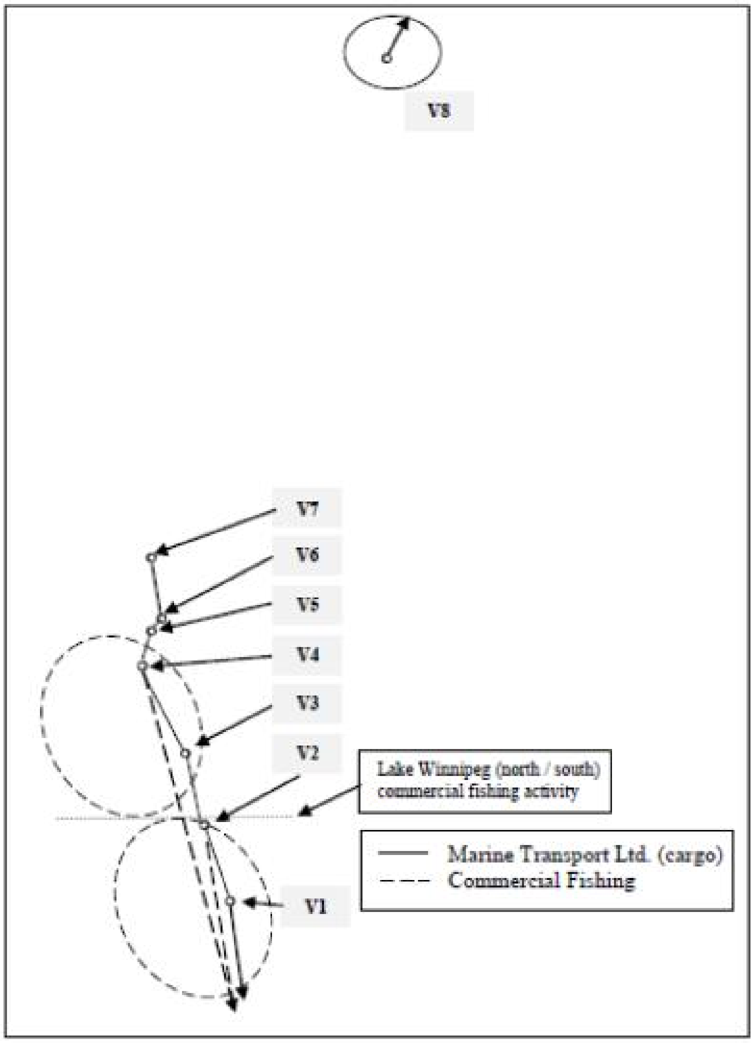

Figure I-2 – Historical 1969 Water Transport Network: Detail of Vertices and Edges

Table I-1 - Summary of Vertices on Historical 1969 Water Network	
Vertex	**Place Name**
1	Bloodvein
2	Berens River
3	Poplar River
4	Warren Landing
5	Norway House
6	Rossville
7	Cross Lake
8	Port of Churchill

Appendix J **Existing 2010 Air Transport Network**

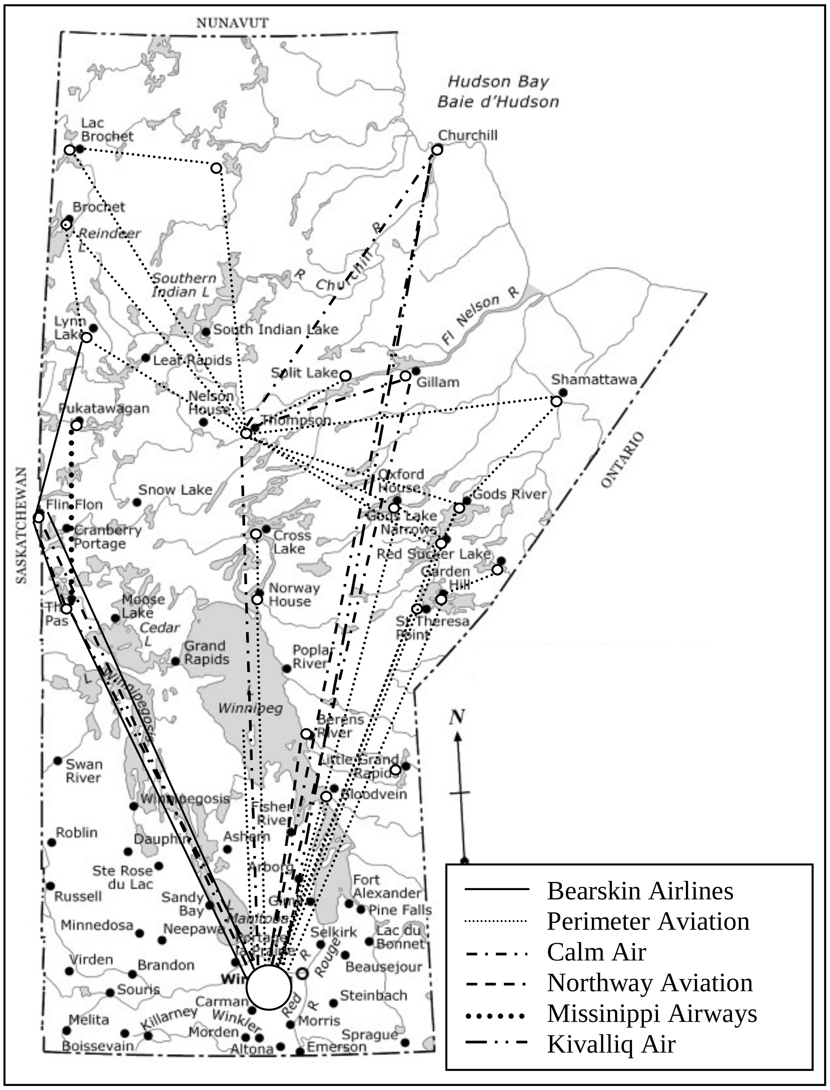

Figure J-1 – Existing 2010 Air Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix J Existing 2010 Air Transport Network

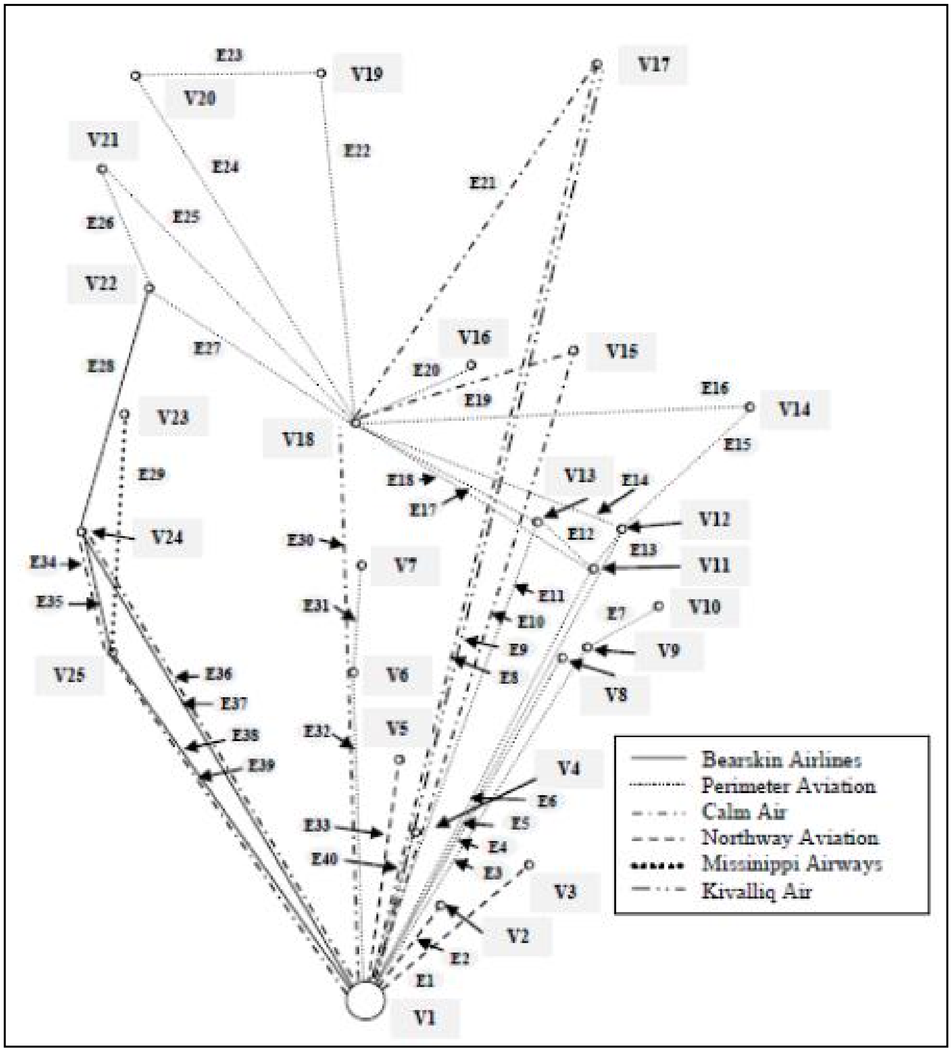

Figure J-2 – Existing 2010 Air Transport Network: Detail of Vertices and Edges

Appendix J Existing 2010 Air Transport Network

Table J-1 – Summary of Edges on Existing 2010 Air Transport Network			
Edge	**Vertices Pair**		**Operator**
1	St. Andrews (1)	Little Grand Rapids (3)	Northway
2	St. Andrews (1)	Bloodvein (2)	Northway
3	Winnipeg (1)	Island Lake (9)	Perimeter
4	Winnipeg (1)	St. Theresa Point (8)	Perimeter
5	Winnipeg (1)	Gods River (12)	Perimeter
6	Winnipeg (1)	Gods Lake Narrows (11)	Perimeter
7	Island Lake (9)	Red Sucker Lake (10)	Perimeter
8	Winnipeg (1)	Churchill (17)	Calm
9	Winnipeg (1)	Churchill (17)	Kivalliq
10	Winnipeg (1)	Gillam (15)	Calm
11	Winnipeg (1)	Oxford House (13)	Perimeter
12	Oxford House (13)	Gods Lake Narrows (11)	Perimeter
13	Gods Lake Narrows (11)	Gods River (12)	Perimeter
14	Gods River (12)	Thompson (18)	Perimeter
15	Gods River (12)	Shamattawa (14)	Perimeter
16	Shamattawa (14)	Thompson (18)	Perimeter
17	Oxford House (13)	Thompson (18)	Perimeter
18	Gods Lake Narrows (11)	Thompson (18)	Perimeter
19	Thompson (18)	Gillam (15)	Calm
20	Thompson (18)	York Landing (16)	Perimeter
21	Thompson (18)	Churchill (17)	Calm
22	Thompson (18)	Tadule Lake (19)	Perimeter
23	Tadule Lake (19)	Lac Brochet (20)	Perimeter
24	Lac Brochet (20)	Thompson (18)	Perimeter
25	Brochet (21)	Thompson (18)	Perimeter
26	Brochet (21)	Lynn Lake (22)	Perimeter
27	Lynn Lake (22)	Thompson (18)	Perimeter
28	Lynn Lake (22)	Flin Flon (24)	Bearskin
29	Pukatawagan (23)	The Pas (25)	Missinippi
30	Winnipeg (1)	Thompson (18)	Calm
31	Norway House (6)	Cross Lake (7)	Perimeter
32	Winnipeg (1)	Norway House (6)	Perimeter
33	Winnipeg (1)	Poplar River (5)	Northway
34	Flin Flon (24)	The Pas (25)	Calm
35	Flin Flon (24)	The Pas (25)	Bearskin
36	Flin Flon (24)	Winnipeg (1)	Calm
37	Flin Flon (24)	Winnipeg (1)	Bearskin
38	The Pas (25)	Winnipeg (1)	Bearskin
39	The Pas (25)	Winnipeg (1)	Calm
40	Winnipeg (1)	Berens River (4)	Northway

Appendix J   Existing 2010 Air Transport Network

Table J-2 - Summary of Vertices on Existing 2010 Air Transport Network	
Vertex	**Place Name**
1	Winnipeg / St. Andrews
2	Bloodvein
3	Little Grand Rapids
4	Berens River
5	Poplar River
6	Norway House
7	Cross Lake
8	St. Theresa Point
9	Island Lake
10	Red Sucker Lake
11	Gods Lake Narrows
12	Gods River
13	Oxford House
14	Shamattawa
15	Gillam
16	York Landing
17	Churchill
18	Thompson
19	Tadule Lake
20	Lac Brochet
21	Brochet
22	Lynn Lake
23	Pukatawagan
24	Flin Flon
25	The Pas

Appendix K Historical 1969 Air Transport Network

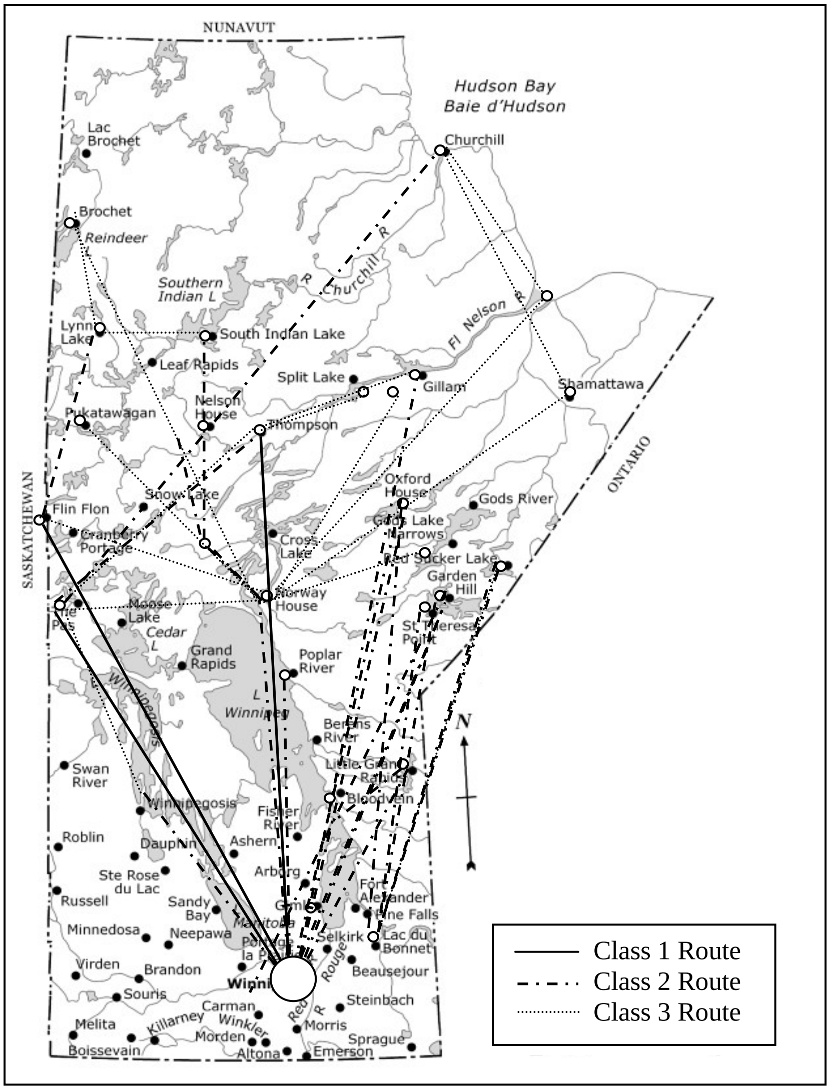

Figure K-1 – Historical 1969 Air Transport Network: Overview

Base map source: Natural Resources Canada (2002). *Non-commercial reproduction authorized.*

Appendix K Historical 1969 Air Transport Network

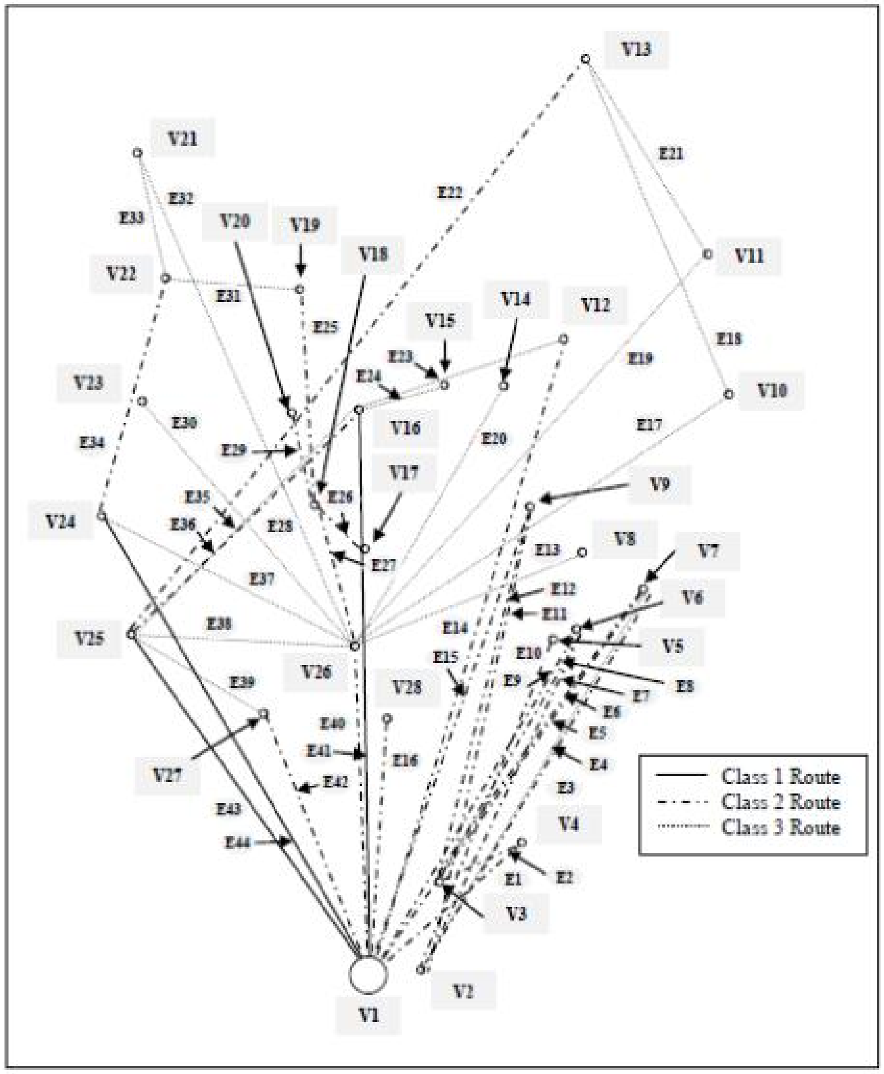

Figure K-2 – Historical 1969 Air Transport Network: Summary of Vertices and Edges

Appendix K Historical 1969 Air Transport Network

Table K-1 – Summary of Edges on Historical 1969 Air Transport Network

Edge	Vertices Pair	
1	Winnipeg (1)	Little Grand Rapids (4)
2	Bloodvein (3)	Little Grand Rapids (4)
3	Riverton (2)	Red Sucker Lake (7)
4	Riverton (2)	Red Sucker Lake (7)
5	Winnipeg (1)	Red Sucker Lake (7)
6	Bloodvein (3)	Red Sucker Lake (7)
7	Riverton (2)	Island Lake (6)
8	Bloodvein (3)	Island Lake (6)
9	Winnipeg (1)	Island Lake (6)
10	Riverton (2)	St. Theresa Point (5)
11	Riverton (2)	Oxford House (9)
12	Bloodvein (3)	Oxford House (9)
13	Norway House (26)	Gods Lake / Gods Lake Narrows (8)
14	Winnipeg (1)	Gillam (12)
15	Winnipeg (1)	Oxford House (9)
16	Winnipeg (1)	Berens River (28)
17	Norway House (26)	Shamattawa (10)
18	Shamattawa (10)	Churchill (13)
19	Norway House (26)	York Factory (11)
20	Norway House (26)	Ilford (14)
21	York Factory (11)	Churchill (13)
22	Churchill (13)	The Pas (25)
23	Thompson (16)	Gillam (12)
24	Thompson (24)	Kelsey (15)
25	Wabowden (18)	South Indian Lake (19)
26	Wabowden (18)	Cross Lake (17)
27	Wabowden (18)	Norway House (26)
28	Norway House (26)	Brochet (21)
29	Nelson House (20)	Wabowden (18)
30	Pukatawagan (23)	Norway House (26)
31	Lynn Lake (22)	South Indian Lake (19)
32	Brochet (21)	Lynn Lake (22)
33	Lynn Lake (22)	Flin Flon (24)
34	The Pas (25)	Thompson (16)
35	The Pas (25)	Thompson (16)
36	Flin Flon (24)	Norway House (26)
37	The Pas (25)	Norway House (26)
38	The Pas (25)	Grand Rapids (27)
39	Winnipeg (1)	Norway House (26)
40	Winnipeg (1)	Thompson (16)
41	Grand Rapids (27)	Winnipeg (1)
42	The Pas (25)	Winnipeg (1)
43	Flin Flon (24)	Winnipeg (1)

Appendix K Historical 1969 Air Transport Network

Table K-2 - Summary of Vertices on Historical 1969 Air Transport Network	
Vertex	**Place Name**
1	Winnipeg / St. Andrews
2	Riverton
3	Bloodvein
4	Little Grand Rapids
5	St. Theresa Point
6	Island Lake
7	Red Sucker Lake
8	Gods Lake / Gods Lake Narrows
9	Oxford House
10	Shamattawa
11	York Factory
12	Gillam
13	Churchill
14	Ilford
15	Kelsey
16	Thompson
17	Cross Lake
18	Wabowden
19	South Indian Lake
20	Nelson House
21	Brochet
22	Lynn Lake
23	Pukatawagan
24	Flin Flon
25	The Pas
26	Norway House
27	Grand Rapids
28	Berens River