THE FOUR OUTCOMES OF TRANSIT AND LAND-USE

Sybil Derrible[1]
Bilal Farooq[2]

Introduction

As urbanization on the planet is increasing past 50%, much stress is exerted on current urban transportation systems all over the world. Similarly, as the number of new city residents is increasing rapidly, much land is used to accommodate, employ and provide other essential services to these new residents, thus creating an intrinsic relationship between the two realms. One particular transport mode having an effect on land-use development is public transportation. The relationship between public transit and land-use, however, can be difficult to capture, notably due to its dynamic feature; indeed, transit lines are commonly implemented on corridors having sufficient population density, which in turn can result in higher population densities, thus requiring an increase in transit service. Consequently, there seems to be a co-evolution between the two realms.

A positive co-evolution of public transportation and land-use is normally desired for many reasons. For example, in medium and high population density areas, with significant land-use development, more people are prone to use transit; positive effects of this higher transit mode share may include lesser congestion, which is often seen as a major issue for the economy of a city *(1)*. Moreover, the presence of public transportation infrastructure also shares a relationship with the livability of a city *(2)*. To enhance land-use development around transit stations, the relatively new concept of Transit Oriented Development (TOD) emerged strongly in the past 20 years and seems promising *(3)*. Nevertheless, such a positive co-evolution is not systematic.

[1] *Sybil Derrible (corresponding author), Ph.D. Candidate, Department of Civil Engineering, University of Toronto, email: sybil.derrible@utoronto.ca

[2] Bilal Farooq, Ph.D. Candidate, Department of Civil Engineering, University of Toronto, email: bilal.farooq@utoronto.ca

The broad goal of this paper is therefore to study this co-evolution for one specific application, the city of Toronto, and identify potential outcomes.

In this paper, we focus mainly on the metro network of Toronto, which started operating in 1954 and currently consists of four lines. Here, metro refers to rapid rail transit with exclusive right-of-way (ROW A), whether it is underground, at grade or elevated. The preference to study metro lines is natural since land-use development is more likely around high-order transit corridors; nonetheless, other transit modes are also discussed. Regarding land-use, we concentrate on measures of demography, residential, and commercial development; areas of 0.5 and 1 km around each metro station are considered. As a result, we define a new conceptual paradigm to estimate the impacts of transit and land-use through the example of four case studies.

More specifically, the objectives of this research are to:

- Present the evolution of the Toronto metro since the 1950's
- Present the evolution of land-use and demographics in Toronto since the 1950's
- Propose a paradigm accounting for the different trends
- Illustrate this paradigm through practical examples

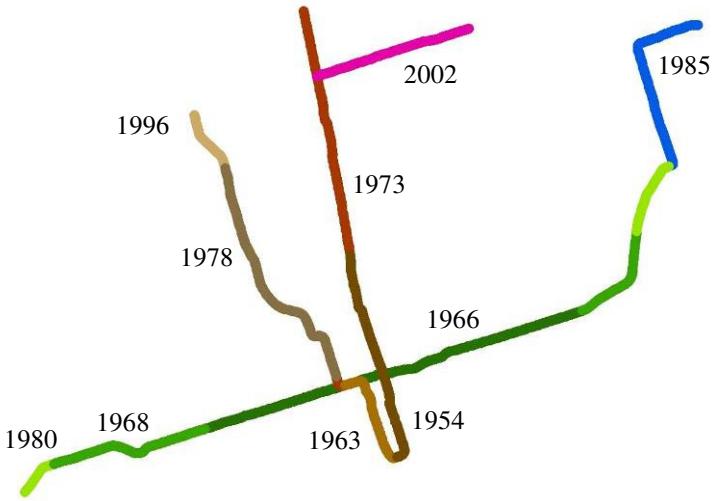
First, in the next section, we will provide a historical description of the metro system of Toronto. We will also present the trends in land-use development in Toronto. Then, we will then introduce a new paradigm based on transit investment and land-use policies. We have notably identified four types of neighbourhoods that are illustrated by taking real-life examples in the city of Toronto.

Historical Trends

A brief history of the Toronto metro system

With privately-owned transit lines operating since 1861, the city of Toronto public transit authority, the Toronto Transit Commission (TTC), was created in 1920 *(4)*. Figure 1 illustrates the four metro lines of Toronto (three subway lines and the Scarborough RT line), segmented according to date opened.

Figure 1: The Toronto metro system segmented by opening date



Despite early rejections at the beginning of the 20th century, the first metro line (Yonge line) opened in 1954, favoured by the end of World War II and accompanied by rapid economic and demographic growth. It ran a 7.4 km stretch with 12 stations, notably servicing the central business district (CBD). This choice location of Yonge St. was natural. Prior to the construction of the metro line, a streetcar line existed and was overstressed. Demand therefore already existed, and land-use was dense. Subsequently, another stretch of the Yonge metro line opened in 1963 on University Ave, servicing another area of the downtown, where demand was also high.

The second metro line (Bloor line) opened in 1966, servicing 20 stations and running 12 km; additions to the line occurred in 1968 with nine new stations. This choice of location was first debated (the other choice being Queen St.), but was then preferred on Bloor St. due to its rapid growth.

In 1973, the Yonge line was extended North on Yonge St. (five new stations) to capture the market from the former municipality of North York. In 1978, the University Ave. stretch of the Yonge line also expended North on Spadina Ave (seven new stations), therefore becoming the Yonge-University-Spadina line. The location of the

Spadina line was much debated in the 1970's and was finally placed in the middle of an expressway. This decision seriously hindered accessibility to the stations (longer walks), which consequently limited land-use development in the area to this day.

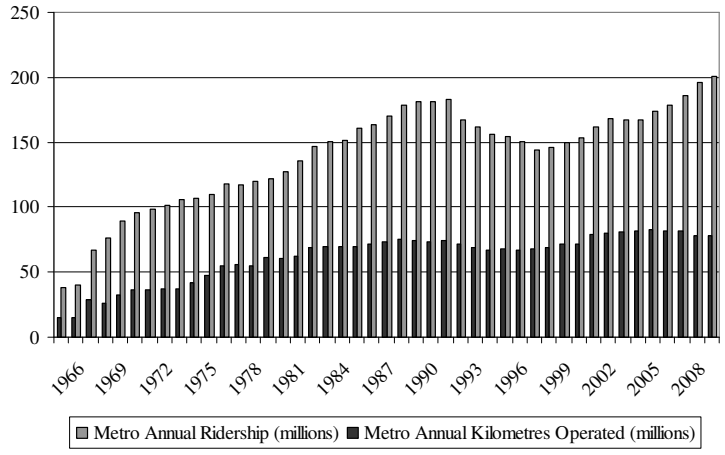
After the addition of two new stations on the Bloor line in 1980, the third metro line (Scarborough rapid transit line) opened in 1985; a lighter technology was used in this instance, although the line still enjoyed an exclusive right-of-way (ROW A).

Finally, the fourth metro line (Sheppard line) opened in 2002 along Sheppard Ave. East, servicing 5 stations on 5.5 km. A thorough account of the history of the metro system can be found in Transit Toronto *(5)*.

Today, the TTC metro system consists of these four lines, totalling 68.75 km of one-way service and 69 stations.

With the construction of new lines and extensions, we generally see a steady increase in the annual metro ridership (Figure 2).

Figure 2: Historical characteristics of the Toronto metro system



On average, ridership grew by 3.72% from 1954 and 2008. Nevertheless, in the period 1990-2002, a decrease of 0.52% per year on average is observable, due notably to a slow economy. From 1954

to 1990, annual ridership growth was 5.34%, and 2.59% in 2002-2008. It is also worth remembering that there were no investments in the metro network between 1985 and 2002.
A similar pattern can be seen in annual kilometre operated since the opening of the first line (Figure 2). It is interesting to see how a decrease similar to ridership occurred in the 1990's. On average, annual kilometres operated increased by 1.97% a year; this difference in magnitude to the average ridership growth may result from increasing economies of scale and network effects. The study of transit network effects has been given much attention recently, and the literature is growing fast on this particular topic; notable contributions include *(6-8)*.

The Evolution of demographics and land-use in Toronto

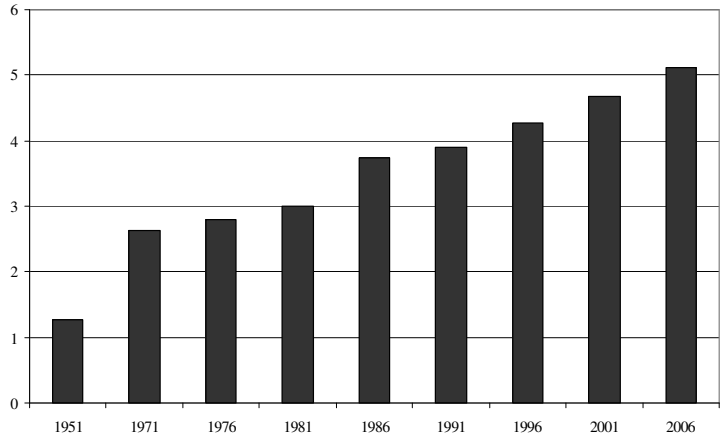
In the 1960's, due to the political uncertainity in Quebec, created by the Quebec soverenity movement, many national and international corporations moved their head offices from Montreal (the business capital of Canada at that time) to Toronto. This historic event and the growing postwar momentum rapidly thrusted Toronto into becoming the business and financial capital of Canada. Today, Toronto is the third biggest financial centre of North America after New York and Chicago. The phenominal economic growth attracted more and more people to the city and thus the population of the city and the surrounding suburbs experienced a rapid growth (Figure 3). The Toronto Census Metropolitan Area (CMA), which is the city of Toronto and its adjacent municipalities, is maintaining a population growth rate of 9.8% and is the most attractive destination of the new migrants arriving in Canada.

High level of economic growth and population increase has encouraged high level of activity in the residential and commercial land-use market. From historic data and economic studies, we see strong evidence that the spatial distribution and value of this development is greatly influenced by the transportation system in general and the public transport system of Toronto in particular.

Within the catchment area of metro stations, we see a high concentration of both new commercial and residential land use. Haider and Miller *(9)* found a positive correlation with the proximity

of metro station for the new housing built in Toronto during 1996 to 2001.

Figure 3: Population of Toronto CMA (millions)



Farooq, Miller, and Haider *(10)* also reported the preference by the builders for proximity to metro station in terms of location decision for the new office buildings.

By looking at the historic trends in new developments within the proximity of the metro stations (Figure 4), we observe a gradual rise in both commercial and residential land use. This increase in the densification around metro stations is dominated by commercial land use. Between 1980 and 2000, the percentage increase in the residential land use was 41% while the office space increased by 75%. This dominance is a result of higher demand for commercial space in metro station proximity. Toronto's economy is dominated by the office based employment sector. In 2005, office sector had a share of 45% in the total number of employments in Toronto *(10)*. Elgar, Farooq, and Miller *(11)* reported that small to medium firms significantly prefer to be located near a metro station. This results in the increase in the demand for the development of the office buildings in the proximity of metro stations.

Figure 4: Land-use characteristics around Toronto metro stations

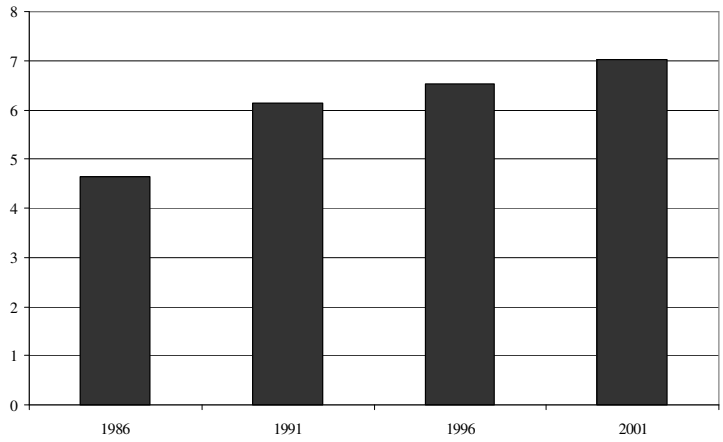


Figure 4a: Total housing (100,000) within one kilometre of a metro station

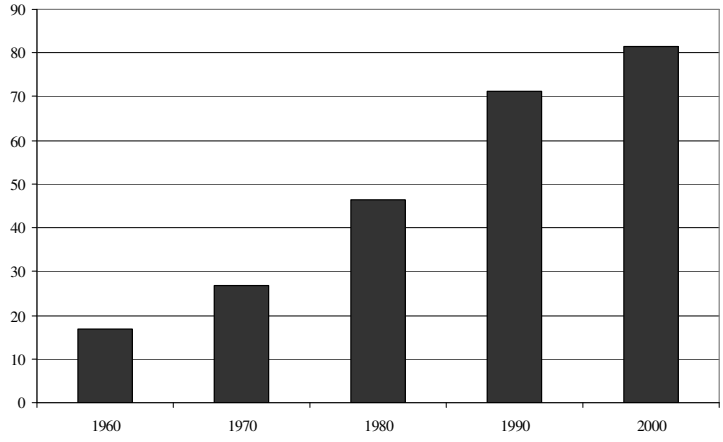


Figure 4b: Office space (million sqr. ft.) within half a kilometre of a metro station

Previous studies on the value of the land-use in Toronto also found that the proximity to metro station has a positive effect on the value. Haider and Miller *(12)* reported that the average price of the houses that are within 1 km of a metro station is 21% higher than the rest of housing stock sold during 1995. Farooq, Miller, and Haider *(10)* also reported a highly positive effect of metro station proximity on the office space rent. They found that the average increase in the asking rent due to the proximity to a metro station was about 10%.

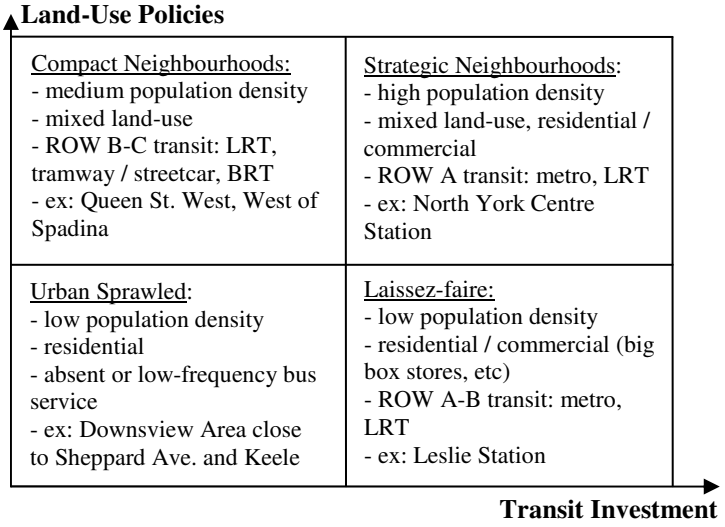
From historic data and the econometric studies done on the land use in Toronto, we generally see that the increase in the accessibility resulting from the transit investments is followed by the increase in the commercial and residential land use activity. The value of the built space also shows a notable increase due to the resulting increase in the accessibility. These evidences reinforce the basic paradigm of positive co-evolution of public transportation and land-use. However, it should be noted that the positive effect on the land use observed in Toronto cannot be entirely attributed to the increase in accessibility resulting from the metro system. The increased accessibility is also supported by the neighbourhood location features, regional economic conditions, built-space market growth, and the local land use policies in successful densification and increase in the value of built space. A metro station by station level analysis of the effects of public transit on the land-use reveals that if the public transit investments are not supported by the above mentioned factors, the evidence of positive co-evolution may not exist.

A New Paradigm: Transit Investment and Land-Use Policies

From observing the historical trends in Toronto, it appears that the relationship between land-use and public transportation is strong. At a macroscopic level, the land-use positive effects generated by investing in public transportation seem certain and unchallenged. By looking at a more detailed scale (i.e. on a station by station basis), however, we can see that this relationship is not systematic. In theory, the construction of new transit lines is preferred on dense corridors that constitute the main market for this line. In addition, the construction of this line will be supported by land-use policy

initiatives to favour densification and enhance ridership. In practice, however, different scenarios are possible, whether it is due to property value issues (i.e. the price to purchase land), zoning conflicts (i.e. stakeholders on specific stations), inaction (i.e. self-organization of land-use around stations) or simple political will. Overall, we identify four extreme types of neighbourhoods: urban sprawled, laissez-faire, compact, and strategic. Figure 5 integrates these four neighbourhoods with public transit investment and land-use policies. The characteristics reported on figure 5 are neither exhaustive, nor systematic, but are most frequent. Moreover, it should be mentioned that a mix of these types is also possible.

Figure 5: Transit investment and land-use policies: a new paradigm



In this section, we illustrate practical examples for each of the neighbourhood type identified on figure 5. We also describe the characteristics of these neighbourhoods more thoroughly. On figure 5, ROW A refers to exclusive right-of-way (completely separated); ROW B refers to semi-exclusive right-of-way (sharing crossroads with automobile traffic); ROW C refers to shared right-of-way with

auto traffic. The acronym BRT stands for Bus Rapid Transit and LRT for Light Rail Transit.

Urban Sprawled Neighbourhood

The concept of urban sprawl is now commonly accepted in the scientific community. With the rapid economic growth after World War II, a mass migration of people occurred in suburban areas due to the inexpensive value of land and the dream of home ownership. Being mostly residential, these areas contain mainly single-detached houses. Moreover, the topology of the roads is often adverse to public transportation (i.e. winding roads), thus non-pedestrian-friendly (i.e. longer walks to transit stop). Consequently, these neighbourhoods typically have little or no access to transit and are significantly automobile-dependent.

Figure 6: Satellite view of neighbourhood in Downsview area; Source for pictures: Google Earth© Satellite View for City of Toronto

Toronto is not an exception and contains many such neighbourhoods. One example is the Downsview area close to Sheppard Ave. and Keele St. Figure 6 shows a satellite view of this neighbourhood; some of the characteristics enlisted here are clearly

observable. A street view can be seen in the bottom left quadrant of figure 8.

Compact Neighbourhood

We define compact neighbourhoods as medium density corridors with potential for further land-use development, which may be hindered by the absence of higher order transit. In Toronto, King St. and Queen St. are particularly good examples; the latter being shown in the top left quadrant of figure 8. Such streets have mixed land-use properties, with duplex and row houses, both for residential and commercial purposes. They can have overstressed transit lines with a shared right-of-way (ROW C) transit, as it is the case for Queen St, which has a streetcar line, or transit lines with semi-exclusive right-of-way (ROW B), e.g., light rail transit (LRT) line. These corridors typically have the potential to support metro lines and also have the potential for further land-use development.

The example of Queen St. is particularly indicative. As mentioned previously, it was first a candidate for the location of the second subway line in the 1960's. Today, the Toronto region transportation authority, Metrolinx, is planning to build a subway line on Queen St. in their 25-year plan *(13)*.

Laissez-faire Neighbourhood

In this paper, laissez-faire neighbourhoods have low population density (i.e. hence low density land-use development), but have access to transit with (semi)-exclusive right-of-way (ROW A and/or ROW B), e.g., metro, LRT. This can be due notably to inexistent or minimal land-use policies. Metro stations can be seen as self-organizing systems, whereby development emerges organically; however, this process is not systematic or can be lengthy. On the contrary, land-use policies can act as catalysts to encourage land-use development and more importantly to control the type of development; for instance by favouring transit-orient developments (TOD).

In Toronto, the community around Leslie station (Sheppard line) can be seen as such a laissez-faire neighbourhood. Figure 7 shows a

satellite view of Leslie station; a street view can be seen on the bottom right quadrant of figure 8.

Figure 7: Satellite view of neighbourhood by Leslie station; Leslie station is shown within the red square; Source for pictures: Google Earth© Satellite View for City of Toronto

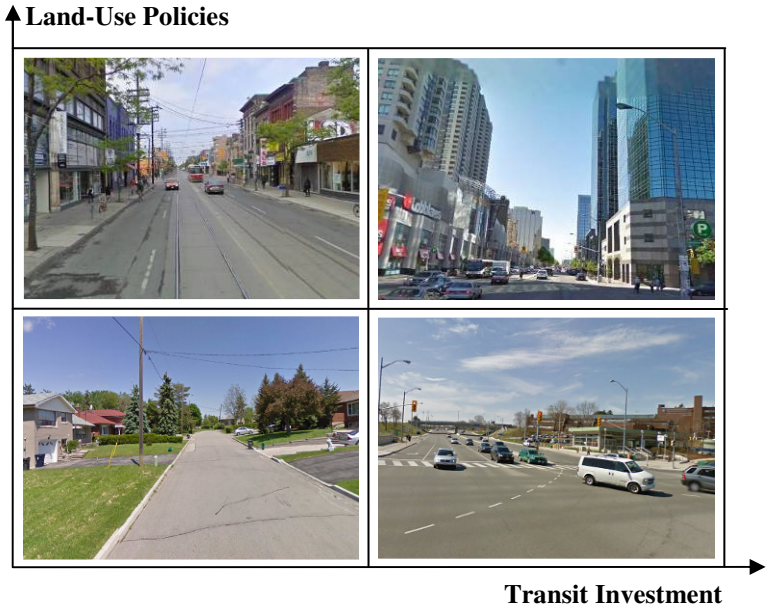
Surroundings contain mainly single detached houses, and the street topology is not pedestrian friendly, impeding accessibility to transit. Moreover, many big box stores are adjacent to the station and are mainly accessible by automobiles, which required much land for parking spaces.

Strategic Neighbourhood

For this research, we define strategic neighbourhoods as areas containing both high-order transit and dense land-use development (e.g., apartment buildings). These neighbourhoods have commercial and residential land-use, although commercial land-use may be predominant. Transit can take the form of metro lines with exclusive right-of-way (ROW A) or even well-integrated LRT lines with semi-exclusive right-of-way (ROW B).

As an example, North York Centre contains both characteristics; top right quadrant on figure 8. Before the creation of the City of Toronto in 1998, which amalgamated six surrounding municipalities, North York used to be a municipality; North York Centre was therefore the business district of this municipality. With the expansion of the Yonge subway line in 1973, significant land-use development occurred which attracted businesses. Not only did it do so, it also attracted residents who wanted to have quick access to the Toronto CBD.

Figure 8: Examples for the four neighborhoods; Source for pictures: Google Earth© Street View for City of Toronto



Conclusion

The co-evolution of public transportation and land-use is a particularly interesting topic to study. It remains, however, inherently

complex to understand, notably due to its dynamic feature. In this paper, we chose to look at this co-evolution for the particular case of the city of Toronto in the past 50 years.

We first presented the evolution of the Toronto metro system since its opening in 1954, which now consists of four lines, servicing 69 stations on 68.75km of one-way rail tracks. Subsequently, we presented the evolution of several land-use indicators in Toronto in the past 50 years. It appears that the public transportation network has a significant impact on the distribution of land-use development in the region. For instance, both rents and houses are higher in the vicinity of metro stations. Moreover, the demand for office space is also significantly higher close to metro stations.

Although in general, the presence of public transportation has a positive effect on land-use, this phenomenon is not systematic at the microscopic level. As a result, we proposed a new conceptual paradigm to capture some of the features observed here. This paradigm is based along axes of transit investment and land-use policies. We clearly identified four possible outcomes (i.e., here four types of neighbourhoods); these are: urban-sprawled, compact, laissez-faire and strategic neighbourhood. Urban-sprawled areas have little or no transit access, partly due to the low population density and a non-pedestrian-friendly road design. Compact neighbourhoods normally have medium population density, but overstressed transit lines, which can hinder land-use development. Laissez-faire areas have high-order transit lines, but insufficient population density due to no or minimal land-use policies. Finally, strategic neighbourhoods enjoy both characteristics (high-order transit and land-use policies), which allowed for significant land-use development.

This paper therefore reaffirms the presence of a relationship between public transportation and land-use. However, there seems to be several possible outcomes, and the role of land-use policies is not to be undermined.

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