Developing a CBA methodology for the Scenario-based land-use impact assessment of proposed rail investments in the Leipzig Region

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This paper develops a methodological approach to be utilised for the evaluation of transport-land-use impacts of rapid rail investments in the Leipzig Region with the potential for this approach to be used for other European regions. Various land development scenarios are generated from the MOLAND Model[4] applications.

The land-use scenarios considered in this research are a baseline scenario of dispersed development and an alternative scenario of more compact urban developments associated with potential rapid rail provisions in the Leipzig Region.

The appraisal of transport-land-use relationships is subject to the use of economic indicators and can be evaluated based on alternative land development scenarios developed for the Leipzig Area. In this context, key elements of a Cost-Benefit Analysis (CBA) approach will be developed for the evaluation of potential costs of urban rail provisions with its alternative. This will contribute to the existing framework for the transport policy and planning decisions concerning Leipzig and other regions internationally.

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[4] MOLAND simulates various development conditions by using the historical land-use data through the utilisation of cellular modeling.

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Introduction

In the recent decades, there has been an increasing trend of non-metropolitan growth in peri-urban areas, although varying in intensity and scale throughout different urban centres. Evidence of contrasting development trends have emerged with an urban regeneration driven return of development to central areas of economically strong regions. In contrast, in regions with lower levels of economic growth a gradual dispersal of development into peri-urban areas has occurred potentially weakening central core areas such as Leipzig[5].

It is recognised that dispersed patterns have significant implications for long-term urban development patterns. This type of development in the built-up area is generally associated with high social, economic and environmental costs. This paper will focus on empirical evidence related to alternative development patterns emerging in Leipzig Region to assist in evaluating the effectiveness of policy measures. In addition, the paper will explore policy support evaluation measures relating to the Cost Benefit Analysis (CBA) tool in assisting the evaluation of new rapid rail infrastructure proposals.

Given this framework, the following section focuses on various land development scenarios ranging from urban compaction to dispersal in the Leipzig Region. In section 3, a CBA methodology on land-use impact assessment of new rail provisions is provided for the Leipzig Area, and followed by conclusions.

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Scenarios for the Leipzig Region

A number of scenarios were developed with key policy stakeholders following focus group meetings in the region as part of research in the Plurel project (Lavalle *et al.*, 2009). Two likely scenarios are considered for the Leipzig Region in this paper which take into account both dispersed and more compact development patterns. In this respect, the transportation-land-use relationship in Leipzig will be evaluated considering: 1) a dis-

[5] Leipzig area has been experiencing a shrinkage process following the German reunification starting from the early 1990s. Following the population decline, a further undesirable consequence of the economic crisis in this period is the rapidly growing vacancy rates causing disinvestment, neighbourhood blight effects and decaying infrastructure in those areas of high vacancy rates (Glock and Häussermann, 2004). The outer city became an attractive place for investors considering the absence of planning regulations and policies.

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persed development *hyper-tech* scenario, and 2) a more compact development scenario, each developed with the assistance of the MOLAND Model.

Scenario 1: Hyper-Tech Scenario of dispersed development

This scenario is characterised by a rapid technology advance and consequent growth in the economy. New industrial and commercial growth take place in the entire area, in particular this growth is mainly directed to the Halle (the second most important urban area) and other towns located south of Leipzig (Fig. 1a). The impacts of steady growth in population and economy can be seen in the form of dispersed developments comprising residential, commercial and industrial areas (Lavalle *et al.*, 2009).

The most important feature of this scenario is the insufficient provision of rapid rail infrastructures linked with urban growth and the result is a form of dispersed settlements. There are only minor improvements in the national roads and provisions of links and extensions to the motorways and airport. The absence of a rapid rail investment, passive management of urban development and low environmental protection in this scenario all contribute to a dispersed urban development.

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Scenario 2: Scenario of compact development

According to the compact development scenario, it is assumed that demographic and economic growth will be in line with present trends (slight population growth due to low fertility rates, aging of population and slight in-migration; moderate economic development in key sectors) with only limited increased investments in infrastructure construction to be undertaken (Fig. 1b). In this respect, demolished residential areas will be replaced by infill development of residences and other land uses which leads to a compaction of the existing urban area.

Among main transportation projects to be developed are fast railway links to Munich, Berlin and Erfurt which will serve public transport from surrounding areas to the Leipzig Region in this scenario. The intensification of development in the existing urban areas will result in an increase in access to urban activities *i.e.* jobs, public services, recreation, etc., benefits from access to multi-modal travel options *i.e.* walking, cycling, etc., and reductions in transport-related emissions and pollution. The compact urban form of this scenario is supported by a high environmental protection poli-

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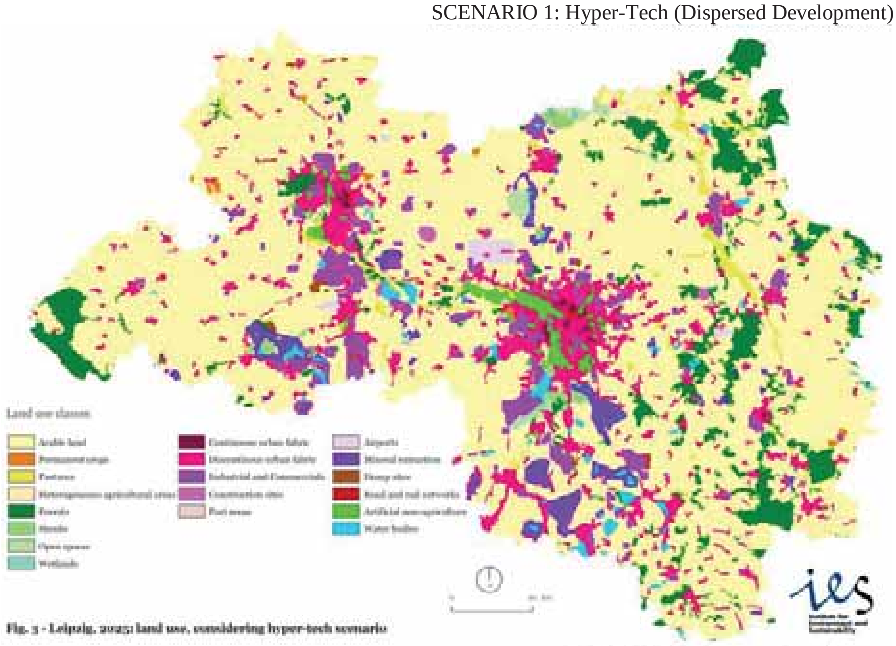
cy which is in contrast to a low environmental protection of the hyper-tech scenario of dispersed development.

SCENARIO 1: Hyper-Tech (Dispersed Development)



SCENARIO 2: Compact Development

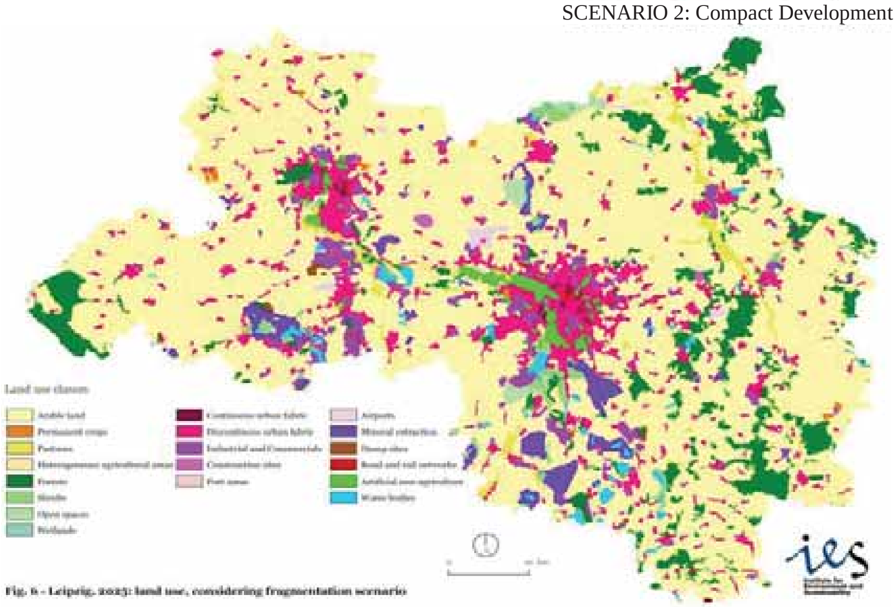


Fig. 1 – Scenarios for the Leipzig Region *Source: Lavalle et al. (2009).*

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A CBA Methodology for the impact evaluation of the rapid rail investments in the Leipzig Region

The scenario-based CBA methodology developed specifically for the Leipzig Region is based on the literature searching the existing evaluation methodologies of transport policies for a general comparison of such methodologies within EU countries or internationally (see Bristow and Nellthorp, 2000; Odgaard, Kelly and Laird, 2005; and others). Assisted by this literature, common impacts are specified for the land-use impact assessment of rapid rail investments in the Leipzig Region. Considering common impacts and indicators given in this literature, the indicators utilised in this research are based on four main types of criteria including direct impacts of transport infrastructure provision (costs/capital investments of rapid rail), socio-economic impacts (costs of providing public services, road vehicle operation costs, road network travel time, accident costs), transportation network effects (operating costs and revenues of proposed rail line), and energy and environmental impacts (CO_2 and local area emissions). The following section will develop a CBA methodology for the calculation of these impacts and indicators which can be evaluated for each of the scenarios considered in this research including dispersed and compact development cases.

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Data and methodology on Impact-Indicator evaluation

To establish an estimate of the likely costs and benefits of the alternative development scenarios, it is necessary to first identify critical impacts and then to establish a reliable basis for monetising the costs and benefits associated with each alternatives.

Accident Costs

This study suggests applications of the figures in serious injury, slight injury and fatal accidents within the catchment of a proposed rapid rail line for computing accident cost savings in the Leipzig Region if the rail investment strategy is followed. In this regard, the road accident costs for the Leipzig case are derived from HEATCO (2004) comprising the value of safety per casualty (willingness-to-pay values) and direct and indirect economic costs (see Tab. 1). For the forecast of future growth in road accident

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costs, the rate of growth in real GNP (or GDP) per person employed is suggested for use concerning Leipzig (see Federal Statistical Office, 2010a).

For calculating accident rates, data comprising the number of personal injury accidents in the local area adjacent to the proposed rapid rail system is required. For the calculation of changes in accident rates between the scenarios *i.e.* hyper-tech and compact scenarios, transportation model forecasts of average (local) road network speed (both in peak and off-peak time periods) information is needed. In assistance with this information, the generic equation showing the relationship between changes in accident frequency and the mean speed from Baruya and Finch (1994) can be utilised to compute the changes in accident rates between the subject scenarios.

The next step is to compute area total estimated rates of casualties and collisions for the two scenarios (peak/off-peak hour totals) and to calculate the changes of rates of casualties and collisions between the scenarios. The changes in accident rates between the scenarios can be valued by using the accident costs in Tab. 1.

Tab. 1 – Forecasted value of accident costs at factor prices (from 2008 onwards)[6].

Year	***Values at factor costs (€)***		
	Fatal per casualty	***Serious injury per casualty***	***Slight injury per casualty***
2008	1,677,893	232,073	18,768
2009	1,621,181	224,229	18,134
2010-2020	1,677,274×1.01m	231,987×1.01m	18,761×1.01m

Vehicle Operation Costs

The unit vehicle operating costs are clearly dependent on the prices of goods within a region (*i.e.* price of oil, vehicle parts, etc.), the transport network characteristics, and vehicle utilisation. However, the operating cost relationships for road vehicles is more generic and transferable between countries (HEATCO, 2004). Since this is the case, cost functions computed originally for the UK can be adapted to the German case (DfT, 2009). This is done by computing the annual efficiency changes up to the year 2010 first and then by converting these figures to market values by applying the appropriate market price of fuel in Germany. The fuel prices are provided

[6] m=0 for the year 2010, m=1 for 2011, …, m=10 for the year 2020. Regarding the post-2020 period, values from favourable and unfavourable condition scenarios were computed and can be requested from the authors.

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for unleaded petrol and diesel type fuels for the year 2010[7]. The monetary values were obtained by applying the average fuel prices to the parameter values provided by DfT (2009) (see Tab. 2). For the future fuel prices, moderate/high price assumptions of crude oil derived from the EU-27 PRIMES energy system model can be considered. Based on the non-fuel relationship provided by the DfT (2009), UK values (at resource costs) were adapted to the Leipzig case by using Purchasing Power Parity conversion, and then inflated to the 2010 values by using the Consumer Price Index (CPI). Non-fuel costs per kilometre can be computed in a similar way as with fuel costs.

Tab. 2 – Fuel costs per kilometer at factor prices[8], Germany (in Cents 2010).

	Fuel costs for	
Average speed	**CAR**	**PSV**
10 km/h	10.46	28.73
20 km/h	8.39	21.65
30 km/h	6.87	17.02
40 km/h	5.82	14.42
50 km/h	5.18	13.38
60 km/h	4.86	13.46
70 km/h	4.81	14.23
80 km/h	4.94	15.24
90 km/h	5.18	16.04

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For the calculation of road vehicle operation costs, transportation model forecasts (*e.g.* MOLAND Model) are required for the change in total distance travelled and average vehicle speeds in the whole road network between hyper-tech and compact scenarios. These figures will also represent changes in total traffic flows in peak and off-peak periods for a number of specified future years. Fuel vehicle operation costs can be calculated by using the following general formula (see Federal Ministry of Transport, Building and Urban Development, 2003, part IIIb):

$$FC = \sum_s \sum_v \Delta FL_s \times BGW_v + \Delta KV_s \times KT \qquad (1)$$

where FC is fuel operation cost, v is index vehicle group, s is index road segment, FL is vehicle mileage (km/year), ΔFL is the vehicle mileage difference in with rail (compact) and without rail (hyper-tech) scenarios (km/year), BGW is operating cost base value (€/km), KV is the fuel consumption per km, KT represents fuel costs in future years (€).

In the case of a compact development scenario developed for the Leipzig Region, the provision of a rapid rail investment necessitates including

[7] See Europe's Energy Portal, available at: http://www.energy.eu.

[8] PSV refers to public service vehicles.

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rail operating costs and revenues into the CBA model. Rail operating costs comprise fixed and variable costs. Fixed costs are those which are independent of traffic volume changes *i.e.* operation, maintenance and replacement costs. On the other hand, variable costs are those changing with the traffic volume (see Tab. 3).

For rail operating revenues, passenger demand data for the newly introduced rail network is required on annual basis. This information can be estimated through a multi-modal transportation model (*e.g.* MOLAND) covering the Leipzig Region. In this regard, transportation model will utilise socio-economic and land-use data to distribute number of trips between existing transport modes and proposed rapid rail system. In line with the passenger demand forecasts for the proposed rapid rail network, average fare estimates are required on annual basis for the calculation of rail operating revenues within project appraisal period.

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Tab. 3 – Elements of Rail Operating Costs for the Leipzig Region. Source: World Bank (2005).

Cost factors		
Vehicle ownership costs	***Vehicle maintenance costs***	***Transportation costs***
Locomotives/coaches (Replacement cost)	Rolling stock/spare parts (Unit cost/Train) Equipment/parts (Unit cost/km-line) Security (Unit cost/km-line) Insurance (Unit cost/km-line)	Train fuel (Unit cost in gross ton-km) Power traction (Unit cost in kWh/ton-km) Train crew wages (Actual by cost centre) Locomotive crew wages (Actual by cost centre) Station operations/other cost (Unit cost/train-km) Billing (Unit cost/car load)

Value of time

As the vehicular traffic on the road network will be reduced due to a shift from car-based transportation to the proposed rail scheme, there will be substantial reduction in journey times. The forecasts in total travel time in the compact and hyper-tech scenarios for all traffic flows in the peak and off-peak periods can be derived from the application of transport model in the Leipzig Region. Benefits from modal shifts between transport systems can be derived by:

$$B = \sum_T VM_{P\text{-}PV(T)} \times \left(K_{PV(T)} - K_{P(T)}\right) \qquad (2)$$

where B represents benefits achieved from transport modal shifts, VM is the shifted vehicle mileage/travel time, K is the total transport cost, PV,

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