Redimensioning Montreal:
Circulation and Urban Form, 1846-1918

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Abstract

The purpose of this thesis is to explore certain of the dynamics associated with the physical transformation of cities, using Montreal between 1846 and 1918 as a case study. Beyond the typical description or classification of urban forms, this study deals with the essential problem of how changes in form occurred as the city underwent a rapid growth and industrialization. Drawing insights from three different bodies of research – neoclassical theories of land rent, Marxian theories of capital accumulation, and space syntax theories of urban form – a theoretical and methodological approach is formulated which considers the city as a dynamic system, and acknowledges circulation as the driving force behind urban morphological change. It is argued that the built form of Montreal was continuously shaped and reshaped by the evolving strategies of a local "growth machine" which sought to reduce the turnover time of capital by "redimensioning" the urban "vascular system": that is, the streets, sidewalks, tracks, bridges, elevators, and canals, within which circulation takes place. This claim is interrogated and developed in each chapter through a series of empirical analyses utilizing evidence from several high-quality sources (e.g. atlases, municipal tax rolls, city surveyor reports, building inspector reports, photographs, and newspapers) to investigate the critical processes of building and rebuilding associated with phenomena such as destructive fires, the modernization of the port, street widenings, and the reconfiguration of the street grid. Each investigation explores the relationship between circulation and urban morphology. The series of investigations revealed certain regularities with respect to the spatial and temporal properties of morphological change. Consistent with expectations based on existing theories and research, the findings confirm the importance of centrality and accessibility to urban form, for the distribution of rents, and for patterns of land use. The findings also point to the pressures imposed by the cyclical nature of capital accumulation in the built environment. Each wave of urban growth brought a dramatic increase in the flow of goods and people through the city, increased competition for land, raised the bid-rent curve, and intensified pressure to adapt built forms inherited from the past to accommodate new demands.

Résumé

L'objectif de cette thèse est d'explorer certains des procès associés à la transformation physico-spatiale des villes, en utilisant comme cas la ville de Montréal et son évolution entre 1846 et 1918. Au-delà d'une simple description et classification convenue des formes urbaines, cette étude traite d'un problème essentiel en questionnant le "comment" des transformations de la forme urbaine à un moment où la ville connaissait une croissance et une industrialisation rapides. En s'appuyant sur trois traditions de recherche - les théories néo-classiques de la rente foncière, les théories marxistes de l'accumulation du capital, et les théories de la syntaxe spatiale des formes urbaines - une approche théorique et méthodologique est proposée, qui considère la ville en tant que système dynamique et voit dans la circulation la principale force motrice du changement morphologique. Cette thèse avance que l'environnement bâti de Montréal fut sans cesse modelé et remodelé par l'effet des stratégies changeantes des tenants locaux de la croissance économique (la "growth machine"), qui s'employèrent à réduire le cycle de la plus-value en redimensionnant périodiquement le "système vasculaire" de la ville ; une expression par laquelle il faut entendre ici: les rues, les trottoirs, les voies ferrées, les ponts, les élévateurs à grains et les canaux navigables, bref toutes les infrastructures destinées à servir la circulation des biens et des personnes. Cette interprétation est soupesée et développée dans chacun des chapitres de cette thèse par une série d'analyses s'appuyant sur des données provenant de plusieurs sources de grande qualité (atlas, registres d'impôt foncier, rapports d'inspecteurs des chemins et d'inspecteurs en bâtiments, photographies et journaux d'époque), afin d'investiguer les procès cruciaux de construction et reconstruction associés à des phénomènes tels les incendies, la modernisation du port, les travaux d'élargissement de rues, ou encore la reconfiguration du réseau des rues. Chaque analyse explore le rapport entre la circulation des biens et des personnes et la morphologie urbaine. La série d'analyses révèle un certain nombre de régularités en ce qui a trait aux propriétés spatiales et temporelles du changement morphologique. De manière concordante avec ce que les théories et recherches précédentes pouvaient laisser entrevoir, les résultats de cette recherche confirment l'importance des facteurs de "centralité" et d'accessibilité de la forme urbaine pour la distribution des valeurs foncières et la structure des usages. Les résultats soulignent aussi les pressions induites par la nature cyclique de l'accumulation du capital qui se cristallise dans l'environnement bâti. Chaque vague de croissance urbaine entraîna une augmentation dramatique du flot des biens et des personnes à travers la ville, augmenta la compétition pour l'appropriation du foncier, fit augmenter la courbe du "bid-rent," et intensifia la pression à l'adaptation des formes bâties héritées afin de satisfaire les besoins nouveaux qui se faisaient jour.

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CHAPTER 1

Introduction: Reconsidering Urban Morphology

> *Plan and excavate and build as we can, we cannot keep abreast of our requirements. What seems enormous to-day, fit to withstand the demands of the next half century, is almost to-morrow found inadequate.*
>
> – Montreal Daily Star, 1910[1]

> *Constant revolutionising of production, uninterrupted disturbance of all social conditions, everlasting uncertainty and agitation distinguish the bourgeois epoch from all earlier ones . . . All that is solid melts into air, all that is holy is profaned, and man is at last compelled to face with sober sense his real conditions of life and his relations with his kind.*
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> – Marx and Engels, 1847[2]

"THE LATEST OF MONTREAL'S ANCIENT MANSIONS TO FALL BEFORE CONTRACTOR," read the obituary in the Herald.[3] The Morin House had stood anonymously on Craig Street for over a century, until one day in 1910 the old stone structure was reduced to a pile of rubble to make room for a "modern" three-storey factory building. Why was the destruction of the Morin House newsworthy? Big cities like turn-of-the-century Montreal are repeatedly torn apart: houses are razed, factories rebuilt, roads resurfaced, canals reshaped, churches recycled, bridges redimensioned, and office buildings re-imagined.

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[1] *Montreal Daily Star* (1910, 23).

[2] Marx and Engels (1977, 39).

[3] *Montreal Daily Herald* (1910, 13).

The city is constantly being "retrofitted" to meet the changing demands of capital. What was atypical about the story of this building, the reason it made the headlines, was that it had survived for so long!

When the Morin House was built, at the edge of a small stream just outside the old city walls, Montreal was still a compact, pre-industrial, "walking city." Until the mid-nineteenth century, Montreal was without rail connections and its physical size was constrained by natural limits: the capacity of the immediate countryside to supply its perishable foodstuffs; and the ability of people to move about on foot, by water, or by horse-drawn vehicles. By the late-1840s, telegraphic communications had been established with far away cities, steam-powered ships had reached the harbour, railway connections were imminent, and there were plans for a great bridge to span the mighty St Lawrence River. With the old fortifications torn down and the little stream at their door covered by a wide thoroughfare, the occupants of the Morin House were in a good position to observe the fantastic transformation that would take place in their city over the next 60 or so years. The purpose of this thesis is to investigate certain of the dynamics associated with the physical transformation of an industrial city between the mid-nineteenth century and the end of World War I. In pursuing this objective, I first design a theoretical and methodological approach which recognizes circulation as the driving force behind changes in urban form. I then apply it to Montreal, as a case study of the changing morphology of a North American city.

THE CHANGING MORPHOLOGY OF A RAPIDLY INDUSTRIALIZING CITY

The study of urban form, or *urban morphology*, has a long tradition in geography, and in recent decades, has attracted much attention from scholars in planning, architecture, history, and archaeology.[4] Early work by geographers such as M.R.G. Conzen helped to develop methods for classifying urban elements, and decades of inductively driven, "morphographic," case studies have served to identify the features common to cities, and the features which make cities distinctive.[5] This work has contributed to our understanding of the relation between micro and macro forms: the problems of scale, and the hierarchy in the system. Moudon (1997) explains that there are three fundamental components to urban morphological analysis. The first basic principle is that urban form is defined by three fundamental physical elements: buildings (and voids), lots, and streets.[6] Secondly, urban form can be examined at different degrees of resolution, typically starting with the individual building/lot and "zooming out" to the block, neighbourhood, city, and region. Thirdly, urban form must be understood historically, since every built component

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[4] Within geography, the roots of urban morphology are deepest in the *morphogenetic* tradition of central Europe, dating back to the work of Schluter (1899), and popularised in the anglo-world by M.R.G. Conzen. There are several historical overviews of the field, particularly by self-proclaimed "Conzenian" geographers Jeremy Whitehand (1992; 1987a; 1987b; 1987c; 1981; Whitehand and Larkham 1992) and Terry Slater (1990). Moudon (1997; 1994; 1992) has also reviewed the literature, and gives attention to work by urban designers and architects of the so-called "Italian" and "French" traditions of urban morphology.

[5] The most influential work is Conzen (1960). For a review of M.R.G. Conzen's contributions to the field, see Whitehand (1981).

[6] I argue that this latter component, streets, includes movement systems of all kinds: sidewalks, alleys, canals, tracks.

experiences continuous transformation and replacement.[7]

Despite many valuable contributions, it is argued here that the crucial problem of how the form of a city changes has not been afforded the attention it deserves. As Jeremy Whitehand, editor of the journal *Urban Morphology,* has conceded, "urban morphologists have been less interested in conceptualizations of process than in description and classification."[8] Any structures built today are likely to undergo changes throughout their lifespans. Although technological change often seems rapid (especially in today's computer age), it is possible that social obsolescence is even more rapid, as there exists "a continuous state of tension between the spatial organization of society (which is made up of increments of assets each created in its own era) and the form of spatial organization demanded by the new social order emerging here and now."[9] All elements of urban form change, whether we plan for it or not. As a consequence, if we are to make better use of our resources (financial, material, and natural), we need to gain a better understanding of how change occurs in our cities, or more specifically, how urban forms are retrofitted.

The city has so far been inadequately studied as a dynamic: the problem of emergence or change in form. Simultaneous analysis in dimensions of space and time is the challenge in all sciences, apparent in distinct branches such as embryology and

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[7] Moudon (1997).

[8] Whitehand (1992, 2). Since the quantitative revolution of the 1960s, urban morphologists have suffered much criticism from other urban geographers, who complain that the work is methodologically and theoretically weak (e.g. Carter 1984).

[9] Harvey (1972, 1).

evolution, and is especially bright in our experience and in early scientific work on the morphology of the butterfly, the tadpole, or the seedling.[10] Recognized in these sciences is the problem of the hierarchical relationship between micro and macro processes of evolution of form, ranging from gene and protein to animal ecology. A hierarchy is "a system of behavioural interconnections wherein the higher levels constrain and control the lower levels to various degrees depending on the time constants of the behaviour."[11] In biology, larger structures generally behave more slowly and, therefore, not only do slow entities regulate fast ones, but large entities usually constrain the smaller ones. This also applies to the built environment.[12] The physical characteristics of the town site regulate the street pattern, the street plan dictates the block or lot plan, the shape of the lots confines potential building forms, the structure of the building governs room size and layout, and the room layout restricts the location of fixtures and furnishings. The rate of change of the components varies greatly; room contents may change daily, while the physical site can last centuries.

The "blueprint" of a machine is not a functional machine (the patent office is full of them). We are looking at a working system, and therefore we need to move beyond the simple "before-and-after" analyses of static maps, to understand urban morphogenesis.

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[10] For example, see Thompson (1961, originally published in 1917), as well as Thom (1972; 1989), Thom et al (1983), and Sinnott (1960; 1963).

[11] Allen and Starr (1982, xiv).

[12] I have demonstrated this hierarchical relationship elsewhere with respect to the micro-morphogenesis of single-family dwellings in a Montreal suburb (Gilliland 1996).

In 1917, the biologist D'Arcy Thompson concluded "the form of an object is a `diagram of forces,'"[13] implying that by analysing the form, we can make an interpretation of the processes which give rise to it. Although Thompson focussed his attention on entities such as seashells, fleas, soap bubbles and bones, we can also conceive of the form(s) of cities as expressions of the forces exerted upon them during their existence. A city, like an animal or a tree, is an open system. It maintains itself in a continuous inflow and outflow, a building up and breaking down of components, never being in a state of equilibrium, but growing over time, and therefore changing in morphology.[14] This conceptualization raises several important questions: What are the forces? How is energy channelled? What timing is critical? What controls are operating on the processes at a particular stage? Using Montreal as a case study, this study aims to probe the connections between the built form of a North American city between the mid-nineteenth century and World War I, and the historical forces that have produced it. In this thesis, I approach the city as an accumulation of countless individual and group actions, themselves compelled by historico-cultural traditions and wider socio-economic forces. I argue that the built form of Montreal was continuously shaped and reshaped by the evolving strategies of the local "growth machine," and driven by the wider flux of capital accumulation. In order to investigate this claim, I ask the following question: Between 1846 and 1918, how was the old city, Montreal as of 1846, perennially re-fitted and tailored to meet changes in the

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[13] Thompson (1961, 11).

[14] See Olson (1982).

needs of capital?

My goal is not only to describe important changes to Montreal's urban form, but to inform us about the processes from which the changes emerged. My story is about the reshaping of the city, the transformation of one city into another, the re-fitting of an already urbanized space into a next-generation urban space. It is not about the transformation of rural space to urban space, development of land at the fringe, or the larger process of "city-building," which has traditionally garnered more attention from urban researchers.[15] The reshaping or rebuilding process is different in that one does not have the option of large tracts of unbuilt (inexpensive) land: every square foot comes at a high price, at cost of demolition, and at a risk of contestation. It is a process of repeated adaptation of the parts: recycling, reusing, readjusting, renewing, reimagining. Form is an outcome, a crystallization of process, but in the case of the city it goes on changing, unlike most animals which cannot endure amputation or regrow critical limbs.

The city's built form is the world's most dramatic visible expression of capital accumulation. This is recognized in the images we hold of "skyscraper cities": New York, Chicago, and Hong Kong.[16] Through our experience of the city, we are informed of the

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[15] On the "city-building" process, see Olson (1997), Orum (1995), Vance (1990), and Konvitz (1985). See Schmid (1968; 1970) and Bryant et al (1982) on the transformation of land at the "rural-urban fringe." The British morphologists have dedicated much attention to "fringe-belts" (e.g. Carter and Wheatley 1979; Whitehand 1967; 1987a; 1987b; 1987c).

[16] This is undoubtedly the primary reason that skyscrapers have been the focus of so much scholarly attention. Historical studies have tended to emphasize economic and cultural considerations. Among the most interesting works are: Gad and Holdsworth (1984; 1985; 1987a; 1987b), Condit (1952; 1964), Gottman (1966), Domosh (1988), Fenske and Holdsworth (1992), Willis (1995), Landau and Condit (1996), and Holleran (1996). The Montreal experience with skyscrapers has also been written about (Gournay 1998; Vanlaethem 1998; Forget 1990) and does not need to be repeated here.

working of capital and the working of power; the city is a "theatre of accumulation."[17] We experience a city, from moving around (mostly on foot) in its public space, through its "vascular system" of streets, sidewalks, alleys, railway lines, bridges, and canals. It is from the perspective of the urban vascular system that I observe and interpret the processes of morphological change. Particular attention is given to the configuration of the street network and the morphology of individual streetscapes, the organization of the waterfront and the dimensions of the canal, grain elevators, the harbour and its approaches, all of which channelled movement in the city and access to "the public," in which people presented their "public" images.

While I use the organic metaphor of the "vascular system," I recognize that a street network does not evolve naturally, but rather as a result of decisions of many agents and wider socio-economic processes.[18] The most powerful justification for using the term "urban vascular system" comes from the persistent popularity of comparing flows of traffic to blood, from Enlightenment planners of eighteenth-century French and German cities, to architects and engineers in the "industrial cities" of Britain and North America.[19]

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[17] The representation of the urban setting as theatre and of social life as drama and performance are recurrent themes in Walter Benjamin's writings. In his essays on Berlin, for example, the city forms a "theatre of purchases" (1985, 327). I prefer "Theatres of Accumulation", which is the title of a book by Armstrong and McGee (1985).

[18] Kropf (1998) and Malfroy (1998) have identified the utility of evolutionary or organic metaphors in urban morphology. The lexicon of urban morphology includes the terms "genesis," "evolution," and "organism." Architects of the so-called "Italian school" of "typomorphology" have also borrowed "cell," "mutation," and "tissue" from biology. The definition and usage of popular terms in urban morphology can be found in glossaries by Malfroy (1986) and Larkham and Jones (1991).

[19] British architect J.B. Waring argued that the large city "has arteries and veins, or large and small thoroughfares, through which the blood corpuscles, in the shape of men and women, continually circulate" (1873). The tramway engineers of Montreal repeatedly argued that the streets suffered from

In present-day Montreal, rush hour reports from the "eye-in-the-sky" traffic helicopter regularly speak of the "clogged arteries" below. The comparisons are probably as old as William Harvey's (1578-1657) discoveries regarding the circulation of blood in animals in the mid-seventeenth century.[20] Marx had read Dr Harvey, and made a similar comparison: "The circulation of capital is at the same time its becoming, its growth, its vital process. If anything needed to be compared with the circulation of the blood, it was not the formal circulation of money, but the content-filled circulation of capital."[21]

Why study Montreal? In the nineteenth century, and for most of the twentieth, Montreal was "Canada's Metropolis," the nation's largest city and its industrial powerhouse. During the latter half of the nineteenth century, Montreal underwent a rapid industrialization, experiencing massive surges of immigration and construction like other East Coast cities in North America, and the expansions of capital, we posit, produced a similar set of changes in the built form of the city. Fortunately, Montreal has historical records which are superior to any city in North America, data sources which make such an ambitious study possible. This research also benefits from a substantial body of high-quality background literature, particularly on the urban polity.[22]

"arterio-sclerosis" (e.g. Seurot 1929a; 1929b). See Sennett (1994) on the use of vascular analogies by Enlightenment planners. Of course, every vascular system needs a heart, which, in the North American metropolis, is the central financial/business district.

[20] The breakthrough was published as *Exercitatio anatomica de motu cordis et sanguinis in animalbus* in 1651 (reprinted in Clendening 1960).

[21] Marx (1973, 517).

[22] For anyone planning to undertake historical research on Montreal, the first step is to consult the comprehensive bibliographies provided in Burgess et al (1992) and copies of the *Revue d'histoire de l'Amérique française.* Many general histories of the city exist, but for quality and breadth of coverage,

Waves of immigration from overseas and a steady flow of migrants from the countryside facilitated a doubling of the population every twenty years, from 49,000 in 1850, to 107,000 in 1871, to 217,000 in 1891, 468,000 in 1911. The key statistics are displayed in Figure 1.1.[23] Large-scale industrialization was associated with improvements in transport infrastructure, such as canal building, channel dredging, and the introduction of railways, which enhanced communications with foreign markets.[24] From the time the first permanent wharves were installed (1830s), until the onset of World War I, arrivals of ocean-going vessels increased one-hundred fold. Accessibility to mass transit – the street railway – made it possible for workers to live farther from their places of employment, and the central business district came to serve a larger area. The switch from horsepower to electricity in 1892 momentarily sped up the rate of increase in public transit usage. Land speculation drove the extension of the street network and tramway lines, which, in turn, dictated the trajectory of urban expansion, radiating out from the core in lines to the east,

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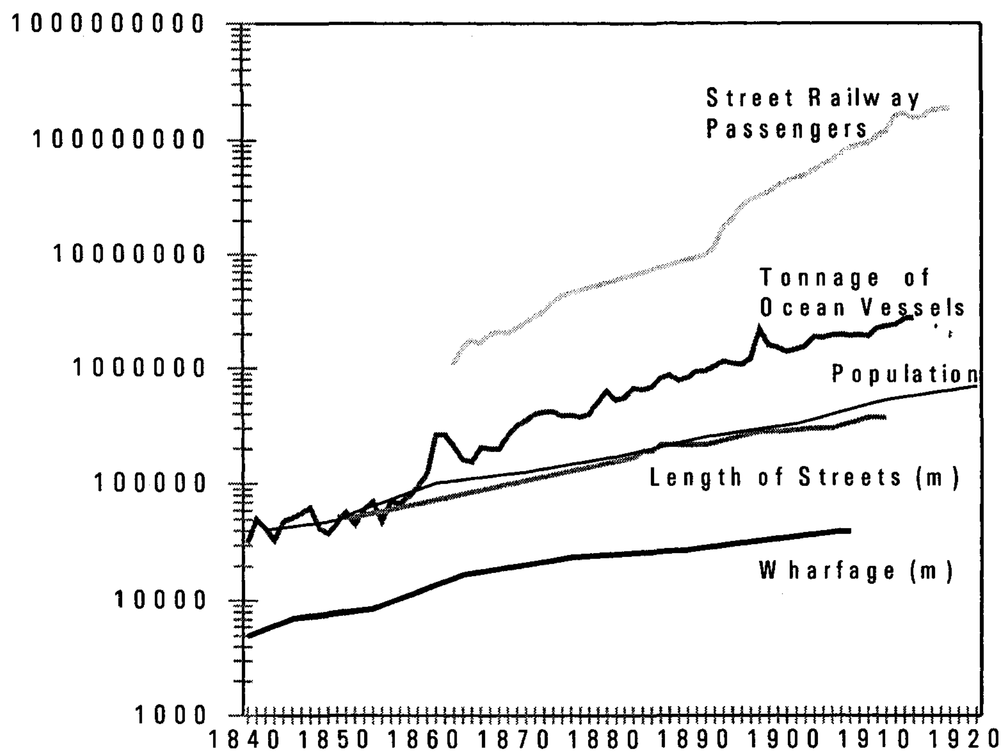
Linteau (1992) is the best (particularly for background on urban polity). Robert (1994) provides a comprehensive review of the cartographic sources, and an essential manual for every Montreal historian's desktop. First published in 1974, Marsan (1994) still offers the best (if not only) historical overview of Montreal's architecture and urban form. Several other select studies provide a useful background on urbanization and urban form in Montreal during the industrial period (for example, Hanna 1986; Olson and Hanna 1990; Hanna and Olson 1993; Gilliland and Olson 1998; Gournay and Vanlaethem 1998; Dufaux 2000; Lewis 2000).

[23] Data for the total length of the street network were gathered from annual reports of the City Surveyor, and Atherton (1914). Population is reported in the decennial Census. Tramway statistics can be found in the annual reports of individual companies, Montreal Street Railway Company (1910), and Vigneau and Richard (1996). Port statistics are reported in the annual reports of the Harbour Commissioners, as well as Hamelin and Roby (1971) and Linteau (1972). Unfortunately, statistics on railway traffic are available only at the national level and not for individual stations or cities.

[24] Hanna (1998) provides an overview of the importance of transport infrastructure, particularly the railways, to the historical development of Montreal.



1.1 Growth of traffic, vascular system, and urban population, 1840-1918
Sources: Vigneau and Richard (1996); MSRC (1910); *Annual Reports of Harbour Commissioners*; Census Canada; Atherton (1914); *Annual Reports of City Surveyor*; Linteau (1972; 1992).

west, and north.[25]

It is worthwhile at this point to take a quick look at growth in the system, and its "allometry," that is, the way in which the various components (seen in Figure 1.1), are dimensioned in relation to one another.[26] (We will return to this in later chapters.) Steeper slopes indicate that the rate of growth of traffic, the lifeblood of the city, was faster than the growth rate for elements of the vascular system itself.[27] The periodic introduction of faster and more powerful engines, and larger vessels, meant that, over a given length of

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[25] With respect to cardinal points, I have retained traditional Montreal usage. For example, what has historically been referred to as the east end is, in reality, the north end. Montreal grew up along the banks of the St Lawrence River and for some unknown reason, all streets that run parallel to the river are considered to this day to be on an east-west axis. Another historical axis of growth, St Lawrence Street, runs perpendicular from the river out from the central core in what is considered by locals to be a northerly direction (but is truly westward). This street has long been thought of as the dividing line between east and west, and around the turn of the century, the street numbering system was re-ordered so that St Lawrence Street was "point zero" for all east-west streets. The street has also long been considered the line between English and French Montreal (see Podmore 1999). In 1850, Montreal's population was about half English and half French (and the proportion of English has been declining ever since). The bilingual heritage of the city is reflected in its street and ward names. Although the modern standard is to use the French names (legally, if not popularly), to maintain historical accuracy, in this dissertation I have decided to use the names which were most commonly found in the historical records. For the sake of consistency, I use the same names (and spellings) as the Goad atlas of 1881.

[26] The basic growth equation is $Q_t = Q_0 e^{at}$, where Q is a quantity (e.g. of capital), t is the time elapsed since time 0 and a is a rate of profit, interest, or growth. This is the *exponential law* found in many fields (see Bertalanffy 1968). Equations of allometry or proportional growth are *power laws* of the general form $Q_1 = bQ_2^{\propto}$. They state the value of one variable Q_1 in terms of another Q_2 (typically body mass M) raised to some power $\propto$ (b is the value for Q_1 when $Q_2 = 1$). In biology the equation is traditionally written as $Y = Y_0 M^b$. In the logarithmic form, the equation becomes: $\log Q_1 = \log b + \propto \log Q_2$, or $\log Y = \log Y_0 + b(\log M)$. This allometric equation applies to a diverse range of morphological, physiological, biochemical, and phylogenetic data (see Gould 1966; Bertalanffy 1968), and we should also expect allometric relations of this form to characterize many urban "building blocks" (Olson 1982). Similar laws describe basic geometrical relationships. The surface areas of spheres and cubes, for example, scale in proportion to volume raised to the 2/3 power: $SA = V^{0.67}$. For interesting new work on allometry, see West et al (1997) and Enquist et al (1998).

[27] Most biological phenomena scale as quarter powers of body mass (M). For example, rates of cellular metabolism and heartbeat scale as $M^{-1/4}$, and times of blood circulation scale as $M^{1/4}$ (West et al. 1997).

road or stretch of the harbour, much greater volumes of goods and people were being moved at much greater speeds than ever before. The "speed up" resulting from transport innovations is only half the story of the redimensioning of the urban time-space; we must also consider the physical characteristics of the vascular system itself. Although the data displayed for the vascular system is uni-dimensional (length in metres), we are, in reality, looking at a three-dimensional system. Since growth of the urban organism is, with rare exceptions, monotonic, we might also expect the cross-section of vital arteries to increase in width and area, and thus, the overall volume of the vascular system to expand. In other words, the sheer growth of the whole, beyond the limits of the city in 1846, repeatedly forces the reshaping or re-adaptation of older, pre-existing parts of the city.

Massive increases in the flow of traffic in and out of the city periodically created "bottlenecks" in the centre, which compelled the widening of outmoded streets and the multiplication of railway lines through well-established neighbourhoods, brutally destroying the pre-existing urban fabric and radically altering streetscapes.[28] In the central core, the streetscapes were remodelled into "canyons." As competition grew more intense for the two-dimensional space on the ground, land values escalated, and increasingly taller buildings were erected in order to achieve returns on investments and symbolic domination of the skies.[29] Industrialization also introduced new forms, such as the massive elevators which came to dominate the "bird's-eye" views from the mountain and the river. New

[28] Kellet (1969) offers a comprehensive examination of the railway as an agent of urban redevelopment in nineteenth-century cities in the UK.

[29] Gad and Holdsworth (1984; 1985; 1988) explored the historical evolution of Toronto's King Street "canyon."

dwelling types – the duplex, triplex, and their derivatives, as well as the apartment house – were introduced to accommodate the growing population. A higher density of built spaces on smaller parcels of land resulted in a higher-stacking and tighter-packing of residents.[30]

To confine my analysis, I have adopted the space-frame of the built-up city of 1846 and the time-frame of industrialization (the Industrial Revolution in North America, and the emergence of the "Industrial City"). Cities grow fast and with decided rhythms. I am working from the rhythm of city-building itself: four distinct cycles of urban construction and urban expansion between the (global) economic crash of the late-1840s until the end of World War I (See Figure 1.2).[31] This thesis tackles a very large problem (larger than initially expected), so I cut it down to several questions I think are fundamental, posing problems as a series of investigations, in the expectation that others might pursue other studies along these lines. The urban vascular system served as the platform for choosing which forms to study, and each investigation explores the relationship between circulation and urban form.

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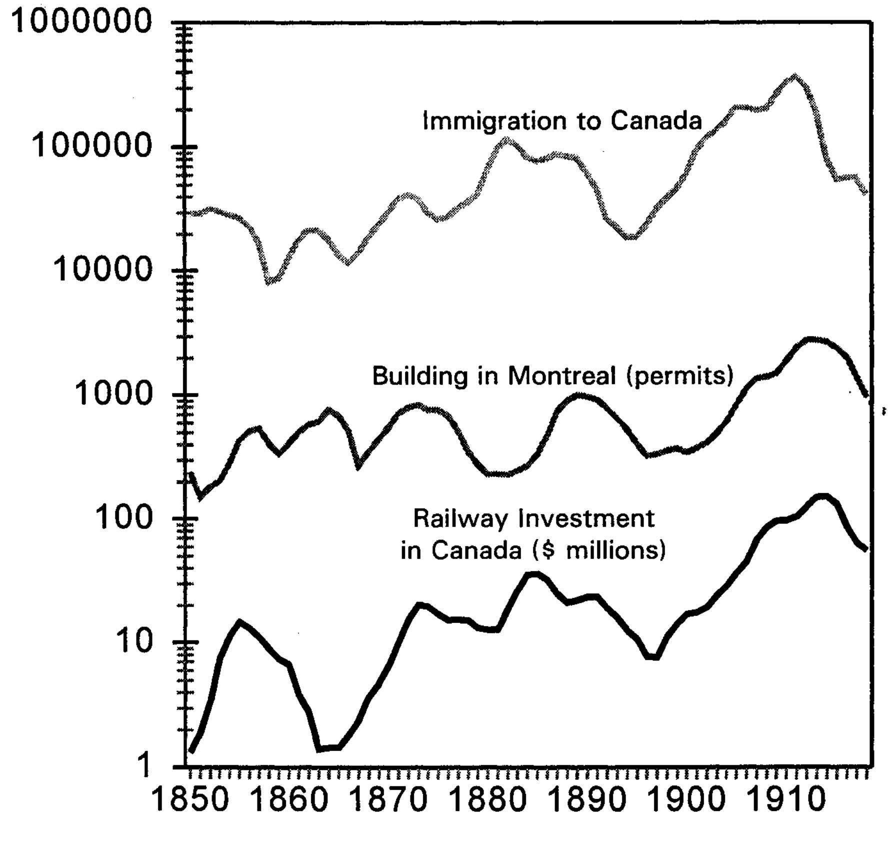
[30] Gilliland and Olson (1998). See also Hanna (1986) and Dufaux (2000) on Montreal-style `plex' housing.

[31] The year 1846 was also a convenient start date for this study because we have access to a detailed map of the city in 1846 by James Cane.



1.2 Montreal grew in boom and bust fashion

Note: Data smoothed with three-year moving average. *Sources: Annual Reports of the Building Inspector*; Urquhart and Buckley (1965); Hanna (1986).

THEORETICAL UNDERPINNINGS

The search for the principles which shape the city, for the formative and adaptive processes operating in urban spaces, is presently a major goal in the field of urban studies.[32] What bodies of theory are helpful? The city is not readily treated as an organism, at least not more than the current mystique of "Gaia" in ecology.[33] A city involves processes of "decision" of a great many people over time, operating at different moments and intervening at different scales, governed by different objectives, each with a confined view or control of small parts. I have recourse here to three bodies of theory which I see as complementary: urban-rent theories derived by land economists and regional scientists of the 1960s and `70s; Marxian theories of capital accumulation "spatialized" by geographers in the 1970s and `80s; and *space syntax* theories developed by architects and urban designers in the 1980s and `90s.

The popular real estate maxim about the three most important qualities of a property – location, location, and location – was every bit as applicable to the mid-nineteenth century as it is today. Being near the city centre was critical for urban residents

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[32] See Slater (1990) and Whitehand (1985).

[33] In the past decade, numerous studies have attempted to measure and simulate changes in urban form using "fractal geometry" and "cellular automata" (esp. Batty and Longley 1994; see also Batty and Xie 1994; Makse et al 1995; Batty et al 1997; Couclelis 1997; Bandini and Worsch 2000). This line of work has concentrated on macro-level changes in the areal extent of the city, or how the shape of the urban footprint can be deciphered using techniques like GIS, remote sensing and "fuzzy logic" (White and Engelen 2000; Dragicevic and Marceau 2000). The emphasis of this work is on method, and it has, thus far, contributed very little to theory (Benguigui et al 2000; Torrens and O'Sullivan 2001). A further critique of such research is that "explanatory" breakthroughs seem to be more contingent on the exponential growth of computer processor speed, rather than any understanding of the wider forces driving urban morphogenesis. In this sense, their logic truly is fuzzy.

as most had to walk into town to work, shop, or to participate in communal activities such as organized prayer. The introduction of public transit, first the horse tram and then the electric streetcar, made it more convenient for residents to live greater distances from the central core and increased the monetary value and desirability of downtown property, since businesses were able to reach a larger labour force and greater consumer base. Traditional models of the internal structure of cities, particularly "bid-rent theory" popularized by Alonso in the 1960s and founded on the work of von Thünen a century earlier, confirm the importance of the land-value gradient to the centred pattern of urban land use.[34] The key principle is that land uses are spatially organized according to their financial capacity to compete for land, and this is controlled by the value, profit, or utility that an activity derives from accessibility to all the others. Commercial uses typically "out-bid" residential, institutional, and industrial uses in the competition for central sites. As we move out of the centre, land values decrease, reflecting poorer access, reduced utility and lessened competition, and, in general, we observe that the bulk and density of built forms diminish. The gradient of land values, therefore, reflects both the use of land and urban form.

The land rent modelers of the 1960s, who focussed on current challenges of marketing or future-oriented "plans," tended to ignore the dynamic nature of the city. The theory therefore falls short of explaining historical changes to urban form. Although the

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[34] The most influential examples are Alonso (1964), Muth (1969) and Mills (1972). See also Thrall (1987) for a more recent application.

critiques are well known,[35] certain shortcomings should be noted in order to identify what new directions are necessary. A model is, by definition, a simplification; and the simplifications which in the 1960s opened our eyes to the geometry of urban systems severely limit the power of such models for the historical study of the city. The first problem with such models is their static and ahistoric nature: the "bid-rent curve" is treated at a single moment in time. They are not conceived as models of development, and the same causal factors are assumed to have existed since the dawn of time. A more fundamental objection to such models is that they reduce "space" to a linear distance between two points and the cost to overcome that distance. Urban land is treated as a two-dimensional, featureless plane, without local variations of drainage or circulation of air. Parcels large and small are assumed to have the same value per square foot in a given location, and transaction costs are ignored although we know that they are considerable where lots are fragmented and subject to ground rents, mortgages, or dowers. While theoretically possible, releasing the constraints of such assumptions promptly renders the models unworkable. In short, such models have tended to ignore the dynamic nature of the city as well as its three-dimensionality. While empirically established bid-rent curves may well reflect changed "surfaces" of competition and suggest changes in locational advantage, the theory, as it has been developed, offers few pointers to frame our expectations of changes in the shape of the curve. The only firm expectation is: As a city

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[35] Neoclassical economic models of the city have been well-critiqued elsewhere (Hunt and Schwartz 1972; Barnbrock 1974; Knox 1994).

grows (and most do), land values should increase.[36] Marxian theory has offered more dynamic, growth-sensitive explanations for understanding the process of urban morphogenesis in relation to the dynamics of capitalist development.[37] By incorporating these more dynamic interpretations, it is possible to formulate testable hypotheses as to the speed, scale, intensity, and trajectory of urban morphological change.

A city comprises numerous physical components, as different in form as streets, piers, and skyscrapers, as different in their functions as factories, schools, and dwellings. All of these elements can be conceived of as masses of "built capital," which constitute an infrastructure for production, exchange, and consumption, permitting the further expansion of capital.[38] While the principal studies of land rent theory conceive of the organization of urban space purely in terms of demand and use values, the concept of built capital reminds us that each physical component also has an exchange value. Urban forms reflect the decisions of people who controlled property and deployed the labour of others,[39] with the purpose of raising the values of their property and the profits derived from it. Sociologists John Logan and Harvey Molotch argue that "the pursuit of exchange

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[36] Whitehand examined how bid rents changed over time, particularly with respect to "fringe belts" (1972a; 1972b; 1987); however, he offered little explanation for change or what drives the cyclical rhythm. His logic and conclusions were fiercely contested by Daunton (1978). See also comments by Rodger (1978) and reply by Whitehand (1978).

[37] David Harvey's (1972; 1982; 1985; 1989) interpretations of Marx's theories of capital accumulation can be consulted for a more detailed discussion of the urban process under capitalism (see also Mandel 1975; Castells 1977; Walker 1978; 1981; and Smith 1990.

[38] Harvey (1985).

[39] Self-building can also exist, particularly at small scales (e.g. the dwelling) (Harris 1996).

exchange values so permeates the life of localities that cities become organized as enterprises devoted to the increase of aggregate rent levels through the intensification of land use. The city becomes, in effect, a `growth machine'."[40] Conventional land rent theory has been applied to the process of suburbanization or conversion of land from rural to urban uses,[41] and speculative operations clearly point to anticipation of profits from a growth machine.[42] In Montreal one can observe growth machine strategies in the central core and on the fringe in every boom.[43]

Capital accumulation proceeds in distinct cycles of growth and crisis. The periodic crises of capitalism are not random fluctuations, but recurrent contradictions arising from the logic of accumulation itself. The entire capitalist cycle, according to Mandel, is "the consequence of accelerated capital accumulation, overaccumulation, decelerated capital accumulation, and underinvestment."[44] During an upswing, we find an increase in the mass and rate of profit, and a rise in both the volume and rhythm of accumulation. But after a certain period of accelerated accumulation, it becomes difficult for the accumulated capital to achieve valorization (i.e., for capital to increase its own value by the production of surplus-value). At this stage, there exists "excess" capital

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[40] Logan and Molotch (1987, 13).

[41] Schmid (1968; 1970).

[42] Warner (1978) and Cronon (1991).

[43] Hanna (1986); Germain and Rose (2000); and Gordon (1978). Compare with Hoyt (1933) on Chicago, and Olson (1979; 1997) on Baltimore.

[44] Mandel (1975, 109).

a low, unsatisfactory rate of profit. This situation is referred to as "overaccumulation." The tendency toward overaccumulation is manifest in a variety of ways: overproduction of commodities (a glut on the market); falling rates of profit; surplus capital (including idle productive capacity, as well as a lack of profitable avenues for investment); and surplus labour. Overaccumulation is usually accompanied by a temporary shift of capital flows into built capital (and machinery) which function as aids, rather than direct inputs, to production and consumption activities.[45] During a crisis and ensuing period of depression, the mass and rate of profit decline, and the volume and rhythm of capital accumulation decrease. At this time, capital is devalorized and partially destroyed in value, and this results in underinvestment. These periods when capital is devalorized and underinvested serve once again to raise the average rate of profit of the entire mass of accumulated capital, which in turn allows the intensification of production and capital accumulation. Therefore, the ultimate result of a crisis will be a "forced rationalization" of the economy, and the beginning of a new cycle of accumulation.

The cyclical nature of the accumulation of built capital has been well described, and is apparent in Montreal (Figure 1.2), although the interpretation of the causal factors and periodicities remains controversial and even obscure.[46] Swings of fifteen to twenty-five years duration, known as Kuznets cycles, are those most relevant to construction. Since investment in built capital is often a sign of growing overaccumulation, city-building

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[45] Harvey (1985).

[46] For alternative investigations of the building cycle, see Hoyt (1933), Olson (1979; 1982; 1997), Harvey (1985), Hanna (1986), Whitehand (1987) and Berry (1991).

tends to occur in waves with steep peaks just before depressions.[47] If we look at the construction cycle in terms of urban morphology, every twenty years or so, another boom produces a new ring of construction at the fringe and another round of reconstruction at the centre. Each surge of growth brings a dramatic increase in flows of traffic through the city, intensifies competition for land, and raises the bid-rent curve. Adapting the built environment to accommodate massive waves of growth requires much more than the redevelopment of privately-owned buildings. Each surge of growth creates potentially serious problems of congestion in an outmoded urban core. To relieve congestion and restore profitable conditions, cities must, again and again, remove barriers to circulation and expand the capacity of the vascular system: e.g., periodically open new streets and widen existing ones, widen and deepen canals, and redimension sewer and water systems.

Marx argued that capitalism "cannot exist without constantly revolutionising the instruments of production, and thereby the relations of production, and with them the whole relations of society."[48] Due to the pressures of market competition, investors must periodically expand their economic base, lower the costs of production, speed up circulation, or "crank up" the "growth machine" to a higher level. With respect to the urban vascular system, this means finding ways to increase the throughput of traffic, at minimum cost and with minimum delay. One of the most powerful ways to lower costs and reduce turnover time is to intensify the exploitation of labour; to lower wages, for

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[47] Abramovitz (1961), Walker (1978), and Harvey (1985).

[48] Marx and Engels (1977, 38).

example, or to increase the length of the work day.[49] This is especially effective in the construction and transportation sectors, because they are so labour-intensive. Such a strategy naturally meets resistance, but the building cycle is closely associated with periods of in-migration (seen in Figure 1.2), which expands the pool of vulnerable low-wage workers.[50]

An alternative method of increasing circulation is to introduce new technology. Each new cycle of growth is associated with faster and more powerful ships, locomotives, and machinery which, in Marx's vocabulary, works "to tear down every spatial barrier to intercourse," and to "annihilate this space with time."[51] Since the throughput of traffic is dependent upon the shape and dimensions of the urban vascular system, there exists a direct relationship between transport innovation and investment in built capital (as seen in Figure 1.2). Use of larger and more powerful ships and trains requires further investment to deepen channels, canals and harbours, to lengthen and heighten piers, to add new railway lines and roads, and to expand areas for shunting, hoisting and storing goods (e.g., railway stations, elevators and warehouses). One effect of incessant technological innovation is to devalue or destroy past investments and radically transform the urban

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[49] "The maximum of profit is, therefore, limited by the physical minimum of wages and the physical maximum of the working day. It is evident that between the two limits of this maximum rate of profit an immense scale of variations is possible. The fixation of its actual degree is only settled by the continuous struggle between capital and labour" (Marx 1968, 226).

[50] Marx referred to this labour supply as the "industrial reserve army." The greater the labour surplus and the more rapid its rate of expansion, the easier it is for investors to exploit their work force, and conversely, worker resistance is likely to be more powerful during periods of low in-migration.

[51] Marx (1973). The phenomenon has also been referred to as a "time-space convergence" (See Janelle 1968; Harvey 1990).

landscape. One turn-of-the-century civic booster explained: "To make Montreal the modern, up-to-date city it is, the older town, in the construction and equipment of which public debts had been incurred, had to be demolished."[52] This "creative destruction"[53] is embedded in the circulation of capital and periodically accelerated, heightening the exhilaration of speed and reinforcing the ideology of progress, and at the same time exacerbating instability and insecurity.

Although economic land rent theory received a great deal of criticism from Marxian geographers in the 1970s (as part of a backlash against the quantitative revolution), the two theoretical approaches are compatible, as both conceptualize urban structure and social behaviour as a logic of circulation.[54] In this thesis, I also draw theoretical and methodological insights from a third research tradition known as *space syntax*. Space syntax is generally described as a set of theories and techniques for the representation, quantification, and interpretation of the spatial configuration of buildings and settlements. Configuration is simply defined as "relations taking into account other relations," and the guiding rationale for focussing on configuration is that "it is 'how things are put together' that matters."[55] The basic strategy of the space syntax approach to urban morphology is to examine spatial representations of the built form of cities to try

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[52] Chambers (1903, 67).

[53] Schumpeter further developed the argument that the innovational process "incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one . . . Creative Destruction is the essential fact about capitalism" (1950, 83).

[54] A Marxian theory of rent has been elaborated by Harvey (1974; 1982, 330-372).

[55] Hillier (1996, 1). See also Hillier et al (1987).

urban morphology is to examine spatial representations of the built form of cities to try to comprehend their structure, and then to explore the ways in which the apparent structure is related to observable function (e.g. circulation). To the extent that results are consistent over time and between cities, some theoretical insights have been forwarded.

Space syntax adopts a conception of circulation as a key to all of architectural and urban design: movement within a city, through a building, between rooms of a house, or even inside the space of a lab, museum, classroom, or dining room.[56] It originated with architects, as a theorization of architecture, in their search for ways to diagram and measure properties of physical and spatial structure, and the need to answer questions about the potential outcomes of different design choices.[57] Around the same time that regional scientists were using graph theory to analyse "connectivity" in transportation systems, a small group of architects recognized the utility of graph-theoretic concepts for interpreting building layouts.[58] Graph theory belongs to a branch of mathematics known

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[56] Space syntax has been used most often to examine the layouts of houses (e.g. Hillier and Hanson 1984; Hanson 1991; Hanson 1998; Bustard 1999; Major and Sarris 2001). On the organization of research labs, see Penn et al (1999), and for museum layouts (Choi 1999).

[57] Most contributions to "theory" in architecture have been "normative," or prescriptive in nature; they have been aimed at telling us how buildings or cities *should* be built, rather than telling us *how* and *why* they are built the way they are. There have been some important contributions of this genre (e.g. Alexander et al 1977). The primary focus of architects from the "Italian School" of typomorphology, is to develop a theory of design resting on historical city-building traditions (Moudon 1997).

[58] For early foundations of the space syntax theory in architecture, see the work of Cambridge University architects: March and Steadman (1971); Martin and March (1972); Martin (1972); Steadman (1976). For a contemporary commentary, see Alexander (1966). In the 1960s, graph theory was being used to examine connectivity in the interstate highway system of the U.S. (Garrison 1960), and the internal airline routes of Guatemala and Honduras (Garrison and Marble 1965). The essential textbook on graph theory for both architects and geographers is Buckley and Harary (1990). A review of the work in geography is provided by Tinkler (1977).

geographic or metric distance and are unchanged by any continuous deformation.[59] An everyday example of applied topology is the subway map. The route map of the Montreal métro, for example, will not tell you the distance between the McGill and Champ-de-Mars stations (since it is not to scale), but it will tell you how the lines connect between them. In other words, the map gives you topological rather than geometric information. Topological representations coincide with how we commonly perceive space and describe it to others: from McGill to Champ-de-Mars, you take the Honoré-Beaugrand line three stops to Berri-UQAM, then transfer to the Côte-Vertu line, and travel one stop to Champ-de-Mars.

Space syntax methods are based on a topological representation of the street network, or the entire "public" space through which people and vehicles move. By measuring the properties of network patterns, considered not merely as localized spatial elements (i.e. one particular street or intersection), but as an entire configuration of elements each related to the others, it is possible to investigate the effects of design of the street network on patterns of social behaviour, such as the way that pedestrian and vehicular flows are distributed. This method of configurational analysis, although deceptively simple, turns out to be remarkably powerful in detecting patterns in what might otherwise appear as complex disorder. Empirical studies have demonstrated a strong correlation between space syntax measures of network configuration and traffic

[59] It should be noted that in cartography, topology refers to *combinatorial topology*. The other branch, *point-set* or *algebraic* topology, is used as the basis for relational databases in GIS (Chrisman 1997).

flows (pedestrian and vehicular).[60] In addition, recent case studies indicate that there may be a link between spatial configuration and other social, environmental, and behavioural features of urban life and form, such as the distribution of land uses, the diffusion of automobile pollution, the spatial patterning of hostile interactions such as crime, and the evolution of built densities.[61]

From consistent results over numerous empirical studies, two associated theoretical propositions have been derived. The first is a theory of "natural movement," which argues that movement patterns are governed primarily by the configuration of the street network, which organizes simplest and most direct routes (with fewest changes of direction) to and from all locations in an area.[62] The theory makes intuitive sense, since the city is a structure in which origins and destinations are scattered everywhere (although with obvious biases toward major intersections and high density areas). In the case of most cities, movement generally happens "from everywhere to everywhere else," and therefore, Hillier (1996) has argued that the structure of the street network itself can explain a great deal of the variation in movement.

A second theory, of the "movement economy," suggests that

> it is the reciprocal effects of space and movement on each other . . . and the multiplier effects on both that arise from patterns of land use and building densities, which are themselves influenced by the space-movement relation, that

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[60] Penn et al (1998).

[61] See Hillier (1996), Croxford et al (1996), Hillier et al (1993), and Penn and Dalton (1994).

[62] See Hillier et al (1993).

> give cities their characteristic structures, and give rise to the sense that everything is working together to create the special kinds of well-being and excitement that we associate with cities at their best.[63]

The theory of the "movement economy" proposes that there is a "central dynamic" to the spatial growth of cities, which links the emerging street network structure (and natural movement) to the distribution of land uses and the density of the built fabric. The theory posits that as the accumulation (and adaptation) of built forms takes place, the emerging spatial structure gives rise to a pattern of natural movement. Land uses which benefit from movement (e.g. commercial) naturally gravitate towards higher-movement locations, while others (e.g. residential) will seek out low movement locations. The extra attraction of the high-movement spaces creates a multiplier effect on movement, which in turn attracts further movement-seeking uses. Settlement patterns thus become networks of busy and quiet areas, with the busiest found in the most spatially integrated areas, the whole process being initiated by the configuration of the street system. While the theory of natural movement notes a regularity, the "movement economy" theory attempts to account for the process by which the apparent affinity between the structure of the network, movement, land uses, and density of the built fabric seems to develop in naturally evolved urban systems.[64]

In an early debate with urban morphologist M.R.G. Conzen, the regional scientist W.L. Garrison argued:

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[63] Hillier (1996, 153).

[64] Hillier (2000; 1996).

> Studies of urban morphology have practically no generality because they have little theoretical orientation . . . Studies lack generality because we fail to include many of the inter-relationships of the townscape. We give little attention to traffic or circulation, for instance, and we fail to give attention to rents . . . We need theory to expand morphological systems so that they include factors and . . . inter-relationships[65]

Although it was not my intention to address Garrison's critique of urban morphology, or to answer the challenge, I believe the theoretical and methodological approach that I have outlined so far does just that. My approach is eclectic; however, upon reflection, it becomes clear that all three bodies of theory from which I draw are complementary, since each theoretical tradition attributes a central role to circulation.[66] Space syntax theories of "natural movement" and the "movement economy" build upon the fundamental bases of land value theory, which emphasize the importance of accessibility and centrality to urban form, the distribution of rents, and patterns of land use. Furthermore, space syntax ideas about movement and urban growth are consistent with a Marxian explanation of morphological change as an outcome of capital's drive to tear down barriers to circulation.

Choice of a theory or a line of argument leads to a choice of method. Some methods have been developed and applied by the three groups, particularly space syntax. Land value theory was the insight which revolutionized methods in urban geography (at

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[65] Quoted in Badcock (1970, 191).

[66] In this thesis, as in other Marxian interpretations of the city (e.g. Harvey 1985), the term "circulation" refers not only to the daily movements of people and goods in, out, and through the city, but also to the flows of money and capital over longer periods of time.

great expense and agitation), responding to a felt want of both theory and method, and it was in the early 1960s that a small group of people made a selection of some branches of mathematics (rather than others). Marxian theory initially harnessed its study of the past to a construction of a future, and again a small group of scholars applied the theory to urban development,[67] and opened up (somewhat) the methods on class and economic analysis, but not urban form. Space syntax is most explicitly a search for "method," combining topology with architecture, in search of a domain theory for the discipline.

PLAN OF THE THESIS

Now that we have surveyed the project, gathered some useful tools, and laid the conceptual foundation, let us examine the plan for the remainder of the work. To investigate various aspects of morphological change in Montreal, each chapter in thesis focuses on a different set of forms, and each investigation conducts a different set of tests, using a variety of methodological techniques.

In Chapter 2, I use "destructive accidents" as a lens through which to examine the problem of change in urban form. Fire is a powerful agent of morphological change. By removing the inertia of built capital, fires generate opportunities to make improvements to the urban habitat, and to make urban land more profitable. Examination of a sample of Montreal properties before and after fires, between 1850 and 1889, suggests that the speed, scale, and intensity of reconstruction vary according to the location of the site and

[67] Namely Mandel (1975), Harvey (1972; 1982; 1985), and Castells (1977).

the timing of destruction. Properties destroyed during economic boom periods and located in areas under the greatest competitive pressure were rebuilt more swiftly, more completely, and with greater inputs of new capital. The rhythm and trajectory of post-fire redevelopment points to the power of capital accumulation in (re)shaping the built form of the city.

The next two chapters concentrate on the urban vascular system, first the arteries and then the capillaries. In most nineteenth-century cities, the waterfront served as the primary interface between the city and the markets of the world. In Chapter 3, I examine how the muddy Montreal waterfront was remodelled into a modern port. More specifically, I demonstrate how the creative destruction of the built environment of the port district was associated with periodic innovations in shipping and cargo handling technology, as well as an intensified exploitation of labour on the docks. I argue that the redimensioning of the waterfront time-space was orchestrated by members of the local "growth machine" and was driven by the wider processes of capital accumulation.

In Chapter 4, my focus is on street widenings, a much-neglected topic in North American urban history. Massive increases in the volume of traffic moving across the waterfront naturally meant greater flows in all parts of the vascular system, and, consequently, perennial problems of congestion in older segments of the out-moded street network. To remove barriers to circulation, the municipal government periodically widened existing streets and cut new ones through delicate urban tissues. Between 1850 and 1918, dozens of streets were widened and thousands of properties were expropriated, to expand and "regularize" Montreal's street plan. Mapping the widened streets elucidates a distinct spatio-temporal pattern of operations. A closer look at individual streets reveals how the urban "growth machine," wielding the blunt instrument of expropriation, destroyed vast amounts of built capital and radically reshaped the urban landscape. The key to street widening operations was the shortening of turnover time and the redimensioning of the channels of circulation, in other words, a reorganization of the urban time-space.

Chapter 5 takes an experimental detour. Using techniques of topological modelling based on the theories of space syntax, I investigate the relationship between circulation and urban form using nineteenth-century Montreal as a case study. Equipped with a series of high-quality historical data sources, the predictive powers of the modelling techniques are tested with empirical evidence regarding meaningful aspects of nineteenth-century urban society, such as traffic flow, street width, land use, and density of the built fabric. The key discovery of this chapter is that the morphological and topological properties of the street network, namely the width of each street segment and its *integration* – its relative location within the system – are strongly correlated with patterns of urban circulation. The results highlight the value of a topological approach to urban modelling.

In Chapter 6, I attempt to weave together the several threads, reflect on the final product, contemplate its shortcomings, and suggest further projects worthy of consideration. It is hoped that this thesis will offer a springboard for future undertakings.

CHAPTER 2

Destructive Accidents: Rebuilding After Fire

> *In cities only change endures. Patterns of habitation are provisional, transformed by the ebb and swell of residency and subject to the forces that work with the sluggishness of the millennial erosion of stone, or with the speed of a stray spark.*
>
> – Spiro Kostof, 1992[1]

In the nineteenth century, most residents of North American cities lived with the constant threat of fire. Rapid industrialization and urbanization, associated with high densities, cheap construction, hazardous mixing of land uses, inadequate means of fire protection, and postponed investment in social overhead, fostered situations in which minor blazes could turn into massive disasters. Smith (1918) estimates that over half of all conflagrations in the world between 1815 and 1915 occurred in North America. Major fires were explosions of the pressure-cooker of untamed urban growth. In the capitalist city, rapid growth meant rapid obsolescence, the constant need for renewal, and hence, changes in urban form, or *morphogenesis*. Although the built fabric of a city is naturally long-lasting and resistant to change, the intervention of a single stray spark, under certain conditions, can greatly accelerate the process of urban morphogenesis. Fire consumed vast sections of Quebec City in 1845 and 1866, St John's, Newfoundland in 1846 and

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[1] Kostof (1992, 280).

1892, Chicago in 1871, Boston in 1872, Saint John, New Brunswick in 1877, and Baltimore in 1904, in each case destroying more than 1,000 buildings, enough to alter permanently the face of the city. This chapter examines the impact of fire on the built form of nineteenth-century Montreal.

My study begins with the summers of 1850 and 1852, when Montreal suffered four separate conflagrations which, in total, destroyed about 1,500 dwellings or nearly one-fifth of the city's housing stock, and rendered homeless approximately 12,000 people, almost one-quarter of the population. My purpose is not to recount the spectacular details which can be found in popular histories,[2] but to consider fire as an agent of urban morphological change. Drawing from two well-established analytic traditions – theories of land rent and building cycles – the analyses presented in this chapter contribute to our understanding of historical processes of urban growth. Given the enormous extent of the fires, we are afforded the opportunity to compare and contrast the rebuilding process in environments with different land uses, at different distances from the city centre, and owned and occupied by different social classes. Montreal never again suffered conflagrations which were as destructive as those in the 1850s; but over the next half century, lesser-scale blazes continued to break out every year, consuming smaller numbers of properties. For the period 1872-1889, by examining a stratified sample of properties destroyed by fires in boom or bust phases of the construction cycle,

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[2] The standards for Montreal are Gray (1949), Jenkins (1966), Rumilly (1970) and Collard (1988). McRobie (1881) provides a " record of prominent fires, thrilling adventures, and hair-breadth escapes" from the perspective of a Montreal fireman.

we can gain insights into how the rebuilding process varied according to the timing of destruction.

Of the case studies of historic conflagrations in several major cities,[3] very few deal explicitly with changes to urban form.[4] Conversely, few morphological studies consider the impact of fire. Marsan (1994), for example, the best known work on the built environment of Montreal, overlooks the subject. Rosen's (1986) examination of great fires in Baltimore, Boston, and Chicago, is the exceptional work which attempts to appraise explicitly the influence of fire on urban growth; but she says little about changes at the micro-scale. In this study, I attempt to deepen our understanding of the impact of fire on urban form by focussing on changes at the block and building level. Fires routinely destroyed large sections of cities, removed the inertia of massive amounts of built capital, and therefore generated opportunities to make improvements to the urban habitat. Rosen (1986) emphasizes how fire removed barriers to improving public infrastructure (water supply, sewers, streets, power system). Bowden (1967; 1982) remarks that buildings erected in the central district of San Francisco after the earthquake and fire of 1906 were much taller than their predecessors; however, he also argues that

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[3] For example, studies such as Bell (1951) and Roubaud (1991) on the Great Fire of London in 1666, and Miller (1990) and Smith (1995) on the Great Chicago Fire of 1871, typically focus on the social and institutional responses to the disasters.

[4] Canadian urban historians have published relatively little on fires. An introduction by Taylor (1979a; 1979b) uncovered only one conference paper focussing on fire in nineteenth-century Canadian cities (later published as Weaver and DeLottinville 1980). Of interest are three papers by Armstrong (1961a; 1961b; 1978) which recount fires in Toronto, 1849 and 1904; Fear (1979) on the complications of implementing land use zoning after fires in Ottawa; Norris (1987) on the role of fire insurance companies in small-town Ontario; and Stein (1996) on fire-fighting technology.

there were no major changes to the street plan due to the rigid combination of piece-meal ownership of private property and laissez-faire municipal government. Burned cities were normally rebuilt in haste, usually to the same two-dimensional plan of streets and lots. Nevertheless, the devastation often initiated fire-conscious regulations and innovations which slowly contributed to new and more durable urban environments.[5] Frost and Jones (1989) point to the increasing "fire-gap" (divergence between size of population and number of major fires) in North American, European, and Australian cities over the nineteenth century. Because fireproof building materials were expensive compared to traditional wood construction, such regulations made it increasingly difficult for working-class families to afford their own homes, particularly in central districts, where by-laws were more rigorously enforced.[6] It has been argued by Bowden (1982) that conflagrations do not radically alter the basic pattern of urban growth, but, instead, accelerate and exaggerate the regular processes already at work.

As an empirical test, I examine the relationship between dependent variables such as speed of reconstruction and degree of change in the intensity of development,[7] as a function of the market situation (location and timing). From small samples of properties before and after fires, I will provide insights into the rebuilding process for several segments of society. I will also briefly discuss how major fires facilitated improvements

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[5] Bowden (1982) and Rosen (1986).

[6] See Harris (1991; 1996).

[7] The term "intensity of development," refers to the concentration of built capital on a lot or lots.

to other components of the urban environment, such as streets. Although it is an erratic or catastrophic process, I shall argue that fire generated predictable changes in the morphology of the city, changes consistent with the demands of the nineteenth-century urban "growth machine." Before turning to an analysis of the findings, the following section outlines the logic guiding the study.

PREDICTING CHANGES IN URBAN FORM

Expectations are derived from two well-established theoretical bases: land rent theories offer a spatial logic, and Marxian explanations of the building cycle provide a logic in time. The theories of urban structure derived in the 1960s indicate the importance of the land-value gradient to the pattern of land use in the city.[8] Commercial uses usually outbid all other uses in the competition for centrally-located sites, and therefore, as we move out of the centre, land values drop, reflecting reduced utility and lessened competition, and the bulk and density of built forms diminish.[9] A reliable indication of the firm empirical correlation of centrality, land value, and built form is the intuition of newcomers to a city — even the most naïve of tourists and immigrants — to seek the action where the buildings are taller, more solidly built, and more brightly lit (such as Times Square in New York City).[10] Based on our understanding of such models, we

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[8] For example, Alonso (1964), Muth (1969), and Mills (1972).

[9] See Whitehand (1987).

[10] See discussion in Zukin (1995, 133-142).

would expect that post-fire reconstruction in nineteenth-century Montreal would reflect such a pattern. We might anticipate that burnt properties nearest to the centre of the city will be rebuilt with larger lumps of capital, larger investments per square foot of land, and taller buildings that produce higher rents. Due to intense competition, the reconstruction process is also likely to be swifter on centrally-located sites.

Based on our understanding of the rhythm of accumulation in the built environment, we can make predictions about how the response to fire might vary with the construction cycle. For instance, the conflagrations of 1850 and 1852 occurred during an economic upswing, just as Montreal (and most of the capitalist world) had recovered from the severe economic crisis of the late-1840s. The incentives for a property owner to rebuild are likely to be stronger during an economic upswing rather than a depression. During a boom period, capitalists must rebuild quickly if they are to take advantage of the momentum and maintain a rapid pace of accumulation and high level of profit. Due to increased competition for space during growth periods, vacancy rates will decrease, land values and rents will increase, and therefore property owners are likely to rebuild quickly so that they may continue to collect inflated rents and possibly avoid having to pay high rents to accommodate themselves elsewhere. Competition may be further intensified by the shortages caused by a major conflagration. During boom periods, rebuilding is more likely to involve morphological changes such as the intensification of land use, in order to deal with heightened competition and to take advantage of increased values. On the other hand, during an economic slump, property owners are not under as much pressure to rebuild quickly; they may even resist rebuilding until it becomes more profitable; and if they rebuild, they are more likely to duplicate the old forms, relying on insurance payments, since they do not have easy access to additional capital to redevelop at a larger scale,[11] to a higher standard, or with a new technology.

The theory of building cycles also suggests a mismatch. The city is usually ill-equipped to handle a massive surge of growth. After each boom, maladjustments emerged, and zones which had experienced the greatest competition and most aggravating congestion, ripened for redevelopment. Within our present-day experience, as well as in the nineteenth century, these often take the form of bottlenecks to traffic. Congestion would also include choked-up public services (fire and police), and overloaded systems of water and sewers. All of these forms of congestion, well-documented for nineteenth-century Paris and London,[12] rendered a city vulnerable and reduced the overall rate of capital accumulation. Since built capital is fixed in space, long-lived, and difficult to alter, a perennial source of conflict exists between present demands and the legacy of built capital. This tension can be considered a "contradiction" of capitalist development, as it introduces a constraint on profitability, and creates a need for a breakthrough, if investors are to maintain or restore their rate of profit and the momentum of accumulation. This happens with every surge of growth, and is aggravated by lags in

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[11] By "scale" of a building, I am referring to the overall size or volume. Therefore, the "scale of development" in an area refers to the density of built capital, or building coverage on the particular lots in three-dimensions.

[12] Dyos (1955; 1961), Marchand (1993), and Sutcliffe (1971).

public investments in infrastructure.[13]

Marx argued that "a crisis always forms the starting-point for large new investments . . . it is more or less a new material basis for the next turnover cycle,"[14] and the built capital of the city accounts for the largest part of this material base. Under the pressures of market competition, investors continually strive to reach new markets, lower their costs of production, and speed up circulation. A conflagration, like other forms of crisis, intervenes as a "storm," redistributing the opportunities for profit and restoring efficiency in a congested system. By destroying the built capital invested in past eras, a conflagration has the effect of directing new capital into built form, potentially into new forms, thus stimulating a more efficient infrastructure and accelerating the pace of capital accumulation. With respect to rebuilding after major fires in Montreal, we would expect property owners in areas which have experienced the greatest congestion and the greatest increase in competition for space — in the central core, along the waterfront, and along the thoroughfares which connect the newly developed urban fringes — to rebuild fastest and to make the most significant morphological changes to their properties. We would expect to find new and improved types of buildings and an intensification of land use in these areas. Conversely, we would expect areas under the least pressure (perhaps in residential areas, in cheap labour industries, in "unproductive" social overhead capital

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[13] Public investment is a tool to promote accumulation of privately owned capital, and it may be that when money is scarce and the rate of profit low, private interests will seek more aggressively to manoeuvre public investment. This might include regulated or limited-dividend utilities, use of public borrowing power or public powers of expropriation, e.g., Montreal's flood control investments (Boone 1997), railway and tramway investments, port improvements, or street widenings.

[14] After Mandel (1975).

like schools, in new developments not yet amortized) to rebuild more slowly and experience fewer improvements.

REBUILDING IN THE 1850S: PHOENIX FROM THE ASHES?

Let us now look at the evidence, first the case of the conflagrations of 1850-52, then at a sample of punctual late-nineteenth century fires, and create a sampling design which compares the before-and-after streams of rent generated from lots devastated by fire. Montreal ended the first half of the nineteenth century in a state of turmoil which culminated with the torching of the Parliament Building in 1849. Under a severe economic depression, the city was a powder-keg waiting to explode. Over-speculation in real estate during the boom of the 1840s left many stores and houses "groan[ing] for tenants."[15] This all changed in the early 1850s, when four massive fires wiped out one-fifth of the city's housing stock (see Figure 2.1). The first broke out on June 15th, 1850, and destroyed 207 houses in Griffintown, a predominantly Irish working-class suburb in the west end of the city. About two months later (23 August), while most of Griffintown was still in ruins, 150 buildings were consumed in the St Lawrence Ward, just beyond the old walled city. On June 6th, 1852, another fire engulfed many important business houses in the central core of the city; and a month later, a two-day (July 8-9) conflagration — the worst in Montreal's history — wiped out 1,112 houses in the

[15] Sandham (1870, 26).

predominantly French-Canadian, working-class wards of the east end (see Table 2.1). Each episode of destruction highlighted the dangers of wood construction, narrow streets, and an inadequate water supply. These conflagrations not only devastated vast districts, but, as we shall see, they also presented opportunities to institute widespread changes to the built form of the city.

Table 2.1
Destruction by the conflagration of July 8-9, 1852[a]

Wards	Number of houses destroyed: Stone	Brick	Wood	S&W	Total	Rental Assessment	Number of sufferers: Families	People
St Louis	50	46	451	6	553	$ 38,288	959	4,807
East	19	0	0	0	19	6,720	32	129
St James	42	45	181	8	276	21,968	403	2,314
St Mary	31	53	178	2	264	14,920	343	1,792
Totals	142	144	810	16	1,112	$ 81,896	1,727	9,042

[a]Estimates are considered conservative, e.g., total houses destroyed is exclusive of out buildings or houses at the rear of lots, and persons rendered homeless is exclusive of boarders, lodgers, and others not appearing in municipal records. All monetary estimates are given in dollars at the contemporary exchange rate of four dollars to the pound (McCullough 1984). *Source*: Montreal General Relief Committee, 1853.

The primary source of data for this analysis is Montreal's unique rental tax rolls (*rôles d'évaluation locative*). Available annually since 1847, they provide the names of each business or household head, the type of occupation, the assessed value of the building and land, for tenants a rental value, and for owner-occupiers an estimate of market rent based on floor area. The reliability of this source has been confirmed in several studies.[16] As a theoretical concept, the "rental values" are a meaningful concept, as they represent the flow of income from capital invested in the built landscape. Where precise data on three-dimensional form is not available,[17] rental values offer a convenient surrogate, as they have been shown to correlate perfectly with floor area, and by allowing ten feet height per storey, we can estimate the building "envelope," and thus, the scale of development.[18] The sample database was created by collecting rental values between 1850 and 1861 for all properties fronting upon seven different streets. I sampled three different areas of the city — the central core of "Old Montreal," a ring just outside the city centre, and an east end suburb — and for each street, paired a section destroyed by fire with an adjoining section that was unaffected (Figure 2.1).[19] Before the conflagration, each pair of segments showed the same morphological and socio-economic characteristics. By tracing rental values after the conflagration, we can observe the tempo

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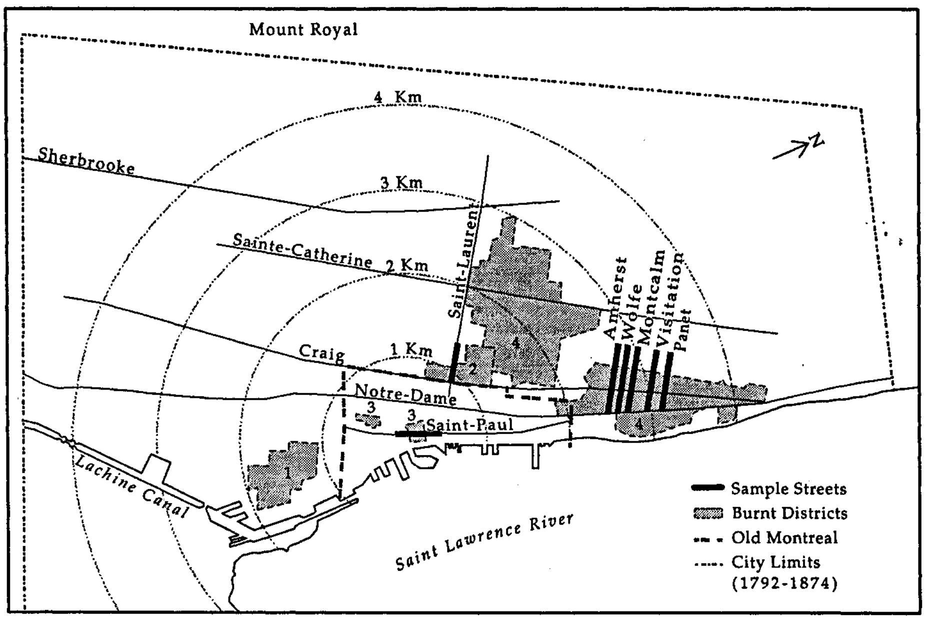
[16] The source is further described and scrutinized in Hanna and Olson (1983), Gilliland (1998), Gilliland and Olson (1998) and Lewis (1990; 2000).

[17] The available cartographic sources are too infrequent and insufficient on their own for identifying the morphological changes generated by the 1850s conflagrations. The first comprehensive insurance atlas for Montreal was produced by Charles E. Goad in 1879, completed in stages by 1881, and updated in 1890. The Goad atlases were similar to those prepared for U.S. cities by the Sanborn company in that they distinguish wood and brick construction, however, the Goad atlases rarely recorded information on building height and land use. According to geographer David Hanna, the earliest available atlas showing heights of Montreal buildings is the Goad update of 1907, but only a few plates still remain in a corporate archive.

[18] By measuring a stratified sample of houses, Hanna and Olson (1983) confirmed the powerful correlation (r=.99) between rents and floor area. For further evidence of the correlation between rents and built form in 3D, see the convincing diagrams in the atlas plates by Hanna and Olson (1993) and Olson and Hanna (1990).

[19] Contemporary newspapers helped identify the burnt districts and provided general accounts of the destruction. The sample design was inspired by experimentation by Stephen Hertzog (1984) and readapted by Robert Lewis for a study of homeownership rates (see Hertzog and Lewis 1986; Lewis 1990). Lewis (1990) ascertained that the rental values reported in the tax rolls before 1854 estimate total rent per building, whereas from 1854 onward they provide rental values for individual dwelling units which, for our purposes in this chapter, can be totalled for each building to make comparisons with the earlier period.



2.1 Burnt districts and sample streets in Montreal, 1850-1852. Fires are numbered: (1) 15 June 1850; (2) 23 August 1850; (3) 6 June 1852; (4) 8-9 July 1852. *Sources*: Cane, J., *Topographical and pictorial map of the City of Montreal,* 1846; *Montreal Pilot,* 26 July 1852; Montreal, *Rôle d'évaluation*, 1849-53.

or rate of redevelopment, and, by comparing the burnt and non-burnt segments, we can measure the scale and intensity of redevelopment of built capital.[20] We can think of the burnt segments as cases of accelerated renewal, and the non-burnt segments as undergoing a more "normal" or organic form of renewal.

The central core street under examination is St Paul, in the heart of Old Montreal.[21] St Paul is one of the oldest streets in the city (opened in 1673), and the earliest atlases show that it was already a crowded street — the most densely built in the town — in the eighteenth century. By the 1850s, it had become almost entirely commercial, densely-packed with two-and-a-half- and three-and-a-half-storey, peaked roofed, stone warehouses occupied by wholesale merchants who sought close proximity to markets and the wharves. The mean annual rent per building was about $650 immediately before the conflagration. While development in the two segments was comparable before the fire, by 1861 the mean rent of buildings in the segment that had burned was much greater ($1,123), almost 40 per cent higher than in the non-burnt segment (see Table 2.2, Figure 2.2). In other words, the burnt segment was rebuilt at a greater scale and a higher intensity of land use. Evidence to support this inference is provided by a contemporary observer, who witnessed the rebuilding activity on St Paul

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[20] The critical assumption is the absence of inflation, and it is, we submit, a reasonable one. The best discussion of temporal variation in rent valuations is found in the testimony of George E. Muir, city assessor, to the Royal Commission on Capital and Labour (1889, 258-64).

[21] The section of St Paul under analysis lies entirely within Centre Ward, between St François Xavier and St Gabriel Streets. The properties between St Joseph Street and Custom House Square (both sides) represent the burnt sample, while the remainder of the properties make up the non-burnt sample. The *Hotel Dieu*, at the northeast corner of St Paul and St Joseph was excluded from the analysis, as assessments for tax free public institutions are not reliable.

Table 2.2
Redevelopment of Sample Street Segments, 1850-1861

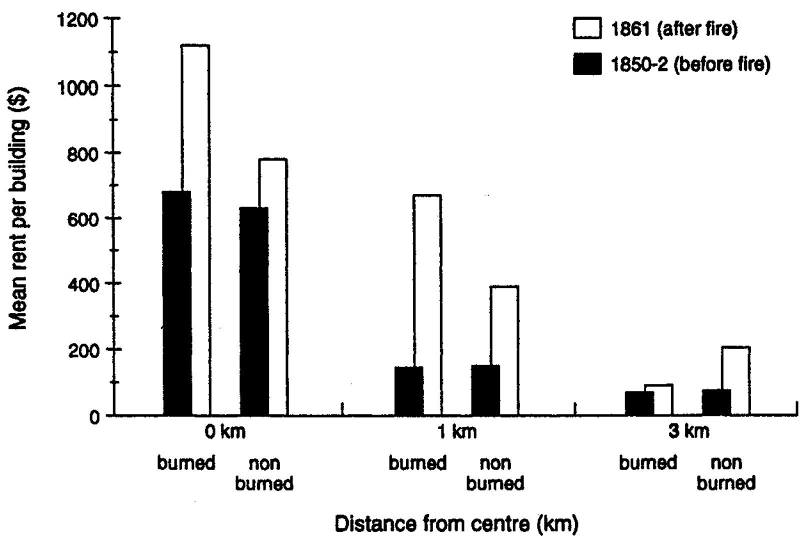
Sample Area	Distance from centre (km)	Segment status	Mean rent per building ($) before fire (1850/52)	after fire (1861)	increase (%)	Sample size (n)
St Paul	0	burnt	688	1,123	63	19
		non-burnt	636	791	24	30
St Laurent	1	burnt	148	683	361	9
		non-burnt	151	406	169	7
St James ward[a]	3	burnt	74	97	31	63
		non-burnt	73	158	116	38

[a]Amherst, Wolfe, Montcalm, Visitation, and Panet streets. *Source*: Montreal, *Rôle d'évaluation*, 1850-1861.

Street about five months after the fire: "All of these are first-class buildings with cut-stone fronts . . . two-thirds of the buildings destroyed . . . will be rebuilt in a better style than before, and re-occupied ere the spring vessels arrive. The other lots are, we understand, in the market for sale, and there can hardly be any more valuable property in the city."[22] D.B. Viger's warehouse at the corner of St Paul and Customs House Square is a typical case of rebuilding. Whereas the burnt structure was two storeys with an attic, its replacement was a full storey higher, and garnered 52% more rent than its predecessor ($1280 vs $840).

Contemporary accounts suggest that St Paul was rebuilt quickly, and this is also shown in the tax records. In the spring of 1853, less than twelve months after the fire,

[22] *Montreal Gazette*, 12 November 1852, p.2.



2.2 Redevelopment of sample street segments, 1850-1861
Source: see Table 2.

there were just two vacant lots remaining, out of twenty which burned; these two properties had changed hands, and would be built upon by the following spring (1854).

If we move just outside the central core, to a section of St Lawrence Street (known as "the Main") destroyed in August 1850, we see an even more dramatic example of rebuilding.[23] This street was opened in the early eighteenth century (1720), but dotted with just a few small houses until the old city walls came down a century later (1802-1817). By 1850, the section under examination was developed largely of small, peaked roof, stone structures at the front of deep lots, with shops on the ground floor and dwellings above. Most of the buildings destroyed on this street were made of stone, two or three storeys high (two-thirds were two-storey), with the upper storey tucked under a steeply sloped roof. One-eighth were one-storey and made of wood.[24] Mean rent per building on both segments was about $150. A decade after the fire (in 1861), mean rent per building in the burnt section had quadrupled (to $683) (Table 2.2, Figure 2.2). Although rents in the section which had escaped the fire also rose considerably over the same period, the mean rent per building was less than two-thirds that in the burnt section. In other words, the burnt area was redeveloped more intensively. Redevelopment was also quick, as all of the properties were rebuilt within two years after the fire. By 1854, mean rent per building in the burnt section was already three times what it was before the fire.

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[23] The two segments under examination are on the east side of St Lawrence Street in St Louis Ward. The burned sample runs from Craig Street to Vitré Street, and the unaffected sample from Vitré to Lagauchetière Street.

[24] *Montreal Gazette*, 26 August 1850, p.2.

The third area under analysis consists of five streets – Amherst, Visitation, Panet, Wolfe, and Montcalm – in the east end of the city.[25] Formerly known as *Faubourg Québec* (or the Quebec Suburb), the area was farmed until the beginning of the nineteenth century. Development was very sparse until the boom of the late 1830s and early 1840s, and the area was inhabited almost entirely by working-class French Canadians. Before the fire, most structures in this area were of wood (65.6%), one storey with attic.[26] Their small mean size was reflected in the relatively low mean rent per building of about $74. Given the distance from the city centre, the small scale development is consistent with our expectations. Unlike the more centrally located sample properties, the suburban properties appear to have been redeveloped at a slower pace and lower density. Although mean rent per building in the burnt segments increased in the decade by one-third, rent in the non-burnt segments more than doubled (Table 2.2, Figure 2.2). In other words, the conflagration hindered the evolution of this area. Evidence to support this claim is provided by a newspaper reporter, who, three months after the fire, remarked: "In the suburbs, the rebuilding by the poor people who suffered by the July fire is by no means general yet, but there are a great number of buildings going up. Many of these are not so good as the houses destroyed."[27] A closer look reveals that redevelopment was

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[25] Even though this area lay within the city limits as of 1792, it was still commonly referred to as a suburb, or *faubourg,* and its physical and social characteristics were as such. The sample comprises properties on the west side of the five aforementioned streets within St James Ward. The burnt stretches run from St Mary Street (also known as Notre Dame East) to Lagauchetière Street, and the unaffected stretches from Lagauchetière to Dorchester Street.

[26] Montreal General Relief Committee (1853).

[27] *Montreal Gazette*, 12 November 1852, p.2.

much slower in this suburban district than in the more central regions. On Wolfe Street, only one-fifth of properties had been redeveloped by 1853, a year after the fire, and just over half by 1854.

While not all of the burnt properties were recreated like "a phoenix rising from the ashes," the decade following the conflagrations was a period of unprecedented growth for the city in general. Rapid expansion of the population (from 57,000 in 1852 to 90,000 in 1861) was accommodated by adding a new ring of development at the urban fringe, and by squeezing in and piling higher in the centre. The housing stock effectively doubled between 1852 and 1861 (from 7,000 to 14,000).[28] Thanks to the intervention of fire, burnt sections were able to close the gap between the optimal value of capital attained in the last boom and what could be obtained from "sunk" capital. In "re-forming" the burnt districts, new by-laws restricting wood construction inspired the introduction of new fire-resistant materials and building forms which changed the whole look of the city.[29] Whereas in 1852, Montreal, like most mid-nineteenth-century North American cities, was primarily a "city of kindling," by 1861, the majority of buildings were stone-faced or brick-clad. In 1852, 63% of inhabited houses in Montreal were wooden, compared to only 43% in 1861, and 11% in 1891. Since wood shingles were banned, and slate and tin

[28] Figures provided in published summaries of census returns. See also Hanna (1980).

[29] In French Régime Montreal (1642-1760), wood shingles were outlawed in 1676, and stone construction was mandated after a conflagration in 1721 (Lambert and Stewart 1992); however, these regulations had apparently lapsed by the time the newly incorporated city published its first by-laws in 1833. In 1842 the city was re-incorporated, and the ban on wood construction was reinstated, but only for the central core; after the disastrous summer of 1850, a new by-law prohibited wooden buildings across the entire city. A proviso to the City Charter of 1865 allowed the erection of wooden buildings if encased in brick work, and wooden roofs if covered with a fire- and water-proof composition.

were expensive, the flat roof, covered with felt, tar and gravel, made its first appearance in Montreal, as an economical alternative to the traditional peaked roof.[30] This innovation allowed the construction of a more nearly cubic building, which provided owners with more rentable space. The flat roof was a prominent feature of commercial buildings erected in the 1850s, in the "Renaissance Revival" and "Proto-Rationalist" styles imported from Britain and the United States;[31] it was also a definitive characteristic of the Montreal "duplex," a type of superimposed flat which achieved widespread popularity during a subsequent boom period (1866-80), and which has dominated the urban landscape of Montreal to this day.[32]

REBUILDING DURING BOOM AND BUST, 1872-1889

While the preceding analysis demonstrated distinct spatial variations in post-fire rebuilding behaviour across the city, what remains to be seen is how the response to fire might vary with the construction cycle. The conflagrations of the early 1850s occurred at the beginning of an economic upswing, when incentives to rebuild were likely to be strong. To see how the reconstruction process might have been affected by economic depression, we need a second investigation. To identify temporal variations in the post-

[30] See discussion in Hanna (1986).

[31] Styles of architecture in Montreal are identified in Rémillard and Merrett (1990).

[32] On the history of the duplex, see Hanna (1986) and Dufaux (2000).

fire reconstruction process, I compiled morphological data for a sample of properties (20) totally destroyed by fires at different stages between two construction peaks (1872 and 1889). Drawn from the *Annual Reports of the Fire Department*, the sample, mapped in Figure 2.3, included properties from different areas of the city, in different uses, and from different socio-economic environments (see Table 2.3).[33] Details on pre-fire building form (such as type of construction and number of storeys) and the extent of damage (physical and financial) were gleaned from newspaper accounts. To observe the pace of reconstruction, tax roll data were gathered for each burnt property beginning one year before the fire until three years after. As before, changes in the scale of development can be expressed as increases or decreases in total rental value. Supplemental information on the rebuilt forms was obtained from building permits, insurance atlases, historical photographs and sketches.[34]

Although the size of the sample is small – ten properties destroyed during a boom period plus ten destroyed during a depression[35] – the evidence nonetheless suggests that

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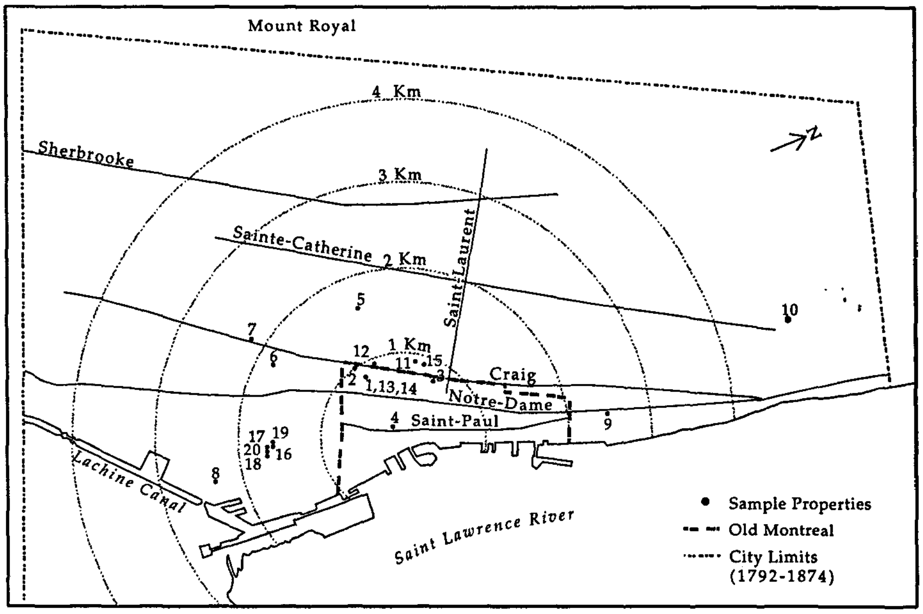
[33] Comprehensive chronological listings of fires are available beginning in 1872 (*Annual Reports of the Montreal Fire Department*). The sample represents about one-quarter of all developed properties (excluding barns, sheds and outbuildings) recorded as "totally destroyed" by fire between 1872 and 1889.

[34] Building permits are tabulated in the *Annual Reports of the Inspector of Buildings*. The permits which survive for the years 1868 to 1877 (less 1872) provided additional post-fire morphological data, such as number of storeys, structural and roofing materials, and a measure of building frontage (see Hanna 1986). For certain sample properties burnt between 1882 and 1889, the Goad maps were compared for additional signs of morphological change (building materials, footprint, and lot plan). The research value of insurance atlases has been thoroughly discussed (Lamb 1961; Hayward 1973; Aspinall 1975; Bloomfield 1982; Wright 1983; Hanna 1986; Tunbridge 1986; Keister 1993; Keller 1993; and Harris 1997).

[35] The boom periods (1872-75 and 1884-89 inclusive) of high construction in Montreal, and the bust period (1876-1883 inclusive) can be seen in Figure 1.2. The cyclical rhythm is the same in most North American cities (Riggleman 1933; Berry 1991).



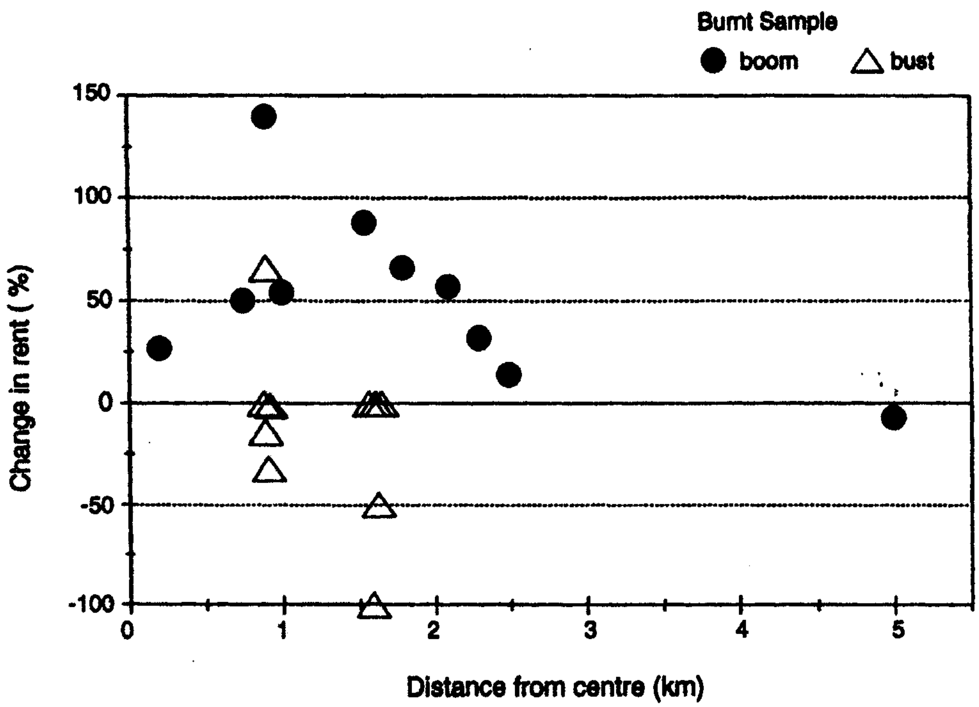
2.3 Location of sample properties burnt in Montreal between 1872 and 1889.
Source: see Table 3.

Table 2.3
Redevelopment of Sample Properties Burnt Between 1872 and 1889

Sample bldg #	Cycle stage	Fire year	Primary building use	Ring from centre	Pre-Fire rent ($)	Post-Fire rent ($)	Rent Change (%)	Years to rebuild	Insurance coverage
1	Boom	1886	Hall	1	4,510	10,850	+ 140	1	Total
2	Boom	1872	Auction house	1	1,950	3,000	+ 54	2	Total
3	Boom	1872	Foundry	1	1,000	1,500	+ 50	1	Mostly
4	Boom	1885	Warehouse	1	2,000	2,530	+ 27	2	Mostly
5	Boom	1885	Factory	2	800	1,500	+ 88	1	Half
6	Boom	1873	Planing Mill	2	600	1,000	+ 66	1	None
7	Boom	1888	Bakery	3	860	1,350	+ 57	1	n.a.
8	Boom	1886	Factory	3	340	450	+ 32	1	n.a.
9	Boom	1875	Bakery	3	700	800	+ 14	1	n.a.
10	Boom	1886	Factory	5	1,500	1,400	- 7	2	Partly
11	Bust	1883	Factory	1	900	1,500	+ 66	3	Partly
12	Bust	1883	Foundry	1	1,710	1,950	+ 14	2	Mostly
13	Bust	1879	Hall	1	5,000	4,950	- 1	1	Total
14	Bust	1881	Hall	1	4,950	4,950	0	1	Total
15	Bust	1877	Factory	1	1,300	890	- 32	1	Total
16	Bust	1877	Lumber yard	2	300	300	0	1	Total
17	Bust	1877	Lumber yard	2	250	250	0	1	Total
18	Bust	1877	Dwelling	2	100	100	0	1	None
19	Bust	1877	Dwelling	2	200	100	- 50	3	Half
20	Bust	1877	Dwelling	2	140	0	- 100	>5	None

Sources: Montreal, *Annual Reports of Fire Department*, 1872-1889; Montreal, *Rôle d'évaluation*, 1871-1895; *Montreal Gazette*, 1872-1889; *La Presse*, 1872-1889; *Montreal Daily Star*, 1872-1889; *Montreal Herald*, 1872-1889.

the response to fire is affected by its timing in the construction cycle. While most sample properties were redeveloped quickly – two-thirds within twelve months – properties destroyed during boom periods were more likely to experience a rapid recovery (Table 2.3). All sample buildings razed during boom periods were rebuilt within two years, whereas 30% burnt during depressions were still in ruins after two years. In addition, at least 40% of owners of properties burnt during depressions waited until a boom period to rebuild.



2.4 Redevelopment of sample properties burnt between 1872 and 1889.
Source: see Table 3.

During boom periods, post-fire redevelopment was also more likely to involve morphological changes. Rental values of this group of properties were almost always significantly greater than those before the fire, suggesting that they were redeveloped at a greater scale and intensity (Table 2.3, Figure 2.4). The lots were not changed; and a higher rental value accurately reflects the addition of floor area. Eight out of ten new buildings had a rental value at least 20% greater than before the fire (mean rent was 52% greater after rebuilding). A typical example is the industrial building on Dowd Street (#6 in sample) which was destroyed in 1885 and replaced the following year with a taller structure (five vs three storeys), which covered a larger proportion of the lot (68% vs 60%), offered therefore almost double (1.88 times) the floor area, and garnered almost twice (1.88 times) the rental value ($1,500 vs $800).[36]

In contrast to the boom period trends, morphological change was much less likely to occur during depression periods: half of the properties destroyed between 1876 and 1883 were rebuilt to their original scale. Nordheimer's concert hall on St James Street, for example, was twice consumed during the depression period, in 1879 and 1881 (#13 and #14 in sample), and each time rebuilt exactly the same as before. Conversely, after the hall burned again in 1886, during a boom period (#1), it was rebuilt on a much grander scale, and more than doubled in rental value (from $4,510 to $10,850). Whereas the old hall was a three-storey, box-like structure of simple construction, the new five-storey building was constructed of red sandstone imported from Scotland, and two of its

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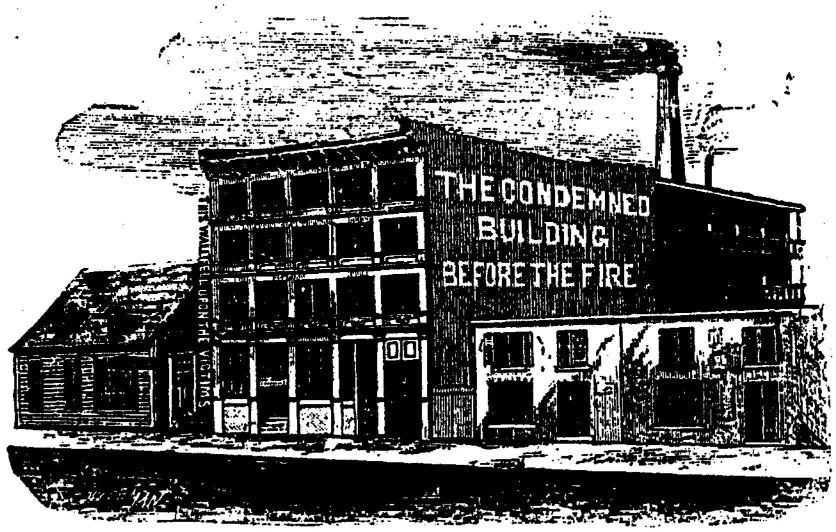
[36] Lot coverage equals area of the building footprint divided by area of the lot, measured before and after the fire using the Goad atlas of 1881 and its update for 1890.

storeys were dedicated to office space for rent. When morphological change did occur during bust periods, the new structure was likely to be on a smaller scale: 30% of burnt properties displayed significantly lower rents after the fire (and one had not been redeveloped after five years). In the set of depression fires, the only case which shows an increase in scale was an industrial building on Coté Street (#11) which burnt in 1883 and was sold immediately to a new owner who waited three years until an economic upswing before rebuilding. The more typical story of reconstruction during times of depression is that of John Bulmer's industrial building on St Urbain Street (#15). Built in 1873, on the eve of the business and building crash, the top floor of the four-storey, "Proto-Rationalist" style loft building (Figure 2.5) remained vacant for four years. The building burned down in 1877, and he rebuilt a few months after the fire, with only three storeys.

Snapshots of St Urbain Street before and after the fire provide clues as to how the circulation of capital reshaped the urban landscape at the micro-scale, and how the process of urban renewal, particularly in the densely-built industrial city, could be radically accelerated by the intervention of fire. The peaked-roof, wooden house at left of Figure 2.5 was typical of buildings in the suburbs outside of Old Montreal before the massive conflagrations of the 1850s; whereas Bulmer's stone-faced, industrial loft and the pair of brick-clad, Montreal "duplexes" erected in typical row formation (in 1870), were products of a subsequent wave of urban (re)development (1866-1880), which incorporated new technologies, new materials, new styles, and transformed the image and scale of the pre-industrial streetscape.



BEFORE THE SLAUGHTER.

The Novelty Company's Building on St. Urbain Street before the Fire.

AFTER THE SLAUGHTER.

The Ruins of the Novelty Company's Building, shewing: A, Crushed Roof of Undertaker's Store; B, the Yard where the Firemen were Killed; C, the Remnant of Wall that fell and Crushed the Men.

2.5 Built fabric of St Urbain Street section before and after fire.
Source: *Montreal Star*, 7 May 1877.

DISCUSSION AND CONCLUSION

How can we account for the differences in the patterns of redevelopment within the sample? The findings are consistent with my predictions regarding the rhythm and trajectory of investment in the built environment. Redevelopment was most intense in the central areas, on streets such as St Paul, where competition for space was most extreme, and where there existed the greatest pressure to remodel the built environment to fit the needs of a changed economic environment. St Paul was already heavily developed before the conflagration, with very little open space remaining;[37] therefore, if property owners were to expand their built capital to take advantage of the escalating demand for central sites and to meet the expanding needs of a booming economy, they would have to build higher. To do so, however, would probably necessitate destruction of existing buildings first: the massive sunk capital would have to be replaced, new capital would have to be raised, and business and leases would have to be interrupted while reconstruction took place. The conflagration, therefore, removed some of the barriers to performing morphological changes, by offering property owners a *tabula rasa* upon which to rebuild. Rosen (1986) argues that the physical durability of buildings was one of the most important frictions impeding the environmental redevelopment process in nineteenth-century cities of the United States. Since there were no municipal regulations with respect to building height in Montreal (until 1901),[38] the only restrictions on rebuilding

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[37] As can be observed on the Cane map of 1846.

[38] Before 1900 there were occasions, after certain street widenings, where owners were required by special by-laws to rebuild to a minimum height (see Chapter 4).

Table 2.4
Estimated Losses and Insurance Coverage in Conflagrations of 1850s

Fire #	Date of Fire	Estimate of Losses ($ 000s)	Losses Insured ($ 000s)	Proportion of Losses Insured (%)
1	June 1850	320	90	28
2	August 1850	240	87	36
3	June 1852	834	609	73
4	July 1852	2,163	740	34
	Sum	3,557	1,526	43

Sources: *Montreal Gazette*, 18 June 1850; 26 August 1850; 12 July 1852; 23 July 1852; *Montreal Pilot*, 26 July 1852; Montreal General Relief Committee, 1853.

higher were the limits of existing construction technology, their economic means, and, of course, the perception of potential returns. Redevelopment of St Paul Street was quick and intense because as much as three-quarters of the losses incurred were covered by insurance (see Table 2.4), and, more importantly, business had to carry on. Messrs Seymour & Whitney, for example, owners of a typical wholesale warehouse on St Paul, started rebuilding immediately after the fire, and reopened on the 1st of September, twelve weeks after the conflagration.[39] Raising the necessary capital was little problem for Seymour & Whitney, as they were fully insured. In fact, their stock and building was insured with two separate companies ($14,000 in property with the Globe Agency, and $12,000 stock with Phoenix Company), presumably to spread the risk in case one company went bankrupt. According to Norris (1987), great fires often bankrupted small or local insurance companies.

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[39] *Montreal Gazette*, 12 November 1852, p. 2.

The reconstruction of properties on St Lawrence Street after the fire of 1850 was also dramatic. Why was there such a significant increase in the scale of development on this street? Post-conflagration Montreal experienced a population and economic boom in which competition for space in the city centre became fierce. By the 1850s lot coverage in Old Montreal was already almost total, but lots in the central suburbs were large, with plenty of room to expand. Properties in the old *Faubourg Saint-Laurent* became prime real estate during this time, especially since the old city walls, or, in M.R.G. Conzen's (1960) terminology, the "fixation lines," had recently been removed. St Lawrence Street was the primary axis between the central suburbs and the old city; and this was reflected in the value, scale, and intensity of redevelopment.

Why was post-conflagration redevelopment in the east end suburb much slower and less dramatic than in the central districts? Demand for space in the suburbs was weaker and alternative sites were available, therefore the potential stream of rents in more remote locations was lower, and the incentives for owners to rebuild were weaker. After a major disaster, the socioeconomic classes and types of businesses that have the greatest reserves and resiliency are always the first to be successfully reestablished.[40] In 1850, wealthy residents of nineteenth-century cities such as Montreal still occupied the centre, their exodus had not yet begun, and the poorest inhabited the periphery.[41] A greater

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[40] See Haas et al (1977) and Bowden (1967; 1982).

[41] Hanna (1980, 51) argues that "Old Montreal in 1850 was still the focal point for the homes of wealthy Montrealers." In Montreal, it was the conflagrations, as well as a devastating outbreak of cholera (1854) that drove the 1850s migration of wealthy citizens from the crowded central core to the more spacious and airy suburban plots near the slopes of Mount Royal (Hanna 1980).

amount of capital was available for rebuilding in the core than in the suburbs. It was estimated that three-quarters of the losses in the core were covered by insurance, compared to only a third in the suburbs (Table 2.4), and almost every party affected in the core was at least partly insured, whereas less than one-quarter of the sufferers in the suburbs had any coverage.[42] Credit was much harder to secure for small owners in the suburbs who would have had little collateral; most had lost their lifetime savings in the capital sunk into their properties, both homes and workshops. Another deterrent to immediate reinvestment by this poorly insured group would have been the perceived risk of potential losses in future conflagrations. Weaver and DeLottinville (1980) speculate that much of the nineteenth-century city was cheaply built and rebuilt because it was likely to be burned down. Stricter regulations (and enforcement) against wooden construction within the city limits would have reassured a certain class of owners (and insurance companies) that their investments in built capital would be more secure than before, but for the less-fortunate group of owners in the suburbs, "fire-proof" materials (stone or brick) were prohibitively expensive. Wealthier property owners could cover the additional costs for materials (and missed opportunities) by erecting larger buildings with more rentable space. Evidence suggests that less-fortunate owners in the burnt districts typically redeveloped their properties in two stages: first, by erecting the most basic shelter in wood; and then, by encasing the structure in brick as soon as finances

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[42] See Montreal General Relief Committee (1853).

permitted.[43] By delaying the brickwork an owner risked being fined; therefore, many working-class residents petitioned the City to allow them to delay the bricking of their homes without repercussions.[44]

Given our understanding of the cyclical nature of capital accumulation in the built environment, it is not surprising to find temporal variations in the reconstruction process. The evidence for individual properties burnt between 1872 and 1889 suggests that the incentives to rebuild were stronger during an economic upswing rather than a depression. The outcomes confirm our expectations: during boom periods, rebuilding was more likely to involve morphological changes such as the intensification of land use; and these changes appeared to be greatest on more central properties, which were under the greatest competitive pressure. On the other hand, during an economic slump, property owners were not under as much pressure to rebuild quickly. They resisted rebuilding until it became more profitable; and they more often duplicated the old form, relying on insurance awarded, since they did not have access to additional capital to redevelop at a larger scale.

By levelling buildings that stood in the way, major fires facilitated improvements to circulation. I have already identified, and we shall see again in Chapter 4 in more detail, the need to widen, extend, and improve city streets. In densely built urban cores,

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[43] In the months immediately following the conflagration, editorialists often expressed concern over the number of wooden buildings being erected in the city, and declared their approval when owners of wooden buildings were prosecuted (for example, see *Montreal Pilot*, 16 July 1852, *Montreal Gazette*, 5 August 1852).

[44] For example, see petition dated 23 Novembre 1858, to the Fire Inspector and Members of the City Council of Montreal, by Jean Baptiste Berthelet, Paul Leveillé, Edouard Dépati, and Joseph Ouellet, labourers of Montreal.

where the amount of capital sunk into the built environment is greatest, street openings and widenings were costly and were sometimes resisted by the property owners who were expected to pay for them. Fire removed the "inertia"of built capital. For instance, when the Herald newspaper building on Victoria Square was razed by fire in 1887, the City blocked its reconstruction. The building which had "long been an eyesore, detracting from the beauty of the square"[45] had also become an obstacle to traffic, and its removal helped improve circulation around the square (see Figure 2.6). All of the street widenings in Montreal between 1850 and 1854 occurred in the burnt districts. The most significant work in the city centre during the 1850s was the widening of sections of St Paul, St Joseph, and Capital Streets, where property owners petitioned for the project. While civic leaders promoted wider streets as fire breaks and passed a by-law in 1851 demanding a minimum width of 60 feet for new streets, merchants in the crowded central core realized that wider streets would assist in the flow of goods in and out of their stores.[46] The conflagration also gave the city an opportunity to improve streets in the rapidly developing suburbs. The widening of St Catherine Street from 24 to 60 feet helped it become an important commercial strip, and Craig Street was extended eastward through the entire burnt district at a width of 80 feet. The City had had plans for this project since the 1840s, but experienced a difficult time in acquiring the land. It was not until the conflagration totally destroyed the area of the proposed extension that the remaining properties were expropriated.

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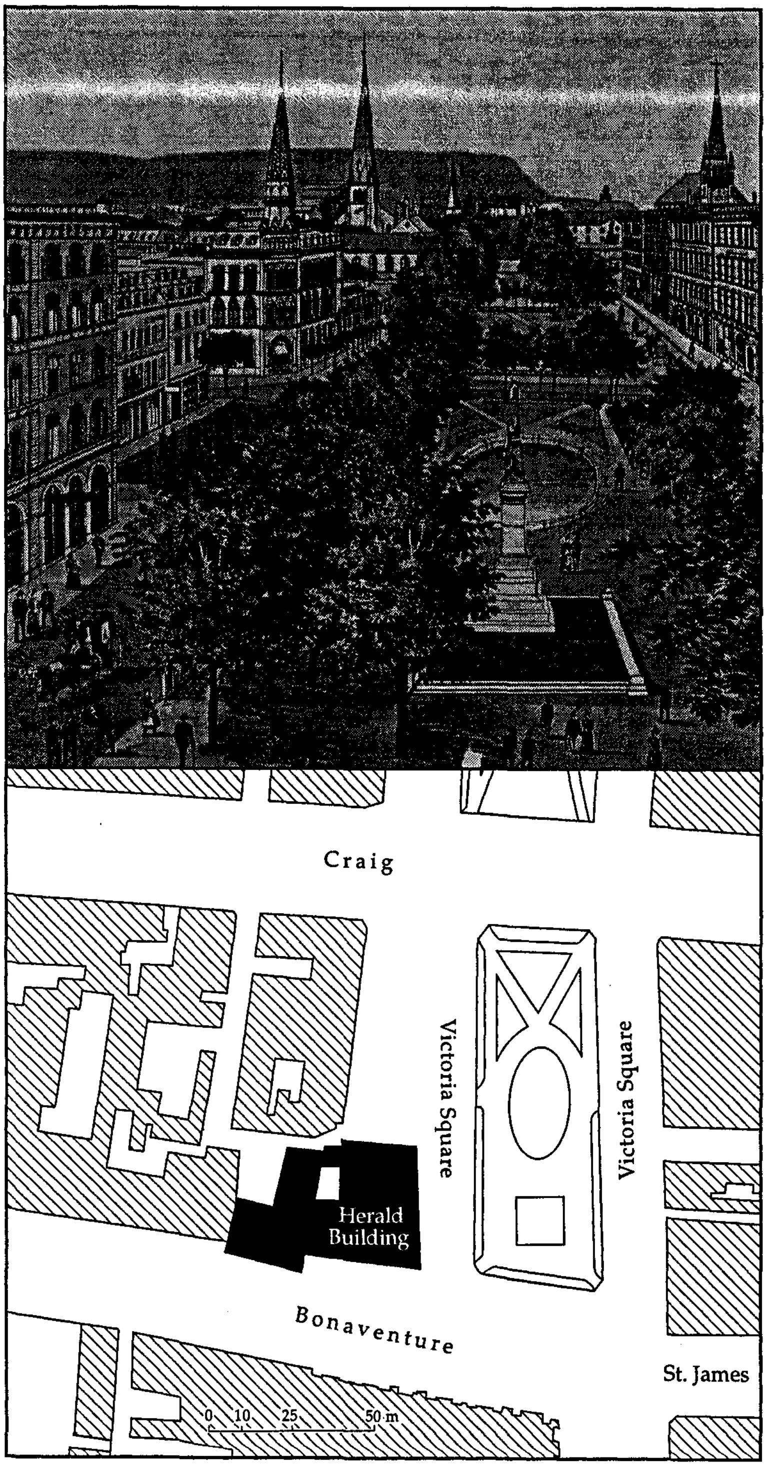
[45] *Montreal Gazette*, 27 August 1887, p.2.

[46] On St Paul, one of the only premises to survive the fire was a house owned by Viger and occupied by a hatter named Brown. This building represented a roadblock to the widening, and City Council ordered it torn down or moved back on the lot by spring (of 1853) (*Report of the City Surveyor* 1852).



2.6 Sketch and plan of Victoria Square showing position of Herald Building.
Sources: *New Album of Montreal Views*, c1885; Goad, C.E., *At!as of the City of Montreal*, 1890.

With most street improvement projects came the construction or replacement of urban infrastructure embedded in the street system, such as drains, water mains, sidewalks, and later in the nineteenth-century, gas pipes and electrical wiring. For instance, the conflagrations of 1850 and 1852 induced a massive overhaul of the water system by highlighting its inadequacy and stirring up public demand for improvements. Thus, even though a new water system was just completed in 1849, between 1853 and 1856 the City built a new reservoir and pumping station with five times greater capacity, and dug up and redimensioned several kilometres of water mains.[47] Craig Street was formed with "hard rubbish" gathered from the ruins of the July 1852 fire, the surface was macadamized, and the project completed with wooden sidewalks. Road building was a means of utilizing surplus labour during economic crises. Since in Montreal the destitute were often put to work on stone-breaking for roads, sufferers of the conflagration probably helped build Craig Street out of the remains of their own homes and neighbourhoods.

Consistent with expectations, the speed, intensity, and scale of post-fire redevelopment varied according to the centrality of the site and the timing of destruction. Properties located in areas under the greatest competitive pressure were most likely to be rebuilt quickly and to exhibit morphological changes which increased the height of the building, the building footprint on the lot, and the building envelope, as well as the solidity and durability of materials. Likewise, street improvements were most likely to be

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[47] Montreal General Railway Celebration Committee (1856).

carried out in the congested central core and along the main thoroughfares which connected the city with the newly developing suburbs. Evidence suggested that the basic pattern of urban growth which existed in Montreal before the conflagrations of the 1850s was not radically altered during the reconstruction period, but merely intensified: the slope of the cone of rental values was steepened, reflecting the play of demand and acceleration of activity in the city. The physical form of the city, reaching its greatest heights and density at the centre, was an accurate translation into stone of the accumulation of capital.

Properties destroyed during boom periods were rebuilt more swiftly, more completely, and with greater inputs of new capital, compared to those destroyed during depressions. The findings point to the pressures imposed by the cyclical nature of accumulation in the built environment. Each surge of urban growth brought a dramatic increase in the flow of goods and people through the city, increased competition for land, and intensified pressure to adapt built forms inherited from the past to accommodate new demands. Since built capital is frozen in place, long-lived, and difficult to change, a perennial source of conflict exists between contemporary demands and the legacy of investments in the built environment. In the nineteenth-century city, each new surge of growth produced massive congestion, or periodic foul-up of the urban growth machine. Fire, therefore, was an important agent of urban morphological change in the nineteenth-century city. Whether sporadic and catastrophic, or perennial and cumulative, fires provided opportunities to make much-needed improvements to the urban environment by removing the inertia of built capital, by levelling the structures which stood in the way.

The evidence points to the power of capital accumulation in determining the form of redevelopment: the response to the crank-up of land values in the previous boom (past 20 years or so); the significance of a landowner's access to capital and the availability of capital at a critical moment of truth; and the landowner's vision of a stream of profits or rents in the future (the next 20 or so years). As reconstruction was achieved, typically the owner's stream of income was enhanced, accumulation was accelerated, the stream of income (from taxes) to the urban Corporation was enhanced, flows of traffic were accelerated, and the profitability of the growth machine was again, for a few years, restored.

CHAPTER 3

Muddy Shore to Modern Port: Redimensioning the Waterfront Time-Space

> *The more production comes to rest on exchange value, hence on exchange, the more important do the physical conditions of exchange – the means of communication and transport – become for the costs of circulation. Capital by its nature drives beyond every spatial barrier. Thus the creation of the physical conditions of exchange – of the means of communication and transport – the annihilation of space by time – becomes an extraordinary necessity for it.*
>
> – Karl Marx, 1858[1]

For Montreal in the mid-nineteenth century, as for most port cities, the waterfront was the interface between the city and the markets of the world. My aim in this chapter is to examine the redimensioning of this critical urban time-space, a process indicative of both the process of modernization and the experience of modernity.[2]

The waterfront of Montreal at mid-century was anything but modern. Few ocean-going vessels of the day attempted to sail up the St Lawrence River as far as Montreal because of an opposing current and the shallowness of the harbour and its approaches. When Hugh Allan, the future millionaire and owner of the Montreal Ocean Steamship

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[1] Marx (1973, 524).

[2] "Modernization," according to Soja (1989, 27), "is a continuous process of societal restructuring that is periodically accelerated to produce a significant recomposition of space-time-being in their concrete forms, a change in the nature and experience of modernity that arises primarily from the historical and geographical dynamics of modes of production."

Company, landed in the port in 1826 at age 16, the 300 ton brig called *Favourite* required the aid of a steamtug, as well as ten oxen and 50 men pulling from shore. There were no docks or piers as he was used to in Scotland, thus the ship was anchored uneasily with its bilge against the muddy river bank, and the crew skidded the cargo, one piece at a time, down a crude wooden gangway to the beach, where carters waited with their wagons backed up to the axles in water, to haul the goods into the city.[3]

A port is a place where land and water-borne transport systems converge, where cargo and passenger traffic are exchanged across a waterfront (see Figure 3.1). The efficiency of the port, and the health of the urban economy as a whole, is represented by its ability to maximize traffic through this physical space at minimum cost and with minimum delay.[4] The waterfront, therefore, is at once both an interface and a barrier to exchange. The configuration of a port may contribute to its efficiency, or may form costly barriers, as Hugh Allan discovered on his first trip to Montreal. For cities to grow they must, again and again, remove barriers to circulation and expand the capacity of the urban vascular system; in particular, they must periodically redimension the entire landscape of the port.

Montreal, like other Eastern port cities of North America, underwent rapid industrialization during the second half of the nineteenth century; in synchrony, every 20

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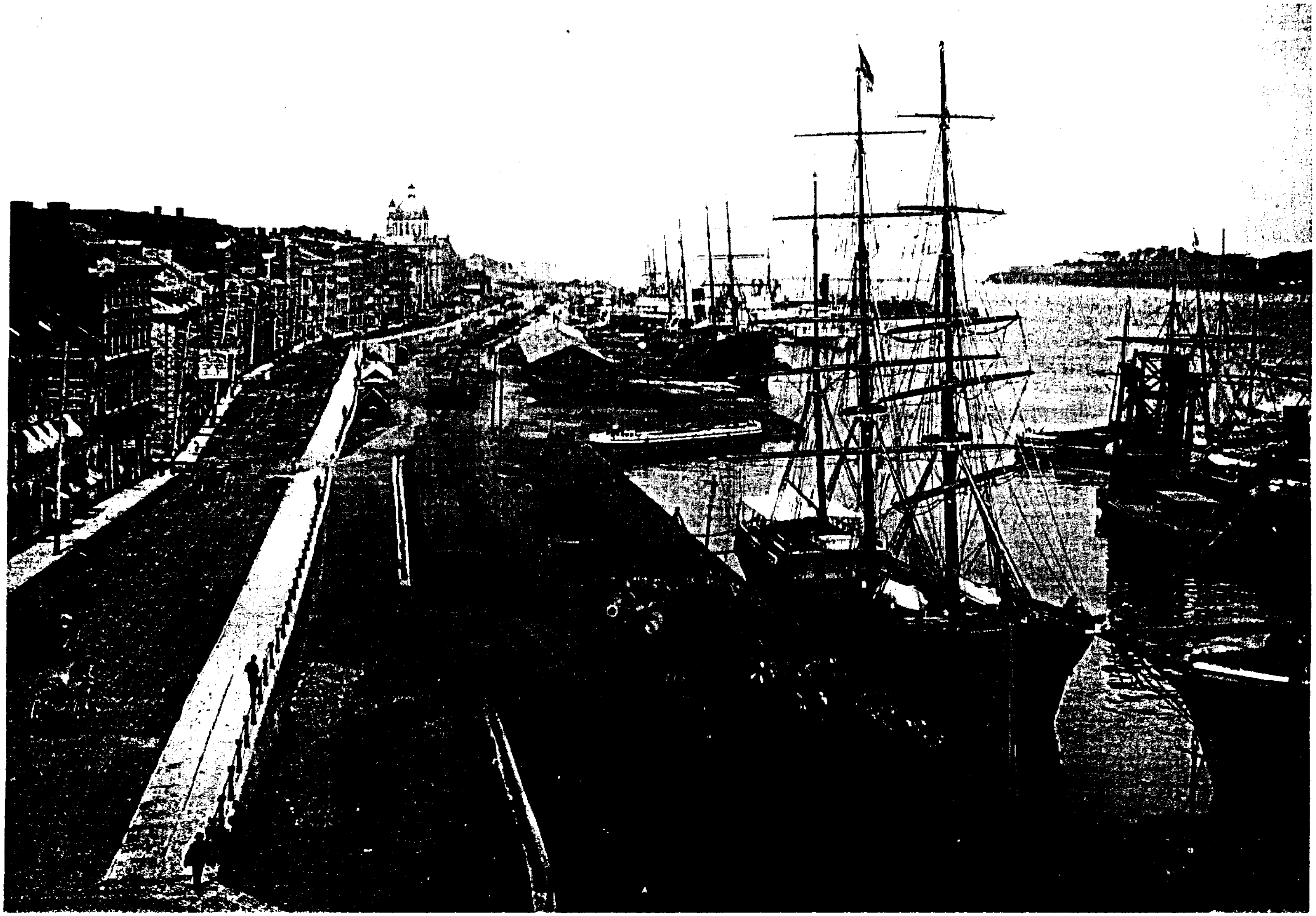
[3] The tonnage of a ship is the cubic capacity of the permanently enclosed space (i.e. hull, superstructure and deckhouses) calculated on the basis of 100 cubic feet being equal to one gross ton (Bonsor 1975). This opening paragraph was created using details of Allan's life provided in Appleton (1974), as well as other general descriptions of the port at this time (for example, see Talbot 1826; Atherton 1935; GRHPM 1982; Grant 1992).

[4] The most comprehensive studies on port functions are Hoyle and Pinder (1989) and Mayer (1988).



3.1 The interface between Montreal and the world in the 1880s.
Source: Archives du Port de Montréal #2201

years or so, a surge of immigration, investment, and construction (recall Figure 1.2).[5] Each wave of investment brought new technologies and structures which made older methods and facilities obsolete. The port area was periodically re-created to handle larger and faster ships and trains, to move a larger volume of goods in and out of the city: channels were widened and deepened, piers were added and lengthened, elevators and warehouses were built and rebuilt to carry heavier loads, rail-lines were introduced and augmented in parallel. Each round of "creative destruction" intensified circulation, raised the city's metabolism, and increased the effectiveness of connections between the city and its hinterland, the city and the world economy. The key to these changes was the shortening of turnover time by a redimensioning of the channels of circulation; in other words, the reorganization of the waterfront time-space.

This chapter examines the redimensioning of the Montreal waterfront from the mid-nineteenth century until the onset of World War I. This redimensioning, as we shall see, generated new shapes and functions in a three-dimensional space. To understand the processes which continually reshape the city, we need to keep in mind the compelling logic of the urban economy, that is the revolutionary dynamics of capitalism. In the remainder of this chapter I will provide evidence in support of the argument that technological change and the re-organization of labour were preconditions for the reformation, or modernization, of the waterfront, and these changes were a response to the demands of the nineteenth-century urban growth machine to speed up circulation. I

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[5] Mandel (1975) has made a close analysis of railway investment. See also Isard (1942).

begin with an examination of the growth machine and port management, follow with an investigation of the important technological innovations and the redimensioning of the waterfront time-space, and then conclude with a discussion of the way in which workers and citizens experienced these changes on the waterfront.

THE PORT AND THE GROWTH MACHINE

Even though Montreal was closer to European ports than its competitors – 2,760 nautical miles to Liverpool, compared to 2,861 from Boston, 3,043 from New York, and 3,335 from Baltimore – it was frozen for five months of the year, a serious disadvantage compared to the ice-free ports of the United States.[6] Modernization and restructuring of the waterfront was a strategy the Montreal growth machine used to hold onto its market, and to draw trade away from the rival ports. Although growth is usually portrayed as beneficial to everyone, its advantages and disadvantages are, in actuality, unevenly distributed.[7] All of the "built capital" of the city, described in Chapter 2, was created with human labour, literally petrified into stone for generations. Urban forms reflect the decisions of people who controlled property and deployed the labour of others, with the purpose of raising the values of their property and the stream of profits derived from it.

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[6] By 1908, the use of icebreakers began to extend the shipping season by one to two weeks. For example, between 1874 and 1907, the last ship to sail for the sea from Montreal left anywhere between November 20th and December 4th, whereas between 1908 and 1918, the last ship left somewhere between November 26th and December 14th (Tombs 1926). For further historical details on the Port of Montreal, see Cowie (1915).

[7] See Smith (1990) on uneven development.

Logan and Molotch (1987) argue that property owners, or "place entrepreneurs," in their constant pursuit of exchange values, form coalitions, or "growth machines," which then attempt to manoeuvre public investment towards the end of increasing profits by increasing the demand for their land.

The development of the port of Montreal was managed by a "growth coalition," a network of entrepreneurs who were in a position to benefit most directly from the enhanced flow of traffic. The Montreal Harbour Commissioners, established in 1830,[8] were the "river and railway barons" who deployed the commercial, industrial, and financial capital of the city.[9] Two of the original three Commissioners were prominent members of the business community: George Moffatt made his fortune in the fur trade, Jules Quesnel was a successful importer and member of the provincial Legislative Council, and the third, Captain Robert S. Piper, was a member of the Royal Engineers, enlisted for technical support. By the 1870s, Hugh Allan, the boy who had arrived on the *Favourite*, was "Sir Hugh," owner and president of the Montreal Ocean Steamship Company, and the quintessential "river baron." Not only was he President of the Board of Trade, but he sat on the board of many of the city's leading transport companies and financial institutions (see Table 3.1).[10] In a constant quest for profits, the growth

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[8] The Commissioners were appointed to carry into effect the Act of the Provincial Legislature, 10 and 11 Geo. IV, chap.28, "An Act to provide for the improvement and enlargement of the Harbour of Montreal."

[9] See Tulchinsky (1977) on the early "river barons."

[10] One position Hugh Allan did not hold was Harbour Commissioner. He left that one for his younger brother Andrew, commissioner from 1873-1906 (Atherton 1914).

Table 3.1
Business Activities* of Sir Hugh Allan (1810 - 1882)

Knighted (1871)

Public Offices

Board of Trade President (1851-1882)

Transport Sector

Millar & Company Forwarders (1835)
Montreal Great Northern Railway (1847)
Champlain & St Lawrence Railway (1847)
St Gabriel Lock Company (1850)
Montreal Telegraph Company (1852)
Montreal Ocean Steamship Company (1854)
Montreal Railway Terminus Company (1861)
Northern Colonisation Railway (1871)
Montreal and Champlain Railroad (1872)
Canadian Pacific Railway (1872)
Richelieu & Ontario Navigation Company (1876)
Canadian Navigation Company
Lake Memphremagog Navigation Company

Financial Sector

Bank of Montreal (1849)
City Bank (1856)
Merchants Bank (1861)
Canada Marine Insurance Company (1868)
Citizens Assurance Company (1869)
Montreal Credit Company (1871)
Provincial Permanent Building Society (1871)
Canada Life Assurance Company (1872)

Other Business Ventures

Canada Rolling Stock (1870)
Montreal Warehousing Company (1870)
Mulgrave Gold Mining Company
Vermont & Canada Marble Company

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* Companies for which Allan was president or director
Sources: Montreal Board of Trade (1893); Chambers (1903); Atherton (1914); Appleton (1974); Slack (1988).

machine of Montreal attempted, with considerable success, to obtain inputs – great dollops of capital – from colonial and military governments, then from the provincial purse, and later from the Dominion or federal government.[11]

MODERNIZATION AND THE WATERFRONT TIME-SPACE

On the eve of World War I, Frederick Cowie, Chief Engineer for the Harbour Commissioners, noted that

> a few years ago the bulk of Western grain came to Montreal in barges. These vessels, without machinery and with small crews, could afford to hold grain in storage until the ocean ship was ready for it . . . With the enlargement of the canals, much of the grain now comes to Montreal in steamers . . . These vessels cannot afford to wait, but must unload their cargo at once, otherwise they will not choose this port.[12]

Since the onset of industrialization, inter-urban competition has operated as an "external coercive power" over individual cities, forcing them to yield to the discipline and logic of capitalist development, while inducing, and reproducing, certain patterns of development.[13] In order to capture a greater share of global trade from competing growth machines, Montreal was compelled, over and over, to redimension its waterfront.

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[11] For a more detailed examination of the organizational structure of the Harbour Commissioners, see Brouillard (1979); on the politics surrounding railway and port investments, see Young (1972), Tulchinsky (1977), Linteau (1992) and Hanna (1998).

[12] Cowie (1913, 180).

[13] Harvey (1989, 10) makes this point with respect to the transition from Fordist to post-Fordist urban regimes; however, the roots of "globalization" are old and deep.

Technical changes in the movement and handling of goods were a precondition for this redimensioning, and these changes emerged in response to commercial challenges to reach new markets, lower costs, and reduce turnover time. The important changes were not initiated in Montreal, but in cities like Glasgow, Liverpool, and rival New York City, and were then imposed on Montreal.

Each wave of investment brought technical changes in marine engineering with respect to propulsion systems, hulls, and superstructures, which, taken together, enabled larger ships to travel faster, at lower unit costs, and with greater reliability. To document the impact of the modernization of shipping with respect to Montreal, we can examine changes in the fleet of the Montreal Ocean Steamship Company – also known as the Allan Line – the largest and most influential shipping company associated with the port during the study period.[14] Figure 3.2 shows the largest ship entering the port of Montreal at the crest of each investment wave. In wooden sailing ships of the 1830s, a journey such as Hugh Allan's first trip from Greenock to Montreal took about 6 weeks, and 4 weeks to return.[15] By 1856, the 1700-ton capacity iron steamships of the Allan Royal Mail Line were making regularly scheduled trips from Montreal to Liverpool in under

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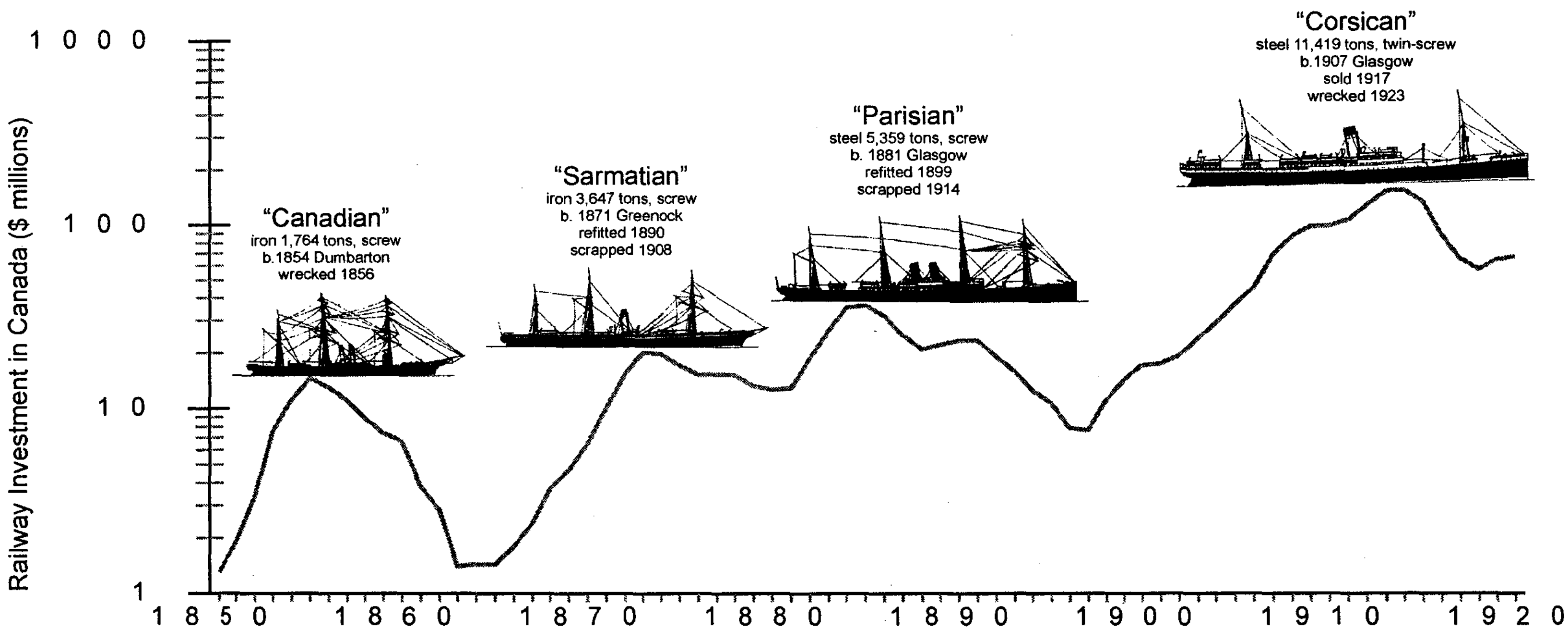
[14] For example, in 1892, the Allan's owned more ships entering the port than any other company (84 out of 735) and shipped the greatest quantity of goods (total tonnage of 203,953 out of 1,036,707) (*Annual Report of Harbour Commissioners* 1892). For a history of the Montreal Ocean Steamship Company, established in 1854, and Allan's early sailing vessels, see Appleton (1974). Specifications for all of the ships in Allan's fleet between 1854 and 1917 (until it was taken over by Canadian Pacific), are provided in Bonsor (1975, 278-325).

[15] Appleton (1974).



3.2 Waves of investment and size of largest ships in port

Sources: Bonsor (1975); Appleton (1974); Urquhart and Buckley 1965; Buckley 1974.

two weeks.[16] Hugh Allan publicly stated that ships of 1,700 tons were the most suitable for the Montreal trade, however, "year by year the Allans launched new boats, always bigger and faster."[17] By 1881, steam-power dominated, and Allan's vessel the *Parisian*, with its steel hull, multiple-compound steam engine, superstructure of decks, and machinery for handling cargo, defined the image of modernity for contemporaries.[18] It had three times the capacity of the 1856 vessel and reduced the travel time from Montreal to Greenock to just 10 days, barely a third the time of the *Favourite*.

Spectacular advances in the size and speed of steamships were associated with massive increases in the flow of trade through the port of Montreal. For example, ocean arrivals totalled less than 28,000 tons in 1832 and grew at a rate of about 6.6% per year: doubling by 1850, growing one-hundred fold by 1914 (see Figure 3.3).[19] Montreal's share of world trade also grew continuously from approximately 0.3% in 1850, to 0.6% in1872,

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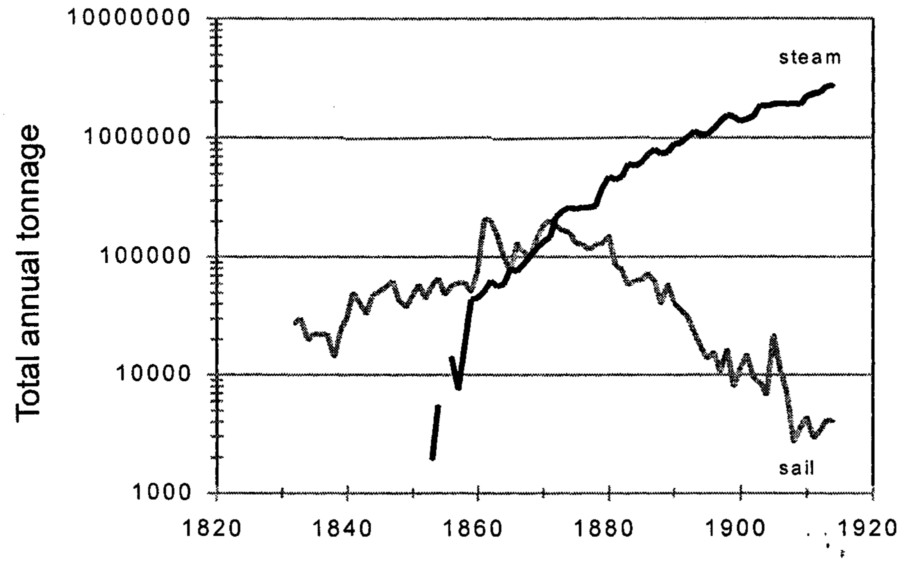
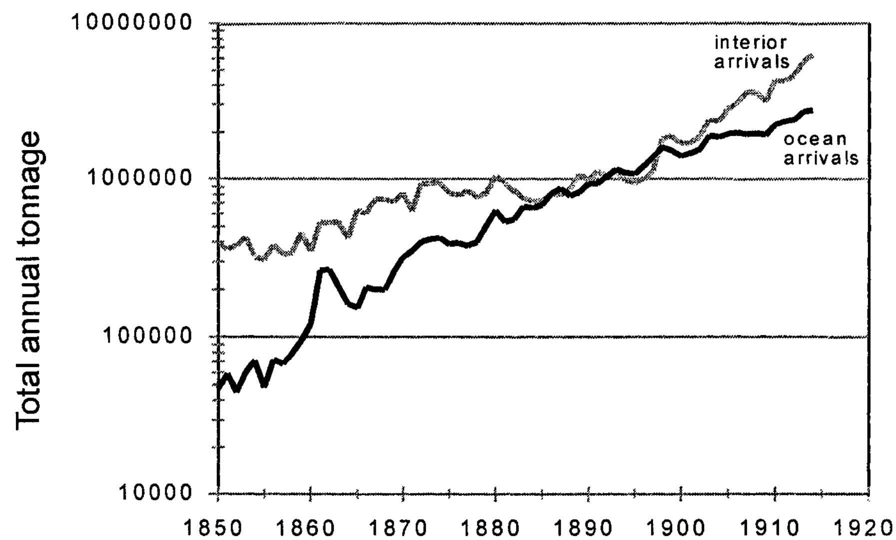
[16] Involved in the bi-weekly service of the Allan Royal Mail Line were the *Canadian, Indian, Anglo-Saxon*, and *North American.* The *Canadian* was the first steamship owned by the Allans. It was 277-feet long, had a capacity of 1764 tons, and provided accommodation for 80 first class passengers and 350 in steerage. Passages from Liverpool to Quebec cost eighteen guineas (approximately $80) in cabin class and eight guineas in steerage. These early steamers were propelled by single-screw, 2-cylinder engines (Bonsor 1975; Appleton 1974). Steamers had been used for river service on the St Lawrence as early as 1809. The first steamboat in Canada was John Molson's *Accommodation* which made its inaugural run in 1809 (just two years after Fulton's "Clermont" on the Hudson) from Montreal to Quebec in 78 hours.

[17] Atherton (1914, 581).

[18] In 1881, for the first time, a greater number of ships arriving in Montreal from overseas were steam powered (321 versus 248 sailing ships) (*Annual Report of Harbour Commissioner*). For a short time the *Parisian* was the largest steel steamship in the world. It was 440-feet long and could accommodate 150 first class, 100 second, and 1,000 steerage passengers. It was "fitted with four double-ended marine boilers supplying steam at 70 pounds per square inch to a three-cylinder compound engine of Gothic proportions which proved to be magnificently reliable. The *Parisian* completed 150 voyages without significant trouble" (Appleton 1974, 139).

[19] To best describe the exponential annual growth in ship traffic from overseas and the interior, we use the basic growth equation: $Q_t = Q_0 e^{at}$ (as discussed in Chapter 1, note 26*).





3.3 Tonnage of ships entering Port of Montreal. Top: sail vs steam ocean arrivals. Bottom: interior vs ocean arrivals. *Sources*: Hamelin and Roby (1971); Linteau (1972); *Annual Reports of Harbour Commissioners*.

to 0.8% by 1913.[20] Traffic arriving from the interior of Canada was even greater than that from overseas, increasing from about 400,000 tons in 1850 to 6.3 million by 1914; however, the rate of increase was lower, at about 3.9% per year (Figure 3.3).[21] These massive increases in traffic required, for each new surge, a redimensioning of the vascular system: namely the enlargement of the Lachine Canal, the St Lawrence River ship channel, the harbour and wharfage space.

The first piece of major surgery performed on the traffic arteries was a bypass: the 13.4 kilometre long Lachine Canal, completed in 1825, allowed vessels drawing 4.5 feet (1.5 m) to avoid the Lachine Rapids on the St Lawrence and connected Montreal to the Great Lakes.[22] Ocean-going vessels at that time drew close to 10 feet (3 m), so water travel beyond Montreal still involved transshipment to freight canoes (*bateaux*) or Durham boats. The size of the largest vessels on the canal was determined by the capacity of the locks, which, to compete with the Erie Canal (which was drawing more traffic from the Canadian West to the Port of New York), was quadrupled in the 1840s,

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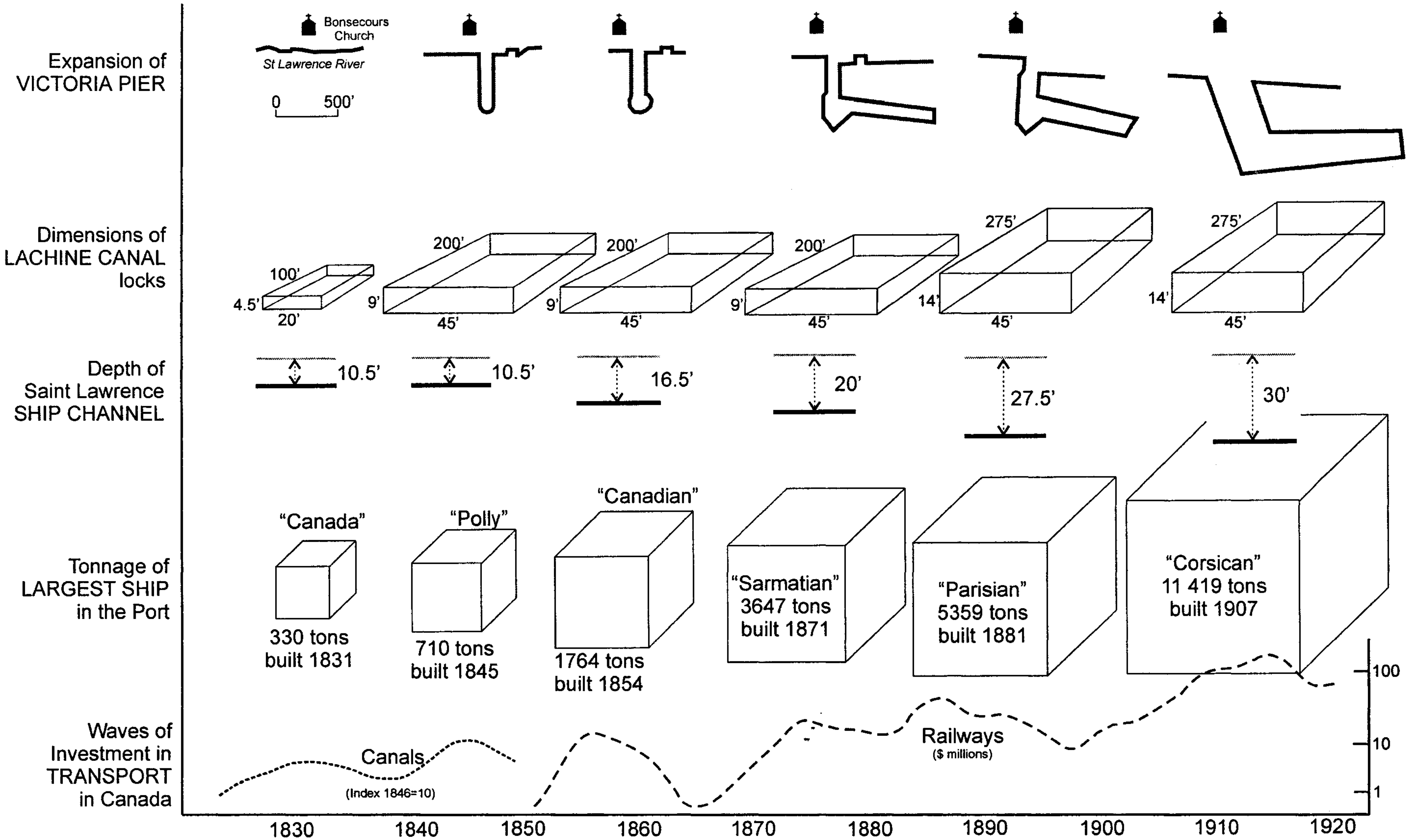
[20] Statistics on the growth of world trade can be found in Imlah (1958). Further trade data for Montreal can be found in Hamelin and Roby (1971) and Linteau (1972).

[21] *Annual Reports of the Harbour Commissioner* (1914-1918); Board of Trade (1893); Urquhart and Buckley (1965); Hamelin and Roby (1971).

[22] The work was initiated by private entrepreneurs (Company of the Proprietors of the Lachine Canal), but taken over and completed by the Province of Lower Canada. Before the opening of the canal, supplies were usually carted over land to Lachine for forwarding upstream by bateaux and Durham boats. The bateau was a flat-bottomed skiff about 12.5 metres long, two to three metres wide in the centre with pointed ends and had a capacity of about five tons. It was provided with masts and lug sails, and was typically managed by a crew of four, plus a pilot. The Durham boat was a flat-bottomed barge with keel and centre-board and rounded bows. It was about 25 to 30 metres long, three metres across, and had a capacity of almost 50 tons downstream (eastbound), but averaged only about eight tons upstream, due to the rapids (Tombs 1926).



3.4 Correlated growth on the Montreal waterfront, 1830-1914.
Sources: Annual Reports of Harbour Commissioners; Atherton (1914); Montreal Board of Trade (1893); Bonsor (1975); various cartographic sources.

and again in the 1870s.[23] The redimensioning of the locks is represented in Figure 3.4.

The size of the largest ocean-going vessels entering the Port of Montreal was constrained by the dimensions of the natural ship channel between Montreal and the sea, which was less than 3.5 metres (10.5 feet) in some places. Between 1850 and 1918, to keep up with the quantum leaps being made in the size of ships on the Atlantic, particularly those servicing the Clydeside ports of Scotland (i.e., Greenock and Glasgow), the Harbour Commissioners repeatedly dredged the channel, achieving a depth of about 10 metres (30 feet) in 1912 (see Table 3.2).[24] The allometric relationship, diagramed in Figure 3.4, is graphed in Figure 3.5, and the steep slope of the curve (3.2) indicates that a 10% increase in channel depth was associated with a 32% increase in the tonnage of the largest ship entering the port. Alternatively, we can state that a 10% increase in the size of the largest ship in the port was related to a 2.9% increase in the depth of the ship channel.[25] Combined with periodic expansion of piers, improvements to the channel

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[23] The canal itself was only 48 feet wide with a depth of 4.5 feet in the 1820s (1821-25); however, it was enlarged to a width of 120 feet and a depth of 9 feet in the 1840s (1842-48), and again to a depth of 14 feet in the 1870s (1875-78). By 1862, the canal was widened so that two vessels could pass safely. In addition, during each episode of redimensioning, the number of locks was reduced, which further diminished turnover time on the canal. For further details on the Lachine Canal, see: Bergeron et al. (1983), Willis (1983), McNally (1982), and Tulchinsky (1960).

[24] All of the work was carried out by the Harbour Commission and financed by tonnage-dues until 1888, when the Dominion Government officially recognized the St Lawrence as "the national route of Canada," and assumed the debt and further expenses incurred with respect to deepening the channel. The machinery used for dredging the St Lawrence was made by the same Scottish manufacturer of the equipment used to deepen the Clyde. For further discussion on the development of the ship channel, see Corley (1967), Cowie (1915), and Montreal Board of Trade (1893).

[25] Using the *power equation*, we can state the allometric relationship as: *Tonnage of Largest Ship* = 6.714 (*Metres of Channel Depth*)$^{3.192}$. Alternatively, the relationship can be expressed in the logarithmic form as: log (*Tonnage of Largest Ship*) = 0.827 + 3.192 (log *Metres of Channel Depth*). The coefficient of determination (r^2) = 0.936, level of significance (p-value) = 0.000.

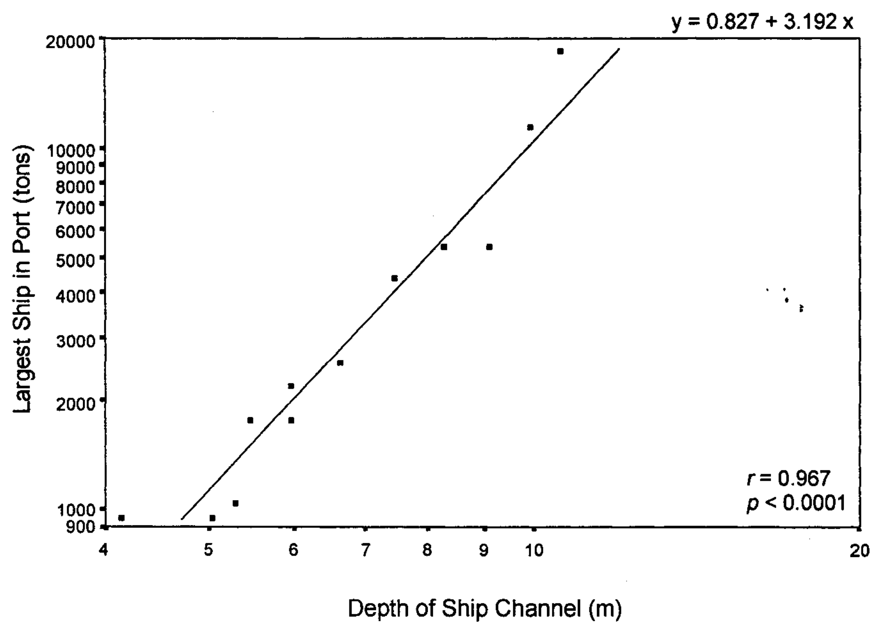
Table 3.2
Redimensioning of Montreal Ship Channel

Year	Depth of Channel (ft)
pre-1850	10.5
1851	12.5
1852	15.2
1855	16.5
1857	18.0
1866	20.0
1878	22.5
1882	25.0
1887	27.5
1907	30.0
1925	35.0

Note: Breadth of channel increased to 75' in 1850, to 150' in 1855, to 450' in 1897.
Sources: Atherton 1935; Montreal Board of Trade 1893; *Annual Reports of harbour Commissioners*

allowed the port to handle increasingly longer, taller, and deeper ships, and thus, a larger volume of goods in and out of the city.

The membrane between land and water is also critical; its form limits the scale at which goods can move across it. Here we focus on the edging of piers. Before 1830 there had been no official attempts to improve the port; there existed only a few hundred feet of privately-built wooden docks which were torn up by the magnificent ice shoves each spring. Due to the increased traffic brought by the new Lachine Canal, it became apparent to local merchants and politicians that permanent wharves were necessary. Between 1830 and 1833, the first Harbour Commissioners ordered the construction of ramps between the beach and the street (which was raised to about 20 feet above water),



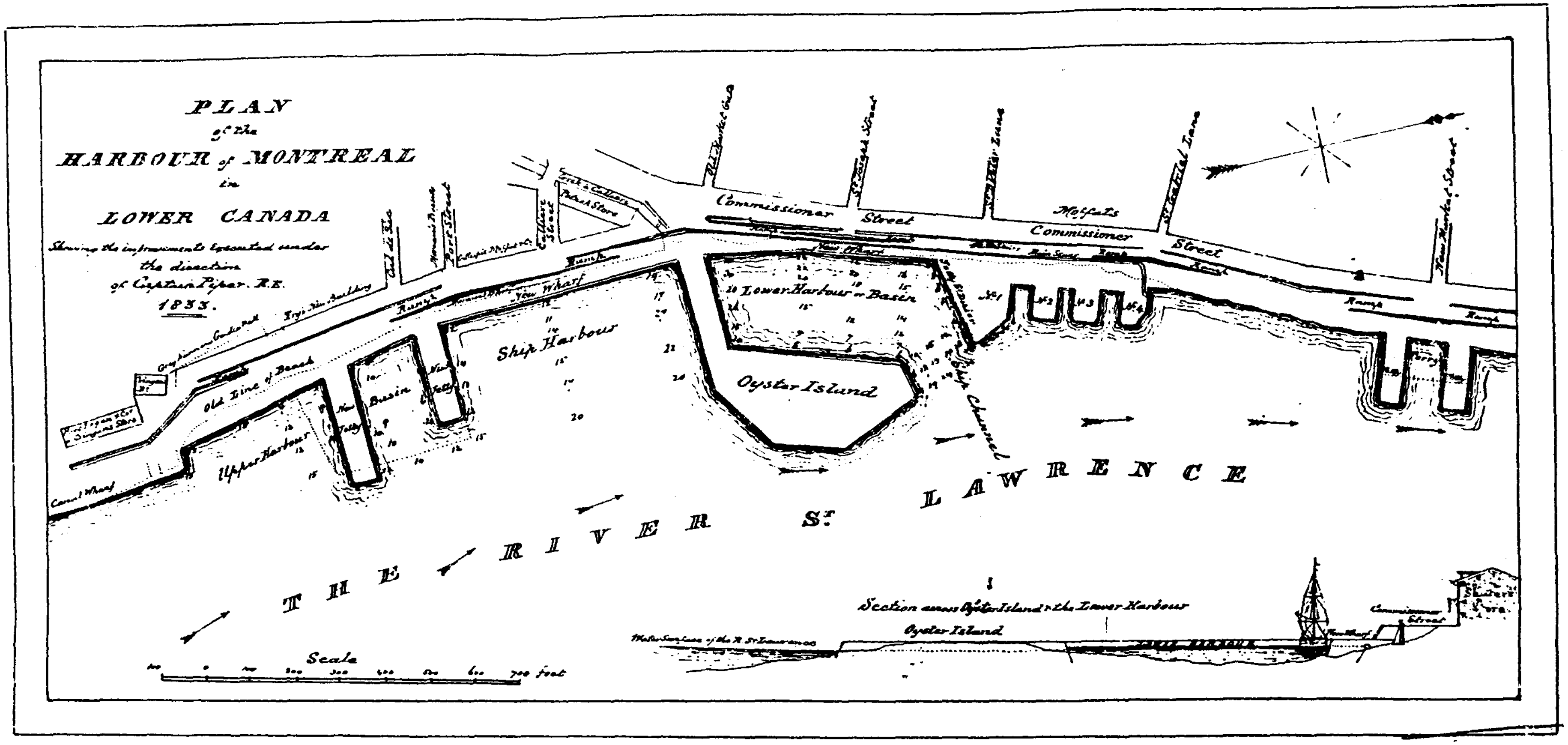
3.5 Relation between depth of ship channel and largest ship in port
Sources: see Table 3.2 and Bonsor (1975).

slips for Durham boats, and a wharf that encompassed the old mud flat of Market Island (see Figure 3.6). These harbour improvements were praised by members of the Montreal business elite, who nevertheless argued that much more accommodation for shipping and greater facilities for transhipment were necessary. Delays cost money, and some ships from overseas were being held in port for as long as three weeks before being able to secure a berth for unloading. The Committee on Roads and Improvements reasoned: "the great expense of such detention and the numerous other impediments to which commerce is at present subject, would far exceed the interest of capital, sufficient to make Montreal one of the most commodious ports on the Continent of America."[26] By 1847, the Commissioners undertook further works, including the widening and macadamizing of Commissioners street, and the building of new piers (Molson, Wellington, Russel, and Victoria).

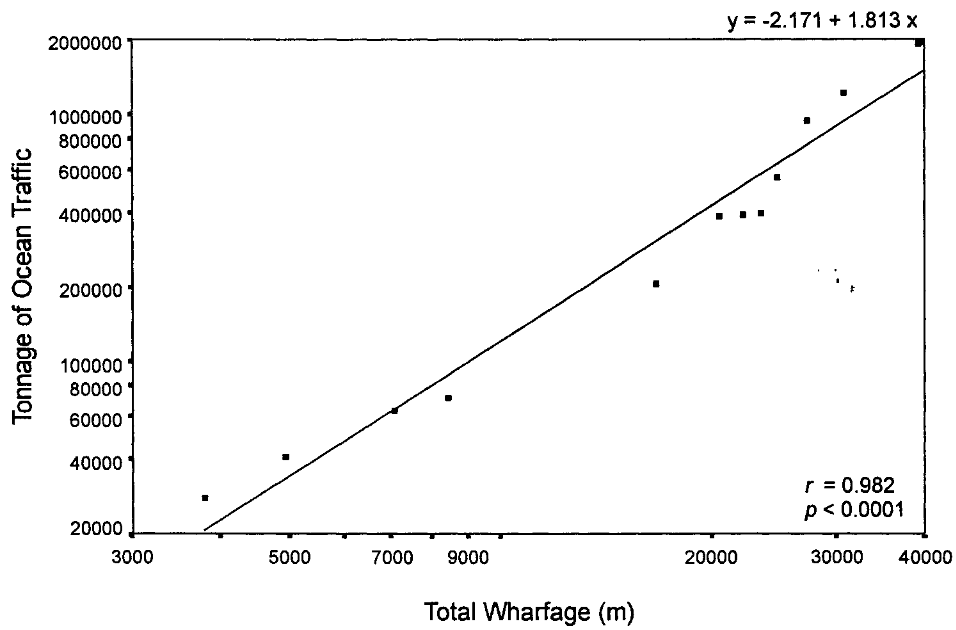
Although there were no large-scale pier-building projects carried out again until the boom of the late-1880s, increased ship traffic demanded a tripling of the total wharfage over the latter half of the century (see Figure 3.7). Most of the expansion of wharf space came, not by transforming the congested central portion of the port, but by developing new wharves downstream of the city (see Table 3.3).[27] Figure 3.7 reveals that an addition of 10% more wharf space was associated with a 18% increase in total ship

[26] Committee on Roads and Improvements (1841, 1). Document signed by Jules Quesnel (Chairman), O. Berthelet, Thomas Phillips, John Redpath, and J. Matthewson.

[27] A global plan for redeveloping the port was prepared in 1877 by chief engineer John Kennedy, but work did not begin until 1891 due to federal politics. The plan was eventually approved by the new Liberal government, and put into action by Minister of Public Works, Israel Tarte. Linteau (1992; 1972) has covered the political wranglings.



3.6 First permanent piers in Montreal, 1833
Source: Piper (1833).



3.7 Relation between total wharfage(m) and total annual tonnage of ships in port. *Sources*: Table 3.3; Hamelin and Roby (1971); Linteau (1972); *Annual Reports of Harbour Commissioners*.

Table 3.3
Expansion of Wharfage Accommodation in Port of Montreal

Year	Wharf Space (lineal ft)
1830	2289
1831	2989
1832	3797
1842	4950
1847	7070
1856	8440
1866	16737
1875	20585
1876	22184
1878	23548
1882	24809
1891	27360
1896	30772
1908	39452
1909	39180

Sources: GRHPM 1982; Atherton 1935; Montreal Board of Trade 1893; *Annual Reports of Harbour Commissioners*

tonnage. Alternatively, we can state that a 10% increase in the total ship tonnage entering Montreal was accommodated by a 5% increase in total wharfage.[28]

The first major improvement of this period was a long guard pier, to protect the harbour during the spring breakup of ice, and a large pier parallel to the entrance of the Lachine Canal (Bickerdyke). Then followed the new high-level piers near the centre, to replace the obsolete piers of the 1830s and 40s (Jacques Cartier [1898-99], Alexandra

[28] Using the *power equation*, we can state the allometric relationship as: *Ocean Tonnage* = 0.007 (*Metres of Wharfage*)$^{1.813}$. Alternatively, the relationship can be expressed in the logarithmic form as: log (*Ocean Tonnage*) = -2.171 + 1.813 (log *Metres of Wharfage*). The coefficient of determination (r^2) = 0.965, level of significance ($p< 0.0001$). The relationship can also be expressed the other way around: *Metres of Wharfage* = 20.045 (*Ocean Tonnage*)$^{0.532}$.

[1899-1901], King Edward [1901-02], and an expanded Victoria [1910]).[29] The evolution of Victoria Pier is illustrated in Figure 3.4. Around the same time, three new high-level piers were built further downriver near the city's border with Maisonneuve: Sutherland, Laurier, and Tarte, named after Liberal politicians who supported the project. By 1914, the total length of wharfage had doubled since the 1870s (see Figure 3.8). Another relentless supporter of these improvements was Raymond Préfontaine, Mayor of Montreal (and thus, ex-officio member of the Harbour Commission) from 1898 to 1902. In 1902 he left municipal politics to become Minister of Marine and Fisheries in Sir Wilfrid Laurier's cabinet (until his death in 1905), but through port improvements, he remained true to his promise to promote development in the east end of Montreal. We shall see his activities as chairman of the Road Department in the next chapter.

Not visible on the two-dimensional plan are the technical changes in cargo-handling and pier-construction which facilitated increased circulation. Again, the breakthrough technology was three-dimensional, changes in the vertical dimension produced the acceleration. To accommodate larger ships, the piers built between 1891 and 1914, as seen in Figure 3.9, were 28 feet above water, four times higher than the oldest piers; and, to handle larger volumes, they contained two-storey steel sheds, equipped with machinery for exchanging cargo between ships and the railcars and horsecarts which ran right through the middle. The increased mechanization – the powerful cranes and conveyors – radically altered the cargo-handling process, or what Allen Pred (1990) dubbed "the berthside ballet."

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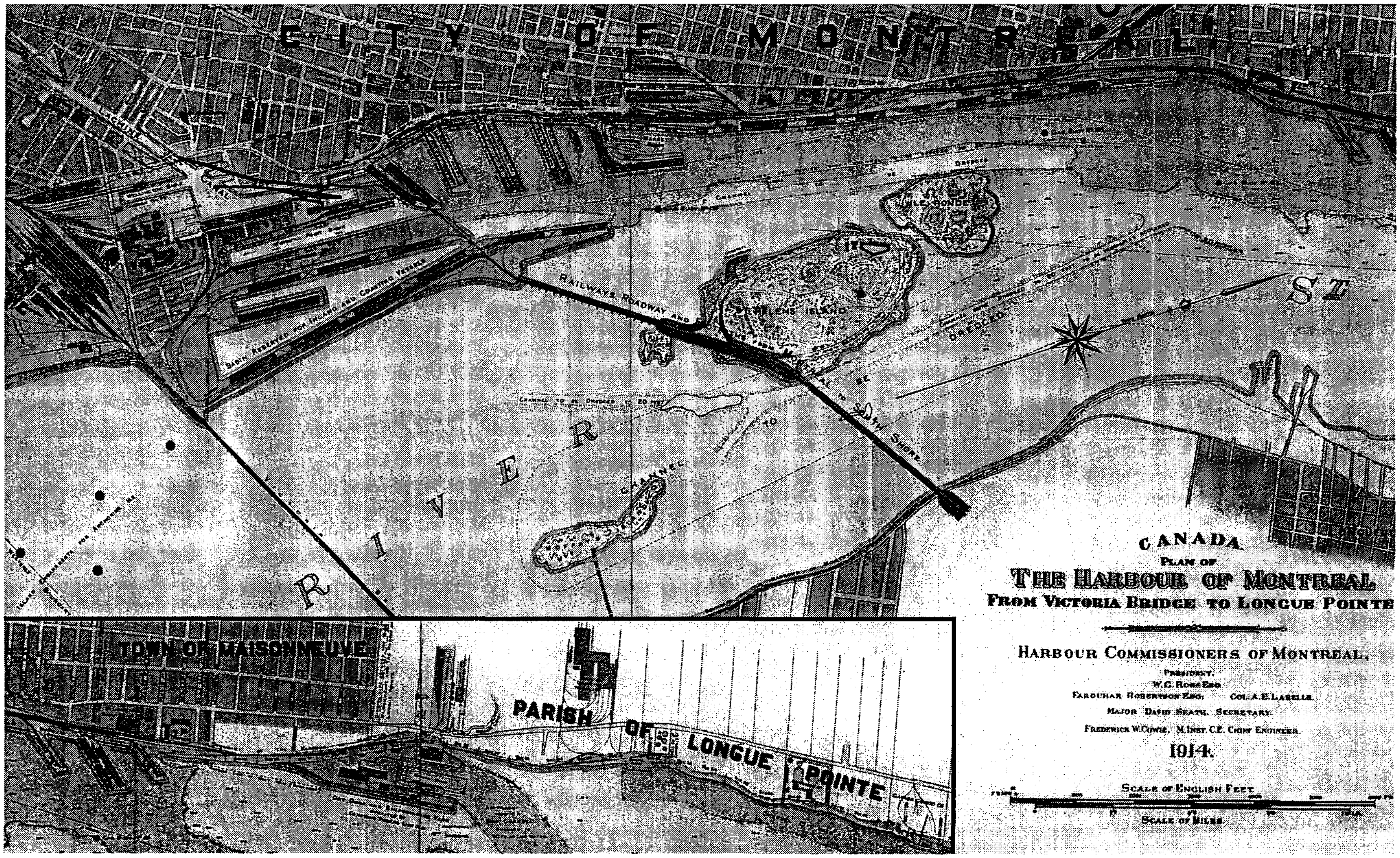
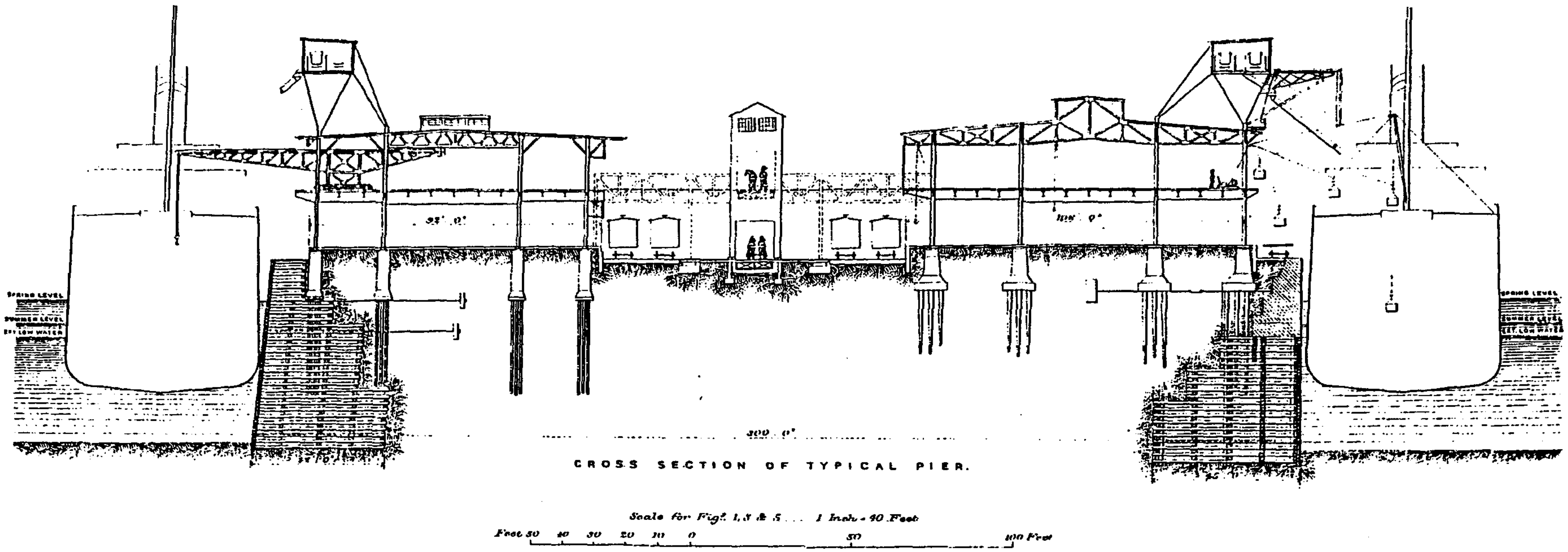
[29] *Reports of the Harbour Commissioners* (1850-1918), Hanna (1998), GRHPM (1982), Brouillard (1979) and Linteau (1972).



3.8 Plan of Montreal Harbour in 1914.
Source: Annual Report of Harbour Commissioners (1914)



3.9 Elevation of typical pier built after 1890
Source: Cowie (1914)

While steam technology helped to break time-space barriers on the sea, the steam locomotive did the same for travel on land. Although the full story of railway developments is beyond the scope of this thesis, a few points with respect to the waterfront deserve attention so that we see the critical zone of interlocking between the two modes.[30] In the 1850s, the Grand Trunk Railway opened a line to ice-free Portland which allowed Montreal merchants to bypass the Port of Montreal in winter, but also served to draw capital south. This line was made possible after the completion of the nearly two-mile-long Victoria Bridge in 1859. As the first bridge to cross the St Lawrence, it relieved a serious obstacle to circulation. Its single track was perceived as a bottleneck so that in 1897 it was recreated as a steel-truss bridge to carry two lines, a road, and a footpath.[31] The Grand Trunk laid the first rails on the docks in 1871, and the Canadian Pacific followed in 1885. Direct shipside access reduced the need for carters, and therefore, greatly reduced costs and turnover time. The attempts of railway corporations to monopolize access to the waterfront have been a bottleneck in port development in many cities.[32] In 1907, the Harbour Commissioners took over management of the tracks and opened up equal access to all companies. By this time, there were 28 miles of tracks on the port which handled about 70,000 boxcars per year;

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[30] A comprehensive history of railway development in Montreal remains to be written. For an overview of the railway story in Montreal, see Hanna (1998).

[31] On Montreal's bridges, see Lelièvre et al. (1999) and Triggs (1992).

[32] Cf. Olson (1997) on Baltimore, Goheen (2000) on Toronto.

and by 1918, the trackage had doubled and the annual volume of rail traffic had tripled.[33]

In the 1880s, upon completing transcontinental links to the Prairies, the Canadian Pacific built the first wooden grain elevators on the Montreal waterfront, and the city captured a major share of the grain trade to Europe.[34] Their massive bulk made them the first structures to challenge the traditional skyline of church steeples. Not limited by the city's ten-storey height restriction (enacted in 1901), the first steel elevators rose to twelve storeys and were truly the tallest buildings in Montreal.[35] These elevators were not merely storage bins, but mechanized grain-handling facilities which operated with gravity flow and steam power. The one-million bushel Grand Trunk elevator was positioned to empty lake freighters on the Lachine Canal side, load ocean-freighters on the Windmill Point basin side, and load and unload rail cars through the middle, at a rate of 100,000 bushels per hour. A 1910 concrete elevator was fifteen storeys high, had a capacity of 2.7 million bushels, and could expel grain at a rate of 150,000 bushels per hour (Figure 3.10). By 1921, Montreal had surpassed New York as the number one grain port of the world.[36]

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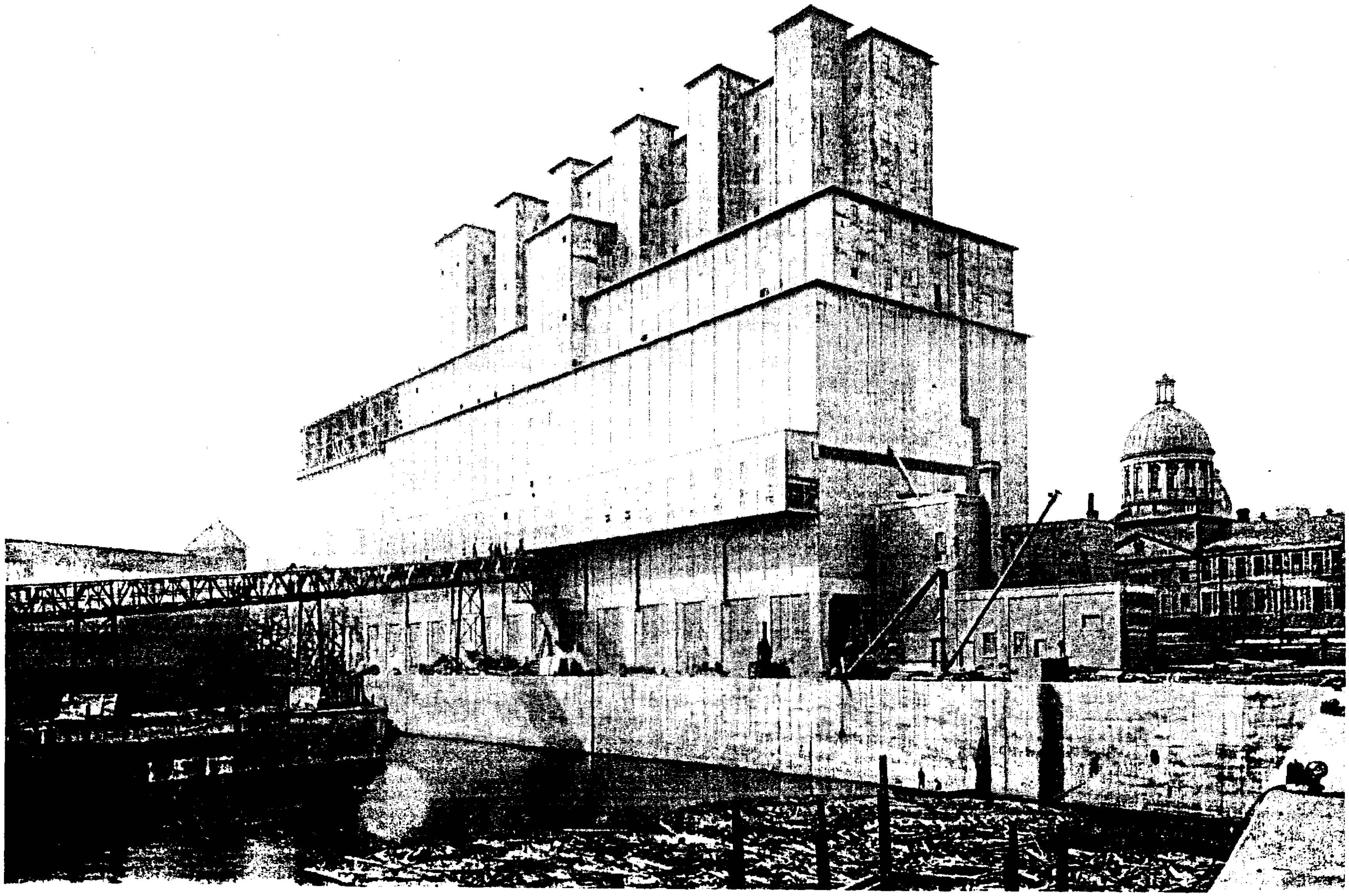
[33] *Report of Harbour Commissioner* (1918).

[34] The first structures for storing grain were built along the canal between 1859 and 1872 by the GTR, through its subsidiary, the Montreal Warehouse Company. These were not true "elevators," but long, linear, low-lying facilities. The first two elevators of the CPR, known as "A" and "B," were built in 1885 and 1887, and each had a capacity of 800,000 bushels (Hanna 1998; GRHPM 1981).

[35] These elevators had a capacity of 1,000,000 bushels. One elevator was constructed by the port (1902-04) and the other was constructed by the GTR (1903-06). (Hanna 1998; GRHPM 1981).

[36] For more information on Montreal grain elevators, see GRHPM (1981), Hanna (1998) and Tombs (1926).



3.10 View of grain elevator #2 in 1912. *Source:* Archives du Port de Montréal #667

One of the most important innovations the Harbour Commissioners instituted (in 1857) to reduce the turnover time of ships in the port was the steam-operated "floating elevator," which could be piloted out into the middle of the harbour to draw grain from the holds of lake vessels and deposit it simultaneously into ocean-bound freighters without touching a wharf.[37] Another important innovation was electricity. In 1880, Montreal became the first port in the world to light all its facilities by electricity, thus making it easier for longshoremen to load and unload cargo all night long (Figure 3.11).

LABOUR ON THE WATERFRONT

The night lighting points to the way in which technological and spatial characteristics of the port had direct implications for the organization of dockside labour. Because investments in facilities and machinery for handling ships and cargo tended to lag behind demand, the efficiency of the port depended heavily on the size, skills, and organization of its labour force. In order to lower the cost of production and speed up the rate of circulation, investors periodically intensified the degree to which they exploited labour. Indeed, testimony to the Royal Commission on Capital and Labour in 1889 reveals that all citizens did not benefit equally from the growth machine. Longshoremen endured miserable working conditions and extremely long shifts in order to reduce the time a ship or boxcar remained in port. The hazards of tasks such as "trimming" grain for hours in the poorly-ventilated hold of a ship were said to have sent "many men . . . to an early grave."

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[37] Tombs (1926).

3.11 Unloading ships by electric light, Montreal in 1880s.
Source: Picturesque Canada

A veteran stevedore testified that he "would prefer to work twenty hours right along in coal dust, to working two hours in grain dust."[38] The typical workday for a longshoreman in the 1880s lasted from 7:00AM until midnight; and shifts often lasted longer, even up to 55 consecutive hours near the close of the navigation season. Management of the Allan Line claimed: "It is absolutely necessary to work for that length of time then. The men are quite willing to do it; there is no compulsion";[39] while at least one Allan Line longshoreman said he had been told by a foreman, "if he was not man enough" to continue working after thirty hours, he would not work again for the company.[40]

Today's unionized dock labour captures a large share of increases in productivity in wages, but in the century before World War I, a perennial squeeze was possible because of surging immigration. Each surge of immigration re-created an exceptionally vulnerable work force for low-wage jobs on the docks. Well documented are the exploitation of Irish labour on the canals during the 1820s and 1840s, on railway construction circa 1851,[41] and Italian labour on the railways, tramways, tunnels and port

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[38] Testimony of John Brennan, Montreal stevedore, in *Royal Commission on Capital and Labor*, Quebec Evidence, 1889, p.150-55. Brennan, a stevedore for 23 years, testifies to the extremely long work shifts (up to 55 hours), the tendency for longshoremen to consume alcohol to stay awake, and workplace hazards.

[39] Testimony of Captain John Barclay, Marine Superintendent of the Allan Line Steamship Co., Montreal, in *Royal Commission on Capital and Labor*, Quebec Evidence, 1889, p. 169.

[40] Testimony of Patrick J. Dalton, Montreal longshoreman, in *Royal Commission on Capital and Labor*, Quebec Evidence, 1889, p. 182.

[41] Way (1997).

circa 1893 and 1913.[42] Whether or not investors could increase the rate of profit depended in part on the degree of resistance displayed by the working class. The greater the labour surplus and the more rapid its rate of expansion, the easier it was to hold down wages on the waterfront. Dock work employed labour gangs which were treated as interchangeable and paid as unskilled labourers, and the work was unstable due to a seven-month season. The history of the port includes a number of important strikes, some of which, like the massive 24-day longshoremen's strike in 1881, paralyzed the circulation of capital in the city (see Table 3.4). During a week-long carter's strike in 1864, one newspaper reported: "The business streets have a kind of Sunday appearance. The vessels have had to stop working, and the port has a holiday."[43] The carters struck again in 1871, but by this time their bargaining power had diminished, with railway cars arriving right onto the docks. Figure 3.12 reveals that the tendency for workers to strike was cyclical in nature, peaking during depression periods, when competition of seaports and entrepreneurs was intensified and transferred to press the competition among labourers beyond the limits of their toleration.

Nineteenth-century courts and police treated labour strikes as "unlawful restraints of trade," and until 1872, the formation of a labour union was considered an act of criminal conspiracy.[44] The 1903 strike by over 2,000 Montreal longshoremen was

[42] Ramirez (1991).

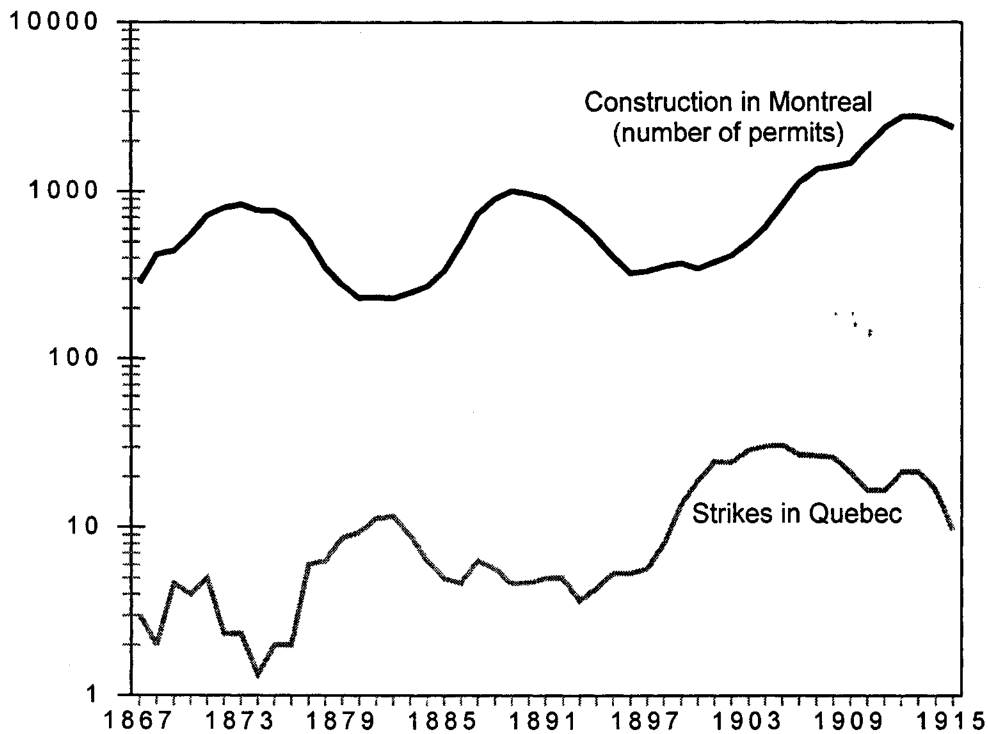
[43] *Montreal Witness*, 1 October 1864; quoted in Heap (1977).

[44] Grey (1949), Linteau, Durocher and Robert (1983).

Table 3.4
Details of dockworker strikes in Montreal, 1846-1900.

Year	Duration (days)	Companies Involved	Number of Strikers	Union	Dispute	Result
1877	8	Allan Line and others	1000		protest salary reduction	in favour of companies
1880	1	Dominion and Beaver	100		demand raise of 5 cents / hr	raise given
1880	9	Allan	200		demand raise	former employees won case
1880		Beaver Company		Society of dock workers	demand raise	company hired scabs
1881	3	Harbor Commission		Society of dock workers	demand raise	work resumed at same salary
1881	24	nine maritime companies	1000	Ship Labourers Society	demand raise	raise given by some companies
1882	13	all maritime companies		Society of dock workers	demand raise	in favour of companies
1886	2	Ogdensburg Coal-towing		Society of dock workers	demand raise	company hired scabs
1887	1	city gas company			demand raise	both parties compromise
1890	13	coal companies	300 to 400		demand raise	in favour of the company
1890	11	Allan company	100		dismissal	in favour of company
1895	12	Dominion Coal	800	coal workers union	non-unionized employees	return to work without conditions
1895	2	Dominion Coal	8	coal workers union	refuse to work Saturday night	in favour of company

Source: Hamelin et al (1970)



3.12 Cycles of construction in Montreal and strikes in Quebec, 1867-1915.
Note: Data smoothed with three-year moving average. *Sources:* Urquhart and Buckley (1965); Hamelin et al (1970); Thwaites (1984).

described in the newspapers as a "civil war." Strikes often failed because of federal and provincial labour legislation, the power of management in the workplace, and the deployment of police. Governments put an early end to strikes by forcing workers into arbitration. Local troops and militia were used regularly, while railways permitted the rapid entry of private security forces and scabs. To combat the longshoremen's strike of 1903, troops from Toronto were brought in to bolster the Montreal militia, while 1,000 workers were imported by the shipping companies as scab labour from Britain.[45]

CONCLUSION

The examination of the port reveals the several levels of competition which are operative in a capitalist society – among ports, among cities, among entrepreneurs, between social classes, and among workers. In the competition of cities, Montreal was forced to periodically redimension its waterfront. Technical changes in the movement and handling of goods were a precondition for this redimensioning, and these changes were developed by investors, ship owners, factory owners, land owners, railway owners, all caught up in their own levels of competition. Control over the means of production included the built environment of the waterfront.

This chapter has only provided a brief picture of the redimensioning of the waterfront. Also important was the symbolic value of the port image and its various

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[45] Young and Dickinson (1988); see also Morton and Copp (1980). For further discussion on labour and class struggle in Atlantic port cities, 1870-1914, see Broeze (1991).

features: for instance, the expansion of the neo-classical Bonsecours Market building which represented progress and stability; or the building and rebuilding of the massive railway stations, by competing lines, constantly trying to outdo each other. In the late-nineteenth century bird's eye views of the port, progress was symbolized with exaggeration of smoke and steam – the waterfront was a place where progress was dramatized, where we sense most acutely the contrast of old and new: for example, the forest of old-fashioned rigging versus funnels or smoke stacks. Invisible in pictures of the port is a very distinctive "soundscape" of whistles and bells and sirens, the shouting of foremen and workers, the creaking of wood, and the clanking of metal, which combines the progress and the disorientation, apparent in the literary and poetic shift from Romanticism to Modernism.

Today, due to the changing nature and importance of the shipping industry, the port of Montreal offers a very different landscape. Since the dominance of containerization and the movement of the working port further away from the city centre, longshoremen have become nearly invisible in Montreal, and the Old Port has been recreated as a landscape of leisure. The piers no longer convey grain into sheds, but tourists into the flea market or cafés. The last of the grain elevators now stand empty, and No. 5 has been adopted as a sounding-board for a symphony of foghorns: a new "postmodern" Romanticism. The elevators are relics of a different time when Montreal was the number one grain port in the world. Their fate lies in the hands of the new growth machine which contemplates their value as attractions to increase the flow of tourists, rather than grain.

CHAPTER 4

Street Widenings: Redimensioning the Streetscape

Montreal is a city that has grown from being a small town, built of narrow streets, and which has outgrown its first conception . . . it is a lesson to all of us who have any interest in good city government, to have a town laid out from the start with wide and straight streets

– Percival St. George, City Surveyor, 1895[1]

As we saw on the waterfront, rapid industrialization was associated with innovations in transportation and massive increases in traffic, and in the discussion of fires, we have already touched on the problems of congestion in the narrow and crooked streets of an ill-adapted urban core. If the traffic across the land-sea interface increased sixty-fold between 1850 and 1918 (recall Figure 1.1), then we can visualize bottlenecks also in the approaches to the wharves, to the railway stations and warehouses in the central core of the city. Since urban traffic circulates within a well-defined "vascular system," substantial increases in the flow of goods in, out, and through the city, should be correlated with the enlargement, or redimensioning, of all of the connected parts of the system; that is, the smaller capillaries like city streets, as well as the major arteries we examined in the last chapter. A vascular system which is inflexible and slow to change will cause congestion that can check urban growth.

The purpose of this chapter is to elucidate why and how the street system of

[1] St. George (1895, 32).

Montreal was "redimensioned" between 1850 and 1918. Evidence suggests that traffic on Montreal streets grew exponentially between the mid-nineteenth century and World War I. We will see that the implementation of new methods for managing streets helped relieve the clotting of traffic, but expansion of the capacity of the urban vascular system often required radical surgery, such as the widening of existing arteries and the opening of new streets, bridges, and tunnels as by-passes. My emphasis in this chapter, therefore, is on street widenings, a phenomenon which, although recurrent and widespread, has largely been neglected in previous historical research on North American cities. It is argued that these acts of "creative destruction," like reconstructions after fire and re-adaptation of the port, were driven by the perennial demands of the urban "growth machine" to reduce turnover time, and hence, to speed up the rate of growth of capital.

Before turning to a comprehensive examination of street widenings in Montreal, I begin the chapter with a brief discussion of the forces behind the redimensioning of the urban streetscape, and an investigation of some of the alternative methods used to improve the flow of traffic on Montreal streets. I will then focus on the spatial and temporal pattern of street widening operations city-wide between 1850 and 1918, and finally, I will perform further analyses on a set of three street widenings, to reveal information about the planning and execution of such operations, and to identify their effects on the urban fabric.

ANNIHILATING SPACE AND TIME ON CITY STREETS

Previous historical research on the physical (re)development of urban circulation systems has focussed primarily on the most spectacular operations in European cities.[2] One of the most dramatic and, consequently, the most familiar cases is the redevelopment of Second Empire Paris by Baron Haussmann under orders from Napoleon III.[3] While critics such as Walter Benjamin have attributed this massive project to the Emperor's concern with internal security, that is, his desire to control uprisings by obliterating the narrow, easily barricaded streets of the Middle Ages,[4] Haussmann's own *Mémoires* suggest that he was more of a sanitary engineer than a politician. Indeed, Haussmann "wanted to make Paris a capital worthy of France, even of Western civilization," but, as David Harvey argues, "in the end he simply helped make it a city in which the circulation of capital became the real imperial power."[5] Haussmann's primary goal was to create a general "circulatory" and "respiratory system" in which problems of traffic flow and ventilation were given priority over aesthetics and beautification.[6] Beyond widening streets and clearing insalubrious buildings, the essential feature of Haussmann's plan was the installation of a

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[2] The best discussions of streets in the past can be found in: Bedarida and Sutcliffe (1980), Anderson (1986), Kostof (1992, 189-243), and Çelik et al (1994).

[3] For a variety of perspectives on Haussmann's works, see: Pinkney (1958); Sutcliffe (1971; 1993); Gaillard (1977); Harvey (1985, 63-220); and Marchand (1993). For a comprehensive examination of change in post-Haussmannian Paris, see Evenson (1979).

[4] See Benjamin (1994).

[5] Harvey (1985, 76).

[6] Haussmann (1890-93). Cf. Choay (1969, 17-19) and Sutcliffe (1971, 11-42).

new sewer network and the cutting of broad diagonal arteries through the densely built fabric of the city. Haussmann's ideas continued to direct Parisian planning into the twentieth century, and had a significant impact on the redevelopment of other European cities, such as London and Rome.[7]

The Parisian model was a major inspiration for the City Beautiful Movement in North America around the turn of the twentieth century. While much has been written about the ideological debates and grand designs (rarely executed), much less is known about the impact of City Beautiful schemes on the transformation of pre-existing built forms.[8] Historians of the North American city have generally given only passing attention to the subject of street widenings, thus downplaying their effect on the city building process.[9] Nevertheless, most North Americans are familiar with the massive expressways carved through their cities in the 1950s, `60s, and `70s. Between Expo`67 and the `76 Olympics, during the pro-growth administration of Mayor Jean Drapeau, seven major expressways were sliced through the urban fabric. Most notorious in North America during this era are the projects of "power broker" Robert Moses, who, in the

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[7] On London, see Clunn (1927) and Schubert and Sutcliffe (1996). On Mussolini's redevelopment of the streets of Rome, see Kostof (1994).

[8] On the City Beautiful movement in North America, see especially: Wilson (1989). Cf. also: Reps (1965, 497-525); Van Nus (1979); Sutcliffe (1981); McCann (1996); and Stelter (2000).

[9] While there have been a few excellent historical studies of street improvements such as paving (McShane 1979), lighting (Bouman 1987), and traffic signals (McShane 1999), to the author's knowledge the subject of street widenings or street realignments has not been sufficiently dealt with for any North American city.

name of progress, directed massive public works which reshaped New York City.[10] In *All that is Solid Melts into Air*, Marshall Berman identifies the paradox of modernity by describing the tragic consequences of a "creatively destructive" act of modernization such as the cutting of a street through densely built neighbourhoods. Berman vividly recalls how Moses, with his "meat ax," cut the Cross-Bronx Expressway through the "heart" of the Bronx, making the once vibrant community "above all, a place to get out of."[11] The metaphor of cutting through meat, organs, or flesh has often been used to describe particularly destructive redevelopment projects. Haussmann used the term *éventrement*, and Mussolini's projects in Rome were called *sventramenti*; both terms literally mean disemboweling, or removing the gut.[12]

While previous historical research suggests that street widenings were typically performed for a number of reasons[13] – sometimes economic, military, political, spiritual, hygienic, or aesthetic – the primary aim was almost always to reduce the turnover time of capital by reshaping the channels of circulation, in other words, redimensioning the urban time-space. We shall see, in this chapter and in the next, that the relationship between street widenings and the intensification of capital accumulation are not entirely

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[10] On Drapeau, see McKenna and Purcell (1980) and Lanken (1986). On Moses, see Caro (1974).

[11] When asked if his expressway work posed any human problems, Robert Moses proclaimed: "When you operate in an overbuilt metropolis, you have to hack your way with a meat ax" (Moses 1970, quoted in Berman 1988, 293-4).

[12] Kostof (1994, 10).

[13] This point is made explicitly with respect to London, in Sutcliffe (1971, 27), and Dyos (1982, 81-86).

straightforward, and therefore they deserve some explanation before we proceed (see Figure 4.1). First of all, street widenings were believed to increase property values (link #1). This belief was built into the law governing expropriation.[14] In reality, the increased values were not a direct effect of the widening, but the result of the increased exchange values that could potentially be garnered from affected properties, with improved "environmental" conditions and the "bottleneck" removed. Every such expenditure was, by the City's definition, an improvement, and the right to "take" land presumed a value exceeding that of the old land use. Since the issue was about the taking of land, the ideological discussion revolved around land values.

While there is no denying that a street *can* accommodate more traffic once it is widened, distinguishing cause and effect is difficult, and has been the subject of much debate among transportation experts.[15] My primary argument in this thesis is that in the growing city, perennial increases in circulation repeatedly forced morphological changes to expand the capacity of the vascular system (link #4). Nevertheless, there are numerous studies which maintain that expanding the capacity of (already congested)

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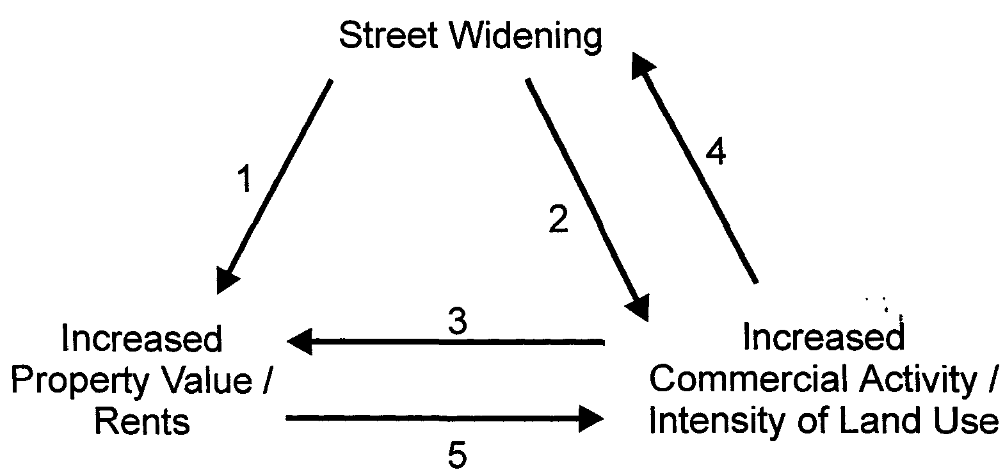
[14] According to the law on expropriations of 1865 (27 and 28 Victoria, Cap. 60, Sec. 13[8]), when compensating property owners who gave up portions of their land for street widenings, the Corporation was instructed to "determine, first, the intrinsic value of the part of the property and premises to be taken, and, secondly, the increased value, if any, of the residue of the property caused by the proposed improvement, and the difference between the intrinsic value of the part of the property and the premises required; and the increased value aforesaid shall constitute the price or compensation which the party or parties interested shall be entitled to, and when the said Commissioners shall determine and award that the increased value is equivalent to or in excess of the intrinsic value of the part of the property and premises required, then they shall not award any price or compensation for the part so required or liable to expropriation." (City Charter 1865, 417).

[15] Downs (1962), Goodwin (1996), DeCorla-Souza (1998), DeCorla-Souza and Cohen (1999), and Lee et al (1999).



4.1 Relations between Street Widening, Land Use, and Property Value routes *causes* additional traffic (link #2). This has been called "induced demand." Most of the perceived increase in travel can usually be explained by the shifting of routes, times, and modes of travel to exploit the new capacity of a given link; therefore traffic is only redistributed, rather than entirely new to the system.[16] Most studies of this type can be criticized for concentrating only on higher-level facilities such as provincial highways, without considering shifts from lower-level channels of movement.[17] While efforts to disentangle the simultaneous relationship between street capacity and traffic have thus far been limited, recent research nevertheless suggests that there exists a two-way relationship between supply and demand.[18] Although it is futile to attempt similar experiments for my historical time period, given the lack of available time-series data for such sophisticated analyses, we will nevertheless uncover historical evidence in this chapter (and the next) which contribute to the ongoing debate.

We have seen, in the port, how accumulation of exchange values depends on the efficiency of circulation, and this guided the actions and strategic efforts of the political "growth machine." The direct connection between circulation and profits –"time is money" – was understood by those who managed and controlled the city streets.

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[16] This phenomenon of shifting behaviour has been referred to as "triple convergence," and it has been used to argue that expanding highway capacity is an ineffective way to relieve congestion (Downs 1962).

[17] For example, DeCorla-Souza and Cohen (1999).

[18] Fulton et al (2000) included forward and backward lags in a model relating change in VMT (vehicle miles travelled) as the dependent variable to the change in LM (lane-miles), and discovered the backward lags were significant while the forward lags were not, thus implying that changes in LM generally precede changes in VMT. Nevertheless, they acknowledge that "this is not quite evidence of causality, i.e. that increases in lane miles *cause* increased VMT, since the results can be explained by `efficient' planning that correctly anticipates future growth in VMT by building new capacity in advance." (Fulton et al 2000, 16).

Joseph Saint-Cyr, president of the Montreal Tramways Commission (1918-34) identified the constant struggle to "annihilate space by time" in the following speech: "Dans toute grande ville, l'élément `vitesse' est un des plus importants . . . La distance est un élément secondaire . . . En effet, si je puis parcourir deux milles en cinq minutes, je ne demeure pas plus loin qu'à cinq minutes de marche. C'est là que l'adage américain `time is money' reçoit sa pleine application."[19] In redimensioning the street system, the exchange value angle was articulated over and over in speeches by politicians and business leaders. In his valedictory address of 1870, Mayor William Workman claimed: "The rapid improvement of our city, as displayed in the widening of our streets, has not only added greatly to the beauty of Montreal, but also to its revenue from the increased value of property which these improvements have brought."[20] Increased property values meant higher tax assessments, and therefore, greater revenues for the Corporation (Figure 4.1, link #1).

Although development is usually portrayed as beneficial to everyone, its advantages and disadvantages are, in actuality, unevenly distributed, and we shall have to consider in particular the spatial impacts, that is, the effects on properties in different locations and available for different uses. As was the case with port improvements, the redimensioning of city streets was managed by a network of entrepreneurs who were in a position to benefit most directly from the enhanced flow of traffic. One of the most

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[19] Saint-Cyr (1926, 19).

[20] Workman (1870, 9).

notorious actors during the latter part of the nineteenth century was Raymond Préfontaine. A brief look into his activities provides a hint of the political mechanism behind the network of lower-level channels operating at the municipal level, as opposed to the higher-level network of finance-capital, with inputs from the provincial and federal governments, which we saw in the case of the port. There are several tiers of capitalists and therefore several tiers of "state" intervention/manipulation. Préfontaine was Mayor of the suburban municipality of Hochelaga (1878-1883), and the first alderman of the new ward of Hochelaga, after he lobbied successfully for its annexation to Montreal (in 1883). Over the two decades following his first election to Montreal City Council (1884), as Chairman of the Road Department (1889-1898), and Mayor of Montreal (1898-1902), Préfontaine vigorously promoted suburban development through annexation, street paving, street widening, and tramway expansion, and was referred to by more than one writer, as "Montreal's Baron Haussmann."[21] As chairman of the Road Department he built an impressive political machine, cleverly using public expenditures to assure his own re-election, much like Robert Moses in twentieth-century New York City. He drew support primarily from the newly annexed wards in the east end where the demand for road improvements and public services was greatest. Class and ethnicity were important components to Préfontaine's machine, as the majority of residents in the newer wards were working class and French-Canadian. One of his harshest critics was George Washington Stephens, alderman for St Antoine ward in the west end, home to many of

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[21] Atherton (1914, 185).

Montreal's anglo-elite, who argued that the City Council had become "a band of speculators . . . who were building up their fortunes at the expense of the older wards."[22] A look at Préfontaine's network reveals that there may have been some truth to Stephens' accusations. Préfontaine's father-in-law, Jean-Baptiste Rolland, and his brother-in-law Jean-Damien Rolland were land developers in Hochelaga; his brother Isaïe was one of the largest landowners on the Island of Montreal.[23] Raymond Préfontaine himself was a shareholder in the Montreal Water and Power Company, the St Lawrence Electric Company, and the Montreal Land Improvement Company. The latter firm profited from developing land in the suburbs. It is no wonder, then, that Préfontaine was a major proponent of annexation and an ardent supporter of street railway expansion. In 1892, Préfontaine was influential in granting the Montreal Street Railway Company (whose yards were in Hochelaga) a favourable thirty-year contract, which contributed relatively little to the city's revenue, but hastened the development of the suburbs.[24] While Préfontaine was often credited for "modernizing" Montreal in the 1890s, it has also been argued that his handling of public funds helped drive the city into massive debt, while lining his own pockets in the process.

Investment in public infrastructure, like other types of construction, displayed a cyclical rhythm (recall Figure 1.2). Roadwork tended to lag just after the peak of each

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[22] *Montreal Daily Herald*, 9 June 1892 (quoted in Gauvin 1978, 24).

[23] See Linteau (1985) and Gauvin (1972; 1978).

[24] The MSRC paid the city an annual fee of 4% on receipts up to $1,000,000, while the Toronto Street Railway paid only 8% per $1,000,000. Both companies paid an additional 2% for every additional $500,000 (Gauvin 1972; Armstrong and Nelles 1986).

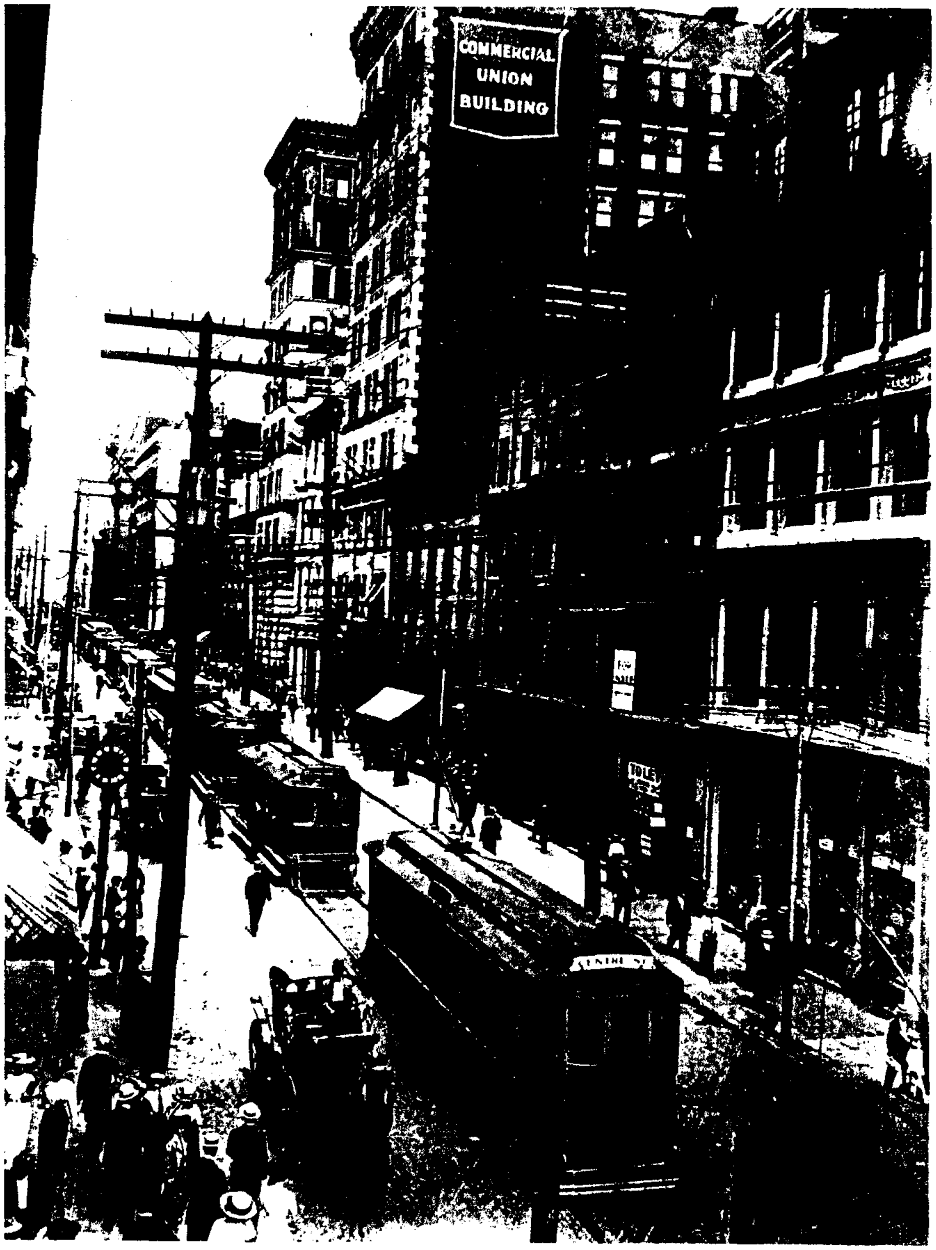
building boom, when capital was readily available and labour was cheap.[25] As discussed above, public investment is a tool to promote accumulation of privately owned capital, and when the rate of profit is low, private interests will typically seek more aggressively to manoeuvre public investment in infrastructure. Road building was a popular government strategy for utilizing surplus labour during crises of over-accumulation. Under the guise of "alleviating the distressed conditions of the labouring classes,"[26] the poor of Montreal were often put to work on stone-breaking. City politicians such as Raymond Préfontaine and James "the people's Jimmy" McShane (Mayor from 1891-93) promoted road works projects as job creators, particularly as "winter work" to support seasonally unemployed labourers (e.g., dockworkers, construction workers). As City Surveyor George Ansley noted, such acts of charity were also good value to the City, due to "the established fact that men work harder when wages are low than when they are high."[27]

In the mid-nineteenth century, Montreal was still a "walking city," traffic was slow-moving, and, as the City Surveyor moaned, the streets were narrow and crooked. Innovations in mass transit, namely the horse tramway (1861) and the electric streetcar (1892), enhanced the ability to move ever greater numbers of passengers through the

[25] The primary data for this study were gathered from the reports of the City Surveyor, available annually since 1842.

[26] Ansley (1876, 15).

[27] Ibid. Also revealing are Mayor James McShane's discussions on winter road work "for purpose of providing labor for the poorer classes" (1892, 3).



4.2 View of busy St James Street, 1910
Source: Knott (1976)

streets, at ever greater speeds.[28] The horse tram was a primitive service, cars were slow (about 8 km per hour) and infrequent, and service was limited to downtown streets. On the other hand, the electric streetcar made frequent passes and could reach speeds of up to 30 kilometres per hour, although it rarely did due to the congestion of horses, carts, and pedestrians on narrow streets (see Figure 4.2). Greater speeds meant decreased travel times, and thus, electrification of the network meant that workers could live farther away from their places of employment, the central business district could serve a wider area, and land speculators could profit from the extension of transit service into newly developing suburbs.[29] Figure 4.3 shows that by 1895 all residents in the City of Montreal, and most suburban residents, lived within a few minutes walk of a streetcar line. As historical geographer Chris Boone (1997) has noted, contract disputes kept the Montreal Street Railway Company lines out of St Louis du Mile End (north of Mt Royal Avenue) until 1901.

To explore the allometric relationship between traffic volumes and dimensions of the urban vascular system we can examine log-log plots comparing, for example, the largest ship entering the harbour with the dimensions of the ship channel, as we saw in the last chapter (Figure 3.5), or, as in Figure 4.4, the total flow of tramway passengers

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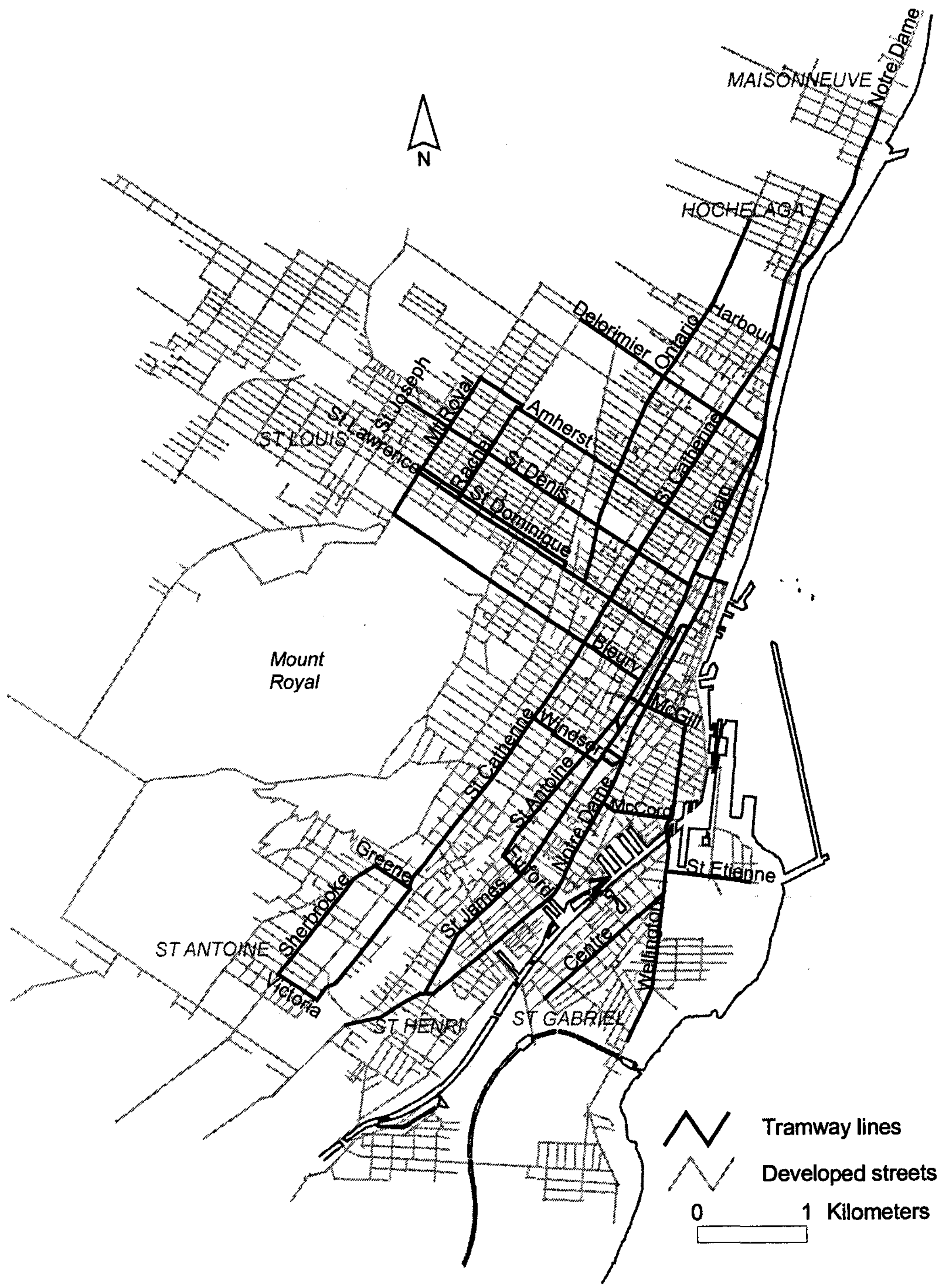
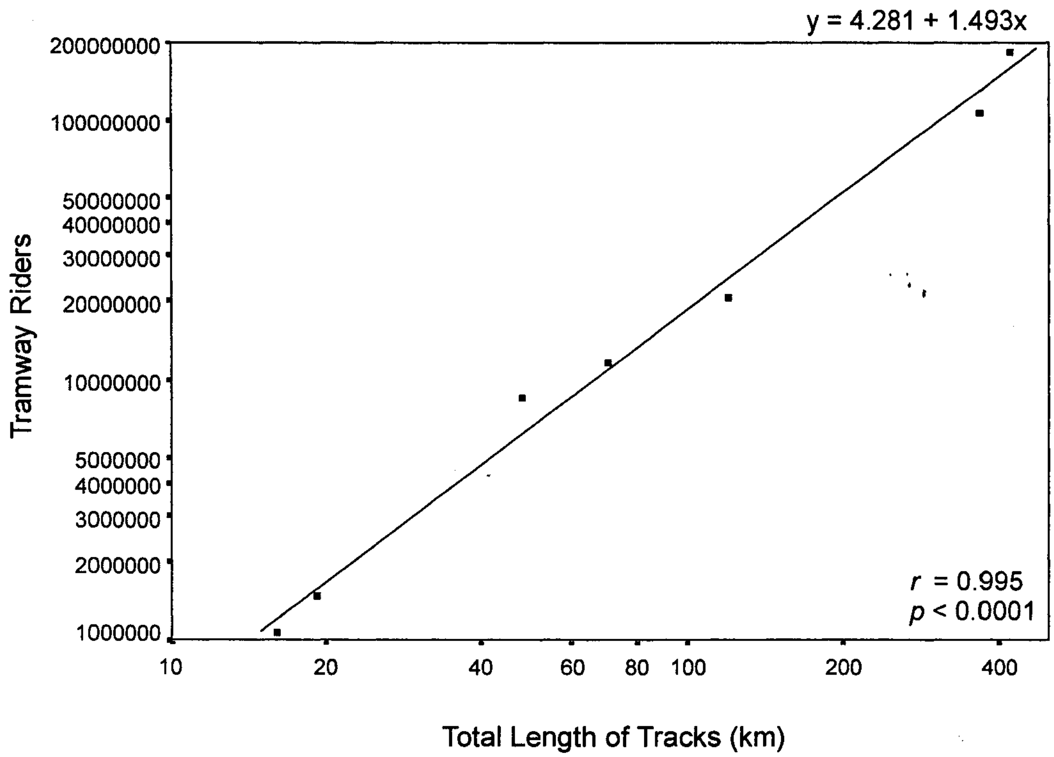
[28] A brief history of the Montreal Street Railway Company (known as Montreal City Passenger Railway from 1861 to 1886) is included in the annual report of 1910 (See MSRC 1910). A comprehensive analysis of tramway development in Montreal is beyond the scope of this thesis, although it deserves to be written. Boone (1996) and Armstrong and Nelles (1986) offer clues to tramway politics and company strategies in Montreal.

[29] Between 1892 and 1912, through 24 separate annexations, the city grew from 5,826 to 26,090 acres (Atherton 1914). The classic work on this subject is Warner (1978). See Boone (1996) and Linteau (1985) for interesting work on Montreal suburbs, St Louis du Mile End and Maisonneuve.



4.3 Electric streetcar lines in Montreal, 1895



4.4 Scatter showing relationship between tramway ridership and total length of tramway tracks (km). *Sources:* Vigneau and Richard (1996); MSRC (1910).

against the total length of trackage in the network. As we saw in the case of port traffic, the scatterplot reveals a virtually perfect linear relationship between flow and dimension. Also consistent with our expectations, a steep slope (1.5) indicates that the rate of growth of transit ridership was faster than the rate at which the rail network expanded.[30] Every 10% increase in the size of the rail network was related to a 15% increase in tramway passengers. The streetcar network is an interesting case because the rails themselves are linear constructs, of a fixed width, and expansion seems to take place in just one dimension (length). This is illusory, since the free and efficient flow of an expanding fleet of streetcars depended on the efficient arrangement of a three-dimensional streetscape.[31] For this reason, we might expect to find streetcar lines on the city's widest thoroughfares, and we can hypothesize that major street widening projects will have been undertaken to accommodate the installation of tracks.[32]

Over the latter half of the nineteenth century, the increased volume and speed of traffic, and the multiplication of various types of vehicles and infrastructures vying for street space, forced the municipal government to devote more attention to street management. The City Surveyor's office made a great effort to keep up with technological

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[30] Using the power equation, we can state the allometric relationship as: *Ridership* = 19099 $(\textit{Kilometres of Tracks})^{1.493}$. Alternatively, the relationship can be expressed in the logarithmic form: log (*Ridership*) = 4.281 + 1.493 (log *Kilometres of Track*) ($r^2 = 0.991$, $p < 0.0001$).

[31] In 1875, the Montreal City Passenger Railway owned about 400 horses, and a fleet of 62 cars, 41 sleighs and 21 omnibuses. By 1889 the Montreal Street Railway Company owned over 1000 horses, 150 cars, 104 sleighs and 49 omnibuses (Montreal Urban Community Transit Commission 1970).

[32] Besides the addition of tracks, improved connectivity of tramway lines was a further factor in boosting ridership, and, as we shall see in Chapter 5, the relative accessibility of a street was an important factor in the location of tramway lines.

advances in methods of paving, lighting, cleaning, snow clearing, and drainage.[33] To keep up with the latest innovations, Montreal's City Surveyor often visited cities in the United States (especially "winter cities" such as Buffalo and Boston) and maintained correspondence with contemporaries from as far away as London. In choosing permanent street pavements for Montreal, for example, City Surveyor George Ansley gathered information from his counterpart in Toronto and members of the American Society of Civil Engineers in Boston, Providence, New Haven, and New York, then evaluated the materials according to the smoothness of the surface, the foothold for horses, facility of removal and replacement, cleanliness, noiselessness, durability, and cost, and then made his decision according to the type of traffic on each street.[34] The first "permanent" street pavements in the city were the square pine and tamarack blocks laid in 1842 on the city's most important streets: Great St James, Place d'Armes, Notre Dame, and St Paul. Six years later the paving was already in a bad state, and it was replaced in the mid-1850s with limestone blocks, which lasted about 11 years. In the 1860s and 1870s, the city experimented with granite and cobble stone.[35] By the 1880s, granite block pavement was recommended for business thoroughfares where traffic was heavy, such as St James, Notre Dame, St Lawrence, Craig, St Paul, Bleury, Wellington and Commissioners; cobble stone was deemed suitable for narrow and less frequented streets such as St Nicholas, St Alexis, Hospital, St Eloi, and

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[33] See annual reports of City Surveyor. While municipal services have been mentioned briefly in histories of Montreal (e.g. Linteau 1992), none of these subjects has been adequately examined for this city.

[34] Ansley (1882).

[35] *Annual Reports of the City Surveyor.*

Fortification Lane; while macadam or broken stone was endorsed for major streets in residential areas, such as Dorchester, St Catherine, Sherbrooke, St Denis, St Hubert, Ontario, and University.[36] By 1895, roughly 15%, or 43 km out of about 275 km, of streets in Montreal were paved.[37] Street paving was just one of the three-dimensional improvements to the urban vascular system which were undertaken to augment traffic flow. We will return to the issue of the geography of street paving in the next chapter.

Traffic management by automatic signals and one-way streets was not introduced into Montreal until after World War I, but another means of promoting traffic flow and cutting travel time was the restriction of certain activities. The city became increasingly more regulated over time: from 24 by-laws on the books in 1865, to 127 by 1880, 257 by 1900, and 682 by 1918. Municipal government exerted greater control over its streets with by-laws regarding such things as: the transport of household waste, explosives, animals, and dead bodies; the operation of tramways and other vehicles for hire; parking; storing materials on the street; peddling and selling; pedestrian behaviours such as begging, noise, drunkenness, and loitering; the maintenance and use of sidewalks; and the encroachment of private buildings on public space. Stricter by-laws helped combat what one self-proclaimed "traffic doctor" referred to as "the arterio-sclerosis of traffic and circulation;" however, to expand the capacity of Montreal's vascular system required radical surgical procedures.[38]

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[36] Ansley (1882).

[37] *Annual Reports of City Surveyor* (1889-1895).

[38] Seurot (1929). In Montreal, the one-way street and automated traffic lights were introduced after WWI (French 1926). See Foster (1979) on traffic planning in the U.S. (1900-1940), and McShane (1999) on the history of traffic control signals. McShane (1999) claims that the first automated traffic signal was

THE SPATIO-TEMPORAL PATTERN OF STREET WIDENINGS

Alterations to the street plan were very difficult, especially when they encroached upon individual property rights. In densely built urban cores, where alterations were usually needed the most, the amount of capital sunk into the built environment was greatest, and thus, street widenings were extremely troublesome and controversial. This is why we find that some of the most magnificent, yet brutally destructive, public works projects were carried out by autocrats in authoritarian regimes (Napoleon III in Paris, Mussolini in Rome, Hitler in Berlin). In early nineteenth-century Montreal, the municipal corporation had no effective power to take land for public improvements, as the seizure of private land without the consent of its owner was forbidden until 1845.[39] Throughout the latter half of the nineteenth century expropriation legislation was in a constant state of flux, as the municipal government attempted to expand its right to intervene over private property within the city. The provisions of the City Charter relating to expropriation were amended ten times between 1864 and 1891.[40] The significant trend was toward erosion of a property owner's right to veto an improvement. While many modifications were made, two basic elements of expropriation law remained: (1) owners who fronted on the

located in Cleveland in 1914.

[39] See comments by first Mayor of Montreal, Jacques Viger (1840), on the "defectiveness" of existing road laws. Amendments to the Charter in 1845 (Section 82) made it lawful for the City Council "to purchase and acquire" any land required for opening and widening streets and improving public places provided that it does not exceed 100 feet in depth (Montreal 1845, 56).

[40] See Citizens' Association (1869), Spira (1992), and various editions of Montreal City Charter.

improved right of way were indemnified for their losses, whether by jury or by amicable arrangement; and (2) directly affected owners were assessed for a share of the cost of improvement: typically one-half, but ranging from one-third to the whole. While the taking of private property for public use was never a simple procedure, between 1850 and 1918, the municipal government of Montreal managed to expropriate thousands of properties to open and widen its streets.[41] A closer examination of these operations reveals that there was a distinct spatial and temporal pattern to street widenings in Montreal.

Between 1850 and 1918, approximately 45 kilometres of streets were widened throughout the city.[42] Most widenings occurred in the centre of the city, where traffic was heaviest and the streets were old and narrow (see Figure 4.5). Almost all of the widened streets were originally laid out before 1850, when Montreal was still very compact and

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[41] Over 2250 properties were expropriated between 1850 and 1900. The primary data for this study were gathered from the annual reports of the City Surveyor, which, between 1842 and 1894, contain information on streets widened, opened, and properties expropriated. After 1894 the annual reports are less detailed, and therefore, to ensure reliability up to 1918, the database was evaluated and supplemented with information painstakingly gathered from minutes of the Road Committee, dossiers of the Expropriation Committee, amendments to the City Charter, and reports of the City Treasurer and Comptroller (all located at the Archives de la Ville de Montréal). To ensure integrity of the database, the findings were systematically checked against various historical atlases and the official homologation plan of the city (Archives Nationales du Québec).

[42] The maps presented here only include streets that were already built upon at the end of each boom period, and exclude those streets which appear on the original source maps, but were just laid out or merely projections. The primary cartographic sources for this period include: Cane (1846), Plunkett and Brady (1872), Goad (1881; 1890; 1912; 1918), Pinsoneault (1907). City Surveyor reports indicate that engineers Plunkett and Brady were contracted in 1863 to deliver their map by 1865, but in 1868, their field notes were transferred to the city, and then to Walter Shanley, who completed the map in 1872 (see *Annual Report of the City Surveyor*, 1866, especially pages 9-10). Hanna (1986) argues that the map is accurate up to 1869. For further discussion of the atlases, see Hanna (1986).

4.5 Street Widenings in Montreal, 1850-1918
Source: see Note 40

there were few restrictions on how a road should be built.[43] As hypothesized, the most important projects involved the widening of streets with tramway lines (St Antoine, St Lawrence, St James, Notre Dame and Bleury), and the major thoroughfares which connected the core with newly-developing suburbs (compare Figures 4.3 and 4.5). With the introduction of railways, many of the smaller streets surrounding the stations (indicated with stars) had to be widened to handle traffic increases at these nodes.[44]

The temporal pattern of street widening operations, like that of urban construction in general, was cyclical in nature. Let us now take a look at the widenings carried out in successive phases of the building cycle (1850-1866, 1867-1880, 1881-1900, 1901-1918). Most of the work carried out during the 1850-1866 building cycle occurred near the height of the building boom.[45] In the early 1860s, the Corporation widened large sections of several major streets, including Notre Dame, St Bonaventure (St James West), St Catherine, Bleury, Guy, and Sherbrooke (see Figure 4.6). While these streets are major arteries in the city today, in the mid-nineteenth century most were barely 30 feet wide,

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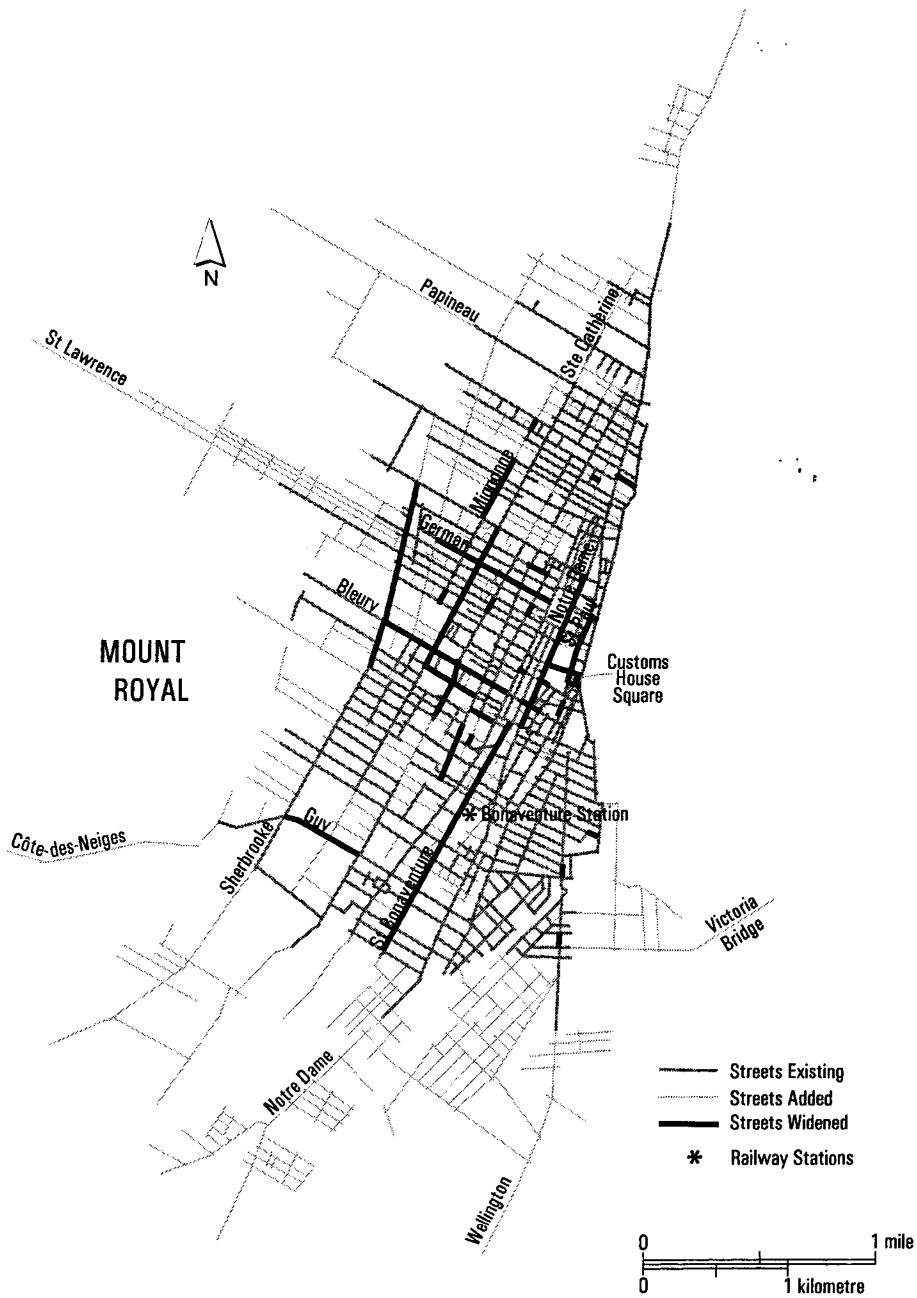
[43] Before the incorporation of 1842, the mode of opening, widening and straightening streets was established according an act of 1796, which set a minimum width of 30 feet for new streets (Viger 1840).

[44] The Grand Trunk Railway built its Bonaventure Station in the west end on Chaboillez Square in 1847, and then, between 1885 and 1889, they erected a new station at the corner of Peel and St Antoine Streets. The Canadian Pacific Railway erected Dalhousie Square Station (1882-83) just east of the CBD, Windsor Station (1888-89) on Windsor (now Peel) Street, a block away from the GTR's Bonaventure Station, and then Viger Station (1890s) in the east, to replace the aging Dalhousie Station (see Hanna 1998). For a discussion of the impact of railways on the internal morphology of nineteenth-century cities see Kellett (1969).

[45] Between 1850 and 1866, the rhythm of building in Montreal was actually represented by two mini-cycles (recall Figure 1.2). The regular Kuznets rhythm was likely disturbed by the late-1850s dip in immigration to the city from overseas, as well as a sequence of major disasters in the 1850s such as the conflagrations and cholera outbreaks.



4.6 Streets widened and added in Montreal, 1850-66
Source: see Note 40

and some, like Guy and Sherbrooke Streets, were sparsely settled suburban roads. St Catherine Street was predominantly residential at the time, but its widening from 24 feet to 60 feet made room for the first "uptown" line of the horse tramway in 1865, and began its conversion into a fashionable commercial street which gradually drew shoppers and stores away from established business streets in the old core. Bleury was an important link between the old city and the élite "new town" developing near the slopes of Mount Royal. St Bonaventure Street was straightened and widened to about 32 feet to accommodate traffic generated by the Bonaventure Railway Station. The most impressive project during this period was the widening of Notre Dame Street from 30 feet to 44 feet in the central business district. (We will discuss this project in more depth later.) Widenings in the intensely developed central core of "Old Montreal" were difficult because they involved the destruction of a massive amount of built capital. When widenings did occur in the central core, projects were typically small, involving a single block or building.[46]

As described in Chapter 2, several widenings took place earlier in the cycle, in the districts destroyed by the conflagrations of 1850 and 1852. In the burnt districts of the central core for example, St Paul and St Sulpice Streets were widened, as well as the area around Custom House Square. Destruction in the suburbs expedited the widening of St Catherine (east of St Lawrence) and German Street. Major fires facilitated such improvements by levelling the physical, economic, and psychological barriers that stood

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[46] For example, before the new Post Office was erected at the corner of St Francois Xavier and St James, the City negotiated a few extra feet to widen St Francois Xavier.

in the way. Before rebuilding on crowded Saint-Paul Street, the burnt-out merchants petitioned for the widening of their street, offering to meet the cost of the improvement. Since the owners already had to rebuild anyway, they recognized that there was an opportunity to improve traffic flows on their busy commercial street, and to increase the value of their properties.[47] The street frontage was what gave lots their value. For commercial purposes, the greater the circulation, the greater the value of the location, and property owners normally contributed in proportion to their frontage for the cost of a street improvement (including grading, paving, drains, water mains, and sidewalks), and therefore, they occasionally petitioned against infrastructural improvement. While the City usually had to pay "damages" to owners whose properties were expropriated, assessments were lower when the lots were in ruins, and therefore, the municipal government also looked upon a conflagration as a special opportunity to make much needed improvements. In reaction to the fiery summer of 1850, the City not only passed a by-law banning wood construction, but leading citizens also demanded wider streets as fire breaks, and the City set a minimum of 60 feet for new streets. By 1865, after the economic crisis hit the building sector, the law was changed again, and the required width was reduced to 40 feet.[48]

Whereas nearly 12 kilometres of streets were widened in between 1850 and 1866, fewer than 5 kilometres were widened during the next cycle, 1867-1880 (see Figure 4.7).

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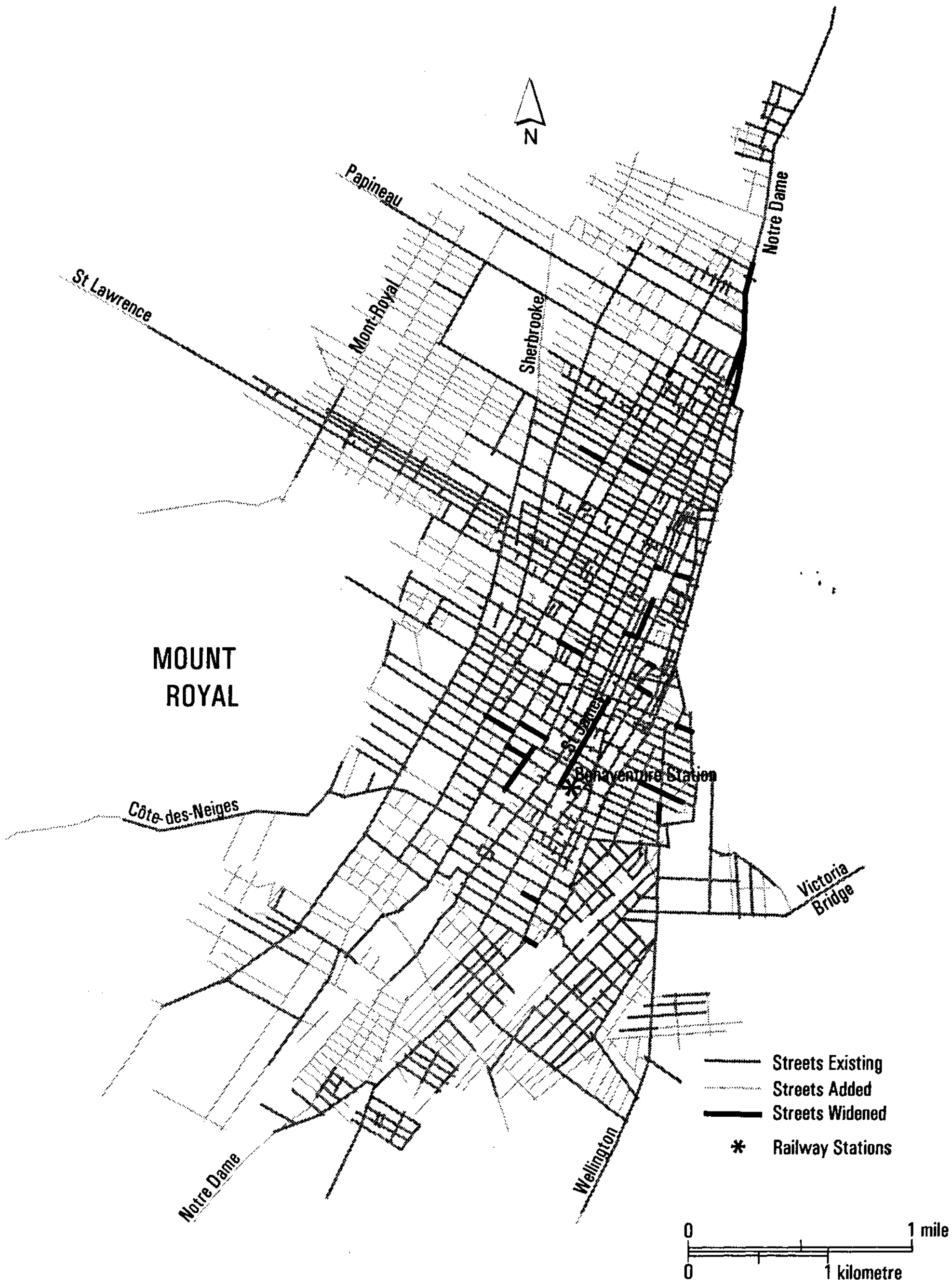
[47] See the *Report of the City Surveyor*, 1852, p.3.

[48] *An Act to Amend and Consolidate the provisions of the ordinance to incorporate the City and Town of Montreal* (1851, p.51); *Charter of the City of Montreal* (1865, Chap. 29, Sec. 2).



4.7 Streets widened and added in Montreal, 1867-1880
Source: see Note 40.

The most noteworthy operation carried out during this period was the widening of St James Street – headquarters to most of the city's financial institutions – to a uniform width of 60 feet throughout.[49] The map also suggests that traffic was escalating around Bonaventure Railway Station: not only were several small sections of streets in the vicinity of the station widened, but, in 1880, the St Bonaventure Street link between the railway station and "downtown" was further enlarged to about 40 feet. St Mary Street (Notre Dame East) was widened to 65 feet between Papineau Square and the eastern limits. Traffic on this street was particularly heavy since it was the main thoroughfare between the central core of the city and the eastern suburbs, the Longueuil ferry wharf, and major industries such as Molson's Brewery. It was also the sole route in and out of the city for tram cars travelling to and from the Montreal City Passenger Railway stables and yards located just east of the city in Hochelaga.

Although fewer streets were widened during the cycle 1867-1880, it was a crucial period in the planning of Montreal. Between 1874 and 1881, the City Surveyor's office developed an official "homologation" plan showing the actual and proposed lines of every street at a scale of 1:960.[50] All property owners were bound to keep future construction

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[49] The portion widened was known as Little St James Street, whereas the section immediately to the west was known as Great St James Street. After the widening, both sections were known simply as St James Street.

[50] Homologation plans for the central wards were drawn first, and then the suburban wards were added later as annexed. For details see, *An Act to Revise and Consolidate the Charter of the City of Montreal and the Several Acts Amending the Same*, 1874, Sections 168-172. Although the homologation plan was not the first map or plan of Montreal to show the streets to be opened or extended (such plans date back to the seventeenth century, see Robert 1994) , it is believed that this was the first large-scale plan to show the streets to be widened and the desired width of every street in the city. The following comments suggest that the City Surveyor (P. MacQuisten) considered the issue of long-term planning for

behind the new homologation line. Contrary to the common notion that the nineteenth-century city developed "organically" without planning,[51] this plan, which was continually annotated and updated over the next century, illustrates that as early as the 1870s – almost two full decades before the first electric streetcar – the municipal corporation had a comprehensive strategy for widening major arteries and "regularizing" the street network. French planning historian Françoise Choay defines "regularization" – a term also used by Haussmann – as "that form of critical planning whose explicit purpose is to regularize the disordered city, to disclose its new order by means of a pure, schematic layout which will disentangle it from its dross, the sediment of past and present failures."[52] The idea for this plan in Montreal was most likely borrowed from France, as Darin (1987) notes that a French law of 1807 required all towns with more than two thousand inhabitants to establish "un plan général d'alignement" upon which the municipal council would mark proposed realignments of all streets.

Between 1881 and 1900, the city widened more than 13 kilometres of streets (see Figure 4.8). Many of the changes proposed on the homologation plan, including the

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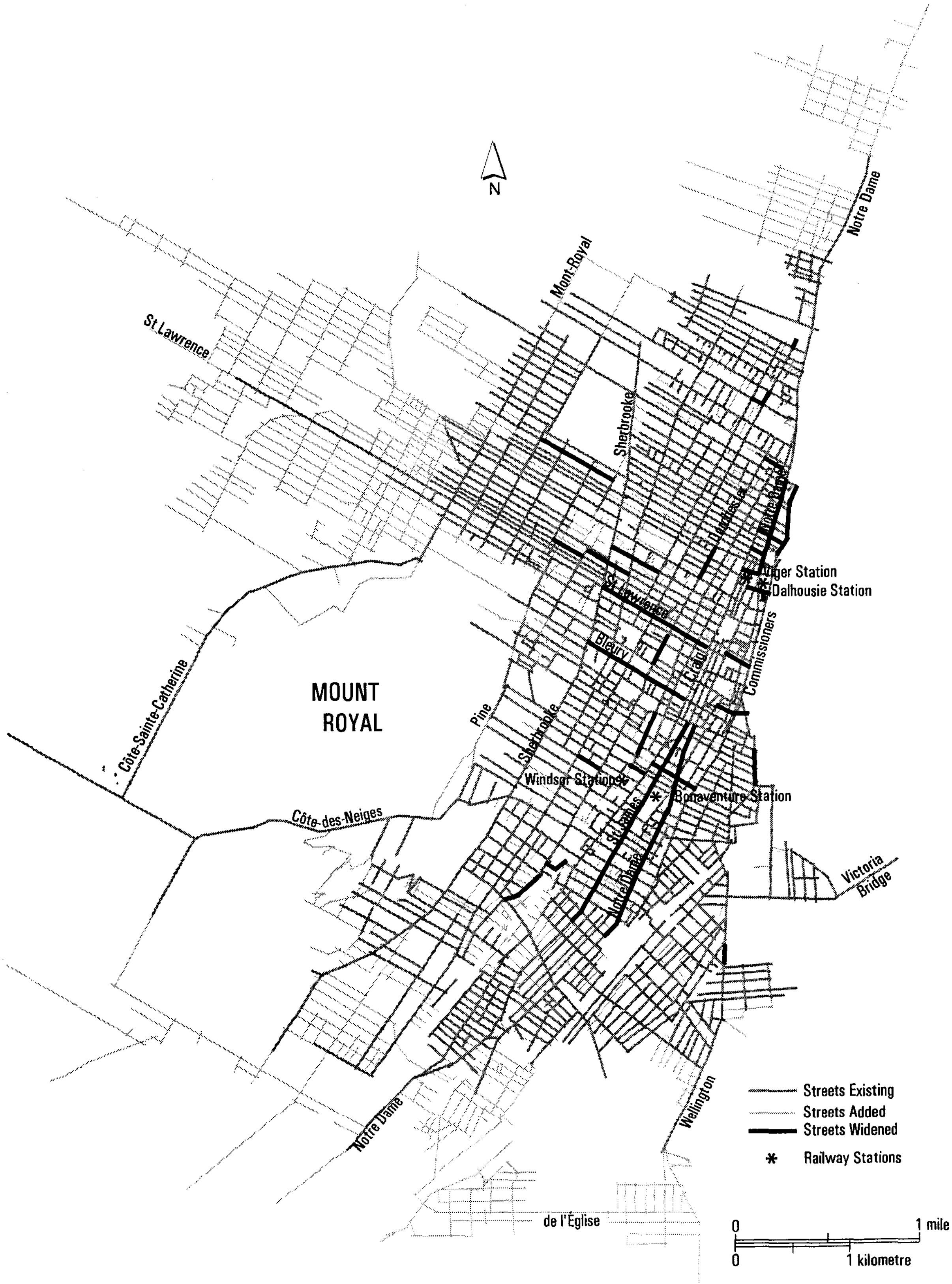
street widenings at least a decade before the homologation plan was created. "I would recommend that the Council should decide which business thoroughfares require widening, and that so much money be set apart each year for widening by sections as the finances of the city will allow, – securing, at the same time, all vacant lots, or lots that may become vacant in any section of the street, proposed to be widened; by doing so, instead of a street being in a transition state for an indefinite period as formerly, it will, in the course of a few years, have an unbroken line and add to the beauty and value of the city." (*Report of the City Surveyor* 1864, 9).

[51] Jean-Claude Marsan, for example, claims the first attempt at "overall planning" came in 1944 (Marsan 1981, 329).

[52] Choay (1969, 15).



4.8 Streets widened and added in Montreal, 1881-1900
Source: see Note 40

widening of large sections of several major arteries, were undertaken near the peak of the building boom (1889-1891). The eastern section of Commissioners Street was enlarged to 80 feet, as part of a port improvement project which included the extension of railway lines along the waterfront. To accommodate the rapid expansion of railway traffic in and out of Montreal, both the Grand Trunk and Canadian Pacific companies erected colossal new stations east and west of the core. To keep pace with the traffic in and out of the new stations, the Corporation of Montreal widened several smaller streets in the vicinity and once again enlarged St James West (formerly St Bonaventure), achieving a width of approximately 75 feet throughout most of its length from Old Montreal to the western boundary with St Cunégonde.[53] The widening of some of the city's oldest and most important thoroughfares – Bleury, St James West (formerly St Bonaventure), St Lawrence, Notre Dame East (formerly St Mary) and Notre Dame West (formerly St Joseph) – was part of the major public works initiated within the first few years of Raymond Préfontaine's tenure as chairman of the Road Department. Bleury and Notre Dame West were widened to about 60 feet, Notre Dame East to 65 feet, and St Lawrence Street to 67 feet. (We will investigate the latter two operations later.) By 1895, these streets had become primary routes for the electric streetcar.

This was a highly active period for municipal improvements, until compensation for expropriations had increased the municipal debt to such "alarming proportions" that in

[53] During a typical day (from 7am to 6pm) in 1891, almost 2500 horse carts passed by this section of St James Street (*Annual Report of City Surveyor* 1891).

1894 the government temporarily ceased expropriating.[54] Between 1889 and 1896 the Corporation spent more than $6,500,000 on expropriations for street widenings. During the same period the City's total debts had risen from $22,000,000 to more than $25,000,000, whereas the annual general revenue in 1896 was less than $2,900,000. Because costs of expropriation were charged to the debt fund rather than to the annual budget, the street widening projects carried out by the Road Department under Préfontaine were the primary cause of the new indebtedness. In 1898, Mayor Richard Wilson-Smith proclaimed: "The clause introduced into our Charter, relieving the City from carrying out further expropriations until such time as she has sufficient funds on hand to pay for them, has, I believe, been the salvation of the city. And in my opinion, no further expropriations or improvements, such as street widenings, should be carried out for the present."[55] The mayor argued that expropriation had become prohibitively expensive because unscrupulous property owners brought forth overpaid expert witnesses who exaggerated property values, causing overruns to the preliminary financial arrangements anticipated by the City. "Notwithstanding the great expenditure," the City Surveyor argued in 1895, "no one can reasonably say that the great majority of the streets of this city have not been greatly improved, and if the town has become more regular in

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[54] See report of Mayor Wilson-Smith (1898, 15), and *Annual Report of the City Treasurer* (1895, 3).

[55] Wilson-Smith (1898, 7-8). Expropriation became more expensive by a clause introduced in 1889 which required the city to pay for the residue of an expropriated lot whenever it was shallower than 40 feet (or 50 feet in the case of St Lawrence); however, it is likely that the City often made a profit from selling the residuals. In 1897, Wilson-Smith requested authorization from the Provincial Legislature to float a temporary loan of $1,500,000 but was denied.

the width and straightness of its thoroughfares it is from this expropriation law."[56]

In the first decades of the twentieth century, during the fourth cycle (1901-1918), disciples of the City Beautiful planning movement proposed bold plans for the redesign of Montreal. These included cutting broad diagonal streets eastward and westward from Victoria Square, the busiest area of the city. None of these plans ever made it off the drawing board.[57] Nevertheless, more than 15 kilometres of streets were widened during this period. The most remarkable (see Figure 4.9) were in fact extensions of projects begun in earlier generations, such as the widening of St Lawrence Street and Notre Dame Street in their outlying stretches.[58] St Lawrence was enlarged above Sherbrooke Street, so that the entire stretch from Craig to Mount Royal reached an approximate width of 67 feet throughout. The extreme western and eastern portions of Notre Dame Street were also widened, so that the street was now almost 65 feet wide within the limits of the city, except in Old Montreal, where the width remained at 44 feet. Another major project during this period was the widening of St Antoine Street. This street was one of the busiest in the city due to its proximity to downtown, the Windsor and Bonaventure railway stations, and to the new street railway terminus on Craig Street. Also noteworthy during this phase were expansions to 70 feet of two suburban roads, Côte-Sainte-Catherine and Côte-des-Neiges, north of the mountain near the borders with Outremont and the Town of Mount Royal.

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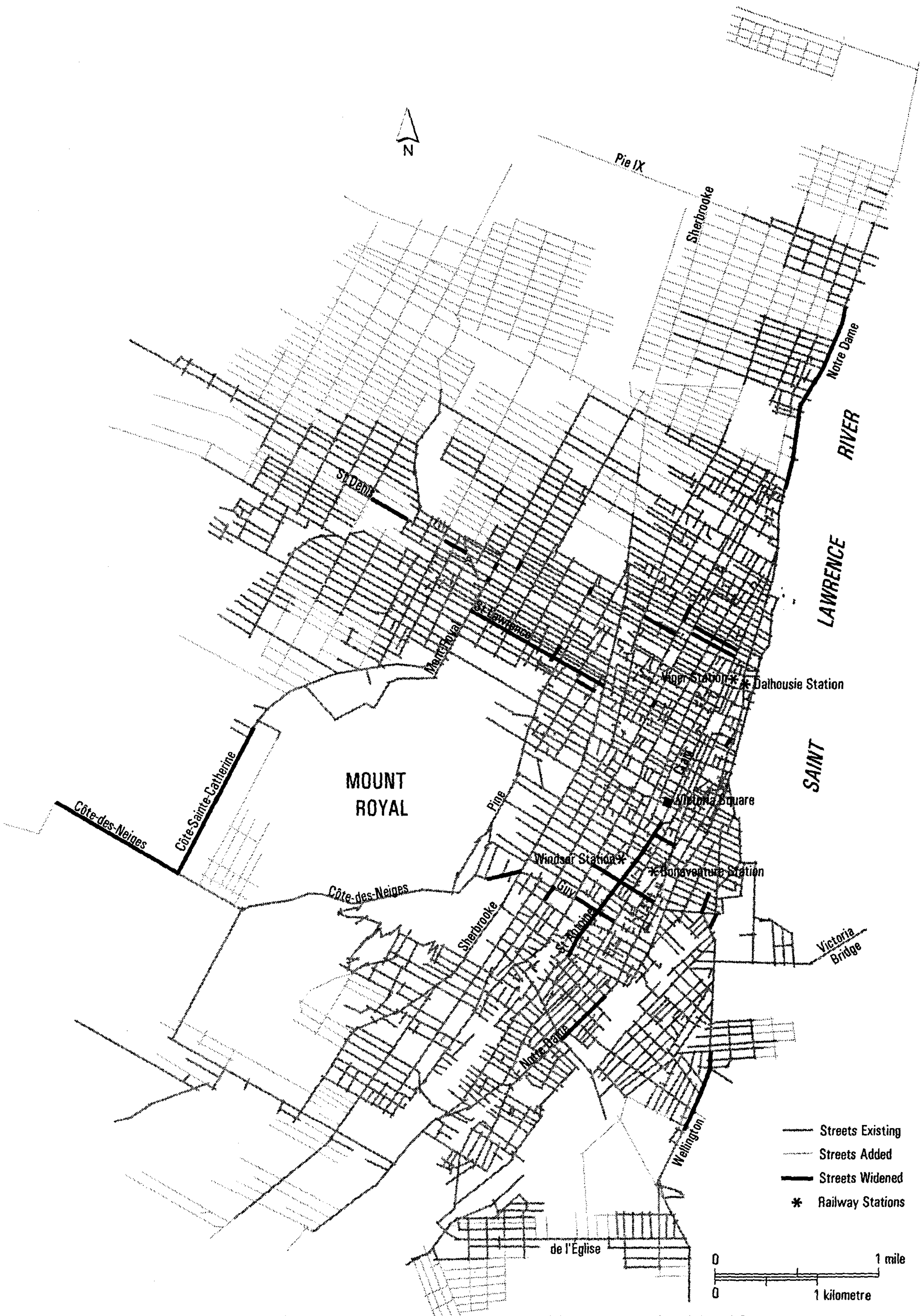
[56] St George (1895, 33).

[57] *Canadian Municipal Journal* (1909). See also Vanlaethem (1998).

[58] This was a crucial period in the history of Montreal's suburban development, as 21 suburban municipalities were annexed to the city between 1905 and 1910 (Atherton 1914).



4.9 Streets widened and added in Montreal, 1901-18

Source: see Note 40

The first years of the twentieth century were important ones in the history of planning in Montreal. First, in 1901, the minimum width of new streets was expanded to 80 feet (66 feet in special circumstances). This amendment is impressive considering that for most of the nineteenth century, only two streets (Craig and McGill) were as wide as 80 feet, and to grasp the timing we need to notice that in a decade of electric mass transit, new demands had arisen.[59] Second, the year 1901 also witnessed the implementation of the first comprehensive set of building regulations. For the first time, the municipal government established height limits, conceived in relation to the width of the street (to a maximum of 10 storeys, or 130 feet).[60] Narrow streets would limit the development of fronting lots to their full speculative potential. What seems a restraint on development (by limiting building heights and enlarging public space) was in fact a mechanism for allowing taller buildings, one of those rules which mean the opposite of what they state.

The redimensioning of streets was associated with accelerating the circulation of capital, including increasing the value of private property. We have thus far seen numerous links between street widening, land use and property value which make Figure 4.1 a crude over-simplification of the stream of "benefits." In the following section, we will also see how the apportionment of benefits, between fronting owners and other interests generated conflict.

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[59] In 1901 there were a trivial number of gasoline-powered motor vehicles on the city streets. The very first in Montreal, in 1899, was owned by U.H Dandurand. Veilleux (1997) notes that in 1907 there were only 162 motor vehicles registered to Montrealers.

[60] By-law 270 on streets and by-law 260 on building regulations (adopted 4 February 1901).

A CLOSER LOOK AT THE WIDENING PROCESS

Now that we have a basic understanding of the logic, magnitude, and patterning of street widening operations in Montreal, we can, in a set of case studies, investigate the impact of such operations on the urban fabric. Investigations with two streets, Notre Dame and St Lawrence, allow us to analyse three major widening operations over 35 years. They involved acquisitions – individually negotiated or executed by the Superior Court – of nearly 200 properties, at a cost of nearly one and a half million dollars. The case studies are drawn from three different areas of the city – the central core of "Old Montreal," a zone just outside the old city centre, and an east end suburb – and for each case, we can compare expropriated and non-expropriated sides of the street. Let us look at the widenings on Notre Dame and St Lawrence in more detail, to appraise the impact on urban form, property values, and municipal revenues, as well as the human consequences.

Notre Dame Street, long the city's principal thoroughfare, was laid out in 1672 at a width of 30 feet (9.1 m). As shown in Figures 4.6 to 4.9, between 1850 and 1918, the street was widened in stages throughout most of its length. In the 1860s, the central portion was widened to 44 feet (13.4 m), and then in successive cycles by 1912, the remaining sections from Hochelaga in the east to St Cunégonde in the west – almost 8 km – were widened to 60-65 feet (between 18.3 and 19.8 m). The suburban municipalities at either end were annexed in 1883 and 1905 respectively.

Let us now take a closer look at the first widening of Notre Dame Street, from 30 to 44 feet in the centre. For most of the nineteenth century, this section of Notre Dame was one of the most prestigious shopping addresses in the city, and in 1861 it was chosen for the inaugural run of the Montreal City Passenger Railway. Although certain proprietors had petitioned for widening in 1854, the project was not initiated until 1864, and promptly completed by 1868.[61] This project marked the introduction of the practice of expropriating all the required properties at once, and carrying out the work in four large sections. Under the old method of piecemeal acquisition as properties became vacant, a street could be left with a "broken" or irregular building line for several years.[62]

The new method was also more profitable for the municipal corporation: since all properties affected were assumed to undergo an instantaneous increase in value, the City could charge an additional tax assessment.[63] Let us use this case of Notre Dame Street to appraise the impact on property values and municipal resources. On this street, the widening clearly inflated property values. Some properties which sold for $2.50 per square foot just before the widening were selling for $7.00 immediately after. The City was quick to cash in on the bonanza: in February 1864, the City took from Pierre Malo a property located at the corner of Notre Dame and St Peter Streets containing 2229 square feet, and the jury awarded Malo $6,687 compensation. Less than four months later, when

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[61] The first two parcels of land were acquired from the petitioners in 1854, another property was procured in 1863, three more in 1864, and the remaining 49 properties were acquired all at once in 1865 (*Report of City Surveyor* 1854, 1863, 1864, 1865).

[62] See "Law on Expropriations, &c." (27 and 28 Victoria, Cap. 60), in *Charter and By-Laws of the City of Montreal* (1865).

[63] City Surveyor P. MacQuisten explained the logic: "When a strip of land, say 30 feet long by 10 feet deep, is taken to widen a street, the remainder of the lot cannot be considered to have been increased in value, if the buildings on each side of it project ten feet beyond its front, and no additional assessment will be received from it." (*Report of the City Surveyor* 1864, 9).

the widening had been completed, the City sold the residue of the property, 1387 square feet, to Jean-Baptiste Beaudry for $6,640, virtually the same price they had paid for the entire property.[64] This amounted to a 60% mark-up in price per square foot, and it also meant that the Corporation had wiped out the cost of acquisition. This was the philosophy which the City optimistically espoused, but this case was exceptional. The total cost of expropriating the 55 required properties was $309,880 at an average award of $9.06 per square foot. The Corporation, responsible for one half of the cost of the improvement – for which they took out a $150,000 loan – left the other half to be paid by the fronting proprietors, by means of a special assessment levied over one year.[65]

What impact did the widening have on the streetscape? Given that the first 14 feet of every structure on the north side was demolished, between McGill Street and Dalhousie Square, it is safe to say that the streetscape was radically altered. But how was the street redeveloped after the widening? In Chapter 2, we found that the scale and intensity of redevelopment after devastating fires varied according to the centrality of the site and the timing of destruction. Since the demolished properties on Notre Dame Street were centrally located, and the operations took place in the middle of a building boom, we can therefore expect to find that the properties were rebuilt quickly, and that they incorporated morphological changes which increased the building envelope. We can test

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[64] *Report of the City Surveyor* (1865). By 1872, this corner property was assessed at $18,000 (*Rôle d'évaluation* 1872)

[65] *Annual Report of City Surveyor* (1854, 1863, 1864, 1865). The "special assessment" varied according to section, ranging from $1.19 to $2.53 per $100 of assessed value of property. See "Law on Expropriations, &c." (27 and 28 Victoria, Cap. 60), especially article 30 (pp.425-427) in *Charter and By-Laws of the City of Montreal* (1865) and amendments published in 1870.

Table 4.1
Rental values per building in sample areas before and after street widenings

Sample area	Distance from centre (km)	Side of street	Mean rent per building ($) before widening	after widening	increase (%)	Sample Size before (n)	/ after (n)
Notre Dame (West Ward)	0	expropriated	713	1709	140	32	27
		non-expropriated	880	1225	39	26	26
St Laurent	1	expropriated	779	1531	97	29	29
		non-expropriated	1052	1261	20	29	29
Notre Dame (St James Ward)	3	expropriated	440	415	-6	35	29
		non-expropriated.	505	535	6	25	30

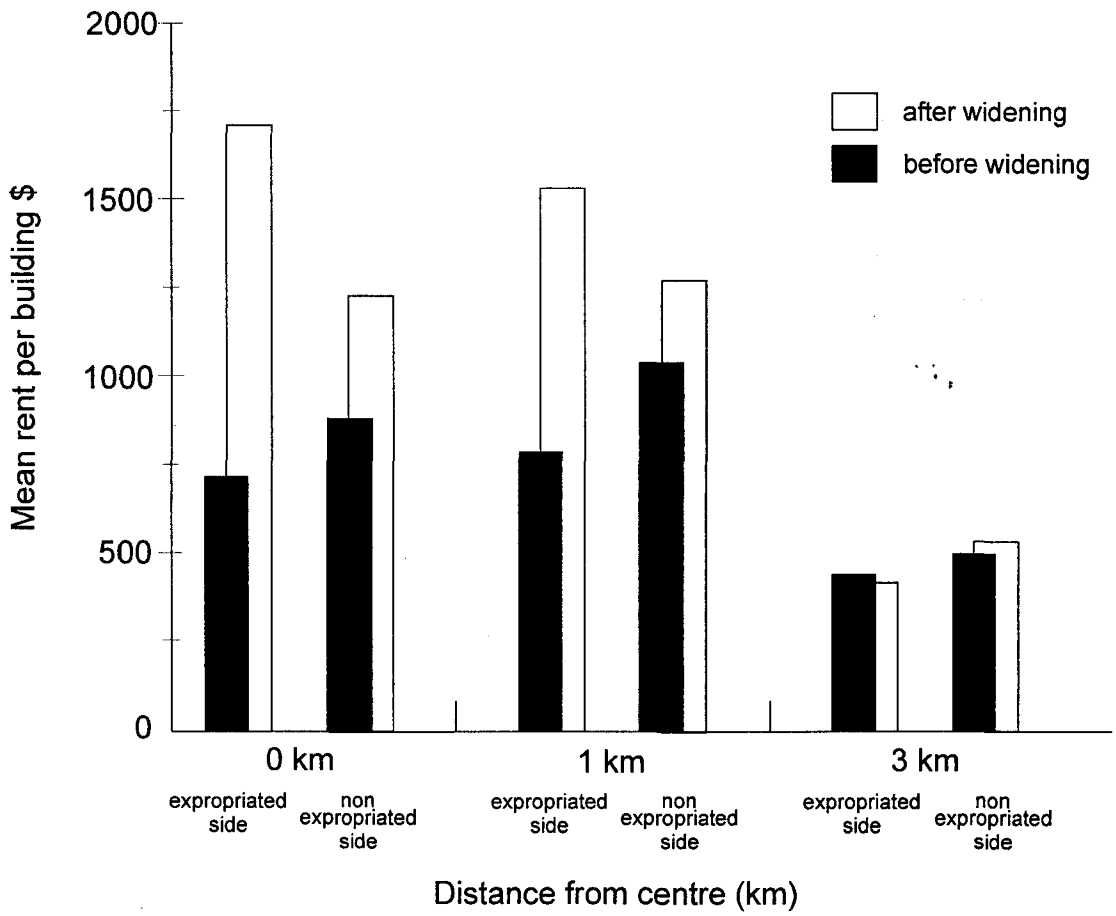
Note: Values for Notre Dame (West) are from 1862-1872, values for St Laurent are from 1888-1900, and for Notre Dame (St James Ward) are from 1890-1900. *Source:* Montreal, *Rôle d'évaluation*, 1862-1900.

these hypotheses in the same way we investigated the impact of the fires in Chapter 2, by comparing the before-and-after stream of rent generated from affected lots.

In 1862, immediately before the widening, the mean annual rent per building was $713 on the north side of the street, and $880 on the south side, suggesting that buildings on the south side, on average, were of a slightly larger scale than those across the street (see Table 4.1, Figure 4.10).[66] This might be the reason that the north side was chosen for expropriation instead of the south side.[67] By 1872, a few years after the widening was completed, mean annual rent per building was much higher (40%) on the north side which

[66] The sample consists of all properties fronting on Notre Dame (both sides) between McGill Street and St François Xavier Street in the years 1862 and 1872. Recall that the "scale" of a building refers to its overall size or volume, and "scale of development" in an area refers to the density of built capital, or building coverage on the particular lots in three-dimensions.

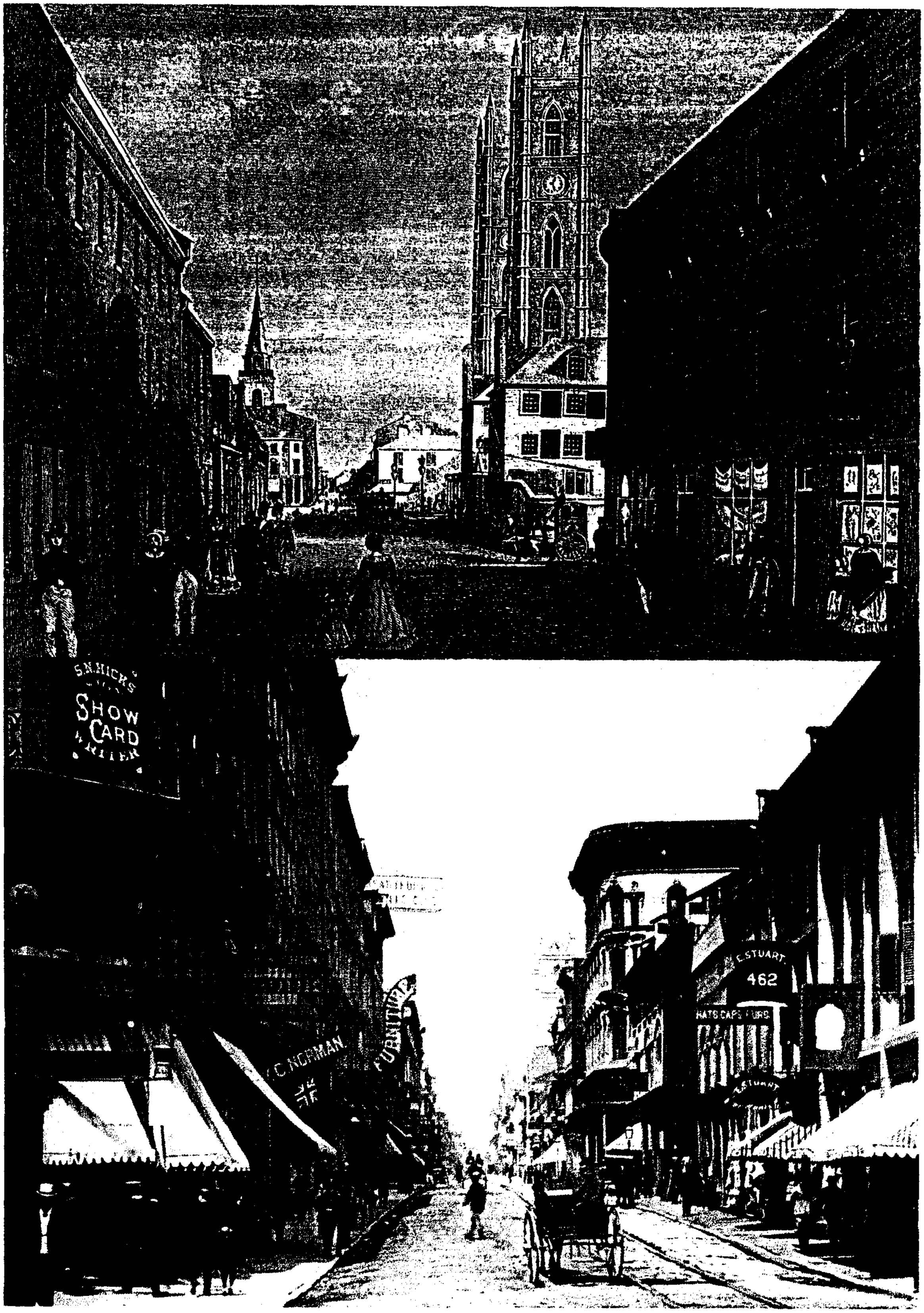
[67] A more likely reason is that the city did not dare to disturb its most cherished monument, the Notre Dame Basilica, nor the Sulpician Seminary, which are located on the south side.



4.10 Redevelopment of three widened streets. Before and after building rents on expropriated and non-expropriated sides of Notre Dame Street (1862-1872), St Lawrence Street (1888-1900), and Notre Dame Street East (1890-1900). *Sources: Rôle d'évaluation* (1862-1900).

had been partially expropriated and destroyed, than on the south side ($1709 versus $1225). The fact that the mean annual rent per building on the north side of the street more than doubled (140% increase) between 1862 and 1872 indicates that the new buildings put up after the widening were, on average, of much larger size – taller, bulkier, with more floor space – than those which were destroyed for the widening. Given that mean rent on the south side of the street also rose substantially (39%) between 1862 and 1872, it is suggested that some of the owners on this side may also have rebuilt their properties to a greater scale, or performed morphological changes to create more rentable space (e.g., the addition of storeys), to take advantage of increased commercial activity, and to attract higher-order commercial functions (such as banking and insurance) to such prime locations. Owners may have also been pressed to collect more rent by the obligation to pay for a share of the widening.

Historical illustrations and photographs of the Notre Dame streetscape appear to support these findings. Figure 4.11 (top) gives an impression of what the cases study area looked like to the pedestrian at ground level before the widening. Most of the street was lined with two-and-a-half and three-and-a half storey stone structures, with a few one-and-a-halves, and all of the buildings had peaked roofs. A generation after the widening (Figure 4.11, bottom), it is clear that the north side (photo left side) had been rebuilt primarily with taller, four-storey, flat-roofed structures. A typical example of redevelopment on the north side was A. M. Delisle's property, on the corner of Dollard Street (just beyond the "furniture" sign at left in photo). In 1862, Delisle's two-storey building housed a tailor and a shoemaker, both of whom lived upstairs, and the total



4.11 Looking East along Notre Dame Street toward Place d'Armes in 1850s (top) and in 1880s (bottom). *Source: Illustrated London News*, 25 August 1860; Montreal Gazette Archives.

annual rent was $1000. The new four-storey building was entirely commercial, with a tailor and jeweller sharing the ground floor, another tailor on the second floor, and a shoemaker on the third and fourth floors; the total rent of the new building was $1840. The widening helped eliminate the dwelling-over-the-shop habitat, which was already nearing extinction in the central core due to the powerful demand by commercial activities for such prime locations and their ability to pay higher rents.[68] The photograph at the bottom also confirms that a few properties on the south side, although not expropriated, were redeveloped to a greater scale. For example, the prominent four-storey commercial building with a flat roof and heavy cornice at the corner of St Helen (which projects above the others on the right side of the photo) was erected in 1869, on the site of the old Recollets Church.[69]

The case of the old Recollets Church property raises questions regarding property transfers and the subdivision or consolidation of lots. How much property changed hands due to the widening? Approximately two-thirds of the properties on the north side were transferred to new owners between 1862 and 1872, fewer than one-quarter on the south

[68] In 1862, there were no buildings on the street that were entirely residential, however, over four-fifths of buildings on the north side, and three-quarters on the south side contained dwellings upstairs. A decade later, however, only one property on the north side, and less than one-third on the south side contained residential components. Robert (1994) estimates that by 1852, barely one-tenth of Montreal's population lived in the central core of the city.

[69] This building, owned by W.F. Kay, contained approximately 18,400 square feet of floor space, and had a total annual rental value of $2900 in 1872. Although religious institutions were exempt from the tax assessment, the 1862 tax roll provides an estimate of $1640 total annual rent for the church property. To the immediate east of Kay's building was another four-storey commercial building erected by the Shaw brothers in 1868, after they also purchased church property from the Fabrique. The total annual rent of the Shaw building was also $2900 in 1872.

side. The widening encouraged the sale of properties, since it inflated values on the street. Not every owner would be seen as an equally good prospect for financing; however, the timing was favourable for obtaining additional capital. Since the stream of rents from tenants and business activities had already been interrupted due to the widening, the timing was ideal to sell. As was the case with Pierre Malo's property, noted earlier, some properties were sold first to the city, and then to a new owner. In some cases, the widening made a lot too small for the owner to rebuild profitably, and such residual slips of land were sold to neighbours. This practice of lot consolidation explains why, in Table 4.1, a greater number of buildings are recorded on the north side before the widening than after (32 versus 27). Unlike the experience of redevelopment after fires, where we found that the number of lots did not change, and the owners presumably rebuilt to the old lot lines, street widenings forced a change in the morphology of *every* lot on one side of the street, and occasionally encouraged the consolidation or agglomeration of individual pieces of land to form larger lots, upon which larger buildings could be erected.

The findings indicate that the widening had a considerable impact on the redevelopment of both sides of Notre Dame. Greater concentrations of capital generated taller, bulkier, and more spacious buildings, which garnered higher rents per building, and radically altered the Notre Dame streetscape.

For our second case study, we return to St Lawrence Street, to that section of the "Main" which was partially destroyed in the great conflagration of 1850. In Chapter 2 we saw how the east side of this street experienced a dramatic reconstruction after the fire. In a decade in which Montreal experienced the rapid onset of industrialization and a near doubling of its population, the "destructive accident" provided the owners an opportunity to rebuild on a larger scale, intensifying land use to take advantage of the escalating demand for central city sites and rapidly inflating property values. During the second half of the nineteenth century, St Lawrence Street was transformed from the mixed-use main street of the St Lawrence Suburb to one of the most important commercial thoroughfares in the industrial city; it was the primary north-south link between the downtown, with its port and financial district, and the rapidly expanding suburbs to the north. As we have seen in Figures 4.8 and 4.9, between 1880 and 1918, the street was widened over a 2.7 kilometre stretch from Craig Street to the suburb of St Louis du Mile End (annexed in 1910). Between 1888 and 1892, the lower portion, between Craig and Sherbrooke, was widened from 47 to 67 feet, and between 1903 and 1905, the widening was completed up to Mt Royal Avenue.

How was St Lawrence Street redeveloped after the widening? Given the centrality and timing of the widening project, we should expect to find that the redevelopment process on St Lawrence was similar to what we discovered on Notre Dame. To test this hypothesis, let us take a closer look at the widening of the lower portion, from Craig to Sherbrooke, less than one kilometre from the city centre. In the 1880s, property owners in this section petitioned the city to pave and widen their street so that it might be placed on an equal footing with other commercial arteries, such as Notre Dame and St James.[70]

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[70] The petitions for paving and widening were submitted in 1881 and 1888 respectively (Commission de la voirie, *Rapports adoptés*, 26 March 1881; Commission de la voirie, *Procès Verbaux*, 12 May 1888).

Since the homologation lines for this street had already been established in 1874 and St Lawrence was undoubtedly one of the busiest streets in the city,[71] the city would have eventually carried out the widening; therefore, the petitioners merely accelerated the process. The work of expropriating, demolishing, and rebuilding of 68 properties on the west side began in 1889 and was completed in three sections by 1892. The compensation for expropriation was $677,701.[72] To investigate effects on the redevelopment of St Lawrence Street, I collected rental data for a sample of properties before and after the widening.[73] In 1888, just before the work was authorized, mean annual rent per building was $779 on the west side and $1052 on the east side of the street (Table 4.1; Figure 4.10). The more intensive development on the east side is a consequence of what our empirical analyses showed (Chapter 2) as the impact of the fires: burnt properties on the east side had been redeveloped to a greater scale than the non-burnt sections. This may also be the reason why the homologation line was originally established on the west instead of the east side. Before the widening, this street contained mostly two-and-a-half and three-storey buildings, with shops on the ground floor and the homes of the

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Some of the information for this section on St Lawrence Street was gathered in cooperation with my colleague Julie Podmore, who has written about gender relations along the "Main" over the past century (Podmore 1999).

[71] Almost 3000 vehicles passed down this street every business day – including one horse tram every 4 or 5 minutes – making it one of the busiest arteries in the city. Traffic counts were taken during a typical business day between 7am and 6pm (*Annual Report of City Surveyor* 1891).

[72] The work was to begin May 1, 1889, and be completed within three years (*Annual Report of City Surveyor* 1889).

[73] The sample comprises all properties on both sides of the street between Craig Street and Dorchester Street in 1888 and 1900. The total cost of expropriating these 29 properties was $303,994, and the average reimbursement of $9.41 per square foot (*Annual Report of City Surveyor* 1889).

shopkeepers upstairs. About one-half of the buildings expropriated on the west side were made of stone, one-fifth of brick, one-sixth a combination of brick or stone with wood, and one-sixth constructed entirely of wood.[74] This confirms our suspicion that at least one-sixth of all structures on the west side had been constructed before the great conflagrations of the 1850s, prior to the law banning wooden buildings.

A by-law specially enacted for this widening demanded that all new structures have stone or iron fronts and be no less than three storeys (or 35 feet from sidewalk to roof),[75] and therefore demanded a considerable improvement in the scale of investment and quality of architecture. Almost a decade after the widening (in 1900), mean rent per building in the expropriated section had doubled (to $1531) (Table 4.1, Figure 4.10). Rents on the side which had not been expropriated rose by less – one-fifth – and mean rent per building was lower (by one-sixth) than in the expropriated section. In other words, the west side was now redeveloped to a higher intensity than the east. A photograph taken in 1892[76] shows that buildings on the west side (photo left) were taller than those on the east (see Figure 4.12). All of the buildings on the west side after the widening were a minimum of three storeys and several were larger; whereas most of the buildings on the east side were two-and-a-half or three-and-a-half storeys. A typical example of rebuilding was Lucie Perrault's four-storey, cut-stone building on the

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[74] *Annual Report of City Surveyor* (1889).

[75] By-law 161, passed on October 1, 1888.

[76] Although Demchinksy (1985) and Lessard (1992) date the photo earlier, the presence of the double-track (which was laid in 1892) and the horse tramway (which last ran in 1892) confirm the date.

4.12 St Lawrence Street rebuilt after widening, circa 1892.
Source: Notman Collection, McCord Museum.

northwest corner of St Lawrence and Craig Street (photo left), erected shortly after the old building was torn down in 1889. The old building was a stone two-and-a-half, occupied by a grocery on the ground floor, with a dentist's office and residence upstairs, and produced a yearly stream of rents of $1800. The new building, with the same owner,[77] garnered twice the rents ($3510), and contained an inn, a merchant tailor, and several offices for an architect, agents, notary, and lawyers. The changes of occupancy are indicative of the changing function of the street during this period, from one that served the needs of the local neighbourhood, to one that served a clientele from all over the city.[78] The introduction of parallel electric streetcar lines in 1892 created direct links between the lower "Main" and suburbs in all directions, making it one of the busiest streets in the city.

For a third study we move farther from the city centre to the eastern section of Notre Dame Street (formerly St Mary) between Lacroix and Papineau Road (see Figure 4.13). In the first half of the nineteenth century, Notre Dame East developed as the main commercial axis of a primarily working-class, French-Canadian neighbourhood known as "Faubourg Québec." During the second half of the nineteenth century, this street served as the primary thoroughfare between Old Montreal and the rapidly expanding industrial developments along the east end waterfront, and in the suburbs of Hochelaga and

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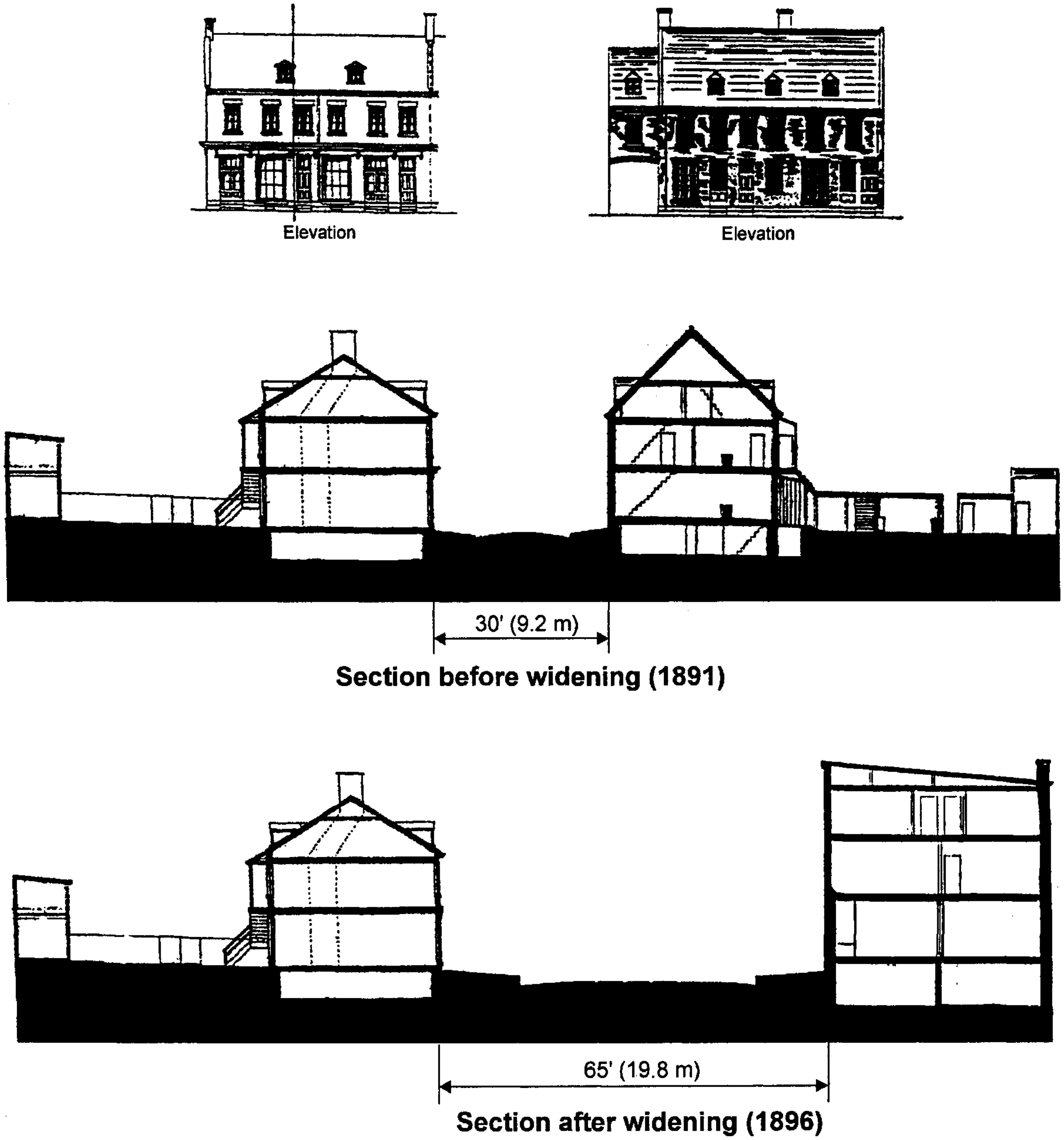
[77] One-third of the properties on the west side had changed owners between 1888 and 1900. Three of these properties had been subdivided, and another three had been amalgamated with neighbouring properties. On the east side, barely one in seven properties had been transferred between 1888 and 1900.

[78] For further discussion of the character of St Lawrence (1890s to 1990s), see Podmore (1999).



4.13 Typical section of Notre Dame East before and after widening.
Sources: compiled from original drawings and information found in *Archives Nationales du Québec*, Cour Supérieur de Montréal, Dossier Référé #184; Goad (1890); and *Annual Reports of City Surveyor* (1890-96).

Maisonneuve.[79] To widen this stretch from about 45 to 65 feet the City, in 1891, expropriated and demolished the entire north side, which contained 59 properties, assessed at about a quarter of a million dollars. The total cost of expropriation was $443,268, or $7.36 per square foot. A large portion were properties less than 40 years old, rebuilt after having been destroyed by the conflagration of 1852 (recall Figure 2.1). Because the by-laws enacted after the fire prohibited wood exteriors, most of the buildings expropriated in the 1890s were brick-clad (70%).[80] About one-third were three storeys and one-half were two-and-a-halfs, similar to the ones shown in the elevations and section at the top of Figure 4.13.[81] By-laws enacted for the widening, however, required new construction to be of dressed stone or iron fronts, and not less than three storeys high, thus prescribing a significant transformation of the streetscape.[82] Testimony made it clear that council envisioned a landscape of continuous communal frontage.

An examination of rental assessments per building on Notre Dame Street East before and after the widening suggests that redevelopment here was substantially different

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[79] On the industrial landscape of nineteenth-century Montreal, see Lewis (2000).

[80] The remaining 30% were stone, or mixed stone and brick. Details can be found in the report of the City Surveyor (1891) and in the public notice of expropriation published in local newspapers (*Montreal Gazette*, 28 February 1891).

[81] The remaining one-sixth were one or two-storeys. There were no buildings higher than three-storeys (Cour Supérieur de Montréal, Dossier Référé #184. *Ville de Montréal vs. Rue Notre Dame.* Archives Nationales du Québec).

[82] By-law 168, passed 16 September 1889, repealed by By-law 175, passed 18 November 1889.

than on the more central portion of Notre Dame and lower St Lawrence Street.[83] In 1890, shortly before the expropriations, the mean annual rent per building was $440 on the north side and $505 on the south side, indicating that buildings on the south side, on average, were moderately larger than those across the street (see Figure 4.10, Table 4.1). The discovery that buildings on the side to be expropriated were relatively smaller, on average, that those on the opposite side is consistent with what we found in the other two cases, and, again, may have been factor in choosing which side to expropriate. By 1900, a few years after the street was widened, the mean rent per building was essentially the same as before: $415 and $535 on the north side and south side respectively. The evidence therefore seems to suggest that owners on the north side rebuilt to a similar scale as before, and most owners on the south side did not alter their buildings at all. Most owners on the north side chose to rebuild to the legal minimum of three-storeys, typically with a shop on the ground floor and dwellings above, as in the example at the bottom-right of Figure 4.13.[84]

While politicians such as Raymond Préfontaine and "expert witnesses"[85] from the

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[83] The sample database consists of all properties within St James Ward, between Lacroix and Visitation on the north side, and Lacroix to Barclay on the south side. Average awards for expropriation were much higher in this portion, than in the section between Visitation/Barclay and Papineau Road ($10.05 versus $4.81 per square foot).

[84] "The buildings put up on that street [Notre Dame] are three stories in height, the ground floor being devoted to stores and the two storeys above to dwellings"(*Canadian Architect and Builder* 1895, 8).

[85] "Some of our local architects have done very little architectural work for several years past, their services having been in demand as valuators in the case of property required to be expropriated by the city for street widening purposes. The work is said to have proved very remunerative, particularly in the case of the city's valuators. One firm of architects are said to have received in fees in one year for work of this kind not less than $20,000." (*Canadian Architect and Builder* 1894, 66).

real estate industry believed that widening Notre-Dame would enhance its status as a leading thoroughfare, the evidence suggests something different. Some small-time owners objected to having to rebuild in stone, which was much more costly than the more commonly-used brick.[86] Other property owners protested having to pay for half of the project, since it was of no benefit to them. J.O. Joseph, for example, who owned a small house less than 30 metres from both the Canadian Rubber Company and Molson's Brewery, argued: "En principe, toute expropriation doit être payée par le bénéfice due, les contribuables peuvent en râtisser mais celle-ci a été ruineuse, désastreuse. C'est la ville qui nous a causé de dommage, elle est tenue de le réparer."[87] Nevertheless, under the current expropriation law, they had no power to veto the improvement.[88] Whereas most of the properties on St Lawrence were rebuilt within a year after being destroyed, the work on Notre Dame East was fraught with delays. The widening project seriously disrupted private lives and business activities of hundreds of people. "Hundreds of dwellings, shops, factories, breweries, bar rooms, hotels, boarding houses . . . converted

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[86] For example, Elzéar Bélanger pleaded: "Pendant que nous étions forcés de construire à grands frais, des édifices en pierre, de trois étages, on amendait les règlements en faveur de certaine compagnie, pour lui permettre d'ériger des bâtiments en brique. On me dit même que l'on ne s'est pas donné la peine d'amender les règlements, à ce sujet, et que ces constructions ont été érigées d'une manière irrégulière" (*La Presse* 2 February 1902).

[87] *La Presse* (2 February 1902). Half of the cost of the widening was to be paid by the city, the other half to be paid by the proprietors on both sides of the street to a depth of 50 feet between Dalhousie Square and Frontenac Street. The amount owed was payable in up to ten annual installments at an annual rate of 6% interest. See: 54 Victoria, Cap. 78, Sec. 2; 55 and 56 Victoria, Cap. 49, Sec. 22, printed in *Charter and By-Laws of the City of Montreal.*

[88] On the veto rights, see expropriation law (54 Victoria, Cap. 78, Sec. 3), printed in *Charter and By-Laws of the City of Montreal.*

into dust and debris . . . a sufficient population moved out to furnish a good-sized city."[89] A conservative estimate (based on 1861 Census) before the widening suggests that the 59 expropriated properties contained as many as 115 households and almost 700 persons. The biggest blow was to the owners of small businesses, who claimed that, during the three to four years it took to complete the project, they lost most of their clientele to other commercial streets (notably Craig and Sainte Catherine Street).[90] To rub salt in the wounds, many of the small owners who had rebuilt after the widening, again had their properties taken from them a few years later in order to expand the Viger Station and rail yards. This project offers an example of the demands of "big capital" taking priority over "petty capital," that is, small business owners were removed for the benefit of railway companies, and industries such as Molson's and the Dominion Rubber Company located at the far eastern end of the street. In the name of East End development, a once thriving neighbourhood was destroyed, and the obituary read:

> In the main, the buildings and blocks which have been removed had outgrown their usefulness and their removal must have come ere long anyway. Yet Montreal to-day is paying large interest on the cost of widening and improving that very Notre Dame street east which is now being converted into a lane through a railway yard, where it was once Montreal's great business thoroughfare.[91]

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[89] *Montreal Star*, 28 August 1909.

[90] Accounts of J. Wright and E. Bélanger, merchants on Notre Dame (*La Presse*, 2 February 1902).

[91] *Montreal Star*, 28 August 1909.

DISCUSSION AND CONCLUSION

How can we explain the differences in the patterns of redevelopment in the three case studies of widened streets? The findings are consistent with earlier predictions regarding the rhythm and trajectory of investment in the built environment, and are comparable to the findings with respect to the rebuilding after fire in Chapter 2. Properties located in the more central areas of the city – lower St Lawrence and Notre Dame in Old Montreal – were rebuilt with larger lumps of capital, that is, with larger investments per square foot of land, with taller buildings that produce higher rents. Redevelopment was most intense in these central areas where land values were highest, where competition for space was most extreme, and where there existed the most pressure to adapt the built environment to accommodate the needs of a rapidly industrializing economy.

As anticipated, the timing of the project was an important factor in determining the scale and intensity of redevelopment. For property owners on Notre Dame East, demolition and rebuilding took place during an inopportune moment, the beginning of a "bust" period in construction. Indeed, in 1895 a local contractor claimed that "had it not been for the rebuilding of that [part of Notre Dame] street, Montreal would have witnessed the poorest year of building operations ever recorded in its annals."[92] Conversely, the widening of the other case study streets took place during boom periods, when there would have been loans available and a strong incentive to rebuild to a greater scale and intensity in order to deal

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[92] *Canadian Architect and Builder* (1895, 8).

with heightened competition and to take advantage of increased values.

The fact that owners on the central portion of Notre Dame and on St Lawrence petitioned for street widening, while owners on Notre Dame East protested against widening, provides further compelling evidence that owners in the centrally located areas were more anxious to redevelop their properties than owners on Notre Dame East. By petitioning for the improvement, property owners sought to remove barriers (physical, financial, psychological) to redevelopment. The first major obstacle was the reality of the homologation line. Since all new structures had to be erected behind the new line, which in the case of St Lawrence was drawn 20 feet deeper than the old line, ambitious property owners had fewer square feet upon which to rebuild. This impediment could be overcome by the potential for increased rental and property values; however, since property values did not increase until the street was widened completely, with all neighbouring owners having rebuilt to the new line, there existed a serious disincentive for individual proprietors to act alone.

The physical durability of existing structures, and the amount of built capital invested in them, also acted as barriers to redevelopment. As in the case of accidental destruction by fire, planned demolition, or "creative destruction," also eliminated the inertia of built capital, and therefore offered the property owners a *tabula rasa* upon which to rebuild and to intensify the accumulation of capital. Owners were not completely free to build as they pleased, however, since the City in some instances restricted the type of material to be used, the minimum number of storeys, and the minimum height from sidewalk to roof.[93] Presumably the City established such regulations in order to guarantee an adequate tax base after the widening.

Another factor affecting redevelopment after a widening was the availability of capital. The practice of compensating proprietors for their losses helped to remove the financial barrier to redevelopment in the same way that insurance coverage assisted redevelopment after fire. Considering the different patterns of redevelopment in the case studies, we might expect to find that the compensation awarded to proprietors on Notre Dame East was not as substantial as the awards to proprietors in the central areas. On the contrary, the average award to owners on Notre Dame East ($10.05 per square foot) was more generous than the average award to owners on lower St Lawrence ($9.41 per square foot) and the central portion of Notre Dame ($8.31).[94] Although the awards seem equitable, especially when compared with the assessed values before expropriation, they were not exactly windfalls for the owners. In fact, some owners on Notre Dame East hired their own expert witnesses and contested the awards in court, arguing that the City did not consider the totality of losses, since they overlooked items such as building fixtures, lost business, and the good will of the customers.[95] Furthermore, since owners were required to pay for half of

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[93] See By-laws 161 (St Lawrence) and 175 (Notre Dame East), passed in 1889.

[94] Furthermore, if we compare these figures with the assessed value of the property before expropriation, we find that the awards per square foot on Notre Dame East were 7.7 times higher than the assessed property value per square foot ($1.30); whereas the awards on St Lawrence were only 2.9 times higher than the assessed value per square foot ($3.16) (Note: pre-expropriation areas are unavailable for the central portion of Notre Dame).

[95] Cour Supérieur de Montréal, Dossier Référé #184, *Ville de Montréal vs. Rue Notre Dame* (Archives Nationales du Québec).

the widening, much of the award money came from their own pockets.

The disastrous effects of the widening on Notre Dame Street East demonstrates a widespread failure to recognize the incoherence of municipal actions. It was clear that the eastern section of Notre Dame did not follow the trend in increased exchange value as did the more central portion. Indeed, as we have seen, the heavy traffic through Notre Dame East was not an asset to the retail enterprise along its frontage. Nevertheless, based on the assertion that a widening benefited all, the City could charge all abutting owners for the cost of the work, and could increase its revenue by collecting higher taxes on properties fronting on "improved" streets.

In 1895, City Surveyor Percival St. George confessed in a public lecture that the homologation plan adopted two decades earlier "was a hardship necessitated by the condition in which the great growth of the city found itself, and some means had to be taken in order to make the streets wider."[96] St George's statement is interesting for two reasons. First, it supports my main argument that alterations to the urban vascular system were a response to the massive congestion associated with rapid development. The homologation plan was not only a strategy to accommodate future growth, but it was primarily also a mechanism to cope with existing congestion. Second, the "hardship" he refers to was that experienced by the city government, due to the large debt resulting from expropriation payments. There was no recognition in his speech of the suffering of property owners; in fact, the opposite was true. The City Surveyor suggested that a fixed award of no more than

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[96] St George (1895, 32). St. George's lecture "On Streets and Drains" was part of a series on municipal administration delivered in association with the Young Men's Christian Association.

25% to 50% above the assessed value of the property would be adequate to "compensate owners for the forced sale . . . and the proprietor would not object to it, as he would look forward some day to being expropriated himself."[97] The fact that owners on Notre Dame East protested their compensation amounts, which were typically 770% above the assessment values, suggests that the City Surveyor's cost-saving ideas were unrealistic. It was a good thing for St. George that the City Surveyor was appointed, not elected.

Architectural historian Spiro Kostof argued that "expropriation is rarely welcomed by those who inhabit the condemned property, and it is always an arbitrary intervention performed coercively."[98] Although it is true that individual property owners in late-nineteenth century Montreal had little power to resist expropriation, the fact that owners on St Lawrence Street and the central portion of Notre Dame Street petitioned in favour of street widenings implies that expropriation was sometimes welcomed by proprietors. Furthermore, the evidence presented in this chapter suggests that the expropriation of property and the widening of streets in Montreal were not entirely arbitrary processes; on the contrary, several regularities were apparent. There was, for example, a distinct spatial and temporal pattern to street widening operations between 1850 and 1918. Most widening projects took place when and where the urban vascular system was most congested: that is, after periods of intense urban development, and in areas where competition for space was most fierce, namely the old and narrow streets of the central core, the major thoroughfares

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97 St. George (1895, 33).

98 Kostof (1992, 266).

and streetcar routes to the suburbs, and the approaches to the railway stations and docks.

In this chapter we have explored how the built form of Montreal was continuously shaped and reshaped by members of a local "growth machine" committed to increasing rents, property values, and municipal revenues, through the intensification of land use. Regularities with respect to the spatio-temporal patterns of expropriation, widening, and rebuilding in Montreal point to the pressures imposed by the cyclical nature of accumulation in the built environment. Each wave of urban growth was associated with a massive surge in the flow of traffic into, out of, and through the city, increased competition for urban land, extreme congestion of public infrastructures, a periodic foul-up of the growth machine, and, consequently, an intensified pressure to adapt the inherited built landscape to accommodate new demands. Since built capital is fixed in place and slow to change, a continuous source of conflict exists between contemporary demands and the legacy of investments in the built environment. Each new wave of growth and associated crises repeatedly forced the "creative destruction" of the exchange values of past investments in the built environment, in order to restore the profitability of the growth machine for future accumulation. Investments in street widenings, like reconstructions after fire and the reorganization of the port, were a way for the local growth machine to remove congestion in the vascular system, to "annihilate space" in relation to time, and hence, to speed up the rate of growth of capital – paving the way for the next more extensive and more destructive crisis which would come along.

CHAPTER 5

Network Topology: Reconfiguring the Urban Vascular System

> *Suppose I want to understand the "structure" of something. Just what exactly does this mean? It means, of course, that I want to make a simple picture of it, which lets me grasp it as a whole. And it means, too, that as far as possible, I want to paint this picture out of as few elements as possible. The fewer the elements there are, the richer the relationships between them, and the more of the picture lies in the "structure" of these relationships.*
>
> – Christopher Alexander, 1979[1]

As we saw in Chapter 3, rapid industrialization and urbanization in the late-nineteenth century was associated with massive increases in the flows of goods and people in and out of the city; we also observed in Chapter 4 a corresponding increase in movement on city streets, which led to widenings of major arteries. While urban geographers and historians have written much about transport innovations and development at the rural-urban fringe of North American cities, including the impact of the streetcar and automobile on suburban expansion,[2] very little empirical research has been carried out on the historical dynamics of traffic circulation and urban morphology. We have somehow taken for granted that the relationship exists. The purpose of this chapter is to provide a

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[1] Alexander (1979, 34).

[2] The most well-known include Dyos' studies of the railway and urban transformation in Victorian London (Dyos et al 1982), Warner (1978) on "streetcar suburbs" around Boston, and Jackson (1985) and Garreau (1991) on the impact of the automobile on suburbanizationin the United States.

better understanding of the relationship between urban form and circulation. To do so, I adopt a topological approach to urban modelling, consistent with a growing body of theoretically-grounded and empirically-tested research which suggests that the physical structure of the urban grid is itself a primary predictor of patterns of urban movement.[3]

Using techniques based on theories of *space syntax*, in this chapter I investigate changes in the configuration of the street network of Montreal over the second half of the nineteenth century. The space syntax approach to configurational analysis is topological, as it considers the connections between places, rather than the distances between them. Having found good empirical studies of traffic flow in Montreal about 1890, I select a sample of street segments of known traffic, then collect data on their width, fronting land uses, and intensity of development, from paving records, taxrolls, and directories. I also make a particular study of bank locations in that period, 1880 to 1903. I can relate these to the configuration of the street system, as expressed in terms of space syntax measures. This requires some explanation of the various measures of connectivity and system dimensions, and some digressions into critique of those measures. Few studies look at the trends or dynamics of street configuration, and we will be able to observe some intriguing elements of stability, as well as a leap of development in the street hierarchy. While space syntax methods have been previously applied to an analysis of street plans of the past,[4] the research presented here represents the first time that the parameters of the

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[3] The key references are Hillier et al (1993), Hillier (1996), Penn et al (1998), Peponis et al (1989).

[4] Kubat (1999) used space syntax techniques to examine the changing morphology of the central core of Istanbul (in 1840, 1922, and 1964). Hanson and Hillier (1993) compared the plan of central London in

configurational models have been systematically tested against historical data. In the published literature, real-world traffic observations have been used exclusively in modern studies of small neighbourhoods or sub-districts, primarily within metropolitan London. The key discovery presented here is that the space syntax measures of the topological properties of the street network, namely the relative location of each street segment within the system, are strongly correlated with the traffic it carries. The results of my analyses highlight the potential of a configurational approach to modelling urban movement. There are fundamental reasons why the study of spatial configuration is important to urban analysis. The growth and survival of a city depend on efficient circulation: of goods, people, capital, and ideas.[5] The fundamental role of the city is to preserve vital connections and to provide opportunities for exchange and interaction. As a city grows, it becomes increasingly important that the spatial configuration of its circulation system provide a sense of orientation and promote ease of movement, in order to encourage encounters and to maintain viable relationships between people in different parts of the city. An essential function of the urban fabric is, therefore, to provide an intelligible structure within which parts are identified and related to the whole.[6] Space syntax analysis is aimed at revealing this structure.

This chapter is divided into four parts, beginning with a detailed description of the

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1677 with the modern plan. Read (2000) examined plans of central Amsterdam between the 14th and 17th centuries.

[5] See, for example, Meier's (1962) treatise on the communications theory of urban growth.

[6] Lynch (1960).

methodology. In the second part of the chapter, the street network of Montreal in 1846, 1866, 1881 and 1901 is digitally "reconstructed" and then analytically "deconstructed" using space syntax and GIS techniques to reveal its configurational properties over time. In the third section, the predictive powers of space syntax techniques are tested using data on traffic flows, street widths, land use, and intensity of development. Before concluding the chapter, we conduct another series of experiments to determine whether space syntax can offer additional insights to our findings from earlier chapters with respect to rebuilding after fires, and the spatial pattern of investments in street widenings, paving, and the streetcar network.

SPACE SYNTAX CONCEPTS AND METHODOLOGY

Although recent studies have highlighted its advantages, the use of GIS-based techniques in the field of urban morphology is still relatively rare.[7] The power and potential of GIS for examining the evolution of the urban vascular system, for example, have not yet been adequately tapped. In the industry-standard ArcView software, a *Network Analysis* extension allows one to solve three basic kinds of problems: to choose the shortest route between stops in a network (for example, bus stops or railway stations); to identify the closest facility to a given location; and to delimit the service area of a facility. While

[7] Koster (1998). See also Holtier et al (2000), Campari (1998), and Hunter and Williamson (1990). In contrast to the urban morphologists, transportation researchers have embraced geographic information systems (GIS-T), and have made a number of important advancements (see Miller and Shaw 2001).

these are arguably useful problem-solving techniques, still missing are adequate descriptors or parameters of the network as a system. Miller and Shaw (2001) argue that a massive gulf still exists between the rich features and attributes of transportation systems in the real world and the data models used for their representation within a computer. Methods which involve connections, relations, or interactions between places have rarely been developed within a GIS, partly because the standard mode of representation depends on ascribing all geographic phenomena to a collection of points, lines, and polygons (another kind of topology), and phenomena which build relationships on top of these elements add a layer of complexity which most GIS software cannot easily handle.[8] It is argued here that adding a more precise description of the configuration of the street network in terms of locations, origins, destinations, and paths can strengthen existing models of urban circulation, and can help us to understand how the design and evolution of the street system affect other patterns of social behaviour.

Space syntax theories and techniques are based on the notion that social relationships and interactions are determined by the spatial order which has been crystallized into a long-lived structure of built capital. In other words, human behaviour does not merely "happen" in space: "Encountering, congregating, avoiding, interacting, dwelling, conferring are not attributes of individuals, but patterns, or configurations, formed by groups or collections of people. They depend on an engineered pattern of co-

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[8] This point has been made explicitly by Jiang et al (1999) and Miller and Shaw (2001). In recent years, numerous transportation specialists have been pre-occupied with the problem of how to adapt GIS to handle data such as origin-destination flows, complex paths, and temporal changes (Goodchild 1998; see also Spear and Lakshmanan 1998; Golledge 1998; Shaw 1993).

presence, and indeed co-absence."[9] Most human activities can be carried out in most spaces; however, "the relation between space and social existence does not lie at the level of the individual space, or individual activity. It lies in the relations between configurations of people and configurations of space."[10] The basic approach of space syntax is to examine spatial representations of urban forms (city plans, building layouts), to decompose them to formulate their mathematical regularities, and then to explore the ways in which the apparent structure is related to observable functions.

Space syntax methods are based on a topological representation of the "public" or "free" space in which people and vehicles circulate. As we move through a space, at most (if not all) locations, the space can be comprehended as a "vista," which, in turn, can be roughly represented by a straight line. An *axial map* of a circulation network is a representation which comprises the fewest longest lines of sight and movement, or visibility and permeability, that are necessary to cover the area of interest – in this project, the built-up area of the city in a specified year. The number and length of *axial lines* in the map are functions of the degree to which other parts of the system are directly accessible and visible from various points. Axial lines are straight, since a straight line is the only path of movement that we are sure to see all at once from any of its points (since curved paths can be partly obscured behind structures).[11] Axial distance is not a metric

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[9] Hillier (1996, 29).

[10] Hillier (1996, 31).

[11] The term "axial line" belongs to the language of space syntax. In plane geometry, a line is infinite, and therefore, it might be more appropriate to refer to the elements of the axial map as "arcs" or "segments," since these have two end-points. As we shall see, however, in space syntax analysis the end-

distance, but a topological distance; it is a measure of the number of changes in direction. It is based on a "yes" or "no" property. Can I see this place from that one? Can I reach this place without passing through that one? Axial distance therefore relates to the intelligibility of spatial patterns and a sense of orientation within them. It also relates to the way people think about space; for example, we speak of a place as "two bus stops away," and we direct people to "transfer at the third station," or "turn at the next intersection." These are locations in a topology.[12]

Figure 5.1 (top) displays the axial map for a section of the street network in "Old Montreal" in 1881. Contrary to conventional applications of graph theory, in space syntax the street segments or axial lines are treated as "nodes" or "vertices" and the intersections between axial lines – the corners, crossings or major bends in the street – are treated as the elementary relations between spaces, the "edges" or "links" in graph theory terminology (see bottom left of Figure 5.1).[13] In this way, space syntax concepts are a

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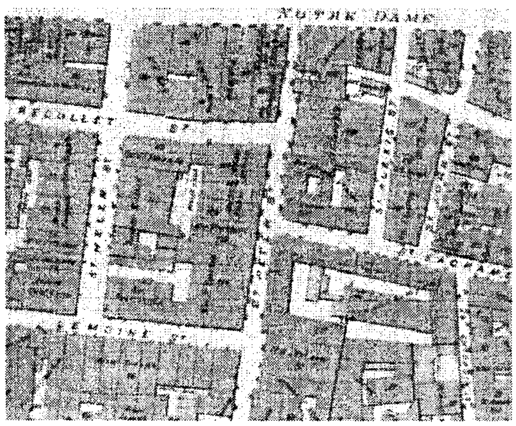
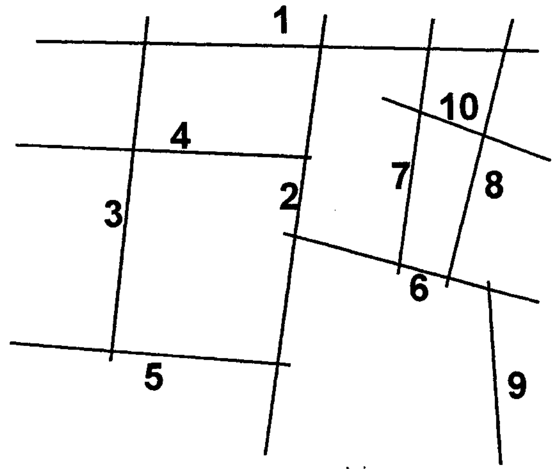
points of a street segment are not the object of attention, rather it is the point(s) of intersection with other street segments which are of primary concern. For a detailed discussion of the logic and methodology of axial maps, see Peponis (1998), Cerdeira (1996), and Hillier and Hanson (1984).

[12] Although emphasis on the "axial line" makes intuitive sense, this conception is not without problems. A basic argument of space syntax is that all space has a social logic which can be understood as the interaction between occupants and outsiders; however, it is not clear as to how the meaning and importance of "lines of sight" differs between visitors and locals, although we can expect that great differences must exist. Furthermore, the technique is more appropriate for pedestrian movement (for which it was designed), rather than vehicular movement, which faces restrictions such as speed limits and one-way streets. Although these restrictions were less important in the nineteenth-century context – since there were no one-way streets in Montreal until the 1920s and speed was limited naturally by horse-power and technology – there were undoubtedly other important regulators of traffic patterns, such as street width and pavement quality.

[13] For conventional terminology in graph theory, see Buckley and Harary (1990). The language of GIS is more specific: nodes located at the bend of a line are known as "vertices," and nodes at the end-points of lines are referred to as "dangles." Intersections of lines are not nodes by default, but can be manipulated to become vertices for network analysis.



A



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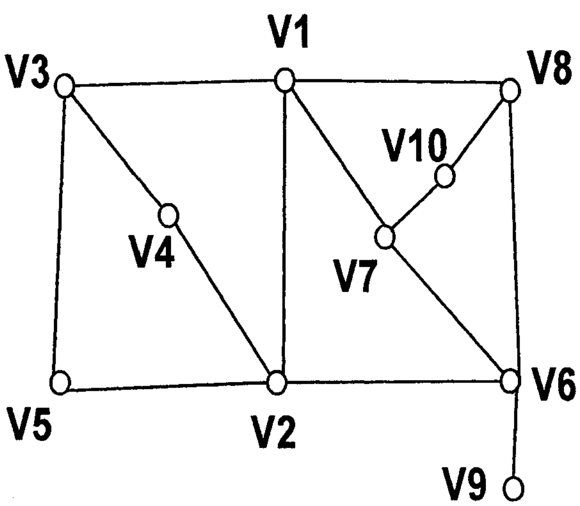

C

0	1	2	3	4	5	6	7	8	9	10
1	0	1	1	0	0	0	1	1	0	0
2	1	0	0	1	1	1	0	0	0	0
3	1	0	0	1	1	0	0	0	0	0
4	0	1	1	0	0	0	0	0	0	0
5	0	1	1	0	0	0	0	0	0	0
6	0	1	0	0	0	0	1	1	1	0
7	1	0	0	0	0	1	0	0	0	1
8	1	0	0	0	0	1	0	0	0	1
9	0	0	0	0	0	1	0	0	0	0
10	0	0	0	0	0	0	1	1	0	0

D

5.1 Section of Goad (1881) atlas for Old Montreal (A), the axial map (B), associated graph (C), and edge matrix (D).

variation on traditional graph theory widely employed in transportation studies since 1960, and a component of the "new" urban geography or regional science models of the 1960s.[14] Since movement within a city can originate or terminate from any point along a street segment, it is reasonable that the axial line or street segment itself should be our reference point for analysis, rather than its endpoints, corners, or crossings. As Christopher Alexander has noted, "the fewer the elements there are, the richer the relationships between them, and the more of the picture lies in the `structure' of these relationships."[15] The axial map is a simple picture which lets us grasp the whole of the network structure. It is this simplicity, however, which has been the primary focus of criticism regarding space syntax analysis. It has been argued that by using a simple line representation of space, and then analysing it topologically, space syntax ignores too much geometric and metric detail to be a credible measure of the accessibility of a specific location or network.[16] However, "far from ignoring geometric and metric properties," Bill Hillier argues that "the `line graph' internalises them into its structure of the graph and in doing so allows the graph analysis to pick up the nonlocal, or extrinsic, properties of spaces that are critical to the movement dynamics through which a city evolves its essential structures."[17] The "nonlocal" properties of an element are those

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[14] See Garrison (1960), Garrison and Marble (1965), and Tinkler (1977).

[15] Alexander (1979, 34).

[16] For general criticisms of space syntax methodology, see Kropf (1998), and Osman and Suliman (1994).

[17] Hillier (1999, 169).

which are defined by its relation to all others in the system. Since cities are essentially nonlocal systems, the method of space syntax offers an effective tool for understanding the underlying orderliness of urban space.

Whereas the significance of axial maps arises from the conceptual framework within which they are defined, and their relevance depends upon correlations between their properties and social behaviours, their objectivity arises from the rigour and repeatability of the methods used to generate them. It can be argued that the procedures used to create the axial map – manually using a two-dimensional map or plan – confounds problems of misrepresentation, particularly in a city such as Montreal, where changes in topography can be drastic. The only way we can ascertain whether the axial map is an accurate representation of a space is to actually go to that space and then move through it. Of course, this is impractical when dealing with large systems, and virtually impossible when dealing with urban landscapes of the past. Despite potential problems, the axial map has, in previous studies, been tested in the field and was demonstrated to be robust.[18] Nevertheless, as with any urban model or abstraction of reality, we need to take care in how we use and interpret the axial map.

As mentioned in Chapter 1, space syntax techniques were not originally aimed at modelling urban circulation, but at understanding the "spatial logic" of the urban grid.[19] Nevertheless, numerous tests of the topological analysis with real-world observations

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[18] See Hillier and Hanson (1984) and Peponis (1998).

[19] Hillier and Hanson (1984).

have revealed, over and over, that certain configurational properties of the street network were reliable predictors of patterns of pedestrian and vehicular movement. Based on a computational representation of the axial map as a graph, several useful measures of urban structure have been derived within space syntax. One of the most basic measures is how many other nodes are directly connected to each individual node. In graph theory, this is usually referred to as the *valency* of a node. In space syntax, the *connectivity* value of an axial line is simply the total number of other axial lines that intersect it. Figure 5.1 (bottom right) displays the connectivity matrix for the sample map. Axial line #1, for instance, has a connectivity of four, since it is intersected by four other streets (2, 3, 7, and 8).

The central concept of accessibility in space syntax is *integration.* Integration measures the relationship of each axial line to the network as a whole. The *integration value* of an axial line is a function of the minimum number of other axial lines that must be used in order to reach all other parts of the system from that axial line. Since integration is about topological, not geometric, accessibility, the term *depth* (instead of *distance*) is typically used in space syntax studies to describe how far spaces lie from each other within a network. The depth of a node (axial line) is defined as the minimum number of steps (or turns) required to reach all other nodes (axial lines), and is defined as:

$$\sum_{j=1}^{n} d_{ij}$$

where d_{ij} is the shortest path – made up of fewest turns – between two nodes (axial lines) *i* and *j*. Alfonso Shimbel (1953), in his work on the structure of communication networks, called this measure *dispersion D*, and his "D-matrix" is widely-used in transportation and communications applications of network analysis today.[20] In the context of social networks, Frank Harary (1959) referred to this measure as the *status* of a graph. Within space syntax, depth is calculated as *mean depth* (*MD*) for every axial line as follows:

$$MD_i = \frac{\sum_{j=1}^{n} d_{ij}}{n - 1}$$

where *n* is the number of nodes (axial lines) of the entire graph. According to Hillier and Hanson (1984), relations of depth necessarily involve "asymmetry," because a space is only deep from other spaces if it is necessary to pass through intervening spaces to reach them. In space syntax, a "normalisation" procedure is used to remove from the total depth calculation the effect of the number of elements in the graph, or the size of the city. This is done by comparing how deep the system is from a particular axial line with how deep or shallow it theoretically could be, by using the equation:

$$RA_i = \frac{2(MD_i - 1)}{n - 2}$$

[20] See, for example, Wheeler and O'Kelly (1999).

where *RA* stands for the "relative asymmetry" of a line.[21] This formula will give a value between 0 and 1, with high values indicating a space which is deep or segregated in the system, and low values a space which is shallow or integrated. When reporting results, it is common practice to use the reciprocal of this value, so that higher values correspond to higher integration, and lower values signify lower integration, which is arguably more intuitive.[22] Relative asymmetry can therefore be thought of as a measure of integration; however, a further adjustment is made to allow for scale differences between axial maps, as shown below:

$$RRA_i = \frac{RA_i}{D_n}$$

where *RRA* stands for *real relative asymmetry*, and *D* is the *RA* value for the root of a diamond-shaped system. Hillier and Hanson (1984) argue that this normalizationprocedure takes account of the fact that both buildings and settlements become relatively less deep as they grow, and therefore, the *D*-value provides a standardised value for the integration parameter so that systems of different sizes can be

[21] The importance of this measure has been fully discussed in Steadman (1983), Hillier and Hanson (1984), and Hillier (1996).

[22] Nevertheless, there seems to be no widespread agreement on which method of reporting *RA* or integration values is best, since both have been used in the published literature. For instance, Kubat (1999) and Hillier and Hanson (1984) use "straight" integration, whereas Penn et al (1998), Hillier (1996), Hillier et al (1993) use the reciprocal. Needless to say, this inconsistency is incredibly confusing for the uninitiated reader. In the reporting of integration in this thesis, I use the more intuitive reciprocal values.

compared. While this makes sense for comparing two cities of different sizes, it remains to be seen as to how this procedure influences our examination of how an individual street network changes over time.[23]

The space syntax parameter of *connectivity* is a highly localized measure of accessibility, as it only takes into consideration other axial lines at a topological depth of just one step away (radius-1). On the other hand, integration is a "global" measure since it considers relations between a given axial line and all other axial lines in the system as a whole (radius-n), and for this reason, it is usually described as *global integration.* Research has revealed that another useful measure of accessibility is integration calculated within a few steps (usually three) from each line in every direction (radius-3). This can be thought of as *local integration* because it reveals the local properties of a network. Empirical studies have suggested that pedestrian movement is more strongly correlated with local, rather than global measures of integration; the reverse is true for vehicular movement.[24]

Having erected the conceptual and methodological scaffolding, we will now construct and analyse a series of *axial maps* for nineteenth-century Montreal using *Axwoman*, an experimental new extension for ArcView.[25] To create a proper axial map,

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[23] The logic and utility of the *D*-value is discussed in Hillier and Hanson (1984, especially 112-3), Kruger (1989), and Teklenberg et al (1993). It is calculated according to the formula:

$$D_n = 2\{n(\lg_2{}^{((n+2)/3)-1)} + 1)\} / [(n-1)(n-2)].$$

[24] See Hillier (1996), Hillier et al (1993), Penn et al (1993), and Peponis et al (1989).

[25] The extension was produced by Bin Jiang at the Centre for Advanced Spatial Analysis (University College London) and is a scaled-down version of the Mac-based *Axman* program developed by researchers

it is crucial that the original source map show accurate street widths and building footprints. Fortunately, we have access to several high-quality historical atlases which contain the necessary precision at moments appropriate for observing redevelopment in each boom.[26] For the years 1846, 1866, 1881 and 1901, an axial map was created in three steps: (1) scanning the original map; (2) importing the scanned image into ArcView and geo-rectifying[27] it using the *Image Analysis* extension; and (3) tracing lines of sight and access using the line draw function of *Axwoman.*

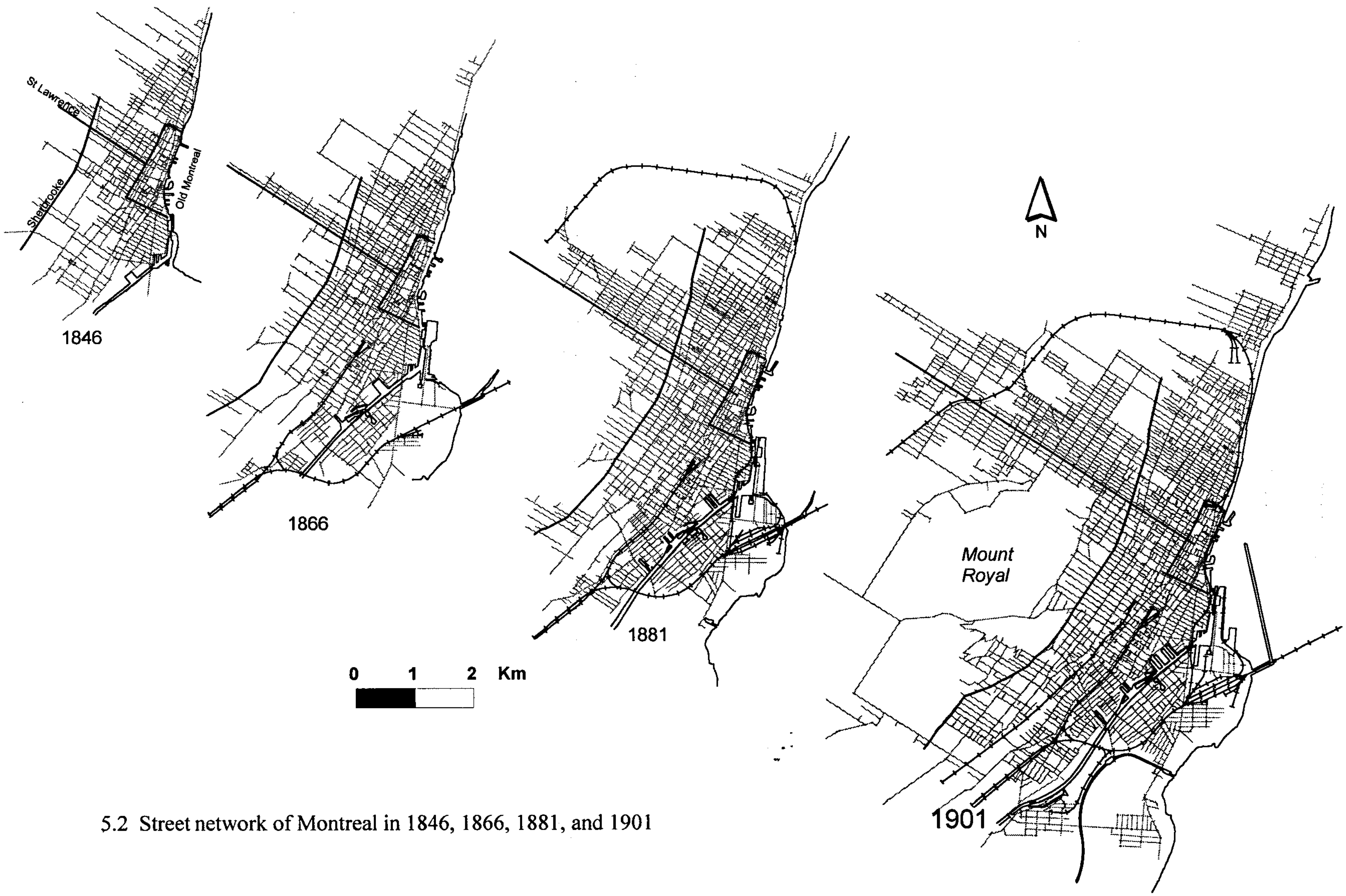
CONFIGURATIONAL MODELLING OF THE VASCULAR SYSTEM

How did the street network of Montreal evolve over the second half of the nineteenth century? Figure 5.2 shows the extent of the network in 1846, 1866, 1881, and 1901, reflecting the massive waves of urban expansion. Before we examine the space syntax measures, let us consider some of the basic properties of the street network in each study period (see Table 5.1). Between 1846 and 1901, the total number of axial lines in the

at the Bartlett School of Architecture and Planning (UCL). Only Axwoman runs on a desktop GIS, but the software, still in the developmental stages, produces a more limited range of statistics and is prone to crashing when processing maps of large street systems. Due to these limitations, I was unable to produce statistics for the axial map of Montreal in 1918. For further discussion of Axwoman, see Jiang et al (2000); Jiang et al (1999); and Batty et al (1998).

[26] The cartographic sources are: Cane (1846), Plunkett and Brady (1872), Hopkins (1879), Goad (1881), Goad (1890), and Pinsonneault (1907).

[27] Geo-rectification, or "warping" of the original maps is not necessary for space syntax analysis, but this procedure was undertaken so that the analysis could contribute to a larger GIS project aimed at creating a multi-layered, historical geodatabase for Montreal (NCE-Geoide, grant: HSS56). It has the advantage that successive maps can be viewed as "overlays," one on another.



5.2 Street network of Montreal in 1846, 1866, 1881, and 1901

Table 5.1
Properties of the Montreal Street Network (1846, 1866, 1881, 1901)

	1846	1866	1881	1901
Number of axial lines	277	474	687	1181
Total length of axial lines (km)[1]	119	214	301	506
mean length	0.43	0.45	0.44	0.43
minimum length	0.35	0.40	0.36	0.25
maximum length	2.1	3.6	3.7	6.0
Number of intersections	722	1238	1755	2844
Intersections / Axial lines[2]	2.6	2.6	2.6	2.4
Gamma index[3] ($\gamma = e / e_{max}$)	0.88	0.87	0.85	0.80
Axial lines / Square kilometres of urbanized area	29.9	27.9	29.7	23.2

[1] Due to how the axial map is constructed (with dangles or overlaps), the total length of axial lines will always be considerably higher than the total length of streets in the city (recall Figure 1.1).
[2] This measure resembles the Beta index: $\beta = e / v$. The higher the β the more connected the network.
[3] The Gamma index evaluates the relative connectedness of a network. It is the ratio between the actual number of edges (e) in a network and the maximum possible number. In a planar graph, it is calculated as $\gamma = e / 3(v - 2)$. In this analysis I offer a variation of the Gamma index, using intersections to represent the number of edges, and axial lines as nodes. For further discussion of graph theory techniques for transportation analysis, see: Wheeler and O'Kelly (1999); Taaffe et al (1996); and Garrison (1965).
Sources: total length of streets estimated from *Annual Reports of City Surveyor* and Atherton (1914); all other data produced using Axwoman, ArcView and related scripts.

network grew considerably, from 277 to 1181. While the mean length of axial lines in the system changed little over time, the length of the longest axial line increased with each surge of growth: from 2.1 kilometres in 1846 to 6.0 kilometres in 1901.[28] Although

[28] In 1846, the longest axial line was Sherbrooke Street West; however, the street was only sparsely settled at this time. In 1866 and 1901, the longest axial line in the system was St Lawrence, while in 1881, St Denis Street was slightly longer than St Lawrence (that is, urban development had spread farther up St Denis by 1881). The index of population per axial line also grew in successive booms (from 159 in 1846, 217 in 1866, 249 in 1881, and 275 in 1901).

the total number of intersections in the system grew from 722 in 1846, to 2844 in 1901, the average number of intersections per axial line remained relatively stable (between 2.6 and 2.4), therefore suggesting that the basic structural properties of the street network may not have changed much as the system expanded. The city prior to the automobile was probably structured in a grid with a certain scale. By comparing the number of observed links (intersections) in the system for each period with the maximum possible number of links, we see that the network actually became slightly less connected over time (from 0.88 in 1846 to 0.80 in 1901).[29] The elongated pattern of the street network in later periods was likely comprised of a greater number of dead-ends, lanes and poorly-connected suburban streets. Consistent with this claim is the evidence that the density of axial lines per square kilometre of urban area also decreased over the latter half of the century, particularly between 1881 and 1901 (see Table 5.1). This, I suspect, is a consequence of repeated annexations of suburbs which were not as fully developed as the central city.[30]

Let us now turn to an investigation of the syntactical properties of the network, by interpreting connectivity, global and local integration. On each map, axial lines are

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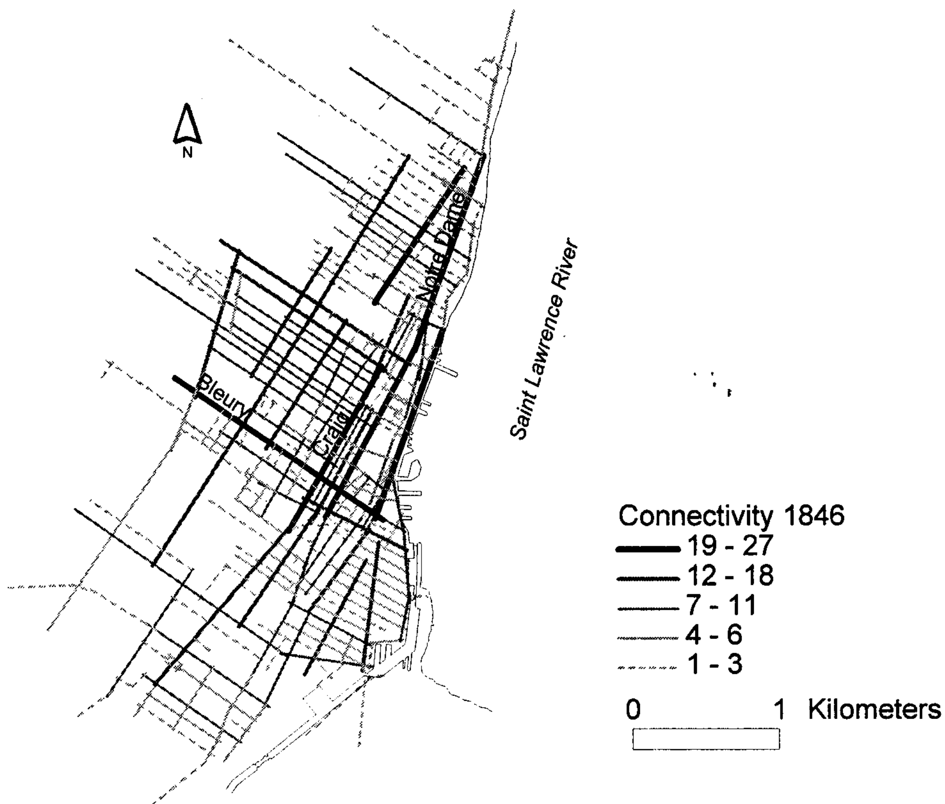
[29] This measure is a variation on the "Gamma index," a commonly-used indicator of network accessibility in transportation research (See note 3, Table 5.1).

[30] Population density in Montreal fluctuated from approximately 5.6 persons per square kilometre of developed land in 1846, to 5.3 in 1866, to 7.2 in 1881, to 5.9 in 1901. The drop in population density between 1881 and 1901, was primarily due to the annexation of surrounding villages: Hochelaga (1883), St Jean Baptiste (1886), St Gabriel (1887), and St Louis du Mile End (1894). These suburbs contained approximately 22,500 persons and about 11 square kilometres of land, for an average population density of only 2 persons per kilometre (Atherton 1914). Population density figures were calculated by dividing the estimated population (see Figure 1.1), by an approximation of the developed area of the city, measured as the "footprint," or area surrounding each axial map.

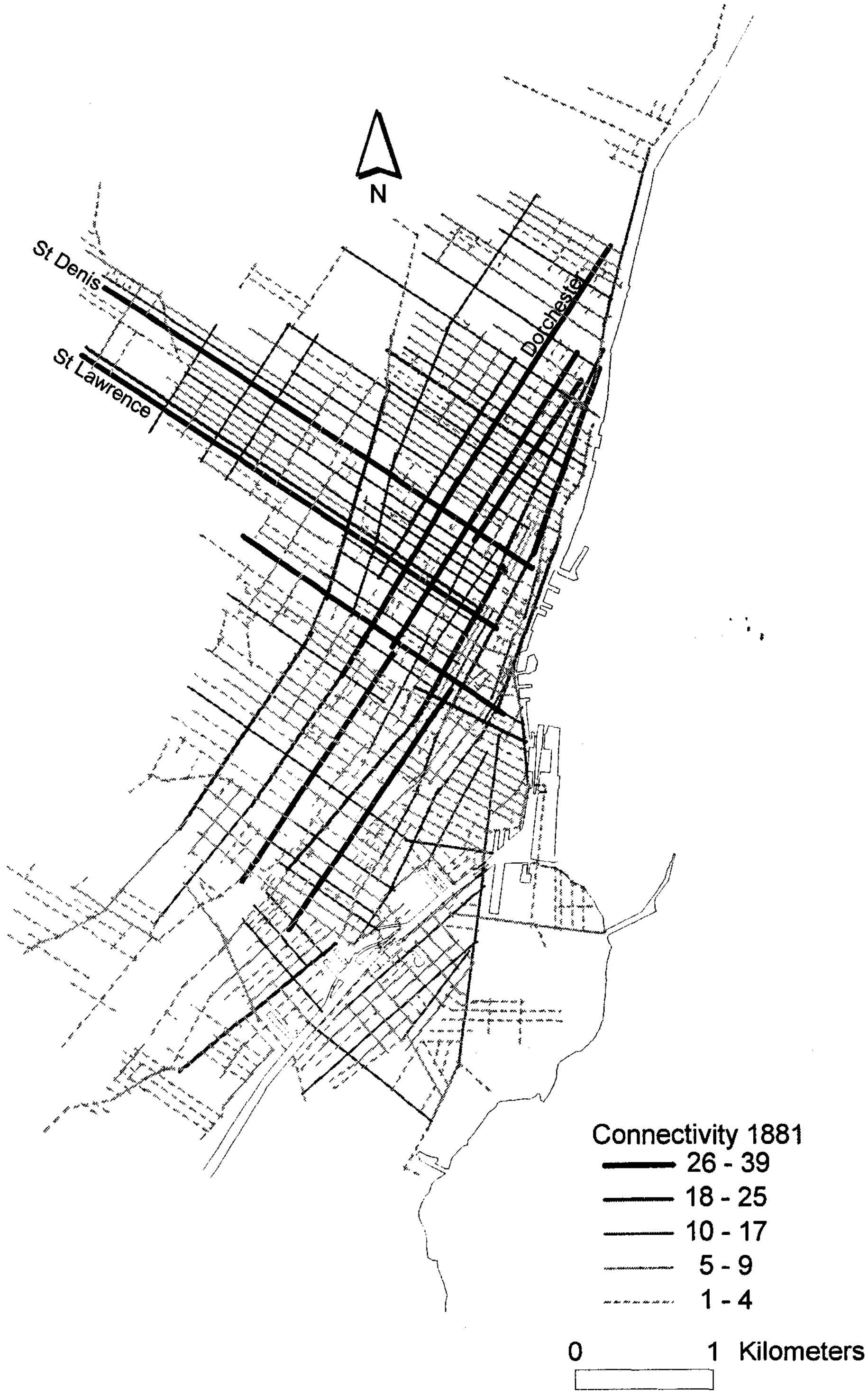
shaded from lightest to darkest in order of increasing connectivity or integration, calculated using the formulae described above. Let us first consider the highly localized measure of connectivity (Figures 5.3 to 5.6). The best connected street segments in each period were, naturally, some of the longest and most centrally-located axial lines in the network.[31] The most highly connected street on each map tended to be one that linked the old core with the suburbs, following the trajectory of growth of the city itself. For this reason, the best connected streets were mostly east-west arteries, which ran parallel to the St Lawrence River. In 1846, for example, the best connected street was Notre Dame, within the heart of the city, and in the Faubourg Quebec immediately east of the core (segments we discussed in the previous chapter on street widenings). Dorchester Street, just north of Old Montreal, was the most highly connected street in 1866 and 1881. In 1901, as the city expanded to the north, the best connected street was St Lawrence. Also noteworthy in 1901, was Mt Royal Avenue, the "top of the line" for the streetcar. It appears as one of the most connected streets in the system (4th place out of 1181 streets), consistent with its emerging status as a suburban main street. As the city expanded, the number of highly connected streets remained relatively small; since the maximum length of axial lines in the system grew (recall Table 5.1), the set of best connected streets tended to extend over a larger area in the city. Since mean connectivity of axial lines in the system remained stable at about five connections, it appears that the basic structure of

[31] While there was a clear correlation between connectivity value and length of the axial line, the correlation was not as strong as might be expected (r-squared values ranged between 0.49 and 0.68), which suggests that connectivity was also the result of other (more meaningful) factors such as centrality.

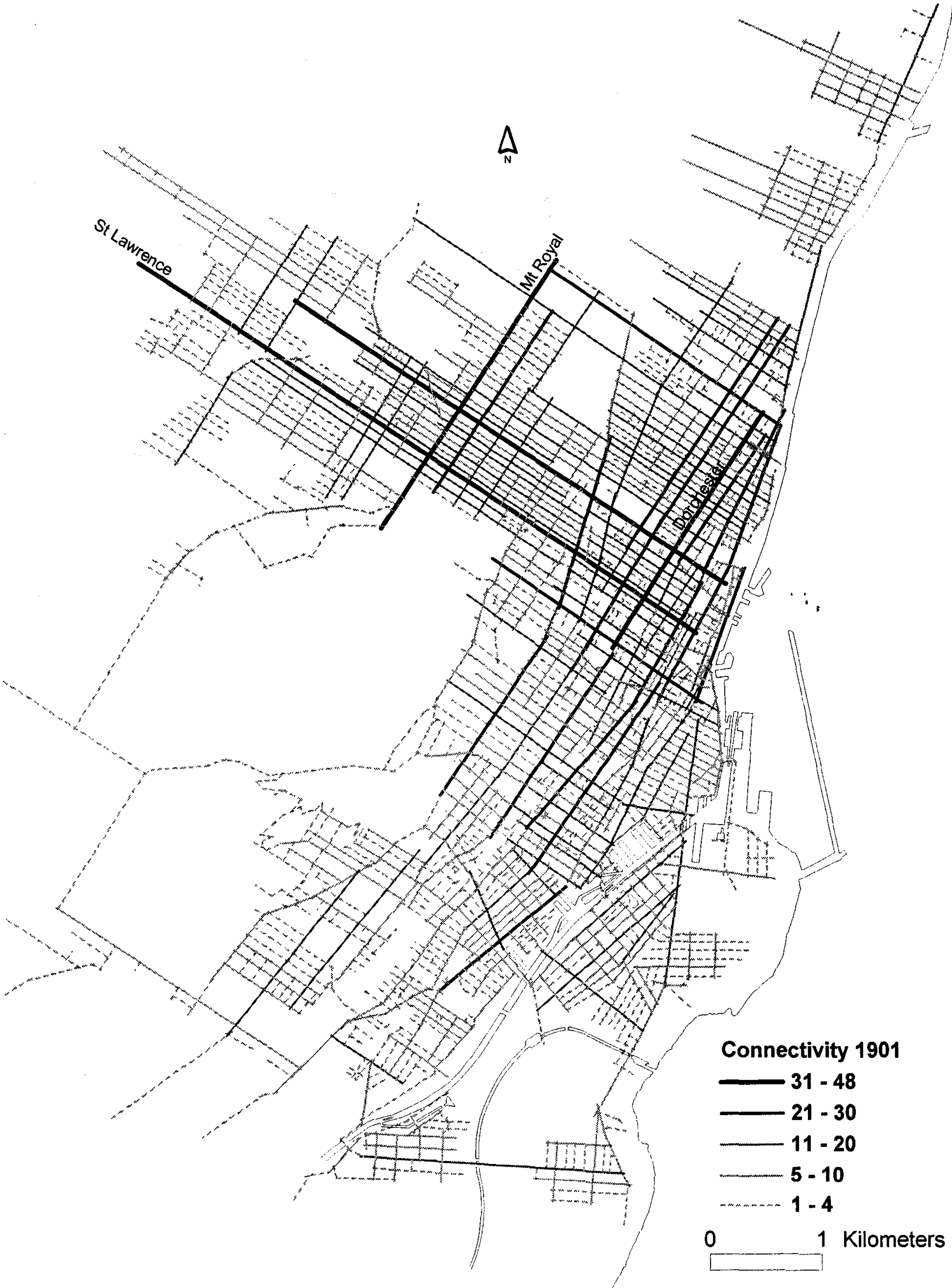


5.3 Connectivity map of Montreal in 1846

5.4 Connectivity map of Montreal in 1866



5.5 Connectivity map of Montreal in 1881



5.6 Connectivity map of Montreal in 1901

the street network did not change, but maximum connectivity, that is, the value for the most connected street segment, increased in each period: from 27 in 1846, to 37 in 1866, 39 in 1866, and 48 in 1901 (Table 5.2).[32] The rapid spatial expansion of the network after each boom, accompanied by the increasing length of axial lines, resulted in a small number of streets becoming dramatically more connected within the system over time. The connectivity value of St Lawrence Street, for example, increased in each study period: from 11, to 24, to 26, to 48 (changing rank from 22nd to1st place in the network). On the other hand, the connectivity value of Notre Dame Street East was stalled at 27 for each time period (gradually falling from 1st to 11th position). The changing relative rank of these two street segments is consistent with what we have already learned about the differing patterns of redevelopment on these streets after street widenings in the 1890s. By examining the distribution of connectivity values for each year (see Figure 5.7, top left) together with the maps, we can see that the general impact of urban growth on the system was not only the dramatic increase in connectivity of a few highly connected street segments in the central core, but also the addition of a large number of poorly-connected streets to the system, primarily at the rural-urban fringe.

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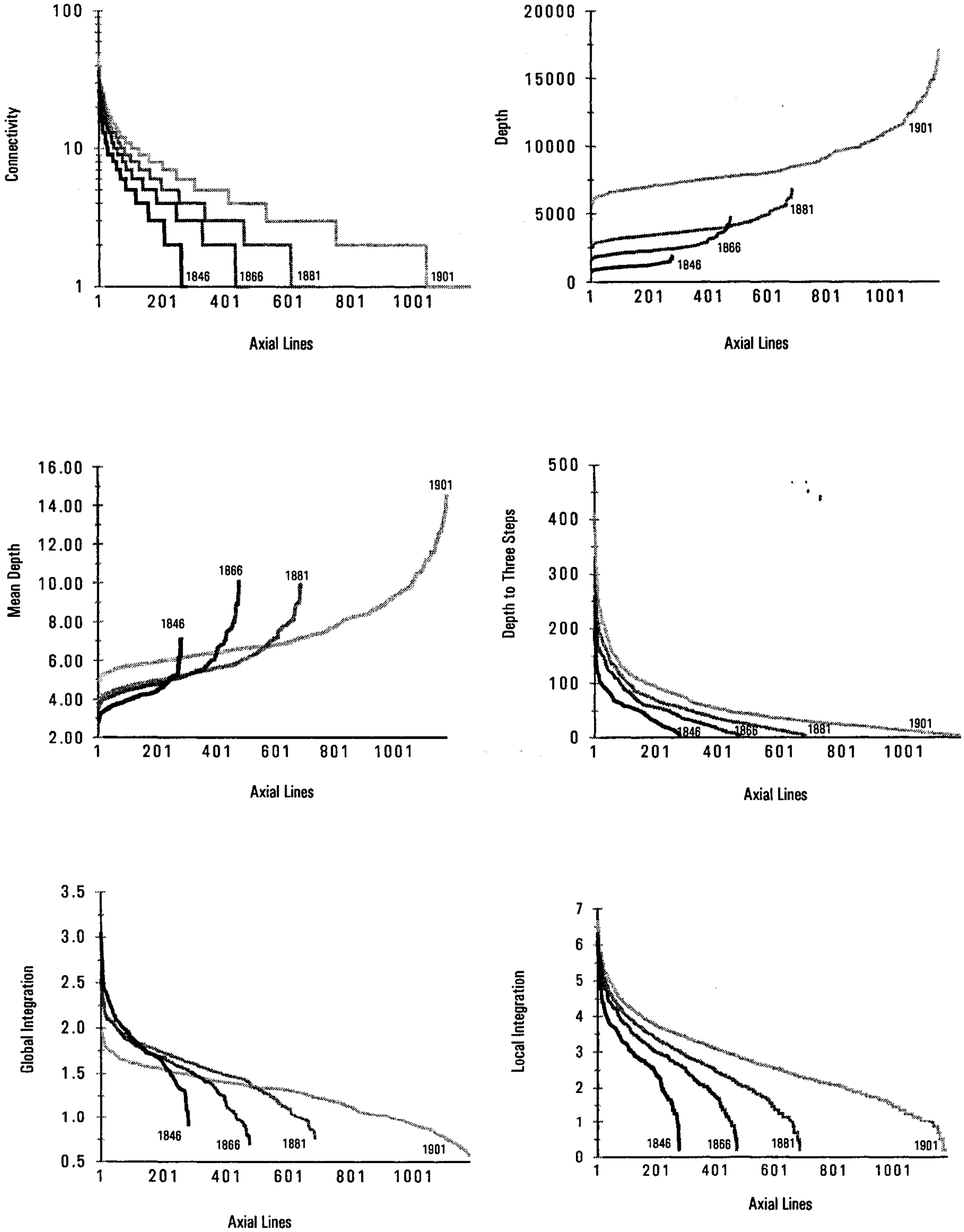
[32] In his comparative study of a sample of "organic" cities in England and Iran, Karimi (1997) reported lower values for connectivity. For example, the *mean connectivity* values ranged between 3.1 and 3.7 for the English cities, and between 2.7 and 3.0 in the Iranian cities. Likewise, the maximum connectivity values were much lower, averaging 17 for the English cities and 11 for the Iranian cities. The differences in connectivity can be explained by the fact that the typical street network of these so-called "organic" cities resembled a dendritic pattern made up of many smaller axial lines, whereas the network in Montreal was laid out and developed in a more traditional grid pattern, with longer streets which met at right angles. On the patterns of street grids, see Reps (1965).

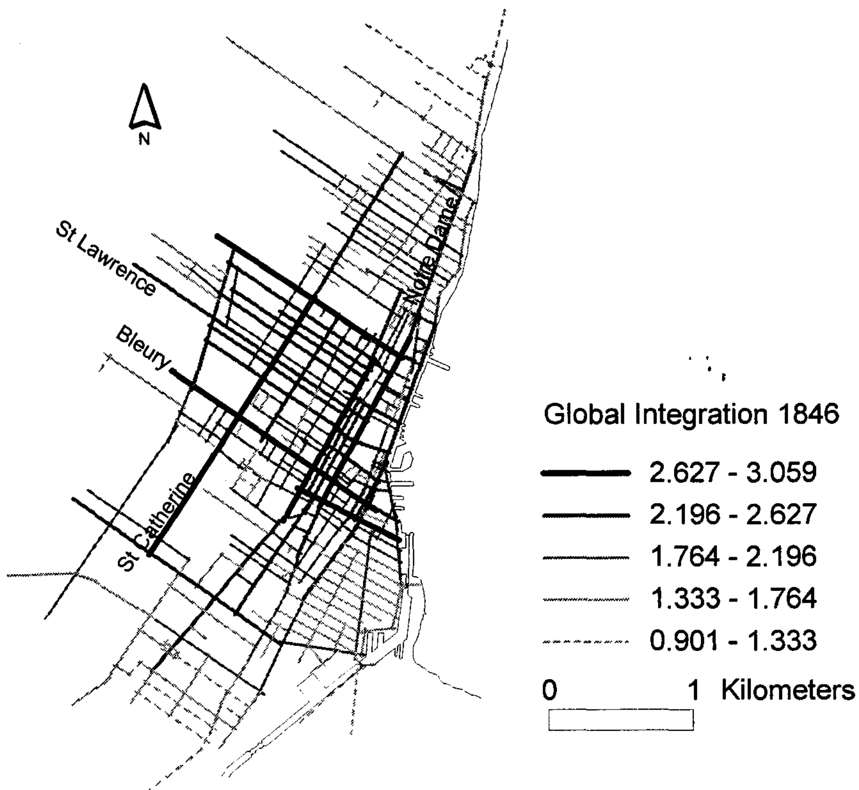
Table 5.2
Summary of Syntactical Properties for Montreal Street Network (1846, 1866, 1881, 1901)

	1846	1866	1881	1901
Connectivity				
mean	5.2	5.2	5.1	4.8
minimum	1	1	1	1
maximum	27	37	39	48
Depth				
mean	1166	2504	3926	8786
minimum	778	1650	2576	5739
maximum	1980	4813	6819	17207
Mean Depth				
mean	4.126	5.080	5.512	7.096
minimum	2.819	3.488	3.755	4.864
maximum	7.174	10.175	9.940	14.582
Global integration [radius n]				
mean	1.797	1.567	1.533	1.261
minimum	0.901	0.689	0.767	0.562
maximum	3.059	2.542	2.488	1.975
Depth to three steps				
mean	53	59	58	54
minimum	3	3	3	3
maximum	198	261	284	414
Local integration [radius 3]				
mean	2.865	2.852	2.779	2.676
minimum	0.211	0.211	0.211	0.211
maximum	6.120	6.339	6.363	6.706

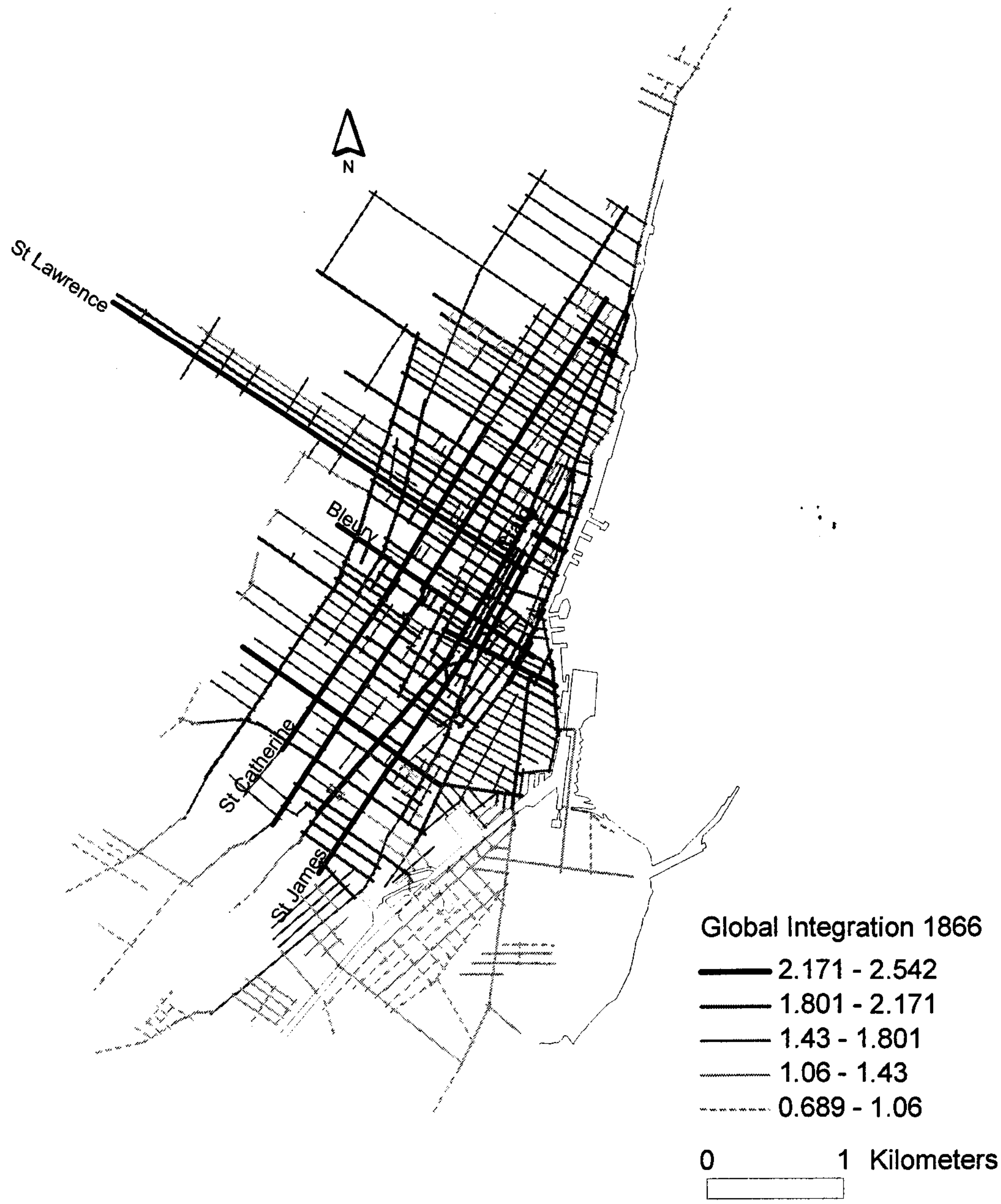


5.7 Distribution of syntactical values for the street network of Montreal, 1846-1901.
Note: Data arranged from most connected / integrated to least connected / integrated.

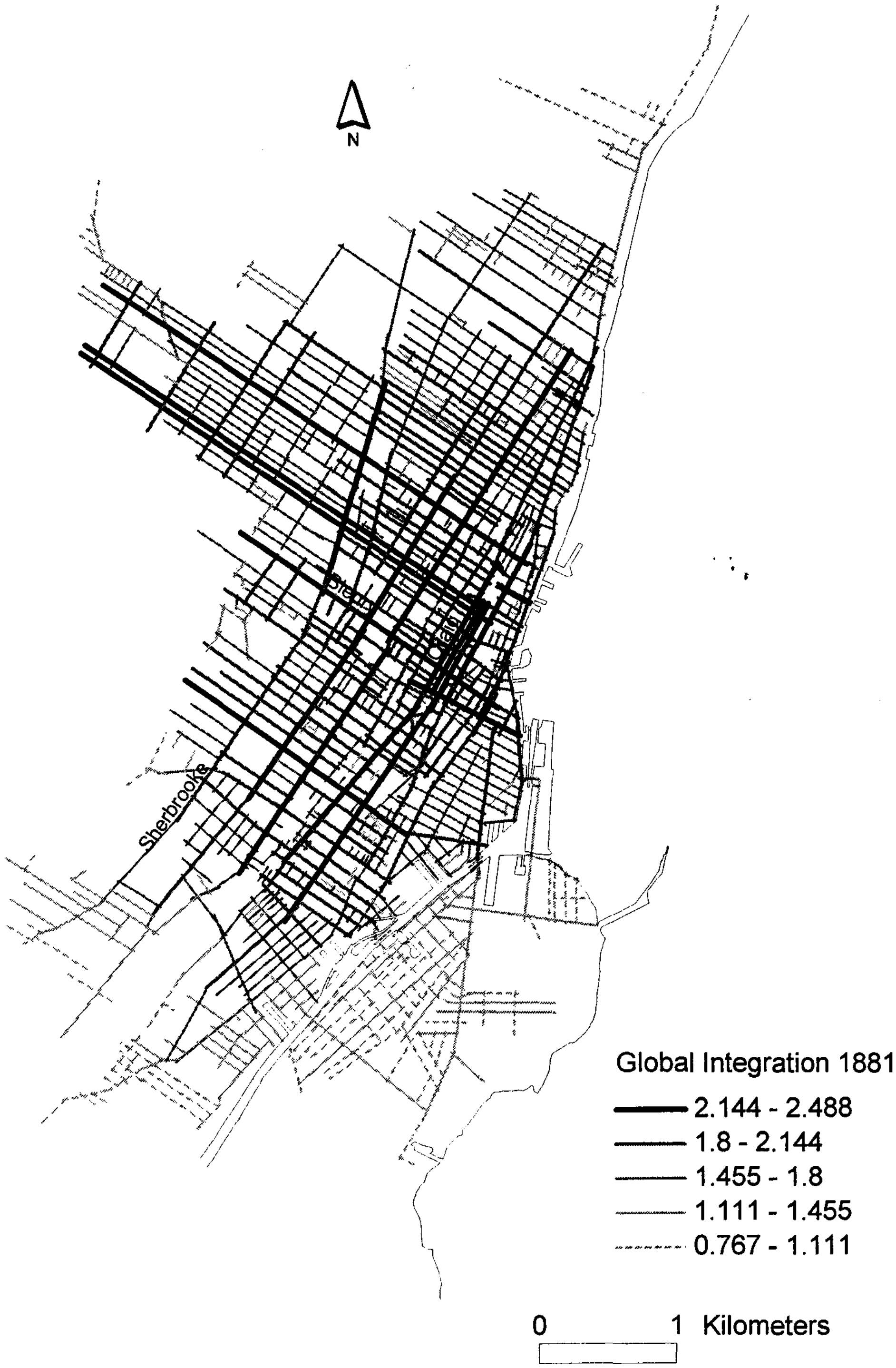
Let us now focus our attention on the measure of global integration (Figures 5.8 to 5.11). From a brief study of the maps, several factors seem intuitively apparent. First, it is clear to anyone familiar with Montreal that there is a relationship between the historical importance of streets and their degree of integration. On each map, major thoroughfares such as Notre Dame, St James, St Catherine, Bleury, and St Lawrence, have high integration values, whereas less significant cross-streets and suburban streets have low integration values. In each period, the two most integrated streets in the system cross each other at right angles such that their intersection has a "peak integration value." In 1846, for example, the two most highly integrated streets were Notre Dame and St Peter in the heart of the commercial core. As we know from our discussion in Chapter 4, Notre Dame Street was one of the most important commercial arteries in the city at this time; and St Peter (including its continuation Bleury Street), was the primary link between the harbour and the "new town" developing toward the slopes of Mount Royal. It too, underwent major widenings between 1846 and 1866 (recall Figure 4.7). In the next two study periods, the St Peter/Bleury axial line remained the most integrated in the system; but, by this time Craig Street had become the second most integrated street. Craig Street – we will see later in the chapter – was one of the widest and busiest streets in the city. This shift is consistent with the beginning of a general movement of business activities and urban investments (such as the new railway stations and the expansion of the Lachine Canal) westward out of the old city. The centre of activity in Montreal at this time was just two blocks west along Craig at Victoria Square (the former hay market turned office district). Between 1846 and 1901, the relative position of St Catherine Street and



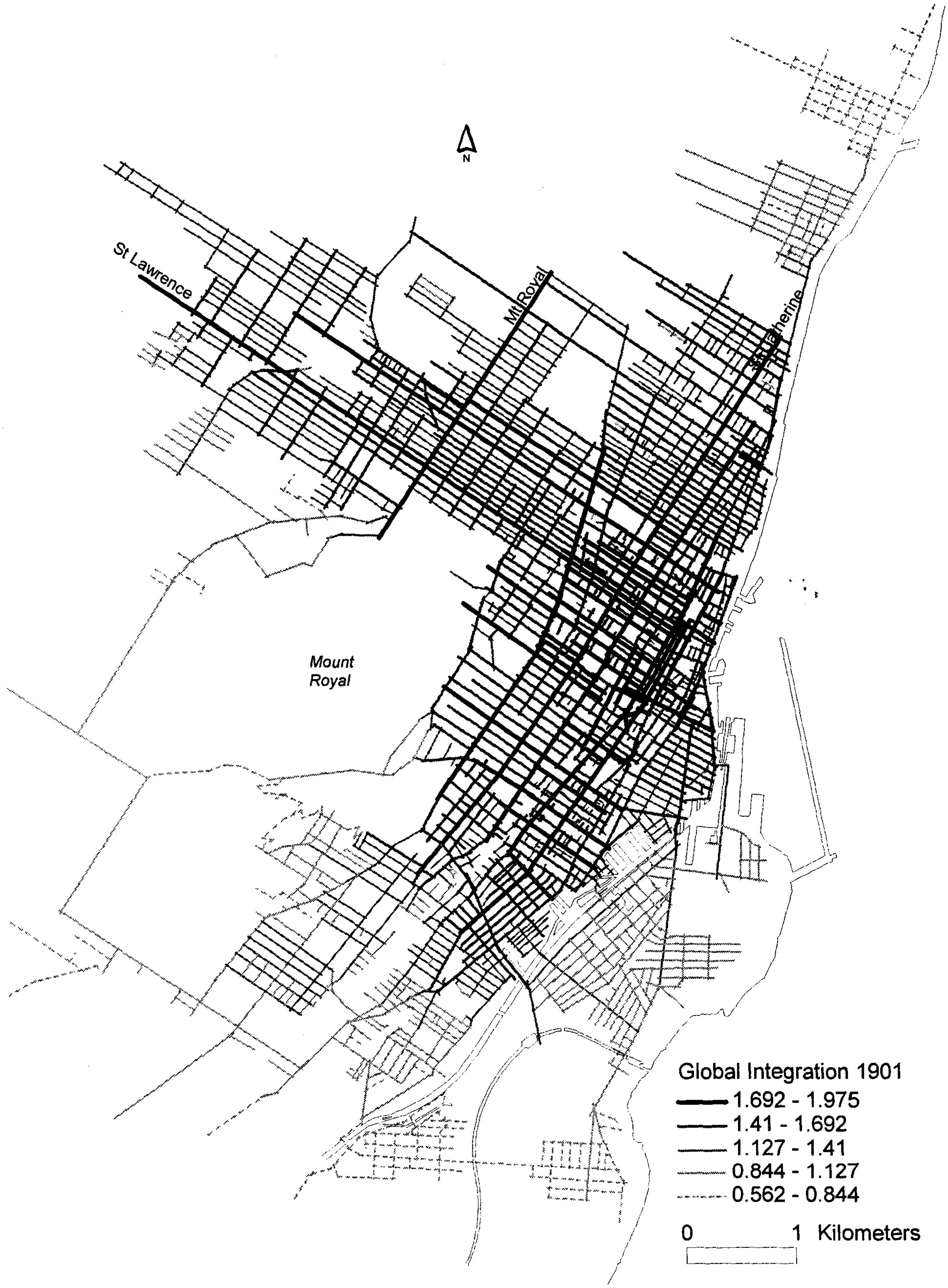
5.8 Global integration map of Montreal in 1846



5.9 Global integration map of Montreal in 1866



5.10 Global integration map of Montreal in 1881



5.11 Global integration map of Montreal in 1901

St Lawrence Street in the network had moved up from 5th and 7th, to 1st and 2nd place respectively. By the end of the nineteenth century, both streets had been widened and maintained a twinned-set of streetcar tracks, consistent with their status as Montreal's major shopping thoroughfares. Although it is no longer the most attractive business location, the intersection of these two streets is still widely perceived today as the "centre" of Montreal.

Another striking feature on each of the global integration maps is the existence of an integrated lattice of darkest axial lines which correspond to the central commercial and retail areas of Montreal. In each period, this "spatial core" is made up of a small percentage (about 3 to 4%) of streets which are much more highly integrated than others, and which include the main thoroughfares connecting the CBD and port district with newly developing suburbs.[33] On the graph of the distribution of global integration values for each period, existence of the integration core is revealed by the sharp change in slope near the y-axis (see Figure 5.7, bottom left). In their study of the morphology of Greek cities, Peponis et al (1989) proposed a somewhat arbitrary standardization of the core as the top 10% of integrated lines in the system. A more careful look at the distribution of values for Montreal seems to indicate that the top 10% of values in each period encompasses a primary and secondary core of highly integrated streets, which roughly corresponds to the primary commercial axes in the city and a secondary core of mixed use streets which feed into them. The growth of the whole system means that after each

[33] On the concept of the "spatial core," see Peponis et al (1989).

boom period this core has expanded in absolute terms, to include a greater number of streets. This result is expected given what we know about the historical processes of urban growth, and how, over time, commercial uses are able to "outbid" residential uses for centrally located sites.

Another interesting feature of the set of maps is that the old core of the city (Old Montreal) remained highly integrated in each period. Its primary business arteries, such as Notre Dame, St Peter, McGill, Craig, and St James, almost always appear in the top category. The majority of shorter and narrower side streets appear as second category streets on each map; these were mixed use at mid-century, but almost entirely commercial by 1901. A closer look at the data reveals that although the aforementioned streets remained among the top 1% of the most highly integrated in the city, all but St James Street dropped in rank between 1846 and 1901.[34] These shifts are consistent with evidence that the integration core gradually moved away from the waterfront, as the city expanded.

What more can the integration values tell us about how the network changed over time? The integration of the entire network is given by the *mean global integration* of all its lines. A consistent decline in the mean, from 1.797 in 1846 to 1.261 in 1901, suggests that as the sheer size of the street network expanded over time, it became slightly less integrated (see Table 5.2). In their study of six Greek cities, Peponis et al (1989) report

[34] Between 1846 and 1901, St Peter Street dropped from being the most highly integrated in the network to the sixth highest, Notre Dame went from 2nd to 8th place, and McGill from 3rd to 9th. Another commercial street, St Paul, plummeted from 8th to 118th position, but remained in the top 10%. Meanwhile, during the same period St James Street rose from 11th to 7th place (from the top 4% to the top 0.5% of all lines).

mean global integration values of 1.39. According to Hillier (1996), the mean global integration value of Greater London is 0.774, and for the City of London alone, it is 1.70. Karimi (1997) reports mean global integration values of 0.966 for English cities and 0.482 for Iranian cities. As the network grows, it naturally becomes "deeper." This fact is reflected in the statistic for *depth,* which, we can recall, measures the total number of steps required to get from one node to all other nodes in the system. Depth must increase with growth because every additional line in the system adds at least one more step to the total depth value for each line. Since the values for *mean depth* in Montreal increased between 1846 and 1901, it appears that the street network became relatively deeper over time. When a street is added to the network, whether it increases or decreases values for mean depth depends on its position. As mentioned earlier, any expansion at the urban fringe was associated with accretion of an ever greater number of dead-ends and poorly-connected suburban streets.

The four curves of distribution of global integration values appear to have the same basic shape (Figure 5.7, bottom left). Each curve reveals a small primary core of highly integrated streets, a slightly larger secondary core, a much larger middle district, and then roughly two categories of poorly integrated streets.[35] While the steady decreases in the mean, maximum, and minimum values of global integration support the argument that the network became less integrated over time, they also raise important questions about how these values can and should be interpreted. How does the standardizationof

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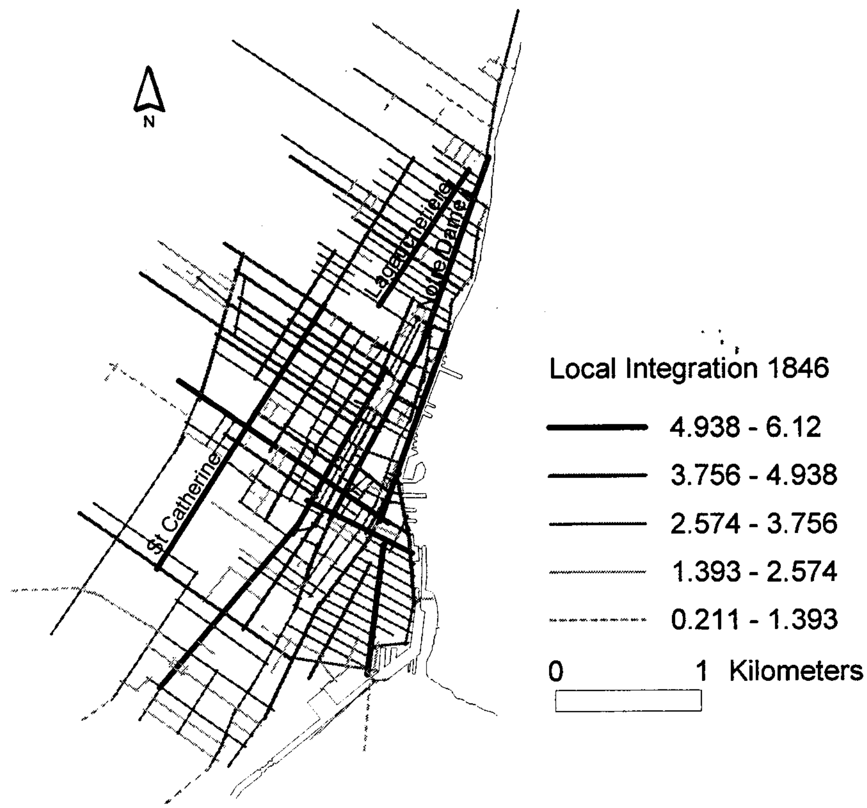
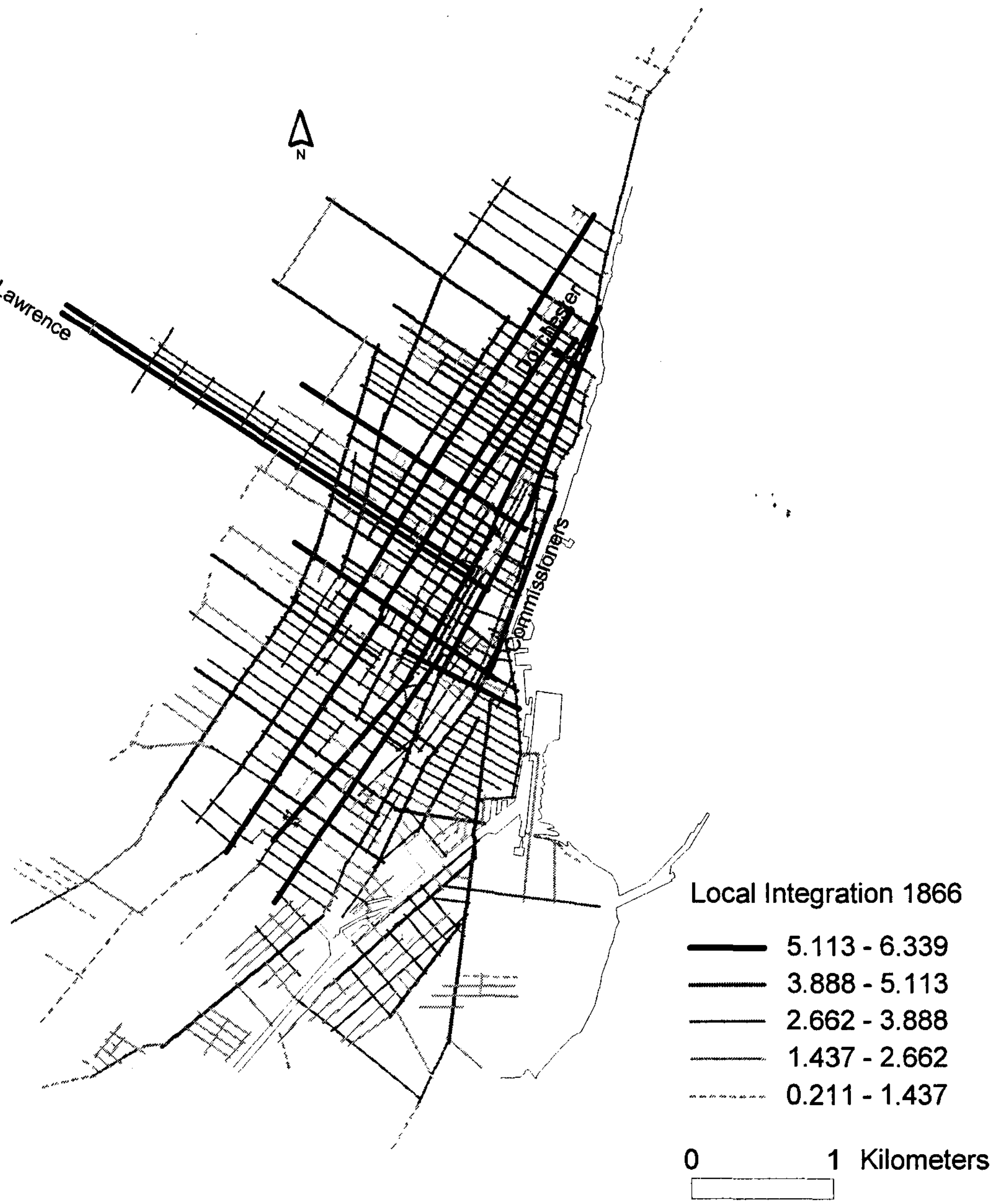
[35] An analysis of these curves was used to devise the key for the five categories of streets displayed on the global integration maps.

integration values affect our interpretation of change over time? As mentioned earlier, global integration values represent a measure of *mean depth*, which has been transformed so that systems of different sizes can be compared. Comparing the graphs of the two measures (Figure 5.7, left side middle and bottom) reveals that the curves of global integration appear to be an approximate mirror-image of the *mean depth* curves, and therefore the standardizationprocedure has not radically altered the general shape of the distribution of values within the network as a whole. What are we to make of the finding that the global integration value of the St Peter/Bleury axis decreased from 3.06 to 2.49 between 1846 and 1881, even though it remained the most highly integrated street in the entire network during the same period? Similarly, how can we explain why the global integration value of St James Street decreased from 2.43 to 1.91 between 1846 and 1901, while at the same time its rank in the system overall increased from 11th to 7th place? Since integration is always a distribution of values, we need to focus our attention on the way the whole system changes from period to period. The finding that one street segment has become more integrated (or more segregated) tells us little, unless we know what the rest of the system is doing. This notion applies in particular to studies of the changing relationship between integration and patterns of urban movement. If we look at the city during different times of day, for example, clearly there is likely to be more traffic at noon than at midnight in absolute terms, but the distribution of traffic throughout the system may nevertheless vary in a consistent way.

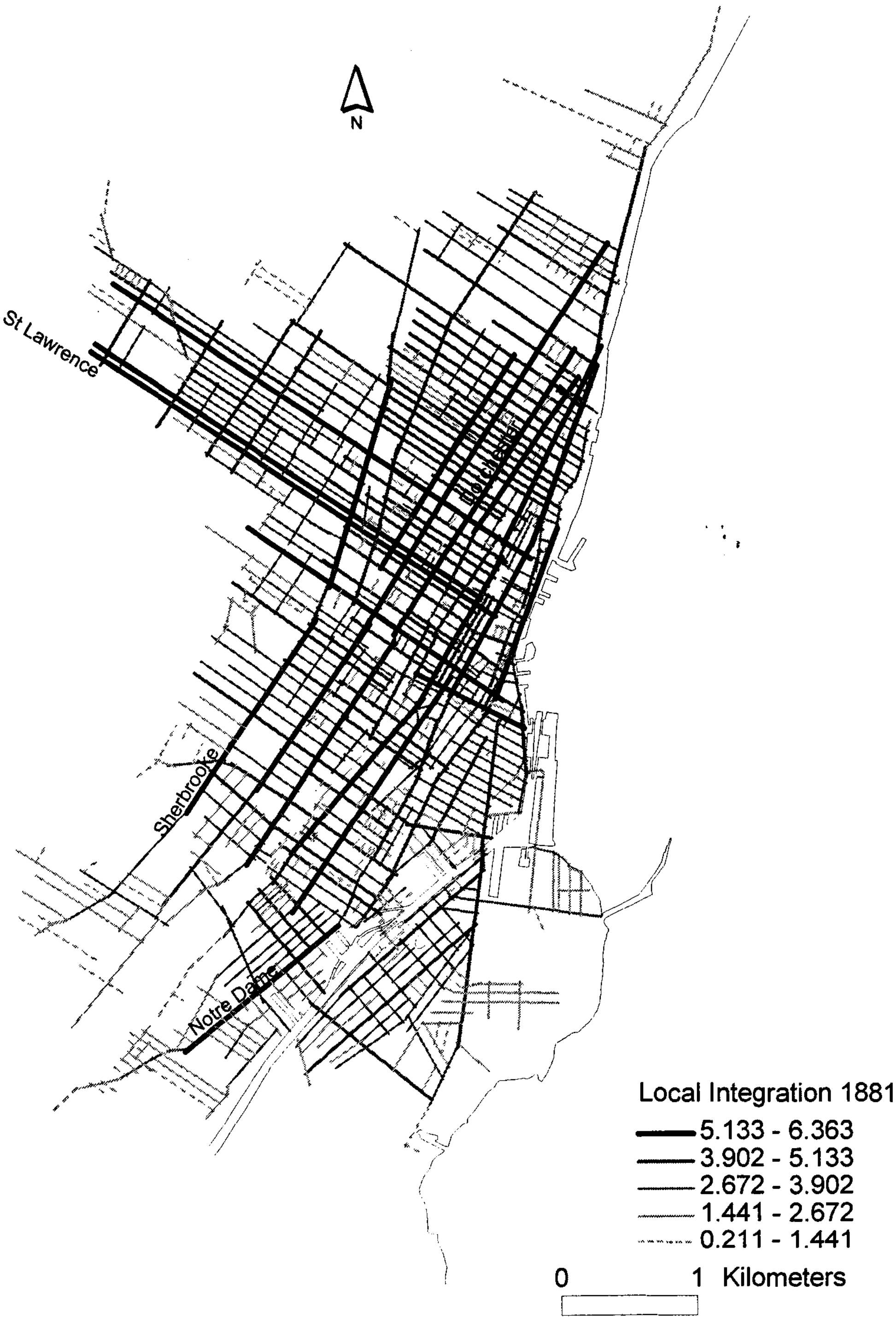
An examination of the *local integration* maps (Figures 5.12 to 5.15) reveals that various street segments figure differently with regard to the extent of their catchments;



5.12 Local integration map of Montreal in 1846



5.13 Local integration map of Montreal in 1866



5.14 Local integration map of Montreal in 1881

5.15 Local integration map of Montreal in 1901

that is, some streets such as Lagauchetière East are locally, but not globally integrated; while others such as St Catherine Street (arguably the most important retail street in the city since the late-nineteenth century) are both locally and globally integrated. In general, maps of local integration tend to resemble the connectivity maps. This finding is understandable, since connectivity is merely integration to one step away, or to a radius of one, whereas local integration is integration to three steps away. Both are measures of local accessibility. As was the case of global integration, streets with the highest local integration values tended to be long and centrally-located. A number of the locally integrated streets in each period were mixed use streets and arteries of residential districts. In 1846, the two streets with highest local integration values were Notre Dame East and Lagauchetière East. The former, as we have already discussed, was the main commercial street of the Faubourg Quebec and a historically important thoroughfare; the latter, on the other hand, was a mixed-use artery which had been built up within the previous twenty years. Dorchester Street had the highest local integration value in both 1866 and 1881, and in 1901, the most locally integrated street was St Lawrence.

The mean value of local integration in the network remained relatively stable but decreased slightly over time (from 2.87 in 1846, to 2.68 in 1901). On the other hand, the maximum local integration value in the system increased slightly over time (from 6.12 in 1846, to 6.71 in 1901). Hillier (1996) indicates that the *mean local integration* value for Greater London is 2.34. The mean local integration value for the City of London today (2.61) is comparable to the value for Montreal in 1901 (2.68). In his study of "organic" cities, Karimi (1997) reported mean local integration values of 2.03 in English cities, and

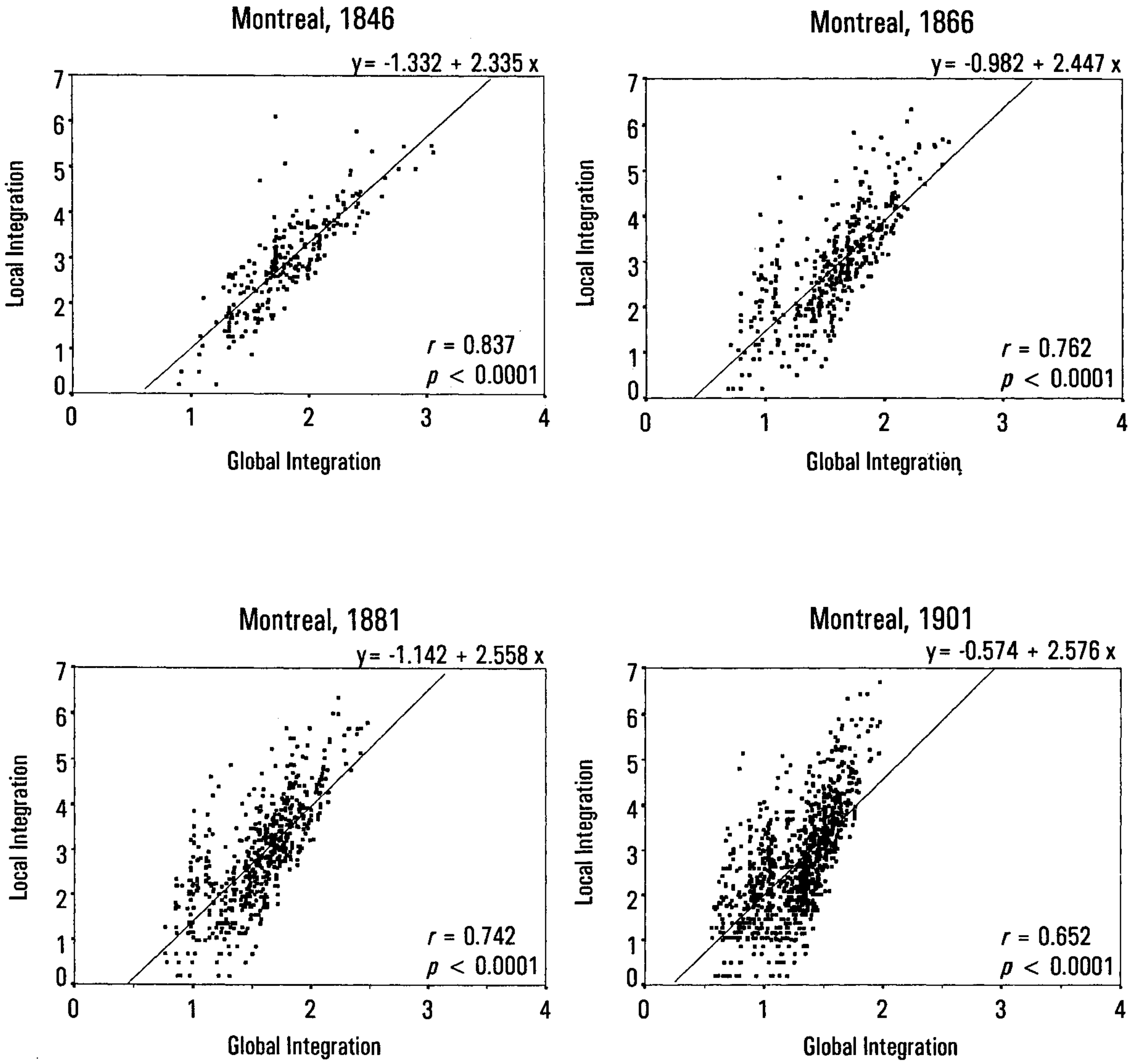
1.60 in Iranian cities. An examination of the curves of local integration values in 1846, 1866, 1881, and 1901 (Figure 5.7, bottom right) confirms that there was a slight increase in the maximum value, but the overall distribution of values did not change much from year to year. The increase in maximum value, and the local integration value of other highly ranked streets in each period, is likely due to the general increase in the actual length of street segments, as well as the infilling of new streets within the central core (within three steps of major streets).

A comparison of the statistics for each period reveals that the correlation between local and global integration diminished over time. As seen in Table 5.3, the r^2 values decreased continuously. The scattergrams in Figure 5.16 not only indicate that the correlation between the two variables gradually weakened, but the steepening slope and the

Table 5.3
Correlations between Syntactical Variables of Street Network (1846, 1866, 1881, 1901).

	1846	1866	1881	1901
Correlation (r^2) between Connectivity and Global Integration	0.486	0.305	0.302	0.194
Correlation (r^2) between Local Integration and Global Integration	0.700	0.581	0.551	0.425
Correlation (r^2) between Connectivity and Local Integration	0.744	0.692	0.696	0.669

Note: See Figure 5.16



5.16 Correlation between global and local integration values for all street segments, 1846, 1866, 1881 and 1900 greater variance values also suggest the increasing importance of sub-centres independent of the global core.[36] This phenomenon is well-described in urban geography texts and is usually attributed to the arrival of the streetcar and the expansion of its network.[37] It is something we observe in the creation of neighbourhood churches and schools, the choice of parade routes, and the appearance of sports leagues and lodges in the social life of the city during the late-nineteenth century.[38]

In space syntax terminology, the correlation between connectivity and global integration is referred to as the "intelligibility" of the system, since it is a measure of the degree to which the global properties of the network are discernible from the highly local properties. It has been suggested by Hillier (1996) that an r^2 value of greater than 0.45 represents an "intelligible" system. Using this guideline, we can see that the street network of Montreal went from being an intelligible system in 1846 (with an r^2 value of 0.486), to an incomprehensible system in later periods. As mentioned earlier, the maps of local integration closely resemble the maps of connectivity in each period, primarily because both were measures of the local properties of the system. Considering the importance of the emerging neighbourhood structure, we should also examine the "local intelligibility," or the correlation between connectivity and local integration. We can see

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[36] According to Hillier (1996), the r^2 value for the correlation between local and global integration for the City of London is 0.675 and for Greater London it is 0.166. Karimi (2000) reports data from other unpublished studies, indicating that European cities have average r^2 values of 0.269 and U.S. cities (no mention of which ones) tend to have r^2 values of 0.302.

[37] See Hartshorn (1992) and Gallion and Eisner (1980).

[38] See Trigger (1997) and Olson (1995).

from Table 5.3, that the correlation between these two variables was also strong. As expected, the r^2 values were high, but they also decreased slightly over time. The findings seem to point to an increasing inability to comprehend the entire city structure through the arrangement of its local parts; however, we should be cautious about the conclusions we make regarding the "intelligibility" of the system. In the lexicon of space syntax, intelligibility is a technical term with a specific and quantifiable definition, whereas in lay usage, the term refers to the more general, qualitative characteristics which relate to the capability of being understood. Furthermore, in the field of urban design, Kevin Lynch has introduced the concepts of "legibility" and "imageability" to describe and analyse the perceptual characteristics of urban spaces which he argues are necessary for "good city form."[39] Besides the local street pattern, there are many physical elements which can enhance intelligibility, or the way that we perceive urban spaces, including natural landmarks such as a mountain or coastline, or monumental human constructions such as church steeples, skyscrapers, or public statues. Ultimately, the lack of intelligibility of the global structure in a commercial or industrial city has to be compensated by a relative accessibility to the core. This is essential for exchange within the city between locals, and with visiting merchants and clients.

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[39] See Lynch (1960; 1990).

TESTING THE PREDICTIVE PERFORMANCE OF SPACE SYNTAX

The series of global and local integration maps readily make sense to anyone with an intimate knowledge of Montreal. The results of the configurational modelling seem to correspond with what we know about historical building and land use patterns from published sources,[40] and from what we can learn by walking and observing the inherited urban landscape itself. Much less clear, however, is whether the integration maps tell us anything new about the reality of urban society in the nineteenth century. Empirical studies of the modern city have demonstrated a strong correlation between network configuration and traffic flows (pedestrian and vehicular).[41] Recent case studies also suggest that there may be a relationship between spatial configuration and other social, environmental, and behavioural features of urban life and form, such as the distribution of land uses, the diffusion of automobile pollution, the spatial patterning of hostile interactions such as crime, and the evolution of built densities.[42] In this section, I test the predictive powers of space syntax by comparing the computed syntactical values with contemporary empirical evidence of traffic flow, street width, land use, and intensity of development.

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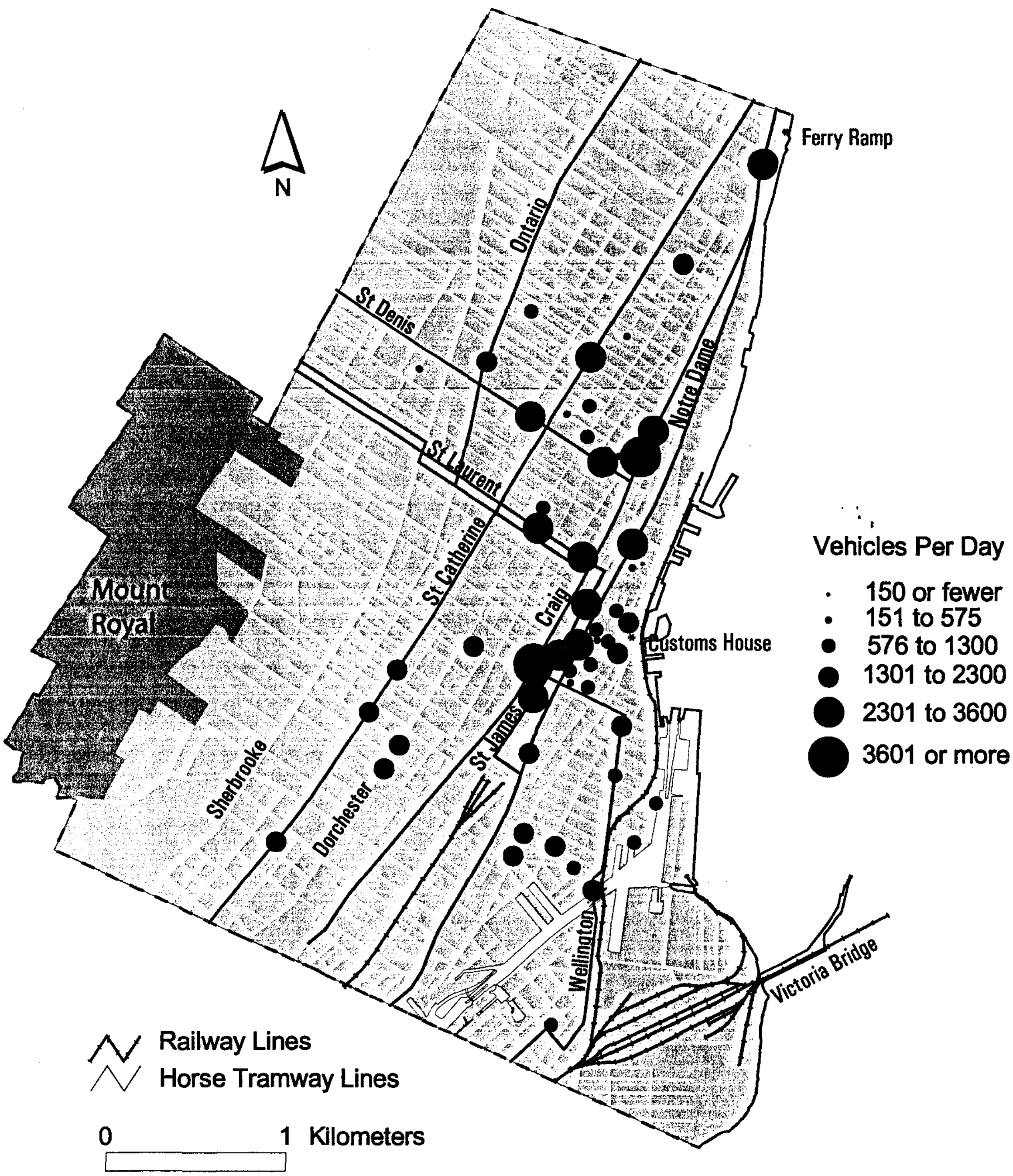
[40] See, for example, Robert (1994), Marsan (1994), and Gournay and Vanlaethem (1998).

[41] Evidence suggests that vehicular traffic is more strongly correlated with global integration than local integration; and pedestrian movement is better correlated with local integration (Hillier 1996).

[42] See Hillier (1996), Croxford et al (1996), Hillier et al (1993), and Penn and Dalton (1994).

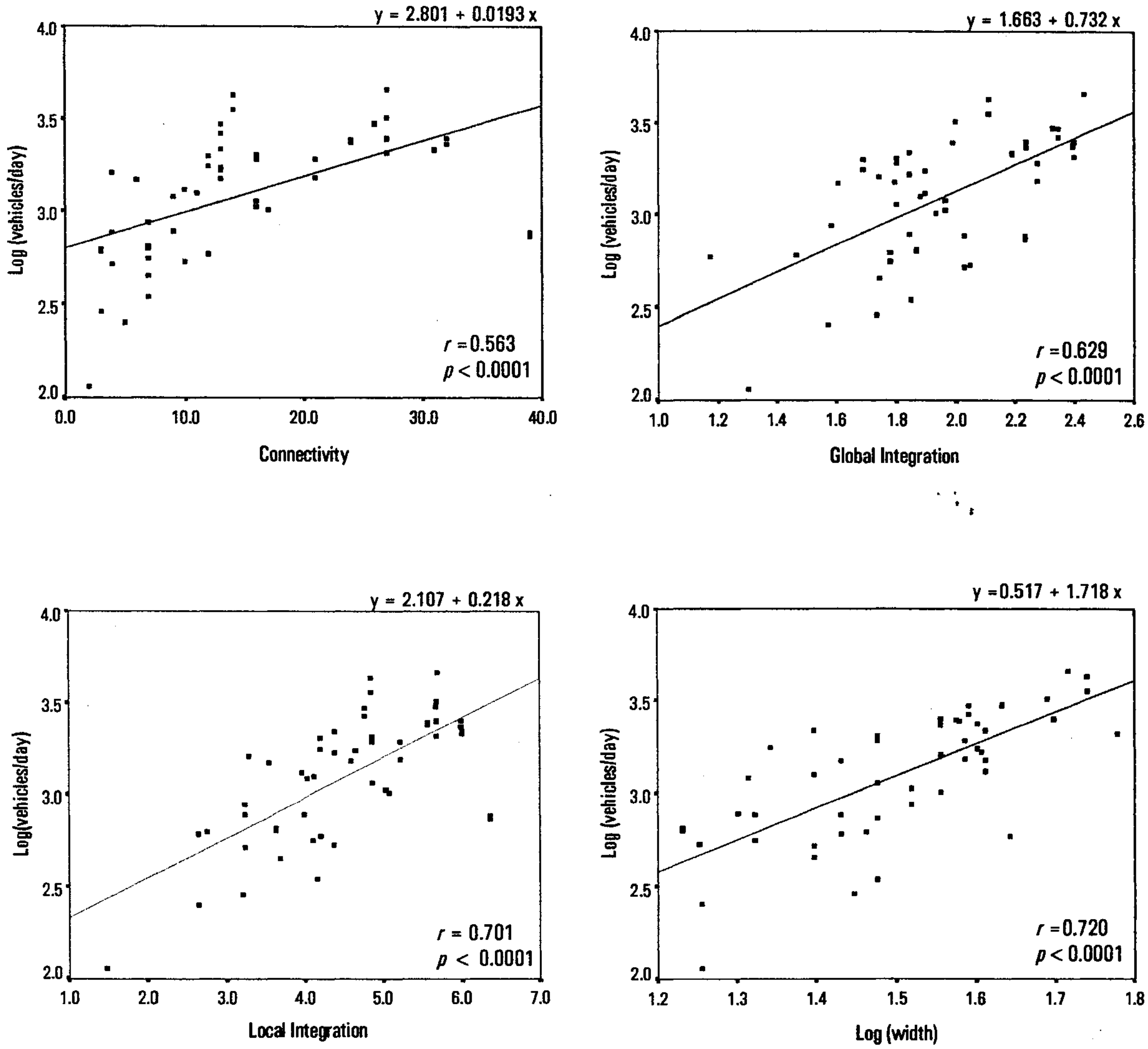
An exceptional source of data used for this analysis is the historical traffic surveys conducted by the City Surveyor's office between 1889 and 1891. These surveys were initiated just prior to the electrification of the tramway. His investigations indicate that even when all vehicles were horse-drawn, traffic was already a serious problem! From these surveys, daily traffic flows can be calculated for 53 street segments, or *observation gates* throughout the city. The values represent the mean daily average of six days (Monday-Saturday, 7am-6pm). Although most of the gates were located on main streets in the centre of the city, the sample also contained locations outside of the central business district. Since the surveys were originally conducted for the purpose of making decisions regarding street pavements, there is a risk that the counts might be biased toward high-flow business streets, but this is not a problem. The frequency distribution of observations is skewed toward the lower values: that is, most street segments carry low traffic flows with only a relatively small number carrying the highest flows. Figure 5.17 illustrates the pattern of traffic flows across the city. Traffic flow at each observation gate is represented by a graduated circle, sized according to the mean daily flow of vehicles. A careful comparison of this map with the global integration map for 1881 (Figure 5.10) suggests a relationship between integration and circulation. To be more certain the attribute tables were subjected to further statistical analysis.

Figure 5.18 shows the scattergrams and statistics of the correlations between vehicular flow and the space syntax measures of connectivity, global integration, and



5.17 Traffic observations in Montreal, 1889-91

Source: Annual Reports of City Surveyor



5.18 Correlations between traffic flow and measures of connectivity, global integration, local integration, and street width local integration.[43] Simple connectivity proved to be the weakest predictor of traffic flow out of the three syntactical parameters (*r*=0.56, significant at 0.0001). While the scattergram at the top right of Figure 5.18 shows a good correlation between global integration and traffic flow, the correlation coefficient (*r*=0.63, significant at 0.0001) is lower than expected. Previous case studies of vehicular and pedestrian movement with integration values typically report correlation coefficients (*r*-values) between 0.68 and 0.89.[44] The lower correlation in this study might be explained by the fact that the entire city was used for the analysis, rather than a sub-district or neighbourhood, as was the case in most of these other studies.[45] Figure 5.18 (bottom left) shows that vehicular flow is slightly more correlated with radius-3 (local) integration (r = 0.70, significant at 0.0001) than it is with global integration. Radius-3 integration, because it is a measure of local properties, is said to be a better predictor of pedestrian movement than global integration, which is argued to be a better predictor of vehicular traffic. A possible explanation as to why vehicular traffic in nineteenth-century Montreal was more correlated with radius-3 integration than with global integration lies in the different nature of the traffic. Modern

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[43] Since the frequency distribution of the dependent variable, vehicular flow, is moderately skewed, we use a logarithmic transformation to "normalise" the variable so that a few observations with extreme values will not cause an undue effect on apparent correlations.

[44] Hillier et al (1987), Peponis et al (1989), Hillier et al (1993), and Penn et al (1998).

[45] Separate neighbourhoods or suburbs, by design, are homogeneous in form and tend to have their own sub-structure when viewed in isolation, which might not appear when considered in the network structure as a whole. Furthermore, by extracting a set of streets out of the system the topology changes and a pronounced "edge effect" might distort values; for example, it will attribute lower integration values to streets at the edge of a neighbourhood, which otherwise might have high integration values when considered in the system as a whole (with all its connections).

studies of vehicular traffic refer to motor vehicles, whereas in the case of Montreal circa 1890, traffic was mostly carts pulled by a single horse, in addition to a smaller number of double-horsed carts, and horse-powered trams. In many ways, a walking or trotting horse has more in common with a walking human being than it does a Honda Accord.

One of the primary complaints about space syntax methodology is that it does not take into consideration the capacity of individual links. Using information provided in historical reports of the City Surveyor, I gathered data on the effective width (measured curb to curb) of each street segment for which traffic observations were available.[46] The correlation between average daily vehicular traffic and effective street width can be seen in the scattergram in Figure 5.18 (bottom right). A "log-log" relationship was expected because, as we saw in Chapter 3 on the port, the correlation between the flow of traffic and the dimensions of the urban vascular system is an "allometric" relationship of correlated growth, best explained by the *power* equation.[47] The scattergram shows a good correlation and the coefficient of correlation is a bit stronger ($r = 0.72$, significant at 0.0001) than those reported for the syntactical parameters; it is suggested, therefore, that the capacity of street segments may be an important factor in predicting flows, or vice-versa.

To my knowledge, only one published study has attempted to incorporate street

[46] Since the width of sidewalks can vary greatly throughout the city, I argue that these curb-to-curb measurements are a more accurate reflection of true street capacity than what can be derived from available historical atlases (which almost always show property lines, but never show sidewalks).

[47] Recall Chapter 1, note 26.

width into space syntax analysis. Penn et al (1998) performed a multiple regression analysis on vehicular traffic (dependent variable) using both street width and global integration as independent variables, and reported that these two factors alone accounted for the majority of the variance in traffic flows from street to street. While my own experiments do suggest that traffic flows were significantly correlated with the configurational and morphological parameters of the street network, I am unwilling at this point to make the claim, as Penn et al (1998) do, that integration and street width were the primary "generators" of traffic, without further statistical analysis. The fundamental weakness in their otherwise impressive study is that they have not dealt with the problems of identifying "cause" and "effect" which have tormented transportation researchers for decades (recall discussion connected to Figure 4.1). While the evidence for Montreal (circa 1889-91) indicates that wider streets carried more traffic, it is also just as likely that traffic flow influenced street width. As we saw in the previous chapter, the city widened streets which were most congested, that is, which carried the heaviest traffic. It is a classic "chicken and egg" problem. Recent efforts to disentangle the simultaneous relationship between street capacity and traffic flows have suggested that there exists a strong two-way relationship between supply and demand.[48] Unfortunately, given the lack of adequate historical data to serve as suitable instrument variables, I am unable to perform similar experiments for the nineteenth-century context.[49] Nevertheless, the

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[48] Fulton et al (2000).

[49] For a discussion of the instrumental variable estimation technique, see Kennedy (1998, chapter 10).

findings of the simple correlations raise interesting questions about methods of traffic management. As we learned in Chapter 4, the period between 1881 and 1901 was an active time for street improvements in Montreal, as several highly integrated streets, including St Laurent, Bleury, Notre Dame, and St James, underwent major widening projects during this period. Later in the chapter, I will attempt further experiments to investigate the relationship between street widenings and configuration.

Consistent with classic economic-behavioural theories of land use and transportation,[50] Hillier (1996) argues that there is a "central dynamic" to the spatial growth of cities which links the emerging street network structure to the distribution of land uses and the density of the built fabric. If we think of the city as a mechanism for generating communication, as proposed by Meier (1982), then it follows that certain places or streets will have a greater potential for interaction than others, depending on their relative position with respect to the structure of the circulatory system. Such locations tend to have higher densities of development to take advantage of their privileged position, and higher densities in turn have a multiplier effect, by means of which more development may be attracted.[51] Hillier (1996) has dubbed this the "movement economy." Land uses which seek movement (i.e., commercial) gravitate toward higher movement locations, while others (i.e., residential) will seek out, or be

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[50] The classic examples include Alonso (1964), Mills (1972), and Muth (1969).

[51] It is generally believed that in mono-centric cities, such as nineteenth-century Montreal, traffic activity is highest in the central core, where the built fabric is most densely developed (Meyer and Miller 1984). Due to changing patterns of suburbanization(e.g., edge cities) and improvements in transportation and communications, the applicability of such notions to cities today has been heavily debated (see Hartshorn 1992; Taaffe et al 1996; Giuliano 1995).

designed as, low movement locations. The extra attraction of the high movement spaces creates a multiplier effect on movement, which in turn attracts further movement-seeking uses.[52] Urban systems thus become networks of busy and inactive areas, with the busiest found in the most spatially integrated areas, the whole process being initiated by the configuration of the street system.[53] Since the primary concern of this chapter is to examine the relationship between the structure of the urban vascular system and patterns of circulation, we need to investigate the impact of the grid-circulation relation on other characteristics of the nineteenth-century city. In the following section, I conduct another set of experiments to determine whether traffic flow and global integration were correlated with land use and intensity of development.

How should land use be categorized? How can we measure density of the built fabric, or intensity of land use? Judicious decisions must be made, keeping in mind the available sources and economy of labour. The traditional land use distinction is between residential and non-residential activities, but additional sub-categories (industrial, institutional, retail) are usually considered in the models. The concept of development density or intensity has nowhere been adequately conceptualized or defined. An ideal measure would be the "floor area ratio" (FAR), which is calculated by dividing the total

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[52] The essential component of land use-transportation models is the spatial interaction between zones of employment and zones of residence. Since the likelihood of a given zone receiving trips depends on the amount of activity in that zone, and how far it is from other zones, the gravity concept is well suited to this prediction problem (see Creighton 1970; Mackett 1985; Berechman and Gordon 1985; Bolduc et al 1989; Newman 1996). Empirical research indicates that commercial uses are by far the largest generator (Shuldiner 1965).

[53] Hillier (2000; 1996). Sometimes major traffic generators (e.g., factories) are located on streets with low integration values, and thus should be considered the "initiators" of activity in an area.

floor area of a building by the area of its lot: e.g., a two-storey building covering the entire lot will have a FAR of two, a ten-storey building covering exactly half the lot will have a FAR of five. Unfortunately, the atlases of the period, despite their precision in two-dimensional surveys, do not show building heights. For the present day, building height alone might be an adequate surrogate. In the 1880s, however, the vast majority of buildings were two or three storeys, and thus lacked the diversity to be revealing, particularly on streets outside Old Montreal. The historical atlases do show building footprints, and it is therefore possible to calculate the ratio of open-to-built space for each property in two dimensions, although the exercise would be tedious.[54] We might consider using average land values as a measure, but nineteenth-century property assessments varied greatly according to ward, assessor, whims of the market, and political influence, and are therefore unreliable for my experiment.[55]

As a substitute, our best available source is the "income stream" from property, available from municipal tax rolls. Available annually since 1847, the rolls record for every address in the city: a rental value assessed on market rent. Hanna and Olson (1983) demonstrated that the rental values recorded in the nineteenth century are correlated near perfectly with floor area.[56] To adapt this as an estimate of intensity of land use, I calculate a "rent density": the total rent of all properties fronting on a given street

[54] Of course, this exercise would be almost instantaneous if the data were available in a GIS.

[55] See Levine (1984).

[56] Business and residential uses were assessed at the same rate. For more information on the tax rolls, see Hanna (1986), Gilliland (1998), Gilliland and Olson (1998), and Lewis (2000).

segment where traffic was surveyed (between the two nearest intersections), as recorded in the tax roll of 1890, divided by the frontage, on both sides, as measured from the Goad Atlas of 1890. To classify land use, I used the standard distinction, residential versus non-residential activity, and experimented with two measures: (1) the number of non-residential addresses divided by the total number of all addresses per street; and (2) the proportion of total rent per street from business spaces.[57]

From the scattergrams on the left side of Figure 5.19 we can see that there was no significant correlation of any of the parameters for type or intensity of land use with vehicular flow. The findings seem to suggest that the amount of traffic flowing through a given location was not related to the amount of commercial activity on the street segment, nor was it associated with intensity of development on the street. Based on the theory of the "movement economy," we should expect to find that type and intensity of land use are correlated with the configurational properties of the network. The scattergram on the top right side of Figure 5.19 shows a weak but significant correlation of mean rent per foot front with the global integration value of the corresponding axial line (r=0.531, p significant to 0.0001). The results suggest, that the scale or intensity of development on a street segment was associated with its relative position in the street network. On the other hand, the two scattergrams at the bottom right of Figure 5.19 indicate little relation of global integration to land use. This latter finding was surprising, given the overall arguments of space syntax.

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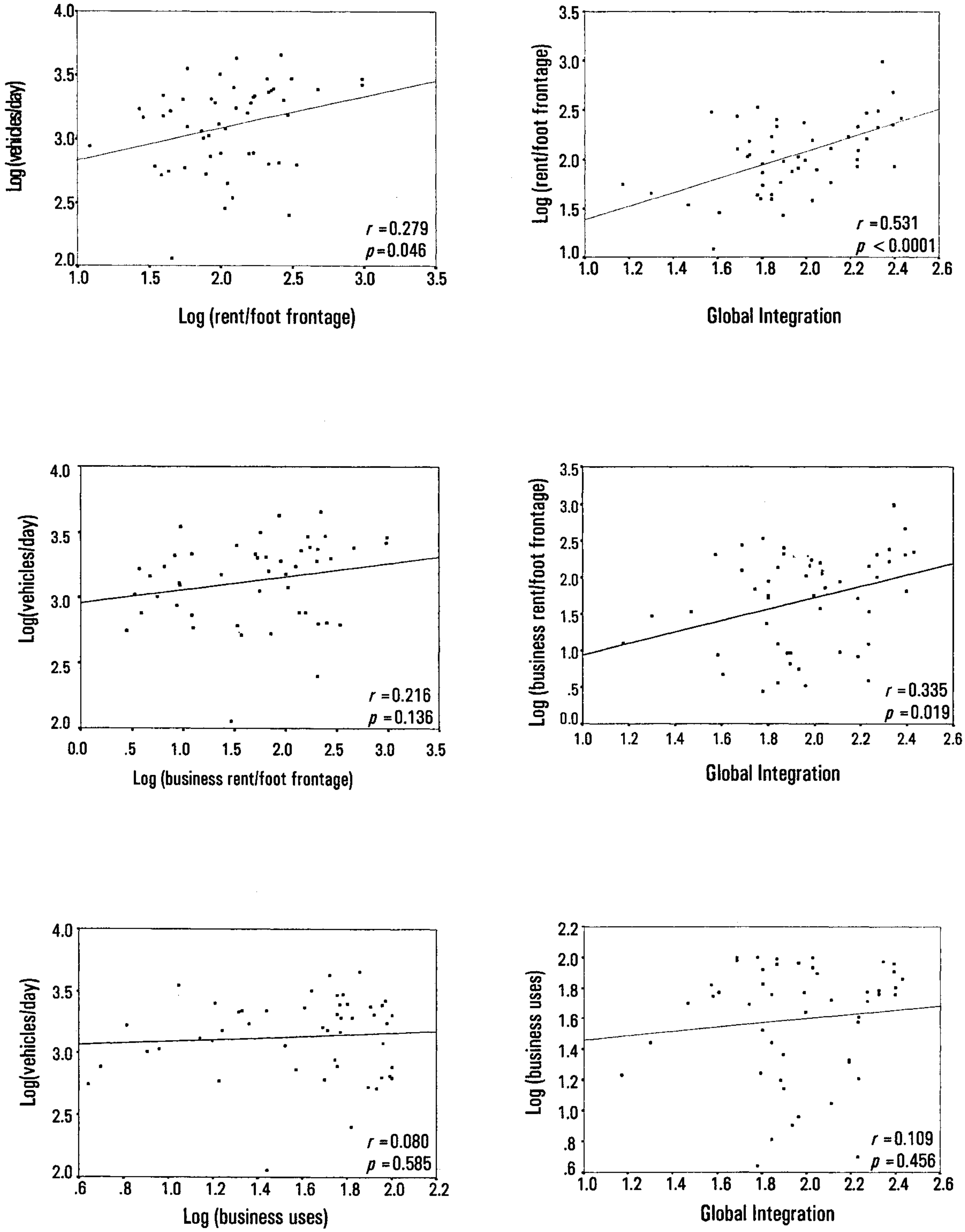
[57] The assessor distinguished a dwelling from a workplace or business.



5.19 Correlations between traffic flow and measures of intensity of development and land use (left side), and correlations between global integration and measures of Intensity of development and land use (right side)

Before concluding that there was no relationship between configuration and land use, let us consider an alternative experiment, which considers the spatial geography of Montreal banks in 1881 and 1903. Bank buildings are usually the tallest and most impressive buildings in a modern city, and numerous studies have focussed on the symbolic power expressed in their architecture.[58] On the other hand, very little has been said about the siting of banks across the urban landscape. I chose to focus on banks because they are known to demand high communication and visibility, and they are a high-order activity in the urban hierarchy. Because of the well-known importance of "face-to-face" relations of trust in banking, their traffic demand is likely to involve pedestrians and "people-movers," but banks would not make significant demands on carts and heavy hauling. Given that banks are able to outbid most others for prime locations, we should expect to find banks located on the most important streets, with highest local and global integration values. In 1881, Montreal was the undisputed finance capital of Canada; it was home to 16 different banks, all of which were headquartered in the central core of the city (see Figure 5.20).[59] Only one bank at this time, the City and District Savings Bank, had branches outside of Old Montreal (not shown on the map): an east end branch on St Catherine East, a west end branch on Notre Dame West, and another on Wellington Street in St Ann Ward, a working-class district southwest of the core. The evolution of the central banking district is an excellent example of the "movement

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[58] For example, Bernstein (1989).

[59] *Lovell's City Directory* (1881). See Naylor (1975) on the role of banks in Canadian development. On the rise and fall of French banks in Quebec, see Rudin (1985).

Banks at Corners

Non-Corner Banks

Global Integration 1881

2.144 - 2.488

1.8 - 2.144

1.455 - 1.8

1.111 - 1.455

0.767 - 1.111

Head Offices
1. Bank of Montreal
2. Banque d'Hochelaga
3. Banque du Peuple
4. Banque Jacques Cartier
5. Banque Nationale
6. Banque Ville Marie
7. City and District Savings Bank
8. Exchange Bank
9. Merchant's Bank
10. Molson's Bank

Branches (Head Office Location)
11. Bank of Toronto (Toronto)
12. Canadian Bank of Commerce (Toronto)
13. Ontario Bank (Toronto)
14. Quebec Bank (Quebec)
15. Union Bank of Lower Canada (Quebec)
16. Bank of British North America (London)

Suburban Branches (not on map)
17. City and District Savings (St Catherine E)
18. City and District Savings (Notre Dame W)
19. City and District Savings (Wellington St)

5.20 Location of banks in 1881

Source: Lovell's Directory (1881)

economy" at work. In 1820, the Bank of Montreal, the largest and most prestigious of all, established its position on St James Street, a highly integrated street and one of the leading commercial thoroughfares in the city at the time.[60] Within the next two decades other financial institutions, such as the Bank of British North America and the Bank of Upper Canada, would be drawn to St James, eventually forming the financial core of the nation. As we can see in Figure 5.20, the centre of gravity of the banking district in 1881 was located near the Bank of Montreal on Place d'Armes, and it was confined to just a few blocks bounded by four of the most highly-integrated streets (top 1%) in the city: St James, Notre Dame, St Peter, and St Lawrence. Most (17 of 19) of the bank buildings were located at corners, intersections, or fronted on a public square. Street intersections and public squares are special places of exchange and interaction, because of their heightened visibility in the urban grid.

By the turn of the century, Montreal had grown to approximately 325,000 inhabitants and had extended its territory in every direction. Rapid urban growth offered an expanding market, and to capture a greater share of savings from competing institutions, many banks chose to open branches outside the old commercial core. During the boom period between 1881 and 1903, the number of bank addresses in the city tripled from 19 to 59.[61] Mapping bank locations, in conjunction with the "global integration core," reveals

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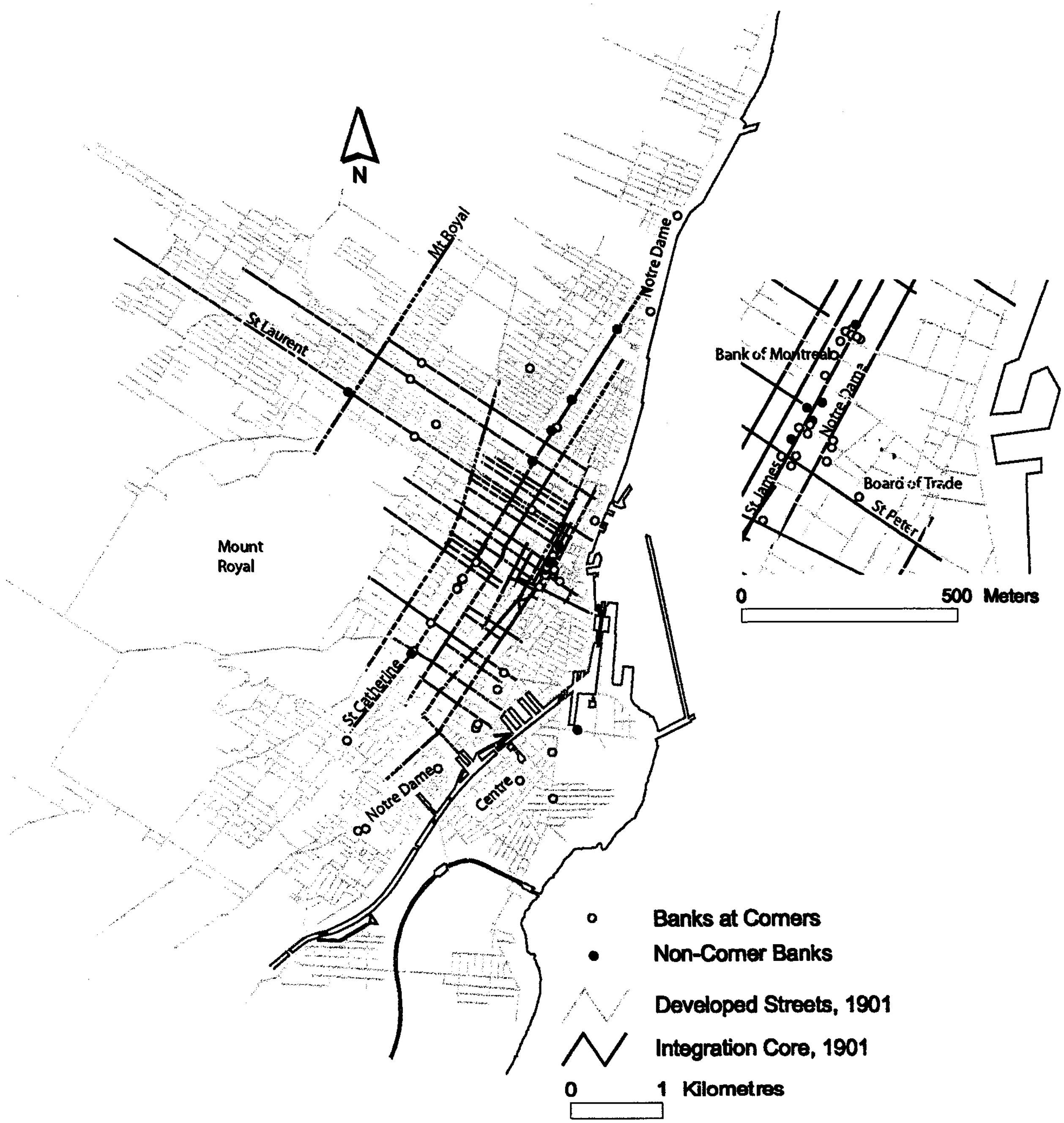
[60] The first building was established on St Paul Street in 1817. After it burned down in 1820, however, the bank set up operations on St James Street, and has remained there to this day. The present building dates from 1845-47 (Bosworth 1839; Jenkins 1966).

[61] Bank addresses were taken from *Lovell's City Directory* (1902-3).



5.21 Location of banks and integration core of Montreal, 1901
Source: Lovell's Directory (1903)

three important changes (see Figure 5.21). The most visible trend is the explosion of branch banking. While only one of sixteen banks in 1881 had branch operations, by 1903, over half of the city's institutions (12 out of 22) had branches, in addition to head offices in the financial district.[62] A second trend that can be detected from the map is that most of the bank buildings, branches and main offices, were located within the "global integration core." For instance, fifteen bank branches were located along St Catherine Street, which, as mentioned earlier, was one of the most important "uptown" shopping districts in the city at this time, and its central portion was the most highly integrated segment in the network. Third, the majority (80%) of banks chose street corners, which heightened opportunities for interaction by essentially doubling the axial visibility. Many banks were in fact located at the intersection of two highly integrated streets; in other words, they occupied some of the most accessible locations in the city.

Figure 5.22 offers us a different lens through which to view the influence of the grid-circulation relation on land use. On the scattergrams showing the correlation between local and global integration for all street segments in 1881 and 1901, I have identified the number of banks on each segment.[63] In 1881, banks are confined to just six

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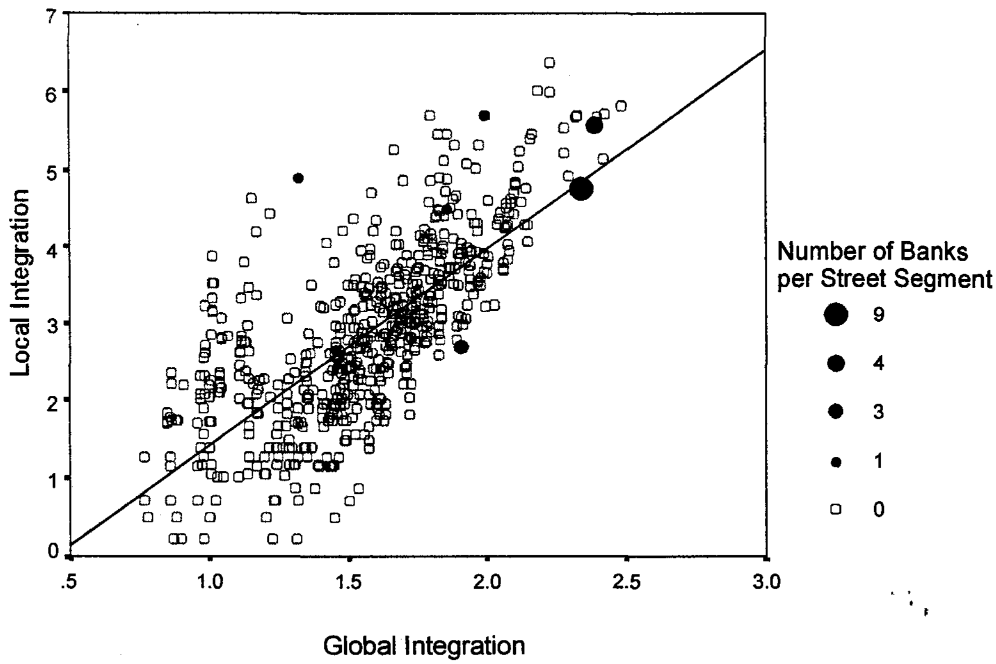
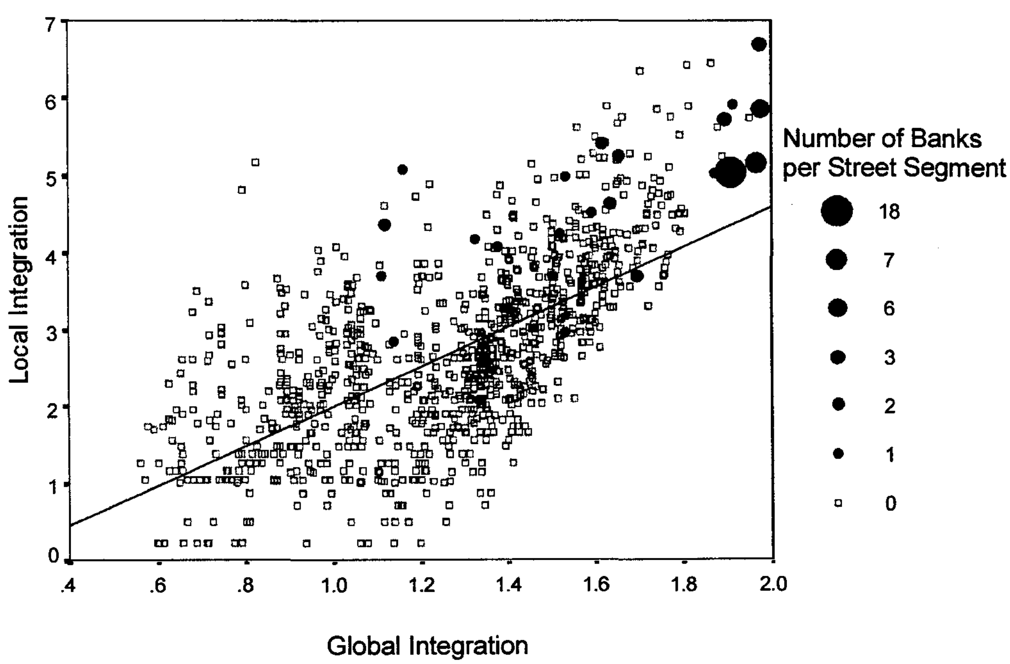
[62] In addition to their head offices in the financial district, the Montreal City and District Savings Bank and the Banque d'Hochelaga had six suburban branches, the Merchant's Bank of Canada had five branches, and the Bank of Montreal had three branches. While the number of institutions in Old Montreal increased by 50% between 1881 and 1903, it is believed that many of these new addresses were merely offices.

[63] In cases where a bank was located on a street corner, I used the official street address to assign it to the appropriate axial line. An argument could be made for assigning corner banks to the axial line with the highest integration value, since the more highly integrated street segment, likely had an important influence on the choice of location. If this practice was adopted, the relationship between bank location and integration would appear stronger.





5.22 Scattergrams showing local and global integration for banking streets in 1881 and 1901 of the 687 axial lines in the system, and these lines are among the most highly integrated – locally and globally. The mean global integration value of banking streets was 42% higher than the mean for all lines in the entire system (2.18 vs 1.53), and the mean local integration was a full 62% higher (4.49 vs 2.78). In 1901, we find that the mean global integration of street segments containing banks was again, as in 1881, 40% higher than mean global integration for the entire system (1.77 vs 1.26), and the mean local integration of banking streets was 88% higher (5.03 vs 2.68). What we see emerging by 1901, is a new two-tier system – the head office and its branches – matched to a two-tier street system whose emergence was also demonstrated in the space syntax figures. The data would support the argument that local integration was becoming more important for the siting of a bank. Since local integration is a measure of local rather than global properties of the network, it is a better indicator of accessibility patterns at the neighbourhood level. The findings are therefore not surprising, since the primary purpose of opening a new branch would have been to attract and serve a clientele at the neighbourhood level. This explains why we find banks on Centre Street and Wellington Street in the working-class neighbourhood of Point St Charles, even though these two streets are below average in global integration: the district was connected to the rest of the city only by a few bridges across the Lachine Canal. On the other hand, because of their relative position in the neighbourhood and higher-than-average local integration values, these two streets evolved as commercial axes in the neighbourhood, and remain so to this day.

DISCUSSION AND CONCLUSION

Before we conclude, let us take a "U-turn," and go back to see if space syntax can offer any new insights into the interpretation of the findings of experiments from previous chapters. What, for example, is the relationship between the integration values and the nature of rebuilding on streets devastated by the conflagrations or street widenings? In Chapter 2, we saw that the speed, scale, and intensity of rebuilding after fire was influenced by the centrality of the site. Redevelopment was most intense in the central areas, on streets such as St Paul and St Lawrence, where competition for space was greatest, and where there was pressure to adapt the built environment to a profitable economic environment. We recall from Table 2.2 that rebuilding was more intense on St Lawrence Street than on St Paul Street, even though the latter seemed to be at the centre of the highly-developed business district. An examination of the syntactical parameters for the case study streets in 1846, just before the fire, reveals that St Lawrence Street was in fact more highly integrated within the urban grid. On global integration it ranked 7th out of 277, St Paul 109th, and on local integration it ranked 20th, St Paul 57th.[64]

Where streets were widened (Chapter 4), we found that properties on the more centrally located streets were most likely to be rebuilt quickly and to exhibit morphological changes which increased the amount of rentable space. Here too, the

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[64] In 1846, global integration values were: 2.62 for St Lawrence; 1.85 for St Paul; and 1.98 for the St James Ward streets. Local integration values were: 4.37 for St Lawrence; 3.69 for St Paul; and 3.58 for the sample streets in St James Ward.

evidence suggests properties located on streets with the highest integration values underwent the most significant changes in scale. The central portion of Notre Dame Street, for example, experienced the most dramatic redevelopment – mean rent per building increased 140% – and this was the street with the second highest global integration value in the entire system (of 277). As reported in Chapter 4, property owners on lower St Lawrence rebuilt taller and deeper into the lots, whereas owners on Notre Dame Street East merely rebuilt as before. As expected, the syntactical values indicate that St Lawrence Street was more globally integrated, that is, it held a central position in the network (8th of 687), while Notre Dame Street East ranked 177th.[65] Although the number of cases is rather small, the findings point to the importance of topological centrality. The relative position of a street within the system as a whole may be a more meaningful indicator of the potential for redevelopment.

In Chapter 4, we saw how increased flows of traffic in each generation caused serious bottlenecks which forced periodic "redimensioning" of the vascular system. If the syntactical techniques are truly effective at predicting movement patterns as claimed, then we might expect to find a relationship between the topological, or one-dimensional, properties of the grid, and the two- and three-dimensional adjustments to the street network. That is, we should expect to find that streets which were widened or paved by the City, and those which acquired streetcar lines, will also be highly-integrated within the network. This hypothesis works under the assumption that the City (and the Montreal

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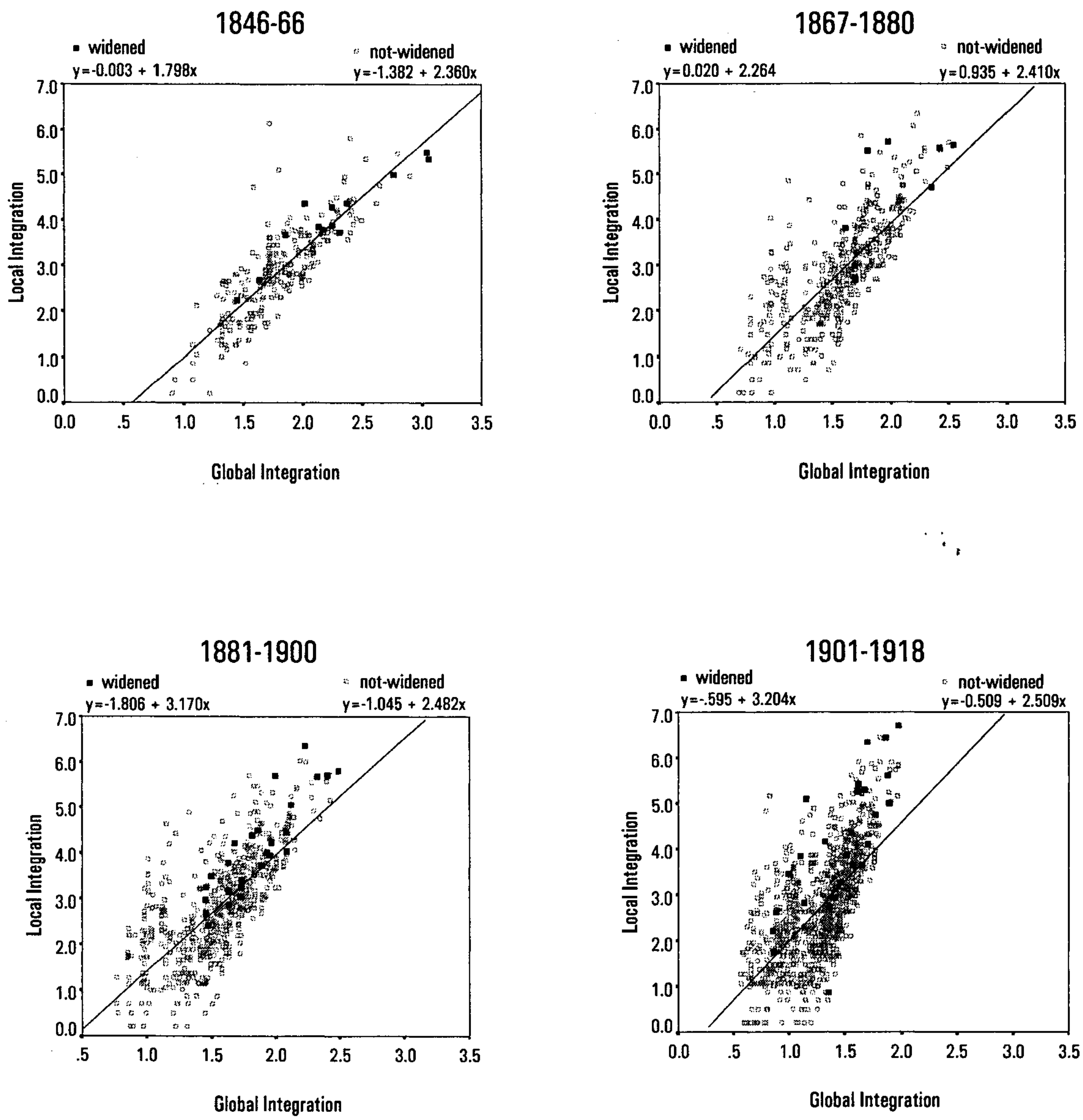
[65] In 1881, St Lawrence Street had a global integration value of 2.32 and a local integration value of 5.68; whereas Notre Dame had a global value of 1.99 and a local value of 5.68.

Street Railway Company) acted rationally and with knowledge of traffic volumes and the grid-circulation relation. Of course, this was not always the case, as contradictory pressures from outside parties (public and private) often influenced the decision-making process. Nevertheless, it is likely that these pressures would also be greatest for high-integration streets. Despite these complications, it is worthwhile to briefly investigate the configurational properties of streets which have been redimensioned, in order to shed further light on the grid-circulation relation.

Was there a relationship between integration and the choice of streets to be widened? If streets with high integration values are also the streets with the highest traffic flows, they might experience greater congestion and evoke demand for widening. The statistics reveal that in every cycle, the integration values of widened streets were higher than those of streets not widened.[66] The mean global integration value of widened streets was higher by 28% in 1846, 29% in 1867, 21% in 1881, and 16% in 1901. The mean local integration for widened streets was 44% higher than the mean for non-widened streets in 1846, 62% higher in 1867, 48% higher in 1881, and 55% higher in 1901. The evidence therefore supports the hypothesis that street widenings were more likely to occur on high integration streets. Plotting the distributions of integration values for widened streets versus non-widened streets in each period reveals another interesting trend (Figure 5.23). Although the slope of the values for non-widened streets changed very little, from 2.36 in 1846, to 2.41 in 1867, 2.48 in 1881, and 2.51 in 1901, the slope

[66] Integration values are for the beginning of the cycle, before the widening.



5.23 Scattergrams showing local and global integration values for streets widened and not widened, 1846-1918 for widened streets steepened steadily, from 1.80 in 1846, to 2.26 in 1867, to 3.17 in 1881, to 3.20. The trend suggests that local integration became more important over time. If we turn back to Figure 4.10, we can see that most street widenings between 1901 and 1918 took place outside the central core, on neighbourhood arteries such as Wellington Street in Point St Charles and Notre Dame East in Hochelaga, which had high local integration values but below average global integration values. The findings are consistent with our earlier observation that a two-tier system had developed by 1901, and also remind us that at about the same time, electric streetcar service had been extended to the suburban main streets.

To further explore this notion, let us take a look at the configurational properties of streets which contained tracks for the electric streetcar. Figure 5.24 reveals that in Montreal in 1895, as was the case in other nineteenth-century North American cities,[67] streetcar lines were primarily found on the leading commercial arteries. With few exceptions, these were the main shopping and banking streets of the central core and surrounding neighbourhoods.[68] The scattergram shows that streetcar service was overwhelmingly located on streets with high local and global integration values. Indeed, the mean global integration value of streets with streetcar service was 18% higher than the mean of the network (1.49 vs 1.26), and the mean local integration value was 59%

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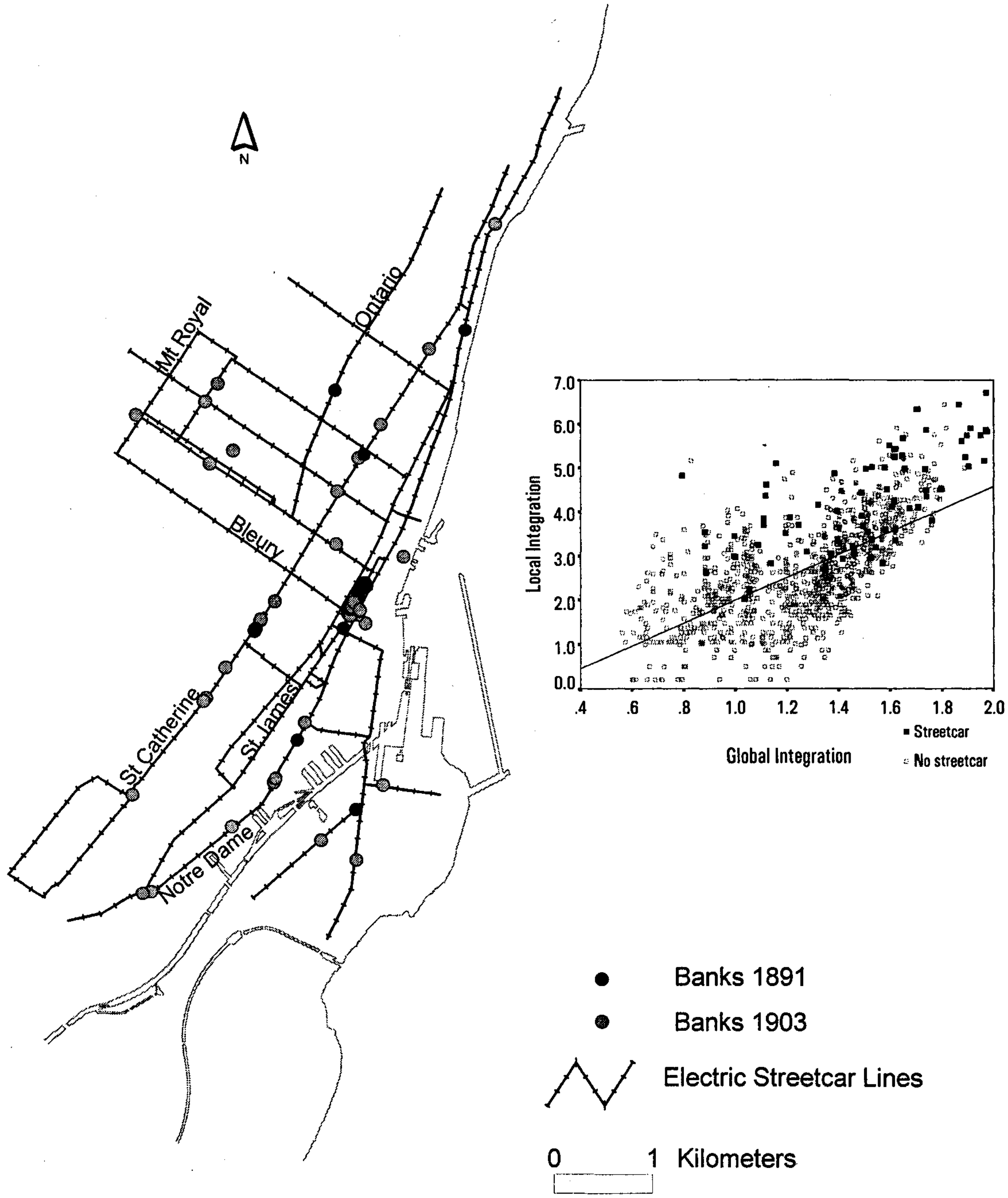
[67] For examples from Toronto, see Doucet (1982) and Davis (1979). See also Linteau (1988).

[68] The exceptions point to the importance of traffic generators. For example, St Etienne Street in Pt St Charles lead to the shops of the Grand Trunk Railway, one of the largest employers in the city (see Lewis 2000).

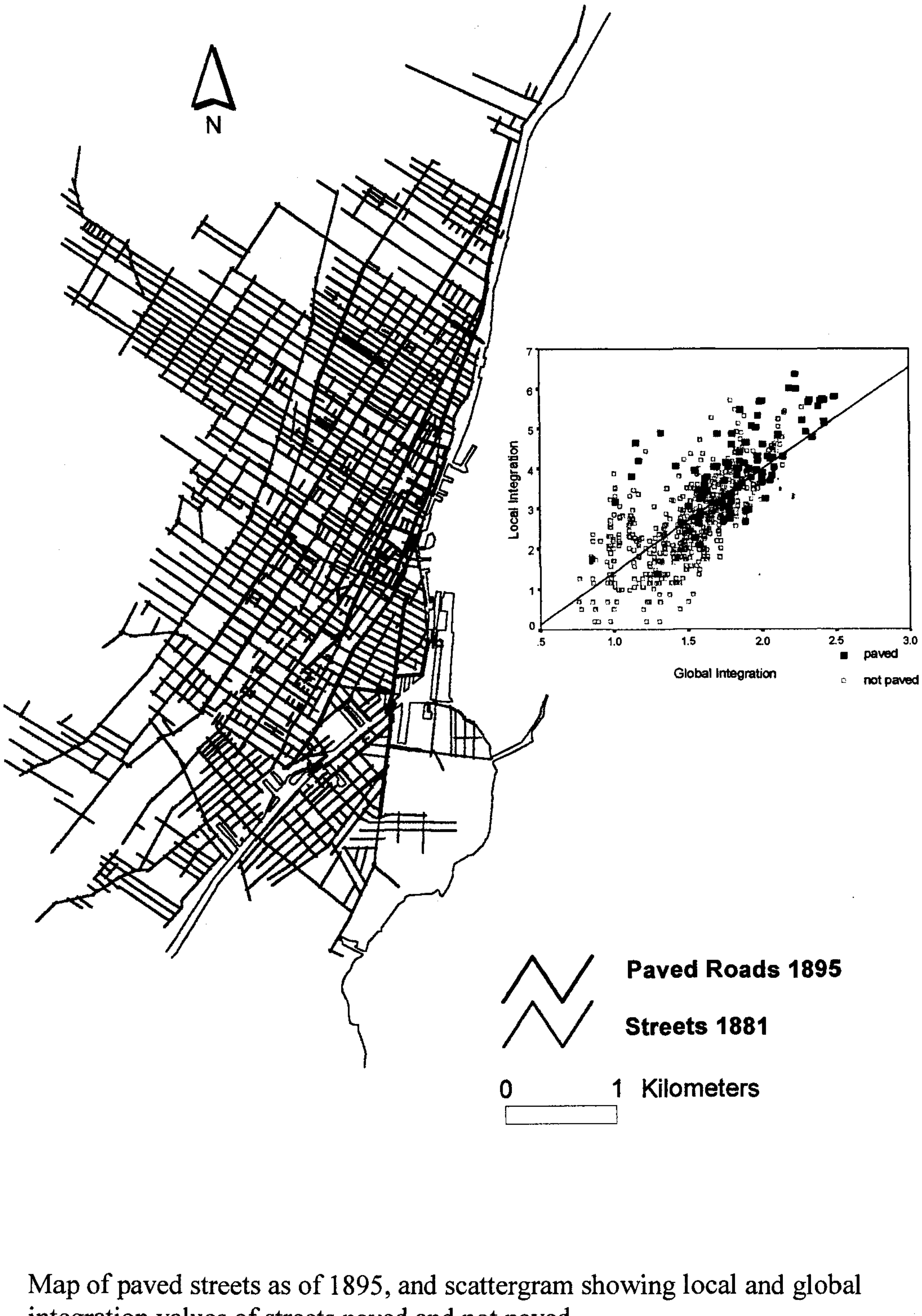


5.24 Map of banks in 1891 and 1903 and streetcar lines 1895, and scattergram showing local and global integration of streets with electric streetcar lines higher than the mean of the system (4.27 vs 2.68). The map indicates that almost all of the banks in 1903 (95%) were located on streetcar lines. Occupying street corners, most were close to streetcar stops. Highlighting the six branches existing in 1891 – just before the introduction of streetcar service in 1892 – reveals two important trends. Although branch banking was not widespread until there was streetcar service to the suburbs, the branches that existed prior to the streetcar were located on streets which would be tracked by 1895.[69] The evidence therefore suggests that the spatial patterning of both banks and tracks are, in large part, a result of the inherited structure of the street grid, which organizes simplest routes to and from all locations in the system.

Figure 5.25 indicates all of the streets which were paved as of 1895 (about 43 km out of 275 km, or 16%). The pattern includes most streets in the old core and is strongly correlated with streetcar lines (in fact, the Montreal Street Railway Company was required by law to pave a few feet on either side of its tracks.) Paved streets were among the most highly integrated in the city. Mean global integration of paved streets was 20% higher than the mean for the entire system, and the mean local integration was 43% higher.

Space syntax theory suggests that a "multiplier effect" exists whereby the configuration of the grid generates movement, which tends to attract commercial activity, and which in turn invites more movement. In this study, based upon the residential versus non-residential distinction, the type of land use did not appear to be correlated with

[69] It grew from three branches in 1881, to six branches in 1891, to 34 in 1903 (*Lovell's Directory*).



5.25 Map of paved streets as of 1895, and scattergram showing local and global integration values of streets paved and not paved
Source: Annual Reports of City Surveyor (1842-1895)

traffic flow or integration. The poor correlation, however, might have been the result of inadequate measures being used to represent land use: the proportion of non-residential versus residential uses; and the proportion of rentable space dedicated to non-residential uses. The simple residential/non-residential dichotomy is apparently too coarse a measure, as it does not take into consideration the diversity of types of land uses. Certain business activities, such as a department store, a factory, or a railway station will undoubtedly generate and attract greater amounts of activity than, say, a shoemaker, a corner grocer, or a barbershop. With a more sensitive estimate for land use, the correlation with traffic and integration might have been stronger. Indeed, when we took a closer look at the location of bank buildings in Montreal for two different periods (one growth surge apart), it was revealed that these high-order business activities were almost always located on highly integrated streets within the "integration core." By exploring the configurational properties of banking streets in this way, displayed on maps and scattergrams, we were able to derive valuable insights into the relationship between the grid-circulation relation and land use. It would be worthwhile, in the future, to take a similar look at a range of specific land uses, in terms of their need/preference for high-integration streets, either global or local. One might distinguish wholesale from retail grocers (and large versus small ones). We might expect neighbourhood shops, such as pharmacies, to be located on corners with high local integration values. One might find something similar with churches, elementary schools, or a difference between the medical élite (hospital staff, specialists, and university doctors) versus other doctors.

The space syntax approach is essentially one-dimensional; it considers the relative accessibility and connectivity of places, one to another, rather than the linear distance between them. It can be argued that the topological approach neglects too much physical detail to provide a realistic model of urban movement. Likewise, we need to sort out the effect of topography on aspects of accessibility and intelligibility, and build this into the model. Further development of existing space syntax techniques may allow us to encompass more explicitly the third dimension. This will allow us to examine more thoroughly the relationship between the structure of urban space and the structure of urban experience.

In this chapter, I have attempted an application of space syntax techniques to examine the relationship between circulation and urban form in nineteenth-century Montreal. In examining the street network over time, a configurational analysis revealed two fundamental properties of the urban structure: its centrality, and the differentiation of local parts in their global context. Whether topological or geographical, centrality provides a collective destination, a point of convergence in the system. Since mean global integration decreased over time, it was suggested that the street network became less centralized or more segregated over time. On the other hand, the central core of a few highly integrated streets expanded over time. The integration core comprises the main commercial arteries, the principal places in the city where people interacted with each other. As the network expanded, the relation between the local and global measures of accessibility changed, pointing to the increasing importance of sub-centres, separate from the old core of the city. For the period 1881-1901, we observe an interesting dynamic which seems to represent a boost in the system and a differentiation of the hierarchy. This is logical as the overall system increases in size. Although the measure of global integration does not reflect it (because of the way the measure is computed), the total population, total market, total traffic have doubled, and the radius of movement has increased; this forces a differentiation, and it makes local integration (of subsystems) distinct from the global, and of value to certain activities.

The availability of a rich source of historical data on traffic flows in Montreal allowed me to test whether the space syntax techniques were as effective at estimating patterns of horse-powered traffic as they have been previously argued to be for predicting automobile and pedestrian movement in modern cities. The key discovery in this chapter is that the morphological and topological properties of the street network, namely the effective width of each street segment and its relative position in the system as a whole, are useful predictors of patterns of urban circulation. The findings therefore suggest that space syntax techniques of topological modelling are of great value to urban researchers, not only as a descriptive tool which can be applied in the study of the morphology of the urban street system, but also as a model of how the street grid influences circulation, and how the grid-circulation affects other aspects of urban behaviour. Although historical in nature, this chapter has offered several examples of how configurational analysis using GIS might be used to aid in the decision-making process with respect to market analysis, infrastructure planning, and urban design in cities today.

CHAPTER 6

Conclusion: "Relentless Sweep of Structural Progress"

"Year by year the old landmarks disappear before the relentless sweep of structural progress"

– Montreal Daily Herald[1]

"In the convulsions of the commodity economy we begin to recognize the monuments of the bourgeoisie as ruins even before they have crumbled"

– Walter Benjamin[2]

The aim of this thesis has been to explore certain of the dynamics associated with urban morphological change, using Montreal (1846-1918) as a case study. Rather than trying to describe and classify all of the important changes in form, my primary goal has been to provide a better understanding of how changes in form occurred, as the city underwent a rapid growth and industrialization. In pursuing this objective, I designed a theoretical and methodological approach which acknowledges circulation as the driving force behind urban morphological change; and then, in each chapter, carried out a series of experiments which explored specific relationships between circulation and urban form.

From the results of various experiments, it is possible to identify certain regularities with respect to the spatial and temporal patterns of morphological change.

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[1] *Montreal Daily Herald* (1910, 13).

[2] Benjamin (1986, 162).

One of the key discoveries in each chapter was the importance of centrality. Case studies of reconstruction after fires and street widenings, for example, revealed that centrally-located properties were most likely to be rebuilt quickly and to exhibit morphological changes which increased the height of the building, the building footprint on the lot, and the building envelope. Likewise, street improvements such as pavings and widenings, and the tracks for the electric streetcar, were concentrated primarily on streets in the central core and along the main thoroughfares which connected the central city with rapidly developing suburban wards. Centrality is an essential property of urban form in that it brings people and activities into contact with each other, and it creates a collective destination or point of convergence. With respect to circulation and urban form, I define centrality in terms of relative accessibility, rather than straightforward geographic or metric distance. Configurational analyses using space syntax techniques highlighted the importance of topological centrality, or how every element relates to every other element in the urban system. We found within the hierarchy of streets an "integration core" of a few well-positioned streets which corresponded to the major commercial arteries of high traffic, and which were more likely to be paved, widened, or tracked. As the street system grew, that lattice of integration extended to a larger area and incorporated a greater number of streets. The reorganization of the waterfront was undertaken to improve Montreal's centrality at a larger scale; that is, it was part of the perennial struggle to improve its accessibility to advance its position in relation to its competitors – New York, Boston, Philadelphia, Liverpool, Glasgow – within the global system of port cities.

Another significant finding revealed in the various experiments was the importance of timing. Like most major cities, Montreal grew in boom and bust fashion. Every 15 to 20 years, another boom produced a new ring of construction at the fringe and another round of reconstruction at the centre. Experiments dealing with reconstruction after fires and street widenings revealed that properties destroyed during boom periods were rebuilt more swiftly, more completely, and with greater inputs of new capital, compared to those destroyed during depressions. Most street widenings were carried out near the peak of a boom, when capital was readily available and labour was cheap. The findings point to the pressures imposed by the cyclical nature of accumulation in the built environment. Each wave of urban growth brought a dramatic increase in the flow of goods and people through the city, increased competition for land, raised the bid-rent curve, and intensified pressure to adapt built forms inherited from the past to accommodate new demands. Each new surge forced the creative destruction of past capital investments in the built environment in order to restore the profitability of the "growth machine" for future accumulation. The reorganization of the port, reconstructions after fire, and the redimensioning of the streets were ways for the local growth machine to periodically remove congestion in the urban vascular system, to "annihilate space" in relation to time, and hence, to speed up the rate of accumulation of capital.

My theoretical and methodological strategy arose out of a dissatisfaction with prevailing approaches in urban morphology, which tend to be more concerned with the description and classification of types of form than the processes which gave rise to the changes in form. By thinking about urban morphology in terms of circulation we treat the city as a dynamic system. Like most living systems, a city operates in a higher-order system of exchange with other cities, and its growth and survival are dependent on the throughput of materials and energy. Capital accumulates by tapping the stream of throughputs. Circulation is facilitated by investment of capital into infrastructure such as streets, bridges, tracks, channels, sidewalks, and canals; and circulation is constrained by the dimensions of this vascular system. Since the growth of capital occurs through its circulation, it is logical to examine morphological changes in relation to processes of circulation. This conceptualization allowed me to draw insights from three different theories: neoclassical theories of land rent, Marxian theories of capital accumulation, and space syntax theories of urban form. Although from very different intellectual traditions, these three bodies of theory are coherent in that each has circulation as a central focus. They are complementary because scholars from the different disciplines have focussed on different and rather limited aspects of a highly integrated system. It can be argued that the regularities identified with respect to the spatial and temporal properties of morphological change are consistent with expectations based on the three different theories. The importance of centrality and accessibility to urban form, for the distribution of rents, and for patterns of land use are fundamental components of both neoclassical land value theories and space syntax arguments about patterns of "natural movement." Furthermore, the apparent boom and bust rhythms, and the notion of centrality as a function of accessibility rather than mere distance, are entirely consistent with a Marxian explanation of morphological change as an outcome of capital's drive to tear down barriers to circulation.

Although this thesis has contributed to our understanding of morphological change, there are, I admit, numerous gaps in the story. Investigations and experiments were conceived from a variety of theoretical insights, and were performed according to the realities, operational constraints, and options, with respect to the available empirical data. Some elements associated with circulation and urban form have been difficult to address due to a lack of sufficient and accessible information. Historical data on city finances, for example, are scattered and sketchy, and there is a serious want for a proper financial and fiscal history of Montreal. After all, as one contemporary observer noted: "Great business thoroughfares cannot be widened, new arteries of local trade opened and old municipal buildings replaced by new and larger ones without the expenditure of money, and much of it."[3]

The discussion of expropriation reveals that we are in need of a history of property, property ownership, and property owners. Sweeny (1995) has written about the "commutation" of property in the pre-industrial city, but little has been said for Montreal after the mid-nineteenth century, despite the interesting source in "rental valuations."[4] The two topics, municipal finances and property ownership, would make ideal theses on their own. My perspective on the circulation of capital might have been more effective if there existed an adequate body of research in these areas.

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[3] Chambers (1903, 67).

[4] See also Linteau and Robert (1974) on the question of land ownership.

The readaptations of the vascular system involved riding rather roughshod over owners and users. Details of the battles fought over expropriation and amounts of compensation can be found in the records of the Superior Court and in the local newspapers, and the minutes (*procès-verbaux*) of the Road Department reveal cases where property owners petitioned for street widenings. A careful study of the timing of petitions and protests, combined with an investigation of the critical moments at which changes were made to expropriation law and the municipal debt, is required to answer the question of who were the winners and losers. The theoretical approach I have taken in this thesis might be well adapted to new historical analyses of urban growth as a site of political struggle.[5]

A Marxian geographer would undoubtedly suggest that I delve deeper into questions of class struggle and the roles of labour. I found several hints that exploitation of labour was crucial to the readaptation and the functioning of the growth machine. We observed, for example, that the tendency for workers to strike was cyclical in nature, peaking during depression periods, when competition among cities, among entrepreneurs, and between social classes was intensified and transferred to press the competition among workers beyond the limits of their toleration. We might also expect to find seasonal variations in conflicts between capital and labour, in relation to the shipping calendar.

In reducing the project to manageable proportions, I have necessarily ignored several important subjects, and for others, I have revealed only the tip of the iceberg. A

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[5] For example, Pincetl (1999) and Jessop et al (1999).

serious omission is the problem of topography. In a city so fixated on its mountain, this is a glaring omission indeed! Street plans for 1901 and 1918 reveal that the mountain was an important obstacle in the development of the city. In an era reliant on horsepower, steep slopes were a critical spatial barrier to circulation. Throughout the nineteenth century, the city spent a great deal of effort to minimize the grade of its streets, and some clues to the historical practices of street "grading" and "levelling" are provided in the reports of the City Surveyor and minutes of the Road Department. Every time a street was widened, it was also graded and levelled. With accurate elevations, further research could be undertaken to determine the influence of changes in elevation on "lines of sight," inadequately treated within space syntax, and space syntax therefore could be better theorized in "3-D." Furthermore, my finding that Montreal banks tended to choose corner locations of high-integration for their head offices and branches suggests that certain visual properties which typically concern architects and planners – perspectives, visibility, and imageability – are worth exploring further in space syntax, particularly in relation to the possible tradeoffs between intelligibility and accessibility. The results with respect to banks suggest that it would be worthwhile to conduct further studies of other institutions and monumental architecture from this point of view.

The theoretical framework constructed in this thesis has allowed us to deal with the important interconnections among various specialized systems of movement. If the infrastructure of the port served as the major arteries, and the streets represented the finer-scale capillaries, then the network of rails extending throughout the city can be conceived of as the veins in the hierarchical structure of the urban vascular system. The story is incomplete without a proper treatment of the impact of railways and streetcars. The histories of trains and streetcars, particularly the vehicles and memorabilia, have been given a great deal of attention from so-called "amateur enthusiasts," but the widespread impact of these transportation systems on the built fabric and internal structure of the city remains to be properly investigated in the Canadian context. As seen in Chapter 4, the introduction of tramways to already congested city streets contributed to the necessity for street widenings. The private tramway companies were involved in a never-ending battle with the City for the right to occupy the streets. Armstrong and Nelles (1986) have described the politics of tramways in Canadian cities, the municipal wrangles, and the company spreadsheets. Young (1972) and Hanna (1998) have offered a few clues to the federal and provincial politics and the critical timing of railway installations in Montreal; however, much work remains to be done. In Chapter 3, I alluded to the importance of the railway to the port, and in Chapter 4, I noted how Notre Dame Street East was demolished a second time to make room for the expansion of the Viger railway yards. These are mere hints of the railway "land hunger" that Kellett (1969) has described for British cities. The impacts of the railway and tramway on circulation and urban form are subjects for future dissertations, hopefully using the framework I have established.

Although I have focussed my attention on the transformation of Montreal between 1846 and 1918, it is believed that my theoretical and methodological strategy would be equally applicable to other cities, over different time periods. I approach a city as the accumulation of countless individual and group actions, themselves regulated by historical and cultural traditions and compelled by wider social and economic forces.

While I have sought to explain certain regularities in the timing and patterning of change in cities, my approach leaves room for the wide diversity of forms that may result from individual and group responses to various opportunities.

Testing the modern theories and methods in a historical context confirmed a strong correlation between circulation and urban form. Furthermore, the findings lend support to the theoretical argument that the circulation-form relationship is a key determinant of other factors such as land use and investment in street improvements. It is believed, therefore, that the findings of this research have important implications for the planning and redesign of contemporary cities. Since my goal has been to understand morphological change, I have focussed on the reshaping or readaptations of the city, rather than growth at the rural-urban fringe. We have observed that the readaptation process is different from suburban conversion in that one does not have large tracts of unbuilt land: every square foot comes at a high price, a cost of demolition, and a risk of contestation. We have also seen that these costs were thrown onto the public. It can be argued that these findings are just as relevant today as they were a century ago. Because centrality is most intense in the "old city," the perennial reconfigurations concentrate their "creative destruction" in the areas of past investments, and come into contradiction with "historical value," and all of those associations with identity of a city. Nonprofit organizations such as "Heritage Montreal" have long argued the importance of built heritage to cultural identity, "collective memory," and "quality of life," and various levels of government now recognize the importance of heritage and urban identity to the ability to compete for talent, tourism, and a city's ability to perform on the world stage. The traditional notion that "historic preservation" is an antonym for "urban economic development" is outdated. Despite such recognitions, contemporary experience suggests that the current administration in Montreal is indifferent to issues of built heritage and is more concerned with "urban development at any cost."[6] This thesis has shown that the building of a city is not an event, but a relentless process of reconsidering, rebuilding, reorganizing, redimensioning, reconfiguring, and renegotiating. If we are to make better use of our resources – natural, financial, material, and cultural – we need to understand how change occurs in our cities.

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[6] Beaudet (1999, 3).

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