# An option generation tool for potential urban transport policy packages

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## Abstract

Several studies have indicated that option generation - the development of a range of strategic policy options to tackle identified transport problems – is the weakest link in current transport planning practice. Local authorities all too often limit themselves to pre-conceived solutions, focus on supply-side rather than demand-side polices, and are unaware of the potential of novel solutions. This is even more the case for the development of packages of policy instruments, in which each can be expected to support the others by making it more effective or easier to implement.

A decision-support tool has been developed, based on the transport policy knowledgebase, KonSULT, which generates possible policy packages. It can do this in one of two ways: by taking a single user-specified policy instrument, and identifying the other policy instruments in KonSULT which might best support it; or by taking a user-specified shortlist of up to ten policy instruments, and identifying those combinations which might perform best in the specified context. In both cases the user specifies whether the emphasis should be on synergy or on the resolution of barriers. The tool then uses a matrix of interaction scores based on the literature and on professional judgment. Further research has since been carried out to provide improved estimates for the synergy interaction scores.

The paper describes the development and application of the tool. It reports the results of the further research, and discusses future developments.

*Keywords: urban transport; option generation; policy packages; synergy*

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# 1 INTRODUCTION

Transport planners face wide ranging challenges in attempting to create more sustainable urban transport systems (ECMT, 2002; DGTREN, 2007). Fortunately they have access to an increasingly wide range of policy instruments. While information on the performance of some of the more recently developed policy instruments is limited, some guidance is available from a number of sources. The principal ones are the VTPI TDM encyclopaedia (www.vtpi.org/tdm) and the KonSULT knowledgebase (www.konsult.leeds.ac.uk) (KonSULT, 2010). Other sources such as ELTIS provide case studies of successful policy interventions (www.eltis.org). However, very little guidance is available on how to select potentially suitable policy instruments in the first instance; a challenge that has become more significant as the number of possible policy instruments has expanded.

We refer to this process as Option Generation. What evidence there is suggests that Option Generation is rarely regarded as a key stage in the strategy or scheme formulation process. A study by Atkins (2007) for the UK Department for Transport of its Local Transport Plan process suggests that local authorities, in England at least, tend not to innovate, but rather to pursue schemes which have been under consideration for a long period, and to focus on infrastructure projects and management-based improvements to the infrastructure, rather than considering enhancements to public transport or ways of managing demand. The final report on the study confirmed that policy instruments involving public transport improvements, demand management and environmental enhancement were given less emphasis in both the first and second round of Local Transport Plans. The UK Eddington Report (Eddington, 2006) outlines the need succinctly: "Unless a wide range of appropriate options is considered, there is a risk that the best options are overlooked and money could be wasted. A good option generation process is crucial to ensure that the transport interventions that offer the highest returns can be found. The full range of options should look across all modes and include making better use of the existing transport system, including better pricing; investing in assets that increase capacity ….; investment in fixed infrastructure; and combinations of these options."

Option generation techniques can be applied at each of three levels: the selection of detailed design options for a specified scheme, such as a bus rapid transit route or road user charging scheme; the selection of specific policy instruments, such as bus rapid transit or road user charging, for inclusion in a strategy; and the packaging of different policy instruments, which might include, for example, bus rapid transit and road user charging, to form an overall strategy. The tool described in this paper deals with the second and third of these levels.

This distinction between schemes and strategies is an important one, and permeated the work of the DISTILLATE research programme on the development of decision support tools (May, 2009; May, Marsden and Shepherd, 2010). In the UK context, guidance on the first round of Local Transport Plans (DETR, 2000) had already stressed the importance of developing an overall strategy, but had given little guidance on how to do so. It became increasingly clear that many local authorities were unclear as to the meaning of a strategy, and tended to think in terms of a set of separately specified and unconnected policies (Atkins, 2005). In parallel, guidance on strategy development was emerging from related research (Lautso et al, 2004; May et al, 2005a; May, Kelly and Shepherd, 2006). It became clear that local authorities could adopt a strategy-led approach, in which the strategy was defined broadly, and developed as a set of more specific policy instruments, or a scheme related approach, in which individual policy instruments are selected and then packaged in ways which make them more effective. The tool described in this paper is designed to facilitate both of these approaches.

One element of the DISTILLATE research programme was the development of option generation tools for both schemes and strategies (Jones et al, 2009). Following a literature review in which types of option generation method were identified in transport and other public policy sectors, four types of option generation tool were developed, covering both schemes and strategies, and reflecting both “inside the box” and “outside the box” methods (Jones et al, 2009). This paper describes the further development of one of these four methods, based on the KonSULT knowledgebase on urban transport policy instruments (Matthews et al, 2002). The KonSULT option generation tool focuses on strategy identification, and uses library search techniques; it is therefore, in the categorisation of Jones et al (2009), an “inside the box” method.

Within the DISTILLATE research programme, the KonSULT option generation tool was developed to allow the user to identify those individual policy instruments which were most relevant to his or her context (Kelly et al, 2008). We summarise this method in Section 2 of this paper. An early version of a facility to identify pairs of policy instruments was also developed, and this has subsequently been expanded to allow the user to identify those policy instruments which best complement a given instrument, and to develop the best combinations of up to five policy instruments. It is this facility for the generation of policy packages which is the focus of this paper. It draws on our earlier work on the principles of integration (May et al, 2006), which we outline in Section 3. We describe the method in Section 4. The method was initially developed using values of the benefits of integration based on the principles in May et al (2006) and on professional judgment. Subsequently we have calculated such values from a sketch planning model of land use and transport policies, MARS (Pfaffenbichler et al, 2008), applied to the city of Leeds. We present these results in Section 5, and discuss their implications for the future development of the KonSULT option generation tool in Section 6.

# 2 THE KONSULT OPTION GENERATION TOOL FOR INDIVIDUAL INSTRUMENTS

KonSULT is a web- based knowledgebase designed to provide evidence on the performance of a wide range of transport and land use policy instruments. It can be accessed at www.konsult.leeds.ac.uk. A fuller description of its development can be found in Jopson et al. (2004) and Kelly et al (2008). The database contains a list of 60 policy instruments based on a taxonomy developed by May and Still (2000) and extended by Matthews and May (2001). The policy instruments are grouped into six high level categories of: land use interventions, behavioural and attitudinal measures, infrastructure projects, management and operational measures, information provision, and pricing. Updating the website is an ongoing process and to date 46 out of the 60 policy instruments have been populated with information. For each of these policy instruments there are five sets of specific information available to the user in the database:

1. a taxonomy and description that defines the instrument, its aims and technological requirements;
2. a first principles assessment that looks at why that instrument should be introduced, considers its anticipated demand and supply impacts, assesses the resulting positive or negative contributions to key policy objectives and problems, and identifies likely winners or losers and barriers to implementation;
3. evidence on performance, illustrated with a series of case studies describing specific interventions, and empirical evidence on their impacts on the same set of objectives and problems examined within the first principles assessment;
4. a summary of the contribution that the instrument is expected to make and the contexts in which it is likely to be most effective and
5. an identified set of complementary instruments that would work well with the selected instrument by helping to overcome barriers or enhance its positive impacts (the example for traffic calming is provided in Figure 3).

This database has been used as the basis for the KonSULT option generation tool described in this paper. The tool is accessed through the database website (www.konsult.leeds.ac.uk). It has been designed to take decision makers through a series of steps to identify suitable policy instruments based on their requirements.

Step 1 requires the decision maker to identify his or her responsibilities. The three categories offered are: decision makers from national organisations (e.g. national government), regional organisations (e.g. regional assemblies) and local government (e.g. city council). This selection recognises the fact that each level of government has limited powers to implement certain policy instruments. For example typically only the national government can modify fuel taxes. Where a policy instrument is not relevant to that organisation it is removed from the pool of policy instruments available.

Step 2 requires the decision maker to select the area type where the policy instrument is to be applied. This recognises that not all policy instruments will be as successful in all areas. This judgement is based on the information contained in the database on the contexts in which each policy instrument is likely to be most effective/least effective. In the database each policy instrument has been scored on a scale of 0 – 5 to classify how suitable it is in each area type. For example, the policy instrument park and ride scores 5 for applications along a transport corridor, but only 1 in a district centre. It is this score that is used in the option generation tool to weight how successful a particular policy instrument will be in each context. The area types are defined either by settlement size (large town or city >100k; small town or city<100k) or by location within a city (town or city centre; inner suburb, outer suburb, district centre, corridor). The user may broaden the search by specifying ‘any area type’.

Step 3 focuses on the objectives, problems or performance indicators (as shown in Figure 1) that are of particular concern to the user. The effectiveness of each policy instrument’s contribution to the objectives, problems and performance indicators has been assessed on an 11 point scale (-5 to +5) within the database. This determines the contribution (positive or negative) and the strength of this contribution for each policy instrument to each of the categories in Figure 1. This scoring system provides the key driver for determining how suitable each policy instrument is for the selected criteria.

The user is first asked to specify whether the search should be based on objectives, problems or indicators (to avoid double counting). The user is then able to identify those objectives (or problems, or indicators) of interest, and weight them on a scale of 0-5 to indicate which are of most importance. An example of this step is provided in Figure 1, in which the user has opted to focus on problems, has selected three problems of concern, and has decided that congestion is of high importance and the other two are slightly less important.

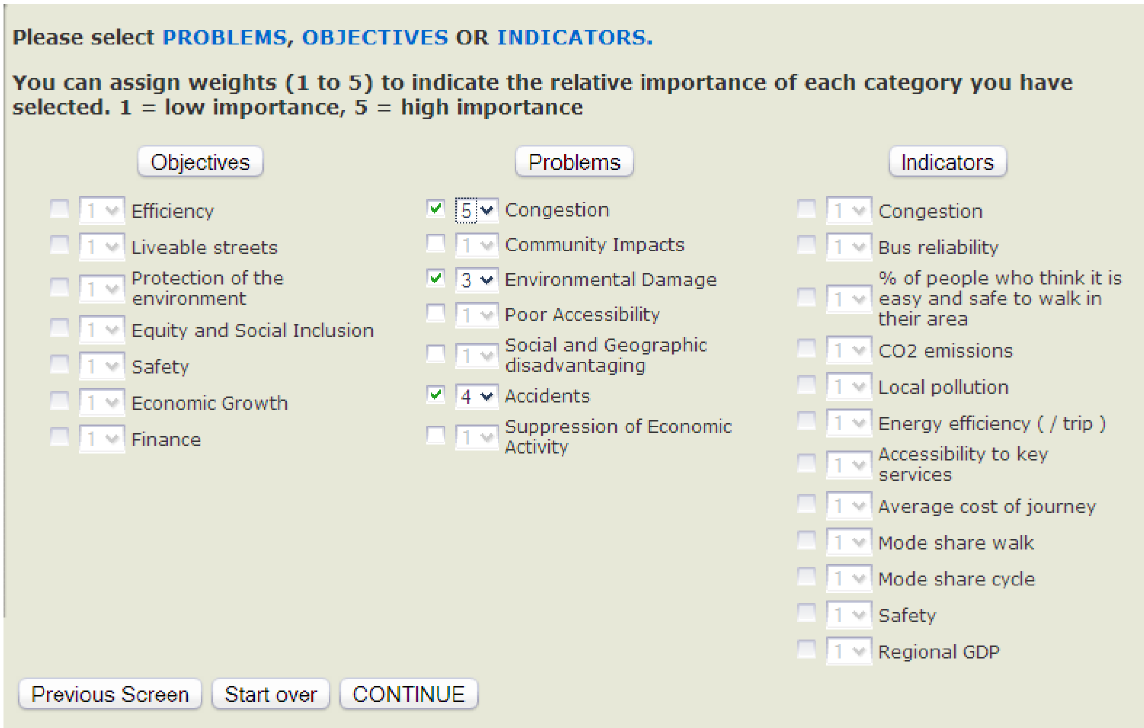
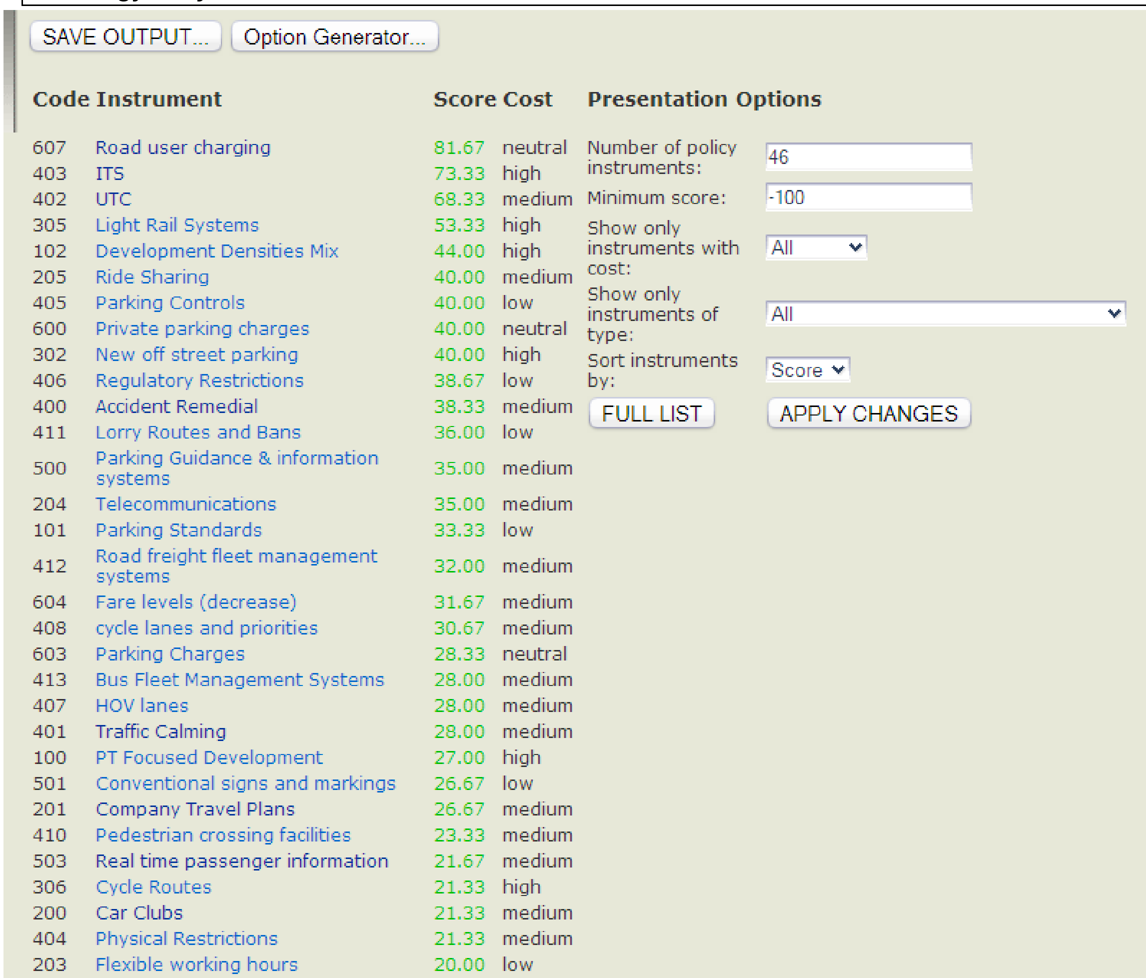



Figure 1: The Objective, Problem and Indicator specification screen

In addition to specifying the desirable attributes of policy instruments by the categories of objectives, problems and indicators, it is also possible to specify the strategy which the user wishes to pursue. For example, a decision maker may have a strategy of wanting to improve the use of public transport. The functionality for this option is the same as for objectives/ problems and indicators in that the user can select and then weight relevant strategies from a list.

Based on the inputs to each of these stages, the option generator produces a ranked list of policy instruments based on the user's selection criteria, as illustrated in Figure 2. The inputs into the KonSULT option generator which produced this list are shown in the box below. It can be seen that, based on these search criteria, road user charging would be the most effective policy instrument for meeting the problems being considered. The score of 81.67 for this instrument is generated by taking the scores from KonSULT's eleven-point scales and weighting them as specified by the user (Kelly et al, 2008). Absolute values (which typically approach 100 for the best options) are somewhat arbitrary, but relative values can be used to indicate the relative performance of different solutions.

**Selection criteria used to generate Figure 2**
User Group: *Local Authority*
Area Type: *Town or City Centre*
Objectives/ problems/ indicators: *Problems*
Problems being considered and weightings:
*Congestion (weight 5)*
*Accidents (weight 4)*
*Environmental Damage (weight 3)*
Strategy: *Any*


SAVE OUTPUT... Option Generator...

| Code | Instrument | Score | Cost |
|---|---|---|---|
| 607 | Road user charging | 81.67 | neutral |
| 403 | ITS | 73.33 | high |
| 402 | UTC | 68.33 | medium |
| 305 | Light Rail Systems | 53.33 | high |
| 102 | Development Densities Mix | 44.00 | high |
| 205 | Ride Sharing | 40.00 | medium |
| 405 | Parking Controls | 40.00 | low |
| 600 | Private parking charges | 40.00 | neutral |
| 302 | New off street parking | 40.00 | high |
| 406 | Regulatory Restrictions | 38.67 | low |
| 400 | Accident Remedial | 38.33 | medium |
| 411 | Lorry Routes and Bans | 36.00 | low |
| 500 | Parking Guidance & information systems | 35.00 | medium |
| 204 | Telecommunications | 35.00 | medium |
| 101 | Parking Standards | 33.33 | low |
| 412 | Road freight fleet management systems | 32.00 | medium |
| 604 | Fare levels (decrease) | 31.67 | medium |
| 408 | cycle lanes and priorities | 30.67 | medium |
| 603 | Parking Charges | 28.33 | neutral |
| 413 | Bus Fleet Management Systems | 28.00 | medium |
| 407 | HOV lanes | 28.00 | medium |
| 401 | Traffic Calming | 28.00 | medium |
| 100 | PT Focused Development | 27.00 | high |
| 501 | Conventional signs and markings | 26.67 | low |
| 201 | Company Travel Plans | 26.67 | medium |
| 410 | Pedestrian crossing facilities | 23.33 | medium |
| 503 | Real time passenger information | 21.67 | medium |
| 306 | Cycle Routes | 21.33 | high |
| 200 | Car Clubs | 21.33 | medium |
| 404 | Physical Restrictions | 21.33 | medium |
| 203 | Flexible working hours | 20.00 | low |

Presentation Options
Number of policy instruments: 46
Minimum score: -100
Show only instruments with cost: All
Show only instruments of type: All
Sort instruments by: Score
FULL LIST APPLY CHANGES

*Figure 2: KonSULT Output: Ranked policy instruments based on example selection criteria*

Figure 2 displays the use of the option generation tool for individual policy instruments. This tool has been developed further to extend this from individual policy instrument to packages. This is achieved on the tool by clicking on the **option generator** tab in Figure 2. The process of integrating policy instruments and creating packages will be described in the next section.

# 3 THE PRINCIPLES OF INTEGRATION

Integration as a principle in urban transport policy is frequently advocated, but rarely defined. A distinction can be drawn between operational integration, usually of public transport services and fares, and strategic integration, between transport policy instruments with land use, with policy instruments in other sectors, and spatially between parts of a conurbation. Given the range of policy instruments and the scales at which they can be implemented, design of effective strategically integrated policies is complex. In our earlier review of the principles of integration (May et al, 2006), we concluded that most integrated strategies are developed either in pursuit of synergy, or as a means of overcoming barriers, or both.

Synergy occurs when the simultaneous use of two or more instruments gives a greater benefit than the sum of the benefits of using either one of them alone:

*Welfare gain (A+B) > Welfare gain A + Welfare gain B.*

Synergy as defined is a special case of complementarity, which exists when the use of two instruments gives greater total benefits than the use of either alone (Mayeres et al, 2003):

*Welfare gain (A+B) > Welfare gain A, and*
*Welfare gain (A+B) > Welfare gain B.*

The case studies investigated in our earlier paper (May et al, 2006) show little evidence of synergy in performance against objectives, though there is some evidence of synergy in responses within the transport system. Subsequent investigation has suggested that this may occur primarily because two individual elements of a strategy designed to reduce, say, the adverse impacts of car use, will both impact in part on the same group of users. Their combined impact on car use will thus be less than the sum of their impacts taken individually.

The principal barriers to be overcome in strategy development have been identified elsewhere as institutional, financial, acceptability-related, technological and regulatory (May et al, 2005b; May and Crass, 2007). Financial and acceptability barriers, in particular, can be overcome by careful integration of different policy instruments, thus increasing the chance of the strategy being implemented. However, the overall benefit is likely to be less; thus a strategy focused on overcoming barriers is likely to be less effective than one designed in pursuit of complementarity.

# 4 THE KONSULT OPTION GENERATION TOOL FOR PACKAGES

Discussions with local authorities on the usefulness of the initial KonSULT option generation tool highlighted two further types of application which would be of assistance. The first application involved selecting a policy instrument of interest and then identifying those other policy instruments which would best complement it; this we referred to as the complementary instruments tool. The second application was more general, and involved identifying the best combinations of a given list of policy instruments, taken two or more at a time; this we referred to as the packaging facility. Each is outlined more fully below.

The original version of KonSULT already provided a section in the description of each instrument which identified those policy instruments which might best complement it. This used a table to identify possible instruments under four broad headings:

- overcoming financial barriers;
- overcoming political barriers;
- compensating losers; and
- reinforcing the benefits..

Figure 3 provides an example. The last of these columns, which corresponds to the concept of synergy or complementarity, as outlined above, was completed in all cases. The other three, which relate to the concept of overcoming barriers, were only completed where the barrier concerned applied to the given policy instrument. The table was completed based on professional judgment, rather than using an analytical treatment.

| Types of instrument | Instruments to overcome financial barriers | Instruments to overcome political barriers | Instruments to compensate losers | Instruments to reinforce benefits |
|---|---|---|---|---|
| **Land use measures** | - | | | Development densities, development pattern and development mix |
| **Attitudinal and behavioral measures** | - | - | - | - |
| **Infrastructure measures** | - | | | Park and ride, cycle routes, pedestrian routes and pedestrian areas |
| **Management of the infrastructure** | - | Cycle lanes and priorities | Conventional traffic management | Conventional traffic management, physical restrictions and cycle lanes and priorities |
| **Information provision** | - | - | - | Conventional direction signing and static direction signs |
| **Pricing** | - | - | - | - |

Figure 3: Example of the complementary instruments table for the policy instrument traffic calming

It was decided to suppress these tables, and replace them by the complementary instruments tool, which was designed to allow the user to identify complementary instruments which would reinforce the benefits, or which would overcome any barriers of concern. This required a scoring system which would indicate the extent to which any given policy instrument complemented the instrument in question (referred to as the synergy matrix) and the extent to which any given policy instrument would overcome barriers to the implementation of the instrument in question (referred to as the barriers matrix). Analytically, this can be represented as giving a combination score, $S_{(X+Y)}$, for two instruments X and Y, defined as:

$$S_{(X+Y)} = S_X + S_Y + I_{(X+Y)},$$

Where $I_{(X+Y)}$ is the interaction score for the pair of instruments X and Y, taken either from the synergy matrix ($I_{Sy(X+Y)}$) or the barriers matrix ($I_{B(X+Y)}$), as selected by the user. The derivation of these matrices is described below.

The procedure for identifying appropriate pairs of instruments, in the packaging tool, was able to make use of the same procedures; the only difference being that the user starts with a list of possible instruments, to be considered in pairs, rather than starting with an instrument of interest to be coupled with any of a list of other instruments. This procedure could then be expanded to consider sets of three, four or five policy instruments taken together; this in turn required an assessment of how the concepts of synergy and of barrier resolution applied to a three-, four- or five-way combination. This was done, straightforwardly, by assuming that, for a set of n instruments, the interaction score was simply the sum of the pairwise interaction scores for each pair of instruments. Thus, for three instruments, X, Y and Z, the score for the package, $S_{(X+Y+Z)}$, is given by:

$$S_{(X+Y+Z)} = S_X + S_Y + S_Z + I_{(X+Y)} + I_{(Y+Z)} + I_{(Z+X)}$$

One practical constraint arising in the use of the packaging tool was the number of combinations to be considered. There are, for example, approaching 1.4m combinations of five policy instruments which can be identified from the 46 policy instruments currently in KonSULT. To overcome this problem, it was decided to ask the user to choose a shortlist of at most ten policy instruments to be packaged.

Both the synergy and barriers matrices were based on the concepts developed in an earlier European research project, PROSPECTS (May and Matthews, 2007), which had developed a Decision-Makers' Guidebook, providing advice on the formulation of sustainable urban transport strategies (May et al, 2005b). This Guidebook is also now incorporated into KonSULT, thus facilitating links between concepts and practice. The Guidebook included a chapter on strategy formulation, which in turn included a table illustrating the ways in which pairs of policy instruments might interact. This table, reproduced in Figure 4, uses the six-fold categorisation of policy instruments adopted in KonSULT, and shows, for each pair, whether one category can reinforce another by adding to its benefits or by overcoming its barriers. This conceptual approach formed the basis of the synergy and barriers matrices, both of which, for simplicity, were only developed at the level of categories of measure.

| These Instruments | Contribute to these instruments in the ways shown | | | | | |
|---|---|---|---|---|---|---|
| | Land use | Infrastructure | Management | Information | Attitudes | Pricing |
| Land use | | ❋ | | | | ❋ |
| Infrastructure | ❋✚ | | ⦿ | | | ⦿ |
| Management | ❋✚ | ❋⦿✚ | | | ❋ | ❋⦿✚ |
| Information | ❋ | ❋⦿ | ❋⦿✚ | | ❋ | ❋⦿✚ |
| Attitudes | ❋⦿ | ❋⦿ | ❋⦿ | | | ⦿ |
| Pricing | ❋✚ | ❋◈✚ | ❋◈✚ | ◈⦿ | ❋ | |

Key: ❋ benefits reinforced ◈ financial barriers reduced
⦿ political barriers reduced ✚ compensation for losers

Source: May et al (2005b)

Figure 4: Interaction matrix from Decision-Makers' Guidebook

The development of the barriers matrix was straightforward. A positive score was allocated for every cell in Figure 4 in which the resolution of a barrier was identified. Given the magnitude of the performance scores for individual policy instruments which, as shown in Figure 2, typically had a maximum value of around 100, it was decided to allocate a score of 5 for the resolution of one barrier, 10 for two, and 20 for the resolution of all three. This gave the barriers matrix shown in Table 1.

Table 1: Barriers Matrix

| | Land use | Infrastructure | Management | Information | Attitudes | Pricing |
|---|---|---|---|---|---|---|
| Land use | 0 | | | | | |
| Infrastructure | +5 | 0 | | | | |
| Management | +5 | +10 | 0 | | | |
| Information | 0 | +5 | +10 | 0 | | |
| Attitudes | +5 | +5 | +5 | 0 | 0 | |
| Pricing | +5 | +20 | +20 | +20 | +5 | 0 |

The approach to the development of the synergy matrix was less obvious. The limited evidence on synergy, outlined above, suggested that true synergy rarely occurs, and that the benefit from a pair of policy instruments is likely to be less than the sum of their individual benefits, while still being greater than either benefit taken on its own (thus displaying complementarity). This implied imposing a negative score for the synergy effect. The magnitude of these negative scores was chosen very broadly on the basis of the first principles assessment of the impact of each category of policy instrument on demand and on supply. Where two policy instruments were both likely to influence demand in the same direction (for example by encouraging a switch from car use to public transport), it was assumed that there would be some duplication, and that the negative score should be greater. Conversely, where one influenced demand and the other supply, it was assumed that there would be less duplication, and hence a lower negative score. Based on these principles, the synergy matrix shown in Table 2 was developed, which simply used four levels of synergy effect, ranging from -5 to -30.

Table 2: Synergy Matrix

| | Land use | Infrastructure | Management | Information | Attitudes | Pricing |
|---|---|---|---|---|---|---|
| Land use | -30 | | | | | |
| Infrastructure | -20 | -30 | | | | |
| Management | -20 | -10 | -30 | | | |
| Information | -20 | -10 | -5 | -30 | | |
| Attitudes | -20 | -20 | -10 | -20 | -30 | |
| Pricing | -20 | -10 | -5 | -5 | -10 | -30 |

The user screen for the combined complementary instruments and packaging tools is shown in Figure 5, and sample outputs from the two in Figures 6 and 7. Initial tests of the output, and discussions with practitioners, have suggested that both produce credible outputs but, as indicated earlier, it was considered necessary to carry out further analysis to check on the values used in the matrices.

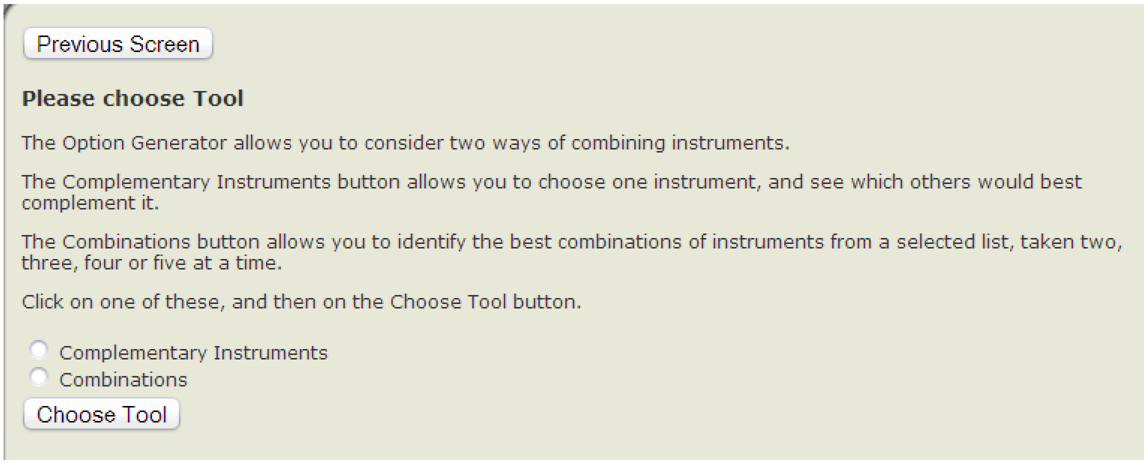



Figure 5: User Screen for the combined complementary instruments and packages tools


| Rank | Instrument1 | Instrument2 | Combined | Matrix | Total |
|---|---|---|---|---|---|
| 1 | Road user charging | ITS | 155.00 | -5 | 150.00 |
| 2 | Road user charging | UTC | 150.00 | -5 | 145.00 |
| 3 | Road user charging | Light Rail Systems | 135.00 | -10 | 125.00 |
| 4 | Road user charging | Parking Controls | 121.67 | -5 | 116.67 |
| 5 | Road user charging | Regulatory Restrictions | 120.33 | -5 | 115.33 |
| 6 | Road user charging | Accident Remedial | 120.00 | -5 | 115.00 |
| 7 | Road user charging | New off street parking | 121.67 | -10 | 111.67 |
| 8 | Road user charging | Ride Sharing | 121.67 | -10 | 111.67 |
| 9 | Road user charging | Development Densities Mix | 125.67 | -20 | 105.67 |
| 10 | Road user charging | Private parking charges | 121.67 | -30 | 91.67 |

Figure 6: Example output from the complementary instrument tool (using the synergy matrix) and key policy instrument road user charging

**Presentation Options**

Number of policy instrument combinations: 252

Minimum score: -100

FULL LIST | APPLY CHANGES

| Rank | Instrument1 | Instrument2 | Instrument3 | Combined | Matrix | Total |
|---|---|---|---|---|---|---|
| 1 | UTC | ITS | Road user charging | 223.33 | 40 | 263.33 |
| 2 | Light Rail Systems | ITS | Road user charging | 208.33 | 50 | 258.33 |
| 3 | Light Rail Systems | UTC | Road user charging | 203.33 | 50 | 253.33 |
| 4 | New off street parking | ITS | Road user charging | 195.00 | 50 | 245.00 |
| 5 | New off street parking | UTC | Road user charging | 190.00 | 50 | 240.00 |
| 6 | ITS | Private parking charges | Road user charging | 195.00 | 40 | 235.00 |
| 7 | ITS | Parking Controls | Road user charging | 195.00 | 40 | 235.00 |
| 8 | Accident Remedial | ITS | Road user charging | 193.33 | 40 | 233.33 |
| 9 | UTC | Parking Controls | Road user charging | 190.00 | 40 | 230.00 |
| 10 | UTC | Private parking charges | Road user charging | 190.00 | 40 | 230.00 |
| 11 | Development Densities Mix | ITS | Road user charging | 199.00 | 30 | 229.00 |
| 12 | Accident Remedial | UTC | Road user charging | 188.33 | 40 | 228.33 |
| 13 | Ride Sharing | ITS | Road user charging | 195.00 | 30 | 225.00 |
| 14 | Light Rail Systems | Parking Controls | Road user charging | 175.00 | 50 | 225.00 |
| 15 | Development Densities Mix | UTC | Road user charging | 194.00 | 30 | 224.00 |
| 16 | Light Rail Systems | Accident Remedial | Road user charging | 173.33 | 50 | 223.33 |
| 17 | UTC | ITS | Private parking charges | 181.67 | 40 | 221.67 |
| 18 | Ride Sharing | UTC | Road user charging | 190.00 | 30 | 220.00 |
| 19 | Light Rail Systems | ITS | Private parking charges | 166.67 | 50 | 216.67 |
| 20 | Light Rail Systems | UTC | ITS | 195.00 | 20 | 215.00 |
| 21 | Light Rail Systems | Private parking charges | Road user charging | 175.00 | 40 | 215.00 |
| 22 | New off street parking | Light Rail Systems | Road user charging | 175.00 | 40 | 215.00 |
| 23 | New off street parking | Parking Controls | Road user charging | 161.67 | 50 | 211.67 |
| 24 | Light Rail Systems | UTC | Private parking charges | 161.67 | 50 | 211.67 |
| 25 | New off street parking | Accident Remedial | Road user charging | 160.00 | 50 | 210.00 |
| 26 | Development Densities Mix | Light Rail Systems | Road user charging | 179.00 | 30 | 209.00 |

Figure 7: Example output from the packaging tool for packages of three policy instruments using the barrier matrix and the results from Figure 2

# 5 THE MARS MODEL TESTS

As noted in the introduction, we used the MARS model of Leeds to test the performance of combinations of policy instruments, in order to improve our understanding of the extent to which synergy arises in practice, and hence improve the estimation of the synergy scores above. This section first of all gives a brief overview of the strategic model MARS. It then describes the tests undertaken.

<u>The MARS model</u> MARS is a dynamic Land Use and Transport Interaction model. The basic underlying hypothesis of MARS is that settlements and activities within them are self organising systems. MARS is based on the principles of systems dynamics (Sterman 2000) and synergetics (Haken 1983). The development of MARS started some 10 years ago partly funded by a series of EU-research projects. To date MARS has been

applied to ten European cities (Bari, Edinburgh, Gateshead, Helsinki, Leeds, Madrid, Oslo, Stockholm, Trondheim and Vienna) and three Asian cities (Chiang Mai and Ubon Ratchathani in Thailand and Hanoi in Vietnam). Two more models are also being developed in the USA and Brazil. The present version of MARS is implemented in Vensim®, a System Dynamics programming environment. This environment was designed specifically for dynamic problems, and is therefore an ideal tool to model dynamic processes.

MARS is capable of analysing policy combinations at the city/regional level and assessing their impacts over a 30 year planning period in less than one minute. Figure 8 shows the basic structure of the model. It includes a transport model which simulates the travel behaviour of the population related to their housing and workplace location, a housing development model, a household location choice model, a workplace development model, a workplace location choice model, as well as a fuel consumption and emission model. The sub-models are run iteratively over a 30 year time period. They are linked on the one hand by accessibility as output of the transport model and input into the land use model and on the other hand by the population and workplace distribution as output of the land use model and input into the transport model. The demand for commute trips is based on trip rates and the employed population while the demand for "other" trips is a result of applying a constant time budget, hence any time saved on commute trips will result in an increase in "other" trips. A comprehensive description of MARS can be found in Pfaffenbichler (2003) or Pfaffenbichler et al (2008).

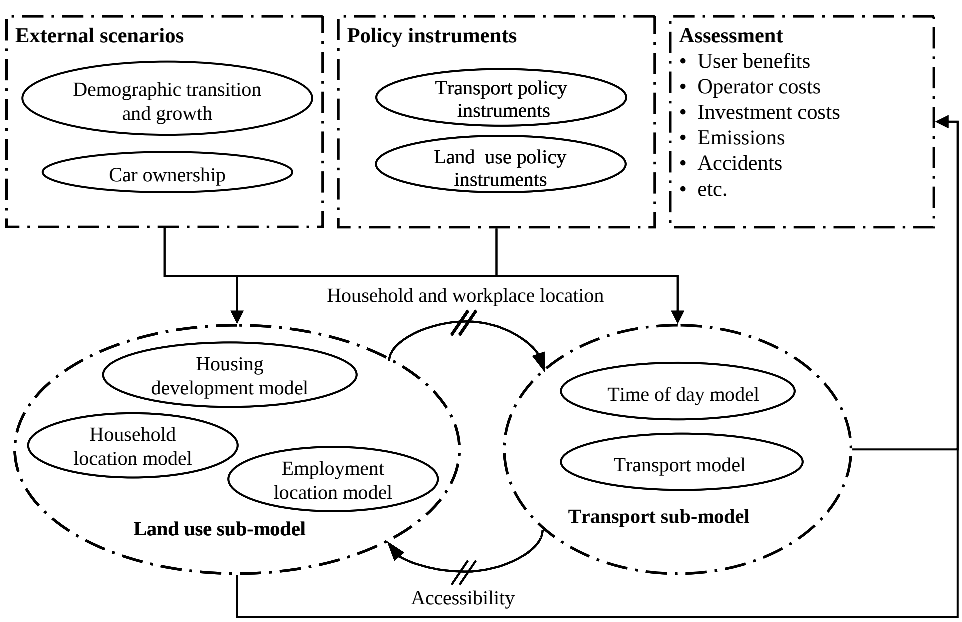



Figure 8: Basic structure of the MARS sub-models

Model tests In order to estimate the extent of synergy between combinations of instruments, a number of policy instruments have been simulated both alone and in combination. Those selected are listed in the first column of Table 3. They are assumed, for simplicity, to be implemented in the fifth year of the 30 year modelling period, which starts in 2001, and then retained at that level for the remaining period. The application levels are shown in the second column of Table 3 and build on earlier work by Shepherd et al (2006) who used a MARS model of Edinburgh to investigate the individual contributions of instruments and their optimal levels when used in isolation taking a welfare function as the means of appraisal.

Table 3: Policy instrument descriptions and levels applied

| Policy Instrument description | Level of application in year 5 and beyond | Short name |
|---|---|---|
| Fares area wide peak and off peak | -50% | Fare |
| Road pricing cordon charge (peak) | 5 euros | RP5 |
| Road pricing cordon charge (peak and off peak) | 5 euros in peak and off-peak | RP5-5 |
| Parking charge (long stay) city centre | Add 5 euros | Park |
| Fuel tax/duty | +100% | Fuel |
| Bus frequency increase (peak and off peak) | +50% peak and off-peak | Freq |
| PT Awareness campaign – area wide | Implemented in year 5 with decreasing impact over time | PT-aware |
| Low cost increases in road capacity e.g. traffic management, signals | +5% | Rcap |

Indicators Rather than use an overall welfare function we have instead looked at the impact of combinations of policy instruments on three indicators:-

1. Total $CO_2$ emitted – well to wheel;
2. Total delay to car users in the peak;
3. Number of accidents.

Each indicator is expressed as a percentage change compared to the do-minimum for the year 2010 (i.e. a notional five years after implementation). These indicators were chosen to reflect three of the five goals from the UK Department for Transport's recently specified goals for delivering a sustainable transport strategy (DaSTS) (DfT, 2008).

Results: single instruments Firstly the instruments were simulated in isolation to record the individual scores for each indicator. This is equivalent to $S_x$ in the above equations but here we have three scores, one for each indicator. Table 4 shows the percentage reduction in year 2010 for each policy using the short name to describe the instrument applied. Reductions are used so that a positive score is beneficial which will ensure that the sign for synergy is negative if the combined score is less than the sum of the individual scores.

The changes in $CO_2$ are a little lower than those for Edinburgh (see Shepherd et al, 2006) and it can be seen that fuel tax rises and fare reductions have the greatest impact in terms of reducing emissions as was also found in the earlier study. Public transport awareness campaigns also have a significant impact as they reduce car trips by attracting users to public transport. Peak only road pricing has less of an impact than does all day road pricing as car use may increase in the off-peak due to the assumed constant time budget in MARS. The other noteworthy result is that increasing public transport frequencies will increase emissions of $CO_2$ due to increased bus kilometres.

Table 4: Changes in indicators for year 2010 - single instruments

| Instrument | % Reduction in $CO_2$ | % Reduction delay (Peak) | % Reduction in Accidents |
|---|---|---|---|
| Fare | 1.94% | 6.05% | 1.31% |
| RP5 | 0.76% | 7.69% | -0.50% |
| RP5-5 | 1.14% | 7.69% | -0.32% |
| Park | 0.42% | 3.34% | -0.18% |
| Fuel | 4.33% | 11.22% | 3.72% |
| Freq | -5.12% | 4.11% | 1.36% |
| PT-aware | 2.92% | 9.22% | 1.95% |
| Rcap | -0.27% | 12.32% | -3.31% |

All policies are seen to reduce the total delay to car users in the peak with road capacity and fuel duty rises being the most effective (again as was seen in earlier work). The changes in accidents are less significant and the sign of the change is harder to predict as accident numbers are affected by changes in both flow and speed. For example increasing road capacity will increase flow and speed which will both contribute to increases in accidents. Again fuel tax rises have the greatest impact.

Results: pairs of instruments The next step in the process is to simulate pair-wise combinations of instruments. Table 5 shows the results for a number of combinations (not the full set due to space and time limitations).

Table 5: Results for pairs of instruments

| Pairs of instruments | % Reduction $CO_2$ | Synergy $CO_2$ | % Reduction Delay | Synergy Delay | % Reduction Accidents | Synergy Accidents |
|---|---|---|---|---|---|---|
| fare-fuel | 6.36% | 0.09% | 17.04% | -0.23% | 5.19% | 0.16% |
| fare-park | 2.37% | 0.01% | 9.29% | -0.10% | 1.15% | 0.02% |
| fare-freq | -2.85% | 0.33% | 10.63% | 0.47% | 2.99% | 0.32% |
| fare-rp5-5 | 3.10% | 0.02% | 13.49% | -0.25% | 1.04% | 0.05% |
| fare-rp5 | 2.71% | 0.01% | 13.49% | -0.24% | 0.84% | 0.03% |
| fare-ptaware | 3.55% | **-1.31%** | 11.08% | **-4.19%** | 2.39% | **-0.87%** |
| fare-rcap | 1.69% | 0.02% | 17.60% | -0.76% | -1.82% | 0.18% |
| rp5-ptaware | 3.69% | 0.02% | 16.54% | -0.37% | 1.48% | 0.04% |
| rp5-fuel | 5.14% | 0.05% | 19.14% | 0.23% | 3.23% | 0.01% |
| rp5-freq | -4.36% | 0.00% | 11.60% | -0.20% | 0.86% | 0.01% |
| rp5-park5 | 0.99% | **-0.19%** | 8.44% | **-2.59%** | -0.52% | 0.16% |
| rp5-rcap | 0.45% | -0.03% | 19.07% | -0.94% | -3.77% | 0.05% |
| rcap-park | 0.14% | -0.01% | 15.29% | -0.37% | -3.47% | 0.02% |
| rcap-freq | -5.34% | 0.05% | 15.89% | -0.54% | -1.80% | 0.15% |
| rcap-fuel | 4.13% | 0.07% | 22.06% | -1.48% | 0.83% | 0.42% |
| rcap-ptaware | 2.68% | 0.03% | 20.39% | -1.15% | -1.10% | 0.27% |
| freq-fuel | -0.65% | 0.14% | 15.20% | -0.13% | 5.27% | 0.19% |
| Park-fuel | 4.78% | 0.02% | 14.58% | 0.01% | 3.56% | 0.02% |
| park-freq | -4.69% | 0.01% | 7.38% | -0.07% | 1.20% | 0.01% |

In Table 5 the synergy columns are calculated from

$$I_{(X+Y)} = S_{(X+Y)} - (S_X + S_Y)$$

that is the ***true*** synergy matrix $I_{(X+Y)}$ is calculated as the combined score $S_{(X+Y)}$ minus the sum of the individual scores (all taken from the simulations). These pair-wise synergies will be used later to estimate the synergy matrices for more complex combinations of instruments, thus testing whether using pairs of instruments to form scores for more complex combinations is a reasonable approach to take.

We take the results for the changes in peak delay first as these are in line with the expectation that synergies are generally negative. From Table 5 we can see that the changes are significant for all pairs of instruments. The most effective combinations include fuel tax increases, road capacity increases and road pricing around the city centre. In terms of synergy scores, most are relatively small and negative which implies that these instruments act almost independently and that results are additive in terms of peak delay. There are some strong negative scores, for example for long term parking charges with road pricing charges in the city centre the synergy is -2.59% which implies a strong overlap between these policies and that it would be unwise to implement both at such a high level. As shown in our earlier work (Shepherd et al, 2006) when such instruments are combined the optimal levels for each are lower. Similarly there is a strong negative score of -4.19% for fare reductions with public transport awareness campaigns. This again implies a strong overlap and that in policy terms it may be that lower fare reductions are justified in the presence of awareness campaigns.

Only three combinations of instruments resulted in positive synergy scores. The score for parking charges plus fuel tax rises is only +0.01% which is insignificant and these instruments can be thought of as perfectly additive. Road pricing in the peak plus fuel tax increases results in a small positive synergy which is difficult to explain. It may be that fuel tax increases affect the longer trips whilst the cordon charge impacts on the shorter trips. Finally fare reductions plus frequency increases result in small positive synergy. This may be because fares act on travel costs while frequency increases act on wait times, thus influencing different elements of generalised cost.

In general we can say that synergy scores for delay are usually low and negative and that higher negative scores will exist where there is a greater overlap in the policy instruments. It would seem reasonable to suggest that no significant positive synergies will exist for the delay indicator.

For the $CO_2$ indicator, overall increases in $CO_2$ are only seen where public transport frequencies are increased. Most synergy values are insignificant yet positive. It is difficult to trace through all the arguments here as the emissions factors are non-linear in speed and therefore differ for each OD pair. In general for the speeds encountered in the urban area the aggregate emissions of $CO_2$ fall with increased speed. The effects of mode shift and re-distribution of trips makes it difficult to determine the level of synergy here. We can however see that the strongest negative synergies are once again for the fare reduction with public transport campaign and for the parking with road pricing pairs. It would therefore seem reasonable to suggest that no real synergy exists and that for $CO_2$ it is better to say that most policies are almost perfectly additive.

For the accidents indicator, some combinations produce an increase in accidents, mainly where increases in road capacity are included. The synergies for pairs of policies for reduction in accidents are all positive (yet very small) except for the combination of fare reductions with public transport campaigns. Again this is due to the non-linear relationship between accidents and speed which differs for each OD pair. In the model accident rate/km will increase with increased speed. In most cases therefore the speed effect is outweighed by the reduction in trips and some very small positive synergy exists for these pairs of instruments.

Results: combinations of instruments The next step in the process was to model combinations of more than two policy instruments. Table 6 shows the results for combinations of up to six instruments with the associated indicators, true synergies calculated from the simulations and an estimated synergy based on the sum of synergy matrices for the relevant pairs of instruments. Taking three policies X, Y and Z as an example the true synergy measured by simulation is taken as

*True synergy* $I_{(X+Y+Z)} = S_{(X+Y+Z)} - (S_X + S_Y + S_Z)$

and the estimated value of the true synergy, calculated from the sum of the synergies of the pairs, is given by:

*Estimated synergy from pairs* $= I_{(X+Y)} + I_{(Y+Z)} + I_{(Z+X)}$

where the values for $I_{(X+Y)}$ etc are taken from the pair-wise simulations shown in Table 5.

This set of tests enables us to investigate whether or not it is reasonable to use sums of relevant pair-wise synergy matrices in forming the synergy score for more complex combinations of policies.

Table 6 shows that for $CO_2$ and accidents the estimated synergy scores are a good match for the true synergies in all cases. In general the synergies are small and positive as was the case with pairs of instruments for these indicators. Regarding the magnitude of the synergy there does not appear to be any pattern for $CO_2$ though the larger values involve fare reductions and frequency increases. For accidents the synergies seem to increase with the number of instruments involved which reflects the fact that all but one of the synergies was positive for pairs of instruments.

For the delay indicator, the estimated synergy values are reasonably accurate once again but there appears to be some evidence that the estimates are less accurate as the number of instruments is increased. However these errors are only in the order of 8% for 5 and 6 instruments. Thus we may conclude that the approach of using the sum of synergy matrices to estimate synergies for complex combinations is reasonable for the purposes of KonSULT. Given the complex interactions, it is however often difficult to estimate the synergy for a given pair of instruments and a given indicator.

Table 6: Results for more complex combinations of instruments

| Combinations of policy instruments | % Reduction $CO_2$ | Synergy $CO_2$ | Synergy estimate from pairs $CO_2$ | % Reduction Delay | Synergy delay | Synergy estimate from pairs delay | % Reduction accidents | Synergy accidents | Synergy estimate from pairs accidents |
|---|---|---|---|---|---|---|---|---|---|
| 3 Instruments | | | | | | | | | |
| Fare-rp5-rcap5 | 2.42% | 0.00% | 0.00% | 24.15% | -1.90% | -1.94% | -2.25% | 0.25% | 0.25% |
| Fare-freq-fuel | 1.70% | 0.54% | 0.55% | 21.46% | 0.08% | 0.10% | 7.07% | 0.68% | 0.68% |
| rcap-freq-fuel | -0.81% | 0.25% | 0.26% | 25.55% | -2.11% | -2.16% | 2.52% | 0.75% | 0.76% |
| Fare-rp5-fuel | 7.17% | 0.14% | 0.14% | 24.69% | -0.26% | -0.24% | 4.73% | 0.20% | 0.21% |
| Fare-rp5-park | 2.94% | -0.18% | -0.18% | 14.22% | -2.86% | -2.94% | 0.84% | 0.21% | 0.21% |
| rcap-rp5-fuel | 4.90% | 0.08% | 0.08% | 29.06% | -2.17% | -2.19% | 0.39% | 0.48% | 0.48% |
| rcap-park-fuel | 4.56% | 0.08% | 0.08% | 25.05% | -1.83% | -1.84% | 0.69% | 0.46% | 0.46% |
| 4 Instruments | | | | | | | | | |
| Fare-rp5-rcap-fuel | 6.96% | 0.20% | 0.20% | 33.94% | -3.34% | -3.42% | 2.06% | 0.85% | 0.85% |
| Fare-freq-rcap-fuel | 1.56% | 0.68% | 0.70% | 31.05% | -2.65% | -2.68% | 4.50% | 1.42% | 1.42% |
| Fare-freq-rp5-rcap | -2.32% | 0.38% | 0.38% | 27.99% | -2.17% | -2.22% | -0.40% | 0.74% | 0.73% |
| 5 Instruments | | | | | | | | | |
| Fare-freq-rp5-rcap-fuel | 2.34% | 0.70% | 0.72% | 37.61% | -3.77% | -3.83% | 4.11% | 1.53% | 1.52% |
| Fare-rp5-cap-fuel-park | 7.21% | 0.03% | 0.02% | 34.63% | -5.98% | -6.48% | 2.09% | 1.06% | 1.07% |
| 6 Instruments | | | | | | | | | |
| Fare-rp5-cap-fuel-park-freq | 2.59% | 0.53% | 0.55% | 38.29% | -6.44% | -6.96% | 4.15% | 1.76% | 1.75% |

# 6 CONCLUSIONS AND NEXT STEPS

This paper identifies the need for improved methods for generating strategic policy options in urban transport, and describes the development of an option generation tool, initially for single instruments, and subsequently for policy packages.

The latter requires a measure of the additional benefits of combining policy instruments, when compared with the sum of their benefits taken individually. The tool allows the user to select scores reflecting these additional benefits in two ways: as a measure of synergy between the instruments concerned, and as a reflection of the extent to which one instrument can overcome the barriers to implementing the other instruments.

Early tests of the tool (Kelly, May and Jopson, 2008) indicated that it was easy to use and to explain to others, and that its results generally appeared intuitively correct. Undocumented reports of subsequent applications confirm these findings. However, as we note in a companion paper (May, Marsden and Shepherd, 2010), the tool has only had limited application to date, perhaps reflecting the lack of emphasis on option generation cited in the reviews summarised in Section 1. While continuing to seek more widespread applications of the tool, we have therefore focused, in this paper, on research to test the assumptions implicit in the tool's treatment of the impacts of integration.

In the initial development of the tool, the additional benefits from integration were assessed somewhat arbitrarily on the basis of professional judgment. This is probably satisfactory for the measure of ability to overcome barriers, which is primarily a qualitative construct. However, synergy can be calculated, and the further research reported in this paper has used a sketch planning model, MARS, for the city of Leeds, to estimate the extent of synergy between selected policy instruments for three performance indicators: delay reduction, $CO_2$ emission reduction and accident reduction.

For pairs of instruments, synergy for delay reduction was negative, and ranged from very small values for policy instruments which act independently, to around 20% of the combined impact for those which to some extent overlap in their impacts. For $CO_2$ reduction, most synergy scores were very small, but positive. Only in four cases did negative synergy arise, and in two of these the value was again around 20% of the combined impact. The same was broadly true for accident reduction, but six combinations produced substantial positive synergy, often in situations where accidents were predicted to increase.

These results suggest that the synergy matrix score levels of -5 to -30 (in Table 2) are broadly correct, but that the values will differ depending on the emphasis in the objective function, and that care will be needed in applying them if the main focus is on accident reduction. However, the results also indicate that policy instruments within the same broad category can perform very differently, and can have synergy effects when combined. The current coarse matrix does not enable these attributes to be reflected, and it will be important, as a next step, to populate an extended matrix with values obtained from analyses of the kind reported in this paper. There may in due course be merit in developing a range of matrices which can be used to reflect the range of objectives which user can specify.

For combinations of instruments, the results indicate that true synergy can be estimated as the sum of the synergies from each pair of instruments in the combination. This holds true for all three performance indicators. Thus the simplified approach to estimating synergy described in the paper has been supported by the model predictions, and can be sustained.

In conclusion, the next step in the development of this policy package option generator should be to expand the interaction matrices to cover the full set of policy instruments, rather than simply the six broad categories, and to provide values based on model tests of pairs of policy instruments as reported in this paper. This work is now in hand.

As a subsequent development, there is a case for having different values in the synergy matrix to reflect different policy objectives, again as generated by model tests. A user specifying a given weighted set of policy objectives (as in Figure 1) would then be assigned a synergy matrix which reflected these weighted objectives.

In parallel, as noted elsewhere (Eddington, 2006, May, Marsden and Shepherd, 2010), further effort is needed to encourage local authorities to give appropriate weight to the process of option generation, and to apply the tools available to support this process. Once local authorities begin to develop, implement and evaluate effective packages of policy instruments, it will be possible to collate the evidence on the effects of such packages, and to use that evidence to enrich option generation tools of the kind described in this paper.

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