LOW CARBON TRANSPORT FUTURES AND WIDER MULTI-CRITERIA IMPACTS.
A VIEW FROM OXFORDSHIRE, UK.

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ABSTRACT

Climate change is a global problem and across the world the transport sector is finding it difficult to break projected increases in carbon dioxide (CO2) emissions. A number of studies have developed future scenarios and policy pathways towards lower carbon emissions in the transport sector. This paper develops some of this work to consider the wider sustainability impacts (economic, social and local environmental) of low carbon transport pathways. It reports on research carried out in Oxfordshire (UK).

Different packages of measures are selected for Oxfordshire and a scenario developed which optimises low carbon and wider sustainability aspirations. A simulation model is developed to help explore the strategic policy choices and tensions evident for decision-makers involved in local transport planning.

The paper argues for a 'strategic conversation' at the sub-regional and city level – based upon future scenario analysis, discussing the priorities for intervention in delivering low carbon and sustainable transport futures. The conclusion made is that a greater focus is required in developing participatory approaches to decision making. Only then will a wider awareness and ownership of potential sustainable transport futures improve, together with a greater acceptance of the need for changes in behaviour.

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INTRODUCTION

Climate change is a global problem and across the world the transport sector is finding it difficult to break projected increases in carbon dioxide (CO_2) emissions. The achievement of low carbon travel, including passenger, freight and international travel, is not taking place. Recent difficulties in finding a consensus for change at the international level (cf. Copenhagen 2009) mean that the onus for action has moved to national, regional, sub-regional and city governments to develop local strategies for carbon efficient lifestyles. The major difficulty is in developing and implementing a strategy of sufficient innovation to contribute significantly to the national CO_2 reduction targets, and in understanding potential wider sustainability impacts. Transport accounts for 24% of CO_2 emissions in the UK (DBERR, 2008), and it is the only sector where emissions continue to rise.

A number of studies have examining the future role of transport in a carbon-constrained world (Åkerman and Höjer, 2006; Hickman et al., 2010; Hickman and Banister, 2007; Schäfer et al., 2009; Sperling and Gordon, 2009; Pridmore et al., 2003; Yang et al., 2009); others consider transport as part of wider energy reduction futures (MacKay, 2009); and there is an earlier literature on developing sustainable transport strategies, for example, the OECD EST! study (2000) and the EU-POSSUM project (1998). All suggest the need for radical trend-breaks in terms of moving towards sustainable transport futures.

Scenario-based methodologies provide a very useful means for examining alternative futures, and there is a wide literature in terms of approach (Frommelt, 2008; Godot, 2000; Lindblom, 1959; Schwartz, 1996; Van der Heijden, 1996; Robinson, 1982, 1990). Multi-criteria appraisal (MCA) has also been well utilised in transport planning, particularly in assessment at the project level, but also for the programme and policy levels. MCA is particularly useful where the different aspects of sustainable mobility need to be examined, and elements of this have been included in WebTAG, which is now the main appraisal methodology used in the UK (DfT, 2010). There seems to be a developing preference for approaches that make greater use of multi-actor participation in the design of appraisal frameworks.

This paper draws on these existing and emerging approaches. It employs a hybrid methodology in combining scenario testing, MCA, participatory involvement through stakeholder discussion, and also a visual simulation of the analysis undertaken. It seeks to systematically 'sift' the available options, and develop future policy packages, scenarios and policy pathways towards lower CO2 emissions in the transport sector. The wider sustainability impacts (economic, social and local environmental) of low carbon pathways are also considered using an MCA methodology (Saxena, 2010). The MCA framework is developed using multi-actor discussion. An Integrated Transport Decision Assessment and Simulation Tool (INTRA-SIM) is developed and used to discuss the various layers of the analysis, in particular to assemble and appraise multiple future potential scenarios. A number of issues seldom explored in the literature are examined, including a systematic sifting of potential interventions, assessment of the implications of low carbon transport scenarios against MCA metrics, MCA used with a participatory element, and participation using a simulation tool that allows a transparent and speedy discussion of multiple options. The analysis reports on research carried out by the authors in Oxfordshire (UK)[1].

The argument developed here promotes a 'strategic conversation' at the local level (county and city scale) to complement efforts at the national and international levels, to help discuss and shape the priorities for intervention in delivering low carbon and sustainable transport futures. The conclusion made is that a greater focus is required in developing participatory approaches to decision making. Only then will a wider awareness and 'ownership' – with a range of stakeholders and the public – of potential sustainable transport futures improve. Ownership is a key missing element in the current debate, and increased ownership of strategies will, in turn, raise levels of political and public acceptability for change.

THE CASE STUDY: OXFORDSHIRE

Oxfordshire is a county with a population of 605,500 (2001 Census, ONS). It comprises the historic University City of Oxford – the "city of dreaming spires" (Arnold, 1866) – with origins stretching back to the 5th Century Saxons. There are

1 The paper draws on work carried out for Oxfordshire County Council by the Halcrow Group and Transport Studies Unit, University of Oxford in developing an Integrated Transport Decision Assessment and Simulation Tool (INTRA-SIM). This is used in the development of the Oxfordshire Local Transport Plan (LTP3; due to be published in 2011) and Regional Oxfordshire Delivering a Sustainable Transport Study (DaSTS; due to be published in late 2010).

also a number of large towns (such as Banbury, Bicester and Didcot), several smaller towns (such as Chipping Norton, Wallingford and Henley), and rural villages and more remote rural areas (Figure 1).

The city of Oxford itself has a population of 165,000 (OCC, 2007) and is a 'county town' that serves a wider sub-regional hinterland, referred to as 'Central Oxfordshire'. The ring of market towns and dormitory settlements is around 10-15 miles from the city. Settlements on the east and south sides of the county are very accessible to London (Oxford is around 60 minutes from London Paddington, and Didcot 45 minutes). Neighbouring major urban areas include Reading, Swindon and Milton Keynes.

The Oxford Green Belt was designated in 1956 and has led to the effective containment of the Oxford urban area. The first County Structure Plan, developed in the 1970s and reflecting the then growth model for London, displaced growth to designated towns beyond the Green Belt, principally Banbury, Bicester, Didcot and Witney. This strategy can be viewed as a forerunner to PPG13 (DETR, 2001), where new residential developed is encouraged in established urban areas. Here facilities can be accessed, there are better prospects for local employment creation and higher levels of public transport accessibility. Sporadic development throughout the county has thus been avoided. The unanticipated problem has been that the level of self containment within the designated growth towns has been low. Although 70 percent of the commuting trips of residents in Oxford are 'short' (less than 5 miles), less than 35 percent of trips from the expanded towns are in the same short distance cohort. The majority of trips are in the 5-25 mile distance band, and most are made by car. Car driver distance per resident worker is 3.9 miles in Oxford relative to 8.5 miles in the expanded towns (Headicar, 2010). This many-many origin and destination travel pattern creates difficulties for public transport provision throughout Oxfordshire, with many tangential journeys evident as well as more conventional radial journeys centred on Oxford. These types of movement are difficult to serve by public transport. Sustainable transport initiatives still need developing in Oxford, but also throughout the outlying towns and villages. It is here that it is most difficult to reduce car dependency. The packaging of initiatives also needs to be wide ranging, including, for example, a revised focus on the strategic location of development. A greater focus on growth in the main urban centres would assist in tackling sustainable transport; hence the need to differentiate between urban areas, beyond the generic aspirations of PPG13 (Hickman et al, 2009b).

INSERT FIGURE 1 HERE

SIFTING OF POTENTIAL INTERVENTIONS AND POLICY PACKAGES

There is a very wide range of potential interventions available for use in the Oxfordshire transport planning context, including potential schemes and wider initiatives. A systematic 'sifting' of the long list of potential options has been carried out, using the process in Figure 2, to consider those with most merit. This method has been developed for and used in the Oxfordshire LTP3 and Oxfordshire Regional DaSTS. This is an iterative process providing the assessment of individual measures against: (Stage 1) national and local policy objectives, problems and opportunities; and (Stage 2) deliverability and feasibility. Refined packages and scenarios are assessed against (Stage 3) the detailed appraisal framework. Stages 1 and 2 represent the initial sifting; with Stage 3 providing the detailed appraisal. This process allows most effort to be focused on the 'likely winners' in terms of transport options.

If a particular intervention does not score well against any of the three stages it is either discounted or modified. The assessment is based upon a semantic scoring scale (+3 for major benefit to -3 for major cost or negative impact). Objectives are derived from the DaSTS objectives (DfT, 2008a) and local LTP objectives if these differ significantly. In Stages 1 and 2 the problems and opportunities are generic to the local area (Oxfordshire). Deliverability and feasibility covers issues such as technical feasibility, environmental or legal 'showstoppers', affordability (capital, revenue, funding), stakeholder acceptability (political, public, operator), value for money and uncertainty and risk. An initial ranking of options and policy packages is then developed. Without a systematic process of this type, the sifting process can tend to be unstructured, and follow individual or political belief and/or aspiration and even prejudice. The process adopted allows a systematic and transparent framework to be followed.

INSERT FIGURE 2 HERE
(Based on Halcrow Group, 2010)

Policy packages (PPs) are derived from the options taken forward. Each typically has a level of 'applicability' – business as usual (BAU), low, medium and high. Schemes and initiatives are selected for different levels of application according to deliverability, feasibility and cost. The following PPs are used within the Oxfordshire INTRA-SIM modelling:

- PP1 Rail
- PP2 Bus
- PP3 Walk
- PP4 Cycle

- PP5 Highway Infrastructure
- PP6 Traffic Demand Management
- PP7 Pricing
- PP8 Parking Management
- PP9 Park and Ride
- PP10 Land Use Planning
- PP11 Behavioural Change
- PP12 Low Emissions Vehicles
- PP13 Alternative Fuels
- PP14 Slower Speeds and Ecological Driving
- PP15 Freight
- PP16 Long Distance Travel Substitution

The more detailed appraisal (Stage 3) provides analysis against the MCA framework. This is developed using WebTAG (DfT, 2010) and DaSTS-based guidance (DfT, 2009) and discussion with local stakeholders, mainly practitioners from Oxfordshire County Council. The Stage 3 appraisal also considers more specific spatial issues by scheme, package and scenario. The latter two levels, by package and scenario, are where measurable and significant impacts are likely to be seen.

MODELLING APPROACH

Each level of policy package application is modelled using the Central Oxfordshire Transport Model (COTOM), which includes a Saturn-based transport model and Emme2 public transport model. Other datasets used include the latest vehicle/speed CO_2 emission factors (DfT, 2008b), modal CO_2 emission factors (Defra, 2009) and spatial planning assumptions from the South East Plan (GOSE, 2009). The following system architecture is used within the modelling:

- Data input and underlying modelling assumptions provided by means of a comma separated text file and an xml file;
- Comma separated text file contents are provided by a detailed spreadsheet based Transport Carbon Calculator (INTRA-SIM CALC);
- A Flash based active-x graphical user interface – this allows non-specialists to engage in the decision-making process.

For all policy packages and enabling mechanisms the MCA outputs are computed relative to the BAU reference case. A working paper provides more details on the INTRA-SIM modelling methodology and assumptions used (Ashiru et al., 2010).

DEVELOPING SCENARIOS AND PARTICIPATORY MCA

The process of moving from the shortlist of policy measures, through to policy packages and scenarios is shown in Figure 3. A scenario is defined within this paper as a ‘cluster’ of policy packages, each at varying levels of application. Impacts are assessed against MCA indicators – hence a low carbon transport scenario can be assessed against wider MCA sustainability impacts (economic, social and local environment). The MCA framework is based upon WebTAG criteria and sub-criteria, with additional input via discussion with local officers at Oxfordshire County Council. A list of the MCA indicators is given in Table 1. The scenario testing and appraisal stages, at both the policy package and scenario levels, can be handled within INTRA-SIM. This speeds the process of analysis enormously and allows for a transparent discussion of priorities. Costing and political and public implementation issues can also be considered, but are dealt with ‘off model’, i.e. considered outside INTRA-SIM.

INSERT FIGURE 3 HERE
INSERT TABLE 1 HERE

AN ‘OPTIMISED’ LOW CARBON SCENARIO

An example of an ‘optimised’ low CO2 transport scenario for 2030 is given in Figure 4 and Table 1, with spatial CO2 impacts in Figure 5 (representing the chosen scenario relative to BAU). A wide selection of the PPs on offer is used, and the total CO2 reduction impact is a saving of 1,343,838 tCO_2 per annum (a 50% reduction relative to the BAU level in 2030). This represents around 2.1 tCO_2 per capita in 2030. A summary of the interventions considered within each of the policy packages of the chosen scenario is also given in Table 1, with a more detailed list in Seaborn et al. (2009).

INSERT FIGURE 4 HERE
INSERT TABLE 2 HERE
INSERT FIGURE 5 HERE

The major CO2 reduction impacts arise from the following PPs:

- PP12 Low emission vehicles (a high level of application): the assumption is very ambitious, representing a total car fleet at an average of 95 gCO2/km and HGVs (fully loaded) at 800 gCO_2/km by 2030. This level of new vehicle technology penetration will be very difficult to achieve across the whole vehicle fleet. The levels (2006) for the current new car fleet are at around 165 gCO_2/km and heavy goods vehicles (HGVs) (fully loaded) at 1100 gCO_2/km. This will take a major effort from the motor manufacturers, responding to mandatory emission standards, which in turn would require UK governmental legislation. Consumer purchasing choice would also need to change markedly, perhaps with subsidy in the early years to encourage mass market purchase of low emission vehicles. Clearly the market, at the moment, does not have the incentive to achieve this level of change. There is a great role at the governmental level to 'demark' the boundaries for commercial operation and consumer choice, i.e. to set up the rules of the market within which businesses can operate successfully but still achieve strategic societal goals, in this case a low emission vehicle fleet. This package by itself achieves 36% of the 50% modelled reduction in CO_2 emissions; hence is extremely important to strategic CO_2 reduction goal achievement.

- PP14 Slower speeds and ecological driving (medium): this has a major impact, representing 20mph speed limits in all major towns and 50mph speed limits on all rural single-carriageway roads; lower speed limits are supported by variable signage and enforcement. There is also a targeted public education campaign concerning ecological driving skills. This package achieves a 5% reduction in CO_2 emissions.
- PP15 Freight (medium): HGV freight movements represent over 20% of traffic on key routes, particularly the A34 and M40, in Oxfordshire and vehicles are high CO_2 emitters. An assumed increase in rail freight capacity between the south coast ports at Southampton and the Midlands and North, together with advisory HGV routing, would reduce heavy goods vehicle traffic through the county. This package also achieves a 5% reduction in CO_2 emissions.

The other selected policy packages also have a direct impact on CO_2 emissions, but the scale of impacts are less than the above. PP1 Rail (medium), PP2 Bus (medium), PP3 Walk, PP4 Cycle, PP9 Park and Ride, PP10 Land Use Planning, PP11 Behavioural Change, for example, all lead to limited emission reductions. The major gains are made when car and freight emissions are tackled (the vast majority of emissions). The interpretation of these types of result needs careful consideration. This is not an argument for not investing in the non car modes, simply a result of the dominance of car use relative to other travel modes. PPs 1-4, 9, 10 and 11 lead to a level of CO_2 reduction and they are also useful for non carbon issues, such as supporting the wider quality of life within, and the liveability of, urban centres. These issues, though critical, are beyond the assessment within the current MCA framework, but they need to be considered as part of the packaging of complementary measures.

The actual modelling assumptions are also critical to the MCA outputs. For example, the initial specification of road pricing (PP7) on the major strategic roads in Oxfordshire actually led to an increase in travel and emissions, as traffic is diverted onto the non-strategic highway (rural roads) and longer travel distances arose. This again provides a useful lesson in terms of process – INTRA-SIM allows a speedy comparison of likely outputs from a series of interventions. Unsuitable impacts (and hence intervention definition) can be revisited and remodelled. In this case, a distance-based charge for the complete network, and better still an emissions-based charge, would lead to a reduction in travel and emissions. Hence the process can be iterative, where interventions are redefined to optimise the achievement against objectives. This is a critical element of objectives-based strategy development.

The spatial distribution of CO_2 emission also varies across the county. The results are interesting under this scenario as the dominant impact of PP12 low emission vehicles means that the largest relative reductions are seen in the non-urban areas, namely in the villages and rural areas where car dependency is highest.

WIDER SUSTAINABILITY IMPACTS

The wider sustainability impacts of low carbon transport scenarios are also of great importance. Feasibly some scenarios may be very beneficial in CO_2 reduction terms, but do less for social or economic objectives. Again INTRA-SIM allows us to 'read across' the different metrics. Just three of the available indicators are discussed here – annual car time (a proxy for the economy[2]), accessibility by train (social) and carbon monoxide (local environment). Figures 6-8 show the spatial impacts, with the composite chart score illustrating aggregate impacts. A number of interpretations can be made:

- Annual car time: decreases in aggregate (by 16,500 aggregate annual hours) – this is viewed as a 'negative' for the economy. The contributory picture is complex, but this is largely a result of investment in public transport, park and ride facilities, land use planning (mainly modelled as reduced trip rates from new development), behavioural change measures and slower speed assumptions. Hence shorter travel distances; mode shift to public transport, walking and cycling; lead to a reduction in car time. This type of result has very profound implications for the appraisal process in the UK and internationally – to re-iterate this is viewed as a 'negative' impact in economic appraisal terms, whereas most transport planners would probably view this as a positive result in 'sustainability' terms.
- Accessibility by train: increased accessibility in the areas surrounding the mainline rail network (Reading-Oxford-Midlands) and assumed new networks (Cotswold line upgrade; Evergreen 3, Oxford-Bicester-London Marylebone; and East-West Rail, Oxford-Milton Keynes-Cambridge-Felixstowe).

[2] This metric is problematic. Annual car time is often correlated to other economic indicators such as GDP. However using such a measure by itself may mean that measures to reduce CO2 emissions are not viewed 'positively' in economic terms, as measured here. Hence INTRA-SIM has a wider variety of indicators available (Table 1). Care however is required in interpreting results, and more work is required in refining available indicators where impacts are often indirect.

- Carbon monoxide: reductions are made virtually across the whole county with the exceptions of clustered increases in some of the urban areas.

INSERT FIGURE 6 HERE
INSERT FIGURE 7 HERE
INSERT FIGURE 8 HERE

Wider impacts can also be explored across the full MCA framework, but are not discussed within this paper.

CONCLUSIONS

The transport sector needs new methodologies to demonstrate and discuss the potential pathways towards deep reductions in CO_2 emissions. There is an emerging set of methodologies, including scenario analysis, which offer much promise to the evaluation and eventual implementation of sustainable transport futures. Low carbon aspirations certainly need to be consistent with wider sustainability aspirations. This has been the main contribution of this paper, in putting forward a hybrid methodology – combining scenario testing, MCA, multi-actor participation and visualisation/simulation techniques – that allows the relative comparison of multiple scenarios against MCA impacts[3].

Different packages of measures can be examined and scenarios developed which optimise low carbon and wider sustainability aspirations. The INTRA-SIM model allows the exploration of the strategic policy choices in a transparent and participatory manner, and it makes explicit some of the tensions evident for decision-makers involved in local transport planning. The central arguments made are summarised below:

1. Oxfordshire provides a challenging case study that offers many transferable lessons. There is a historic and compact central city, with good levels of walking, cycling and public transport, and also a surrounding periphery which is much more dispersed and car dependent.
2. In terms of method, the project sifting and packaging process can be important in ensuring an effective balance of measures for detailed appraisal. Low carbon transport scenarios need to be assessed against multi-criteria impacts. Depending on the composition of the scenario, impacts are likely to vary substantially relative to economic, social and local environmental goals.
3. To achieve deep reductions in transport CO_2 requires wide-ranging scenarios – covering low emission vehicles, rail, bus, walk, cycle, behavioural change, spatial planning, etc. An interesting issue here is remit. The interventions

[3] A related paper will consider in more detail the participatory potential of such methodologies – Hickman, Lucas and Scott, Transport Scenario Analysis and Participatory Approaches, forthcoming.

considered cover the responsibilities of Oxfordshire County Council and other key public and private decision makers, including those at the national and European levels.

4. Policy options and schemes can be iteratively redefined, perhaps with a different specification, network routing, tightening of legislation, or improvement of incentive, to better achieve objectives.
5. Further dimensions that can be explored are scenario costs (particularly in view of current funding constraints within the transport sector), progress against targets or aspirations, and political and public implementability. Often the optimum theoretical strategies fail because little consideration is given to deliverability issues, as illustrated by road pricing regimes.
6. Impacts across multiple indicators often work in different directions, and the use of a tool such as INTRA-SIM illustrates this well. Trade-offs will need to be made in developing future strategies – perhaps aggregate time savings (and aggregate annual car time) become less important; other measures of economic performance are developed; and the achievement of CO_2 reduction, improvement in accessibility, safety and local air quality become more important. MCA also offers the potential to weight objectives and criteria, hence assisting in the achievement of the 'important' strategic societal goals (Hickman et al, 2009c).

There are thus very interesting research avenues to be followed using scenario analysis. In practice terms, there needs to be a 'strategic conversation' at the sub-regional and city level, based upon scenario and MCA analysis, discussing the priorities for intervention in delivering low carbon and sustainable transport futures. A greater focus is required in developing participatory approaches to decision making. Only then will a wider awareness and ownership of potential sustainable transport futures improve. Ownership is a key missing element in the current debate. The intention is that this will lead to greater engagement and acceptance of difficult choices, and the greater potential for effective implementation.

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REFERENCES

Åkerman, J. and Höjer, M. 2006. How Much Transport Can the Climate Stand? Sweden on a Sustainable Path in 2050. Energy Policy, 34**,** 1944-1957.

Arnold, M. 1866. Thyrsis "And That Sweet City with Her Dreaming Spires", Line 19. Macmillan's Magazine.

Ashiru, O., Gachacho, W., Seaborn, C., Saltmarsh, W., Hickman, R. 2010. Oxfordshire Intra-Sim: Modelling Assumptions. London: Halcrow.

Department for Food and Rural Affairs (Defra) 2009. Modal CO_2 Emission Factors London: Defra.

Department for Transport (DfT) 2008a. Delivering a Sustainable Transport Strategy (DaSTS). London: The Stationery Office.

Department for Transport (DfT) 2008b. Vehicle/Speed CO_2 Emission Factors. London: Department for Transport.

Department for Transport (DfT) 2009. Guidance to Regions on Delivering a Sustainable Transport System. London: The Stationery Office.

Department for Transport. (DfT) 2010. Website for Transport Analysis Guidance (WebTAG) [Online]. [Accessed January 2010].

Department of Business Enterprise and Regulatory Reform (DBERR) 2008. Energy Trends. London: National Statistics.

Department of the Environment Transport and the Regions (DETR) 2001. Planning Policy Guidance Note 13: Transport (PPG13), London: The Stationery Office.

EU Possum 1998. Possum: Final Report. European Community Fourth Framework Programme.

Frommelt, O. C. 2008. Strategy, Scenarios and Strategic Conversation: An Exploratory Study in the European Truck Industry. Doctor of Business Adminstration Thesis, University of Nottingham.

Godot, M. 2000. The Art of Scenarios and Strategic Planning. Technological Forecasting and Social Change, 65**,** 3-22.

Government Office for the South East (GOSE) 2009. The South East Plan. Regional Spatial Strategy for the South East of England. Guildford: GOSE.

Halcrow Group. 2010. Swindon DaSTS Policy Options Review. Swindon: Halcrow.

Headicar, P. 2010. PPG13: Evidence of the Strategic Deficit. Town and Country Planning, February.

Hickman, R. Lucas, K. and Scott, L. Transport Scenario Analysis and Participatory Approaches, forthcoming.

Hickman, R., Ashiru, O., Banister, D. 2010. Transport and Climate Change: Simulating the Options for Carbon Reduction in London. Transport Policy, 17(2)**,** 110-125.

Hickman, R., Ashiru, O., Banister, D. 2009a. Achieving Carbon Efficient Transport: Backcasting from London. Transportation Research Record, 2139**,** 172-182.

Hickman, R., Seaborn, C., Headicar, P., Banister, D. 2009b. Planning for Sustainable Travel. Summary Guide. London: Halcrow and CfIT.

Hickman, R., Ashiru, O., Saxena, S., Banister, D. 2009c. Visioning and Backcasting for Transport in London. Stages 3/4 Background Report. (www.vibat.org). London: Halcrow.

Hickman, R. and Banister, D. 2007. Looking over the Horizon: Transport and Reduced CO_2 Emissions in the UK by 2030. Transport Policy, 14(5)**,** 377-387.

Lindblom, C. E. 1959. The Science of Muddling Through. Public Administration Review, 19**,** 79-88.
Mackay, D. J. C. 2009. Sustainable Energy - Without the Hot Air, Cambridge, UIT.
Office for National Statistics (ONS) 2001 Census [Online]. [Accessed January 2010].
Organisation for Economic Co-operation and Development (OECD) 2000. EST! Environmentally Sustainable Transport. Futures, Strategies and Best Practice. Synthesis Report. Paris: OECD.
Oxfordshire County Council (OCC) 2007. Population Estimate. Oxford.
Pridmore, A., Bristow, A., May, T., Tight, M. 2003. Climate Change, Impacts, Future Scenarios and the Role of Transport. Leeds: ITS and Tyndall Centre.
Robinson, J. B. 1982. Energy Backcasting: A Proposed Method of Policy Analysis. Energy Policy, 10**,** 337-344.
Robinson, J. B. 1990. Futures under Glass: A Recipe for People Who Hate to Predict. Futures, 22**,** 820-842.
Saxena, S. 2010. Low Carbon Transport Pathways in Delhi. DPhil (in development), University of Oxford
Schäfer, A., Heywood, J.B., Jacoby, H.D., Waitz, I.A. 2009. Transportation in a Climate-Constrained World, Cambridge, Mass.: MIT.
Schwartz, P. 1996. The Art of the Long View: Paths to Strategic Insight for Yourself and Your Company, New York. London: Currency Doubleday.
Seaborn, C., O'Brien, C. Clegg, J., O'Neill, R. 2009. Oxfordshire LTP3: Policy Options and Packages. Working Paper. London: Halcrow Group.
Sperling, D.and Gordon, D. 2009. Two Billion Cars. Driving toward Sustainability. New York: Oxford University Press.
Van der Heijden, K. A. 1996. Scenarios: The Art of Strategic Conversation, Chichester: John Wiley.
Yang, C., McCollum, D., McCarthy, R., Leighty, W. 2009. Meeting an 80% Reduction in Greenhouse Gas Emissions from Transportation by 2050: A Case Study in California. Transportation Research D, 14**,** 147-156.

TABLES

Table 1: MCA Framework Indicators

Environment (Strategic)	Environment (Local)	Accessibility	Safety	Economy
• Total CO_2 emissions by car, LGV, HGV, bus and rail*	• Population affected by noise • Number of households experiencing noise levels above 68db • Population perceiving a noise nuisance • Population experiencing vibration • Number of households experiencing vibration • Local air quality impacts (by carbon monoxide*, nitrogen dioxide, ozone, sulphur dioxide, particulates)	• Hansen measure of accessibility to Town Centres by mode* • Hansen measure of accessibility to Hospitals by mode • Hansen measure of accessibility to Workplaces by mode • 2026 Households within 30 minutes of Town Centres by mode • 2026 Households within 30 minutes of Hospitals by mode • 2026 Households within 30 minutes of Workplaces by mode	• Number of personal injury accidents (PIAs), based on Stats19 data (2007) • Number of accidents resulting in slight injury • Number of accidents resulting in serious injury • Number of accidents involving fatalities	• Journey time reliability • Junction delays • Travel time on links, by mode* • Access to jobs

*Only partial reporting of the indicators is possible in this paper. The *notation illustrates the indicators used in the later analysis.

Table 2: An 'Optimised' Scenario

Policy Package	Level of Application	CO_2 Impact, relative to BAU 2030	Summary Specification
PP1 Rail	Medium	-766 tCO2 -0.03%	Interchange improvements, Mainline network frequency upgrades (Reading-Oxford-Midlands) and assumed new networks (Cotswold line upgrade; Evergreen 3, Oxford-Bicester-London Marylebone; and East-West rail, Oxford-Milton Keynes-Cambridge-Felixstowe), new Milton Park station.
PP2 Bus	Medium	-7 tCO_2 0.0%	Improved Premium Routes to main housing and employment sites; improved bus services between large towns and small towns; electric and hybrid buses in Oxford.
PP3 Walk	High	-2,145 tCO_2 -0.08%	High quality pedestrian environment and streetscape upgrades in Oxford, larger towns, smaller towns and villages, and connections to Rights of Way network.
PP4 Cycle	High	-1,504 tCO_2 -0.06%	High quality network improvements, integrated cycle parking in Oxford, larger towns, smaller towns and villages, cycle hire schemes in Oxford and large towns. New links from new developments.
PP5 Highway Infrastructure	BAU	0 tCO_2	None
PP6 Active Traffic Management	Medium	+10, 096 tCO_2 +0.38%	Access to Oxford programme, including HOV lane on A34; routeing measures from Transport Networks Review (TNR); Traffic Incident Management (TIM) programme; expansion of real-time monitoring systems across the county.
PP7 Pricing	BAU	0 tCO_2	None
PP8 Parking Management	Medium	-1,943 tCO_2 -0.07%	Reduced parking supply in new developments and maximum standards applied, increased use of controlled parking zones.
PP9 Park and Ride	High	-38,755 tCO_2 -1.45%	Increase capacity at existing sites: Seacourt, Redbridge, Thornhill; new Park and Ride sites for Banbury, Didcot, Bicester, Harwell; informal 'pocket' provision on major corridors.
PP10 Land Use Planning	Medium	-3,914 tCO_2 -0.15%	Development located according to South East Plan but better strategic co-ordination and sustainability travel aspirations achieve 25% lower car trip rates in new developments.

PP11 Behavioural Change	Medium	-918 tCO_2 -0.03%	Enhanced travel planning (workplace and schools), widespread travel awareness campaign including increased availability of pre-trip and en-route information, personalised travel planning in new developments, support for car clubs.
PP12 Low Emissions Vehicles	High (Car/LGV) High (HGV)	-656,503 tCO_2 -24.64% -306,641 tCO_2 -11.51%	A total car/LGV fleet at an average of 95 gCO2/km and HGVs (fully loaded) at 800 gCO2/km.
PP13 Alternative Fuels	Low	-50,263 tCO_2 -1.89%	Very slight increase in car dieselisation and uptake of biofuels in buses – car 20% diesel (from 15%), 80% petrol; HGV 5% LPG, 95% diesel, (from 100%); bus 5% biofuel, 95% diesel 9from 100%).
PP14 Slower Speeds and Ecological Driving	Medium	-147,386 tCO_2 -5.53%	20mph speed limits in all major towns and 50mph speed limits on all rural single-carriageway roads; lower speed limits are supported by variable signage and enforcement. There is also a targeted public education campaign concerning ecological driving skills.
PP15 Freight	Medium	-142, 386 tCO_2 -5.34%	Increase in rail freight capacity between the south coast ports at Southampton and the Midlands and North, together with advisory HGV routing.
PP16 Long Distance Travel Substitution	Medium	-816 tCO_2 -0.03%	Improved coach/rail links to a range of major destinations, including London, Oxford and all London airports, and along major corridors - Birmingham/Manchester, Oxford-Southampton (M40/A34 road/rail corridor), Oxford-Bristol (via Swindon).
Scenario Total (relative to BAU 2030)		**-1,343,838 tCO_2** **-50.43%**	
Per Capita (2030)		**2.07 tCO2**	

Note. Preliminary modelling results subject to change. The modelling is based on individual model runs for each level of application of a policy package. MCA indicator impacts are derived from travel distance, mode share and speed outputs. Additivity is assumed between packages. Clearly this omits potential super-additivity (synergy) and sub-additivity (double counting) effects. This is an area for further research by the study team in terms of methods of optimising packaging process and modelling. Initial thoughts on synergies are given in Hickman *et al* (2009a)

FIGURES

Figure 1: The Oxfordshire Study Area

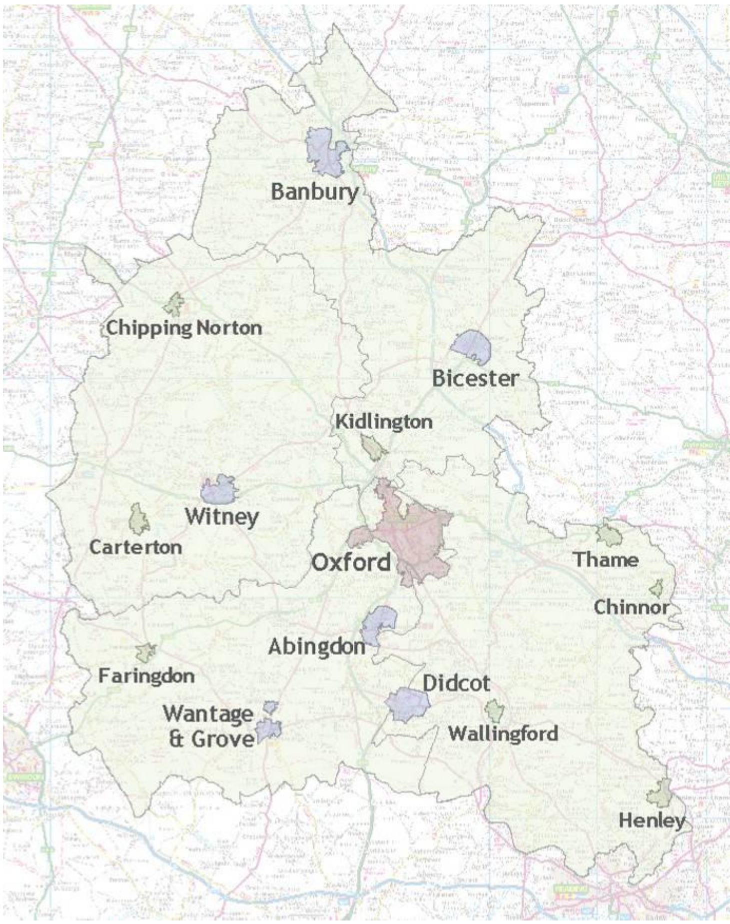

Figure 2: A Systematic 'Sifting' of Available Measures

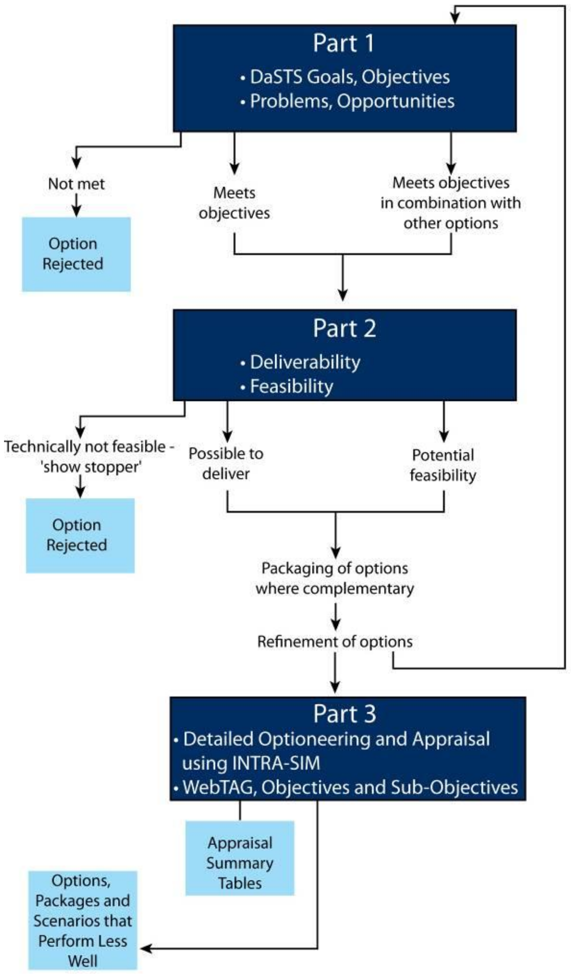

Figure 3: Developing Scenarios and MCA

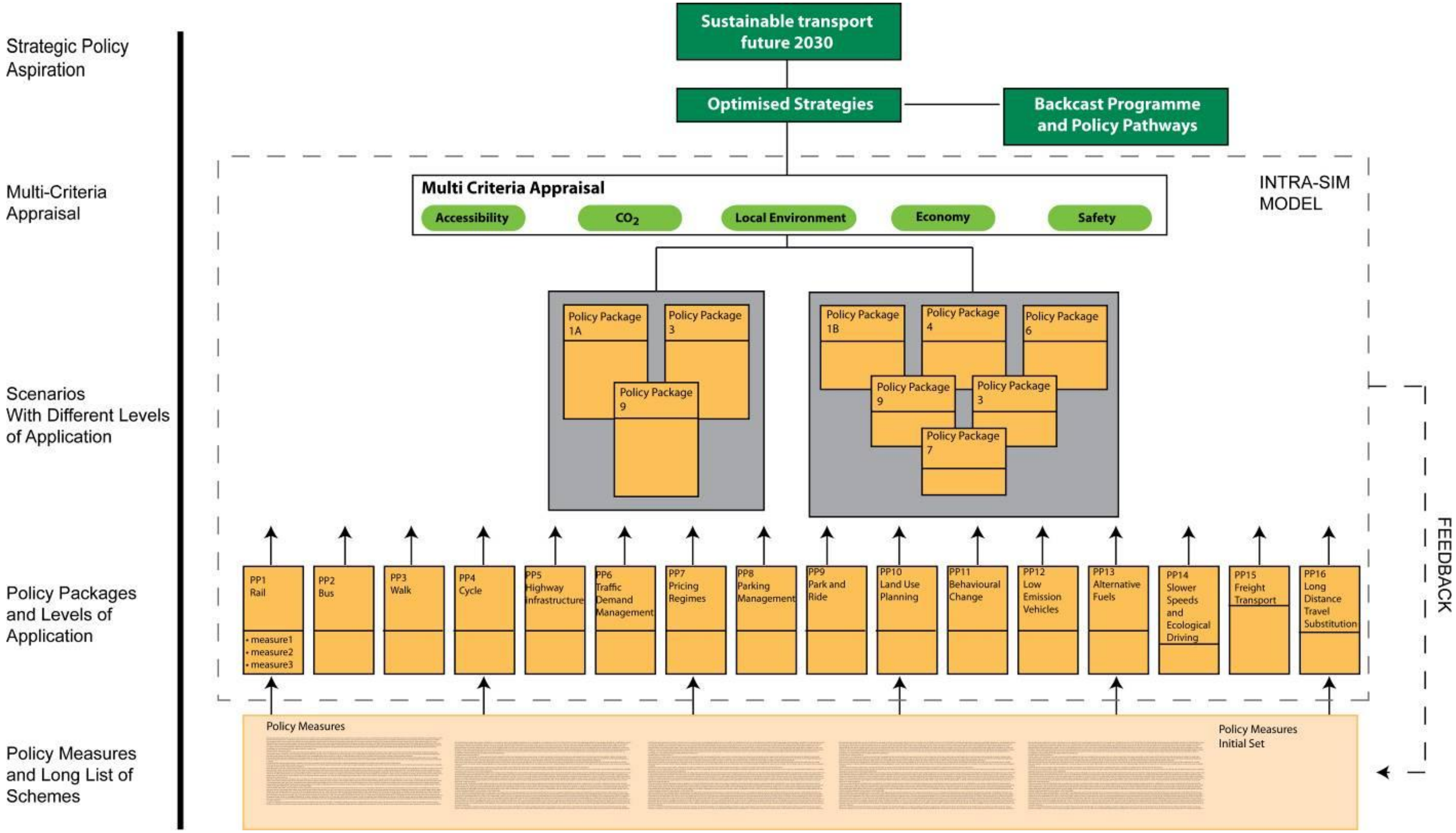

Figure 4: A Low Carbon Scenario for Oxfordshire

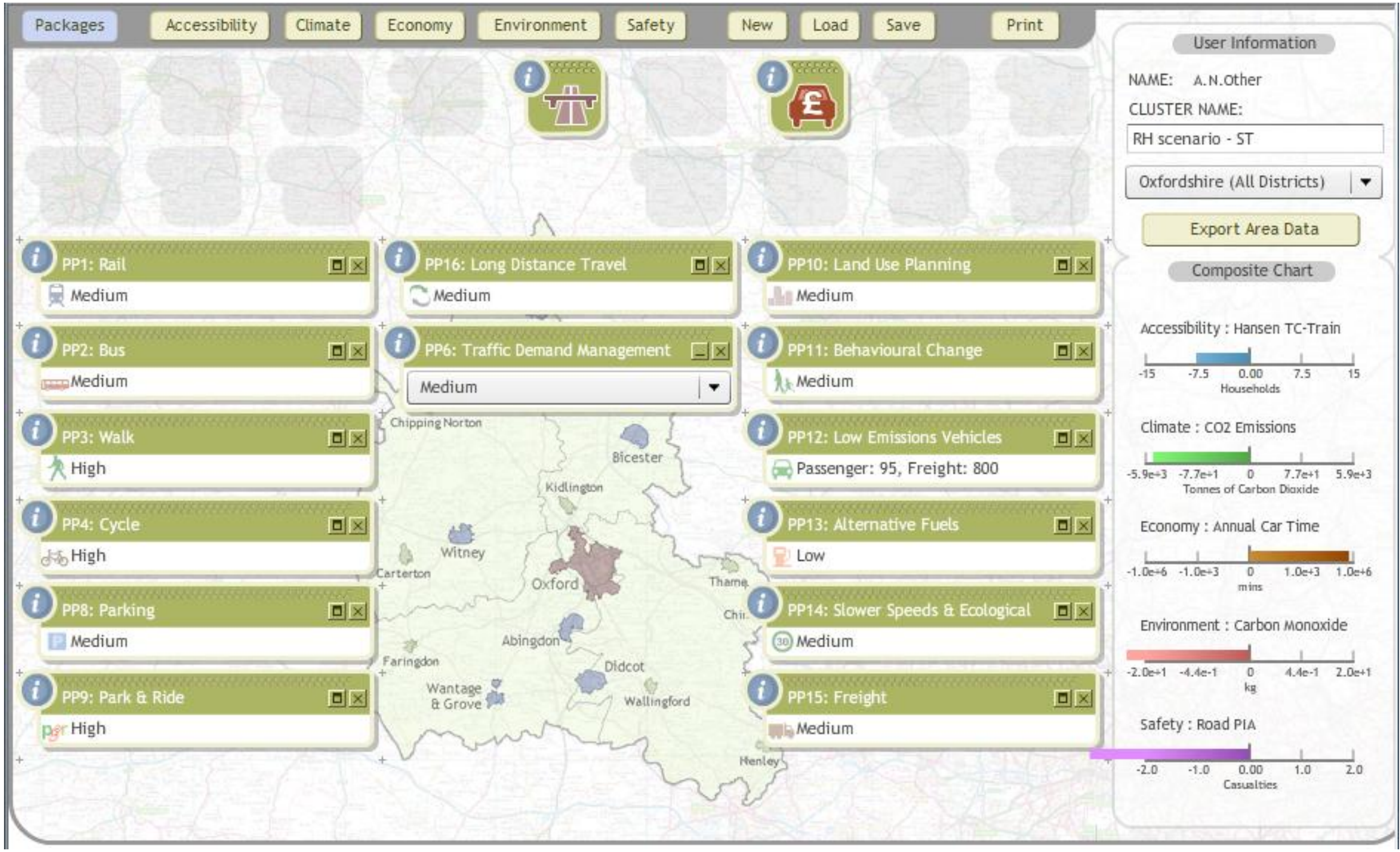

Figure 5: A Low Carbon Scenario for Oxfordshire – Spatial Impacts

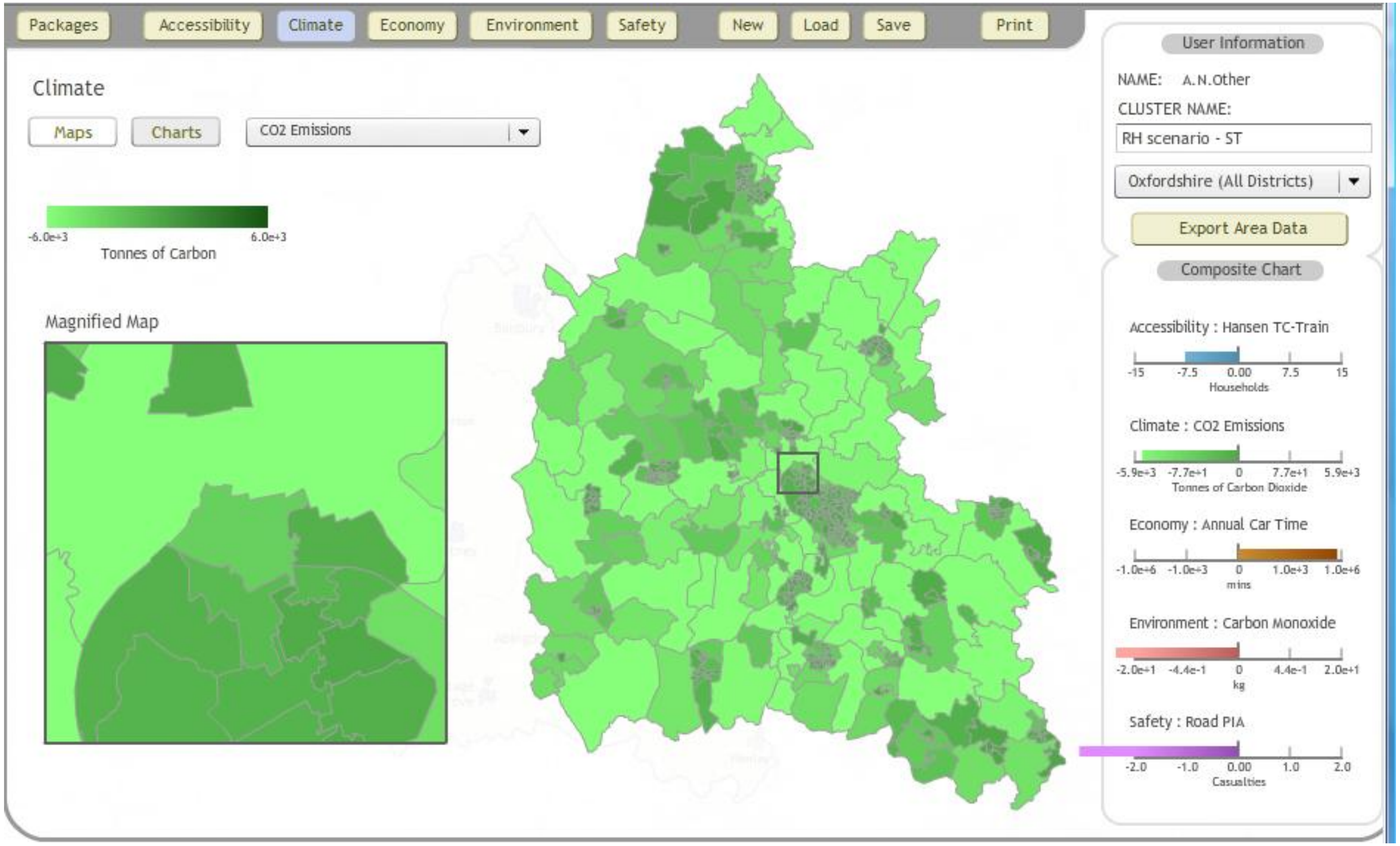

Figure 6: MCA Impacts – Economy (Annual Car Time)

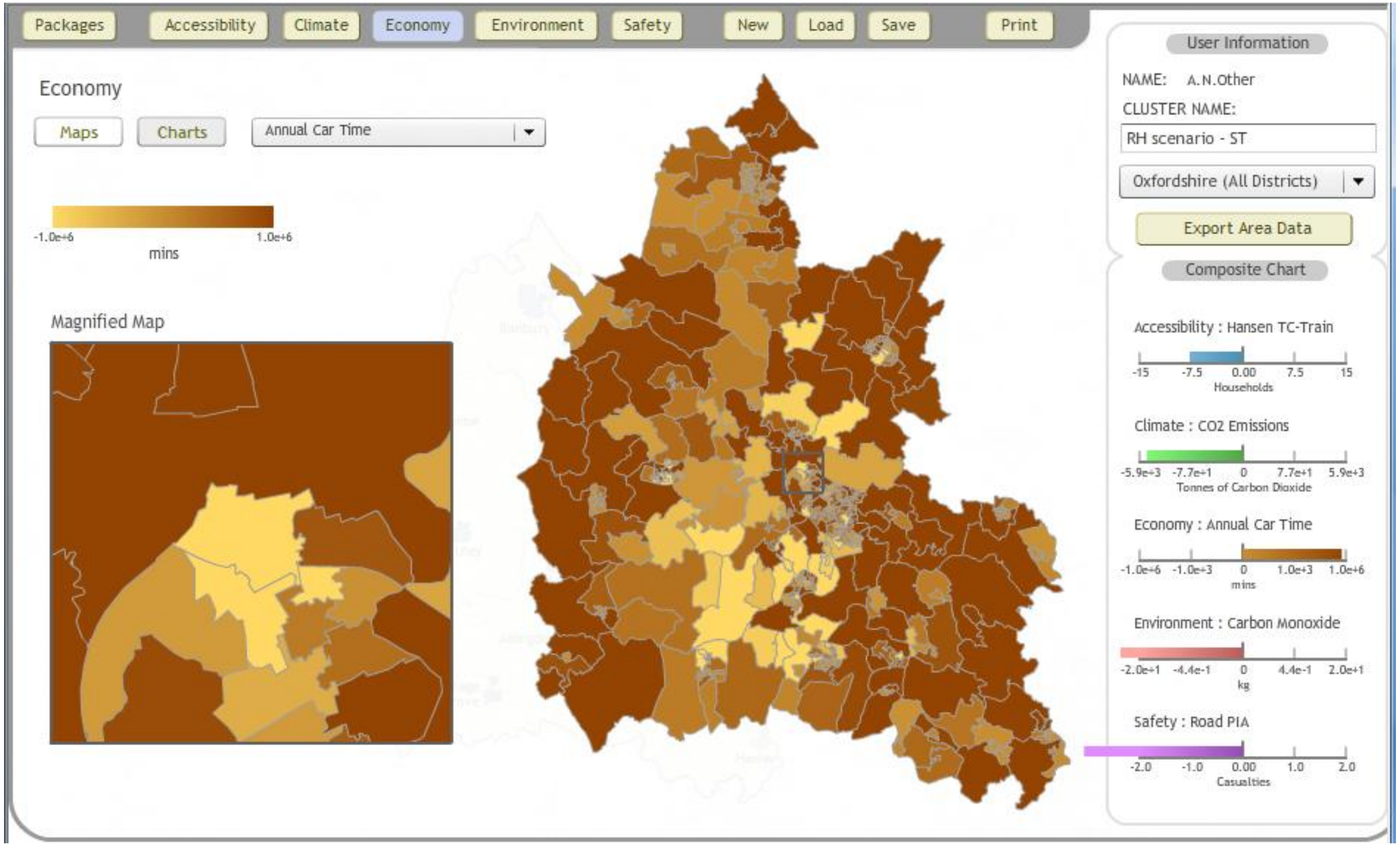

Figure 7: MCA Impacts – Social (Accessibility by Train)

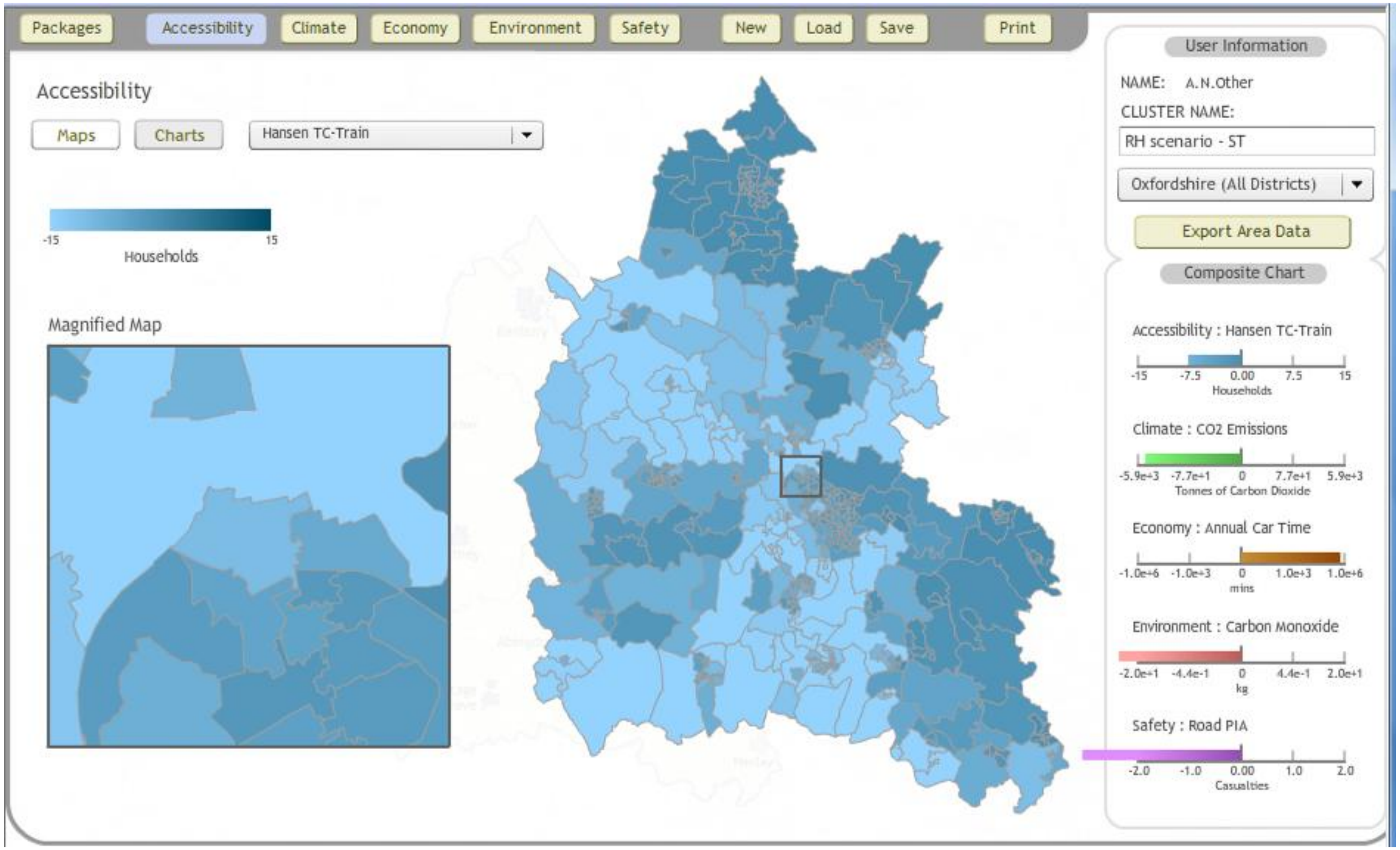

Figure 8: MCA Impacts – Local Environment (Carbon Monoxide)