Agglomeration Benefits of Metrolinx Rapid Transit Project Scenarios
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Executive Summary

Agglomeration economies are an essential part of building the economic case for the Metrolinx Investment Strategy. Agglomeration refers to the spatial concentration of economic activity. Increased concentration of economic activity – whether due to transportation investments or other factors – can generate productivity benefits through labour market pooling, knowledge spillovers, specialization and the sharing of inputs and outputs.

There are several reasons why it is important to understand the agglomeration impacts of transportation infrastructure investments. First, agglomeration economies are almost entirely incremental or additional to the appraisal benefits calculated under conventional transportation user benefits. As a result, this can transform the economic case for a major transportation project and potentially change the priority of a project (relative to others) and hence, also the funding available to the project. In the UK, the £14.8 billion London Crossrail project went from a benefit-cost ratio in the range of 2 – 2.8 with conventional user benefits to one with a range from 3.1 to 4 when agglomeration benefits were incorporated.

Second, agglomeration economies and other wider economic benefits can put the spotlight on the GTHA regional labour market and how transportation investments can help improve the effective operation of the labour market, particularly by achieving a more geographically integrated labour market across the GTHA. Labour market fragmentation in the GTHA means that many firms cannot hire the best workers for their job vacancies and that many workers are also unable to secure the best job matches. The resulting productivity losses can be significant, particularly in sectors such as high technology, financial services, and professional and technical services.

Third, agglomeration benefits also show how transportation investments can contribute to the competitiveness of the GTHA through enhancing specialization, R&D, and innovation, through better economic cluster formation, especially in high technology, financial services and professional services. These industries are not only important sectors in the GTHA but are also the most susceptible to benefit from agglomeration economies.

Using UK Department for Transport methodology, combined with GTHA data for employment and income by industry, this report provides an initial indication of the potential magnitude of agglomeration benefits resulting from two GTHA rapid transit project scenarios inspired by The Big Move. The results of this work suggest that agglomeration benefits of the Current Trends scenario are expected to be $31.4 million in 2031 (measured in 2008 dollars). These benefits would represent a significant addition to GDP in the GTHA in 2031 and would be lost if the scenario was not executed (i.e. if the Today’s Scenario prevailed). The agglomeration benefits are also incremental to the conventional time savings calculated under the transportation user benefits account. In relative terms, these agglomeration benefits could increase the conventional user benefits of the Current Trends scenario by up to 6 per cent and thereby contribute to better project justification and prioritization.

The agglomeration benefits of the High Build scenario would add $114.7 million to GDP in the GTHA in 2031, which represents almost four times the size of the agglomeration benefits under the Current Trends. These agglomeration benefits are higher, because the High Build Scenario is considerably more effective in reducing generalized travel costs and thereby contributing to a greater concentration of economic activity in the region. These agglomeration benefits would represent a significant addition to the GTHA GDP in 2031 and could increase the conventional user benefits for the High Build Scenario by up to 11 per cent in relative terms.

These agglomeration results are intended to be illustrative, because they rely on agglomeration elasticities derived for UK industries rather than those based in the GTHA. Nevertheless, these agglomeration estimates (and the potential for other wider economic benefits) clearly indicate that the rapid transit projects contemplated in The Big Move would bring potentially significant additional economic benefits to the region through agglomeration mechanisms. As such, the benefits of these projects should not only be understood and discussed in terms of conventional travel time and cost savings but also in terms of the added connectivity and proximity that they enable for various industries and a better integration of the GTHA labour market.
1. **Introduction**

1.1 **Purpose of this report**

The purpose of this report is to estimate the agglomeration benefits associated with two rapid transit project scenarios, drawn from The Big Move, for the Greater Toronto and Hamilton Area (GTHA).

Agglomeration refers to the spatial concentration of economic activity. An increased concentration of economic activity can generate productivity benefits through labour market pooling, knowledge spillovers, specialization and the sharing of inputs and outputs. When transportation investments, such as those envisaged under the Big Move Investment Strategy, enable a greater concentration of economic activity by improving mobility and connectivity among existing centres of economic activity in the GTHA, these investments can generate significant improvements in productivity over and above those already accounted for in conventional transportation user benefits.

The remainder of this section provides a fuller description of the sources of agglomeration economies as well as a definition of the other wider economic benefits that have been incorporated into transportation appraisal guidance in the UK and other countries. Specifically, we explain how this analysis of agglomeration economies allows us to focus on the effective operation of the regional labour market in the GTHA and how transportation investments can improve the efficiency of this market, expressed in terms of higher wages and/or lower unemployment outcomes.

Section two examines agglomeration economies in the GTHA context by analyzing the existing patterns of employment densities and productivity in the GTHA. It shows that employment hubs already exist in selected industries which have both higher employment densities and higher productivity than other jobs in the same industry elsewhere in the GTHA region. Section three presents the agglomeration results for two rapid transit project scenarios, the Current Trends and the High Build scenarios relative to a reference scenario, namely Today’s Service. Section four presents concluding remarks.

The methodology used in this report is described in the three Appendices, including potential next steps for advancing empirical research into agglomeration economies and other wider economic benefits as part of assessing and reporting the economic impacts of transportation investment programs in the GTHA in a more comprehensive manner.

1.2 **Importance of agglomeration economies and other wider economic benefits**

There are three reasons why it is important to understand the agglomeration impacts and other wider economic benefits (WEBs) of major transportation investments in the GTHA. First, these agglomeration and other wider economic impacts are almost entirely incremental to the benefits calculated under conventional transportation user benefits. This suggests that conventional transportation appraisals, such as the Benefits Case Analysis approach currently used by Metrolinx, underestimate the magnitude of benefits associated with transportation infrastructure projects. As a result, jurisdictions that have relied on this longstanding analytical approach may well have undervalued and possibly underinvested in transportation infrastructure.

Second, these agglomeration and other wider impacts focus the spotlight on the GTHA regional labour market and how transportation investments can help improve the effective operation of the labour market, particularly by helping achieve a more geographically integrated labour market across the GTHA. Third, agglomeration benefits also show how transportation investments can contribute to the competitiveness of the GTHA in the global economy through enhancing specialization, R&D, and innovation, through better economic cluster formation, especially in Finance, Insurance, and Real Estate, and professional services. These industries are not only important industrial sectors in the GTHA but are also those most susceptible to benefit from agglomeration economies. We examine each of these topics in greater detail below.
1.2.1 Agglomeration economies and other wider economic benefits – definitions

Agglomeration economies and other wider economic impacts focus on the impacts of major transportation infrastructure projects on the performance of the wider economy (i.e. beyond the travel time and cost savings calculated under conventional transportation user benefits). Academic research over the last decade has demonstrated that these impacts do not double-count the time and cost savings calculated under conventional cost-benefit analysis, but are instead incremental to those benefits.¹ Wider economic benefits arising from transportation improvements are usually assessed in several categories, which we describe below, beginning with agglomeration economies, the topic of this report:

**Agglomeration economies**

Agglomeration economies arise when transportation improvements lead to an increased concentration of economic activity, which in turn generates productivity benefits through labour market pooling, knowledge spillovers, specialization, and the sharing of inputs and outputs (i.e. through economy of scale). (Concentration here is defined both in terms of employment per hectare and in terms of the proximity of these jobs to other jobs in the area, based on travel time and costs). For example, when a firm decides to locate additional production in a certain urban area and thereby increases the concentration of economic activity in that area, it captures only part of the benefits of that decision (through higher profits). The portion of the benefits that accrues to other firms (or to workers) in the same area is known as agglomeration economies (or externalities). Because these agglomeration effects are externalities (i.e. the benefits are not fully captured by each firm making the production location decision, but extend to other firms as well), there is a case for devising transportation policies (and other supporting policies) that encourage the spatial concentration of economic activity.

There are two types of agglomeration economies: (1) localization economies, which refer to productivity gains that firms derive from their proximity to other firms in the same industry (e.g. industry clusters, such as high-technology firms located in a single geographic area or employment hub); and (2) urbanization economies, which are productivity gains due to city size and are attributable specifically to the scale of product and labour markets.

**Localization economies** were originally discussed by Alfred Marshall in the late 19th century and are attributed to (i) the benefits of labour market pooling for firms with similar specialized needs, (ii) knowledge sharing and spillovers due to the interaction between such firms, and (iii) the sharing of intermediate inputs between such firms. Localization economies are industry-specific and tend to be most important in financial and professional services, as well as in high-technology sectors. These are all sectors in which firms rely on large and geographically extensive labour markets to find qualified workers.

**Urbanization economies** are attributable to (i) the scale of product markets and labour markets, (ii) access to local public goods (health, education, policing) which are of a higher quality or a lower unit cost, (iii) consumption benefits associated with a critical mass of cultural, entertainment and leisure activities and (iv) any benefits derived from other types of inter-industry interaction.

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Both types of agglomeration economies are incorporated in the latest Department for Transport (DfT) transportation appraisal guidance, based on the empirical work of Dan Graham for the UK,2 and are included in the empirical estimates developed in this report.

It is also important to note that all these agglomeration economies are by definition additional to the impacts estimated in conventional cost-benefit analysis, because the productivity impacts from greater interactions in the input, output, and labour markets are not fully captured by the transportation users who benefit from the generalized transportation costs savings. In fact, agglomeration economies refer to the externalities component of the benefits which arise from increased interactions in the three markets noted above.

Move to More Productive Jobs

The relocation of existing workers to more productive jobs within the same industry has been heralded as an important source of productivity gains. When transportation improvements provide improved accessibility to high-wage, high-productivity jobs, this allows some workers to switch from lower-productivity to higher-productivity jobs within the same regional labour market. For example, one study has argued that this was the largest source of the wider economic benefits in quantitative terms for London’s Crossrail project (see section 1.3 below for details).

In practice, and for the GTHA, for instance, there are at least three conditions which must be met if a transportation investment is to generate productivity gains by enabling workers to switch to more productive jobs:

1. The presence of high-productivity employment hubs. Industries must already have distinct and well-defined high-productivity hubs, where comparable jobs are more productive (in terms of wages and profits earned by firms) than they are in other parts of the region. Section 2 below suggests that there is considerable evidence of such high-productivity hubs for selected industries in the GTHA (e.g. Toronto downtown core and the Airport Corporate Centre in Mississauga).

2. Pre-existing capacity constraints on roadways and/or public transit networks which prevent some workers in the GTHA from accessing jobs in high-productivity employment hubs. If such capacity constraints exist at peak travel times, as they do on 400-series highways and selected municipal highways as well as for selected public transit and commuter rail links (evidence for the latter may be more anecdotal), then it is possible that firms in high productivity employment hubs may be constrained in their job creation (i.e. such firms can create fewer jobs than they would like or they are left with unfilled job vacancies for longer periods of time). If transportation improvements can be shown to add capacity at the key points where capacity on all modes is highly constrained, then these improvements could enable firms in high-productivity employment hubs to attract workers from farther afield and thereby allow such workers to shift to higher productivity jobs.

3. The higher productivity levels of jobs in high-productivity hubs cannot be explained entirely by the higher skill set or effort attributes of workers. There must be some role for agglomeration economies or other sources of "rents", which are defined as wages in excess of the minimum wage required to elicit a given quality of worker. There is no recent direct evidence of this for the GTHA, but a large empirical literature in this area suggests that this phenomenon is likely also applicable to the GTHA regional labour market.3

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The productivity gains resulting from expected labour moves to more productive jobs as a result of major transportation investments are also additional to the impacts estimated in conventional cost-benefit analysis, although the additionality of these productivity gains can be more difficult to establish in practice.

**Increased Labour Force Participation**

A third set of wider economic benefits refers to increases in labour supply resulting from lower commuting costs. Reductions in commuting costs can affect incentives to work and hence, the supply of labour to firms within a labour market catchment area. One supply response can take the form of encouraging some people to join the labour force, since lower transportation costs translate into higher take-home pay. A second supply response can take the form of existing workers working longer hours, which is made possible by time savings from commuting. These mechanisms which boost labour supply and labour force participation can also affect groups with marginal attachment to the labour force, such as second earners in households or socially-excluded groups living in areas with poor public transit connectivity.

The output gains resulting from increased labour force participation made possible as a result of major transportation investments are also additional to the impacts estimated in conventional cost-benefit analysis, because the travel time and cost savings calculated under conventional benefits are based on a fixed employment scenario which doesn’t allow for increased labour supply. However, it is important to note that the welfare gains from increased labour supply are smaller than the output gains, due to the effort expended to supply that labour. 4

**Transportation Impacts under Imperfect Competition**

Major transportation projects can generate productivity gains in imperfectly competitive markets for goods and services (i.e. in instances where prices for goods and services are higher than marginal production costs) due to one or more of the following effects:

1. lower transportation costs provide incentives for the affected firms to increase output, because they face an upward-sloping supply curve under imperfect competition
2. the transportation improvements may also increase product market competition by opening up any hitherto relatively isolated areas to competition from firms outside the area;

Both effects are additional to the impacts estimated in conventional cost-benefit analyses, but both effects tend to be small or even negligible in empirical terms for relatively mature transportation networks.

The four categories of wider economic benefits described above tend to vary in empirical importance in practice, with agglomeration economies and, in some cases, also moves to more productive jobs tending to be the largest. Nevertheless, these wider economic benefits clearly indicate that jurisdictions which have relied exclusively on conventional cost-benefit calculations of transportation user benefits will have underestimated the benefits of the appraised transportation projects. For instance, for Metrolinx and the GTHA, accounting for agglomeration and other wider economic benefits offers an opportunity to enhance the current Benefits Case Analyses carried out on transportation projects.

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4 Conventional cost-benefit analysis measures the welfare gains resulting from a transportation investment (net of the costs of that investment). Welfare gains refer to an improvement in an individual’s well-being, covering both monetary and non-monetary considerations, such as physical well-being and quality of life. An increase in output due to greater labour supply (i.e. more hours of work) does lead to greater welfare. However, the welfare gain consists of the value of the output less the cost to the individual of the additional effort required to produce that output.
1.2.2 Improving the effective operation of the regional GTHA labour market

In conceptual terms, agglomeration economies and other wider economic benefits focus the spotlight on regional labour markets and specifically how the transportation network enables the effective operation of the labour market by matching workers and job vacancies. But why exactly is the labour market important for the appraisal of major transportation investment programs in general and in the GTHA in particular? There are several steps in this reasoning.

First, the importance of the labour market as a contributor to GTHA productivity growth and living standards cannot be underestimated. Employment income represents the vast majority of income sources for most working residents of the GTHA and as such, the effective operation of the labour market is at the heart of the standard of living and economic well-being of most residents.

Second, the state of the transportation network, including highways, commuter rail, and public transit services, is the key ingredient which determines the geographic breadth of a regional labour market. For example, if peak time highway travel along Highways 401 and 403 is subject to serious congestion and delays and public transit alternatives are either congested, non-existent or extremely tedious to use, employers based in the Airport Corporate Centre in the western part of the GTHA region will be unable to attract workers from the Markham in the north and northeast part of the region (and vice-versa, Markham-based employers will be unable to draw from the Mississauga-based labour pool).

This type of labour market fragmentation has become endemic in the GTHA over the last two decades, because most of the employment growth has taken place outside the city core in areas that are often poorly served by public transit and that have since become adversely affected by congestion.

Third, labour market fragmentation means that firms cannot hire the best workers within the regional labour market for their job vacancies and that the workers are unable to secure the best job matches, measured both in terms of wages and non-pecuniary work characteristics. In a simple world where firms had perfect information about the location and performance characteristics of potential hires and workers had all the requisite job characteristics information, the extent of the productivity loss from a sub-standard job matches would be limited to the additional cost required to compensate the best-suited worker to accept a job in a remote employment hub (e.g. $5000/year gross pay as mentioned in footnote 5). In practice, however, labour markets are fraught with partial and incomplete information for both firms and workers. As a result, firms based in one employment hub may invest little or no effort to search for workers in remote employment hubs elsewhere in the GTHA. Similarly, workers located in one part of the GTHA may invest little precious time to search for and cultivate employment opportunities in other parts of the region. This means that the cost of sub-standard job matches in a fragmented labour market such as the GTHA is likely to exceed even the gross wage required to compensate qualified workers for additional commuting time.

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5 Employers could choose to compensate workers for the increased delays (and/or for alternative travel using the 407 ETR toll road). For example, a 20-km one-way trip along the 407 ETR would require employers to compensate employees at least $2000 per year on a net of income tax basis, not including the cost of the additional time it may take for an employee to travel between Markham and Mississauga as compared to a local job. Employers would be required to compensate such a worker on a gross income basis, which could take the compensation required close to $5000 per year, which can represent a significant share of total labour costs for the employer. This may explain anecdotal evidence to the effect that labour market catchment areas for Mississauga-based employers rarely extend to Richmond Hill or Markham and sometimes do not even extend to the downtown Toronto core, depending on the lifestyle preferences of different demographic groups.

6 GTHA employment on a place of work basis grew by 37% between 1986 and 2006, according to Statistics Canada data from the respective Census years. During the same period, employment within the former City of Toronto boundaries increased by only 2 per cent, according to the Toronto Employment Survey for the respective years. By 2006, only 18 per cent of GTHA jobs were located in the former City of Toronto as compared to 24 per cent in 1986.

7 The literature on labour markets in developed economies has provided extensive theoretical foundations and empirical evidence of search externalities, moral hazard and adverse selection, just to mention some of the better-known sources of imperfect information that plague typical labour markets.
Fourth, the size of the labour market catchment area does not matter equally for all industries or all occupations. It is most important in high technology sectors, financial services, and professional and technical services, where job requirements can be highly differentiated and where an employee with just the right professional experience (in terms of specialization and seniority) can be worth much more than another job candidate whose experience may come close but not quite hit all the right requirements. Part of the evidence for this lies in the industry-specific agglomeration elasticities estimated by Daniel Graham for the UK, where he found that agglomeration elasticities for service sector industries could be two or three times higher than the equivalent elasticity for the manufacturing sector.⁸ In the context of the recent and continued shift away from manufacturing employment in the GTHA and surrounding areas and in favour of service sector employment, labour market integration – and specifically, the size of labour market catchment areas across the region – may become an even more important determinant of productivity growth in the GTHA in the future.

In summary, by placing the issue of GTHA labour market integration at the heart of transportation appraisals, it can help planners bring forward cost-effective transportation improvements for suburb-to-suburb commute options and thereby effectively address fragmentation issues. These commute options may include improvements to public transit networks as well as potential road pricing options to facilitate high-value trips. Even a small or modest improvement in the efficiency of the GTHA labour market (through higher wages per employee or shorter unemployment spells) can have a significant impact on the productivity and competitiveness of the region.

1.3 London’s Crossrail: The Agglomeration and Other Wider Economic Benefits of the Project

The London Crossrail project is a new high-frequency, high-capacity railway across London, linking Maidenhead and Heathrow Airport in the western part through to Abbey Wood in the southeast and Shenfield in the northeast. The new railway will operate through a new 21-km tunnel in central London and will also connect to the financial district, which includes both the City of London and Canary Wharf. This £14.8 billion project is currently under construction and is expected to be ready for service through Central London by 2018. When the Crossrail route is fully in service, it will increase London’s rail-based transportation network capacity by 10 per cent.⁹ The project is being delivered by Crossrail Limited, which is a wholly owned subsidiary of Transport for London.

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⁸ See Graham (2007).
Table 1 below shows the conventional transportation user benefits for the Crossrail project, which consist of time savings for the business, commuter and leisure travel markets, as well as the wider economic benefits (WEBs), which consist of agglomeration economies, increased labour force participation, imperfect competition impacts and the move to more productive jobs (M2MPJ). (The latter is shown only in the last row). The results show the impact of the project (i.e. with and without Crossrail) in present value terms, reported for Greater London over a 60-year period, as well as in benefit-cost ratio terms. The range of results in the table is due to different value of time estimates. Several points emerge from these results:

1. The Crossrail project is expected to generate between £5-10 billion in economic value (measured in terms of increased welfare), which translates into a benefit cost ratio of 2 to 2.8. Hence, the project can be justified based on conventional user benefits alone.

2. The WEBs of Crossrail are in the range of £6-42 billion when expressed in GDP terms. These benefits are additional to the conventional user benefits and consist primarily of agglomeration economies. Increased labour participation and the impact of the project under imperfect competition are also included, but these are much more modest in size.10

3. The WEBs of Crossrail are in the range of £6-18 billion when expressed in terms of increased welfare (i.e. after the marginal costs of producing the additional GDP is netted out).

4. After adding in the WEBs, expressed in welfare terms, the revised benefit-cost ratio of Crossrail is in the range of 3.1 to 4.0 or up to twice as high as the conventional benefit-cost ratio.

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10 The relative magnitudes of the different WEBs is based on the results presented in Colin Buchanan “The Economic Benefits of Crossrail”, October 2007 accessed at http://www.crossrail.co.uk/benefits/wider-economic-benefits/.
(5) The last row in the table shows the impact of incorporating the Move to More Productive Jobs (M2MPJ), which would further raise the benefit-cost ratio to a range of 3.5 to 5.9, or up to three times the conventional benefit-cost ratio. However, the M2MPJ results are controversial for several reasons,\textsuperscript{11} which is why they are reported in the Crossrail benefits case only as a sensitivity on the base WEB figures.

(6) These results, which suggest that the WEBS may be worth up to two or three times the conventional user benefits, are likely to be unique to London, which contains one of the highest productivity employment hubs in the world centred around the financial district in the City of London and Canary Wharf.

Table 1: Crossrail – Conventional User Benefits and Wider Economic Benefits

<table>
<thead>
<tr>
<th>Conventional User Benefits</th>
<th>£ bn, PV 2002 prices (unless otherwise noted)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional user benefits</td>
<td>5 - 10</td>
<td></td>
</tr>
<tr>
<td>Conventional benefit-cost ratio (%)</td>
<td>1.97 - 2.76</td>
<td></td>
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| Wider Economic Benefits (WEBS) | |
|--------------------------------|--------------------------------------------|-------|
| GDP benefits (incl. welfare benefits below) | 6 - 42 | Move to More Productive Jobs (M2MPJ) excluded |
| Welfare benefits (incl. increased tax receipts) | 6 - 18 | M2MPJ excluded |
| Benefit-cost ratio (with WEBS) (%) | 3.09 - 3.97 | Based on welfare benefits; M2MPJ excluded |
| Benefit-cost ratio (with WEBS, incl M2MPJ) (%) | 3.53 - 5.87 | Based on welfare benefits; M2MPJ included |


\textsuperscript{11} The M2MPJ results are controversial because they are based on the idea that Crossrail will lead to a net increase in employment in the London area by virtue of relieving capacity constraints in the public transit and commuter rail network. Classic transportation network models assume a fixed level of employment in the forecast year and also assume that all that employment can be accommodated regardless of congestion levels on roads and public transit. The 2007 Buchanan study (“The Economic Benefits of Crossrail”, October 2007) found that between 6,000 and 14,000 jobs would be crowded out by 2016 and between 26,000 and 33,000 jobs would be crowded out in 2026, depending on the type of analysis (link-based vs. cordon-based) used. Implicit in this analysis is the idea that the additional workers who are able to gain employment in London will benefit from a productivity gain, which was capped at 30 per cent by the UK Department for Transport based on a study of worker productivity differentials which are unexplained by worker characteristics. However, there is no mention of the study in question either in the Buchanan study or in the DfT guidance on WEBS. This is of particular concern, because there is a sizable literature on explaining wage differentials and even some of the so-called “unexplained” wage differentials could potentially be explained by unobserved differences between workers (i.e. differences not captured by education or work experience).
2. Agglomeration economies in the GTHA Context

Agglomeration economies mean that increased spatial concentration of economic activity can generate productivity gains expressed in terms of additional output per given level of productive labour and capital resources used. An examination of recent employment density and worker productivity patterns across the GTHA suggests that firms in certain industries are already benefiting from agglomeration economies, because they are organized and located in employment hubs that exhibit both high employment densities and high productivity (relative to jobs located outside these hubs elsewhere in the GTHA).

The remainder of this section describes the current patterns of employment density and labour productivity for selected industries in the GTHA and discusses how the rapid transit project scenarios can contribute to greater agglomeration economies and hence, improved productivity and competitiveness for the GTHA region.

The Importance of Agglomeration Economies for Particular Industries

Agglomeration benefits can arise either due to increased employment densities, measured in terms of employees per geographic area, or due to reductions in generalized costs, measured in terms of travel time and out-of-pocket travel costs, which have the effect of bringing jobs and economic activity closer together within the GTHA. In this study, the concept of effective density takes into account both the number of employees per zone as well as their proximity to economic activity in other zones (measured in terms of generalized costs).

It is well-known that agglomeration economies are more important for some industries than others. For example, the empirical work conducted by Daniel Graham for the UK observed that these agglomeration economies were more important for professional and business service industries than they were for manufacturing industries.

In the GTHA, like other metropolitan areas, employment density varies considerably and far more than does residential population density. The most dense census tract in terms of full-time employees per hectare (2006 census) is in downtown Toronto, at nearly 4000 employees per hectare. This census tract was also home to the highest average employment income per full time worker in the GTHA (for CTs with any significant amount of working population) at $129 thousand per worker. Two other CTs (also in downtown Toronto) had values of over 1000 employees per hectare, while a total of 32 CTs had values over 100.

In Appendix 1, we have mapped the employment density and average employment income by census tract for North American Industry Classification System (NAICS) industries 52 (Finance and Insurance) and 54 (Professional and Technical Services) for all census tracts with full time employment populations in excess of 300. The results suggest that firms and workers in these industries are already benefiting from agglomeration economies, because they are organized and located in employment hubs that exhibit both high employment densities and high productivity (relative to jobs in the same industries but located outside the designated employment hubs elsewhere in the GTHA).

This is relevant for the current analysis, as agglomeration benefits proliferate with the increase in the concentration of employment (and with increased accessibility to other economic activity) within similar or complimentary industries.

Industry Clustering and Higher Income Jobs

The fact that some industries have clustered in specific areas is evidence in itself that agglomeration economies are present and contribute to productivity in high-density employment hubs. Firms have decided to locate in close proximity to like firms over time in part in order to increase connectivity and decrease the cost of interacting with other firms and accessing the extensive labour resources employed by these other firms.
For example, in the case of the finance and insurance sector, both the highest income and the highest productivity employment hubs are located in the Toronto downtown core and the Toronto midtown node (see Figures A1 and A2 in Appendix 1). The other high-productivity employment hubs include the Yonge and Sheppard area just north of Highway 401; the Richmond Hill / Markham area to the northeast, where Highways 404 and the 407 ETR intersect; the Mississauga employment hubs centred around Highways 427, 401 and 403; as well as downtown Hamilton and the area where Highway 400 and the 407 ETR intersect. (Appendix 1 also shows the employment density and productivity maps for the professional and technical services sector in the GTHA for 2006.)

However, employment density is only one of a number of factors that drive productivity and wages. For example, there are low employment density areas with relatively high average incomes in Mississauga for professional and technical services in particular. Meanwhile, finance and insurance employment density around Highway 400 and 407 is relatively low, but average income is above average for the industry.

Nevertheless, the overall results of the employment density and employment income mappings suggest that agglomeration economies do make some contribution to productivity levels in both the finance, and professional and technical services industries.

The Importance of Increasing Connectivity Between High-Productivity Hubs

The value of the agglomeration concept in the context of the GTHA labour market and the rapid transit projects that the Metrolinx Big Move Investment Strategy could enable is that it focuses attention on improving the connectivity between the existing high-productivity employment hubs within the same or similar industries.

Agglomeration benefits can arise either due to increased employment densities or due to reductions in generalized costs, which have the effect of bringing jobs and economic activity closer together within the GTHA. But the level of agglomeration benefits also depends positively on the productivity level of jobs (i.e. GDP per worker, or employment income per worker as a proxy). In other words, if the reduction in generalized costs brings closer together high-productivity employment nodes, this will generate a greater productivity boost compared to the same reduction in generalized costs for lower-productivity nodes.

Increasing Connectivity through the Rapid Transit Projects Enabled by the Metrolinx Big Move Investment Strategy

A brief overview of the individual transportation projects in the High Build scenario allowed us to identify several projects which would be expected to increase connectivity between the industry-specific high-productivity employment hubs identified earlier. These include the following individual projects:

- **The Airport Rail Link** can significantly improve connectivity from downtown Toronto to the large concentration of employment in and around Pearson Airport, which is a high-productivity hub for both the finance, and professional and technical services sectors. This would require that the ARL service target local business and commuter passengers (e.g. through appropriate price differentiation) as well as airport passengers. It would also require high-frequency and convenient onward local transit connections from Pearson Airport to local employment hubs.

- **The Hurontario LRT**. This project would help improve connectivity to and from the employment nodes in Mississauga and Brampton, West of Pearson Airport.

- **The GO extension into Hamilton (and the Hamilton B-Line)** would help to better connect downtown Hamilton to other such hubs, notably downtown Toronto.

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12 The main drivers of productivity growth are investment in human capital, and plant and machinery, both of which can also entail innovative work processes and organization of work. For this reason, we would not expect to see a strong relationship between the employment density and average employment income without controlling for these other sources of productivity growth.
• **The Eglinton Crosstown extension**, subject to scope definition and technology, will improve connectivity into the Toronto midtown employment node, which is a high-productivity hub for both the finance, and professional and technical services sectors.

• **The Yonge Subway Extension to Highway 7** will improve connectivity into the Yonge and Sheppard employment node as well as the Toronto midtown node, both of which are high-productivity hubs for the finance and professional and technical services sectors.

• **The expansion of the York Viva service (VIVA next)**, one of the first wave of The Big Move projects that Metrolinx undertook, would improve connectivity into the growing employment hub around Highways 404 and 407, which contains many high-productivity jobs in professional and technical services as well as finance.

These types of improvements to connectivity and accessibility between high-productivity employment hubs can make a significant contribution to integrating the GTHA labour market outside the downtown core of Toronto and thereby contribute materially to improved productivity and competitiveness for the region overall. Such productivity improvements would be particularly welcome in the current context of relatively flat economy-wide productivity performance across Canada and Ontario. These improvements would contribute directly to higher real incomes and living standards for those who work and live in the GTHA.

### 3. Agglomeration Results for Rapid Transit Project Scenarios

The analysis of agglomeration results in this section involves examining the three rapid transit project scenarios below:

- **Today’s Service** consists of the projects required to maintain the current level of service on the GO network as well as on recently built (or currently under construction) transit projects such as the Spadina subway extension, Mississauga 403 Transitway, Union Station revitalization, and the first phase of the Brampton Züm network.

- **Current Trends** is considered the business-as-usual scenario and includes the projects with announced funding commitments in addition to the state-of-good repair spending in the previous scenario. Projects with announced funding commitments are the Eglinton-Scarborough Crosstown, Airport Rail Link, and portions of the York VIVA BRT.

- **High Build** represents a build out scenario to further advance The Big Move. This includes the following projects introduced at the earliest possible starting date: GO Transit expansion projects including a 5-year service plan as well as two-way all-day service on all corridors; build out of The Big Move 15-year plan, priority municipal (non-GO) projects as well as an allocation for the remaining municipal (non-GO) projects needing funding in The Big Move 15-year plan; and, a project that aims to connect major employment hubs in the region.

The results of our analysis illustrate the order of magnitude agglomeration benefits for the latter two scenarios compared to Today’s Service.

#### 3.1 Results

The following table summarizes the estimated trip-weighted average generalized travel costs and the per cent change for all zone pairs and for each scenario relative to the Today’s Service scenario:
Table 2: Average Generalized Travel Cost and Per Cent Change Relative to Today’s Service for all zone pairs, 2031

<table>
<thead>
<tr>
<th>(in 2008$)</th>
<th>Today’s Service</th>
<th>Current Trends Scenario</th>
<th>% Change from Today’s Service</th>
<th>High Build</th>
<th>% Change from Today’s Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto GC</td>
<td>12.98</td>
<td>12.95</td>
<td>-0.23</td>
<td>12.86</td>
<td>-0.69</td>
</tr>
<tr>
<td>Transit GC</td>
<td>16.64</td>
<td>16.47</td>
<td>-1.02</td>
<td>16.19</td>
<td>-1.70</td>
</tr>
<tr>
<td>All GC</td>
<td>13.83</td>
<td>13.77</td>
<td>-0.43</td>
<td>13.64</td>
<td>-0.94</td>
</tr>
</tbody>
</table>

The estimated reduction in generalized travel costs for the Current Trends scenario compared to the Today’s Service scenario is 0.43 per cent, while the estimated reduction for the High Build scenario compared to the Today’s Service is 0.94 per cent. As a result, we can expect more substantial agglomeration benefits from the High Build scenario. The magnitude of the expected agglomeration benefits are directly correlated with the reduction in generalized costs. The extent to which generalized cost reductions contribute to agglomeration benefits depends on the distribution of employment by industry and which specific zones/industries see substantial reductions in generalized travel costs to and from other zones/industries.

The following table provides the results from the agglomeration benefits for each industry group and under each scenario in 2031.

Table 3: Agglomeration Benefits Relative to Today’s Service, 2031

<table>
<thead>
<tr>
<th>In 2008$ Millions</th>
<th>Current Trends</th>
<th>High Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing and primary</td>
<td>3.23</td>
<td>9.16</td>
</tr>
<tr>
<td>Construction</td>
<td>0.94</td>
<td>2.86</td>
</tr>
<tr>
<td>Trade and consumer</td>
<td>10.20</td>
<td>36.35</td>
</tr>
<tr>
<td>FIRE</td>
<td>17.02</td>
<td>66.34</td>
</tr>
<tr>
<td>Total</td>
<td>31.39</td>
<td>114.70</td>
</tr>
</tbody>
</table>

The agglomeration benefits of the Current Trends scenario in 2031 are expected to be $31.4 million in 2008 dollars. These benefits would represent a significant addition to GDP in the GTHA in 2031 and would be lost if the scenario was not executed (i.e. if the Today’s Scenario prevailed). The agglomeration benefits are also incremental to the conventional time savings calculated under the transportation user benefits account. In relative terms, these
agglomeration benefits could increase the conventional user benefits by up to 6 per cent and thereby contribute to better project justification and prioritization.\textsuperscript{13}

The agglomeration benefits of the High Build scenario would add $114.7 million to GDP in the GTHA in 2031, which represents almost four times the size of the agglomeration benefits under the Current Trends. These agglomeration benefits are higher than those for the Current Trends scenario, because the High Build Scenario is considerably more effective in reducing generalized travel costs and thereby contributing to a greater concentration of economic activity in the region. These agglomeration benefits would represent a significant addition to the GTHA GDP in 2031 and could increase the conventional user benefits for the High Build Scenario by up to 11 per cent in relative terms.

\textbf{Scenario analysis}

The magnitude of the agglomeration benefits depend heavily upon the industry elasticities. In order to provide an indication of the extent to which expected benefits would change with alternative values for industry elasticities, two additional scenarios were run. The low scenario assumed agglomeration elasticities for each industry were two-thirds of the value of the elasticities observed in the UK. The high scenario assumed that agglomeration elasticities were 1.5 times the UK values.

Tables 4 and 5 summarize the low and high scenario results.

\textbf{Table 4 – Agglomeration Benefits Relative to Today’s Service, 2031 (Low Scenario)}

<table>
<thead>
<tr>
<th>In 2008$ Millions</th>
<th>Current Trends</th>
<th>High Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>2.16</td>
<td>6.11</td>
</tr>
<tr>
<td>and primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>0.62</td>
<td>1.91</td>
</tr>
<tr>
<td>Trade and consumer</td>
<td>6.80</td>
<td>24.23</td>
</tr>
<tr>
<td>FIRE</td>
<td>11.35</td>
<td>44.23</td>
</tr>
<tr>
<td>Total</td>
<td>20.93</td>
<td>76.47</td>
</tr>
</tbody>
</table>

\textsuperscript{13} As discussed earlier, conventional user benefits are expressed in welfare terms. Agglomeration benefits were estimated in terms of GDP. Converting the agglomeration benefits into welfare terms may result in a reduction in values in order to account for any incremental costs – notably labour effort or disutility – incurred in delivering the additional GDP. In other words, agglomeration benefits expressed in welfare terms may be lower (in dollar value terms) than those expressed in GDP terms, although it is not possible with the UK DfT methodology available to determine how large the difference may be.
Table 5: Agglomeration Benefits Relative to Today’s Service, 2031 (High Scenario)

<table>
<thead>
<tr>
<th></th>
<th>Current Trends</th>
<th>High Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing and primary</td>
<td>4.85</td>
<td>13.74</td>
</tr>
<tr>
<td>Construction</td>
<td>1.40</td>
<td>4.29</td>
</tr>
<tr>
<td>Trade and consumer</td>
<td>15.30</td>
<td>54.52</td>
</tr>
<tr>
<td>FIRE</td>
<td>25.53</td>
<td>99.50</td>
</tr>
<tr>
<td>Total</td>
<td>47.08</td>
<td>172.05</td>
</tr>
</tbody>
</table>

In the low scenario, agglomeration benefits would amount to $21 million for the Current Trends Scenario and $76.5 million for the High Build Scenario. Under the high scenario, the estimated agglomeration benefits would reach $47 million for the Current Trends Scenario and $172 million for the High Build Scenario. These results provide an indicative range for interpreting the magnitude of the agglomeration benefits relevant to the GTHA rapid transit scenarios.

4. Concluding Remarks

Agglomeration economies are an essential part of building the economic case for the Metrolinx Investment Strategy. This is partly due to the fact that the estimates of agglomeration benefits associated with any one rapid transit project are incremental or additional to the transportation user benefits calculated under conventional benefit-case assessments. But it is also because agglomeration benefits (and other wider economic benefits) put the spotlight on the GTHA regional labour market and how transportation investments help improve the effective operation of the labour market, particularly by helping achieve a more geographically integrated labour market across the GTHA. The quantitative impacts of rapid transit projects which improve the GTHA labour market integration are not fully captured in the agglomeration estimates presented here and would extend beyond these benefits. For example, we did not estimate here the wider economic benefits associated with increased labour supply, imperfect competition and the move to more productive jobs as a result of relieving transit capacity constraints into the Toronto downtown and other GTHA employment hubs.

Agglomeration refers to the spatial concentration of economic activity. An increased concentration of economic activity can generate productivity benefits through labour market pooling, knowledge spillovers, specialization and the sharing of inputs and outputs. When transportation projects, such as those envisaged under the Investment Strategy, enable a greater concentration of economic activity by improving mobility and connectivity among existing centres of economic activity in the GTHA, these investments can generate significant improvements in productivity over and above those already accounted for in conventional transportation user benefits.

The primary motivation for this report is that agglomeration economies and other wider economic impacts are almost entirely incremental to the appraisal benefits calculated under conventional transportation user benefits. This suggests that conventional transportation appraisals have been underestimating the magnitude of benefits associated with transportation infrastructure projects and hence, that jurisdictions which have relied on this
longstanding analytical approach may well have undervalued the overall benefits of transportation infrastructure for the society and the economy.

The results of our empirical work suggest that agglomeration benefits of the Current Trends scenario in 2031 are expected to be $31.4 million in 2008 dollars. These benefits would represent a significant addition to GDP in the GTHA in 2031 and would be lost if the scenario was not executed (i.e. if the Today’s Scenario prevailed). The agglomeration benefits are also incremental to the conventional time savings calculated under the transportation user benefits account. In relative terms, these agglomeration benefits could increase the conventional user benefits by up to 6 per cent and thereby contribute to better project justification and prioritization.

The agglomeration benefits of the High Build scenario would add $114.7 million to GDP in the GTHA in 2031, which represents almost four times the size of the agglomeration benefits under the Current Trends. These agglomeration benefits are higher than those for the Current Trends scenario, because the High Build Scenario is considerably more effective in reducing generalized travel costs and thereby contributing to a greater concentration of economic activity in the region. These agglomeration benefits would represent a significant addition to the GTHA GDP in 2031 and could increase the conventional user benefits for the High Build Scenario by up to 11 per cent in relative terms.

These agglomeration results are intended to be illustrative, because they rely on agglomeration elasticities derived for UK industries rather than those based in the GTHA. Nevertheless, these agglomeration estimates (and the potential for other wider economic benefits) clearly indicate that the rapid transit projects contemplated in The Big Move Investment Strategy would bring additional benefits to the region through agglomeration mechanisms. As such, the benefits of these projects should not only be understood and discussed in terms of conventional travel time and cost savings but also in terms of the added connectivity and proximity that they enable for various industries and a better integration of the GTHA labour market.

A second motivation for this report is that agglomeration economies and other wider economic benefits can put the spotlight on the GTHA regional labour market and how transportation investments can help improve the effective operation of the labour market, particularly by achieving a more geographically integrated labour market across the GTHA. The importance of a labour market focus in building the economic case for the Investment Strategy can be summarized as follows:

- The GTHA regional labour market is the main contributor to the living standards and economic well-being of the region’s residents. It is also one of the main sources of productivity growth and improved competitiveness for the region.
- The state of the transportation network, including highways, commuter rail and public transit services, is the key ingredient which determines the geographic breadth of the regional GTHA labour market.
- Labour market fragmentation in the GTHA (i.e. when firms and workers on one employment hub do not have access to workers and jobs in one or more other employment hubs spread across the region) means that many firms cannot hire the best workers for their job vacancies and that many workers are also unable to secure the best job matches, measured both in terms of wages and non-pecuniary work characteristics. The productivity losses from these substandard job matches can be significant and likely exceed the transportation costs between the disjointed employment hubs.
- The size of the labour market catchment areas within the GTHA is particularly important in high technology sectors, financial services, and professional and technical services, where job requirements can be highly differentiated and where an employee with just the right professional experience will be more productive and will also command a higher wage if matched with the right job vacancy. The larger the regional labour market from which employers can hire (and workers can search for jobs), the more productive and the higher the likely wage for the job. The increased importance of these sectors in the GTHA relative to manufacturing, where agglomeration economies are much smaller in magnitude, suggests that labour market fragmentation may become an even more important impediment to productivity growth in the GTHA in the future.
A brief overview of the individual transportation projects in the High Build scenario allowed us to identify several projects which would be expected to increase connectivity between two or more industry-specific high-productivity employment hubs in the GTHA and thereby contribute to greater productivity growth through agglomeration effects as well as through other wider economic benefits (e.g. potential job moves to higher productivity jobs):

- The Airport Rail Link
- The Hurontario LRT.
- The GO extension into Hamilton (and the Hamilton B-Line)
- The Eglinton Crosstown extension
- The Yonge Subway Extension to Highway 7
- The expansion of the York Viva service (VIVAnext)
Appendix 1. Employment Density and Productivity Maps for Selected Industries in the GTHA

Figure A1 below shows average employment income by place of work and Census Tract for the Finance and Insurance industry in the GTHA in 2006. It shows that the highest income and the highest productivity employment hub are located in the Toronto downtown core, including the midtown node (see inset). The other high-productivity employment hubs include the Yonge and Sheppard area just north of Highway 401; the Richmond Hill / Markham area to the northeast, where Highways 404 and the 407 ETR intersect; the Mississauga employment hubs centred around Highways 427, 401 and 403; as well as downtown Hamilton and the area where Highway 400 and the 407 ETR intersect.

![Figure A1: Average Employment Income by Place of Work and Census Tract, Finance and Insurance, GTHA, 2006](image)

Source: Statistics Canada and AECOM analysis.

Figure A2 below shows the employment density by Place of Work and by Census Tract for the Finance and Insurance industry in the GTHA in 2006. We would not expect employment density to explain the full variation in employment incomes, but we do see that the high-productivity areas in Figure A1 are also high-density employment hubs, notably the downtown core, the Richmond Hill/Markham areas and the Mississauga employment hubs. This
serves as evidence that agglomeration economies are important in the finance and insurance industry, because firms therein have already located as clusters in employment hubs with other firms in the same industry.

**Figure A2: Employment Density by Place of Work and Census Tract, Finance and Insurance, GTHA, 2006**

Source: Statistics Canada and AECOM analysis.

The next two figures show the same employment income and employment density maps for the professional and technical services industry in the GTHA in 2006. We can draw similar conclusions as to the presence of high-productivity employment hubs and the importance of agglomeration economies in the sector.
Figure A3: Average Employment Income by Place of Work and Census Tract, Professional, Scientific and Technical Services, GTHA, 2006

Source: Statistics Canada and AECOM analysis.
Figure A4: Employment Density (Place of Work) by Census Tract, Professional, Scientific and Technical Services, GTHA, 2006

Source: Statistics Canada and AECOM analysis.
Appendix 2. Methodology for Agglomeration Estimates

The methodology used to calculate agglomeration impacts is based on the state-of-the-art empirical work by Daniel Graham and the adaptation of this approach by the UK Department for Transport in its appraisal guidance. This methodology captures both urbanization and localization economies. However, there are several challenges involved in adapting this approach to jurisdictions outside the UK, including obtaining local employment data by industry and by traffic zone; obtaining GDP per worker data by local area (if not by traffic zone) and deriving industry-specific elasticities of productivity with respect to effective density. The methodology we propose here will address the first two of these data challenges, but not the third challenge, where we will instead need to rely on the only elasticities available, which are from the UK empirical work conducted by Graham. For this reason, the methodology proposed here will only claim to provide an illustration of the potential magnitude of the agglomeration impacts at stake.

The equation for calculating the agglomeration impacts is drawn from the UK DfT guidance referred to above and entails adding the following term across all traffic zone pairs within the Greater Toronto and Hamilton Area (GTHA): the elasticities of productivity with respect to effective density multiplied by the percentage change in effective density in the destination zone due to the rapid transit projects under consideration multiplied by the GDP per worker in each industry sector in the zone and multiplied in turn by the industry employment in that zone. The agglomeration benefits are reported in GDP-equivalent terms. We examine each of the above elements in turn:

- **Effective density (ED) of employment by traffic zone within the GTHA.** This index takes into account not just the number (and industry) of employees in a given traffic zone, but also its proximity to other zones in the region based on a measure of average generalized costs between traffic zones.
- **GDP per worker by industry and area for the GTHA.** These data are obtained at the Census Tract level and are intended to provide a base against which to estimate the productivity responses using the industry-specific agglomeration elasticities.
- **Elasticities of productivity with respect to effective density.** These are industry-specific elasticities that estimate the productivity response to increased effective densities. The elasticities used in this analysis were drawn from empirical work conducted by Daniel Graham for the UK.

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14 See D. Graham "Agglomeration, Productivity and Transport Investment" Journal of Transport Economics and Policy (2007) and section 2 of DfT "The Wider Impacts Sub-Objective: TAG Unit 3.5.14" (September 2009). To our knowledge, the UK DfT was the first jurisdiction to formally incorporate agglomeration economies and other wider economic impacts in its transportation appraisal guidance.
The current analysis required generalized travel costs for three Greater Golden Horseshoe (GGH) model runs for the year 2031 corresponding to the three rapid transit project scenarios described at the beginning of section 3.

A2.1 Description of Data Inputs

The following key inputs were employed in order to estimate the agglomeration benefits described above:

**Agglomeration elasticities**

The agglomeration elasticities of production were derived from the empirical work conducted by Daniel Graham for the UK, based on the assumption that similar elasticities of production would apply for industries in the GTHA. The following are the agglomeration elasticities for the four industry/sector aggregations:
Table B2.1: Agglomeration Elasticities

<table>
<thead>
<tr>
<th>Manufacturing and primary</th>
<th>Construction</th>
<th>Trade and consumer services</th>
<th>FIRE and professional services</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.021</td>
<td>0.034</td>
<td>0.024</td>
<td>0.083</td>
</tr>
</tbody>
</table>

Income per worker by census tract and industry
The income per full time worker by census tract (place of work) and two digit NAICS industry data were obtained through a custom data request to Statistics Canada. These data were based on 2006 census data.

Number of full time workers by census tract and industry
The number of full time workers by census tract (place of work) and two digit NAICS industry data were obtained through a custom data request to Statistics Canada. These data were based on 2006 census data.

Forecast of total workers in the GGH for 2021 and 2031
The forecasts of total workers for both 2021 and 2031 were obtained from the GGH model assumptions.

Productivity growth rate and productivity gross up
The labour productivity growth rates from 2006 to 2021 and 2031 were obtained from the Conference Board of Canada’s long run forecast for the Ontario economy. Similarly, the productivity gross up (output relative to wage rates) was also obtained from the CBoC’s Provincial model.

Generalized travel costs by traffic zone pair in the GTHA
The generalized travel costs by traffic zone pairs in the GGH were obtained through GGH model runs for the three investment scenarios. A detailed description of the assumptions and the calculation methodology is found in section A2.4 below.

A2.2 Preparation of Data for Agglomeration Benefit Calculation
Prior to calculating the estimated agglomeration benefits for each investment scenario, the above data needed to be aggregated to common zones and industries. In order to do this the following steps were undertaken:

1. The census tract level employment and income data were aggregated up to the “superzone” level in order to be roughly consistent with zone sizes utilized in the UK methodology developed under the UK DfT guidance.
2. Data for the two digit NAICS industries (employment and income per worker) were aggregated into four industries/sectors consistent with the UK sectors for which agglomeration elasticities were available (see Table A2.1 above).
3. The forecasts for employment by traffic zone for 2031 from the GGH model were aggregated up to the superzone level.
4. The zone/industry populations for 2031 were derived by applying the industry shares per superzone according to the aggregated data from steps 1 and 2 to the forecast of employment by superzone from the GGH model.

5. Income per worker by industry and superzone was multiplied by the productivity gross up for 2006, then by the productivity growth rate from 2006 to 2031 (for the 2031 scenario).

A2.3 Description of Agglomeration Benefit Calculation

The following steps were undertaken to calculate the estimated agglomeration benefits:

1. A matrix of generalized costs by traffic zone pair was calculated through outputs from the GGH model runs in the three investment scenarios. Traffic zone pair GCs were then aggregated into superzone pair GCs for each scenario. A description of assumptions and weighting methodology can be found in Appendix A2.4.

2. The employment population of a given industry in the destination zone of each pair was divided by the GC of that zone pair. This process was repeated for each scenario.

3. The results of the above calculation were summed across all origin zones for each scenario. This provides the effective density measure for each zone and scenario.

4. The per cent change in effective density was calculated for each of the scenarios relative to the Today’s Service scenario.

5. The per cent change in effective density was multiplied by the agglomeration elasticity of production for that industry. The elasticities were based on the estimates from the UK guidance.

6. The product from step 5 was multiplied by the GDP per worker in that zone. This provides the estimate of the agglomeration benefit per worker in dollar terms.

7. The figure from step 6 was multiplied by the working population for that zone.

8. The product from step 6 was then summed across all zones, with the result being the total agglomeration benefits for that scenario and industry.

The above process was repeated for each industry. The extent of benefits in each industry depends on the working population of that industry, the average GDP per worker in that industry, the agglomeration elasticity of that industry and the spatial distribution of workers in that industry.

A2.4 Estimation of Generalized Costs

Agglomeration areas or “superzones” within the GTHA were defined by grouping the census tracts into approximately one hundred zones, which corresponds roughly to the size of the zones used for agglomeration analysis in Greater London and the South East of England. Outside the GTHA, Census Subdivisions (CSD) are used as agglomeration areas.

Generalized costs (GC) of travel were estimated as a trip-weighted average of auto and transit generalized costs. Auto and transit demand and travel times were provided by the Greater Golden Horseshoe (GGH) travel demand model.

Auto Generalized Costs

Auto GCs were calculated as a trip-weighted average of auto driver and auto passenger generalized cost. Auto drivers were defined as auto users who drive either a single-occupant or multi-occupant vehicle. Auto passengers were defined as auto users who ride along in a multi-occupant vehicle.

Auto driver GCs were calculated as a combined cost including the following elements:
• Travel time – converted into $ using a value of time (VoT) of $13.02/hr in 2008 dollars. This is the VoT assumption used in Metrolinx benefit case assessments.

• Tolls paid – a toll matrix is estimated from an auto assignment using the GGH model run output. The matrix contains the toll paid by auto users for travel between each O-D (origin-destination) pair in the GGH.

• Auto Operating Cost (AOC) – AOC is estimated using an average auto operating cost of $0.23 per km. This is the assumption used in the GGH model runs.

• Parking Charges – A parking charge is applied at destination zone end based on the parking costs used in the GGH model run. The parking charges were assumed to be the same in 2021 and 2031.

Of the above cost elements to auto users, only travel time is included in its entirety in the GC for auto passengers. Half of the AOC and parking costs are also included in the GC for auto passengers.

Transit Generalized Costs
Transit GCs were estimated as a trip-weighted average of the GCs for different transit user categories. Transit users were split into:

• GO rail with drive access to P&R station,

• GO Rail with walk or transit access,

• GO Bus users,

• Local transit (including subway) with drive access to P&R station,

• Local transit (including subway) with walk or transit access.

Travel times for GO Bus users have not been provided from the GGH model runs. Hence, GO Bus demand is not included in the estimation of GC. Since the GO Bus demand is not a significant part of the total transit demand, it is unlikely to make a significant difference to the transit GC calculations.

GCs for GO Rail P&R access users were based on the following cost elements:

• Travel time – converted into $ using a value of time (VoT) of $13.02/hr. The VoT assumption of $13.02/hr for transit users is provided by Metrolinx.

• Fares – Revenues from Go Rail fares are provided by the GGH model run. The fare rates for GO Rail users in 2021 and 2031 are assumed to stay at 2006 levels.

• Cost of driving to the P&R station (travel time, tolls and auto operating cost)

GCs for GO Rail walk and local transit access users included travel time and fares as defined above for GO Rail P&R users. In addition, fares on local transit to the GO Rail P&R were also included.

GCs for local transit P&R users were calculated as a sum of the following costs:

• Travel time – converted into $ using a value of time (VoT) of $13.02/hr.

• Fares – Revenues from local transit fares were provided by the GGH model run. The fare rates for local transit users in 2031 were assumed to stay at 2006 levels.

• Cost of driving to the P&R station (travel time, tolls and auto operating cost)

GCs for local transit walk or transit access users is the sum of travel time and fares as defined above for local transit P&R access users.
Average Transport Generalized Cost

Transport GCs by GGH model Traffic Analysis Zone (TAZ) was estimated as a trip-weighted average of the auto and transit GCs. Transport GCs by TAZ is then weighted by trips to calculate the transport GCs for the larger agglomeration zones. In aggregating the transport GCs from GGH model TAZ to aggregation zones, trip weights were fixed across to the values from the reference scenario.

\[
\text{Transport GC by Agglomeration Area} = \frac{\sum_{\text{aggregation areas}} (\text{Transport GC by TAZ} \times \text{Trips by TAZ})}{\sum_{\text{aggregation areas}} \text{Trips by TAZ}}
\]

The above methodology was used to estimate GC of travel between agglomeration areas for 2031 for each of the scenarios examined.

A2.5 Analytical and Data Qualifications

To our knowledge, there has been little or no previous empirical analysis of agglomeration benefits of transportation projects by industry in the GTHA (or in any other Canadian metropolitan area). As a result, the current analysis has relied on estimates of agglomeration elasticities recommended under the UK transport appraisal guidance. While we can intuitively assume that similar patterns of elasticities would be observed in the GTHA (stronger elasticities for professional services relative to manufacturing, for example), the actual levels of the agglomeration elasticities could vary significantly.

Empirical work on the subject has been lacking in part due to the lack of data on output per worker at small spatial scales. Previous work for North American cities (Ciccone and Hall, 1996) was generally conducted at the census metropolitan statistical area, which is too large for the current analysis. Furthermore, output per worker must be disaggregated by industry to some extent, due to the strong evidence that agglomeration elasticities are more important for some industries than others.

In order to develop a base of output per industry at a small enough spatial scale for the current analysis, census tract level income data (by place of work rather than place of residence) were obtained, as described in Section A2.1 above. It was assumed that the relationship between industry wages and industry output was more or less fixed across census tracts. This limiting assumption was due to the inability to observe output per industry at the census tract level directly.

Furthermore, NAICS industry definitions did not conveniently correspond with the sectors for which agglomeration elasticities were observed in the UK. Hence, it was necessary to aggregate industry data into the corresponding sectors. The assumptions made in order to match NAICS industries to those sectors (see Appendix 3) have a direct impact on the resulting agglomeration benefits. For example, if more NAICS industries fell into the professional services sector, it would lead to higher agglomeration benefits (due to the higher agglomeration elasticities observed in that sector).

In addition, there are potential qualifications to the original empirical work conducted by Graham (2007). For example, observations of higher productivity in zones with higher effective densities could be in part the result of higher qualified workers being attracted to those zones, effectively meaning that some of the observed increase in output could actually be the result in an increase in inputs (through labour quality rather than labour quantity).
A2.6 Potential Next Steps for Agglomeration Benefits and Other WEBs in the GTHA

In order to improve the accuracy of the illustrative results provided in the current analysis, a number of steps can be considered. First, an attempt at deriving empirically the agglomeration elasticities relevant for the GTHA can be made by using the census tract level wage data by place of work and industry for 2006 (as well as for 1996 and 2001). There would be no particular need to aggregate census tract level data up to a spatial scale similar to that of the UK work, nor would there be a need to aggregate to the UK sector definitions. However, the data could be tested by aggregating “like” industries in the expectation that interactions which drive the agglomeration benefits are likely to occur across certain industries (in which case there is an expected benefit of greater concentrations of economic activity).

Other potential improvements could include integrating the transportation and land use impacts associated with each scenario. This would result in a different spatial distribution of employment by industry. Under the current analysis, the level and distribution of employment across traffic zones is fixed between scenarios.

In addition to refining the agglomeration calculations, consideration should also be given to analyzing the impact of capacity constraints in the transportation network on employment growth in the downtown core and other high-productivity employment hubs. Combined capacity constraints on the highway links and the public transit (incl. commuter rail) links into the same employment hub could discourage workers from accepting employment and could discourage firms from creating such jobs in the same employment hub. This analysis would provide the basis for estimating the impact of a project scenario in enabling a move to more productive jobs located in selected employment hubs, as was undertaken for the London Crossrail project.
### Appendix 3. Aggregation of NAICS Industries

<table>
<thead>
<tr>
<th>Aggregated Sector</th>
<th>NAICS Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing and primary industries</td>
<td>11 - Agriculture</td>
</tr>
<tr>
<td></td>
<td>21 - Mining and oil and gas extraction</td>
</tr>
<tr>
<td></td>
<td>22 - Utilities</td>
</tr>
<tr>
<td></td>
<td>31-33 - Manufacturing</td>
</tr>
<tr>
<td>Construction</td>
<td>23 - Construction</td>
</tr>
<tr>
<td>Trade and consumer services</td>
<td>41 - Wholesale Trade</td>
</tr>
<tr>
<td></td>
<td>44-45 - Retail Trade</td>
</tr>
<tr>
<td></td>
<td>48-49 - Transportation and Warehousing</td>
</tr>
<tr>
<td></td>
<td>51 - Information and Cultural</td>
</tr>
<tr>
<td></td>
<td>56 - Administrative and Support</td>
</tr>
<tr>
<td></td>
<td>61 - Education</td>
</tr>
<tr>
<td></td>
<td>62 - Health care</td>
</tr>
<tr>
<td></td>
<td>71 - Arts and entertainment</td>
</tr>
<tr>
<td></td>
<td>72 - Accommodation and food services</td>
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<tr>
<td></td>
<td>81 - Other services</td>
</tr>
<tr>
<td></td>
<td>91 - Public administration</td>
</tr>
<tr>
<td>FIRE and Professional Services</td>
<td>52 - Finance and Insurance</td>
</tr>
<tr>
<td></td>
<td>53 - Real estate</td>
</tr>
<tr>
<td></td>
<td>54 - Professional and Technical Services</td>
</tr>
<tr>
<td></td>
<td>55 - Management of companies</td>
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</tbody>
</table>