FLUTE: The application of a land use and transport model to prioritise infrastructure investment

Revill E., Dobson A., Simmonds D.

David Simmonds Consultancy

Dalgleish S.

AECOM

Byers N.

South Yorkshire PTE

1. INTRODUCTION

This paper describes the development and application of a land-use and transport model for the Sheffield City Region. The model is known as FLUTE (an acronym for Forecasting Land Use, Transport and Economy). It was developed in 2012/13 and is based upon the existing EMME-based transport model for the City Region, SYSTM+, and a new DELTA land-use model. It forecasts changes in population, households, employment, along with the floorspace they occupy, and the trip patterns they generate. It has added functionality to model the viability of site development and remediation, and to calculate the impact on GVA of different policy interventions.

The model was used to support preparatory work on Sheffield City Region's City Deal Bid. Specifically it was seen as a tool that would appraise the GVA impacts of schemes in a consistent way. The modelled schemes tested using FLUTE included enhanced public transport, highways and accessibility improvements, pedestrianisation, energy and cycle ways initiatives, site remediation, introduction of broadband and public realm investment.

The following sections firstly introduce the FLUTE model, secondly they describe the Sheffield City Region's Infrastructure Fund and the requirement both for a prioritisation of schemes and the development of a package of infrastructure investment that would benefit the economy of the City Region. The paper then describes the enhancements to the modelling package that were implemented to model the broader range of infrastructure schemes and finally summarises the key findings from the prioritisation exercise.

2. THE FLUTE LAND USE AND TRANSPORT MODEL

2.1 The FLUTE model – modelled processes

The land use and transport model was developed by AECOM and David Simmonds Consultancy (DSC) in 2012/13. It was based upon an application of DSC's DELTA land use package and an enhancement to the existing SYSTM+ transport demand model, which AECOM had constructed two-three years previously.

The main components of the model are illustrated in Figure 1.

Considering these components, the transport and urban models work at the level of zones, whilst the migration and economic models work at the broader level of areas.

Areas typically correspond to the 2001-based travel-to-work areas, at least within the region of main interest; zones represent finer units within these areas.

The *transport model* takes inputs which describe activities and their car ownership (different categories of residents and jobs) by zone, for a given year. From this and from input transport system data it forecasts travel by car and by public transport. In doing so, it estimates costs and times of travel between each pair of zones, allowing for congestion caused by the forecast traffic. This information is passed back to the land use model. A more extensive description of the transport model is provided in section 2.2.

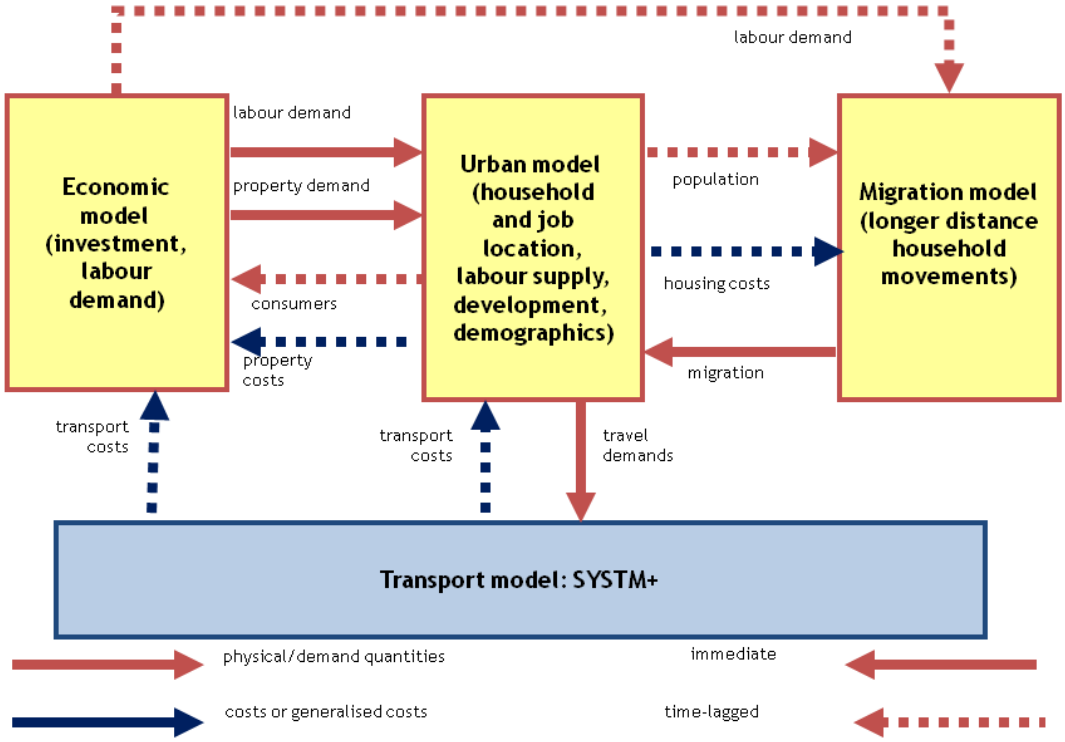


Figure 1 Overview of FLUTE

The land use model comprises an economic model, an urban model and a migration model.

The *economic model* forecasts the growth (or decline) of the sectors of the economy in each of the areas modelled. Employment is initially constrained to be consistent with NTEM v6.2 at Area level. However the model has a variable economic scenario that allows overall levels of growth to 'pivot' around this in response to land use or transport policy interventionForecast changes in employment by sector and area are passed to the urban model.

The *urban model* forecasts the zonal location of households and jobs within the areas that are modelled in detail. Locations are strongly influenced by the supply of built floorspace, and hence the urban model is a set of property models as well as a set of inter-related location models. Locations are also influenced by accessibility, with different measures of accessibility influencing different activities, and by environmental variables. Households are influenced by accessibility to workplaces

and services. Businesses are influenced by accessibility to potential workers and customers.

The locations of households and jobs are fed back to the transport model to generate travel demands. Household numbers are also used to calculate consumer demand for goods and services in each area, for use in the economic model. The rents arising from competition for property in each area affect both the economic and migration models. Information on job opportunities is passed to the migration model.

The *migration model* forecasts migration *between* areas within the modelled area. (Movements *within* areas are forecast in the urban model.) The inputs to this model include job opportunities and housing costs, from the urban model. Job opportunities are a strong incentive to migration; housing costs are a generally weak disincentive.

The FLUTE land use model is essentially a model of land-use and economic *changes* over time, working in one year steps. It has a base year of 2007, so as to be consistent with the base of the original SYSTM+ model. It then has a forecast period that extends to 2031.

The interaction of the land use model and the transport model, described above, typically occurs in every fifth year.

The overall levels of growth in employment and population are calibrated so as to be consistent with an external scenario. For FLUTE this scenario is based upon the Department for Transport's NTEM v6.2 forecasts. These are applied, in the base model, at Area level for employment and at Modelled Area for population and households. A small adjustment was made to the employment forecast for the Barnsley area to reflect concerns of the local council that the NTEM forecasts under-estimated recent economic trends.

The distribution of employment, population and households will be informed by the availability of vacant or new floorspace. This in turn will be strongly influenced by where new development is permitted. The model's inputs of permissible development are based upon information received from the local planning authorities. They reflect their commitments, plan allocations and other assumptions on the future scale and location of development.

2.2 The SYSTM+ Transport Model

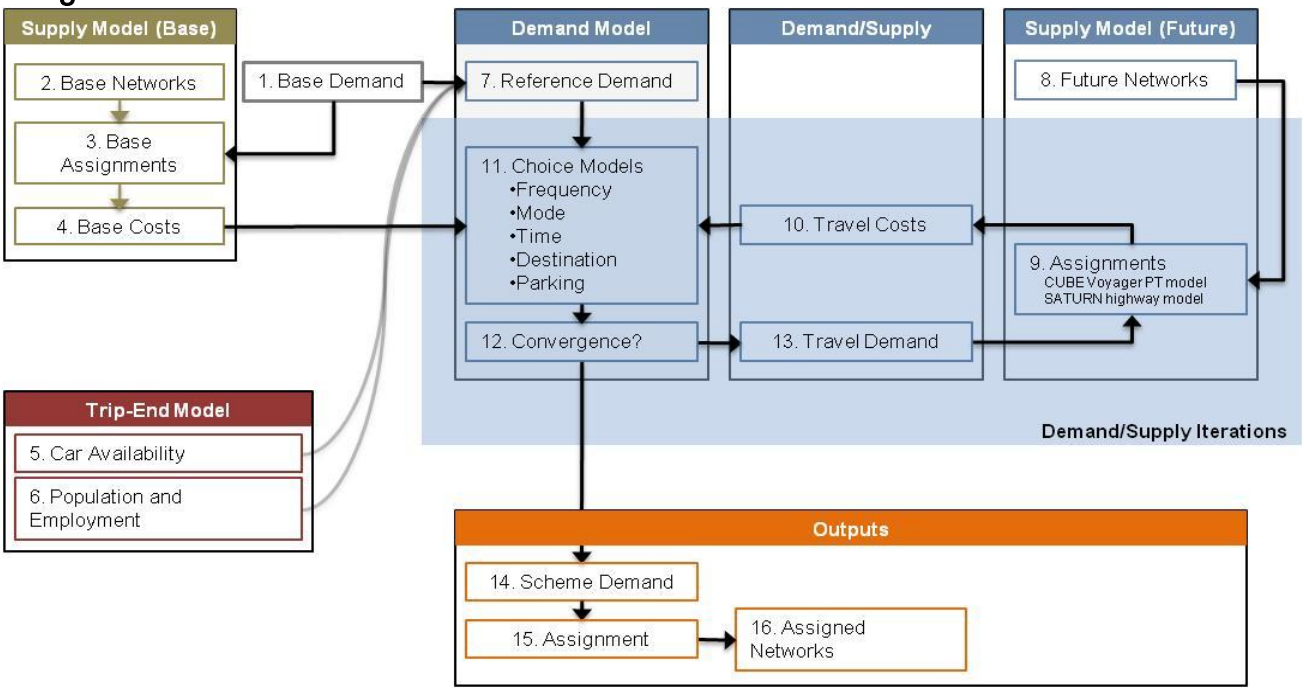
SYSTM+ (South Yorkshire Strategic Transport Model with the + acknowledging the wider coverage of the model across the Sheffield City Region area) is a transport demand model. An overview of the model is set out in **Figure 2.**

SYSTM+ consists of three sub-models. At the heart of the model lies the demand model, which is constructed using EMME software and accepts information on population and employment by zone to create, via the DfT CTripEnd model, an estimate of overall trip making on the transport network that arises. The demand model then uses a WebTAG (Units 10.3.2C – Sept 2009, 3.10.3C – Oct 2009 and 3.10.4C – Sept 2009) compliant structure to determine various transport responses, namely:

- the frequency of trips made for various journey purposes;
- the choice of mode for these trips, influenced by the generalised cost of using various modes as estimated by the model suite;
- the choice of time period for making journeys, where such choice is an option;

- the distribution of trips between a range of destinations, for those journeys where the trip attraction is not fixed (e.g. shopping trips); and
- the choice of using a Park & Ride site as an alternative to urban centre parking.

Figure 2: SYSTM+ Model Structure



A SATURN traffic assignment model and an EMME public transport assignment model provide information on highway network and public transport assignment.

The model suite is completed by the inclusion of a separate parking model, which is capable of modelling the use of Park & Ride sites (to include P&R parking capacity and cost) designed to intercept strategic longer distance trips and car parking cost changes in town and city centres.

2.2 The Geographical Coverage of FLUTE

The Sheffield City Region (SCR) is an area that includes the four South Yorkshire metropolitan authorities of Barnsley, Doncaster, Rotherham and Sheffield along with the neighbouring Shire districts of Bassetlaw, Bolsover, Chesterfield, Derbyshire Dales and North East Derbyshire.

FLUTE's geographical coverage extends beyond the City Region boundary. This is to incorporate the linkages between the SCR and the surrounding areas; residents of adjacent local authority areas will travel to or through SCR on their journeys-to-work whilst some residents of the SCR will commute to workplaces beyond the county boundary.

The model comprises:

- a Fully Modelled Area, which contains the SCR and adjoining parts of West Yorkshire, Lincolnshire, Derbyshire, Nottinghamshire and Staffordshire
- a Buffer Area comprising parts of the former North West, Yorkshire and Humberside, East Midlands, and West Midlands Regions around the Fully Modelled Area.

The Fully Modelled Area and the Buffer Area together comprise the Modelled Area. They are shown in **Error! Reference source not found.**3.

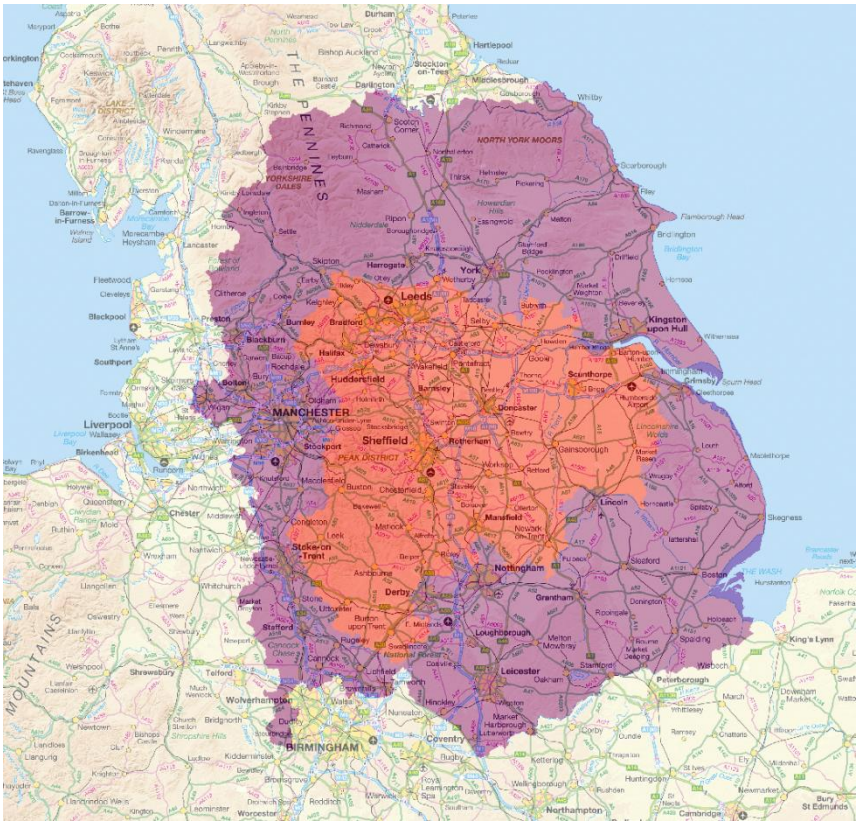


Figure 3 FLUTE's geographical coverage

3. THE SHEFFIELD CITY REGION INFRASTRUCTURE FUND

The Sheffield City Region Investment Fund (SCRIF) forms part of the Sheffield City Deal. The aim of the SCRIF is to develop an investment fund that can finance strategic infrastructure, thereby increasing economic growth within the SCR. The scheme has a primary objective of increasing levels of Gross Value Added (GVA) at the City Region level and secondary objectives of ensuring that access to employment opportunities improve within all City Region districts and within those parts of the City Region that are ranked highest (and hence most deprived) when applying the CLG's Index of Multiple Deprivation (IMD).

An initial invitation for City Region authorities to put forward schemes for SCRIF funding resulted in over 40 separate schemes being identified. From these, a medium list of twenty-six schemes was drawn up. These included those schemes where the planning, costing and scoping were reasonably well advanced. They included schemes requiring:

- site remediation, including the removal of derelict structures and heavily contaminated ground soil;
- the construction of new commercial units;
- improvements to or opening up of site access;
- new highway schemes;
- public transport schemes;
- urban public realm improvements;
- development of green infrastructure; and
- implementation of district heating schemes

The geographical distribution of the schemes is shown in Figure 4.

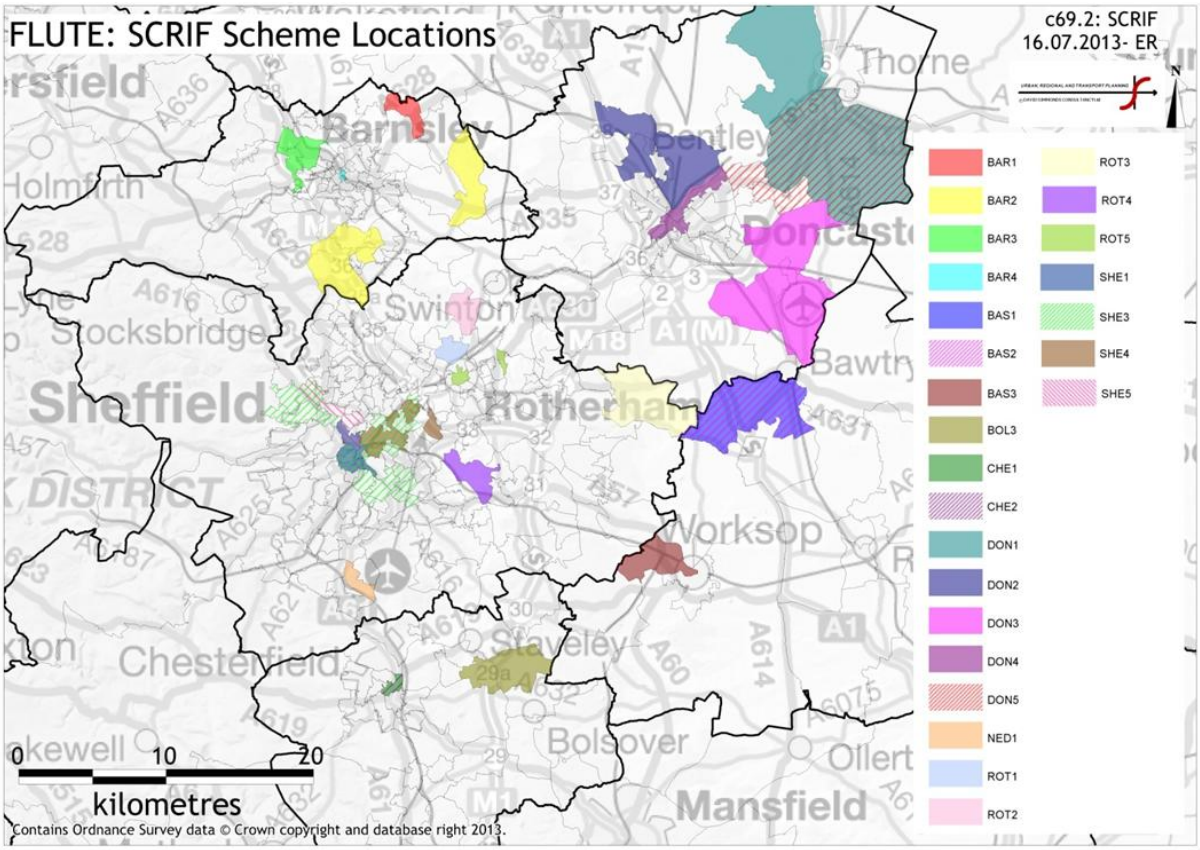


Figure 4 The location of the medium list schemes.

The role for FLUTE was twofold:

- firstly to appraise the economic impact of each scheme upon the City Region in a consistent manner; and
- secondly to appraise packages of scheme both in terms of their impact upon the City Region's GVA and the access to employment of both each district and the areas that scored highest on the IMD ranking.

This role required appraisal that extended beyond the traditional appraisal of land use and transport schemes that similar DELTA applications have been used for. For this it needed:

- some new model enhancements; and
- implementation of DELTA functionality that had not previously been applied within FLUTE.

These changes are described in the next section.

4. MODEL ENHANCEMENTS REQUIRED FOR SCRIF

The model enhancements required for SCRIF formed Stage 2 of the FLUTE development. The key factors that shaped the work of this stage were:

- feedback from the SCR stakeholders; and
- scoping on the likely range of schemes that would need to be tested.

A key piece of feedback, following the initial model runs demonstrating the models capabilities, was that FLUTE was forecasting the development of several commercial sites that would not be developed without considerable public sector intervention. These sites were typically allocations where ground pollution and/or derelict infrastructure made their development commercially unattractive.

A classification of development sites into greenfield, low, medium or high cost brownfield was introduced in response. The three brownfield categories were intended to reflect the varying costs of site remediation and hence the cost of site development. The categories were based upon English Partnership guidance on the costs of development for sites with different levels of pollution or dereliction[i].

In parallel with this multiple development approach a viability function was also introduced. This was applied in each year of the model forecast period as part of DELTA's modelling of the development process. It considered the cost of development (including the site preparation) and compared it to the likely return that the developer and/or landlord would receive. Sites where the returns were less than the cost of development were deemed unviable and were not considered as sites for development (in that year).

The original scoping of sites that would be eligible for SCRIF funding included the range described in the previous section along with flood prevention and sewerage.

The DELTA package lends itself well to modelling these schemes. Its underlying philosophy is one of modelling the decisions and behaviours of the key actors – households, businesses, developers and transport suppliers – and how they respond to policy intervention. In a conventional application (as shown in Figure 5) this approach is used to model changes in the distribution of population, households and employment in response to land use and transportation change. But it is an approach that can equally be applied when considering the responses of households and businesses to other infrastructure intervention and associated policy intervention.

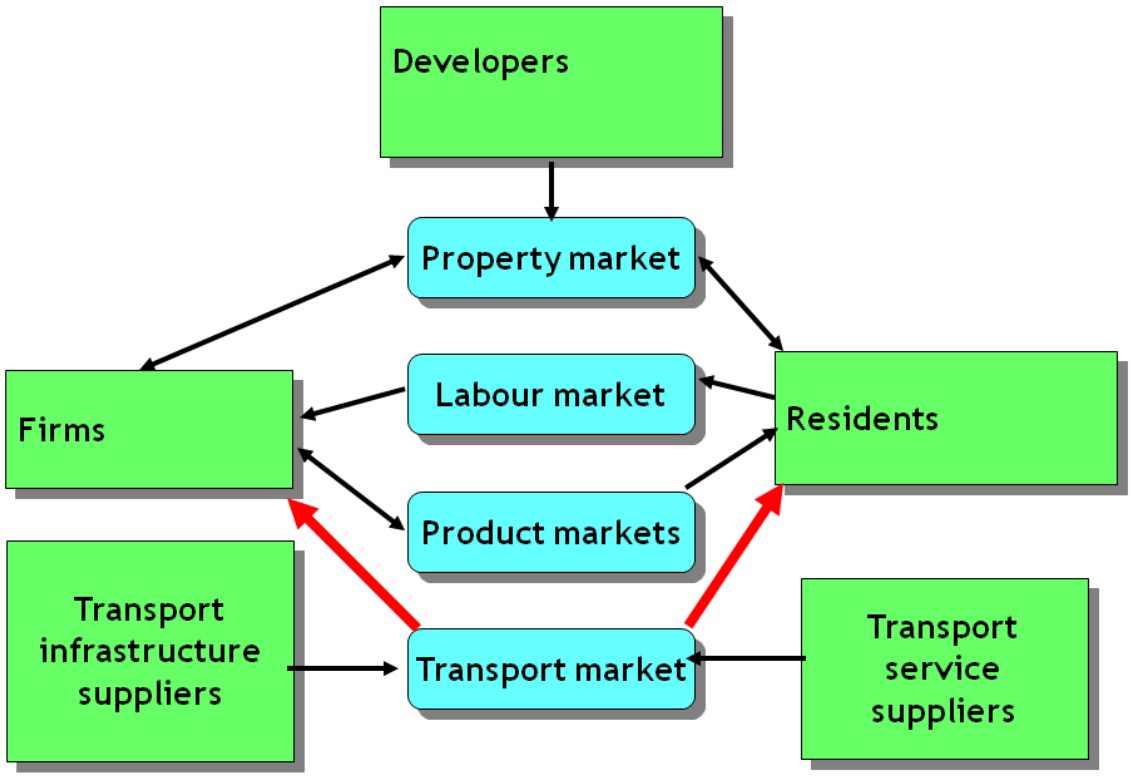


Figure 5 The DELTA structure

In developing FLUTE to allow it appraise a wider range of schemes, we kept a practical focus on how non-transport schemes could and should be represented in FLUTE inputs. The inputs available for adjustment to represent particular schemes or packages are (on the DELTA side)

- how much development is allowed, or imposed, or demolished;
- changes in the costs of development;
- changes in the costs of occupying space (eg higher/lower insurance premiums);
- changes in the quality of housing, or offices, in a zone; and
- changes in the "environment" of a zone.

The following table summarises the approach to modelling the various non-transport infrastructure schemes. Where these involve the modelling of the responses of households or businesses to a change then, where available, this has drawn upon published research.

Table 1 The approaches to modelling non-transport infrastructure

Scheme type	The approach to modelling
Site remediation	SCRIF investment in site remediation would offset the cost of development of a site. By having multiple development processes

	for brownfield development (with high, medium and low cost sites) it was possible to represent the impact of SCRIF investment as a reduction in development costs and the re-assignment of a site (say) from high-cost brownfield to low-cost brownfield. This would increase the likelihood that the development of the site would be 'viable and the site would be modelled as developed.
Improvements to site access	Site access improvements are modelled within FLUTE as improvements in accessibility to or from the zone within which the site is located. Such improvements are input, into the model, in terms of purpose and mode. This will vary according to the scheme being modelled. The effect will be to improve the relative attractiveness of the zone as a place for economic activity and/or households to locate.
Urban public realm schemes	Improvements to public realm will influence the choices of: - businesses as to whether to locate within a zone - workers as to whether to choose to work in a particular area - residents as to whether to live in an area. Adjustments may be made to the model to reflect these choices. These are calibrated so as to replicate the responses observed in research on the impact of public realm investment in London[ii].
Green infrastructure	Green infrastructure will have similar influences upon location choices to those described above for public realm. Schemes that included Green infrastructure were modelled using a similar approach to urban public realm
District heating schemes	District heating schemes that reduce the cost of heating for households and/or businesses will result in reductions in the cost of accommodation (rent plus fixed costs). This will increase the relative attractiveness of the areas with the scheme as places to live and/or work and result in more households and/or employment.
Flood Prevention	Flood prevention schemes can firstly bring forward for development sites that would otherwise not have been developable and secondly reduce the costs of locating in areas benefitting from the scheme as a result of lower insurance premiums. Both of these two consequences are likely to result in an increase in the relative attractiveness of an area as a location for employment (and households).
Broadband	Separate research undertaken for the Scottish Government[iii] and the Halifax Building Society[iv] has estimated the amount that firms and households are prepared to pay for improved Broadband provision. When modelling these schemes the willingness to pay was taken into account in the costs of different locations.

The calculation of GVA for the City Region required the development of a post-model run calculator. For this, a conventional and practical approach to the calculation of GVA impacts has been applied. It is based primarily on changes in employment multiplied by earnings per job. It also takes account of productivity effects arising

both from transport cost savings and from agglomeration effects. The intention in adopting this approach is to maximise consistency of assessment across different schemes and different types of scheme.

The benefits are calculated for a ten year period, based upon output from the FLUTE model run. They final year's output was then extrapolated forward (and held constant) and discounted in order to calculate the benefits over a sixty year period. Benefits were reported in terms of 2010 values.

The key indicator that was applied when prioritising schemes was the ratio of GVA benefit to the SCR to the cost of the scheme to the SCRIF fund.

5. TESTING THE SCRIF SCHEMES

A list of the principal SCRIF schemes and a brief description of the development proposed is available on the Sheffield City Region website[v]. Table 2 summarises the impact on City Region GVA for these schemes. Note that the cost is the proposed contribution from SCRIF, which in some cases was only part of the overall cost of the scheme, but the GVA impact is the full impact of the scheme. Note also that the GVA impact is the impact on the Sheffield City Region, and does not take account of the fact that gains within the SCR may be associated with losses elsewhere. Both points contribute to producing £GVA/£SCRIF ratios which in some cases are extraordinarily high compared to conventional Benefit/Cost ratios.

Table 2 – Reporting on the major schemes

GVA / £ Rank	Name	£GVA (£m)	Cost to SCRIF (£m)	£GVA/£SCRIF
1	M1 J36 to Dearne Valley	3663.9	24.4	150
2	Cudworth – Grimethorpe	204.2	5.3	39
3	Sheffield City Centre	695.3	26.4	26
4	Doncaster DN7	294.2	12.8	23
5	Chesterfield Waterside	72.3	3.2	22
6	Chesterfield Northern Gateway	102.6	7.9	13
7	M1 J37 Claycliffe Link	143.1	11.9	12
8	West Moor Link	193.1	16.3	12
9	Upper Don Valley	604.0	53.4	11
10	Doncaster Urban Centre	268.0	27.8	10
11	Lower Don Valley - Waverley	407.8	45.0	9
12	Gateway to the Sheffield City Region	131.6	15.8	8
13	Harworth Bircotes (transport)	80.2	12.2	7
14	North Doncaster A1-A19 Link	134.8	25.8	5
15	Lower Don Valley - Sheffield	252.9	58.2	4
16	Worksop and Vesuvius Works	77.1	26.5	3
17	Barnsley-Doncaster BRT	81.2	62.5	1
		Total Potential Cost to SCRIF	**435.35**	

The reporting of Costs to SCRIF reflect estimates of cost in July 2013. Refinements to these costs may have taken place since that time.

The schemes that performed well included:

- Commercial developments in locations that are good for businesses, in terms of business-to-business accessibility, and/or business-to-labour market accessibility, or in city-centre locations, close to the strategic highway network, or in areas with relatively high rents.
- Schemes that improve access for businesses, for example where there is an improvement in the capacity of the strategic network or improved connectivity to the strategic network;
- Public realm schemes that were combined with commercial development and that enhance the attractiveness of an area where businesses would want to locate, or people to visit. This is particularly applicable in City Centre locations.
- Retail schemes that are on a scale or in a location that will draw in additional retail expenditure (and employment) into the Region
- Residential developments that are meeting a specific need, for example key workers to overcome a skill shortfall in the labour market.

The schemes that performed poorly included:

- commercial developments in areas where rent levels are low, these invariable had low or no take up.
- Schemes that are focussed on meeting local needs and may simply result in displacement of economic activity from elsewhere within the City Region.
- Site remediation works that only serve to bring forward land in areas of low demand or where there is already a surplus of suitable commercial floorspace.
- Public realm that is primarily targeting improving existing residential areas.
- Residential developments that are restricted to the supply of replacement dwellings or that address specific social need

Following the appraisal of individual schemes several packages of schemes were appraised using FLUTE. For these both the impact on City Region GVA and the impact on accessibility for districts and the most deprived areas was calculated.

In general, the sum of the individual scheme results was greater than the package results. This was particularly so where two or more schemes, in a package, were addressing the needs of the same area. For example where two schemes improved the supply of commercial floorspace to a settlement and whilst each individual scheme provided sufficient supply to meet demand the combined effect was an oversupply.

The preferred package, based upon the initial testing exercise was expected to have a 60-year Present Value Benefit (PVB) of £7,758million at 2010 prices.

6. CONCLUSIONS

This paper has described an application of a land use and transport model for appraising a range of different infrastructure schemes. Whilst the range of infrastructure schemes required some adjustment or enhancement to the model in

order that it could appraise scheme's economic impact in a comparable or consistent manner, the underlying approach to modelling that is in inherent with the DELTA package meant that these adjustments were relatively straightforward.

The exercise to appraise the medium list of schemes has also increased the appreciation of the relative economic benefits of different types of infrastructure scheme. We would anticipate that this appreciation will feedback into the SCRIF process and help to sharpen the type or types of scheme that will be promoted in future years.

Acknowledgement: the views expressed in this paper are those of the authors and not necessarily those of SYPTE, the Sheffield City Region Executive or the individual authorities within the City Region.

[i] English Partnerships Best Practice Note 27 (revised February 2008) Contamination and Dereliction Remediation costs. http://www.englishpartnerships.co.uk/docdownload.aspx?doc=Contamination%20and%20Dereliction%20Remediation%20Costs.pdf&pid=64241OphaK9K2AAJhl5lwMwRzZ4YhYXY

[ii] Transport for London 'valuing urban realm toolkit' https://toolkit.urban-realm.co.uk/

[iii] Halifax Building Supply 'Good broadband a factor for nearly a third when choosing a home', ' http://www.lloydsbankinggroup.com/Media/Press-Releases/2013-Press-Releases/Halifax/Good-broadband-a-factor-for-nearly-a-third-when-choosing-a-home/

[iv] ekogen, research resource, targeting innovation ' Research on broadband and business in Scotland', 2011 http://www.scotland.gov.uk/Resource/Doc/342391/0113934.pdf

[v] http://sheffieldcityregion.org.uk/wp-content/uploads/2013/08/SCRIF-Scheme-List-Page-to-Link.pdf