TOWARDS SCENARIO-BASED IMPACT EVALUATION OF TRANSPORT INFRASTRUCTURE INVESTMENT ON URBAN FORM AND DEVELOPMENT IN THE GREATER DUBLIN AREA

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Abstract. Accessibility and transport provision have played a key role in shaping the development patterns of major urban areas internationally. While future urban development patterns are subject to fluctuations of the economy and resulting resource decisions we can at a minimum explore potential likely future development scenarios based on current evidence and projections. In this study developed with reference to published comparable international research case studies, the environmental sustainability implications of planned rapid rail infrastructure investments on the urban form in the Greater Dublin Area (GDA) have been analysed incorporating the scenario analysis approach. Various scenarios are generated by the MOLAND Model (which simulates alternative development conditions by using historical land use datasets through the utilisation of cellular modelling) applications including: A baseline scenario incorporating a continuation dispersed pattern of urban development, and an alternative scenario with rapid rail-oriented corridor development. These scenarios are subsequently examined. In terms of sustainable urban development considerations, dispersed development in the baseline case indicates costs of such development exceed the benefits. In contrast, the containment policies -as in the public transport-oriented development could achieve benefits over the baseline scenario by reducing the negative consequences of sprawled type of developments. Further explorations incorporating a Cost-Benefit Analysis (CBA) approach is developed to evaluate the sustainability implications of the two different land development scenarios in the Dublin Area. This is assisted by giving emphasis to the impacts of rapid rail investments on urban form and development as raised in the international comparative literature.

Keywords: Urban Form; Development Patterns; Scenario Analysis; MOLAND Model, Rapid Rail Investment; Greater Dublin Area; Cost-Benefit Analysis

1. Introduction and Context

The structure of urban development in the European cities has changed its direction with population growth starting from the 1990s. This growth taking place especially in peri-urban areas has resulted in significant consequences on the development of the urban environment. Most of the cities have experienced dispersed or scattered type of development often referred to as ‘urban sprawl’ in contrast to their more compact structures which evolved until the 1950s (EEA Report, 2006; UNFPA State of World Population Report, 2007). It is evident that economic restructuring and changes in accessibility and personal mobility are inputs in urban sprawl observed in European cities. The European Environment Agency (EEA) in 2006 reported that urban dispersal is now common in countries with high population density and economic activity such as Belgium, Netherlands, France, Southern and Western Germany; and also in regions experienced rapid economic growth such as Poland and Ireland.

Transformation from compact to more dispersed structures has significant implications. First, it necessitates providing infrastructure and services to the low density population on the urban periphery reflecting the main cost of infrastructure provision on the society as a whole. It is also important to mention that there are difficulties in identifying and computing the increased marginal cost of public service provision resulting from dispersed developments. Second, it causes loss in the productive agricultural land and reduction of landscape amenity. And it is also related to indirect externalities such as: negative effects on the air and water quality, increased travel and accessibility costs, and unwanted social equity costs. (See Boyle et.al, 2004; UN-Habitat Report, 2001; 2004). Under this situation, the concepts of urban sustainable development and urban growth management within the context of sustainability have become the focus of interest. The main issue which has mostly attracted the attention is the linkages between urban spatial structure and transport systems which will achieve sustainable urban form and efficient transport provisions in the future (see for example Rickaby, 1987; Breheny, 1995; Hillman, 1996). Efficiency of transportation is closely related to the urban structure since the degree of compactness and density affect commuting distance and time, feasibility of the main transport system, and travel-related energy consumption and pollution levels.

Planning research and practice have shown that rail transport systems can play a critical role in overcoming the problems posed by dispersed or sprawl development patterns in new areas of development (Newman, 1995; Thornblom and Bengtsson, 1997). Among the competing transit technologies are rapid rail, light rail, and express bus. These developments can provide high quality services in terms of reliability, speed, safety, and reduced travel time and act as a substitute for some private car usage. Automobile-oriented planning policies in contrast tend to increase urban sprawl by improving accessibility to urban-fringe locations and by increasing the amount of land required for development (see Litman, 2008). Policies which support rail-based transportation and pedestrian activities tend to encourage more compact and mixed developments. As a consequence of this, rapid rail systems such as metro-based transportation have become a preferred policy approach for avoiding road congestion and other detrimental effects of urban dispersal in future development.

Given this framework, this paper is aimed at examining the scenario-based impacts of new transport provision of Metro North by developing a Cost-Benefit Analysis (CBA) methodology for the economic evaluation of the future land development processes in the Greater Dublin Area (GDA). Literature on transportation research identifies CBA as the most commonly used approach in the national evaluation of transport policy and investments in Europe. For instance, EURET (European Research on Transport)[1] mentioned that a majority of European countries rely on CBA in their national appraisal strategies (see EURET Concerted Action 1.1., 1996). Accordingly, the European Commission (EC) recently published 'A Guide to Cost Benefit Analysis of Investment Projects' contributing to shared European wide project appraisal guidelines in a broad conceptual framework (EC Final Report, 2008). These provided basis for the present study for evaluating the impacts of Metro North investment and urban development in the GDA.

Further to this, in the literature there is wide variety of studies examining different aspects of transportation policies and provisions using the methods provided under CBA approach. The literature can be examined under three main groups: The *first group* analyses the impacts of transportation networks on the structure of land development by applying CBA in either qualitative or quantitative framework. Some examples of qualitative studies are Haywood (1999), Walton and Shaw (2003), Ryan and Throgmorton (2003), Handy (2005) and Donaldson (2005). These studies questioned the effectiveness of transportation policies considering their

[1] EURET (1991-1993) is one of the European Commission research programmes of the second framework of community research and technological development. The programme is aimed at "*harmonization, technical standards, safety requirements and upgrading of best practice for individual operators and all of these results will have a positive impact on the economic and social cohesion of the EU, as well as contributing to an overall improvement in the competitiveness of the European Transport Industry*" (EURET Programme Evaluation Final Report, 1995: 4).

impacts on land development processes and the urban form. There is much literature on quantitative studies which follows the rules and principles of conventional CBA approach (see Adler, 1987): Different country examples are given in Pearce and Nash (1973), Mills (1977), and Rus and Inglada (1997). The first two are examples of an economic appraisal of inter-urban road and motorway schemes in the UK while the third focuses on a CBA of rapid rail transportation in Spain. A common basis for the evaluation of these different modes of transport is the quantification of costs and benefits through a specified time horizon followed by discounted cash flow analysis resulting in Net Present Value (NPV), Benefit-to-Cost Ratio (BCR), and Internal Rate of Return (IRR).

The *second group* of studies focuses on *specific* or selected priority indicators to measure and evaluate the costs and benefits of transportation provisions. In this group, there are analyses of the appraisal of transportation projects through examining the effects on real property prices, and studies on relationships between transportation investments and land-use development through deriving accessibility measures. Relevant studies of this type include Sheppard and Stover (1995), Forrest et.al. (1996), Ryan (1999), and Debrezion et.al. (2007) which research the relationship between property values and transportation provisions. Others incorporate scenario analysis into the accessibility appraisal of integrated transport-land use strategies. This is developed through deriving accessibility measures and examinations of the transport-land use relationship incorporating these accessibility measures on different land development scenarios. Geurs and Van Eck (2003), for example, dealt with accessibility impacts of different land-use scenarios by introducing comprehensive accessibility measures in their integrated transport-land use model for their study area of Netherlands (see also Geurs et.al. 2006).

The *third group* searches the existing evaluation methodologies of transportation policies either within EU or country specific context. Some examples can be found in Bristow and Nellthorp (2000) and Odgaard et.al. (2005). Among these, Bristow and Nellthorp (2000) reviewed the national appraisal frameworks for 14-EU countries and reached two key conclusions: First, standard CBA approach is used widely among EU countries along with the use of Multi-Criteria Analysis (MCA) and descriptive frameworks by some of the countries in the previous stages of project development. Second, the infrastructure investment appraisal is mainly based on a range of socio-economic and environmental impacts. Direct impacts including the 'construction costs', 'vehicle operating costs', 'time savings' and 'safety' are commonly agreed to be included in a CBA by placing a monetary value on each of them. The inclusion and coverage of environmental and socio-economic impacts vary significantly across the countries. In a later study, Odgaard et.al. (2005) reviewed the national appraisal practice in EU countries after the recent expansion of the EU to 25 countries in 2004. In line with Bristow and Nellthorp's (2000) findings, they stated that CBA is widely used in the assessment of transport projects along with the usage of other methods i.e. MCA, quantitative and qualitative assessments in a complementary framework.

The summarised literature provides means for the urban land development impact evaluation of Dublin's Metro North by utilizing the scenario-based CBA approach. In relation with differing sustainability implications resulting from various land-use policies, scenario development has become a common tool among scholars, practitioners and policy makers for the impact assessment of various policies on the land use changes. In practical applications, scenario analysis is achieved through the usage of computer-based land-use/transportation modelling, which provides the basis to simulate alternative land development patterns ranging from urban containment to sprawl or transport-oriented corridor developments. Within this framework, the MOLAND (Monitoring Land Use/Cover Dynamics) Model is developed as part of the Urban Environment Project (UEP)[2] for evaluating the impacts of different policies and programmes on urban development considering the sustainability in urban form and peri-urban-rural relationships. The most important feature of such models is the application of cellular modelling to the land cover-which is named as cellular automata (CA). The MOLAND Model is an example of these models which is based on CA (developed initially by White et.al. 1997). This technique involves a variety of inputs to determine the state of the land-use in each cell according to a set of transition rules-representing the compatibility of land-uses with each other.

[2] UEP is carried out at University College Dublin in the School of Geography, Planning and Environmental Policy/Urban Institute Ireland, and funded by the Environment Protection Agency.

This paper will evaluate two different scenarios of GDA i.e. baseline-*as is*- scenario and *with rail* scenario on the basis of transportation and associated development trends and policy implications. Given these two scenarios, the impacts of metro investment project will be assessed through the selection of related indicators, which are evaluated by utilizing the CBA approach. The second section focuses on scenario analysis and the associated MOLAND Model-used as a tool for the development of scenarios. In section 3, a case study on land-use impact assessment of Metro North investment is provided with the initial CBA results, and followed by conclusions.

2. Urban Land Use Scenarios from MOLAND Model

2.1. MOLAND Model

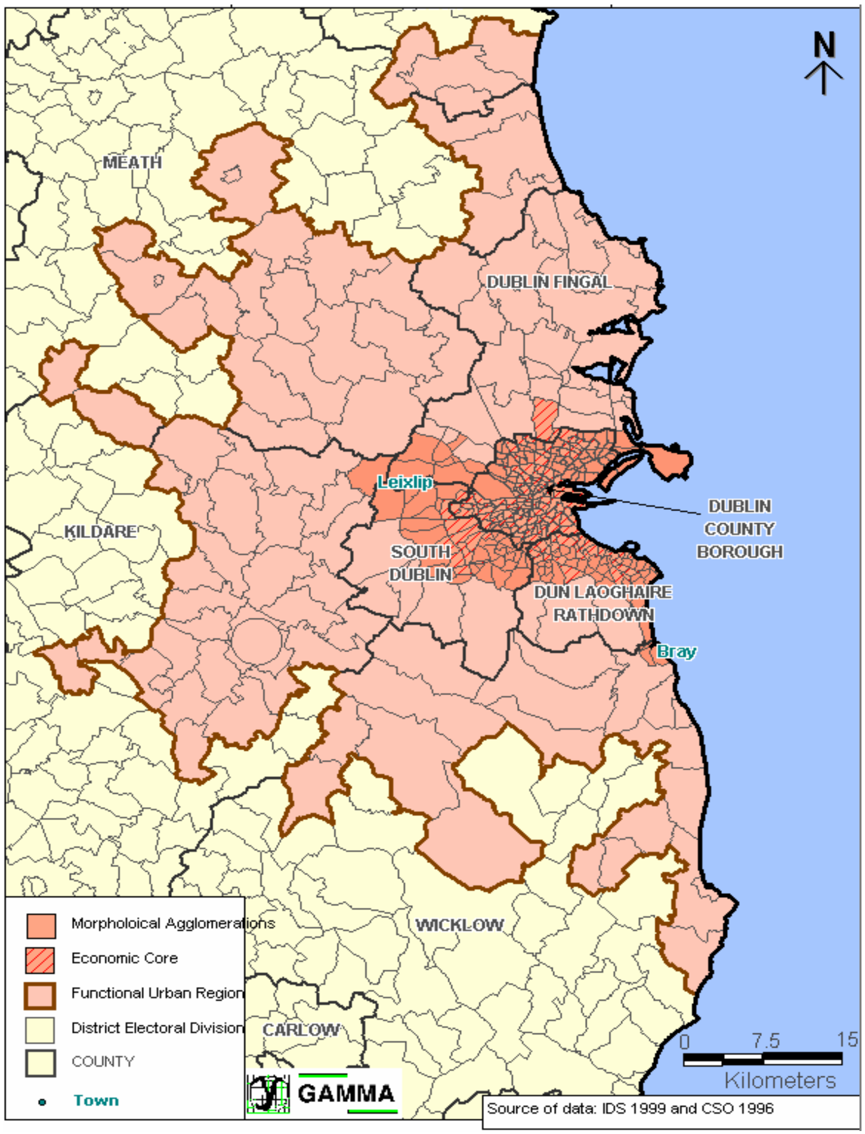
The MOLAND Model was initially developed by the University of Maastricht for the Joint Research Centre (JRC) of the EU with an aim of monitoring, assessing and modelling the development of urban and regional environments. This model has been adapted and calibrated at UCD for use in the Dublin Region. In the regional level, there are four sub-models in MOLAND and identified as: (a) *regional economic sub-model*-calculating sectoral production and employment followed by a spatial allocation among the regions, (b) *regional demographic sub-model*-calculates the growth of regional population and allocates among the regions for the demand of housing, (c) *transportation sub-model*-is a four-stage model calculating the changes in traffic flows and the resultant impacts on land-use accessibility and inter-regional distances, (d) *land-claim sub-model*-translates the regional socio-economic growth numbers into a spatial representation for a further detailed allocation at the cellular (local) level (see Engelen et.al. 2007). The model has four parameters in the local level which are subject to CA modelling practice. These include: (a) *suitability*-referring to the degree to which a cell could support a particular land-use function and related economic/residential activity, (b) *zoning*-represents the institutional planning zones and the associated boundaries, (c) *accessibility*-represents the relative importance of each transportation link/node to each land-use class, and (d) *neighbourhood (transition) rules*-determines the degree to which each land-use function is attracted to/ repelled by each of the other functions present in the neighbourhood (see Lavalle et.al. 2004).

The model developed for GDA has two components including regional and urban land-use sub-models. The model includes an extensive data set covering the years 1990, 2000 and 2006 and utilizes both macro and micro-type parameters. Macro-level data such as GDP and population growth are inputs for the regional sub-model, also affecting the urban land-use sub-model which is run through a CA model. Since the data incorporated in this model comes from disaggregated data set, the micro-model parameters i.e. neighbourhood effects, accessibility, zoning, population, employment indicators etc. can be utilized to explain the micro-level spatial issues. The application of micro-model parameters diverge the model from those incorporating aggregate data sets and relying on large geographic districts.

2.2. Scenario Analysis for the Greater Dublin Area (GDA)

The GDA is composed of four parts including: Dublin Region (Dublin city, Dun Laoghaire-Rathdown, South Dublin, Fingal), Kildare, Meath, and Wicklow (see Figure 1). The economic growth, which has started in the early 1990s, has had substantial impacts on the physical structure of the GDA. Integration within the global economy enhanced the role of Dublin Region in attracting high volumes of foreign direct investment; and in this respect, the Region has become the national focal point of knowledge-based economic growth. This economic development also contributed to equally dramatic changes in the demographic structure. There are significant increases in population levels in the GDA: Within 1996-2002 and 2002-2006 periods, the population in the area increased by annual rates of 1.5 and 2.1 percent, respectively (see Williams et.al., 2007: 34). As the economy has continued to expand, this population growth has accompanied by substantial increases in demand for urban space in order to house the activities of business and employees. However, the supply response to this dramatically increasing demand was not adequate. The reason can be related to the supply shortages due to the market imperfections and inadequate infrastructure provision or the restrictions in planning and zoning regulatory systems. From the early times of economic growth, it is well known that "*the absence of a comprehensive plan integrating the transportation and land-use developments has led to an uncontrolled urban spatial development*" (Williams and Shiels, 2002:1); and as a result, the city is experiencing a significant dispersal of population, housing, and employment functions beyond the existing metropolitan borders (see Figure 1).

Figure 1. Spatial Structure of GDA[3]

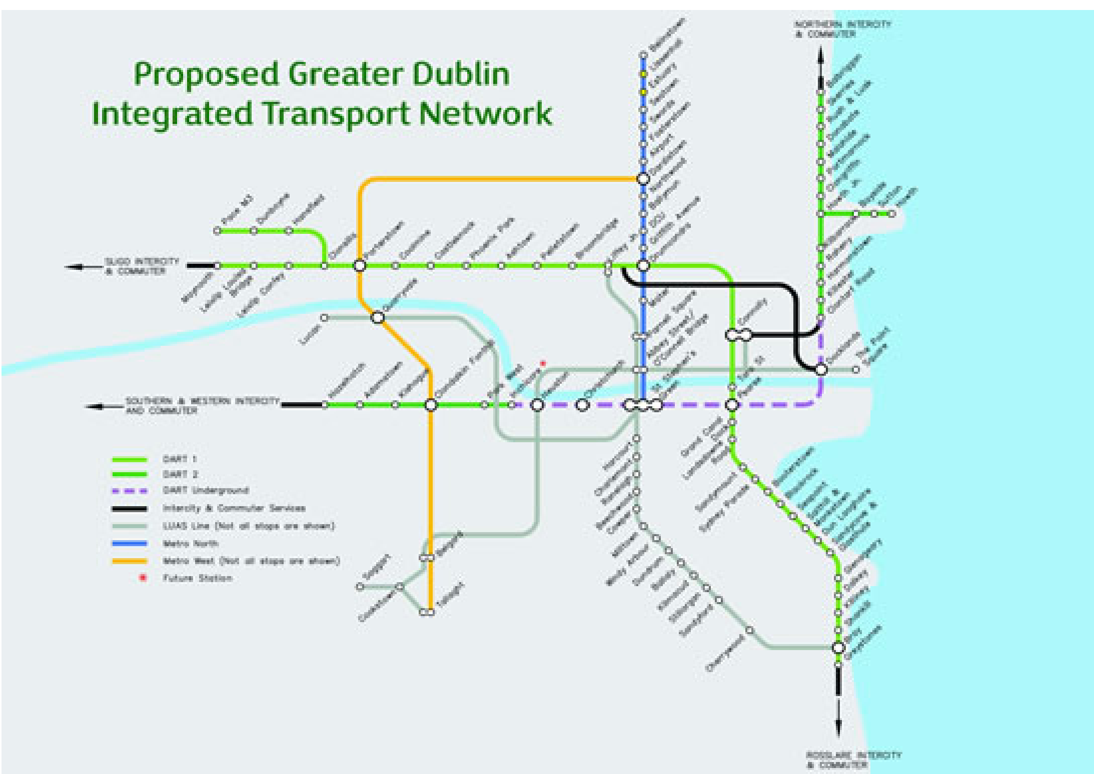


Source: Williams et.al. 2007

[3] **Notes:** (a) Morphological Agglomerations are related to population densities in the contiguous built-up area of Dublin, (b) Economic core includes the main areas of employment and economic activity, (c) Functional Urban Region is defined in relation with the labour force travel patterns.

Following the knowledge-based economic growth of 1990s, the attempts to encourage the emergence of Dublin as a 'knowledge city' have continued (Sokol, 2006: 22). Within this framework, the Dublin-Belfast corridor has gained importance in the last decades since the corridor has been considered as a priority potential area stimulating economic growth. Both national and local planning authorities give great emphasis to the Dublin-Belfast corridor in order to achieve complementary development and good physical interactions within the area (see Cussen and Hetherington, 2006). Accordingly, the growth of Dublin-Belfast corridor is supported by assigning various growth centres in the Area. In either regional or local scale, it is important to support this projected growth by the provision of required transportation infrastructure. To provide transport infrastructure for the expanding population, central government introduced in 2006 a new transportation strategy for the Dublin Region which is known as the Transport 21 project (see Figure 2). There is specific emphasis on the rail investments -in particular the Metro North project- in order to achieve more compact and mixed developments along the rail lines and in urban centres.

Figure 2. Rapid Rail System in Transport 21 Project



Source: Transport 21 (2009)

In this research, we have considered a variety of scenarios taking into account either economic recovery or prolonged recession. Some examples of the scenarios used new transport provision of Metro North as part of the Transport 21 project considering its linkages with future land development processes are discussed in this section. The transportation-land-use relationship will be evaluated by considering different scenarios i.e. a baseline-*as is*- scenario and an alternative compact development scenario i.e. *with metro* developed by the MOLAND Model.

In the case of economic growth, baseline -*as is*- scenario assumes that no new metro investment is carried out within the GDA while the alternative *with metro* scenario includes metro investment project in the north part of the Region. According to the baseline scenario, the city will continue to grow with the present trends, and presented a 'dispersed growth' approach compared to the more compact forms of urban development which will be achieved through the integrated land-use transportation decisions in the local and regional plans. In the alternative scenario, which used metro-based transport infrastructure to encourage a transfer from private transport, resulting efficiency and environmental benefits are examined. In particular this study will examine the extent to which this scenario assists in improving accessibility, and land-use change which supports compact and mixed developments. The key assumptions related to each scenario are shown in Table 1.

From Table 1, compact development is characterised by steady population and economic growth with new high density residential development taking place inside the city, and polycentric urban agglomeration associated with the provision of Metro North and other Transport21 investments. The integrated planning in transportation and land use could support developments such as self-sufficient towns along newly provided public transport corridors limiting the number of commuting trips to the central Dublin Area. Compact urban development scenario outcome (economic growth case) is presented in Figure 3 (b). By contrast, baseline-*as is*- scenario (economic growth case) does not consider rapid rail infrastructure investments but just slight improvements in regional and local roads with better links to the motorways. Under this scenario, new residential constructions i.e. dispersed single-dwelling houses are encouraged in the country side resulting from limited integration in land-use/transport planning and weak

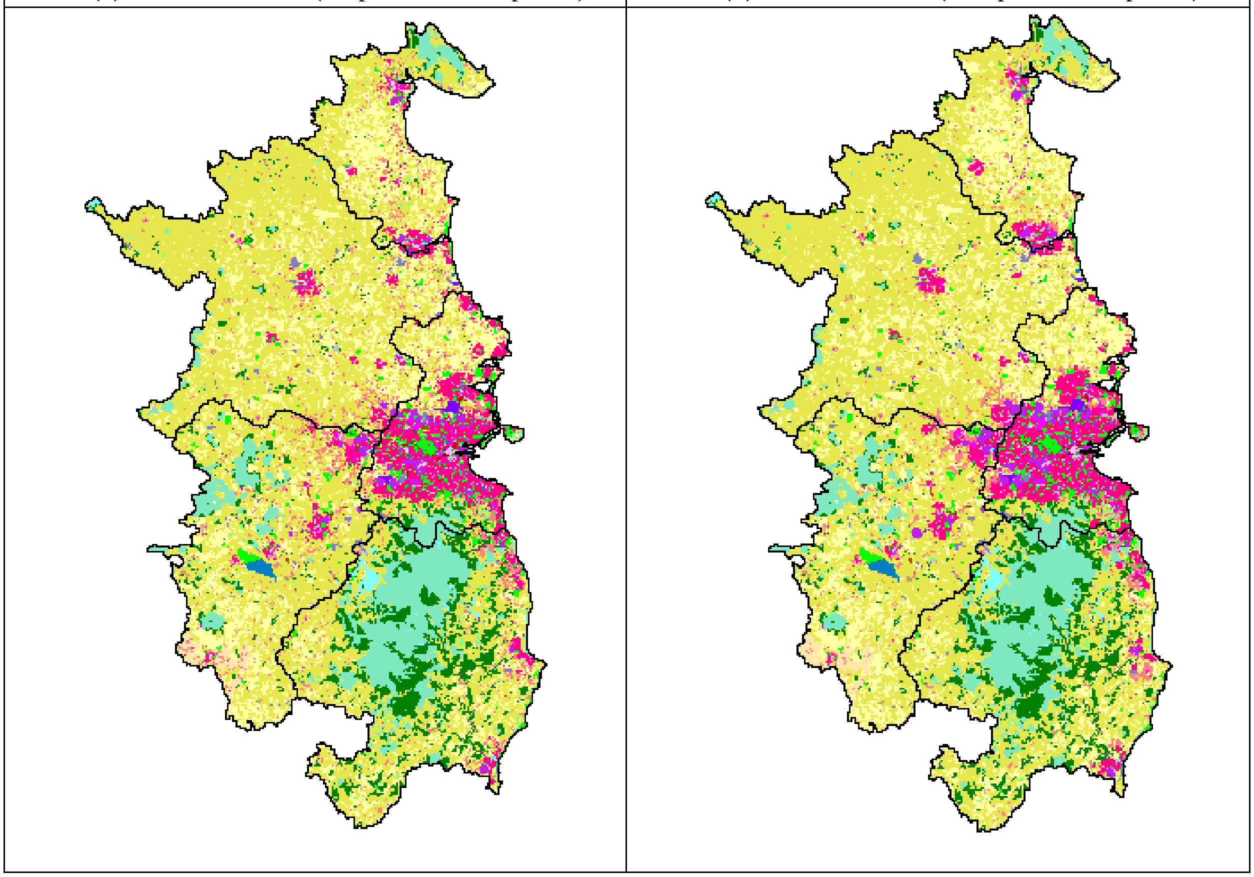
Table 1. Characteristics of Urban Development Scenarios in GDA

	***Baseline-as is*-Scenario: Dispersed Development**		***With Metro* Scenario: Compact Development**
	Continuous Economic Growth	*Prolonged Recession*	*Continuous Economic Growth*
Population	Steady population growth: -In migration -Increased fertility rates	Moderate population growth: -Net zero immigration -Increased fertility rates	Steady population growth: -In migration of young -Increased fertility rates
Economic Trends	-Steady increase in GDP -Investments in manufacturing, human capital, high tech sectors, agriculture -Increase in exports decrease in imports are strongly encouraged -Tourism, agro-tourism and service sectors are strongly encouraged	-Modest increase in GDP (in progress)	-Steady increase in GDP -Invest more in: manufacturing and human capital -Continued investment in high-tech sectors concentrating in existing urban environment -Exports are highly encouraged -Reinforcement of agro-tourism
Spatial Development/ Planning	-New constructions are encouraged in rural hinterland -Improvement of urban infrastructure (roads, information networks, sports/recreation, stores)	-Decline in demand for new development -New residential development in the country side but in limited numbers	-Polycentric urban agglomeration associated with the conservation/ restoration of existing buildings. -New residential development inside the city– increased density by multi-stories buildings.
Transport	-Improvement of regional and local roads - Better links to the motorways	-Investment in Metro North in 2014	-Investment in Metro North in 2014 -Investment in other Transport21 railways in 2020
Overall Trends	-Low environmental protection -Dispersed single-dwelling housing growth in the country side	-Low environmental protection -Small-scale housing growth in the country side	-High environmental protection -Self-sufficient towns limiting commuting to Dublin Area

environmental protection policies. Dispersed development scenario of GDA could be seen in Figure 3 (a). An alternative scenario is the prolonged recession case which considers the prolonged impacts of economic crisis in the GDA. This sub-scenario is characterised by a decline in demand for new residential development as a result of the reduction in economic activity. The new small-scale housing takes place in the countryside but in limited numbers. This will result in dispersed development but at a moderate level compared with the urban dispersal in the continuous economic growth case. Metro North project will take place in this scenario considering that the project will be funded from the EU sources and the economic climate does not have any impact on the initiation of the project but has a major impact on cost-benefit analysis. The modelling work of this scenario by MOLAND is still in progress.

Figure 3. Scenarios of Dispersed and Compact Development based on Economic Growth in the GDA

(a) SCENARIO 1 (Dispersed Development)	**(b) SCENARIO 2** (Compact Development)



3. Scenario-Based Impact Assessment of Metro North: A CBA Approach

3.1. Specification of Impacts and Indicators

Given the literature on the comparison of international and EU country examples for the transport policy evaluations, the common impacts are specified for the appraisal of metro investment project and urban development in the GDA. The selection of related indicators are based on four main types of criteria including direct impacts of transportation infrastructure provision, socio-economic impacts, transportation network effects, and energy and environmental impacts. The list of the suggested impacts and indicators are summarized in Table 2. Considering data accessibility and reliability, the issues of double counting and the major role of specific impacts in the CBA; some of the impacts were eliminated from the analysis as shown in Table 2.

Table 2. Summary of Selected Impacts and Indicators for the Evaluation of Land-Use Impacts of Rapid Rail Investments

Impacts/Indicators[3]	**Suggested Indicators/Impacts for the European Area**
1. Direct Impacts of Transportation Infrastructure Provision: -Transportation Facility Land Values -Development Costs/ Capital Investments -Adjacent Property Values	*Costs/ Capital Investments of Transportation Infrastructure (M)*
2.Socio-Economic Impacts: *a. Land Development Impacts:* -Green Space Preservation -Public Service Costs	*Costs of Providing Public Services (M)*
b. Transportation- Related Impacts: - Savings in Vehicle Operation Costs - Travel Time Savings - Reduction in Risk of Accidents - Comfort and Convenience - Traffic Congestion Effects	*Vehicle Operation Costs (M)* *Travel Time (M)* *Accident Costs (M)*
c. Socio-Economic Development Benefits: -Affordability (Housing) -Affordability (Transport) -Social Inclusion -Socio-Economic Growth -Land-Use/Transport Accessibility -Area Property Values	*Area Property Values (Q)*
3. Transport Network Effects: -Reliability/Quality of Transport Service -Systems' Operating Costs	*Systems' Operating Costs and Revenues (M)*
4. Energy and Environmental Impacts: -Climate Change Emissions (Greenhouse Gas Emissions) -Air/Noise Pollution Exposure - Energy Consumption	*CO_2 Emissions(M)* *Local Air Pollution (M)*

[3]Adapted from: Janic, 2003; Litman, 2008

Note: (M) denotes the indicators with a monetary value while (Q) representing the qualitative or quantitative assessment.

The summary of the cost-benefit evaluation process for the GDA could be summarised as follows: The evaluation process starts with the scenario analysis and the construction of baseline-*as is*- and alternative *with metro* scenarios. In the first stage, impacts and indicators are calculated and valued representing the costs and benefits of *with metro* scenario over the baseline scenario. CBA is applied to all of the monetary valued indicators (see Table 2), and the resultant outcomes are represented by Net Present Value (NPV), Internal Rate of Return (IRR) or Benefit-to-Cost ratio B/C. The economic NPV formula is computed in equation (1) which is followed by the B/C and IRR formulas in equations (2) and (3).

$$ENPV = \sum_{t=0}^{n} a_t S_t = \frac{(b_0 - c_0)}{(1+r)^0} + \frac{(b_1 - c_1)}{(1+r)^1} + ... + \frac{(b_n - c_n)}{(1+r)^n} \qquad (1)$$

$$B/C = \frac{\sum_{t=0}^{n} \left[(b_t) / (1+r)^t \right]}{\sum_{t=0}^{n} \left[(c_t) / (1+r)^t \right]} \qquad (2)$$

$$IRR : \sum_{t=0}^{n} \frac{(b_t - c_t)}{(1+i)^t} = 0 \qquad (3)$$

where S_t is balance of cash flow funds comprising flow of benefits, b_t, and flow of costs, c_t; a_t is discount factor, r is discount rate, n is the evaluation period and (i) in equation (3) is the Internal Rate of Return, equating discounted net benefits to discounted investment costs (see European Commission Final Report, 2008). The outcomes from these three formulas will be used directly in order to compare and evaluate the results from scenario analysis of baseline-*as is* and *with metro* cases.

3.2. Initial Results from CBA

For the CBA of the various scenarios of economic growth[4] i.e. baseline-*as is*- and alternative *with metro*, the first step is to compute the balance of cash flows for each year starting from 2011.[5] The period 2011-2015 is the assumed construction period for the Metro North project, 2016 is the first year of metro operation, and 2029 is the forecast year in which the whole Transport 21 program is assumed to be carried out (see Figure 2). From the cost-benefit cash flow data, ENPV, B/C and IRR values are derived and presented in Table 3 below.

Table 3. Initial Results from Net Present Value of Costs and Benefits as at 2010

Discount Rate	ENPV	B/C Ratio	IRR	Evaluation Period
3.0 %	1,305 million €	1.65/1	0.05967 (6 %)	2011-2045 (35 years)
3.5 %	1,009 million €	1.51/1		
4.0 %	749 million €	1.38/1		
4.5 %	521 million €	1.27/1		
5.0 %	321 million €	1.16/1		

Note: Initial CBA results exclude the value of local air pollution

For the discounted cash flow analysis, a 35 year period is chosen starting from 2011 and ended in 2045. All the values are calculated considering five different discount rates of 3.0%, 3.5%, 4.0%, 4.5%, and 5%. Table 3 indicates that ENPV is significantly positive in continuous growth scenarios across all the different discount rates and there are also benefit-to-cost ratios exceeding 1.0 for each discount rate. IRR is computed as 6% greater than all the discount rates considered. Given these initial CBA results explained above, the next step is to follow with sensitivity analysis to test the effects of uncertainty in the value of indicators. Therefore, sensitivity analysis will be used as a means of testing the robustness of the appraisal outcomes. Initial sensitivity testing will be conducted by focusing on specific indicators in ongoing research, the details of which are summarized in Table 4.

[4] Recession scenario results will be considered in sensitivity analysis, which is currently in progress.
[5] The details for each of the cost-benefit cash flows could be accessed from authors' original research.

Table 4. Summary of Initial Sensitivity Testing

Factors/Impacts subject to Sensitivity Testing	**Sensitivity Test**	**Explanation**
Optimism-bias in capital costs	-40%	Original capital cost estimates will be tested to the capital costs with optimism-bias uplifts
Value of time*	VTTS -20% VTTS +20%	*Uncertainty in National Value of Travel Time Savings (VTTS):* Appraisal results from national appraisal guidelines will be sensitivity tested to VTTS values +/-20 % of those national values
Inter-temporal elasticity to GDP*	$E_{\text{Inter-temporal}} = 0.7$ vs. $E_{\text{Inter-temporal}} = 1.0$	*Treatment of VTTS over time:* Inter-temporal elasticity to GDP per capita growth of 0.7 will be sensitivity tested to elasticity to GDP per capita growth of 1.0.
Elasticity to income for work trips*	$E_{\text{VTTS, Income}}=0.5$ vs. $E_{\text{VTTS, Income}}=1.0$	*Treatment of VTTS based on income variations:* A cross-sectional elasticity to income of 0.5 for passenger work trips will be sensitivity tested to the cross-sectional elasticity to income of 1.0.
Accidents*	Value of safety /3 Value of safety*3	Appraisal results will be sensitivity tested by using v/3 as low and v*3 as high sensitivity
Social discount rate	3.5% compared to 3% 4.0% compared to 3% 4.5% compared to 3% 5.0% compared to 3%	Appraisal results from various discount rates will be tested to those computed by applying the base discount rate of 3%.
Public Service Provision Costs	High growth vs. Low growth projections in population	Public service provision costs computed for high growth scenario population projections will be tested to the costs with low growth scenario population projections

Note: *Adapted from: HEATCO: D5 (2006)

4. Conclusion

In this paper, research on transportation/land-use relationship identifies key linkages and impacts of transportation infrastructure provision on land development trends. A CBA approach is the applied methodology for the evaluation of the impacts of metro-based investments in relation with urban form and development. The paper has identified four main types of criteria for the cost-benefit evaluation of the impacts including direct impacts of transportation infrastructure provision, socio-economic impacts, transportation network effects, and energy and environmental impacts. With an aim to identify certain key inputs, some of the impacts were eliminated from the analysis based on the issues of double counting, lack of available data in the monetisation of specific impacts and the marginal role of some specific impacts in cost-benefit analysis. The values and parameters for the appraisals of capital costs, public service costs, accident rates, vehicle operation costs, systems' operating cost and revenues, travel time and costs of carbon dioxide emissions are specified for the evaluation of metro investments within a scenario analysis framework.

In order to assess sustainability implications of various urban forms resulting from differences in planning policies and implementations, potential urban structure future of GDA has been analyzed by utilizing the scenario analysis carried out by the MOLAND Model. Initially two scenarios are generated from the MOLAND applications, including compact and sprawled developments of economic growth. In terms of sustainable urban development considerations, uncontrolled sprawl in the baseline case is the least desirable one since costs of such development exceeds the benefits. In contrast, compact development policies with continued economic growth -as in the metro-oriented development and consolidation- could achieve considerable benefits over the baseline scenario by reducing the negative consequences of unregulated sprawl. However, scenarios of prolonged recession may have different implications in terms of costs and benefits associated with the resultant urban form of such scenarios. Further research is required in sensitivity analysis to establish if such benefits can still be achieved.

MOLAND modelling and scenario-based cost-benefit analysis provide the basis for governments and local authorities to assess the future of their planning and policy making actions from the point of social welfare gains and losses. The evidence from CBA of this modelling work has pointed out that *with metro* scenario of compact development can have benefits over sprawled development in the baseline scenario. This will allow the CBA approach be used as a policy support tool in discussions of alternative development and investment decisions such as compact versus dispersed developments. Following research linked with this analysis will involve the sensitivity testing of the CBA model, and a further scenario analysis of dispersed development in the GDA under prolonged recession case.

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