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REFLECTIONS ON CALGARY'S SPATIAL STRUCTURE: AN URBAN ECONOMIST'S CRITIQUE OF MUNICIPAL PLANNING IN CALGARY

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SUMMARY

Affordable housing and a manageable commute are central to the well-being of Calgarians. Yet among larger Canadian metropolitan areas today, Calgary already has close to the most expensive housing, and the average journey-to-work time, close to 30 minutes, is as high today as it was in Los Angeles in 2000, when Los Angeles had a population 10 times larger.

Decisions around how Calgary grows are based on the policies within The City's Municipal Development Plan and the Calgary Transportation Plan, which together provide a blueprint for Calgary's spatial development and transportation system. These plans— and therefore, their assumptions about future effects on congestion and rents — are based around a population forecast that does not reflect the historical growth pattern of the city and legitimizes spatial containment.

The shortcomings in these plans, both adopted in 2009, are likely to result in longer commuting times and even more expensive real estate prices. These will be well beyond what The City has prepared citizens to expect and accept, as planners plow ahead with proposals to further entrench the downtown as the dominant employment centre. Calgarians need to be levelled with about the realities that come with pursuing a plan that calls for spatial containment and intensification centred on a single, dominant central business district.

The plans present a vision of the "Good Urban Life," and propose to enforce it through a particular choice of transportation system, through land-use regulation, and through a downtown parking freeze, with little regard to economics. The cost of this vision will in turn discourage new firms and new people from moving to Calgary.

Calgarians should be informed about future transportation costs – for mass transit and automobiles – in congestion, time, and funding. And they must be informed about the effects this will all have on the cost of property for families and businesses. Only then can citizens properly consider their options and choose their city's future. Without that Calgarians may find their quality of life diminished in ways they were never prepared to expect.

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INTRODUCTION

Calgary's urban spatial structure is anomalous, at least by the standards of cities in the United States[1] and when compared to its neighbour to the north, Edmonton. Calgary is an "automobile city" — a city that has seen the bulk of its growth occur during the era of widespread car ownership. In American automobile cities such as Dallas, Houston, Denver, Phoenix, Salt Lake City, Las Vegas, and Tucson, employment is highly decentralized and dispersed, with a well-developed system of employment subcentres outside the central business district (CBD). Also, mass-transit plays only a minor role in those cities' transportation systems and is primarily utilized by non-car owners, especially immigrants and the disadvantaged. In contrast, in Calgary, non-local employment is highly centralized in the CBD, with no employment subcentres outside the central city that are even medium-sized. And while the car is the dominant mode of travel, mass-transit plays an essential role, particularly in the journey to work to the CBD.

In January 2005, the City of Calgary launched a planning process, known as imagineCALGARY, aimed at shaping the city's future. Utilizing a "communicative-planning" approach — which favours the mediation of community discourse rather that the creation of a technically rational plan[2] — city planners received input from 18,000 residents. The result of this 18-month-long process was the "imagineCALGARY Plan for Long Range Urban Sustainability" published in September 2007. Using imagineCALGARY as a jumping-off point, a comprehensive review of Calgary's Municipal Development Plan and Transportation Plan, known as "Plan It Calgary," was launched. The imagineCALGARY Plan and its children, the Municipal Development Plan and the Calgary Transportation Plan, both adopted in 2009, provide a planning roadmap for the city's urban spatial structure and transportation system up to the year 2070.

The Municipal Development Plan (MDP) provides an abundance of nicely designed, coloured maps and architectural drawings, and heart-warming prose as well as some quantification of the plan, including forecasts. But economic analysis is conspicuous only by its complete absence. The Calgary Transportation Plan (CTP) is better, at least costing out proposed improvements and calculating the fares required to achieve a certain level of cost recovery of mass-transit operating expenses, under the ridership forecasts. But it does not address how the ridership forecasts were calculated, and is silent concerning implied average journey-to-work times by mass-transit and car. As these plans are the product of the same parent document, use the same population projections, and focus on the same issues — where Calgarians locate and how they move between locations — the MDP and CTP will be referred to collectively as the "plans." Taken together, the planned development within the plans aims to achieve a more sustainable and livable city in alignment with imagineCALGARY, through the continued concentration of employment in the CBD, expansion of the radial LRT system, transit-oriented development, spatial containment of the city, and intensification. However, without solid, quantitative analysis of the costs and benefits of implementing the plans, it is impossible to assess their soundness.

In reviewing these plans it becomes clear that the city has a three-pronged plan: 1) to have the city centre remain the dominant employment centre; 2) to expand the transportation system by

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[1] The essay uses the term "urban" to refer both to the city of Calgary and to the entire metropolitan area.

[2] S. Campbell and S. Fainstein, *Readings in Planning Theory* (Malden, Mass.: Blackwell, 2003).

emphasizing CBD-oriented mass-transit at the expense of roads, and discouraging auto travel on the downtown commute by imposing a soft parking freeze downtown; and 3) to spatially contain the city's lateral growth. The costs will take the forms of heavy expenditure on mass-transit, considerable increase in journey-to-work times and in auto traffic congestion, and significant increases in rents and property values. As well, the high cost to firms of operating in Calgary, as well as the high cost of living, will discourage new firms from moving to or starting up in Calgary, which can be expected to slow growth. These costs will be significantly higher the higher the rate of population growth.

The outcome may be even worse if the city removes only one of the three prongs from its planning framework. Suppose, for example, that the city were to retain its plan for the city centre to remain the dominant employment centre and for transportation investment to be directed towards CBD-oriented mass-transit, but were to relax regulatory restrictions on the lateral expansion of the city. While this would relieve somewhat the pressure on rents and housing prices, it would result in considerable expansion of the city's commuting watershed. This would result in a substantial increase in average commuting distance, which would lead to significant increases in the average commute time, traffic congestion, and the transportation budget. Thus, the plans' impacts on Calgary's future spatial structure need to be scrutinized. This essay expresses strong and informed skepticism, from the perspective of an urban economist, about the inherent wisdom and economic viability of the plans — the city's vision for Calgary's urban future.

Since the author is an outsider to the city, the arguments put forward are not expertly informed, and some may be off-base. The essay will have succeeded in its purpose if it stimulates enough discussion to persuade the city to provide the technical reports documenting the quantitative economic policy analysis underlying the plans. Made available for public and academic scrutiny, these reports should provide the basis for a constructive and informed policy debate based on numbers rather than wishful thinking.

The essay does not consider details of the plans. Instead, it focuses on four broad aspects of the plans that may adversely impact the Calgary economy.

1. The plans' low population projections, which legitimize spatial containment.
2. The impact on housing rents of the plans' emphasis on spatial containment.
3. The danger of rapidly increasing traffic congestion under the plans.
4. The plans' resistance to economic pressures for subcentre formation.

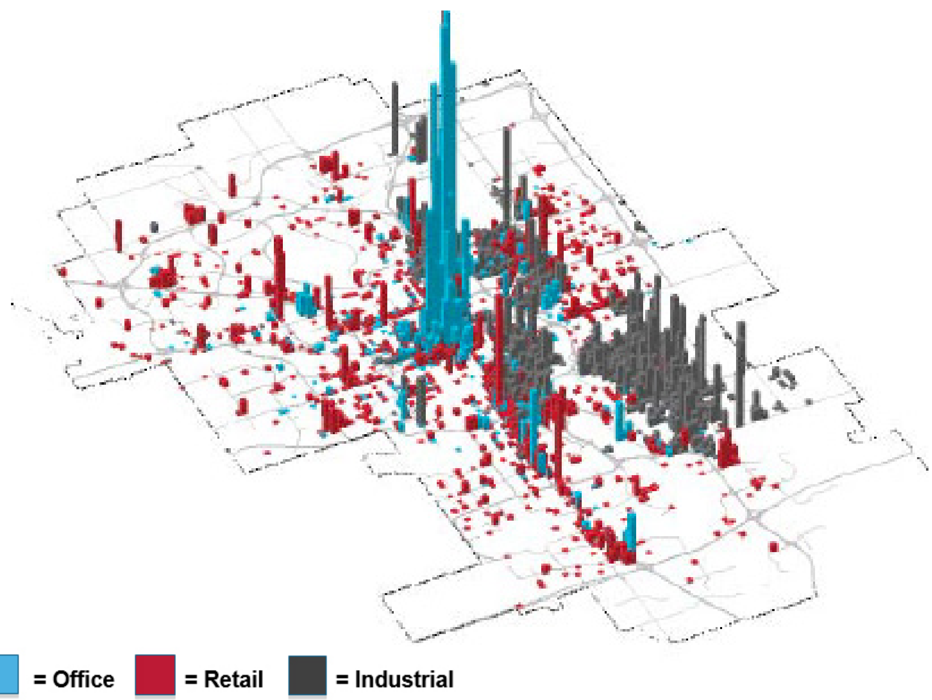
BACKGROUND: CALGARY'S ANOMALOUS SPATIAL STRUCTURE

The evolution of the spatial structure of Canadian metro areas differs in three important respects from that of U.S. metro areas. First, Canadian metro areas did not experience the black migration from the U.S. South that started after the First World War, nor, therefore, the subsequent vicious cycle generated by suburban housing discrimination against blacks — ghettoization of the black community downtown, accompanied by white flight to the suburbs, leading to downtown disinvestment and decay, and further polarization between black and white citizens. Second, mass-transit usage did not decline nor car ownership increase as rapidly in Canadian metro areas as in U.S. metro areas. And third, Canadian metro areas actively pursued policies to slow down the rate of decentralization, and continue to do so, which has been made possible by less jurisdictional fragmentation and stronger metropolitan-planning authorities. Thus, it would be imprudent to compare Calgary's spatial structure to that of U.S. metropolitan areas without strong qualifications.

Nevertheless, by almost any standard, Calgary's spatial structure appears to be anomalous. It is an "automobile city" — it experienced its rapid population growth when the automobile was the dominant form of transportation — and almost all households own cars.[3] While its residential decentralization is characteristic of automobile cities, its employment centralization is decidedly not. Calgary's non-local employment remains highly centralized. Figure 1 below shows the spatial distribution of office, retail, and industrial space in 2013. Three features stand out. First, the hierarchy of retail centres appears quite standard, suggesting that it follows quite closely the pattern of residential location, with the exception of the high concentration of retail space along Macleod Trail, south of the downtown area. Second, industrial space is heavily concentrated east of the downtown area. This is typical of cities with prevailing westerly winds (so that air pollution blows away from residential areas), and in Calgary this tendency has likely been accentuated by zoning policy. Third, office space is highly concentrated in the downtown area, with no obvious office subcentres — this is the apparent anomaly.

FIGURE 1 CITYWIDE DISTRIBUTION OF OFFICE, RETAIL AND INDUSTRIAL SPACES

Source: Calgary Snapshots 2013.



[3] There are now more households in Calgary that have four or more cars than those that have no cars. City of Calgary, "Calgary Snapshots 2013," (2013), http://www.calgary.ca/PDA/LUPP/Documents/Publications/calgary-snapshots-2013.pdf?noredirect=1.

Is Calgary's spatial distribution of employment indeed anomalous? This entails establishing first that the spatial pattern of *employment centres/subcentres* is similar to the spatial distribution of office space shown in Figure 1, and second, that other metropolitan areas that are comparable to Calgary in other respects do not exhibit the same pattern.

Urban economists have an established method of identifying subcentres. First, data are collected on employment and employment density by traffic-analysis zone (TAZ). Second, an employment subcentre is defined to be a set of contiguous TAZs having the properties that each of the constituent TAZs has an employment density exceeding a level d (the employment density cut-off) and that the set of contiguous TAZs together has total employment exceeding D (the employment cut-off). This method was proposed and first applied by Giuliano and Small[4] to the Los Angeles Metropolitan Area. The subcentres so defined are areas of high *absolute* employment densities. The method has subsequently been applied to many other cities. The original application to Los Angeles identified many employment subcentres in Los Angeles and Orange counties, but none in the peripheral counties of Riverside, San Bernardino, and Ventura. Applying the Giuliano and Small method to Calgary identified *zero* subcentres, which supports the impression conveyed by Figure 1.

Recognizing that it is important to identify peripheral as well as central subcentres, researchers have adapted the Giuliano and Small method to take into account not only absolute but also relative employment density. Ban and Arnott[5] (BA hereafter) is perhaps the simplest method. First, it estimates the employment density *gradient* for the metropolitan area under study, which is the average proportional rate at which employment density falls off with distance from the city centre (e.g., 0.20 — or 20 per cent — per kilometer). Second, it defines the subcentre employment density and employment cut-offs so that they fall off at a rate equal to one-half the employment-density gradient. The results are shown in Figure 2. For the city of Calgary itself, the BA method identifies four employment centres. There is the central city, which includes the CBD, inner-city neighbourhoods, such as the Beltline, Mission and Sunalta, as well as North Hill/SAIT Polytechnic along 16th Ave. NW. And there are three employment subcentres: one that stretches along the west and south periphery of the airport and includes the Peter Lougheed Hospital, Sunridge Mall and business and retail areas along Barlow Trail, 36th Street, Memorial Drive and 32nd Avenue NE; a second that stretches from the Chinook Centre to Southcentre malls along Macleod Trail, and includes the predominantly industrial Alyth/Bonnybrook/Manchester neighbourhood; and a third that is centred in the Midnapore and Shawnessy neighbourhoods, including the Shawnessy shopping centre and Midpark and Sunpark business parks along the southern end of Macleod Trail. The approach also identifies eight regional subcentres outside the city limits, two of which are shown in Figure 2 (the city of Airdrie and the town of Cochrane), but no subcentres at the periphery of the city (peripheral subcentres can be interpreted as emerging subcentres). Thus, the BA analysis of subcentres is broadly consistent with the spatial structure of employment conveyed by Figure 1.

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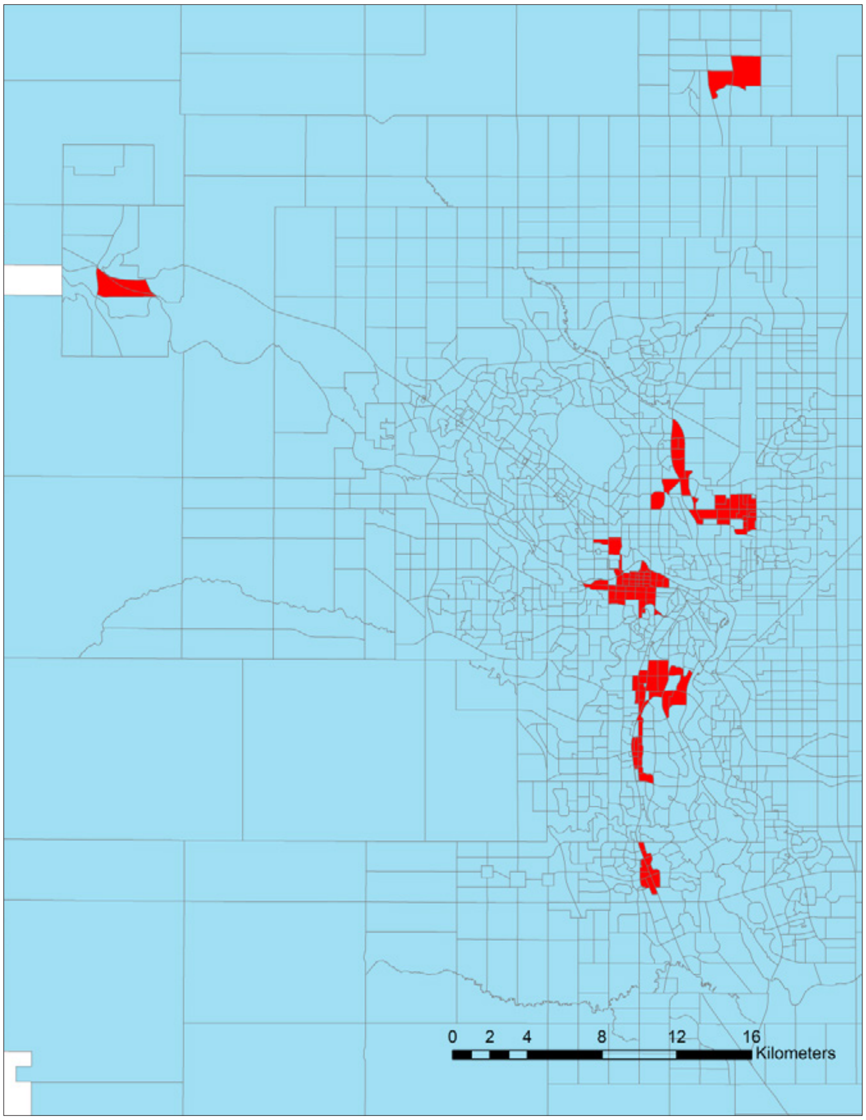
4 G. Giuliano and K. Small, "Subcentres in the Los Angeles region," Regional Science and Urban Economics 21 (1991): 163-182.

5 J. Ban and R. Arnott, "Identifying employment subcentres: The method of exponentially declining cutoffs," Draft (2014).

FIGURE 2 EMPLOYMENT SUBCENTRES IN THE CALGARY REGION, 2014

Prepared by Jifei Ban, using TAZ employment data provided by the City of Calgary.



It is interesting to compare Figure 2 to the city's depiction of Calgary's "activity centres" displayed in Figure 3. The figure is drawn at a finer spatial scale than is Figure 2. Four of the major activity centres (MACs) in Figure 3 overlap the city subcentres identified by the BA method: the first is centred on Sunridge Mall, the second is in Midnapore, and a third and fourth around the Chinook Centre and Southcentre malls that are contiguous in the BA model. Notably missing from the BA model are the MACs in Crowfoot Village and University of Calgary/Foothills Hospital/Alberta Children's Hospital in the city's northwest, and Mount Royal University in the west end. As well, the relatively new Springbank Hill and Seton MACs in the far west and southeast respectively are not mature enough to register in the BA model.

Comparison of Figure 3 with Figure 4, which displays the Calgary LRT Network Plan, shows that many of the remaining community-activity centres lie on existing or planned LRT lines, or are planned MACs themselves (as is the case with the remaining MACs identified in the far north and northwest).

FIGURE 3 EMPLOYMENT CENTRES AND LANDS IN CALGARY 2006

Source: City of Calgary online "MDP Maps."

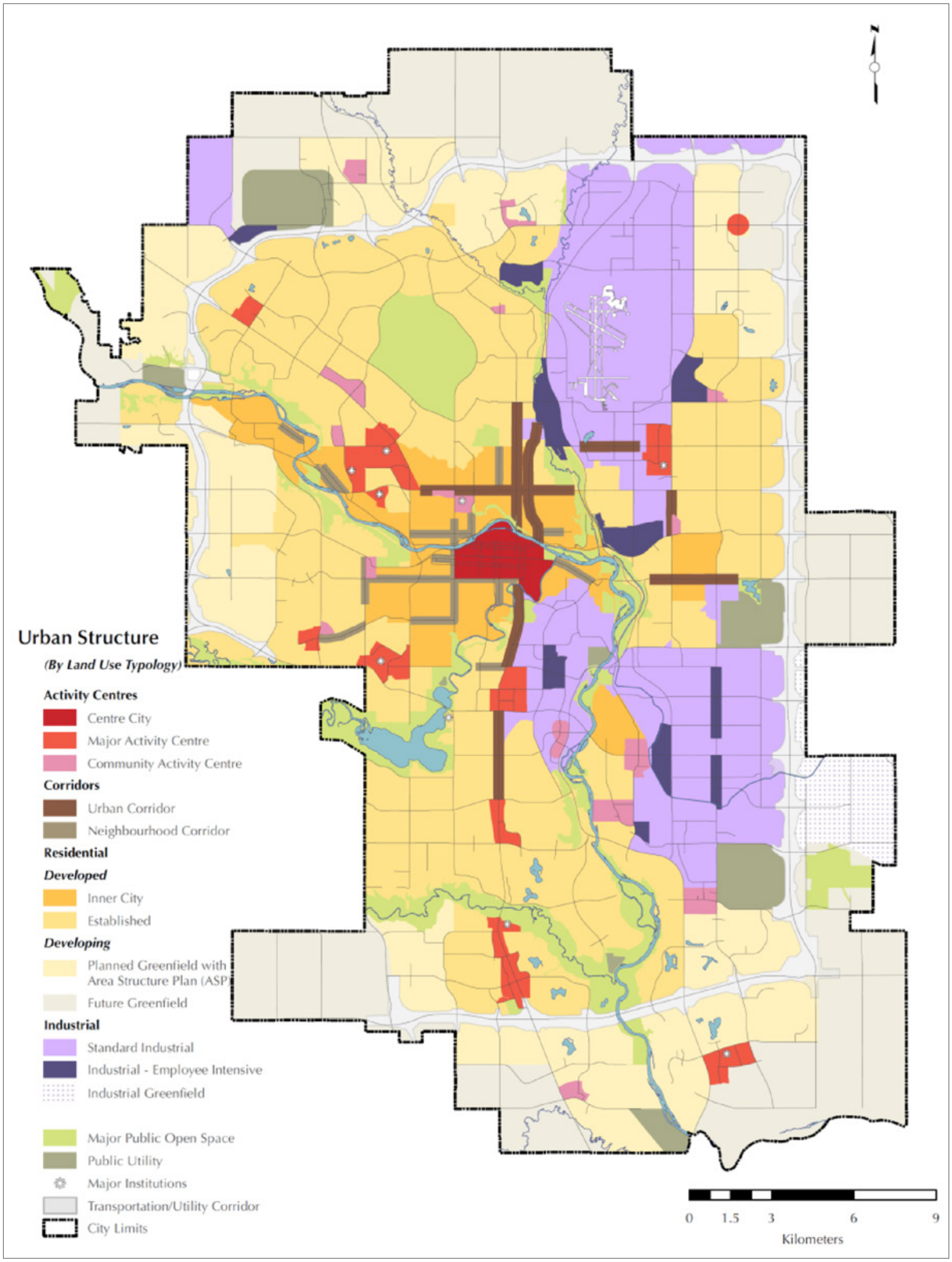
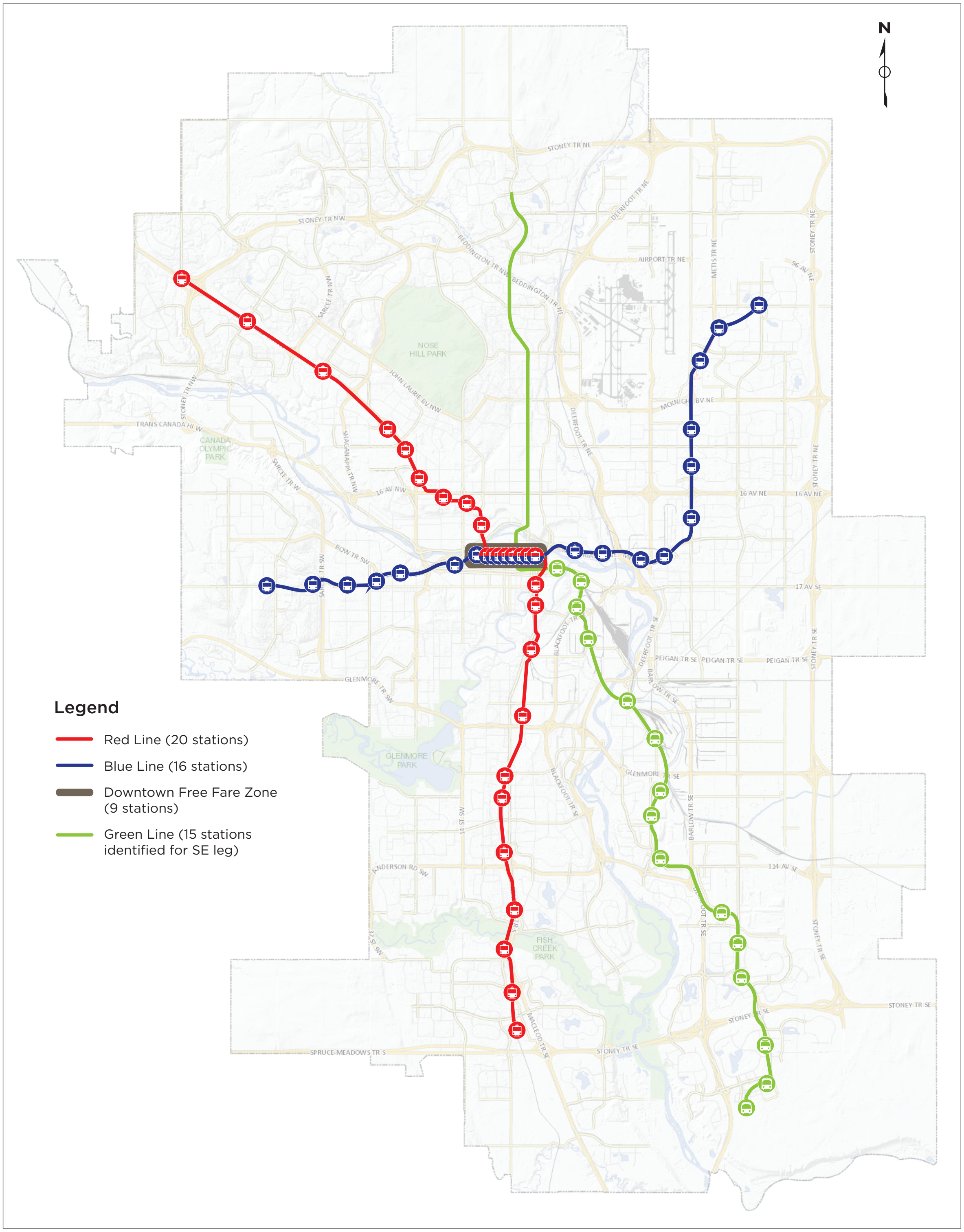


FIGURE 4 CALGARY LRT NETWORK PLAN

Map created using data from Calgary Transit, *Calgary LRT Network Plan*, page 4 and http://www.calgary.ca/Transportation/TI/Pages/Transit-projects/Green-line/map.aspx



Outside the CBD, Calgary has no areas identified as subcentres according to the Giuliano-Small definition, which is based on absolute employment density, but three subcentres according to the Ban-Arnott definition, which is based on a mix of absolute and relative employment density. Exact comparison of Calgary's spatial structure of employment to that of other cities is difficult. There have been few academic studies comparing the pattern of employment subcentres across metropolitan areas, and those that have been done have used somewhat different methods. Table 1 draws together the results of different studies done for U.S. metropolitan areas using 1990 data. Four features stand out. First, the number and types of subcentres vary considerably across metropolitan areas. Second, larger metropolitan areas tend to have more subcentres. Third, Los Angeles and Houston are extreme in their subcentering. Fourth, Calgary is not alone in having zero subcentres according to standard definitions; in 1990, other cities with that status included Buffalo, N.Y., Fresno, Calif. and Salt Lake City, Utah.

TABLE 1 NUMBER OF CENTRES REPORTED BY STUDIES OF SELECTED METROPOLITAN AREAS USING 1990 DATA

Source: Hanson et. al. 2005.

Metro Area	Number of Centres	Study
Atlanta	4 downtowns, including CBD	Full and Hartshorn, 1995
	1 old CBD; 4 edge cities; 3 emerging edge cities	Garreau, 1991
	4 subcentres	McMillen and Smith, 2003
Baltimore	1 old CBD; 3 edge cities; 4 emerging edge cities	Garreau, 1991
	5 subcentres	McMillen and Smith, 2003
Buffalo	0 subcentres	McMillen and Smith, 2003
Denver	1 old CBD; 1 edge city; 1 emerging edge city	Garreau, 1991
	5 subcentres	McMillen and Smith, 2003
Fresno	0 subcentres	McMillen and Smith, 2003
Houston	1 old CBD; 9 edge cities; 2 emerging edge cities;	Garreau, 1991
	8 subcentres	McMillen and Smith, 2003
	3 subcentre rings, 7 employment centres	Craig and Ng, 2001
	25 employment subcentres (within 50 miles of CBD)	McMillen 2001
Indianapolis	11 employment centres	Anderson and Bogart, 2001
	1 subcentre	McMillen and Smith, 2003
Los Angeles	2 old CBDs; 16 edge cities; 8 emerging edge cities	Garreau, 1991
	12 centres	Gordon and Richardson, 1996
	46 subcentres	McMillen and Smith, 2003
	120 employment concentrations (28> 50K jobs, 72 > 10K jobs)	Forstall and Greene, 1997
	19 employment subcentres (within 50 miles of CBD)	McMillen, 2001
Minneapolis-St. Paul	2 old CBDs; 1 edge city; 1 emerging edge city	Garreau, 1991
	7 subcentres	McMillen and Smith, 2003
Phoenix	1 old CBD; 3 edge cities; 4 emerging edge cities; 5 expected edge cities	Garreau, 1991
	5 subcentres	McMillen and Smith, 2003
Pittsburgh	1 old CBD; 1 edge city; 1 emerging edge city	Garreau, 1991
	1 subcentre	McMillen and Smith, 2003
Portland, Ore.	1 old CBD; 1 edge city; 1 emerging edge city	Garreau, 1991
	1 subcentre	McMillen and Smith, 2003
	11 employment centres	Anderson and Bogart, 2001
Salt Lake City	0 subcentres	McMillen and Smith, 2003
Seattle	2 old CBDs; 1 edge city; 3 emerging edge cities	Garreau, 1991
	13 subcentres	McMillen and Smith, 2003

Another way to gauge whether the spatial structure of Calgary's employment is anomalous is to compare it with other cities that one would expect, a priori, to be similar. The metropolitan area chosen for comparison is Denver. Like Calgary, Denver is a spatially isolated, geographically unconstrained, high-plains, automobile city. The population of the Denver metropolitan area is, however, about double that of the Calgary metropolitan area. Denver has a more diversified industrial base than Calgary, and its land-use regulation is by U.S. standards viewed as permissive. Figure 5 displays the spatial distribution of employment density in metropolitan Denver. While not directly comparable to Figures 2 and 3, which focus on employment subcentres, Figure 5 suggests not only that employment in the Denver metropolitan area is more decentralized than in the Calgary metropolitan area, but also that Denver has a well-developed hierarchy of employment subcentres.

FIGURE 5 **2008 WAGE AND SALARY EMPLOYMENT DENSITY**

Source: Denver Regional Council of Governments.

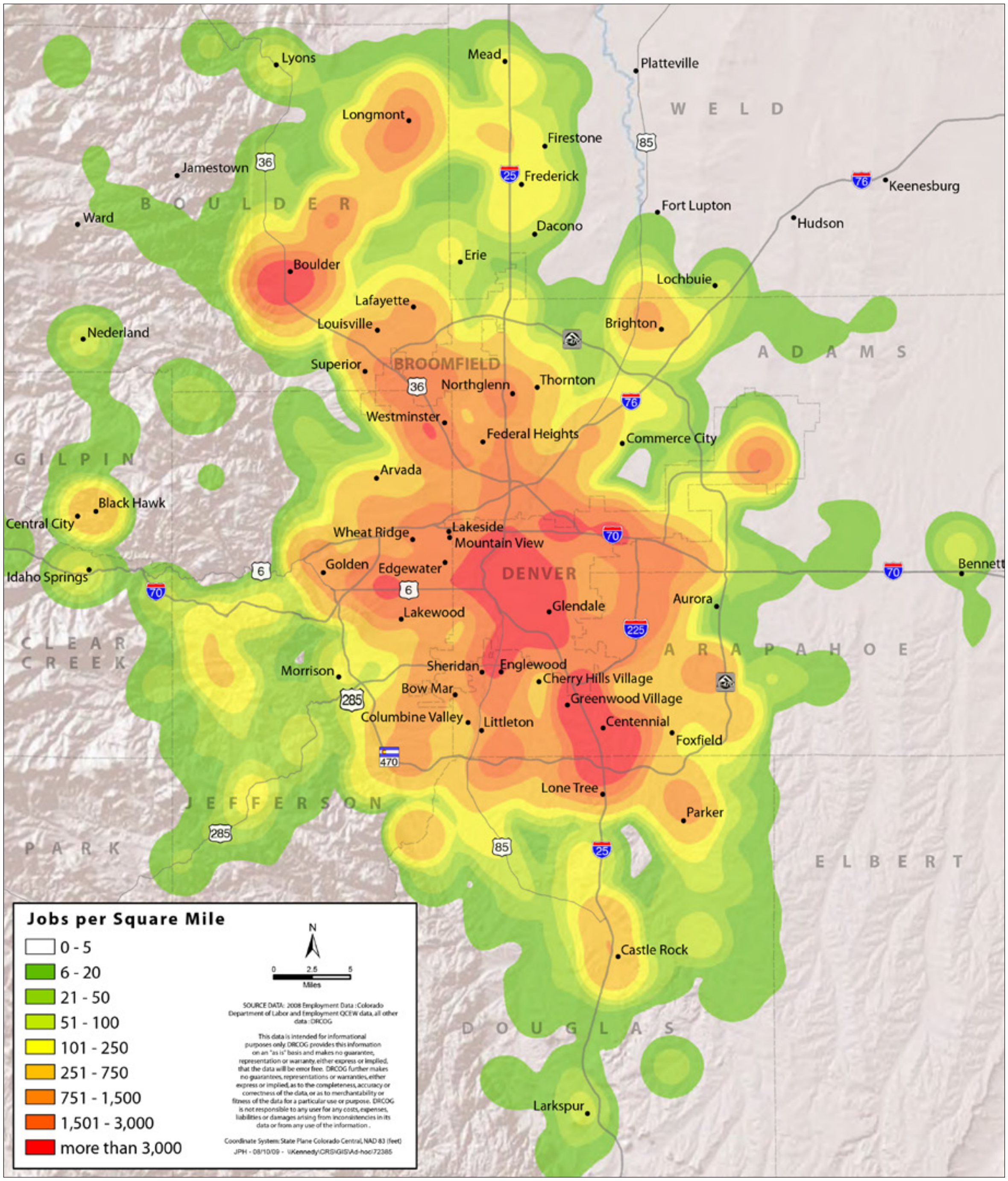
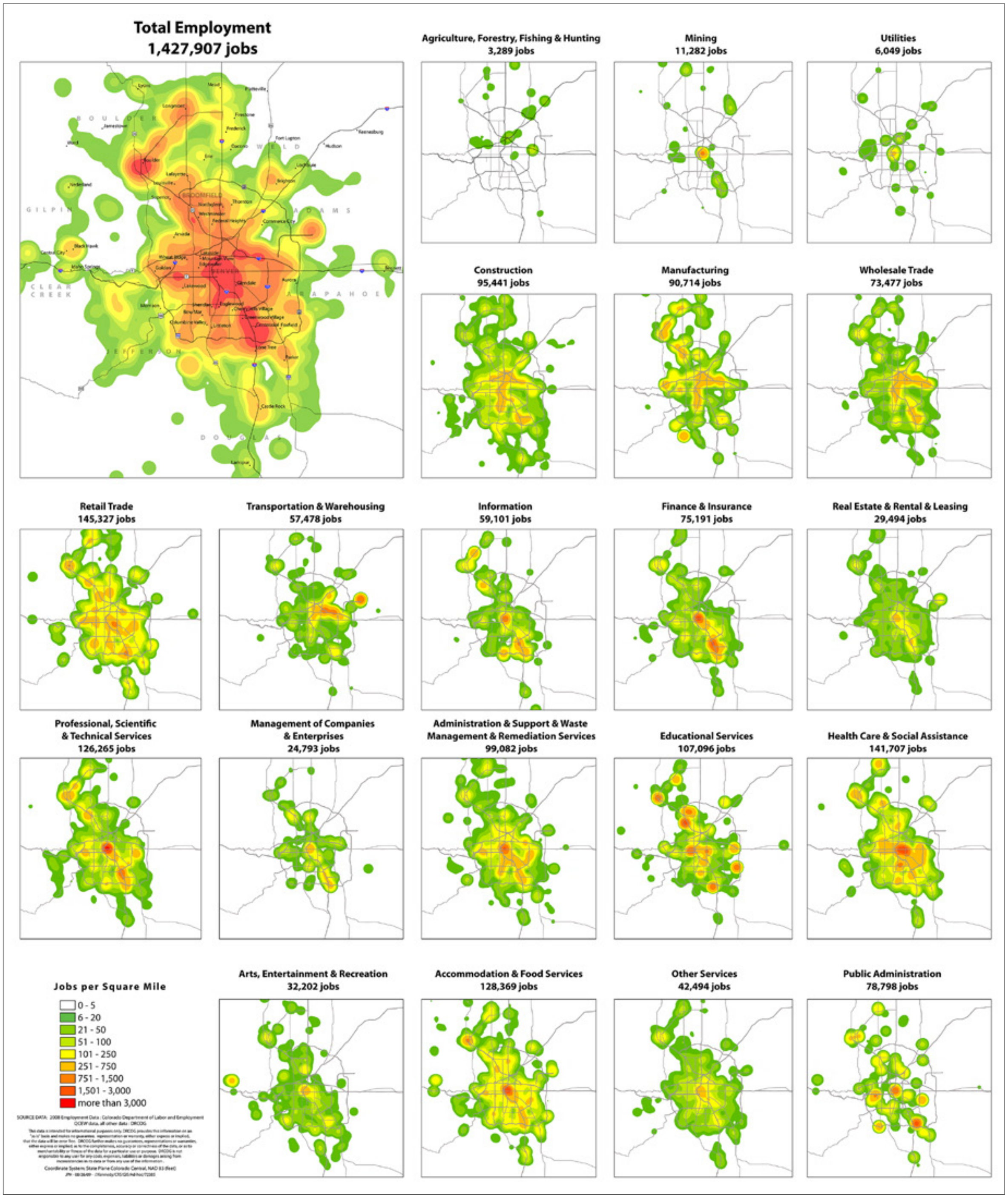


Figure 6 complements Figure 5 by showing the spatial distribution of employment density in the Denver metropolitan area *by industry*. Of particular interest is how different the spatial distribution of employment density is across industries: some industries are considerably more centralized than others (compare finance and insurance with educational services); some industries have considerably more dispersed employment than others (compare accommodation and food services with arts, entertainment, and recreation), holding constant the degree of centralization. Note also that most industry (manufacturing, wholesale trade, and transportation and warehousing) is located in two corridors, one to the south of the central city, the other to the east, somewhat similar to Calgary. Unfortunately, there does not appear to be a comparable figure for Calgary. The biggest difference would no doubt be Calgary's considerably higher spatial concentration of employment density in the downtown core, where its many corporate headquarters are located. Other than that, whether the spatial pattern of employment density by industry would differ markedly between the two metropolitan areas is unclear.

FIGURE 6 2008 WAGE AND EMPLOYMENT DENSITY BY INDUSTRY

Source: Denver Regional Council of Governments.



The tentative conclusion is that the spatial structure of employment in Calgary is anomalous in having such a high proportion of non-local employment in the downtown area, but less anomalous in its lack of sizeable subcentres.

Why does Calgary remain essentially monocentric — with an unusually high proportion of its non-local employment in the downtown area? There are two broad explanations. The first is that Calgary's spatial structure has been driven by economic forces, its monocentricity deriving from its unusual employment composition, especially its exceptionally high concentration of corporate headquarters. The second is that Calgary's urban spatial structure has been imposed by restrictive land-use planning, which has caused its spatial structure to be considerably different from what it would have been if economic forces had been permitted to drive land use.

Unfortunately, no one has yet come up with a persuasive empirical measure of the restrictiveness of a city's land-use planning. The standard measure used by urban economists is based simply on a count of the *number* of regulations.[6] This is not a persuasive measure, however, since the restrictiveness of a set of zoning regulations depends at least as much on how permissive the local zoning board is in granting zoning variances compared to how restrictive the regulations appear on paper.[7]

CALGARY'S PLANNING PROBLEMS FROM AN URBAN ECONOMIST'S PERSPECTIVE

Urban economists often find themselves at loggerheads with urban planners. Their disagreements derive from differences in their professional biases and training. Economists believe in the overall wisdom of the market, though they differ in how important they judge market failures to be and in how extensive they judge the government intervention merited to correct them. Most economists are empiricists, believing that knowledge comes through observation structured by theory.

Planners are more absolutist, particularly when it comes to urban design. This absolutism often extends to a shared vision of elements of the "Good Urban Life," though this vision shifts over time, from Ebenezer Howard's garden cities, to Frank Lloyd Wright's arts-and-crafts architecture, to Le Corbusier's modernist monoliths, to the Pleasantville of postwar suburbia — with its rigid separation of land uses — and to Herbert Gans' and Jane Jacobs' urban villages, the last two of which have evolved into the current post-modernist New Urbanism.

Whatever their political colour, most economists have a strong individualistic and libertarian vein, which provides the basis for their belief in consumer sovereignty: I will respect your tastes in return for your respecting mine. Economists advocate deflecting market forces by selectively correcting market failures rather than opposing them. Consider, for example, "sprawl," defined here as low-density development. To an economist, sprawl is a concern only when density is inefficiently low as a result of distorted prices.

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6 S. Malpezzi, G. Chun and R. Green, "New place-to-place housing price indexes for U.S. metropolitan areas, and their determinants," *Real Estate Economics* 26 (2003): 235-274.

7 The permissiveness of the local zoning board is hard to measure too. The proportion of requests for zoning variances that are granted is not an ideal measure since it may reflect uncertainty about the board's permissiveness as much as it does its permissiveness. If developers were fully informed about what variances the board would grant and what it would not, all requests would be granted.

Thus, the question is not whether cities should be planned, but how they should be planned: how extensively, how flexibly, and through what mix of prices and "quantities" (regulation). The transportation system should not only provide the demanded trips efficiently and accommodate spatial growth, but should also be somewhat directive. Land-use planning should be used to achieve its original intent, to separate incompatible land uses, but this should be done flexibly.[8] Public buildings, monuments, art galleries, and libraries should be provided, as well as public open spaces, including parks, since these are public goods, which the market would underprovide. But beyond these measures, if the prices are right, the market should do a good job of allocating land to not only its highest, but also its best use. Planning, when excessive, is harmful, generating inefficiency in land use.

Calgary's current anomalous spatial structure may be due primarily to its anomalous industrial structure, in particular its status as the only small metropolitan area in North America that is home to a large number of corporate headquarters. A competing explanation is that its current spatial structure is due primarily to planners and policy-makers adhering to New Urbanist ideals on a citywide scale. This has resulted in the city investing heavily in CBD-oriented mass-transit at the expense of the roadway network, imposing a soft parking freeze on downtown parking with the aim of forcing a modal shift away from the car and towards mass-transit ("induced demand for mass-transit") and, through its land-use and other regulatory policies, discouraging or at least not effectively fostering the development of employment subcentres other than transit-oriented development, which entails smaller, mixed-use subcentres around transit stations.

No doubt market forces and planning ideology have both contributed to Calgary's current anomalous spatial structure. The big issue facing Calgarians now is whether to support their decision-makers in continuing the centralizing land-use and transportation policies of the last 30 or 40 years that foster the dominance of the CBD as an employment centre, or whether to resist established planning practice by supporting the formation of employment subcentres, the redirection of transportation investment towards roads, and the spatial expansion of the city both inside and outside the city boundary.

In the economists' ideal world, in which everything is priced efficiently, the economist's advice would be "let the market decide." This would entail congestion-pricing all roads and using the surplus from the revenue collected that is in excess of the operating cost and amortized capital cost to finance new road construction. It would also entail marginal-cost pricing of mass-transit, and using the surplus from the revenue collected, in excess of the operating cost and amortized capital cost, as well as the lump-sum subsidy deriving from mass-transit's increasing returns to scale, to finance capacity expansion. It would also entail land use being driven by the market, with zoning being used only to separate incompatible land uses. But we live in a world that is very different from the economists' ideal world, where, therefore, all policy choices are "second best."

From this perspective, *in general*, planners' opposition to market outcomes is not necessarily misguided. But the city's plans for the next half-century almost certainly are. The city's plans are at least coherent, and if policy follows the plans, the results will not be disastrous. But,

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[8] The rigid separation of land uses characteristic of most American (i.e., both U.S. and Canadian) cities since the 1920s is called Euclidean zoning, but not after Euclid, the geometer, but after a landmark U.S. court case, Euclid v. Ambler, in the 1920s. Recently, there has been a reaction against what is now called "Euclidean I" zoning, and a movement towards "Euclidean II" zoning, which is a more flexible zoning system that accommodates mixed land uses.

especially if population growth continues to exceed its low official projection, following the plans will likely be very costly in terms of both the cost of living and the quality of life.

However, plans are not policy or even proposed policy. They are consensus documents forged after years of negotiation among the major players that provide a vision to guide future policy design. Ambiguous wording masks disagreements and issues that remain to be resolved. Behind a plan, there should be a mass of technical reports that document the forecasts underlying the plan and report on the costs and feasibility of a wide range of policy options that have been considered. These reports, which may be done either by technical experts within the planning department or by outside contractors, should be publicly accessible so that they can inform the public debate.

The reports that are publicly available from the City of Calgary's Planning and Transportation departments contain much unnecessary detail, provide only a fuzzy analytical framework, and fail to get at the central economic issues, which together suggest that the internal technical analysis undertaken by the departments is weak. In light of these concerns, the author undertook rough forecasts of some central effects of the plans for four scenarios or cases. Throughout the paper, dollar magnitudes are in constant (inflation-adjusted) dollars.

Case I: Plan population growth rate and containment — corresponds to a stylized representation of the MDP and CTP, with the city's population forecast and spatial containment (which is treated here as zero growth in the city's residential land area and in the average commuting-trip distance). Population grows at an annual rate of 1.275 per cent, per capita income grows at 1.0 per cent, the transit capital stock grows at 2.0 per cent and the auto capital stock at 1.0 per cent.

Case II: Plan population growth rate and laissez-faire — Case II is the same as Case I except that the city is allowed to expand outward at the "natural" rate. Following Angel et al.,[9] the natural rate of growth of built-up urban area equals 0.6 times the growth rate in per capita income plus 0.8 times the growth rate in population, which equals 1.62 per cent per annum.

Case III: Double plan population growth rate and containment — Case III is the same as Case I, except that the population growth rate is double that assumed in the MDP and CTP.

Case IV: Double plan population growth rate and laissez-faire — Case IV differs from Case I in that both laissez-faire land use and a doubling of the plan-population-growth rate are assumed.

These back-of-the-envelope calculations are no substitute for the more detailed technical reports that should have been done in preparing the plans, but nevertheless raise a number of important points that were ignored in at least the publicly available reports.

[9] S. Angel et al., *The Atlas of Urban Expansion* (Cambridge, Mass.: Lincoln Institute of Land Policy, 2012).

PROBLEM #1: LOW POPULATION PROJECTIONS HAVE BEEN USED TO LEGITIMIZE SPATIAL CONTAINMENT

From the publicly available documents it appears that the city built its plans around a single population forecast. Plans should be formulated taking into account alternative population futures. Not only does this provide planners with an opportunity to think ahead to how the plans would need to be modified in the future, should the future population be significantly lower or higher than in the central forecast, but also it encourages the formulation of a "robust" plan — a plan that can be adapted relatively easily as the uncertain future unfolds.

A major weakness of the current planning process is that it provides the average citizen with little information about what the feasible alternatives and trade-offs are. And, at least in Calgary, it does not provide ready access to the technical reports that went into preparation of the plans. The whole process should be more open and transparent. As it is, the process is unfair. If a citizen or academic objects, it is all too easy for the Planning Department to say, even if politely: "you don't know what you're talking about." And of course the objector doesn't, since she has little information on the basis of which to object.

Planners now base their plans on point forecasts. With advances in the analytical sophistication of forecasts and in computational power, there are increasing calls for forecasting probability distributions of outcomes. This will make the planning process more complex, but will also allow the design of "robust" policies — those that do well under a broad range of scenarios — and of contingency plans.

The plans are based on the assumption that the city's population will grow at an average annual rate of 1.275 per cent, to approximately 2.3 million in 2070, roughly double what it was in 2010. Between 1950 and 2010, also a 60-year period, Calgary's population grew by a factor of five, not two.[10] What is the basis for assuming such a rapid slowdown in the population growth rate? If the city does grow faster than the plans assume, will the plans continue to be sound? The plans are silent on what will happen to population after 2070. If the city's population continues to grow at the same rate as is assumed in the population forecast, or at an even more modest level, will the city's spatial structure comfortably adapt to the continued population growth? In view of the considerable uncertainty about the city's future population, should not the plans outline contingency plans to deal with various population scenarios?

The literature search uncovered no city document that gives the rationale for its population forecast, nor, remarkably, any public discussion of the forecast. The author is not sufficiently well-informed about the local economy to undertake his own population forecast. Nevertheless, it seems odd to assume that the metropolitan area's population growth rate will slow so sharply. Despite the roller-coaster behaviour of the price of oil, and the corresponding ups and downs in the local economy, from a longer-term perspective the Calgary area seems to have been thriving economically. Per capita income is consistently the highest among major Canadian cities. Though clouded in uncertainty, the prospects for the province's oil and gas industry seem good over the forecast period. Technological progress continues to be made in the development of

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[10] Annexations have had a limited impact on Calgary's population growth. The majority have consisted of large tracks of farmland with the odd homestead; however, in the early 1960s several significant communities where annexed, including the then Towns of Montgomery (5,077), Bowness (9,184), Forest Lawn (12,263), and the Hamlet of Midnapore (population data from Statistics Canada 1961 Census).

new energy technologies and alternative fuels, but also in the extraction of oil and natural gas. There seems to be little danger of running out of reserves that can be extracted at competitive prices. Meanwhile, the metropolitan area scores high in terms of quality-of-life measures, except with respect to traffic congestion and the price of housing, which are endogenous rather than exogenous factors. There is abundant room to accommodate population growth. At the national level, it appears likely that population growth will continue more or less at current levels, and perhaps even rise due to increased immigration to offset an increasing dependency ratio.[11] And with a good quality of life and the highest per capita income in Canada, Alberta can be expected to attract migrants from both abroad and the rest of Canada.

Assume, for the sake of argument, that the city population forecast was made in 2008, at a time when the city's population was 1.043 million. Applying the city's forecast population growth rate to the year 2014 gives a 2014 population of 1.126 million. The actual 2014 population was 1.195 million,[12] corresponding to a population growth over the period that is 83 per cent higher than the forecasted amount. It would be a mistake to put too much weight on only six-years' population growth, particularly considering that the city's population growth reflects the volatility of the city's economy. Nevertheless, the experience of those six years is consistent with the city planners' historical record of having, on average, considerably underestimated the city's population growth.[13]

The population forecast is central to the viability of the city plans. If population growth is modest, as forecast, the city might be successful in implementing its vision of a sustainable city, with the CBD as the dominant non-local employment centre, and commuting supported by an expanded, radial LRT system. As shall be argued below, housing costs and commuting times would likely remain approximately stable. But if the rate of population growth substantially exceeds that in the forecast, and if the city adheres to the plans, housing costs and commuting times would rise sharply, to the point where the plans would likely be abandoned or radically altered.

Even if population grows as forecast over the 2010–70 period, what happens after that if the city's population continues to grow after 2070? If the city were to retain the CBD-orientation of its mass-transit system, and were to continue to encourage centralization of employment rather than subcentering, the city would either have to expand upwards, causing rents to increase, or outward, causing commute distances and commute times to increase.

A Model of the Growth Rate of Housing Rents

This subsection will examine these issues by performing some well-informed, albeit rough, back-of-the-envelope calculations. Persuasive quantitative assessment of the plans' effects would require the application of a full-blown computable general-equilibrium model. Nevertheless,

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[11] Statistics Canada, Healthy People, Healthy Places (82-229-X), http://www5.statcan.gc.ca/olc-cel/olc.action?objId=82-229-X&objType=2&lang=en&limit=0. A few years ago the author attended a conference on Australia's urban policy. Interestingly, top billing went to the future of immigration policy, which was viewed as intimately tied to the future evolution of the dependency ratio.

[12] 2014 Civic Census Results, City Clerk's Election and Information Services.

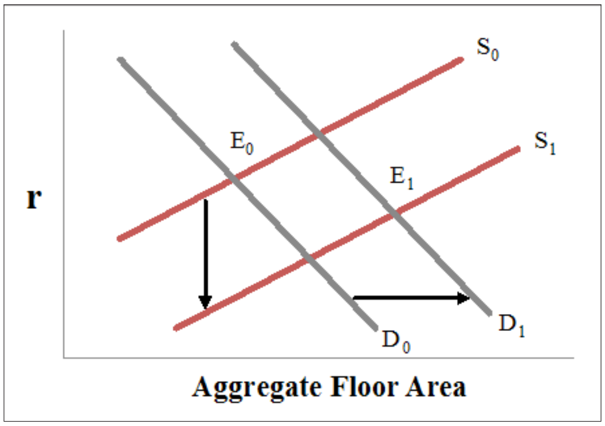
[13] City of Calgary, Transportation Planning, "Mobility Monitor 30: Trends in land use and land use forecasts affecting transportation" (2004), http://www.calgary.ca/Transportation/TP/Pages/Planning/Transportation-Data/Mobility-Monitor.aspx.

back-of-the-envelope calculations based on simplified yet sound models can yield valuable insights. This subsection will report on one set of back-of-the-envelope calculations aimed at determining how rapidly housing rents will grow under two scenarios. The first scenario is the plan, which entails the plan population forecast, as well as a policy of spatial containment. The second scenario is the same, except that population grows at double the rate of that assumed in the plan.

The model has one equation, the equilibrium condition that at all points in time the aggregate demand for housing equals the aggregate supply of housing. Housing rent adjusts so as to clear the housing market. The aggregate quantity of housing is measured by aggregate housing floor area, with no adjustment for quality. The aggregate demand for housing equals population times the per capita demand for housing. The per capita demand for housing is increasing in income and decreasing in rent. The aggregate supply of housing equals the supply of floor area per unit area of land (the floor-area ratio) times the quantity of land devoted to housing. It is assumed that the plans' policy of spatial containment results in the aggregate quantity of land devoted to housing remaining fixed. Thus, with spatial containment, the aggregate supply of housing equals the fixed area of land devoted to housing times the supply of floor area per unit area of land. The supply of floor area per unit area of land is increasing in rent. There is also technical change in housing construction.

The model is illustrated in Figure 7. The aggregate demand curve shifts to the right over time. Under the assumption of a unit-income elasticity of demand for housing, holding rent fixed, the quantity demanded increases at a rate equal to the sum of the population- and income-growth rates. The supply curve shifts down over time; holding quantity fixed, the marginal cost of construction decreases at a rate equal to the rate of technical progress in housing construction. From these shifts, the rate of growth of rents that keeps the quantity of housing supplied and the quantity of housing demanded in balance, can be calculated.

FIGURE 7 THE PROCEDURE TO ESTIMATE THE GROWTH RATE IN RENTS



Note 1: The demand curve shifts out over time due to population and income growth.

Note 2: The supply curve shifts down over time due to decreasing marginal cost of construction deriving from technological progress.

The model abstracts from locational differences and does not treat explicitly the durability of housing. In the empirical application, however, ad hoc adjustments are made for each. Richard Muth was the leading housing economist of his generation, and the model is Muthian in spirit.[14]

Application of the Model to Estimate the Growth Rate in Rents under the Plan, with the Plan Population Forecast and with a Higher Forecast

Details of the procedure, the parameters assumed and their justification, and the calculations are reported in Appendix A.

The first row of Table 2 presents the results for the plan, which assumes the city's implicit forecast annual rate of population growth to 2070 of 1.275 per cent, and an annual growth rate of real per capita income of 1.0 per cent. This case is termed Case I. The second row of Table 2 presents the results for Case III, which differs from Case I only in that the assumed annual rate of population growth is double the city's forecast rate. For each of these two cases, the table presents not only the growth rate in rents, but also the ratio of the population in 2070 to that in 2008 (Pop_{2070}/Pop_{2008}), the ratio of housing rent in 2070 to that in 2008 (r_{2070}/r_{2008}), the implied ratio of average housing unit/apartment size in 2070 to that in 2008 (H_{2070}/H_{2008}), and the implied ratio of the floor-area ratio of housing in 2070 to that in 2008 (FAR_{2070}/FAR_{2008}).

TABLE 2 FORECAST GROWTH IN HOUSING RENT (R), HOUSING-UNIT SIZE (H), AND FLOOR-AREA RATIO (FAR), 2070 COMPARED TO 2008

	Annual population growth rate	Annual housing rent growth rate	Pop_{2070}/Pop_{2008}	r_{2070}/r_{2008}	H_{2070}/H_{2008}	FAR_{2070}/FAR_{2008}
I: Plan population growth rate and containment	1.275%	-0.0313%	2.19	0.981	1.89	4.15
III: Double Plan population growth rate and containment	2.55%	0.288%	4.76	1.19	1.55	7.39

Under the plan in Case I, the annual growth rate of rents is -0.0313 per cent, which implies that the ratio of housing rent in 2070 to that in 2008 will be 0.981 and that the ratio of housing unit size in 2070 to that in 2008 will be 1.89.[15] Since it is assumed that the ratio of the population in 2070 to that of 2008 is 2.19, while the city's land area remains fixed, the floor-area ratio in 2070 will be 4.15 that in 2008. Thus, with the city's population forecast and the other estimated parameters, the policy of spatial containment will result in a very modest decline in housing rent over the period. The upward pressure on housing rents resulting from spatial containment when population and income grow is slightly more than offset by technological progress in housing construction.[16] Technological change in housing construction is often overlooked since it occurs at such a modest rate. Without it, however, a city's housing rents would inexorably rise as it grows.

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14 R. Muth, *Cities and Housing* (Chicago, Ill.: University of Chicago Press, 1969).

15 Since the annual growth rate of per capita income is assumed to be one per cent, and since the demand function is assumed to be Cobb-Douglas, per capita expenditure on housing also grows at one per cent. Since the annual growth rate in rent is -0.03125 per cent, the annual growth rate in floor area per capita is 1.0313 per cent. Since the developed area is assumed to remain the same and population to grow at an annual rate of 1.275 per cent, the growth rate of aggregate floor area is 2.306 per cent.

16 The rate of 0.6 per cent per annum is assumed, based on M. Iacoviello and S. Neri, "Housing market spillovers: Evidence from an estimated DSGE model," *American Economic Journal: Macroeconomics* 2 (2010): 125-164.

In Case III, between 2008 and 2070 the city's population will grow at double the rate in the plan forecast. This implies an annual population growth rate of 2.55 per cent. Again on the assumption that the annual growth rate in income over the period will be one per cent, the implied growth rate of housing rent is 0.288 per cent, which in turn implies that the ratio of housing rent in 2070 to that of 2008 will be 1.1948. Over the same period, housing-unit size will rise by about 55.3 per cent, population by 376 per cent, and the floor-area ratio by about 639 per cent. Thus, a doubling of the population growth rate over the forecast period compared to that of the plan forecast will result in 2070 housing rent being 21.8 per cent higher than with the plan population forecast.

The above back-of-the-envelope calculations are instructive in two respects. First, they quantify what intuition and qualitative reasoning suggest: that the viability of the spatial-containment policy in the plans is sensitive to the future rate of population growth. Under the city's population forecast, spatial containment is a viable policy in the sense that it would not lead to a run-up in rents but, in fact, to a slight decrease. However, under an alternative forecast, that future population growth will follow historical experience, spatial containment would lead to rents increasing at a rate that might generate opposition to the policy.

The second way in which the calculations are instructive is methodological. They have demonstrated that the consistent application of basic urban-economic reasoning can generate considerable insight into the *quantitative* effects of different rates of population growth on housing rents under alternative policy scenarios. In contrast, none of the city's publications related to the plans provide forecasts of housing rents under variants of the plans or under alternative scenarios.

PROBLEM #2: SPATIAL CONTAINMENT WILL CAUSE HOUSING RENTS TO RISE

A research group at the World Bank recently examined the historical spatial growth of metropolitan areas around the world.[17] The studies found an average elasticity of the built-up land area with respect to population of about 0.8, and with respect to per capita income of about 0.6. The City of Calgary's publications make no reference to anticipated income growth or the income elasticity of demand for housing. The historical experience of other cities indicates that spatial containment of a metropolitan area can lead to rapid growth in housing rents and values. Since Calgary rents and values are already high, will the spatial-containment policies proposed in the plan exacerbate housing-affordability problems?

The previous subsection explored how the growth rate of rents is related to the rate of population growth. The calculations there assumed that a policy of spatial containment is in place; specifically, that the amount of land in residential use is held fixed. This subsection explores the cost in terms of housing rent of the policy of spatial containment, using the same model as in the previous section and under the same two population-growth scenarios, the plans' and double the plans'. Except for the growth rate in land area, which reflects the government's land-use policy, the parameters are the same as in the previous section.

17 S. Angel et al., "The persistent decline in urban densities: Global and historical evidence of sprawl," Draft (2010); and Angel et al., *The Atlas*.

The containment policy is naturally measured as a zero growth rate for the land allocated to residential use. The alternative policy is laissez-faire. If zoning is in place, it is accommodating rather than restrictive. Under this policy, the growth rate of built-up area is calculated using the empirical World Bank estimates for the growth rate of the metropolitan built-up area. Some additions to built-up land come through infill, but most come through subdivision development at the metropolitan periphery. A unit of land added at the metropolitan periphery is less valuable than a unit of land closer to the metropolitan centre, and is developed at lower density. For this reason, in the calculations that follow, a one per cent growth rate in the built-up urban area is assumed to correspond to a 0.5 per cent growth rate in the amount of effective land in residential use. With this admittedly crude and ad hoc adjustment,[18] it is assumed that laissez-faire entails a growth rate of residential land area equalling 0.3 times the growth rate of per capita income plus 0.4 times the growth rate of population, which equals 0.810 per cent.

TABLE 3 EFFECTS OF SPATIAL CONTAINMENT ON THE RATE OF GROWTH OF HOUSING RENT, WITH THE PLAN-FORECAST-POPULATION-GROWTH RATE, AND THEN DOUBLE THAT RATE.

Case	Annual population growth rate	Annual effective residential land-area growth rate	Annual housing-rent growth rate	r_{2070}/r_{2008}
I: Plan population growth rate and containment	1.275%	0.0%	-0.0313%	0.981
II: Plan population growth rate and laissez-faire	1.275%	0.810%	-0.234%	0.865
III: Double plan population growth rate and containment	2.55%	0.0%	0.288%	1.19
IV: Double plan population growth rate and laissez-faire	2.55%	1.320%	-0.0425%	0.974

With the plan forecast rate of population growth over the forecast period, the 2070 housing rent is 11.3 per cent higher under the policy of spatial containment than under the laissez-faire land-use policy. With forecast population growth of double this rate, the corresponding number is 22.7 per cent. Qualitatively, this is what one would expect; the higher the rate of population growth, the greater the increase in the rental growth rate due to a policy of spatial containment.

The above estimates are only as accurate as far as the model used is a reasonable description of reality and as the parameter estimates are accurate. The model is economically sound but it is very simple, perhaps too simple. For example, if explicit account were taken of the durability of housing, the housing-supply curve would be significantly less elastic than is implied by the above calculations,[19] especially in the short run. Taking this into account would amplify the effects on housing rent of a higher population growth rate than is assumed in the plan, as well as the effects due to spatial containment.

To explicitly treat the durability of housing would require a model that is considerably more complicated than the very simple back-of-the-envelope model employed here. Nevertheless, it is possible to examine how a lower housing-supply elasticity affects the results by altering the value of one of the parameters, which results in a reduction in the elasticity of the floor-area ratio with respect to housing rent from 3.0 to 2.0. Table 4 reports the results.

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18 If the more sophisticated monocentric-city model were used, this adjustment would not be necessary.

19 In the very short run, housing supply is almost completely inelastic. Over the course of a month, for example, some rehabilitation can be undertaken but no new housing can be constructed. As the time horizon increases, more and more margins of adjustment kick in, so that housing supply becomes increasingly elastic. Empirical studies, both simulation and econometric, indicate that housing is in fact so durable that, even over a period of 60 years, the supply elasticity of housing is substantially below the long-run elasticity employed to derive the results reported in tables 2 and 3.

TABLE 4 EFFECTS OF SPATIAL CONTAINMENT ON THE ANNUAL GROWTH RATE IN RENT, WITH THE PLAN FORECAST POPULATION GROWTH RATE, AND THEN DOUBLE THAT RATE, WITH A HOUSING-SUPPLY ELASTICITY OF 2.0 RATHER THAN TABLE 3'S VALUE OF 3.0.

Case	Annual population growth rate	Annual effective residential land-area growth rate	Housing rental growth rate	r_{2070}/r_{2008}
I: Plan population growth rate and containment	1.275%	0.0%	0.538%	1.39
II: Plan population growth rate and laissez-faire	1.275%	0.810%	0.133%	1.09
III: Double plan population growth rate and containment	2.55%	0.0%	1.18%	2.06
IV: Double plan population growth rate and laissez-faire	2.55%	1.320%	0.515%	1.38

Comparing tables 3 and 4, a lower housing-supply elasticity causes a higher growth rate of rents, and a larger proportional effect of spatial containment on housing rent. With the plan forecast rate of population growth, relative to a laissez-faire land-use policy, a policy of spatial containment would cause rents to rise over the plan period by 28.4 per cent. And with double that population growth rate, relative to a laissez-faire land-use policy, a policy of spatial containment would cause rents to rise over the plan period by 50.1 per cent, which is substantial and more than sufficient to raise strong opposition to the policy.

The model specification implicitly assumes that builders choose the floor-area ratio without restriction, so as to maximize profit. Restrictions on building height and floor-area ratio reduce the housing-supply elasticity. Thus, the tighter these restrictions apply, the more rapid the growth in housing rents. Restrictions on setback or the coverage ratio increase the level of housing rents, rather than their growth rate; thus, setback and coverage-ratio requirements that become increasingly restrictive over time cause an increase in the growth rate of housing rents.

As noted earlier, there is no evidence in the public record that the City of Calgary Planning Department has undertaken an analysis similar to that reported in this section. The city should do so, paying particular attention to accurately estimating Calgary's housing-supply function.

PROBLEM #3: THE DANGER OF RAPIDLY INCREASING TRAFFIC CONGESTION

In recent years, the city has been channelling almost all transportation infrastructure investment into mass-transit.[20] The Calgary Transportation Plan indicates that it plans to continue on this course for the duration of the plan, and is confident that doing so will result in substantial modal shifting away from the car towards mass-transit and non-motorized modes. The empirical literature on modal choice indicates that very large increases in auto travel times would be necessary to induce the change in modal share assumed in the plan. On what basis does the city believe that Calgary is an outlier — that the substantial modal shifting assumed in the plan can be achieved without sharp increases in average commuting times? The plans provide no forecasts of average commuting times. Why not?

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[20] The largest auto-infrastructure project in a generation, the Ring Road (Stoney Trail), is being paid for by Alberta Transportation, and most of the land for the Transportation Utility Corridor (TUC) where it is located was purchased by the Province of Alberta, not the city. The analysis that follows ignores the Ring Road. Since the Ring Road is at the periphery of the city, it has and will continue to reduce average suburb-to-suburb commuting cost. However, it is unlikely to have much impact on average suburb-to-downtown commuting cost.

For more than 30 years, the city has invested heavily in the LRT system but little in the road system, and has restricted the amount of parking downtown. This policy has been successful in increasing the LRT modal share, especially for commuting trips to and from the central city. Also, there is at least the perception that, as a result, traffic congestion has substantially worsened. Since average journey-to-work times tend to be significantly higher for mass-transit than for cars, these trends together suggest that journey-to-work times in Calgary have been increasing over that period. Unfortunately, the trend in average journey-to-work times is not well documented. The only data available are from the 2011 National Household Survey[21] and from TomTom for 2011, 2012, and 2013.[22] The city's TomTom index[23] rose from 19 per cent in 2011 to 22 per cent in 2013, which exceeds Boston's in that year, but this is too short a time period over which to discern a statistically reliable trend.

Between now and 2070, the city plans to continue its policy of expanding the public transit system, especially the LRT system, while investing little in the road system. This section explores some of the implications of this policy if it is continued to 2070. In particular, it investigates how rapidly traffic congestion will worsen and how much average journey-to-work times can be expected to increase.

Even though the proportion of all trips that are commuting trips has been declining steadily over the last 50 years, urban transportation planning still focuses on the adequacy of capacity on the journey to work. There is a good reason for this: traffic density is significantly higher during the rush hours than during other periods of the day. One implication is that, if capacity is adequate for rush-hour traffic, it will be adequate during other periods of the day. Another is that the time loss due to congestion occurs disproportionately during the rush hour. This section follows standard practice in focusing on commuting trips: the journey to work.

It will be useful to start by introducing the standard approach that traffic engineers take to forecasting travel demand and traffic congestion: the four-step model. The four steps or sub-models are (1) trip generation; (2) trip distribution; (3) mode choice; and (4) route choice. Trip generation concerns the aggregate number of trips by trip purpose, recognizing that most travel demand is derived from the demand for activities, and is sensitive to the money and time costs of travel. Trip distribution concerns the origins and destinations of the trips generated in the first step; the outcome of this step is a trip matrix. Mode choice concerns the modal split of trips between each origin-destination pair, and route choice for each mode concerns the distribution of routes chosen by travellers between each origin-destination pair, based on the actual traffic network, aggregated to the level of major roads.

The transportation planner typically has at her disposal two types of data concerning the current and past states of the traffic system, aggregate data and individual sample data collected from travel diaries, which describe in detail the travel experience of individuals over, say, a week. To simplify the discussion, let us suppose that the planner only has data from travel diaries for a

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21 Statistics Canada, National Household Survey (2011), Table 1a and Table 1b.

22 TomTom International B.V., North American Congestion Index, 2012, 2013 and 2014.

23 "The methodology measures travel times during the whole day and during peak periods, and compares these with measured travel times during non-congested periods (free flow). The difference is expressed as a total average percentage increase in travel time. We take into account local roads, arterials and highways. All data is based on actual GPS based measurements…" (TomTom index, 2014). The city index is a trip-weighted index over the year. Defining "excess travel time" as actual travel time minus free-flow travel time, the index gives the ratio of excess travel time to free-flow travel time.

particular week that specify the start and end time of all trips, as well as their purpose and the mode chosen.[24] From this she can estimate the mode-specific trip matrices by period of the day and day of the week, as well as mode-specific travel times between each origin-destination pair by time period. She also has data on the "capacity" of each link of each mode-specific network, where capacity is defined as maximum sustainable flow.

A traffic equilibrium is a traffic allocation such that no traveller can become better off by changing her route, mode, trip pattern, or trip frequency. It is assumed that the observed traffic allocation is a traffic equilibrium. This equilibrium is obtained through the interaction of supply and demand, with equilibrium being achieved through adjustment in levels of traffic congestion. On the supply side are the mode-link-specific congestion functions, each of which specifies how travel times on that mode link increase with the flow on the mode link. On the demand side, there are demand functions, one for each step of the four-step model, which specify the travel choices individuals make as a function of the state of the traffic system.

The transportation planner then assumes the role of a statistician, estimating the parameters of the demand functions and congestion functions that provide the best fit to the data, on the assumption that the data describe a traffic equilibrium. She then has a model of the traffic system that can be used to forecast how traffic equilibrium changes in response to exogenous changes in population, income, fares, and mode-link-specific capacities.

The literature review uncovered some forecasts of LRT ridership and how it would be changed by specific improvements to the LRT system, but no documentation was provided on how the forecasts were generated. Furthermore, neither the MDP nor the CTP, nor any follow-up documents, contain reference to any forecasts of how the proposed transportation plan will affect road-traffic congestion or average journey-to-work times.

An Aggregate Model of Journey-to-Work Times

The remainder of this section will undertake such forecasts, in the spirit of travel-demand forecasting. Since doing this at the level of disaggregation at which travel demand forecasting is typically done would be a major research project, *here the heroic simplification will be made to treat the city as a single spatial unit*. Most traffic engineers will object strongly, since their conventional wisdom is that the more disaggregated the traffic network, the more accurate the traffic forecasts. This is disputable. Recent work by Carlos Daganzo (a leading traffic-flow theorist) and his students at the University of California, Berkeley, has demonstrated that, *at the level of the downtown neighbourhood*, forecasts obtained using an aggregate (traffic engineers use the term macroscopic) model with a more sophisticated[25] treatment of traffic congestion are superior to those obtained using the conventional approach.[26] Nevertheless, since little prior work has been done forecasting the modal split and commute times using models *aggregated to*

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[24] Modes include simple and compound modes. "Drive alone" is a simple mode. "Drive from the origin to the subway station, park, take the subway to close to the destination, and then walk to the destination" is a compound mode.

[25] The conventional approach assumes that the travel speed on a link is related to traffic flow on that link. The more sophisticated approach assumes that the travel speed on a link is instead negatively related to the traffic density on the link, allowing for the treatment of traffic jams.

[26] N. Geroliminis and C. Daganzo, "Existence of urban-scale macroscopic fundamental diagrams," *Transportation Research, Part B* (2008): 759-770.

the level of an entire city,[27] the forecasts developed below should be received with a healthy dose of skepticism. Nonetheless, they will hopefully encourage the City of Calgary's Transportation Planning Department to either release, with full documentation, its internal modal-share and average-commute-time forecasts under the CTP if they have been made, or to undertake well-documented forecasts if they have not.

The Calgary Transportation Plan[28] aims to reduce the auto modal share (for all trips, not just commuting trips) from its current level of 77 per cent to between 55 and 65 per cent, and to roughly double the mass-transit modal share from its current level of nine per cent to between 15 per cent and 20 per cent. While the plan does not explicitly say so, it intends to induce the modal shift from cars to mass-transit not only by extending and upgrading the LRT and bus systems, but also by providing little funding to roads, which will have the effect of increasing road congestion, and by continuing its soft parking freeze downtown, which will increase the price of commuting to downtown by car.

Table 5A gives the 2011 modal shares in the Calgary region for all home-to-work trips[29] for all such trips with a CBD destination, and for all such trips with a destination outside the CBD. It is evident that auto travel is the dominant mode of commuting for workplaces outside the CBD. For workplaces in the CBD, in contrast, mass-transit is now the dominant mode. From the figures below, it can be inferred that 26.8 per cent of workplaces are in the CBD, which is high for a metropolitan area of Calgary's size. Table 5B gives comparable data for 2001 from the same source.

TABLE 5A 2011 WEEKDAY MODE SHARE FOR TRAVEL FROM HOME TO WORK

Mode	Home-to-work mode share — all workplaces	Home-to-work mode share — workplace in the CBD	Home-to-work mode share — workplace outside the CBD
Walk	8.2%	13.9%	6.2%
Bike	2.0%	4.0%	1.3%
Auto driver	64.9%	29.1%	78.0%
Auto passenger	6.2%	7.3%	5.8%
Transit	18.7%	45.7%	8.8%

Source: "Changing Travel Behaviour in the Calgary Region," Travel Behaviour Report Series 2 (October 2013), Figures 12, 13, and 14.

27 An exception is I. Parry and K. Small, "Should urban transit subsidies be reduced?" Discussion Paper (Resources for the Future, 2009).

28 City of Calgary, Calgary Transportation Plan (2009), Table 2 and Figure 6, http://www.calgary.ca/Transportation/TP/Documents/CTP2009/calgary_transportation_plan.pdf.

29 Recent data are available for 2014. For all workplaces, for travel from home to work, the auto modal share was 72.6 per cent, the transit modal share 18.0 per cent, and the active modal share 7.3 per cent.

TABLE 5B 2001 WEEKDAY MODE SHARE FOR TRAVEL FROM HOME TO WORK

Mode	Home-to-work mode share — all workplaces	Home-to-work mode share — workplace in the CBD	Home-to-work mode share — workplace outside the CBD
Walk	6.4%	10.9%	4.7%
Bike	1.6%	2.5%	1.3%
Auto driver	69.6%	38.6%	80.9%
Auto passenger	8.4%	12.0%	7.1%
Transit	13.9%	36.0%	5.9%

Source: Changing Travel Behaviour in the Calgary Region," Travel Behaviour Report Series 2 (October 2013), Figures 12, 13, and 14.

Over the 10-year period from 2001 to 2011, the auto modal share (driver and passenger) for travel from home to work fell from 78.0 to 71.1 per cent for all workplaces, from 50.6 to 36.4 per cent for workplaces in the CBD, and from 88.0 to 83.8 per cent for workplaces outside the CBD. Over the same period, the transit modal share for travel from home to work increased from 13.9 to 18.7 per cent for all workplaces, from 36.0 to 45.7 per cent for workplaces in the CBD, and from 5.9 to 8.8 per cent for workplaces outside the CBD; the active modal share for travel from home to work increased from 8.0 to 10.2 per cent for all workplaces, from 13.4 to 17.9 per cent for workplaces in the CBD, and from 6.0 to 7.5 per cent for workplaces outside the CBD. Such a large fall in the auto modal share for travel from home to work over such a short period of time is extremely unusual among North American cities, and may indeed be unprecedented. This fall is all the more remarkable in light of Calgary's high level of car ownership, which the same document reports. The average auto ownership per household in 2011 in Calgary exceeded 1.81, and more households owned four or more cars than did not own a car.[30]

In order to plan for Calgary's future transportation system, it is important to understand why these remarkable modal shifts occurred. One reason is certainly the expansion of the mass-transit system over the period. Other possible reasons include improved service on the mass-transit system, worsened traffic congestion, higher downtown parking fees, and a change in tastes. No publicly available studies appear to have been done of this issue.[31]

Treating Calgary as a single spatial unit, the analysis that follows provides back-of-the-envelope calculations of modal shares, mode-specific average journey-to-work times, and overall average journey-to-work time. The analysis will also be restricted to the modal split between auto and mass-transit. After adjustment for the difference between the city of Calgary and the Calgary region, the 2011 home-to-work motorized-travel modal split between auto and transit for motorized travel is taken to be 75 per cent and 25 per cent.

Appendix B presents a three-equation model that forms the basis for the back-of-the-envelope calculations. The first equation relates the modal share to the average journey-to-work times by

[30] City of Calgary, *"*Changing travel behaviour in the Calgary region,*"* Travel Behaviour Report Series, Vol. 2. (2013*)*, http://www.calgary.ca/Transportation/TP/Documents/forecasting/Changing%20Travel%20Behaviour%20in%20the%20Calgary%20Region_Vol2_v07_FOR_WEB.pdf?noredirect=.

[31] Mode-choice forecasting is now a ubiquitous and routine element of travel-demand forecasting. The city must have estimated modal-choice demand equations. It should have used these equations to decompose the remarkable modal shifts that occurred between 2001 and 2011 into its explanatory factors. If it has, it should make its studies publicly available. If it has not, it should do so.

the two modes.[32] The second equation gives average commute time by mass-transit as a function of the mass-transit passenger volume and mass-transit transportation infrastructure. The third equation is the analogous equation for auto. Solution of the three-equation system permits calculation of the overall average journey-to-work time.

That appendix also gives the parameter values and functional forms used in the calculations, and provides a justification for them. Five points concerning the calculations bear note. First, in the base year of 2008, the average journey-to-work times by mass-transit and by auto were taken to be 41.4 and 24.7 minutes, respectively. Thus, holding constant the mode-specific average journey-to-work times, a modal shift towards mass-transit would cause an increase in the overall average journey-to-work time. Second, economies of scale in mass-transit are incorporated into the analysis.[33] Third, the rush-hour elasticities of mass-transit ridership with respect to auto- and mass-transit travel times are taken from a recent study for Portland, Ore. reported in Litman.[34] Fourth, the growth rate of the number of commuters is assumed to equal the growth rate of population. And fifth, annual net investment in the mass-transit system is assumed to be two per cent of the value of the mass-transit capital stock, and the corresponding figure for auto infrastructure is taken to be one per cent. The latter figures were simply educated guesses since, remarkably, data were not available for either levels of investment or values of the capital stock in the two modes[35].

Application of the Model to the Four Cases

Once again, the four cases shall be considered: I. Plan population growth, spatial containment; II. Plan population growth, laissez-faire; III. Double plan population growth, spatial containment; and IV. Double plan population growth, laissez-faire. The results for the four cases are reported in Table 6. Unlike in the previous subsection, the endogenous growth rates (e.g., mass-transit modal share) vary with time. Table 6A gives the various growth rates for 2008 for the four cases. Table 6B gives values in 2070.

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[32] The modal share depends on the full price of travel (which includes time and money costs) by the two modes Unfortunately, since data were not available to estimate full prices, the modal share was assumed to depend on the journey-to-work time of the two modes. This would be accurate if all other characteristics of the two modes had remained constant.

[33] These are called Mohring economies of scale after Herbert Mohring ("Optimization and scale economies in urban bus transportation," *American Economic Review* 62 (1972): 591-604.)
Consider doubling both the number of buses and the number of passengers. If this doubling is achieved by doubling the frequency of buses, wait time is reduced. If this doubling is achieved alternatively by doubling the density of the bus network, walking time is reduced.

[34] T. Litman, "Understanding transport demands and elasticities" (Victoria Transport Policy Institute, 2013), www.vtpi.org/elasticities.pdf.

[35] A table in City of Calgary, Calgary Transit, "Strategic Development of Calgary's CTrain System (updated to December 2005)" (https://www.calgarytransit.com/sites/default/files/reports/lrt_strategic_development_update.pdf), reports the total value of LRT assets in 2005 (in 2005 dollars) to be $997 million.

TABLE 6A INITIAL GROWTH RATES IN MASS-TRANSIT MODAL SHARE, MASS-TRANSIT AVERAGE

Case	Exogenous growth rates	Mass-transit modal-share growth rate in 2008	Mass-transit average-trip-time growth rate in 2008	Auto average-trip-time growth rate in 2008	Average commute-time growth rate in 2008
I: Plan population growth rate and containment	g_N: 1.275% g_d: 0.0%	0.0398%	-0.272%	0.131%	-0.00793%
II: Plan population growth rate and laissez-faire land use	g_N:1.275% g_d: 0.81%	-0.0243%	0.492 %	1.09%	0.870%
III: Double plan population growth rate and containment	g_N: 2.55% g_d: 0.0%	0.0146%	0.103%	0.772%	0.534%
IV: Double plan population growth rate and laissez-faire land use	g_N: 2.55% g_d: 0.81%	-0.0899%	1.35%	2.33%	1.96%

Note: g_N is the assumed rate of population growth; g_d is the rate of growth of commuting-trip distance (see below for an explanation).

Case I: Since the transit capital stock grows faster than population, and since there is no change in commuting distance, transit-commute time falls. Since the auto capital stock grows slower than population, and since there is no change in commuting distance, auto-commute time rises. These changes together cause modal switching towards mass-transit. The magnitudes of the changes are small, as is the average growth rate in journey-to-work time, -0.008 per cent. Thus, as parameterized, implementation of the plans would actually cause average commute times to decrease slowly at the beginning of the plan period.

Case II: Under the assumption that the growth rate in commuting distance equals one-half the growth rate in the built-up area, the growth rate in commuting distance is 0.81 per cent per annum. The assumed rates of growth of the mass-transit and auto capital stocks are no longer sufficient to keep commuting times approximately stable, and average commute time initially rises at an annual rate of 0.87 per cent per annum. There are several effects operating on modal choice. Even though average auto-commute times increase proportionally faster than mass-transit-commute times (1.09 versus 0.492 per cent), the mass-transit modal share falls. The reason is that the empirical estimates of the mass-transit modal-share elasticities imply modal shifting from mass-transit to auto if travel times on both modes increase by the same proportion.

Case III: Average commute times initially rise at an annual rate of 0.534 per cent, and there is very slow modal switching to mass-transit.

Case IV: The results indicate that under this alternative scenario, average commute time would increase at an annual rate of about two per cent, in contrast to Case I, where it is more or less stable.

Table 6B gives the mass-transit modal share, as well as the mass-transit, auto, and overall average journey-to-work times in the base year, 2008, and then in 2070 for the four forecast scenarios. The average journey-to-work times are the averages over the two motorized forms of transport, and therefore ignore non-motorized commuting.

TABLE 6B MASS-TRANSIT MODAL SHARE, MASS-TRANSIT AND AUTO AVERAGE COMMUTE TIMES, AND AVERAGE COMMUTE TIME IN 2070

Case	Mass-transit modal share (%)	Mass-transit average commute time (mins)	Auto average commute time (mins)	Average commute time (mins)
0: Base case (2008)	25.0	41.4	24.7	28.9
I: Plan population growth rate and containment (2070)	25.5	35.9	27.0	29.3
II: Plan population growth rate and laissez-faire land use (2070)	24.5	58.1	49.8	51.8
III: Double plan population growth rate and containment (2070)	25.4	44.1	50.4	48.9
IV: Double plan population growth rate and laissez-faire land use (2070)	24.0	95.3	151.6	138.1

The large increases in journey-to-work times illustrate dramatically how apparently modest differences in growth rates magnify into large differences over the 62-year period of the forecasts. These numbers should be interpreted with caution. They emphatically do *not* indicate that Calgary will have a crisis in transportation if either the population grows significantly more rapidly than is indicated in the plan, or if Calgary is allowed to grow spatially, or both. What they rather indicate is that, under any of the alternative scenarios, if commuting times are to be kept at acceptable levels, the CTP would have to invest considerably more in the mass-transit- and auto-transportation systems than in the base case.

Three other points merit comment. The first is that Calgary's experience over the last 30 years of a substantial modal shift towards mass-transit is inconsistent with the very modest changes in modal shares present in the scenario forecasts. One possible explanation is that the assumed mass-transit modal-share elasticities with respect to both mass-transit travel time and auto travel time, which were estimated for Portland, are much lower than those in Calgary, and points to the importance of getting good estimates for Calgary. Since detailed historical data on modal shares are available for Calgary, presumably these critical elasticities have not been estimated because of the lack of historical data on average commute times by mode. Since knowledge of these elasticities is essential for the future design of Calgary's transportation system, the city should start right away annually collecting journey-to-work times by mode. Doing so will be moderately expensive, but far less expensive than designing an inefficient transportation system. The above forecasts were made under the assumption that the only characteristics of the two travel modes that change over the forecast period are travel times. In fact, in recent years, the city, following Boston and San Francisco, has imposed a soft parking freeze downtown, which freezes the amount of garage parking that may be provided for existing buildings and allows new developments to provide parking only up to a regulated *maximum*. The second possible explanation for the much greater modal shifting that has occurred in Calgary than the model would predict is therefore that the Portland elasticities are sound, and that the substantial modal switching that has occurred in Calgary on the downtown journey to work over the last 30 years is due to the very high downtown parking rates (reportedly the second highest in North America, after New York City) that the city's downtown parking policy has caused.[36]

The second point is that favouring investment in mass-transit over investment in the auto system will lead to a fall in the ratio of mass-transit average commute time to auto average commute

[36] M. Toneguzzi, "Only New York tops Calgary in downtown parking rates," *Calgary Herald*, April 2, 2014, http://www.calgaryherald.com/business/Only+York+tops+Calgary+downtown+parking+rates/9690733/story.html.

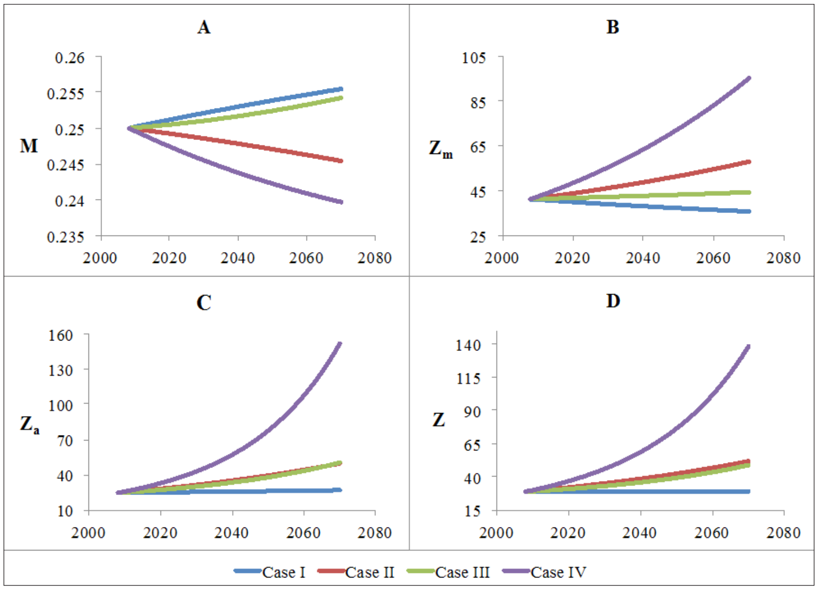
time. This effect is compounded by the presence of increasing returns to scale in the provision of mass-transit.

The third point is that the above scenario forecasts are based on only two modes. More reliable and realistic forecasts would be obtained by expanding the analysis to treat at least a third aggregated, non-motorized mode. If travel times by mass-transit and by car were to rise as rapidly in the alternative scenarios as indicated in the above tables, many commuters would switch to non-motorized modes of commuting, which would reduce mass-transit and auto congestion, bringing down auto and mass-transit travel times.

The above numbers are of interest, but as important as the actual numbers obtained is the method used to obtain them. The method allows a planner to investigate on a broad scale the effects of a policy under a wide range of scenarios, and to ascertain the sensitivity of forecasts to estimates of the central parameters. Did the city undertake such an exercise in developing the MDP or the CTP? Even though there is no public documentation of its having done so, the city must have forecast the effects of the plan on modal shares and on average journey-to-work times under the assumed population forecast. But perhaps the city did not forecast the effects of the plan under alternative assumptions about income- and population-growth rates, or with alternative estimates of the key parameters. In any event, in order to demonstrate the soundness of the plan, the city should make available for public scrutiny the internal analyses that it undertook in preparing the plan.

Figure 8 contains four panels. Each presents the results in Table 6 graphically. For example, Figure 8, Panel A graphs the mass-transit modal share between 2008 and 2070 for each of the four cases.

FIGURE 8 FROM 2008 TO 2070, MASS-TRANSIT MODAL SHARE (A), MASS-TRANSIT AVERAGE COMMUTE TIME (B), AUTO AVERAGE COMMUTE TIME (C), AND AVERAGE COMMUTE TIME (D).



Case I: Plan population growth rate and containment.

Case II: Plan population growth rate and laissez-faire land use.

Case III: Double plan population growth rate and containment.

Case IV: Double plan population growth rate and laissez-faire land use.

Some sensitivity analysis is now undertaken for Case I (plan population growth rate and containment) only. Four exercises are undertaken (shown in Figure 9):

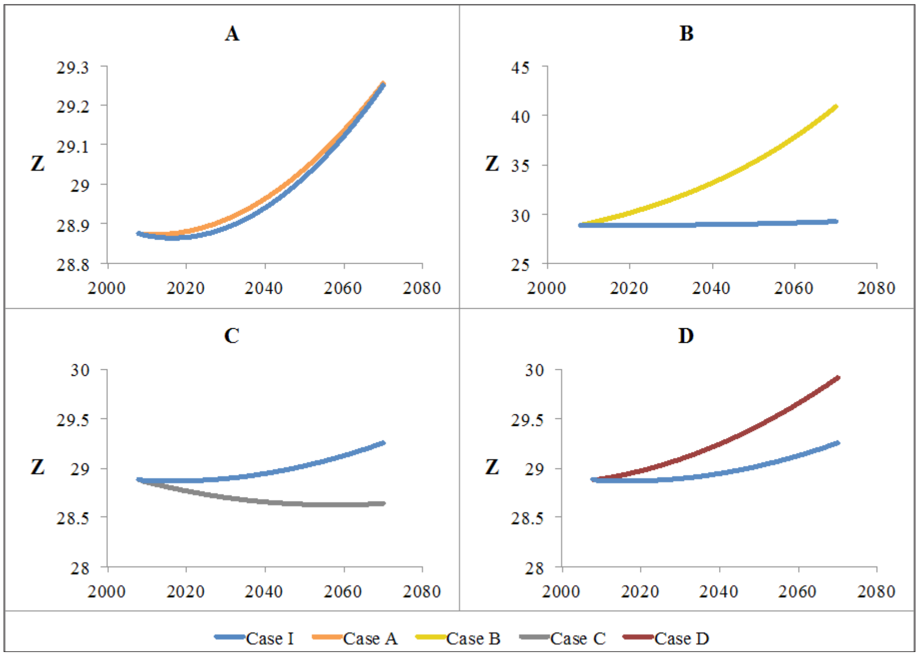
A. Double the mass-transit modal-share elasticities.

B. Reduce the growth rate in auto-transportation infrastructure from 0.01 to 0.00, so that auto-transportation investment just offsets depreciation.

C. Reduce the elasticity of "excess" auto travel time (travel time in excess of free-flow travel time) with respect to the auto-volume-capacity ratio from 1.5 to 1.0.

D. Increase the elasticity of excess auto travel time with respect to the auto-volume-capacity ratio from 1.5 to 2.0.

FIGURE 9 SENSITIVITY ANALYSIS CASES VERSUS CASE I AVERAGE COMMUTE TIMES FROM 2008-2070



Case I: Plan population growth rate and containment.

Case A: Double the mass-transit modal-share elasticities.

Case B: Reduce the growth rate in auto-transportation from 0.01 to 0.00, so that auto-transportation investment just offsets depreciation.

Case C: Reduce the elasticity of excess auto travel time with respect to the auto-volume-capacity ratio from 1.5 to 1.0.

Case D: Increase the elasticity of excess auto travel time with respect to the auto-volume-capacity ratio from 1.5 to 2.0.

Figure 9, Panel A shows the effect of doubling the mass-transit modal-share elasticities. The effects are small, indicating that much larger mass-transit modal-share elasticities than those used in the base case are needed to achieve substantial modal switching over the period.

In the base case, the growth rate in auto-transportation infrastructure was assumed to be 1.0 per cent. This was calibrated ignoring depreciation of the existing infrastructure, and therefore the distinction between gross and net investment. Figure 9, Panel B, indicates what would happen if instead, the investment in auto-transportation infrastructure were entirely offset by depreciation. The result is a sharp increase in mean commuting times over the period of the plan, with the forecast mean commuting time in 2070 increasing from 29.3 minutes to 40.9 minutes. Higher modal-share elasticities would dampen this effect.

Appendix B explains that there is no consensus in the literature concerning the elasticity of excess auto travel time with respect to the auto-volume-capacity ratio. This parameter measures the "degree of congestibility" of the road network — how sensitive excess auto travel times are to traffic density. Figure 9, Panels C and D indicate that, at least under the plan scenario, the results are only modestly sensitive to this parameter.

Taken together, the sensitivity analysis leads to two important insights. The first is that, either the modal-share elasticities are much higher in Calgary than in Portland, or the model is missing something essential that accounts for the substantial switching from car to mass-transit that has occurred in Calgary over the last 30 years, especially in the downtown commute. The leading candidate for the "missing something essential" is the rise in downtown auto-parking rates.[37] The second important result is that, to keep average commute times from rising sharply over the plan period, it will be necessary to expand the capacity of the road system, and not just spend on the road system to offset depreciation.

The back-of-the-envelope calculations demonstrated that average journey-to-work times are sensitive to the population growth rate over the plan period, the land-use policy in place, and the levels of investment in both the mass-transit and auto infrastructures. The back-of-the-envelope calculations were not as successful as had been hoped, since they demonstrated considerably less modal switching than has actually occurred in Calgary over the last three decades. The most obvious reason is that the modal choice equation underlying the calculations did not take into account downtown parking fees. Thus, the results strongly suggest that the dramatic modal shift away from auto travel on commutes with a downtown destination is due primarily to Calgary's soft downtown parking freeze, which has resulted in a sharp increase in Calgary's downtown parking rates. This hypothesis merits further investigation.

Again, the method employed in this section is as important as the specific results. It illustrates that quite simple models can be employed to estimate the effects of alternative land-use and transportation policies on modal choice and average journey-to-work times. And again, there is no evidence that the city has used such modelling in its forecasts. If it has, it should make the results available for public scrutiny. If it has not, it should do so. The city should inform the public about the costs, in terms of average commute times, of the soft downtown parking freeze and of the very low levels of investment in road infrastructure that have occurred over the past 30 years and that are planned for over the duration of the plan. It should also inform the public that, if either population growth is substantially higher than in the plan forecast or the policy of spatial containment turns out not to be viable, substantial increases in journey-to-work times are to be expected unless transportation investment is substantially higher than in the plan forecast. Before endorsing the plans, Calgarians have a right to know the plans' estimated future costs, in terms of travel times and housing rents.

[37] The model could be adapted to account for downtown auto-parking rates by making the modal share depend on the average full prices of travel on the two modes rather than, as is done, on the average travel times on the two modes. The average full price of travel by auto would equal the average time cost of travel by auto plus the money cost of auto travel, including parking.

PROBLEM #4: ECONOMIC PRESSURES TO SUBCENTRE THAT WILL BECOME INCREASINGLY STRONG

Compared to other U.S. cities of comparable size, the automobile cities stand out for their affordability. This affordability has been achieved through horizontal expansion, employment decentralization, and subcentering. The Calgary plans, however, talk of spatial containment of the city; say little or nothing about planning for employment decentralization (except in the context of transit-oriented development) or for subcentres; and, with their centrepiece the Transportation Plan, present continued expansion of the radial and CBD-oriented light rail transit (LRT) system. On what basis does the city believe that economic forces in Calgary are so different from those in the U.S. automobile cities that either strong pressures for employment decentralization will not arise, or if they do arise, that pursuing policies that oppose these pressures will not severely compromise affordability?

On Agglomeration Economies

To start, some background on the economics of agglomeration will be helpful.[38] Why do cities exist? Where, when, and why they first arose remains a matter of dispute since the evidence is archaeological. The first historical cities were located at points of natural advantage, on a river or sea, and arose to facilitate trade based on comparative advantage. For reasons of history, today's cities, too, are all located at points of natural advantage,[39] even if that natural advantage is now largely vestigial.

Today's cities would form and prosper even if space were completely uniform. If this were so, the system of cities would be determined solely by *economies of agglomeration*. "Agglomeration" is the spatial concentration of economic activity. "Economies of agglomeration" is a generic term applying to the collection of economic forces that lead to agglomeration. The costs of agglomeration are tangible — the costs of goods and people transportation, of congestion, pollution, and so on. But the benefits of agglomeration are harder to pin down. They are akin to the dark matter in the universe. They must be there, since otherwise cities would not form, and they must be powerful to offset the obvious costs of living in any of today's mega-cities. And while their aggregate effects can be inferred, most sources of agglomeration are very difficult to measure directly. Cities would form even in the absence of production benefits, since at least some people would be willing to bear the costs of agglomeration in order to enjoy more social contact, a greater variety of consumer goods, and the buzz of the city. However, it seems implausible that the size of today's mega-cities can be accounted for by consumption benefits alone. And indeed, there is a strong theoretical

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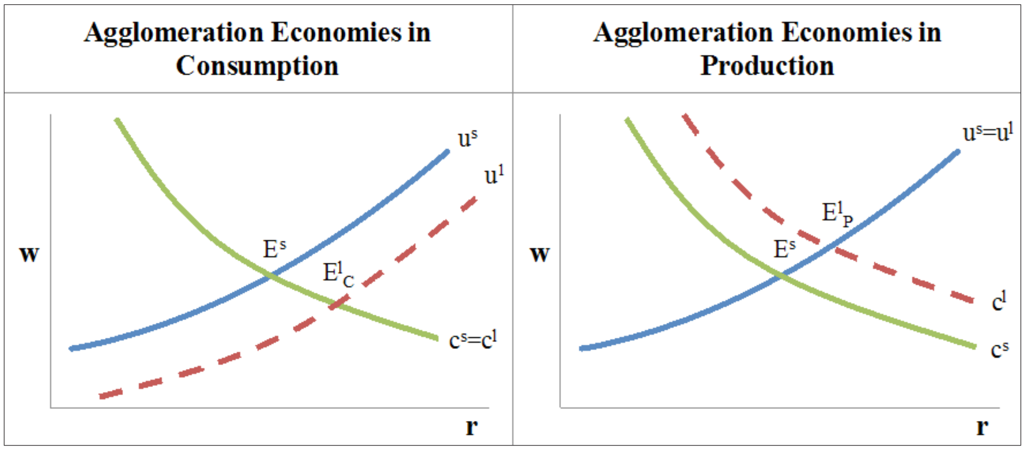
[38] Classics in the literature include: A. Marshall, *Principles of Economics*, 8th. ed. (London: MacMillan, 1920); E. Hoover, *The Location of Economic Activity* (New York: McGraw-Hill, 1948); and J. Jacobs, *The Economy of Cities* (New York: Random House, 1969). J.V. Henderson and J. Thisse, *Handbook of Regional and Urban Economics, Vol. 4: Cities and Geography* (Amsterdam: Elsevier, 2004) and M. Fujita and J. Thisse, *Economics of Agglomeration: Cities, Industrial Location, and Regional Growth* (Cambridge, U.K.: Cambridge University Press, 2002) provide excellent points of entry into the literature. Because the area has been so active, both books are, however, already somewhat outdated.

[39] An apparent anomaly is Brussels, which is located inland and not on any major river. It was originally located on a river, but since then, the river has gone underground.

argument[40] supporting the case that the primary benefits from agglomeration are on the production side.

Consider a very simple model with two factors of production: labour and land. Households migrate freely between cities so that household utility, which depends only on the consumption of housing and a composite consumption good, is independent of location. The composite good is costless to transport so that its price is the same everywhere. In contrast, housing and land are immobile. Compare two cities that have the same natural amenities, one of which has a higher population than the other. Figure 10 is drawn with the housing/land rent, r, on the x-axis and the wage, w, on the y-axis. The solid curves apply to the smaller city, the dashed curves to the larger city. The solid upward-sloping curve displays the combinations of the wage and the rent in the smaller city consistent with achieving the common, equilibrium level of utility. Call it the *smaller-city equilibrium utility curve* (u^s). The solid downward-sloping curve displays the equilibrium combinations of the wage and the rent in the smaller city consistent with the common, equilibrium price of the composite good. Call it *the smaller-city equal-price curve* (c^s).[41] The equilibrium wage and rent in the smaller city are determined by the intersection of the two solid curves, point E^s.

FIGURE 10 AGGLOMERATION ECONOMIES [E^s SHOULD BE THE SAME POINT IN THE TWO PANELS]



Now suppose that the economies of agglomeration arise on the consumption side (C). To achieve the common level of utility, holding rent fixed, residents in the larger city do not require as high a wage to achieve the common utility level. Thus, the dashed larger-city equal-utility curve (u^l) lies below the corresponding smaller-city curve. Meanwhile, the larger-city equal-price curve (c^l) coincides with the corresponding smaller-city curve since, in the absence of agglomeration economies in production, both cities are equally productive. Since equilibrium in the larger city is at the point of intersection of its equal-utility curve and equal-price curve, $E^l_{C,}$ the *equilibrium rent in the larger city is higher than that in the smaller city, and its equilibrium wage is lower.* If, alternatively, agglomeration economies occur on the production side (P), then the equal-utility curves in the two cities coincide but the equal-price curve for the larger city lies above that for the smaller city since the composite good can be produced at the common price with higher wages and rent. In this case, the equilibrium in the larger city is at E^l_p, for which *both*

[40] J. Roback, "Wages, rents, and the quality of life," *Journal of Political Economy* 90 (1982): 1257-1278.

[41] The equal-utility curve plots the indirect utility function, while the equal-price curve plots the factor-price frontier.

the equilibrium rent and the equilibrium wage are higher in the larger city. That both wages and rents are empirically higher in larger cities strongly suggests that agglomeration economies in production dominate those in consumption. The remainder of this subsection focuses on agglomeration economies in production.

The evolution from a manufacturing to a service economy has blurred the division between industries. Workers' skills have become increasingly transferable between industries, with the typical individual now working not only for several different firms over his working life but in more than one industry. Thus, firms are increasingly attracted to cities with large labour pools of diverse and specialized workers. Another major change that has occurred is that, over the last 200 years, in real terms freight costs have fallen 100-fold.[42] Since firm location is less and less influenced by the location of either its major inputs or its consumer base, firms have become increasingly footloose. Yet another change that has occurred is globalization. Firms must now compete with other firms from around the world. In such an environment, the firms that succeed are those with the competitive edge — those that produce consistently innovative products and adapt quickly to changes in business practice, production techniques, and the economic environment. Technological advances in one industry are quickly adapted and applied in other industries. These changes weaken intra-industry agglomeration economies and strengthen inter-industry agglomeration economies, encouraging firms to locate in diversified rather than specialized cities.

In recent years, urban/regional economists have paid increasing attention to the economic geography of innovation. In contrast to the stories offered in much of the literature on agglomeration economies, the literature on the economic geography of innovation is strongly empirical because there are two strong measures of innovation: patents and start-up firms. Two sharp empirical regularities emerge from this literature. The first is that the geographical distribution of patents is very unequally distributed. In the United States, the Greater San Francisco Metropolitan Area (properly the San Jose-San Francisco-Oakland Combined Statistical Area) is considerably ahead of the Boston Metropolitan Area,[43] which is considerably ahead of the Greater New York, Los Angeles, and Chicago Metropolitan Areas, and most other metropolitan areas are not even "on the map." Patents measure only one aspect of innovation, technological innovation, but most likely other aspects of innovation display a similarly unequal geography, with New York dominating innovation in finance and the arts, for example. Another empirical regularity is that start-ups arise disproportionately in large, highly diversified metropolitan areas. Once a start-up's innovative product becomes well established, its production is typically relocated to a non-innovative, smaller, and less diverse metropolitan area where production costs are lower. By both these measures, large, diverse metropolitan areas are engines of innovation.

While economists have not generally been very successful in quantifying *sources* of agglomeration economies, they have undertaken considerable empirical analysis measuring agglomeration economies. The earlier work focused on how wages and labour productivity (value of output per worker) differ by city size. More recent work focuses on how differences in

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[42] E. Glaeser and J. Kohlhase, "Cities, regions and the decline of transport costs," *Papers in Regional Science* 83 (2004): 197-228.

[43] San Francisco's prominence is due to Silicon Valley, which grew to prominence due to links with Stanford University, which is ranked No. 2 in the world in engineering. Boston's lesser prominence derives from start-ups that spun off from research at MIT, which is ranked No. 1 in the world in engineering.

wages and labour productivity, by industry, *within a metropolitan area* are related to the spatial distribution of employment within the metropolitan area. A typical study measures the elasticity of a particular industry's wage rate across locations within a metropolitan area with respect to a distance-weighted measure of proximity to workers in that industry and perhaps other industries.[44]

Figure 11 displays an illustrative result from a recent study.[45] The x-axis measures the industry-specific average elasticity of labour productivity with respect to the density of human capital[46] across metropolitan areas. The y-axis measures the sensitivity of this elasticity to the density of human capital. Thus, for example, average labour productivity in real estate increases on average by 16.0 per cent with a doubling of the density of human capital, more or less independent of the density of human capital. In contrast, the average labour productivity in finance increases on average by 12.0 per cent with a doubling of human capital, but this number is considerably higher when comparing only high-human-capital metropolitan areas. This result suggests that the types of agglomeration economies that affect finance are particularly strong in high-human-capital metropolitan areas.

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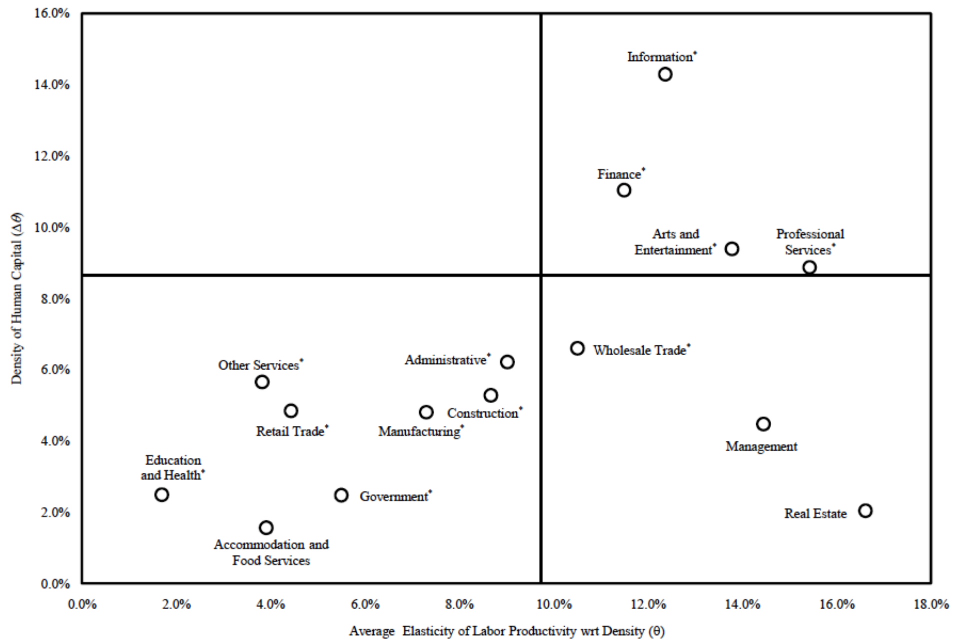
44 Agglomeration economies across pairs of industries are termed co-agglomeration economies. Because industry-classification schemes are so outdated, many of the strong co-agglomeration effects identified empirically would, with a better industry-classification scheme, be measured as occurring within an industry. The most obvious example is the manufacture of motor vehicles and the manufacture of motor-vehicle parts. Another important example is the "logistics" or freight industry, which, according to standard industrial-classification schemes, spans many industries.

45 J. Abel, I. Dey, and T. Gabe, "Productivity and the density of human capital," Staff Report 440 (Federal Reserve Bank of New York, March 2010).

46 A metropolitan area's human-capital density is calculated as the human-capital-weighted average of the human-capital density of its constituent counties. Human-capital density in a county is measured by the number of residents per unit area with a college degree.

FIGURE 11 CLASSIFICATION OF INDUSTRY SECTOR BY AVERAGE AND CHANGE-IN-PRODUCTIVITY EFFECT

Source: J. Abel, I. Dey and T. Gabe, "Productivity and the density of human capital," Staff Report 440 (Federal Reserve Bank of New York: March 2010).



Notes: The density of human capital ($\Delta\theta$) is expressed as the change in θ for a metropolitan area with a human capital stock one standard deviation above tl mean compared to a metropolitan area with a human capital stock one standard deviation below the mean. * indicates that the estimated density of human capital effect ($\Delta\theta$) is statistically significant. Gridlines of 9.7% and 8.7% correspond to aggregate productivity estimates reported in Column (2) of Table 4. Industry sector results based on OLS estimates reported in Table 5.

Empirical studies have produced different results concerning the elasticities of labour productivity with respect to metropolitan population size. There is general agreement, however, about how these elasticities differ by industry. They are highest for corporate headquarters and the FIRE (finance, insurance, and real estate) industries, and are lowest for unskilled and semi-skilled local employment. Furthermore, broadly in accordance with economic theory, firms in industries with higher elasticities locate more centrally since they derive the greatest production benefits from a more central location. An important empirical problem that has not been fully resolved is how to distinguish between agglomeration economies in production and sorting effects. Perhaps lawyers downtown (in a larger metropolitan area) earn a higher income than lawyers in the suburbs (in a smaller metropolitan area) because the best lawyers choose to work downtown (in a larger metropolitan area) where they can get a larger income premium for their skill, and not because they become better lawyers from working where there is a higher density of lawyers. Some progress has been made in resolving this "identification" issue by looking at return migrants. To continue the example, suppose that a lawyer moves from a smaller city to a larger city and then returns to the smaller city. If his income is the same in the smaller city after he returns as it was before he left, it appears likely that working in the bigger city did not increase his productivity.

Intra-metropolitan Spatial Structure, Subcentering and Calgary

This subsection relates subcentering to a metropolitan area's population and industrial structure, as it applies to Calgary. The best place to start is the workhorse of urban economic theory, the monocentric-city model.[47] The model assumes that the metropolitan area has a single dominant centre. Land uses, which may be industrial, commercial, or residential, are arrayed in concentric rings around the metropolitan centre, which is the only export node. There are three central principles:

Principle 1: At each location, land goes to that use that bids the most for it.

Principle 2: In equilibrium, those land uses that bid a higher rent premium (per unit floor area) for a location closer to the metropolitan centre, locate closer to the metropolitan centre.

Principle 3: At each location, floor-space rent and land rent adjust such that the floor-space and land markets clear.

In the traditional monocentric model, agglomeration economies are ignored. Thus, the rent premium that an economic agent is willing to pay to locate a unit distance closer to the metropolitan centre equals its transportation savings. Applying Principle 2 above, in equilibrium, land uses that save more in transportation costs (per unit area of land) from locating closer to the metropolitan centre, locate closer to the metropolitan centre. Thus, in the 19th century, those industries that incurred especially high costs in transporting goods to and from the port or rail yard, located closest to them.

The monocentric model can be extended straightforwardly to treat agglomeration economies. Principle 2 continues to apply, but now the rent premium that a land use is willing to pay for a location closer to the city centre depends not only on its transportation-cost savings from a more central location, but also on the additional agglomeration benefits from production at a more central location.

In the modern metropolis, agglomeration benefits are, for most industries, a more important determinant of the intra-metropolitan location than the cost of transporting commodities. Thus, in the modern *monocentric* metropolis, the industries with the highest elasticity of labour productivity with respect to employment density tend to locate closest to the metropolitan centre. Empirical studies[48] have found this elasticity to be highest for what are called the FIRE (finance, insurance, and real estate) industries and for corporate headquarters. That Calgary's corporate headquarters are almost all located downtown is therefore entirely consistent with our theoretical and empirical knowledge of firm location in the monocentric city.

It is surprising, however, that firms in so many other industries also choose to locate in downtown Calgary, since empirical studies suggest that the other industries experience a

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47 The seminal work on the model is W. Alonso, *Location and Land Use* (Cambridge, Mass.: Harvard University Press, 1964). Theoretical development continued at a rapid pace until the early 1980s, after which it slowed considerably. Even though it is now over 25 years old, M. Fujita, *Urban Economic Theory: Land Use and City Size* (Cambridge, U.K.: Cambridge University Press, 1989) provides the most comprehensive and rigorous treatment of the subject.

48 M. Arzhagi and V. Henderson, "Networking off Madison Avenue," *Review of Economic Studies* 75 (2008): 1011-1038; P. Melo, D. Graham and R. Noland, "A meta-analysis of urban agglomeration economies," *Regional Science and Urban Economics* 39 (2009): 332-342; S. Mun and B. Hutchinson, "Empirical analysis of office rent and agglomeration economies: A case study of Toronto," *Journal of Regional Science* 35 (1995): 437-456.

smaller productivity premium from a more central location. It is not implausible, however. It might be that proximity to corporate headquarters rather than employment density, which the empirical studies capture, provides such a boost to their productivity that a downtown location is profit-maximizing for them, despite the very high rents there. It might also be, however, that a downtown location is not the most profitable for them, but is forced upon them by restrictive land-use regulation. Thus, Calgary's anomalous spatial structure might or might not be due more to its anomalous industrial composition than to restrictive land-use regulation.

Almost all metropolitan areas start as monocentric cities. In smaller monocentric cities, for all but those firms that offer local services, the agglomeration benefits from a central location more than offset the somewhat higher rents there and the somewhat higher wages that need to be paid to workers to offset the higher cost of living they face, which includes commuting and housing costs. But as a monocentric city grows, its spatial structure becomes increasingly unsustainable. Downtown firms face higher and higher rents, and have to pay their workers increasingly higher wages to offset increasing commuting costs. These effects are offset to a greater or lesser extent by larger agglomeration benefits. For those downtown firms in industries with high agglomeration economies, the higher agglomeration benefits from a central location continue to more than offset the higher costs. But for those downtown firms in industries with lower agglomeration economies, eventually the higher costs more than offset the benefits.

The first firm to relocate from the central location to a more peripheral location is the one that experiences the lowest net agglomeration benefits (benefits minus costs). By moving to a more peripheral location, the firm will pay less rent, and can also pay lower wages since workers will accept a reduction in wages in order to save on their commuting costs. Where the firm chooses to relocate to is hard to predict. With locations more distant from the metropolitan come reductions in both benefits and costs. Since different types of agglomeration benefits attenuate at different rates with distance from the city centre, how overall agglomeration benefits fall with distance depends on the industry the firm is in, as well as the industrial composition of the city centre. How overall costs fall off with distance depend on the firm's factor composition and the spatial pattern of transportation costs, including traffic congestion. Once the first firm has successfully relocated, it becomes more attractive for other firms to relocate. Not only does the first firm confer agglomeration benefits on firms that relocate to the same location, but also by its successful relocation it signals the profitability of its new location.[49] With the successful relocation of the second firm, the agglomeration benefits at the new location become even stronger. Thus, the successful relocation of the first firm may trigger "tipping" and the emergence of a new subcentre. The industrial composition of the new subcentre depends on the particular pattern of within-industry and between-industry agglomeration benefits. One might be tempted to hypothesize that the new subcentre would contain other firms in the same industry, but this is generally not correct since, if all agglomeration benefits are intra-industry, one would observe only specialized cities. The pattern of co-agglomeration benefits matter, too. Suppose, for example, that the first firm to move is a hospital. Its relocation will encourage the relocation of the myriad of small health-services firms that may or may not supply and service the hospital.

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[49] A. Caplin and J. Leahy, "Miracle on Sixth Avenue: Information externalities and search," *Economic Journal* 108 (1998): 60-74.

The emergence and growth of the new subcentre will establish new spatial patterns of agglomeration benefits by industry, and a new spatial pattern of rents and traffic congestion. In due time, a second subcentre will emerge, and so on.[50]

The above discussion assumes that land-use restrictions and other regulations impose no impediments to the formation of subcentres. They can easily do so, however, through not only land-use zoning, but also restrictions on floor-area ratios, as well as building-code regulations and parking requirements. A related problem is land assembly by a developer, which is difficult enough for undeveloped land because of the holdout problem, but considerably more difficult for land that is already developed. Thus, the successful development of a subcentre requires more than passive acquiescence by planners, manifest by a generally accommodating stance in the form of willingness to grant zoning variances. It requires their active assistance in the land assembly process as well.

Another set of issues relates to the siting of subcentres. Consider the first firm in the above story of the formation of a subcentre. In moving away from the city centre it faces considerable uncertainty. It has only a vague idea of the relative profitability of alternative sites for its business. It must have an even vaguer idea about whether the area it chooses to relocate to will be attractive to other firms, and whether, therefore, its relocation will trigger the development of a successful subcentre.[51] Thus, the first firm will face considerable uncertainty concerning the profitability of relocation, which will likely cause it to delay relocation beyond the time when it is desirable from a social point of view that a subcentre form.[52] As well, when it does relocate, there is a good chance that its choice of site will be suboptimal from a social point of view. Thus, there is a strong argument to be made for not only active government involvement in the land assembly process once a subcentre initiated by the private sector has started to form, but also in the siting of subcentres.[53]

Because of the uncertainty small firms face in choosing when to relocate and where to relocate to, many subcentres are formed by mega-developers, who develop at such a large scale that they internalize many of the externalities associated with the market formation of subcentres and create the subcentre's agglomeration economies through sheer size.[54]

Because of all the market failures associated with the employment subcentering process, it is unreasonable to claim that the subcentres generated by the market are close to efficient, whether the government opposes subcentering through regulation, adopts a laissez-faire stance with respect to subcentres, or engages in policies that facilitate their development. Nevertheless,

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[50] M. Fujita, P. Krugman and T. Mori, "On the evolution of hierarchical urban systems," *European Economic Review* 43 (1999): 209-251; M. Fujita and T. Mori, "Structural stability and evolution of urban systems," *Regional Science and Urban Economics* 27 (1997): 399-442; M. Fujita and H. Ogawa, "Multiple equilibria and structural transition of non-monocentric urban configurations," *Regional Science and Urban Economics* 12 (1982): 161-196.

[51] Some locations however have obvious advantages as subcentres over others. Freeway intersections are particularly attractive because of their accessibility.

[52] Caplin and Leahy ("Miracle on") model this process in the context of the redevelopment of Sixth Avenue in New York in the late 1980s and early 1990s.

[53] In economic terminology, the process of subcentre formation is rife with market failures. Not only are informational and search externalities important, but also there is an almost complete absence of relevant insurance markets that would allow relocating firms to share with "the market" some of the risk associated with relocation. As well, there are strategic problems associated with land development.

[54] J. Garreau, *Edge City: Life on the New Frontier* (New York: Doubleday, 1991) provides a somewhat journalistic but nevertheless very informative account of the development of large subcentres, which he terms edge cities, in the U.S.

subcentering brings with it very considerable social benefits. Some central-city agglomeration benefits may be lost, but even this is open to reasonable dispute on the grounds that many central cities are so congested that central-city net-agglomeration benefits would be greater with lower central employment density. Even if some central-city agglomeration benefits are lost, these losses are more than offset by the agglomeration benefits at the subcentres and the savings in commuting and other transportation costs they induce.

It is physically possible for Calgary to grow up rather than out, and to remain monocentric. But if the city maintains this course, the cost to Calgarians will become increasingly onerous and the economic pressure to develop subcentres will grow increasingly strong. Eventually — the timing depending on the city's income and population growth — political opposition will force the plans to be abandoned, and subcentering will happen explosively and inefficiently. The CBD-oriented public transportation system will be ill suited to the transportation needs of an increasingly polycentric metropolitan area. The city should rework the plans, by all means retaining some of its elements, but also accommodating an urban future in which Calgary is a polycentric metropolitan area.

CONCLUSION

The City of Calgary's Municipal Development Plan and the Calgary Transportation Plan provide a blueprint for the city's urban spatial development and transportation system up to the year 2070. The plans aim to achieve a more sustainable and livable city through five broad policies: (1) continued concentration of non-local employment in the CBD; (2) expansion of the radial LRT system; (3) transit-oriented development (which entails small, mixed-use centres around some transit stops); (4) spatial containment of the city; and (5) intensification.

This essay has provided a wide-ranging critique of the plans, focusing on four shortcomings in particular: (1) the impact of the plans' low population projections, which legitimize spatial containment; (2) the impact on housing rents of the plans' emphasis on spatial containment; (3) the danger of rapidly increasing traffic congestion under the plans; and (4) the plans' resistance to economic pressures for subcentre formation. The overarching criticism is that, taken together, these shortcomings are likely to lead to a highly inefficient metropolitan spatial structure, entailing substantial cost to Calgarians in the forms of significant rises in rents and property values, and considerable increases in average journey-to-work times and in auto traffic congestion. These costs will in turn discourage new firms and new people from moving to Calgary. The costs will be substantially higher if the rate of population growth exceeds that in the plan forecasts. Since there is little evidence in the publicly available documents that the city considered these costs when formulating the plans, it appears that the plans are based to some extent on wishful thinking.

It is somewhat unfair to criticize plans for their lack of quantification and analysis, since by their nature they are visionary and rhetorical. They put forward a vision of the future, hoping that working together to achieve that vision will establish a sense of community. Plans are rhetorical in the sense that their prime purpose is to persuade a broad cross-section of the community to get on board to work together towards common goals. Through neighbourhood meetings, citizens do have some input into the process but, with the limited information they have, the concerns they express are primarily local. There is then the danger that the broader economic effects of the plans, which are the focus of this essay, get less attention than they merit. The central concern of this essay is not, however, about process, but about outcomes. From this perspective, the worry is that the process of plan preparation in general, and in Calgary in particular, leads to bad policy choices.

Affordable housing and manageable travel are central to the well-being of urban residents. Among larger Canadian metropolitan areas, Calgary already has close to the most expensive housing. The plans call for spatial containment and intensification, for the city to grow up rather than out. This will inevitably lead to an increase in housing rents and property prices. The plans make no mention of this, and indeed there is no indication that housing affordability was addressed in the plan's technical studies. If it has not already done so, the city should commission studies on the effects of spatial containment and intensification on housing rents and property prices. It should also make the studies generally available, so that, after appropriate academic scrutiny and public debate, Calgarians become aware of the extent to which the plans compromise housing affordability.

The average journey-to-work time in Calgary, close to 30 minutes, is as high today as it was in Los Angeles in 2000, when Los Angeles had a population 10 times that of Calgary. Furthermore, the limited evidence is consistent with the widespread impression that the average journey-to-work time in Calgary has been increasing (at least until the recent slowdown due to the fall in the world oil price). Calgary's high and increasing average journey-to-work time is due to two broad city policies. The first is discouragement of auto travel, through underinvestment in the road system and a soft parking freeze downtown. The policy has been successful in reducing the auto modal share, especially on the journey to work, but at the cost of increased traffic congestion and diversion of travel to the intrinsically slower mass-transit modes. If the city continues this policy, as the plans propose, journey-to-work times will likely continue to increase, how rapidly depending on the rate of population growth. The second policy responsible for Calgary's high average commute time is the city's continued encouragement of a monocentric spatial structure, through expansion of its radial, CBD-oriented LRT system and through land-use policies averse to subcentre formation. Since, holding population fixed, a monocentric spatial structure entails a higher average commuting distance than does a polycentric spatial structure, this broad policy will also likely result in an increase in the average journey-to-work time.[55] The plans do not mention journey-to-work times, and indeed there is no indication that they were forecast in the plans' technical studies.

The city has been remiss in not alerting Calgarians that following the plans' recommendations will likely result in substantial increases in the average journey-to-work time. An informal rule of thumb is that commuters tolerate a one-way commute of up to 30 minutes but that each extra minute of commuting becomes increasingly unpleasant. According to this rule, if the plans' recommendations become policy, an increasing proportion of Calgarians will find their quality of life compromised by long commutes.

Among North American cities with a similar population, Calgary is anomalous in having such a high percentage of non-local employment located downtown and no large subcentres. Its

[55] Spatial containment of the city, which the plans propose, will, by itself, reduce journey-to-work times, but at the cost of higher rents and housing prices.

current spatial structure can be partially attributed to natural economic forces, in particular the strong agglomeration economies generated by its exceptional concentration of head offices. However, as the city's population continues to grow, the pressure will intensify for firms in those industries that derive the least benefit from downtown agglomeration economies to move out of the downtown area, to locations where rents and wages are significantly lower. The only accommodation the plans make for these economic pressures is to foster transit-oriented development, which entails small, mixed-use subcentres at selected LRT stations. Not enough is known about the market process of subcentre formation to assert with confidence that the plans' failure to address these economic pressures *at the present time* is misguided. If, however, it is, and if land-use policy suppresses economic forces conducive to larger subcentre formation, the loss in economic vitality could be considerable, and if large unplanned subcentres form, the city will be hamstrung, with a monocentric mass-transit system for a polycentric metropolitan area. Furthermore, unless Calgary's population levels off, which seems unlikely, the day of reckoning will come, if not by 2070 at least later, since large monocentric metropolitan areas are simply not viable.

The plans present a vision of the "Good Urban Life," and propose to enforce it through a particular choice of transportation system, through land-use regulation, and through a downtown parking freeze, with little regard to economics. In so doing, they display both a lack of appreciation for the "wisdom of the market" and a lack of awareness of the power of economic forces.

If, *having been properly informed of the quantified costs and benefits of the plans and of sound alternatives,* Calgarians choose to embrace the vision presented in the plans, so be it. But the plans do not properly inform Calgarians. Rather than presenting an unvarnished economic assessment of the costs and benefits of the plans, along with those of alternatives, the plans offer one choice and, through verbal and visual rhetoric, attempt to persuade the unenlightened of the virtues of that choice. Calgarians deserve more respect for their intelligence and more scope to exercise their freedom to choose.

APPENDIX A: THE GROWTH IN HOUSING RENTS

A.1 The Growth in Housing Rent: Theory

This subsection determines how the rate of growth of housing rents is related to the rates of growth of population, income, and land supply when sufficient investment is made in transportation infrastructure to hold commute times constant. One simplifying assumption is that the only aspect of housing that concerns residents is the floor area of their housing units. Another simplifying assumption is that land that is heterogeneous in terms of accessibility can be aggregated into a measure of "effective land."[56]

The following notation is employed:

$N(t)$	population at time t
$y(t)$	per capita income at time t
$r(t)$	housing rent per unit floor area at time t
$\gamma(t)$	a parameter reflecting technical progress in housing construction
$A^*(t)$	the effective land area devoted to housing at time t
$h^d(y,r)$	per capita demand for floor area, as a function of income and housing rent
$h^s(r,\gamma)$	the profit-maximizing floor-area ratio of housing chosen by developers

The equilibrium condition is that the aggregate demand for housing equals the aggregate supply of housing. This is no more than the condition that housing rent adjusts to clear the market. The aggregate demand for floor area equals population times the per capita demand for floor area. The per capita demand for floor area is increasing in income and decreasing in rent. The aggregate supply of housing equals the supply of floor area per unit area of land times the quantity of land devoted to housing. The supply of floor area per unit area of land is increasing in rent, and γ, which is a parameter reflecting technical progress in housing construction. Thus:

$$N(t)h^d(y(t),r(t)) = A^*(t)h^s(r(t),\gamma). \qquad \text{(A.1)}$$

Since the housing market is assumed to be in equilibrium at all points in time, this equation implies that the growth rate of rents is related to population growth rate, the income growth rate, the growth rate of land supply, the income and rent elasticities of demand, the rent elasticity of supply, and the rate of technical progress in housing construction. Letting g_x denote the growth rate of x and $E_{x:y}$ denote the elasticity of x with respect to y, (A.1) implies that

$$g_N + E_{hd:y}g_y + E_{hd:r}g_r = g_{A^*} + E_{hs:r}g_r + E_{hs:\gamma}\, g_\gamma. \qquad \text{(A.2)}$$

Solving (A.2) for the growth rate of rents gives

$$g_r = (g_N + E_{hd:y}g_y - g_{A^*} - E_{hs:\gamma}g_\gamma) \div (E_{hs;r} - E_{hd:r}). \qquad \text{(A.2')}$$

[56] Employing the monocentric-city model as the basis for the analysis would relax this assumption, but at the cost of increased complexity.

A.2 The Growth in Housing Rent: Application under Spatial Containment

Assuming that the growth rates of population, income, land supply and technical change, as well as the demand and supply elasticities, remain constant over time, and drawing on the empirical literature in urban economics for the magnitude of these growth rates and elasticities, how the growth rate of rent depends on the growth rate of population may be calculated. The following table lists the assumed parameters, defines each, and gives the estimate of its magnitude and its source.

TABLE[1] A PARAMETER ESTIMATES EMPLOYED IN CALCULATING THE GROWTH RATE OF HOUSING RENTS PER UNIT AREA OF FLOOR SPACE UNDER SPATIAL CONTAINMENT

Parameter	Meaning	Estimate	Source
g_N	Plan annual growth rate of population	0.01275	MDP
$E_{hd:y}$	Income elasticity of housing demand	1.0	Muth
g_y	Per capita annual income growth rate	0.01	
$E_{hd:r}$	Rent elasticity of housing demand	- 1.0	Muth
g_{A*}	Plan annual growth rate of effective land area	0	assumed[2]
$E_{hs;r}$	Rent elasticity of housing supply	3.0	calculated[3]
$E_{hs:\gamma}$	Elasticity of housing supply with respect to productivity	4.0	calculated[3]
g_{γ}	Rate of technical change in housing construction[4]	0.006	Iacoviello and Neri
σ	Elasticity of substitution between capital and land in housing construction	1.0	Thorsnes
α	Capital share in housing production	0.75	[5]

Sources:

MDP: City of Calgary, The City of Calgary Municipal Development Plan: Office consolidation, December 2014 (2015), http://www.gccarra.ca/wp-content/uploads/2015/01/mdp-municipal-development-plan.pdf.

Muth: R. Muth, Cities and Housing (Chicago, Ill.: University of Chicago Press, 1969).

Iacoviello and Neri: M. Iacoviello and S. Neri, "Housing market spillovers: Evidence from an estimated DSGE model." American Economic Journal: Macroeconomics 2 (2010): 125-164.

Thorsnes: P. Thorsnes, Consistent estimates of the elasticity of substitution between land and non-land inputs in the production of housing, Journal of Urban Economics 42 (1997): 98-108.

Notes:

1. While the parameters employed draw on a considerable body of empirical literature in urban economics, they are inexact. For several of the parameters, the estimating equations are derived from models that are unrealistic in several respects, as indeed are all models. The reader is encouraged to rework the calculations based on her chosen set of parameter values.
2. Implied by the assumption that the government pursues a policy of spatial containment.
3. The rent elasticity of housing supply is calculated below from the elasticity of substitution between land and capital in the production of housing and the land share in housing production. The elasticity is a long-run elasticity, as is the rent elasticity of housing demand. The elasticity of housing supply with respect to productivity is calculated below too.
4. Iacoviello and Neri's figure is 0.008. It has been adjusted downward to reflect the rise in the cost of construction labour, which the model does not take into account.
5. This includes the cost of not only materials but also of labour.

Richard Muth,[57] the leading housing economist of his generation, argued that, since households have spent more or less the same proportion of their incomes on housing for as long as data have been collected, the rent and income elasticities of demand for housing must be close to 1.0. On this basis, it is assumed that $E_{hd:y} = -E_{hd:r} = 1.0$. The policy of spatial containment implies that $g_{A*} = 0$.

[57] Muth, *Cities and Housing.*

The elasticity of housing supply can be calculated on the basis of three empirical regularities. The first is that the elasticity of substitution between land and capital in the production of housing is close to 1.0, which is the current conventional wisdom.[58] The second is that there are constant returns to scale in the production of housing. The third is that the factor share of capital in the production of housing is 0.75, which is a standard estimate.

The first two empirical regularities imply that the production function for housing has the form $H(t) = \gamma(t)K(t)^{\alpha}L(t)^{1-\alpha}$, where, at time t, H(t) is the quantity of "housing," γ(t) is a time-varying constant reflecting technical change in housing production, K(t) is the amount of capital (non-land factors of production), L(t) is the amount of land used, and α is the capital-factor share in the production of housing. Under the assumption that households are concerned only about the floor area of their units, the quantity of housing is measured by the quantity of floor space, F(t), $F(t) = \gamma(t)K(t)^{\alpha}L(t)^{1-\alpha}$. Since the production function exhibits constant returns to scale, this equation may be rewritten in intensive form as $f(t) = \gamma(t)k(t)^{\alpha}$, where $f(t) \equiv F(t)/L(t)$ is the floor-area ratio at time t, and $k(t) \equiv K(t)/L(t)$ is the corresponding capital-land ratio. Thus, $f(t) = \gamma(t)k(t)^{\alpha}$, so that α is the elasticity of floor area with respect to capital. The number of units of capital needed to provide f(t) units of floor area is therefore $k(t) = [f(t)/\gamma(t)]^{1/\alpha}$. Since the price of a unit of capital is normalized to 1.0, this implies that the marginal cost of a unit of floor area with floor-area ratio f(t) is $[\gamma(t)^{-1/\alpha}f(t)^{1/\alpha -1}]/\alpha = n(t)f(t)^{1/\alpha -1}/\alpha$, where $n(t) \equiv \gamma(t)^{-1/\alpha}$.

The developer chooses floor area to maximize profit, which entails building up to the point where the rent on a unit of floor area just covers its marginal cost: $r(t) = n(t)f(t)^{1/\alpha -1}/\alpha$. Thus, the supply function for floor area per unit area of land, which is also the supply function for housing per unit area of land, is $f(t) = [\alpha r(t)/n(t)]^{\alpha/(1-\alpha)} \equiv \alpha^{\alpha/(1-\alpha)}\gamma(t)^{1/(1-\alpha)}r(t)^{\alpha/(1-\alpha)} = h^s(r(t), \gamma(t))$, so that the supply elasticity of housing (the elasticity of housing supplied with respect to rent) is $E_{hs:r} = \alpha/(1-\alpha)$ and the elasticity of housing supplied with respect to γ is $E_{hs:\gamma} = 1/(1 - \alpha)$.

A.2.1 Rental Growth under Spatial Containment for Two Population Forecasts

The plan proposes to contain the area of the city, which is here interpreted to imply that the growth rate of the city's effective land area is zero: $g_{A*} = 0$. Substituting this and the other assumed parameter values into (A.2) yields the following equation relating the growth rate of rents to the growth rates in population and income under spatial containment.

$$g_r = (g_N + g_y -0.024)/4.0. \qquad \text{(A.3)}$$

All that remains to estimate the growth rate of housing rent under spatial containment under the two population forecasts is to substitute in the assumed growth rates of population and income into (A.3).

A2.2 Laissez-Faire

The growth rate of housing rents under laissez-faire is calculated in the same way as under spatial containment, except that the growth rate of effective land area, g_{A*}, is taken to be 0.3 times the growth rate of per capita income plus 0.4 times the growth rate of population.

[58] P. Thorsnes, "Consistent estimates of the elasticity of substitution between land and non-land inputs in the production of housing," *Journal of Urban Economics* 42 (1997): 98-108.

APPENDIX B: THE GROWTH IN AVERAGE JOURNEY-TO-WORK TIMES

The following notation is employed:

M	the proportion of home-to-work motorized trips by mass-transit
a	auto (superscript)
m	mass-transit (superscript)
T^i	mean travel time in excess of free-flow travel time ("excess travel time" due to congestion) by mode i
F^i	mean free-flow travel time by mode i
Z^i	mean travel time by mode i ($\equiv T^i + F^i$)
s^i	mean excess travel time per kilometre by mode i
f^i	mean free-flow travel time per kilometre by mode i
d^i	mean distance traveled by mode i
N	total number of commuters
K^i	capacity of mode i in commuter-kilometres
X^i	other characteristics of mode i

The equilibrium is described by a system of five equations in the five unknowns, M, T^m, T^a, s^m, s^a.

$$M = M(T^m + F^m, T^a + F^a; X^m, X^a) \qquad \text{(B.1)}$$

This equation indicates that the modal split between transit and car depends on the average travel times of the two modes, plus the other characteristics of the two modes, which include comfort, convenience, travel time reliability, and privacy. The other characteristics of the two modes are assumed to be constant over time, so that they will not appear in the growth equations. The next pair of equations describes relevant features of the congestion technology:

$$s^m = s^m(MNd^m, K^m) \qquad \text{(B.2)}$$

$$s^s = s^a((1 - M)Nd^a, K^a) \qquad \text{(B.3)}$$

s^i is the mean excess travel time loss per kilometre in mode i. Equations (B.2) and (B.3) indicate that the mean excess travel time per kilometre in mode i is a function of the total number of commuter-kilometres by mode i and the capacity of mode i. For auto travel, this is a standard specification; bus travel is rather more complicated.[59]

The current consensus is that mass-transit exhibits increasing returns to scale, in the sense that a doubling of capacity and a doubling of passenger-kilometres results in a reduction in the mean excess travel time. The reason is what is referred to in the transportation economics literature as Mohring economies of scale. A doubling of capacity and passenger-kilometres has minimal effect on the in-vehicle travel time per kilometre, but reduces both waiting time (due to an

[59] There are three major components to mass-transit travel time: time in transit, walking time, and waiting time. Due to boardings and alightings, the congested component of time in transit depends on the mass-transit volume-capacity ratio. There is no congested component of walking time. However, mean walking time depends on the mass-transit-network density, which depends on the level of mass-transit infrastructure. The most difficult component to treat is waiting time. If either mass-transit does not run on time or commuters do not know the schedule, waiting time is inversely related to service frequency, which can be expected to increase with the mass-transit volume-capacity ratio. Here it is assumed that commuters know the schedule, so that waiting time is zero.

increase in schedule frequency) and walking time (due to an increase in the network density).[60] The current consensus is that auto travel exhibits approximately constant returns to scale.

The next pair of equations are simply identities:

$$T^m \equiv s^m d^m \qquad \text{and } T^a \equiv s^a d^a \qquad \text{(B.4)}$$

Each states simply that the average increase in excess travel time per trip equals the average increase in excess travel time per mile times the average number of miles per trip. The final equations are the analogs to (B.4) for the free-flow component of travel time.[61]

$$F^m \equiv f^m d^m \qquad \text{and } F^a \equiv f^a d^a \qquad \text{(B.5)}$$

Substituting (B.4) and (B.5) into (B.1) reduces the equation system to three equations in the three unknowns, M, s^m, and s^a. Rewriting the equation system in terms of growth rates yields

$$g_M = E_{M:Zm} [g_{Tm}(T^m/Z^m) + g_{Fm}(F^m/Z^m)] + E_{M:Za} [g_{Ta}(T^a/Z^a) + g_{Fa}(F^a/Z^a)] \qquad \text{(B.6)}$$

$$g_{1-M} = - [M/(1 - M)]g_M \qquad \text{(B.7)}$$

$$g_{Tm} = g_{sm} + g_{dm} = E_{sm:MNdm}(g_M + g_N + g_{dm}) + E_{sm:Km}g_{Km} \qquad \text{(B.8)}$$

$$g_{Ta} = g_{sa} + g_{da} = E_{sa:MNda}(g_{1-M} + g_N + g_{da}) + E_{sa:Ka}g_{Ka} \qquad \text{(B.9)}$$

$$g_{Fm} = g_{dm} = g_d \; g_{Fa} = g_{da} = g_d \qquad \text{(B.10)}$$

Equation (B.10) incorporates the assumptions that the growth rate in mean trip distance is the same for both modes, and that for each mode, free-flow travel time per kilometre remains constant. Of central interest is how mean commuting time evolves over time. The mean commuting time on mode i is $(s^i + f^i)d^i$. Thus, the overall mean commuting time, Z, is

$$Z = M(s^m + f^m)d^m + (1 - M)(s^a + f^a)d^a. \qquad \text{(B.11)}$$

Table B gives the parameter estimates, as well as their justification. The exogenous elasticities and growth rates corresponding to the various cases are given in the body of the paper.

[60] The Calgary Transportation Plan proposes to extend the existing LRT lines and to add new lines, not to increase the density of stops.

[61] There are three components of the free-flow-component mass-transit trip time: in-transit travel time, walking time (at both the origin and the destination), and waiting time. It is reasonable to assume that the free-flow-component in-transit travel time is a multiple of trip distance. Since the average circumferential distance to the nearest LRT line is proportional to the distance from the CBD, it is also reasonable to assume that walking time is proportional to trip distance. Waiting time has been assumed to be zero.

TABLE B PARAMETER ESTIMATES EMPLOYED IN CALCULATING THE GROWTH RATE OF MEAN COMMUTING TIMES UNDER VARIOUS SCENARIOS

Parameter	Interpretation	Estimate	Source
$E_{M:Zm}$	Elasticity of transit modal share with respect to transit-trip time	-0.129	1
$E_{M:Za}$	Elasticity of transit modal share with respect to auto-trip time	0.036	2
$E_{sm:MNdm}$	Elasticity of excess transit travel time per mile with respect to total transit passenger-kilometres (transit capital stock fixed)	0.9	This assumes that a 10 per cent increase in transit-rider miles, holding fixed the transit capital stock (and hence service frequency), results in a nine per cent increase in the excess mass-transit time per mile, reflecting the time lost due to boarding and alighting.
$E_{sm:Km}$	Elasticity of transit congested travel time per kilometre with respect to transit capital stock (transit passenger-kilometres fixed)	-1.0	This assumes that a 10 per cent increase in transit capital stock results in a 10 per cent decrease in excess mass-transit travel time per kilometre. This elasticity and the previous one together capture modest increasing returns to scale in mass-transit.
g_{Km}	Annual growth rate of transit capital stock	0.02	This corresponds to a 328 per cent increase in the LRT capital stock over the plan period.
$E_{sa:(1-M)Nda}$	Elasticity of excess auto travel time per kilometre with respect to total auto kilometres (auto capital stock fixed)	1.5	3
$E_{sa:Ka}$	Elasticity of auto congested travel time per kilometre with respect to auto capital stock (auto kilometres fixed)	-1.5	This elasticity and the previous one together capture approximately constant returns to scale in auto travel.
g_{Ka}	Annual growth rate of auto capital stock	0.01	This corresponds to an 85 per cent increase in the auto capital stock over the period.[4]

Notes:

1. Litman[62] gives a morning-rush-hour elasticity of transit ridership with respect to transit travel time for Portland, Ore. of -0.129. Portland is known for its high mass-transit modal share compared to U.S. cities of comparable size. $E_{M:Tm}$, in contrast, is the rush-hour elasticity of transit *modal share* with respect to excess transit travel time. Assuming that, on average during the rush hour, excess transit travel time is one-third transit travel time, and that the Calgary elasticity is three times as high as the Portland elasticity, $E_{M:Tm}$ has the same value as the Litman elasticity.
2. Litman[63] gives the morning-rush-hour elasticity of transit ridership with respect to auto travel time for Portland of 0.036. $E_{M:Ta}$, in contrast, is the rush-hour elasticity of transit *modal share* with respect to excess auto travel time. Assuming that, on average during the rush hour, the excess auto time is one-third auto travel time (which is consistent with TomTom[64]), and that the Calgary elasticity is three times as high as the Portland elasticity, $E_{M:Ta}$ has the same value as the Litman elasticity.
3. There is no consensus in the literature on this important elasticity. The U.S. Federal Highway Administration's estimate of this elasticity for single links is 3.5, while in the bottleneck model it is 1.0. For an entire urban area, the elasticity is likely significantly lower than that for a single link, since as traffic volume increases, commuters will on average take more circuitous, less congestible routes to avoid heavy congestion.
4. This may seem modest. However, the city seems to be committed to a policy of minimal expansion of the road system over the plan period. For example, between 2011 and 2013, the number of lane-kilometers of "skeletal roads," major roads, and collectors increased from 6,568 to 6,724, which corresponds to an annual growth rate of 1.18 per cent.[65]

Substituting these parameter values into (B.6) through (B.8) yields

$$g_M = -0.129[g_{Tm}(T^m/Z^m) + g_{Fm}(F^m/Z^m)] + 0.036[g_{Ta}(T^a/Z^a) + g_{Fa}(F^a/Z^a)] \quad \text{(B.6')}$$

$$g_{1-M} = -[M/(1-M)]g_M \quad \text{(B.7')}$$

$$g_{Tm} = 0.9(g_M + g_N + g_{dm}) - 0.02 \quad \text{(B.8')}$$

62 Litman, "Understanding transport," Table 31.

63 ibid.

64 TomTom index, 2013.

65 City of Calgary, data request, area and land-kilometres of roads, 2011-2013.

$$g_{Ta} = 1.5(g_{1\text{-}M} + g_N + g_{da}) - 0.015 \quad \text{(B.9')}$$

$$g_{Fm} = g_{dm} = g_d \quad \text{and} \quad g_{Fa} = g_{da} = g_d \quad \text{(B.10')}$$

According to the National Household Survey, 2011,[66] the average mass-transit commute time and the average auto commute time for Calgary are 41.4 minutes and 24.7 minutes respectively. The literature search uncovered no estimates of average free-flow commute time for either mode. However, the TomTom auto-congestion index indicates that average rush-hour commute time for auto travel is about 1.5 times the free-flow commute time, which would imply that free-flow auto commute time is 16.47 minutes and that excess auto commute time is 8.23 minutes. These are taken as the 2008 values for Calgary. An analogous assumption is made for mass-transit,[67] so that mass-transit free-flow travel time is 27.6 minutes and excess mass-transit time is 13.8 minutes. Thus, in 2008, $F^m = 27.6$, $T^m = 13.8$, $Z^m = 41.4$, $F^a = 16.47$, $T^a = 8.23$, and $Z^a = 24.7$. From (B.11), the value of Z in 2008 is 28.875.

The growth rates will change as the modal share and the ratio of excess to free-flow travel time on each of the two modes change. It was assumed in the text that in 2008 M = 0.25, so that M/(1 - M) = 0.3333.

The procedure for solving this system is now illustrated for Case I: Plan population growth rate, and spatial containment.

Case I: $g_N = 0.01275$, $g_{dm} = g_{da} = g_d = 0$, $g_N + g_{dm} = 0.01275$.

The expressions for g_{Tm} and g_{Ta} from (B.8') and (B.9'), respectively, are substituted into (B.6'), to get an expression for g_M as a function of exogenous parameters only. The value of g_M in 2008 is then calculated, using the base-year values of the free-flow and excess components of travel time by the two modes. The calculated value of g_M in 2008 is then substituted into (B.8') and (B.9') to obtain g_{Tm} and g_{Ta} for 2008. As well, under the policy of spatial containment, $g_d = 0$. Applying these calculated growth rates, the 2009 values of M, T^m and T^a are calculated, and then the process is repeated year by year up to 2070. The above procedure is then repeated for the other three cases.

66 Statistics Canada, National Household Survey, 2011.

67 A more satisfying treatment would separate mass-transit time into walking time, waiting time, and in-vehicle travel time. Walking time would depend on the density of the network; waiting time would depend on the headway between trains (which depends in turn on the utilization rate of trains over the rush hour and the speed of trains); and in-vehicle travel time would depend on the passenger/LRT-car ratio, since this determines the length of time an LRT train waits at a station for passengers to alight and embark.

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Richard Arnott is Distinguished Professor of Economics at the University of California, Riverside. His previous appointments were at Queen's University (1975-1988) and Boston College (1988-2007). His major field of research interest has been urban economic theory, and his current research focuses on the economics of downtown parking and traffic congestion. He has published some 150 articles and has co-edited three journals, the *Journal of Economic Geography*, *Regional Science and Urban Economics*, and *Transportation Research B*.

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