A guide to the application of the TRANUS modeling system to the city of Swindon, UK

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1 About this guide

The purpose of this guide is to help understanding the TRANUS application to the city of Swindon in the UK. TRANUS is an integrated land use and transport modelling system. The system is described in three documents available from www.tranus.com :

- General Description of the TRANUS modelling system
- Mathematical description of TRANUS ('Math Manual')
- Graphical interface and database of TRANUS – TUS ('TUS Manual')
- Models and report-generating programs of TRANUS ('Programs Manual')

These documents will be referred to along this guide. With this guide it is hoped that those interested in applying the modelling system to cities and regions may use the model of Swindon as an example. The TRANUS software is available free from the same site.

The preparation of this guide was made by Tomás de la Barra, Francesca Pagliara and Adriano Reale. We hope that others may send contributions to this first version of the guide.

In this guide you will find an introduction with background information about the application of Swindon. Then the model design is described, explaining how the design is represented in the TRANUS database. Next the data that describes the base-year scenario is explained and also the way in which it is entered to the database and how to run the model. This is followed by the way in which the main results of the base-year scenario may be obtained and general information about how the model was calibrated.

Future scenarios are described next, explaining how the scenario data is entered, the way in which the models are run and the results obtained. The way in which comparative tables are produced for both land use and transport results is described, accompanied with the comparative analysis of the results. Finally suggestions are given so that the reader may build his or her own scenarios to perform additional analysis.

2 About the Swindon application

The application of the TRANUS integrated land use and transport model to the city of Swindon in the UK was the outcome of a two-year research project, funded by the EPSRC in its Sustainable Cities Programme (Grant ref. GR/K 62170, Oct.1995 - Oct. 1997). The project involved collaboration between two universities, two firms of private consultants, and a local authority:

The Open University Centre for Configurational Studies	Prof J P Steadman Dr S Holtier
The University of Manchester School of Architecture	Dr F E Brown Mr J Turner
Modelistica (Caracas, Venezuela)	Dr T de la Barra
Rickaby Thompson Associates (Milton Keynes)	Dr P A Rickaby

The former Borough of Thamesdown, now the Borough of Swindon

Such partnership has a long tradition. Most members of the team originated from The Martin Centre at Cambridge University, UK. In the late 60's and early 70's Cambridge attracted a considerable number of scholars around a number of basic principles. Considerable research was carried out to understand the way in which cities and regions organize in space and evolve through time. The possibility of developing computer models of cities and regions was explored to considerable extent as a way to provide a rational support to the planning process, so that decisions and designs could be based on a solid, rational, basis. The interaction between the transport system, the location of activities and the real estate market was one of the main theoretical principles to be supported.

In this project, an integrated land use, building stock, transport and energy model was built of the town of Swindon (Wilts) with its rural hinterland and adjacent villages. This model predicts the location of floorspace and land used by different activities, and simulates the associated traffic flows. It was used to explore four contrasted scenarios for the growth of Swindon up to the year 2016.

The modeling software is TRANUS, developed by Dr de la Barra of Modelistica. The Swindon model was supported by a comprehensive database of information about population, employment, building stock, land uses, public transport services and the traffic network. The model makes detailed predictions for each of the 56 zones into which the study area was divided and for every link in the transport network. These results were displayed graphically in the ArcView GIS, but other GIS systems may be used to replicate them.

The TRANUS model has a consistent micro-economic basis in random utility theory, and an input-output formulation in the land use sub-model. It is one of very few such models to incorporate energy calculations. In operation, the model starts from the existing level and spatial distribution of basic industry - that is industry that exports goods and services out of the study area. Any increase in basic industrial employment will bring about a corresponding growth in (local) service industries, which the model estimates. Demands are created for new industrial, commercial and residential floorspace. The model simulates the real estate market, takes account of the supply of available land and its relative accessibility through the transport system, and predicts where the new activities will be located. The availability of very detailed data on buildings in Swindon made it possible to develop and test a unique representation of the floorspace market, disaggregated into different building types. All this sets the scene for the simulation of traffic flows.

Depending on the relative locations of housing, industry and services, the model estimates the numbers of trips made for different purposes. It allocates these trips to modes of transport - private car, bus, train, cycle, walking - depending on relative costs and journey times. The resulting traffic is assigned to the network of roads and other transport links depending on distances through the network, and the capacities of the links. Any resulting congestion can affect journey times and cause trips to be re-routed. As the model is run for successive points in time, the interaction of land uses and transport in the first period determines a new pattern of land uses for the second period, and so on. Changes in the transport network, as for example bus lanes, park-and-ride services or restrictions on car traffic, can be introduced as new links in the network and/or changes in the attributes of links. Fuel consumption in transport is calculated for different types of vehicles depending on average speeds in each link in the network. Fuel consumption in buildings is estimated on the basis of floor areas and building types for different activities.

3 Structure of the model of Swindon

The TRANUS modeling system is very general and flexible. Consequently, the first task in developing the model is *model design*, in which the modeler defines the main components that will represent the study area and the way in which such components are related to each other. The definition of sectors in the land use model is outlined, together with the main relationship among them. Details are given about the structure of the floorspace and land markets. The main components of the transport system are also described, including demand categories, modes, link types, public transport routes, and other elements. In both cases, the way in which the design is represented in the modeling software is described in some detail.

In this case the modeling system is being applied to a relatively small English town. What is interesting in this application is that the study area is small with few zones, so that it runs very fast in our PCs of today, but the application is complex in that the structure of the model includes many sectors, floorspace and land, and the transport system also includes many features such as bus lanes, park-and-ride, integrated fares, and so on.

The following sections provide a walk-through tour of the database, beginning with some general definitions, then the land use model and finally the transport model.

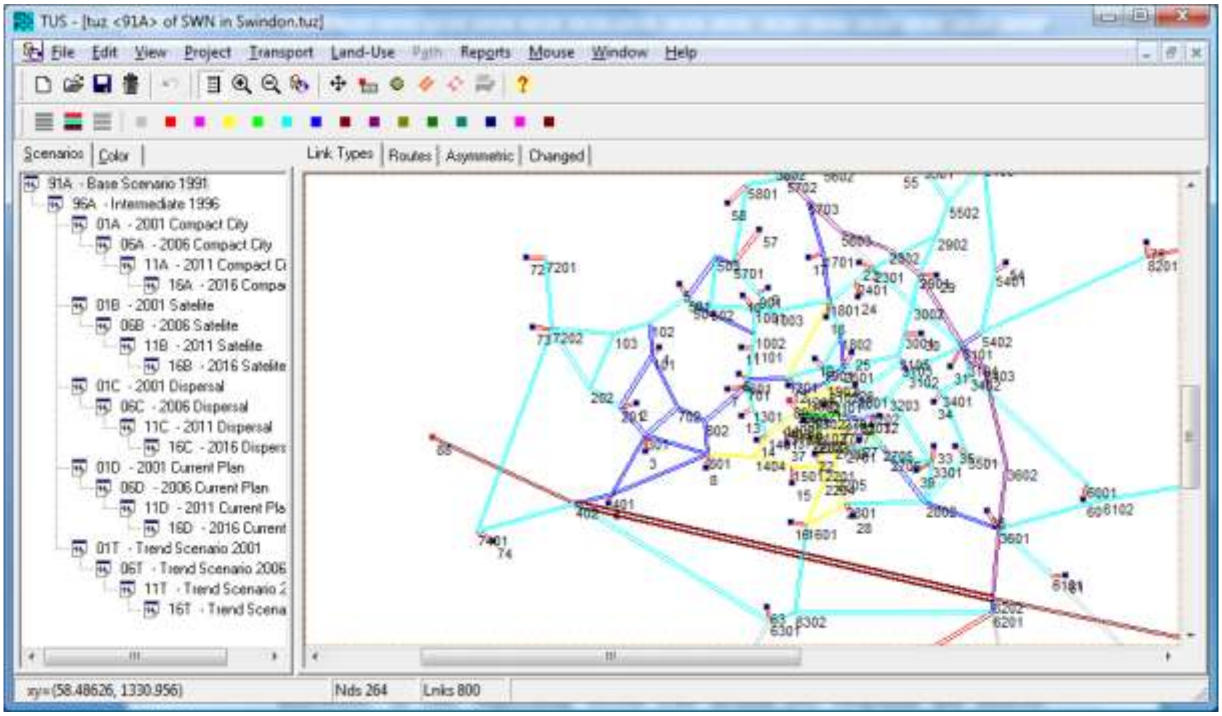
3.1 General definitions

Defining the project

There are two ways of opening a project database: trigger the TRANUS user interface and then go File->Open, or use the Windows explorer to find the Swindon.tuz file and double-click on it. Once the database has been opened, a window similar to the one shown in Figure 1 should appear. The main components of this interface are described in full detail in the corresponding manual. At the top there are several menus, icons to perform tasks and a color palette. The big screen to the right is the *network view* and to the left is the *scenario tree*.

Notice that when you open the application you get a specific view of the network with colors assigned to different entities, scale and other pre-defined elements. This is because the file *Swindon.tuz* is accompanied by another, much smaller, file called *Swindon.ini*. If the accompanying file is not present in the working folder, the network view defaults to some preset values. Most of the presentation settings are defined in the menu View->Options.

Figure 1: Main window of the TRANUS interface with the model of Swindon



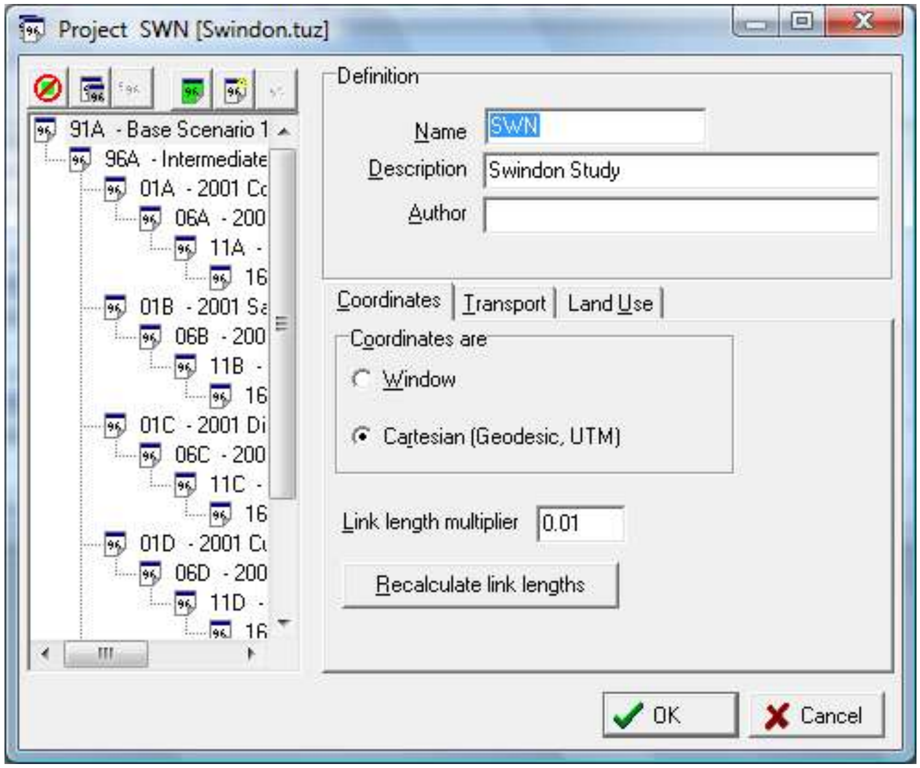
The menu Project->Options will show some general characteristics of the application, as may be seen in Figure 2. The scenario-tree appears to the left. The application is given a three-characters code, in this case *'SWN'*. This code is important because it determines the names given to all files in the database. The description *'Swindon Study'* is less relvant.

Next there are three tabs: Coordinates, Transport and Land Use. The Coordinates tab shows a choice of coordinates system, either Windows or Cartesian. This refers to the way in which the coordinates of the nodes in the network are represented. They may be any units, generally meters, but Windows coordinates have the zero in the upper left corner, while Cartesian have it in the lower left corner. In this application Cartesian coordinates have been specified, and units are in tens of meters. This is because this is a rather old application, since nowadays most coordinate systems are UTM, that is, Cartesian in meters. Link length multiplier is a value used to calculate the length of links in the transport network on the basis of the coordinates of the corresponding nodes (assuming straight lines). As will be seen, link lengths are in kilometers, and because coordinates are in tens of meters, the conversion factor is set to 0.01.

Note that there is a button called *Recalculate link lengths*. When pressed, all link lengths in the network are recalculated.

The other two tabs *Transport* and *Land Use* will be described later.

Figure 2: Menu Project->Options



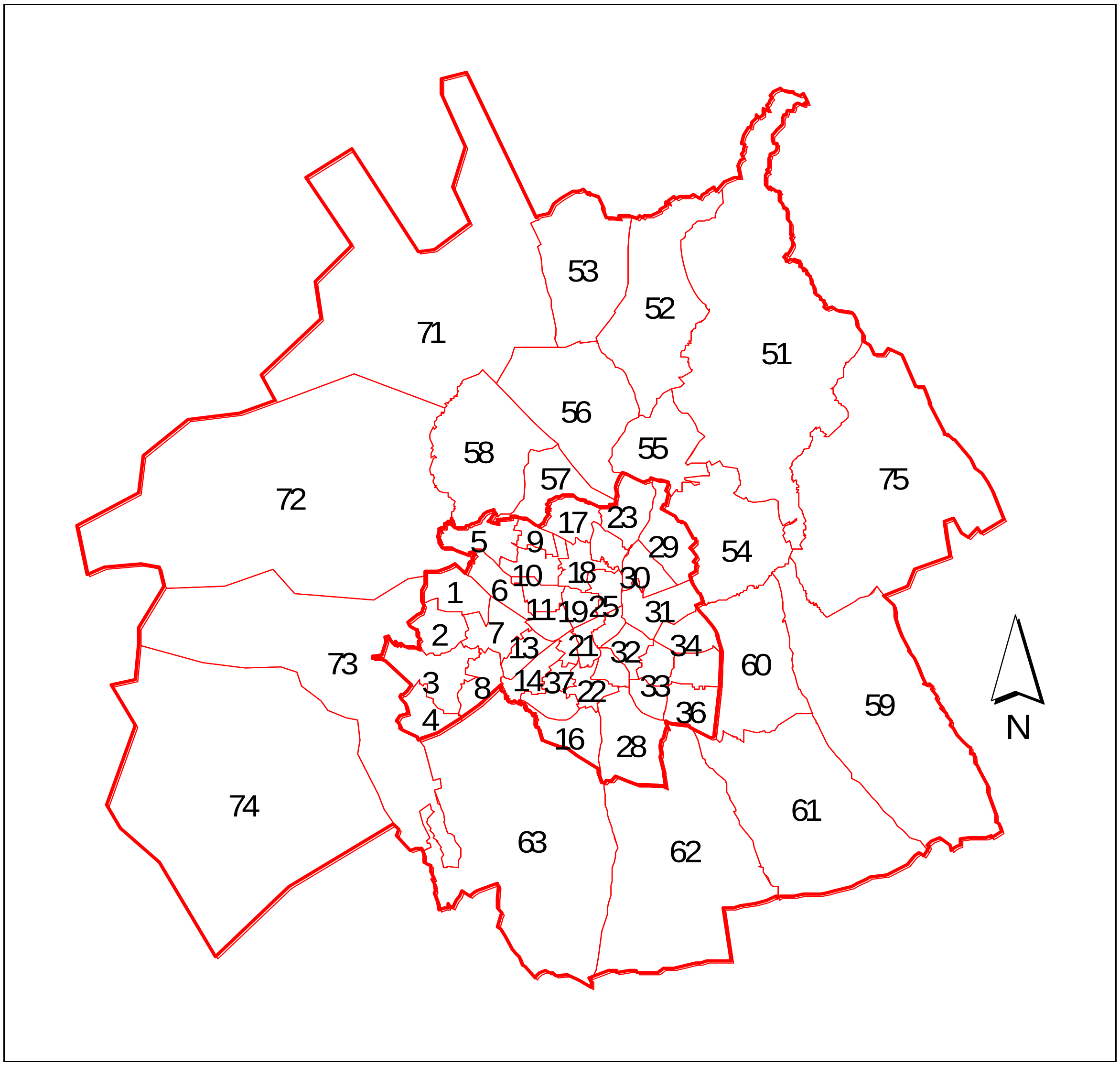
3.2 Definition of the land use model

Study area and zoning

The first element that must be decided in the model definition is the extent of the study area and its division into zones. The study area covered the town of Swindon (Wilts) with its rural hinterland and adjacent villages.

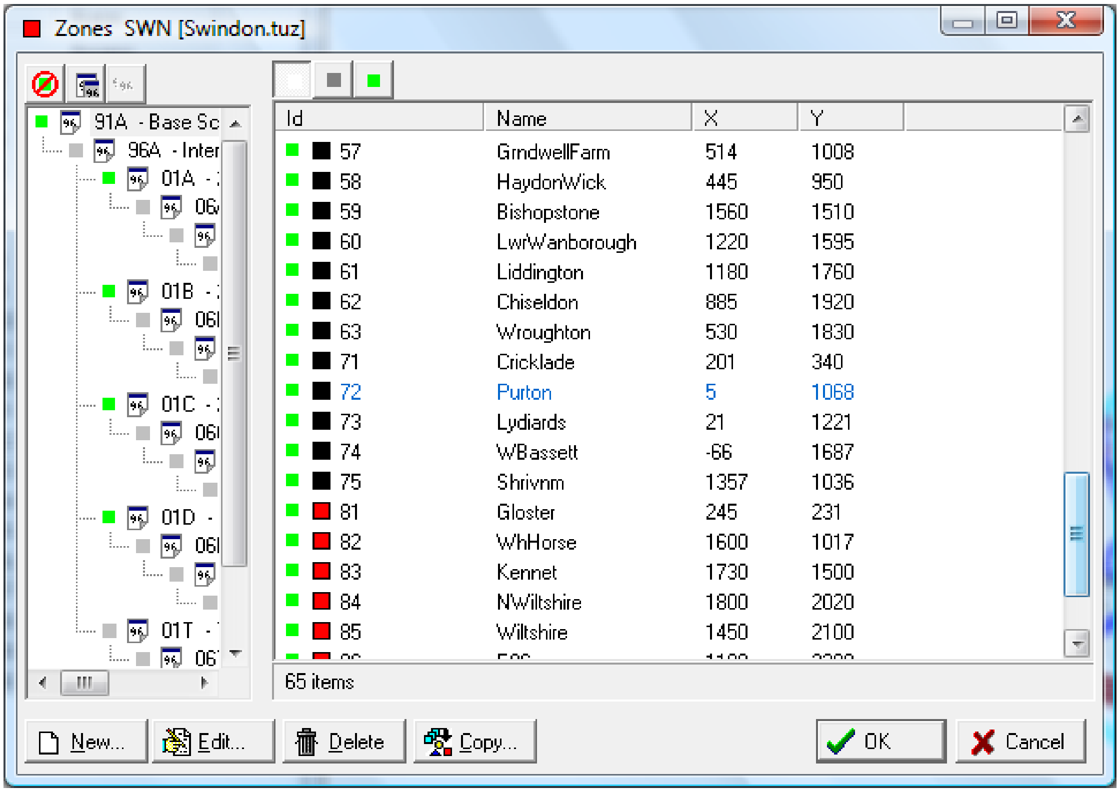
For the purpose of dividing the study area into model zones, aggregations of census tracts were adopted, for a total of 56 internal zones and 9 external zones. As has been mentioned, this is a small number of zones compared to larger applications with ten times or more zones. The study area and the division into zones is presented in Figure 3, highlighting the urban area of Swindon. As may be seen, Swindon is surrounded by a number of satellite villages that gravitate around the city center. A few external zones were also introduced to represent external trips. In TRANUS, zones do not depend on scenarios. The number of zones must be the same for all scenarios and if you add or delete a zone in one scenario, they are automatically modified in all scenarios.

Figure 3: Study area and division into zones



In the TRANUS interface, zones are represented in the menu Project -> Zones. Figure 4 shows a section of the list of zones. Internal zones are assigned a black square, while external zones get a red square. Double-click on any zone in the list (or double click any zone in the network view) to see the data associated with each zone.

Figure 4: The menu Project -> Zones showing the list of zones



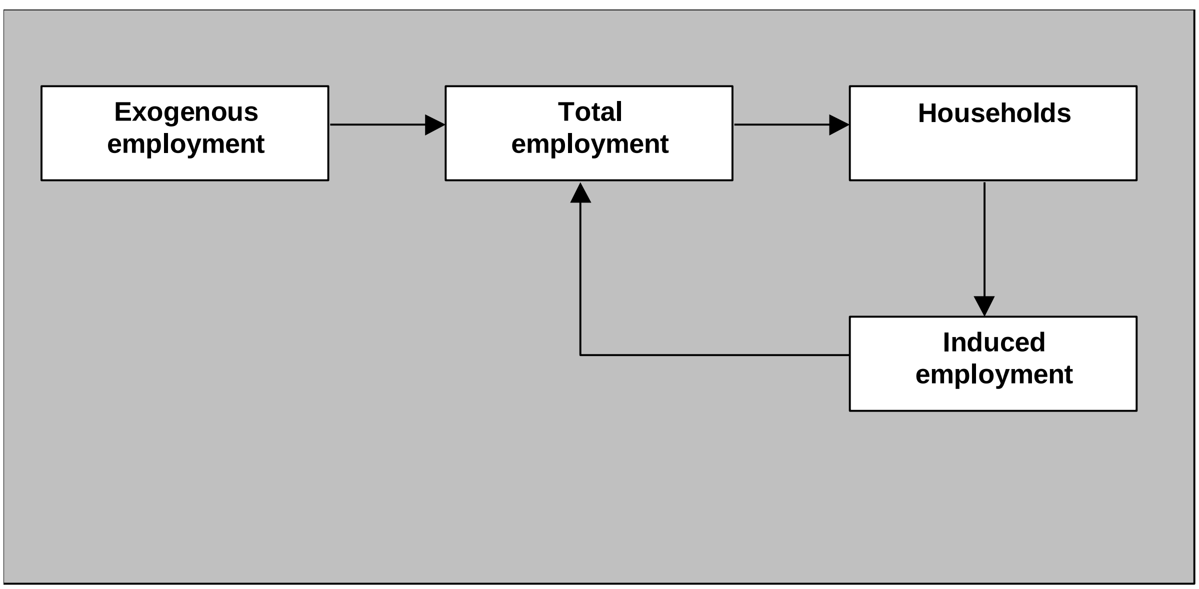
Activities

The urban economy of Swindon was divided into sectors of two types: employment and households. In turn, employment sectors were divided into exogenous and induced. Exogenous activities are assumed to depend on external elements, while induced activities are generated entirely within the study area by other activities. This division corresponds to an *economic base* assumption that is different to the more general *input-output* definition. In Tranus all sectors may have both exogenous as well as induced production. It is common to apply the economic base approach in urban applications for practical reasons. Households were divided into three income groups. In all, the following sectors were defined:

Activity sectors	Type
1 Industry and Agriculture	Exogenous
2 Government	Exogenous
3 Retail and warehousing	Exogenous
4 Office	Induced by households
5 Health	Induced by households
6 Education	Induced by households
8 Health	Induced by households
11 Households high income	Induced by employment
12 Households medium income	Induced by employment
13 Households low income	Induced by employment

The above list gives a *Lowry-type* structure. Exogenous-type activities induce the rest of the activities in the system. In turn, some induced activities generate other induced activities. The sequence is as follows: exogenous activities generate households; households in turn generate induced employment; induced employment generates more households. This sequence, shown in Figure 5 is repeated over and over until all activities have been generated.

Figure 5: Lowry-type structure of activities in the model of Swindon



Floorspace and land types

In this model definition activities consume floorspace of several types, and in turn, each floorspace type consumes land, also of several types. In the model, the consumption of floorspace and land is defined in a flexible way, to allow the model user to specify categories that are relevant to the study area. It is possible to define which activities consume which types of floorspace. Furthermore, a single activity type may choose to consume among several types of floorspace. In Tranus, this is called *substitutive* consumption, and estimated as logit choice probabilities, as described in the *Math Manual*.

The following floorspace and land types were defined:

Floorspace/Land type	Consumed by
21 Sheds floorspace	Agriculture, Industry, Retail and Warehousing
22 Framed floorspace	Agriculture, Industry, Government, Retail, Warehousing and Office
23 Detached floorspace	Households High, Medium and Low
24 Semi-detached floorspace	Households High, Medium and Low
25 Terraces and flats floorspace	Households High, Medium and Low, and Agriculture, Industry, Government, Retail, Warehousing and Offices
31 Industrial land	Sheds and framed buildings
32 Business Parks land	Sheds and framed buildings
33 Mixed land	Framed buildings, terraces and flats, semi and detached houses
34 Residential land	Terraces and flats, semi and detached houses

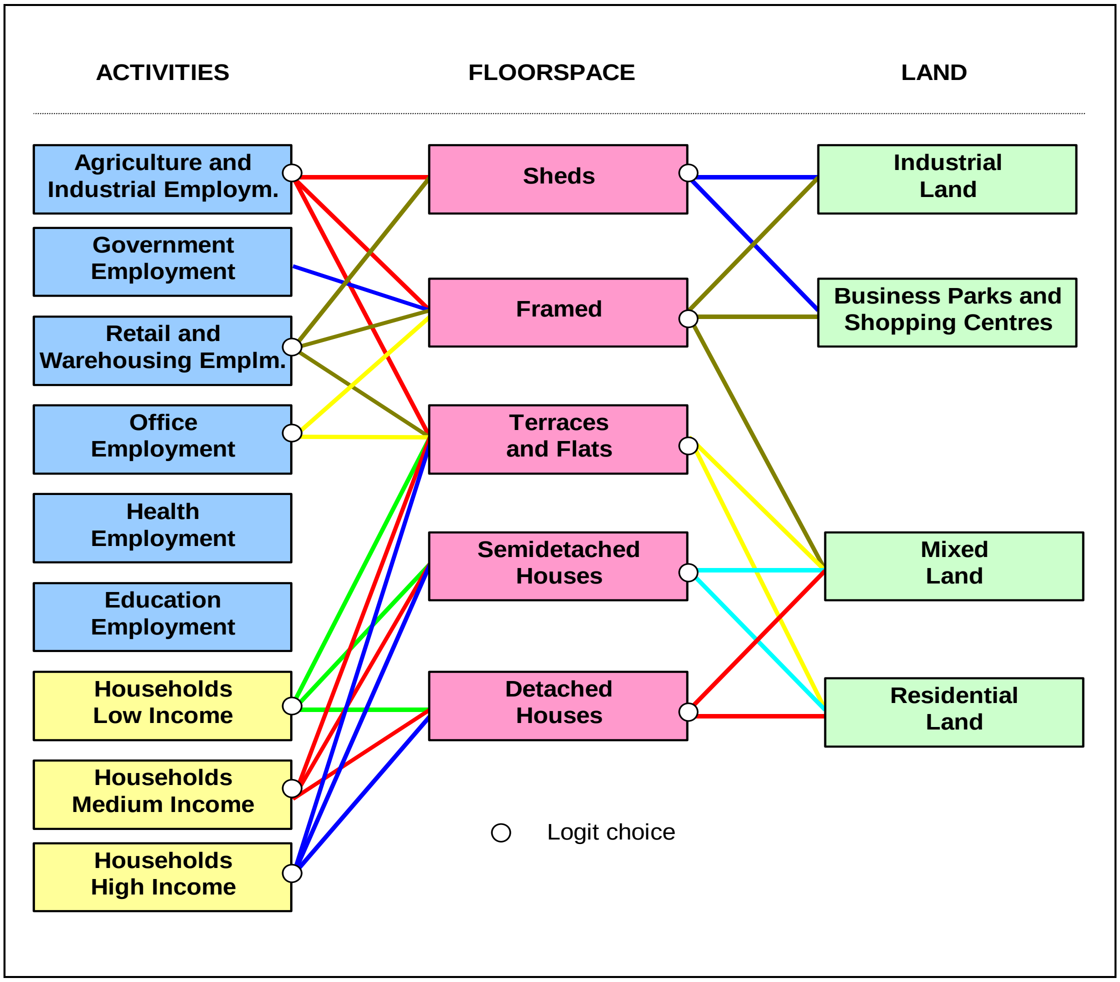
Figure 6 shows diagrammatically the relationships between activities and floorspace types, and between floorspace and land types. The diagram indicates where substitutions are defined, represented as logit choice models. It may be seen that all floorspace markets are related, even if not all possible combinations are defined. A certain distinction can be made between floorspace types typically consumed by employment sectors, and those related to households. However, both employment sectors and households compete for terraces and flats. It is important to allow for this, because in this way the model is able to represent the well know fact that many houses get converted into business. It is probably true that semi and detached houses are also subject to conversions, but this was not made explicit in the model definition for simplicity, and because this phenomenon is less noticeable. Similarly, land sub-markets are also related, because framed buildings may locate in mixed land. This is to account for the typical building with flats and shops in the ground floor.

The various sub-markets are related in other ways, because activities themselves are functionally related. For instance, manufacturing employment does not consume semi and detached houses, but it does induce households, which, in turn, consume residential floorspace types.

Business parks is a relatively new type of land, and small compared to other uses. However, it was thought that it was important to include it in the model definition because of its growing acceptance, and may well grow in the future.

Also note that there are some employment sectors that have been defined as not consuming any type of land. This is the case of health and education. In these cases it was assumed that these activities only consume special land, not incorporated to the real estate market.

Figure 6: Choice sets between activities, floorspace and land



Setting up the definitions in the database

The list of sectors is defined in the Land Use -> Sectors window, as shown in Figure 7. Double-click on any sector in the list (or Ctrl+E) to open the corresponding window with data: code name, description and elasticity, among others. Three types of sectors are possible: exogenous, induced transportable and induced non-transportable.

Figure 8 shows an example of an exogenous sector, defined as a sector in which all production is not consumed by other sectors explicitly. As was mentioned, sectors 1 Industry and 2 Government are declared exogenous in this application. The program knows that these sectors are exogenous because it looks at the table of inputs (described later on) and finds that no other sector consumes these two. Consequently it will expect to find a zero in elasticity, since if no one consumes them, nothing will get transported. This is described as a sector that *does not generate flows*.

Figure 9 shows an example of an induced sector (12 Households medium income) and this is represented by a >zero elasticity value. Finally Figure 10 shows an example of a non-transportable sector (24 Semidetached floorspace). The program knows that this sector is induced, because other sectors consume it, but in this case finds that the elasticity value is zero. Consequently this is an induced non-transportable sector that generates no flows.

Figure 7: The Land Use -> Sectors window

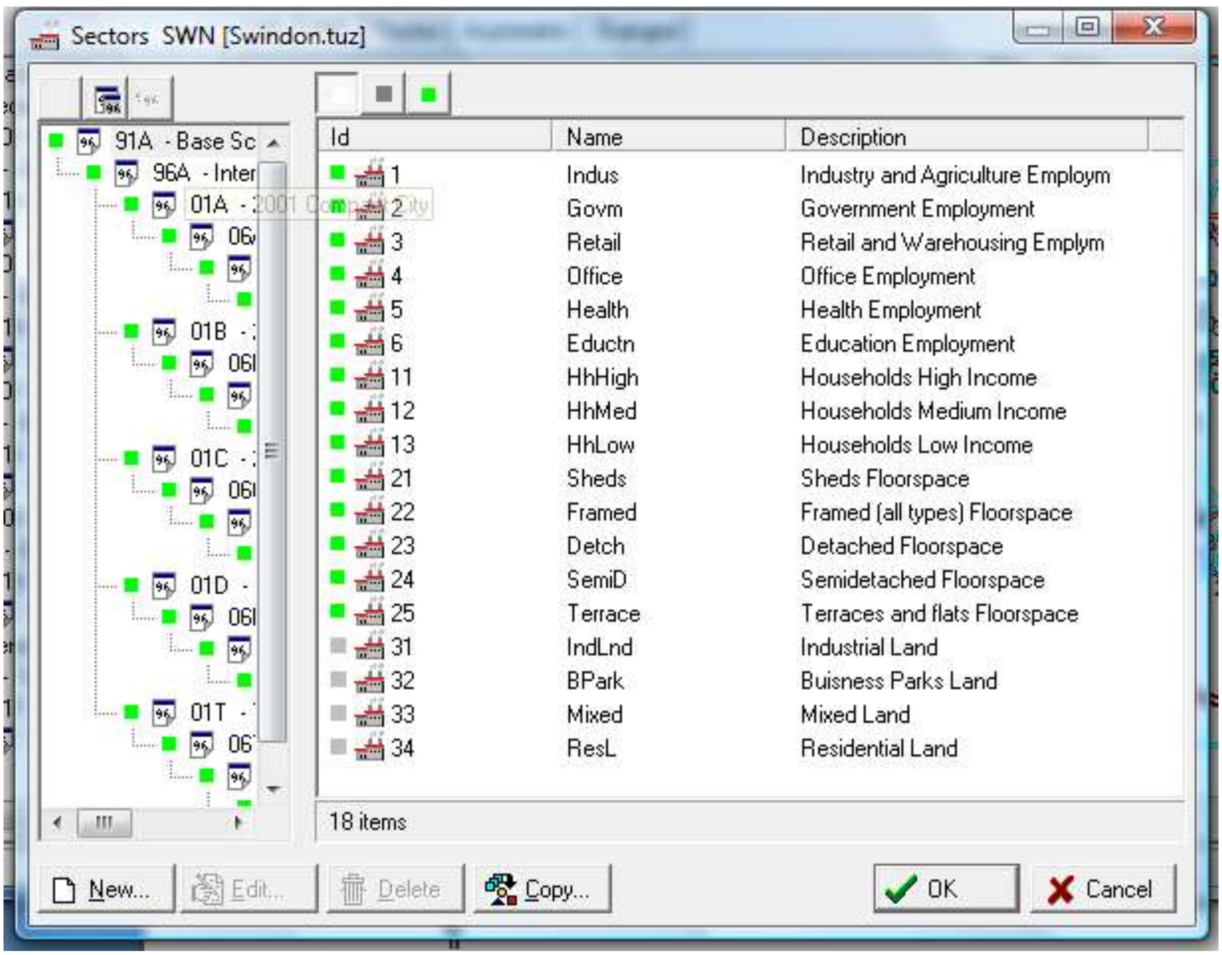


Figure 8: Definition of an exogenous sector in Land Use -> Sectors

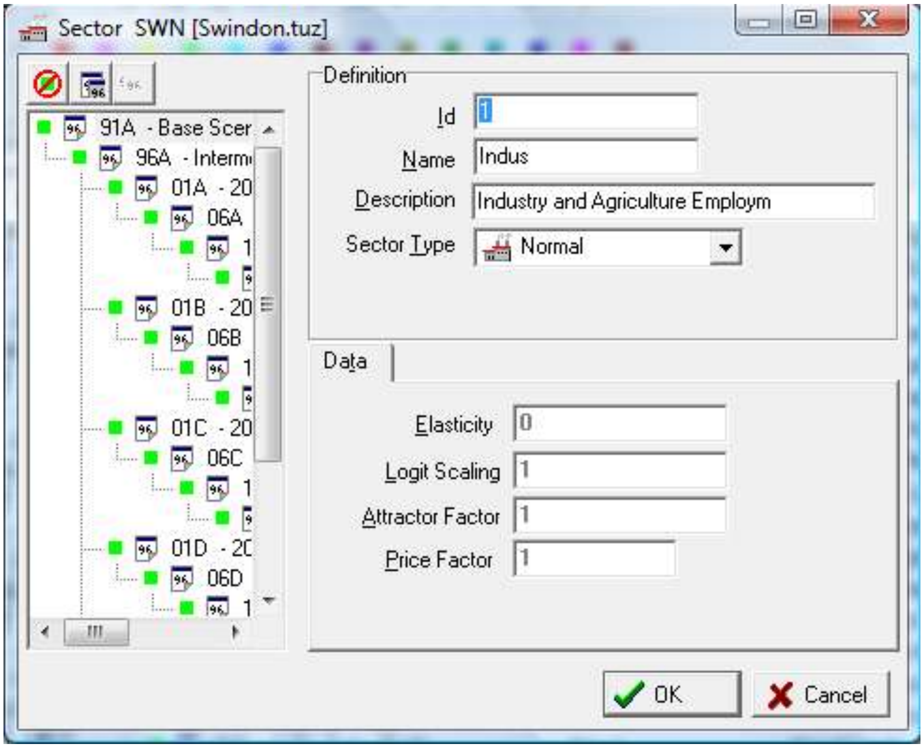


Figure 9: Definition of an induced sector in Land Use -> Sectors

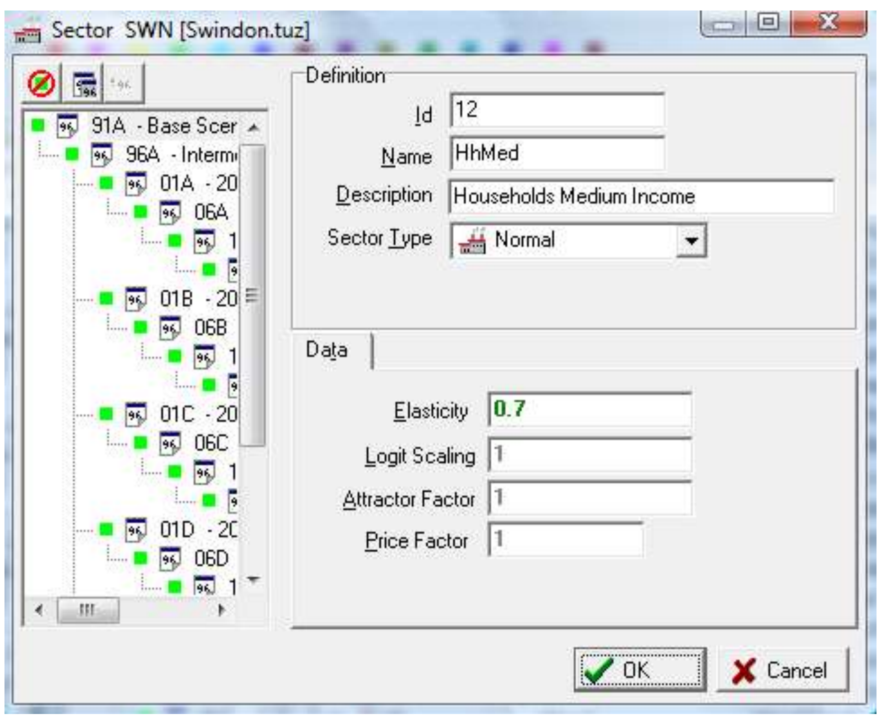
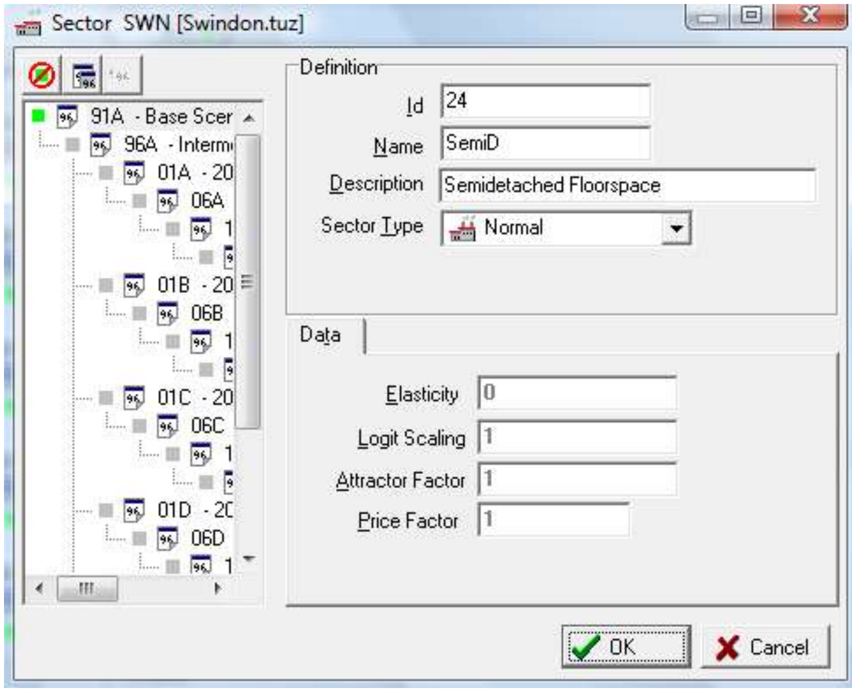


Figure 10: Definition of a non-transportable sector in Land Use -> Sectors



3.3 The land use-transport interface

In the land use model exogenous and induced activities were defined. Because by definition no other activities consume exogenous activities, the model does not generate *flows*. Flows represent the functional relationships between consuming and producing activities. In the case of a pure input-output model such flows represent monetary transactions. In the case of an urban application, it is preferable to represent flows as the amounts of production (jobs or households) of one activity being generated by another one. For example, a job in an exogenous sector 'consumes' a certain amount of households of a certain type. The result is a functional relationship or flow.

Floorspace and land sectors are by nature immobile or non-transportable. In the input-output jargon this means that they have to be consumed in the same zone where they are produced.

Given the definition of sectors in the preceding section (see Figure 5), the following sectors are consumed by other sectors, and hence, generate flows:

Retail and warehousing
Office
Health
Education
Households high income

Households medium income
Households low income

These flows are output from the land use model in the form of origin-destination matrices. They are used by the transportation model to generate actual trips of different types or *transport categories*. In principle, each flow in the land use model gives rise to a transport category. For instance, households are consumed by all types of employment sectors. Hence, each household category *flows* to jobs, generating one matrix each that may be transformed by the transport model to generate trips to work.

The Tranus model allows for the formation of transport categories from socioeconomic flows in a variety of ways. Several flows may be combined into a single transport category in different proportions, or one flow category may be split into several transport categories.

In the case of the Swindon application, a one-to-one relationship was established between flow-generating activity sectors and transport categories, as follows:

Flow-generating activity sector	To transport category
Households low income	Trips to work low income
Households medium income	Trips to work medium income
Households high income	Trips to work high income
Retail and warehousing	Trips to services
Office	Trips to services
Health	Trips to services
Education	Trips to education

As may be seen, each type of household gives rise to an equivalent trips to work category, with the aim of having a degree of disaggregation of transport demand by economic groups. Retail, office and health were all aggregated into a single transport category called ‘trips to services’ adding up all income categories, while education is on its own, but also aggregated over income groups.

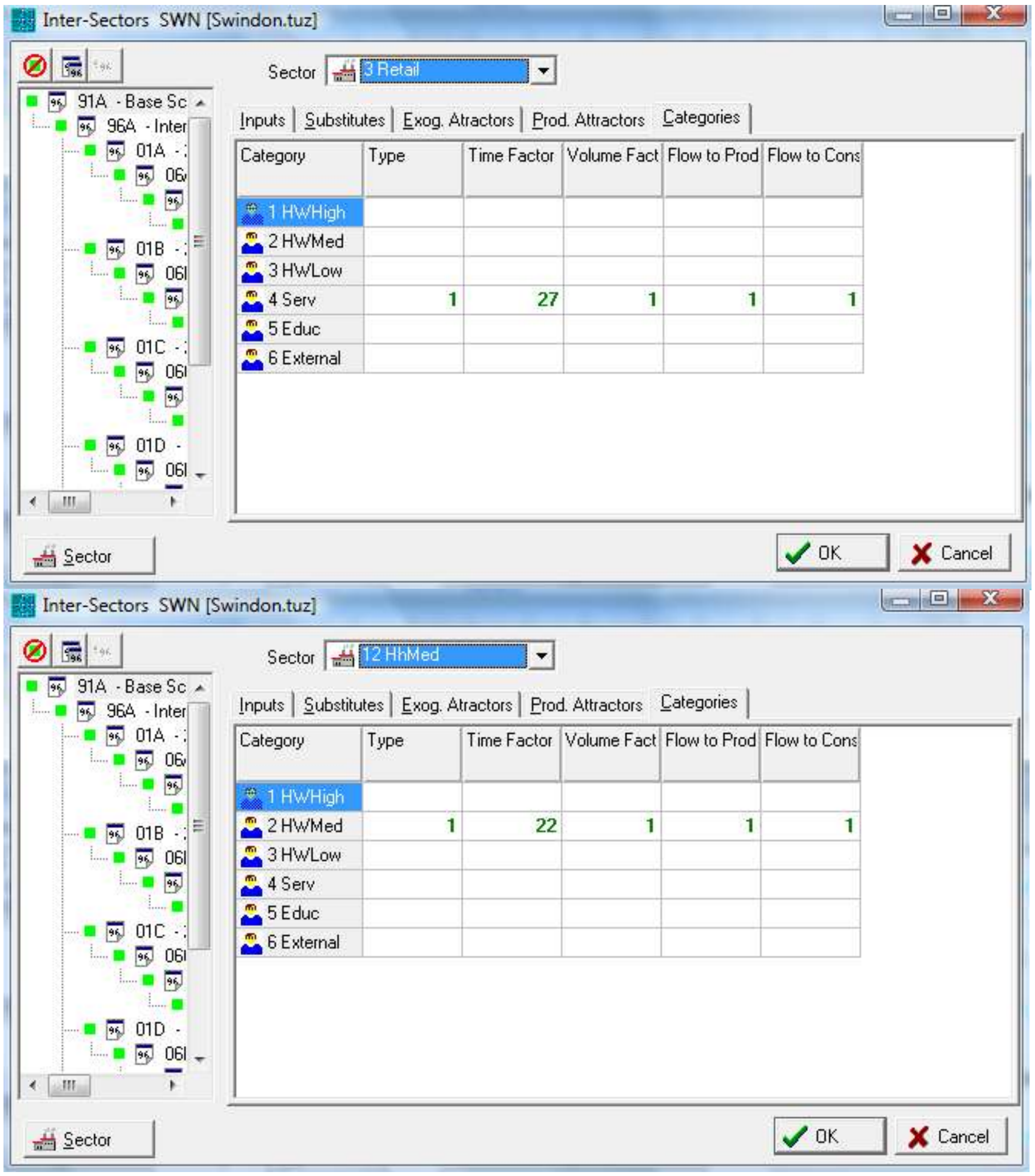
Apart from the formation of transport categories from socioeconomic flows, there are other transformations that may be specified in the land use-transport interface. The main one to consider in this application is the transformation of time units. In the land use model, a month was considered as the basic time unit. This applies mostly to floorspace and land rents. In the case of the transport model a full day was taken as the main time dimension. The relationship between the two units is controlled by a *time factor*, explained further below.

To represent this in the TRANUS interface, the Land Use -> Intersectors -> Categories windows is used, as shown in Figure 11. In the first example sector 3 Retail is generating

Trips to service, while the second example is sector 12 Hhds medium income generating trips to work midium income.

Note that in order to define these relationships, both economic sectors and transport categories must have been defined before-hand. On this basis the software generates the matrices shown automatically.

Figure 11: Generation of transport categories from economic sectors



For each land-use transport relationship some additional parameters must be specified, as may be seen in the figures. These are:

Type: in the model there are two types of flows: 0 for *normal* type and 1 for *commuter* type (check the Math Manual for a detailed description, or press F1 to get a help window on this topic). In this case all flows are commuter type.

Time factor: Sets the relationship between the time scale in the land use model and the transport model. In this application a month was set as the time unit in land use, and a day in transport. There are 30 days in a month, but people travel less on Saturdays and Sundays. Because they do a lot of shopping on Saturdays, a factor of 27 was used for trips to services, and a factor of 22 for work trips.

Volume factor: This is mostly used for flows of production giving rise to freight. Because there is no such sector in commuter flows, a factor of 1 is applied in all cases.

Flow to production/consumption: In the land use model unidirectional flows result. In this case a total-day is assumed for transport, so that we want trips to go and come back, generating symmetrical matrices. To represent this, a factor of 1 is set for both trips to production and to consumption.

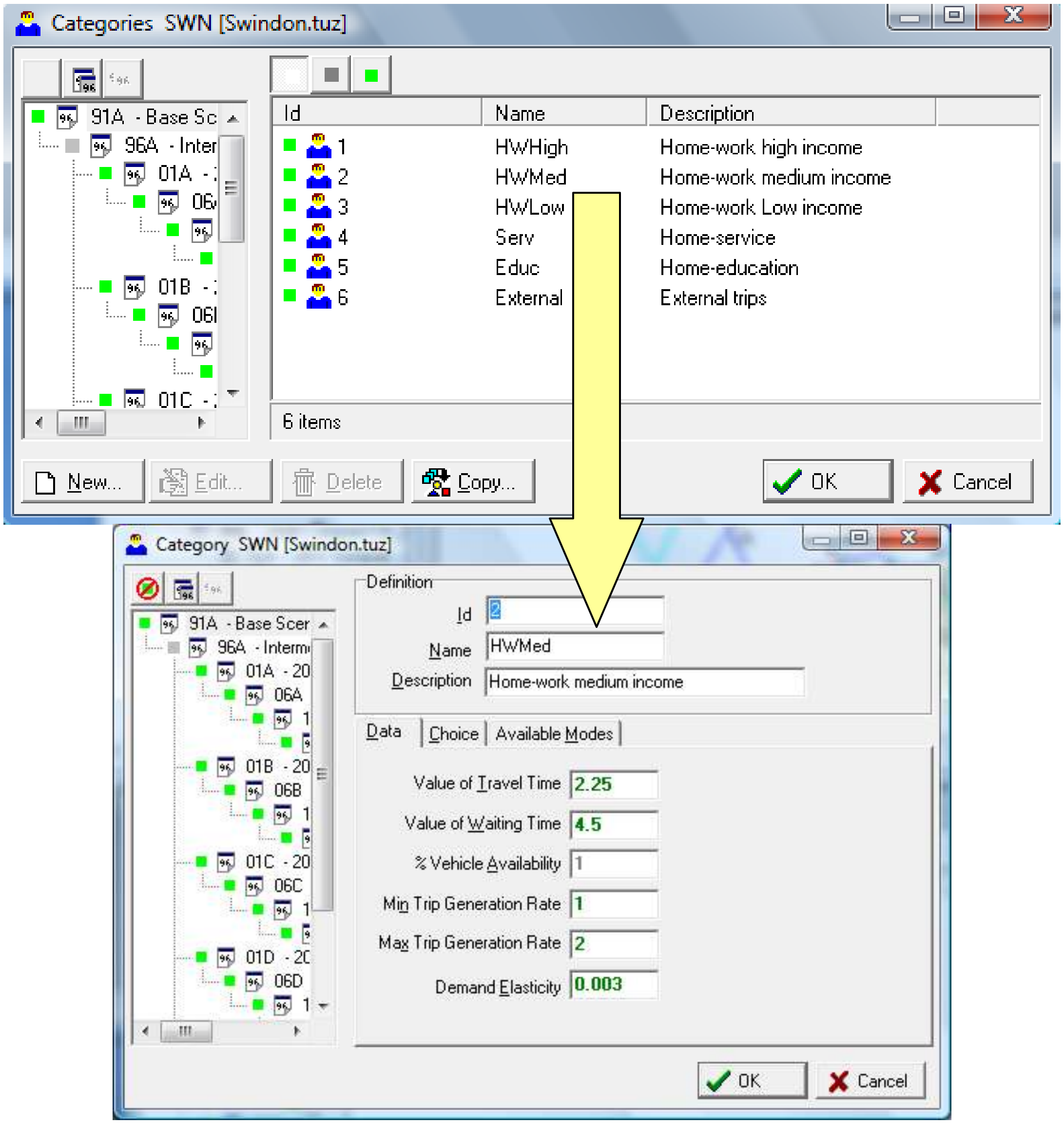
3.4 Definition of the transport model

The definition of the transport model involves two main elements: demand categories and supply categories. Supply, in turn, is divided into two: physical and operative. The physical supply includes the actual roads, railways, metro, LRT, stations, or whatever other elements may be present. Operative supply is composed of the various entities that provide a specific transport service. These may be bus companies, metro operators, park-and-ride operators, and the like. For modeling purposes pedestrians and automobiles are also considered as part of the operative supply.

Demand categories

Demand categories were described in the preceding section. Transport categories are defined in window Transport -> Categories as shown in Figure 12. Double-click on any category in the list to get the data associated with each one, as shown. These values will be described in further sections.

Figure 12: The Transport -> Categories menu



Physical supply

The physical supply of the transport system is represented in the form of a network, composed of links and nodes. The operative supply uses the infrastructure in order to provide transportation services. Zones are special kinds of nodes called *centroids*, where trips begin or end.

Each link in the network has a number of characteristics associated to them, such as distance, capacity, the free-flow speed at which operators may travel, distance-related operating costs, possible tolls and other charges, and many others. To simplify the process of coding all these characteristics for each link, the transport model classifies links by *link type*, so that a number of characteristics common to many links may be coded only once.

For the Swindon model, the link types described in Table 1 were adopted. The list includes all the typical categories of roads and streets, in which each link type represents the area surrounding them (central, peripheral), the hierarchy (motorways, dual carriageways, etc.), and the maximum free-flow speed for cars, that serves as a basis for other types of vehicles.

Special link types were defined for access links to centroids, and several others for future scenarios, such as railways, bus-only lanes, cycle ways, park-and-ride, and others.

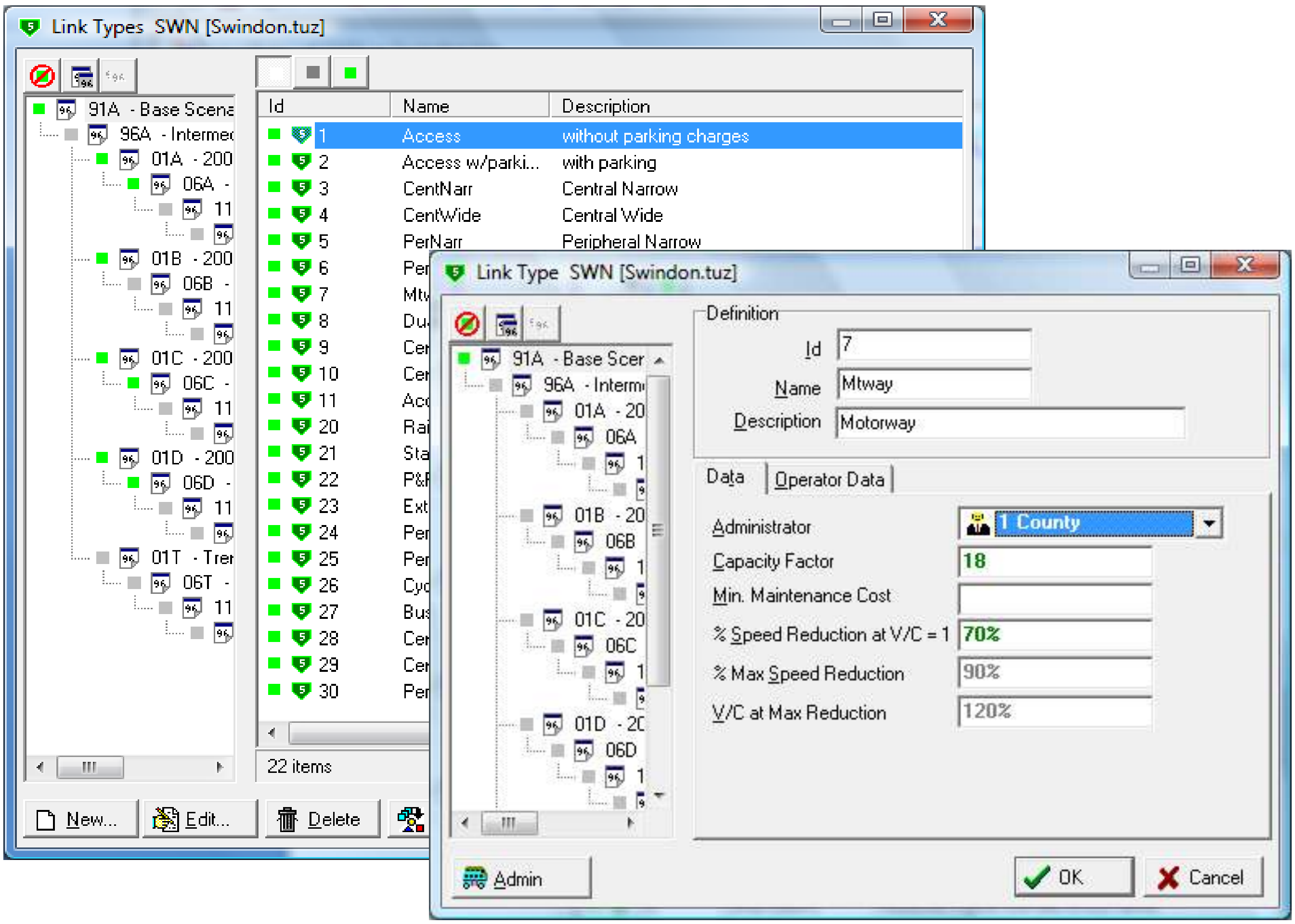
Table 1: Definition of link types

Link type Id	Short name	Description	Reference speed
1	Access	Access to zones without parking charges	25 kph
2	Acc/wpark	Access to zones with parking charges	25 kph
3	CentNarr	Central street narrow	30 kph
4	CentWide	Central street wide	38 kph
5	PerNarr	Peripheral street narrow	45 kph
6	PerBroad	Peripheral street broad	68 kph
7	Mtway	Motorway	90 kph
8	DualCway	Dual carriageway	80 kph
9	CenNarrB	Central street narrow buses only	30 kph
10	CenWideB	Central street wide buses only	35 kph
11	AccessB	Access to zones buses only (pedestrians)	5 kph
20	Railway	Railway line	30 kph
21	Station	Railway station (pedestrians)	5 kph
22	P&R	Park-and-ride	5 kph
23	External	For external zones	68 kph
25	PerNarrRC	Peripheral street reduced capacity (parallel to bus lanes)	65 kph
26	Cycle	Cycle ways	12 kph
27	BusLink	Bus-only lane	35 kph
28	CenNarrRC	Central street narrow reduced capacity (parallel to bus lanes)	30 kph
29	CenBroadRC	Central street broad reduced capacity (parallel to bus lanes)	36 kph

(*) In central zones parking charges were added, thus needing a separate link type
(**) Some centroid connectors require that only cars may use them

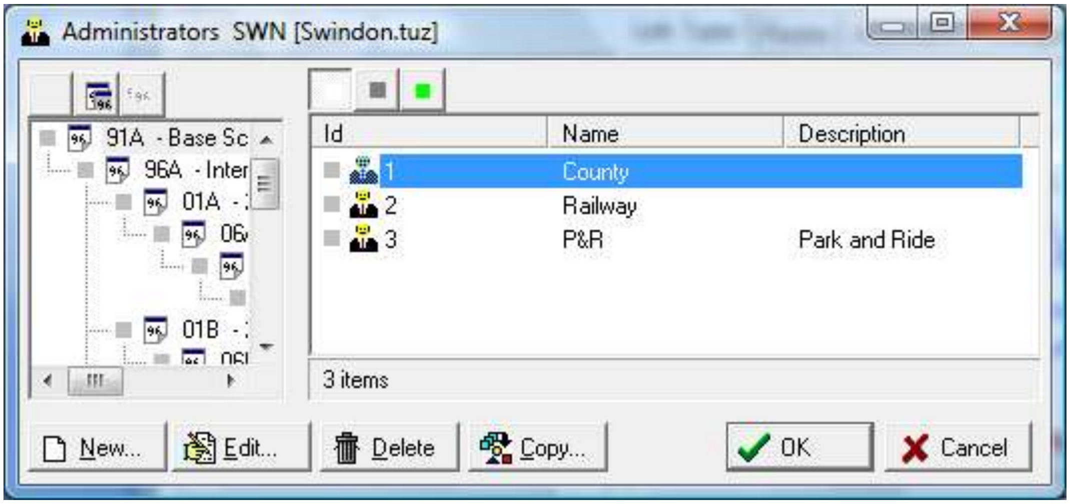
The list of link types is introduced in menu Transport -> Link Types, as shown in Figure 13. Double-click any of the entities in the list to get the data associated with each link type. Such data is discussed later on, but one item relates to the definitions: the Administrator. Each link type must be associated with an administrator.

Figure 13: The Transport-Link Types window



Administrators are entities that are in charge of parts of the network. Administrators pay for maintenance costs, and may charge users for the use of the infrastructure in the form of tolls, airport taxes, parking, and so on. In the Swindon application not much use was made of the concept of administrators, as is common in urban applications. The list of administrators is shown in Figure 14 and may be checked in the Transport -> Administrators window in the model database.

Figure 14: The Transport -> Administrators window



Operative supply

The operative supply in the TRANUS model has three hierarchical levels: modes, operators and routes. Several routes may belong to an operator, and several operators may form a mode. Operators are sort of submodes. Transport demand categories may use one or more modes to travel, as defined by the model user.

Although TRANUS allows for the typical private-public modal split, in the Swindon application a single-mode approach was used: passengers. This approach means that within a single choice set, all combinations are valid, subject to specific restrictions. In the realization of a trip, travelers may freely combine operators. For instance, a traveler may walk to a link where a bus service is available; then take a bus ride to a metro station; take a metro ride; and walk to the final destination. This scheme allows for auto-transit combinations. For example, the traveler may drive a car to a park-and-ride facility, then take the metro, maybe a bus, and walk to the destination. In theoretical terms, the single-mode approach means that the modal split model is skipped altogether. Instead, modal split and assignment are completely integrated. This flexible approach has been successfully applied in most applications in the last ten years, and is highly recommended.

Some combinations may be prohibited. For instance, travelers may be prohibited to change directly from car to bus. They may only change from car to bus through an intermediate P&R operator. The latter means that car-public transport combinations are only allowed at specific locations where such facilities are available. If commodities were to be added to the system, such as truck movements, then a second mode would be required, with additional operators such as heavy and light trucks.

In TRANUS operators may be of four types: normal, transit, transit with routes, and non-motorized. The normal type is used for operators that may move freely around the network, such as cars or trucks. Transit types may also move freely around the network, but charge fares and have a waiting time, such as a taxi. Transit-with-routes type operators are used to specify bus routes, LRT or metro. Non-motorized are used to represent walking and cycling.

In the model of Swindon, the following operators were defined:

Opertator	Type
Single-occupant car (SOV)	Normal
High-occupancy car (HOV)	Normal
Bus	Transit with routes
Minibus	Transit with routes
Walk	Non-motorized
Bicycle	Non-motorized
Rural bus, all types	Transit with routes
Passenger rail	Transit with routes
Park-and-ride	Normal

Note that there are two types of cars: SOV and HOV. These were defined as having an occupancy rate of one and more than two respectively. In this way travelers have the option of driving a car as a single occupant, or sharing the ride with others. This, in turn, has the advantage that average car occupancy is an output of the model, and is sensitive to policy. For instance, an increase in the price of fuel would shift the share of riders from SOV to HOV, increasing average car occupancy. This also means that car occupancy will vary among socioeconomic groups. Because lower income travelers are more sensitive to cost, the shared car is more attractive compared to higher-income groups. The scheme also allows for the introduction of HOV-lanes in future scenarios, as will be seen later.

Two types of buses were defined: regular and express. This distinction was considered necessary because they provide clearly different services, with different speeds and tariffs. Also rural buses were added.

The non-motorized operators included were pedestrians and bicycles.

The rules permitting or restricting combinations among operators may be represented in a *from-to operator* matrix. The model also allows for the specification of integrated fares for specific combinations, but these were not introduced because they don't exist in reality. Integrated tariffs were included in future scenarios as a policy. Table 2 and Figure 15 show which operators may be combined directly.

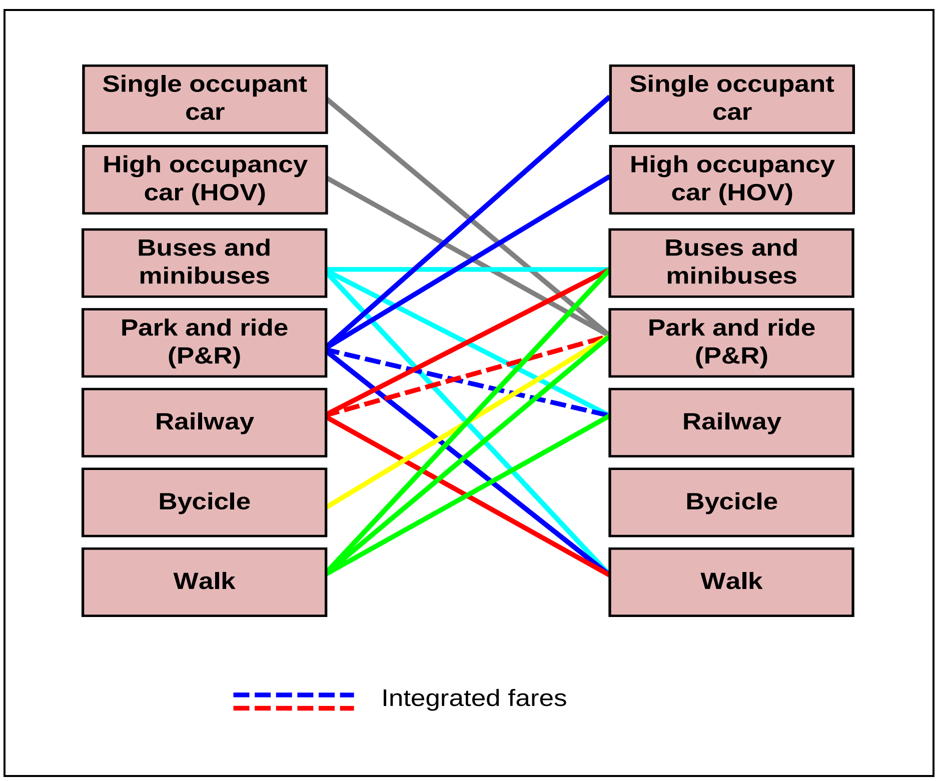
Table 2: Combinations between operators

From/to	SOV	HOV	RegBus	ExpBus	LRTBus	Hartford	Walk	P&R	Metro	LRT
SOV										
HOV										
RegBus										
ExpBus										
LRTBus										
Hartford										
Walk										
P&R										
Metro										
LRT										

Shaded: combinations not allowed

Finally, for each combination of operators and link types, free-flow speeds may be defined. In a same link type, for instance, buses may go slower than cars. It is also possible to ban an operator from a link type. Specifying a speed of zero does this. For example, cars cannot travel along a metro line. The actual table of free-flow speeds is shown in the following chapter.

Figure 15: Possible mode combinations in the transport system



Modes are specified in the Transport -> Modes menu, as shown in Figure 16. Not much in this window because only one mode has been specified.

Figure 16: The Transport -> Modes menu window

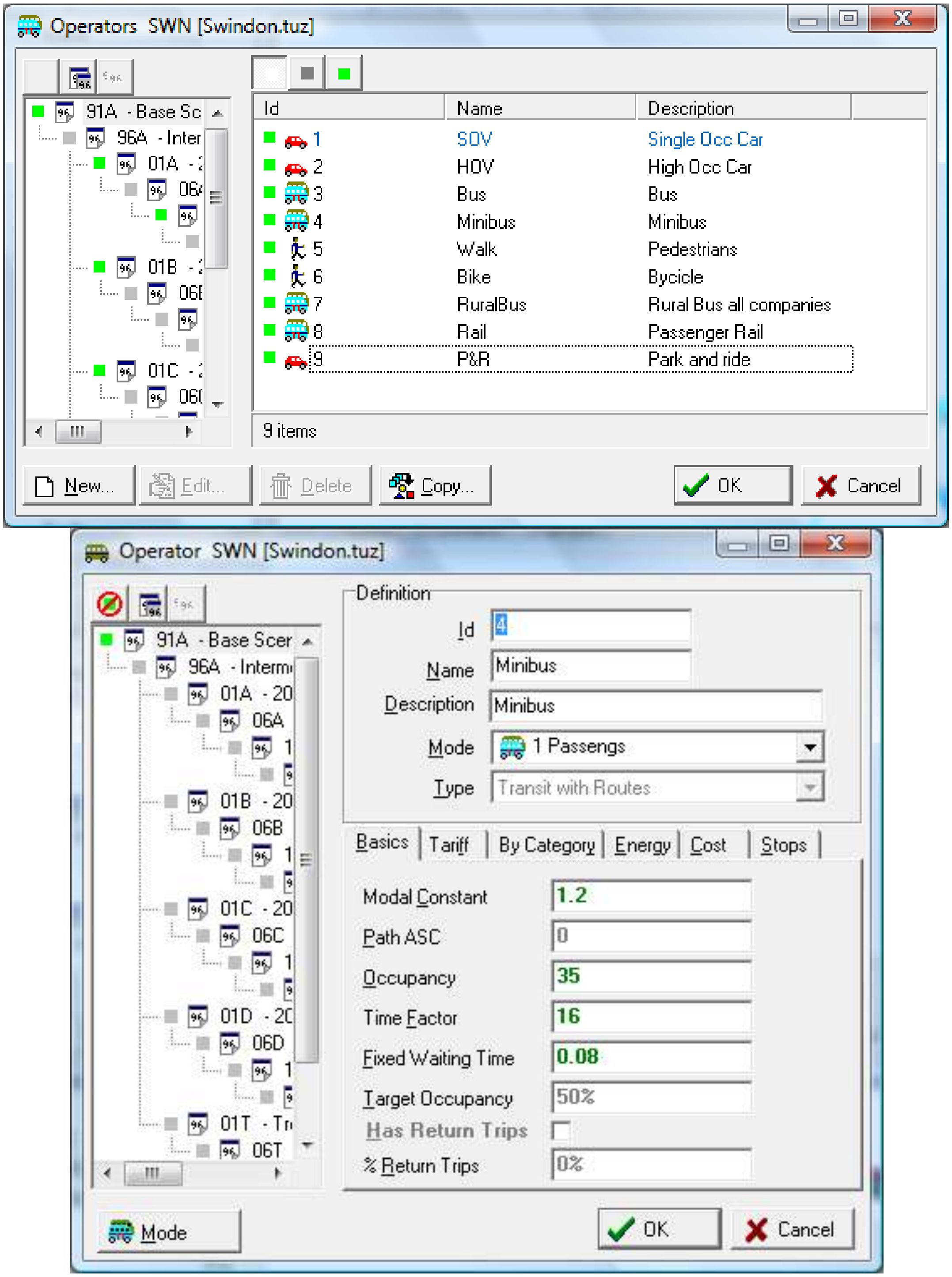
Operators are specified in the Transport -> Operators menu, as shown in Figure 17. An icon is associated with each operator to denote type: a red car for ‘normal’, a blue bus for ‘transit’ (with or without routes) and a walking man for non-motorized.

Double-click on any operator in the list to get the basic parameters associated with each operator, also shown in the figure. Each operator is given a short name and a description, and is assigned to a mode (the only ‘passengers’ mode in this application) and a type. In the example shown it is a minibus specified as ‘transit with routes’.

Occupancy is set to 35. Because this is a transit with routes operator, this value means that the model may only assign passengers to routes of this type up to the capacity. As will be seen, each route has a frequency assigned to it. Multiplying maximum occupancy by frequency yields maximum capacity. In the case of cars, occupancy must be set to the average and demand is always equal to capacity.

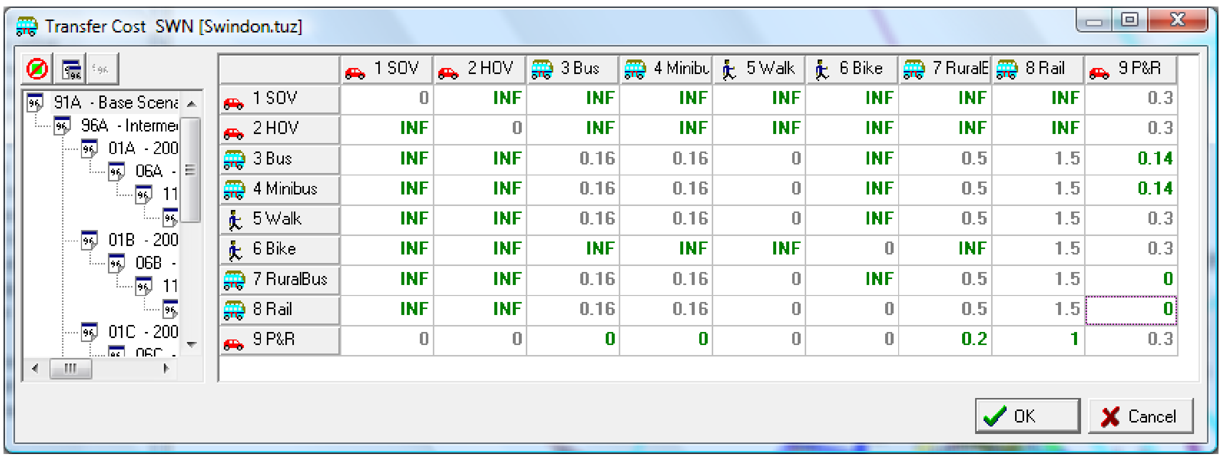
The Time Factor specifies the number of hours that a certain operator operates, in this example 16 hours. This is because this is a total-day application. For a peak-hour application this value would be 1. A minimum waiting time may be specified in decimal hours. In this example it has been set to 0.08 hours (about 5 minutes). Waiting time for transit with routes operators are calculated as half the interval, subject to this minimum value. Note that both Time Factor and Minimum Waiting Time are only meaningful in transit with routes operators.

Figure 17: The Transport -> Operators menu window



The Transport -> Transfers menu specifies which operators may be combined with others and possible integrated fares, as shown in Figure 18. To ban a specific combination a value of *INF* is entered, as for example from operator 2 HOV to operator 3 Bus. A value of zero means that there is no transfer cost for that combination, as in the case of from 4 Minibus to 5 Walk. This means that when you get off the bus and walk, you don't pay anything. If you board a bus, either from walking or from another bus, a fare of 0.16 is paid. A rural bus charges 0.5. Driving a car to a P&R station costs 0.3, but then from the P&R to a bus does not cost anything. This means that the P&R service has an integrated fare with the buses. If a bus is boarded the fare is 0.16, and if you go into a P&R an additional fare of 0.14 is charged before you can pick up your car, to complete the 0.3 integrated fare. Note that in this example you cannot bike to a bus. You cannot walk half the way and then ride a bike or *vice versa*.

Figure 18: The Transport -> Transfers menu window



	1 SOV	2 HOV	3 Bus	4 Minibu	5 Walk	6 Bike	7 RuralE	8 Rail	9 P&R
1 SOV	0	INF	INF	INF	INF	INF	INF	INF	0.3
2 HOV	INF	0	INF	INF	INF	INF	INF	INF	0.3
3 Bus	INF	INF	0.16	0.16	0	INF	0.5	1.5	0.14
4 Minibus	INF	INF	0.16	0.16	0	INF	0.5	1.5	0.14
5 Walk	INF	INF	0.16	0.16	0	INF	0.5	1.5	0.3
6 Bike	INF	INF	INF	INF	INF	0	INF	1.5	0.3
7 RuralBus	INF	INF	0.16	0.16	0	INF	0.5	1.5	0
8 Rail	INF	INF	0.16	0.16	0	0	0.5	1.5	0
9 P&R	0	0	0	0	0	0	0.2	1	0.3

3.5 Land use data

Once the application has been fully defined, as described in the preceding sections, data must be completed both for transport and land use.

Production data

Land use production data is specified for each sector and zone. This is done in the menu Land Use -> Economic Data , as shown in Figure 19. Depending on the nature of the sector, the data may be specified in different ways, so that the figure shows four different cases.

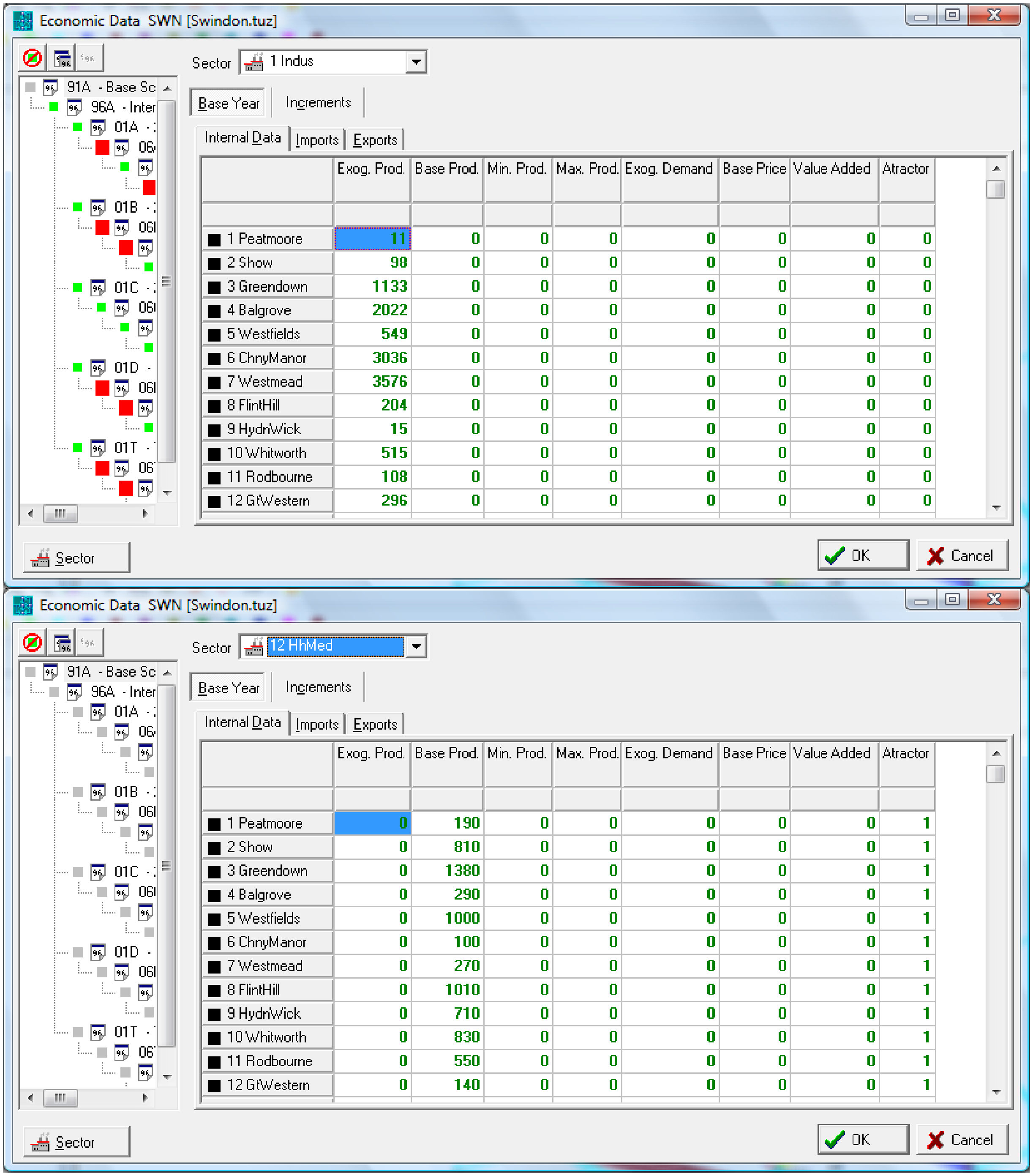
The first window shows a typical exogenous sector, in this case sector 1 Industrial jobs. The data is input in the Exogenous Production column and represents the number of jobs in each zone. The model does not question this data and simply takes them as given values. Exogenous production gives rise to the rest of the activities and land. The column of attractors is not given any values because the model will not use them at this stage. This data may be specified by just typing it in, or by pasting it from another Windows application such as Excel. The latter is definitely the most practical way of doing it.

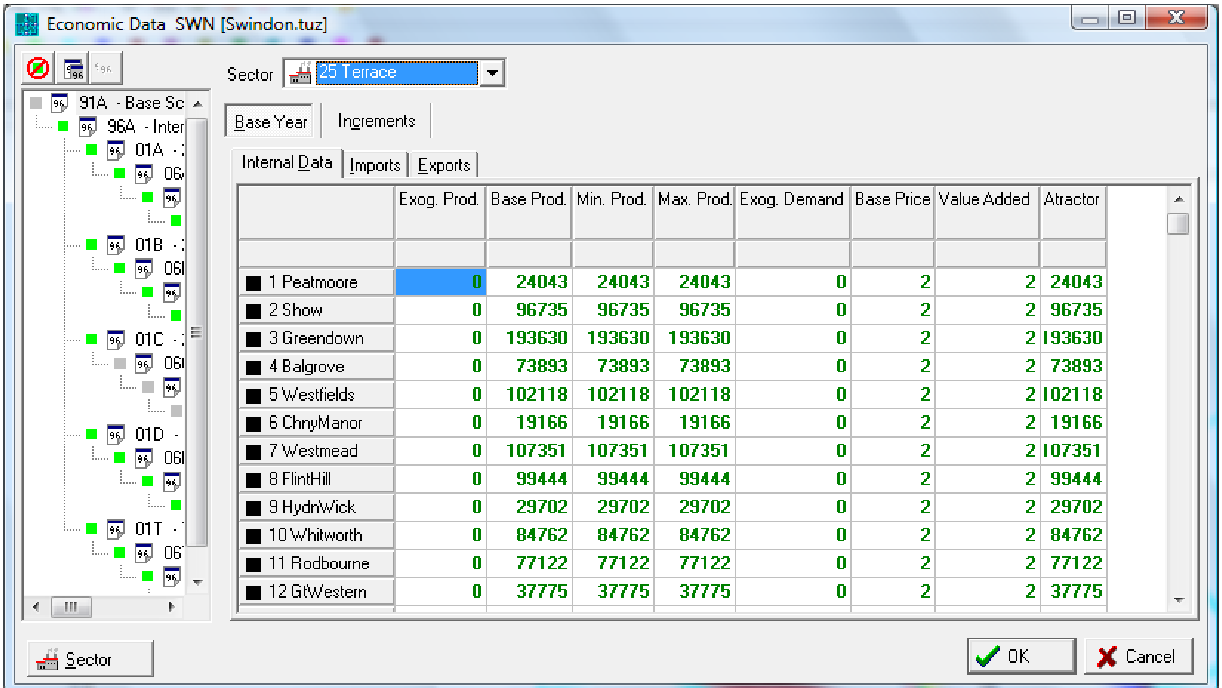
The second case represents an Induced Production sector: 12 Households Medium Income. Induced production is input in the Base Production column. This is no longer given data to the model, since the model must reproduce this information. Consequently the model will take this information and will try to approximate modelled values as much as possible. This will be explained in the next chapter. In this example the column of attractors is set to a value of 1 if there is production in a zone, or zero otherwise. The attractors are used by the model to simulate induced production.

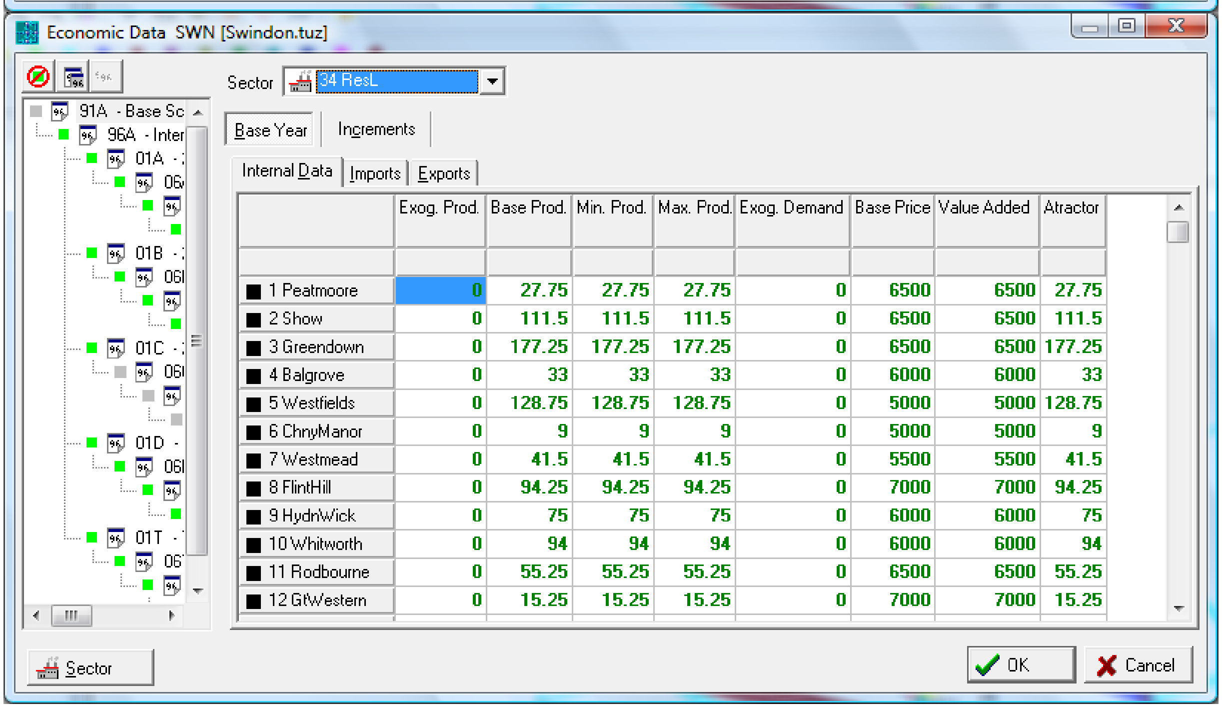
The third case represents a floorspace sector 25 Terrace in square meters. This is also an induced production sector so that production must go in the Base Production column. Just like the population example, the model will take this data as a target and will try to approximate the modelled values as much as possible for the base year. In this case the data has been copied to the Attractors column, in order to help achieve a good simulation. The values have been copied also to the Minimum and Maximum Production columns. The model will not use this information for the base year, but will pass it on the the next time period where they will be used as constraints. Note that a value of 2 has been specified for all Value Added. This is a very approximate way of putting a value to the buildings, in this case £ 2 per m^2.

The fourth case represents a land sector: 34 Residential land in square meters. This is similar to the floorspace example in that the values of production are copied in Base Production, Min and Max Production and Attractors. The difference is that the price of land is specified both in columns Price and Value Added. The model will build a value for the price starting from the Value Added values if any. Consequently it helps the model if the price values are also value added. Strictly speaking, they may be any positive non-zero values.

Figure 19: The Land Use -> Economic data menu window







Intersectorial demand functions

As was described, exogenous production will consume induced production. In this example Industrial and Government jobs consume population, and population in turn consume retail, education and other induced jobs. Then all sectors consume floorspace of various types and floorspace sectors consume land. Some of these relations are said to be *inelastic*, because a single constant value or coefficient represents the relation. This is typical of employment consuming population. In the case of floorspace and land consumption functions are elastic, because the amount of floorspace consumed by per population will depend on price. The same for floorspace consuming land. Furthermore, in this application substitutes were also specified, in which the need for floorspace for a specific activity may be satisfied by several types of floorspace, so that demand will be distributed among several options in a probabilistic way.

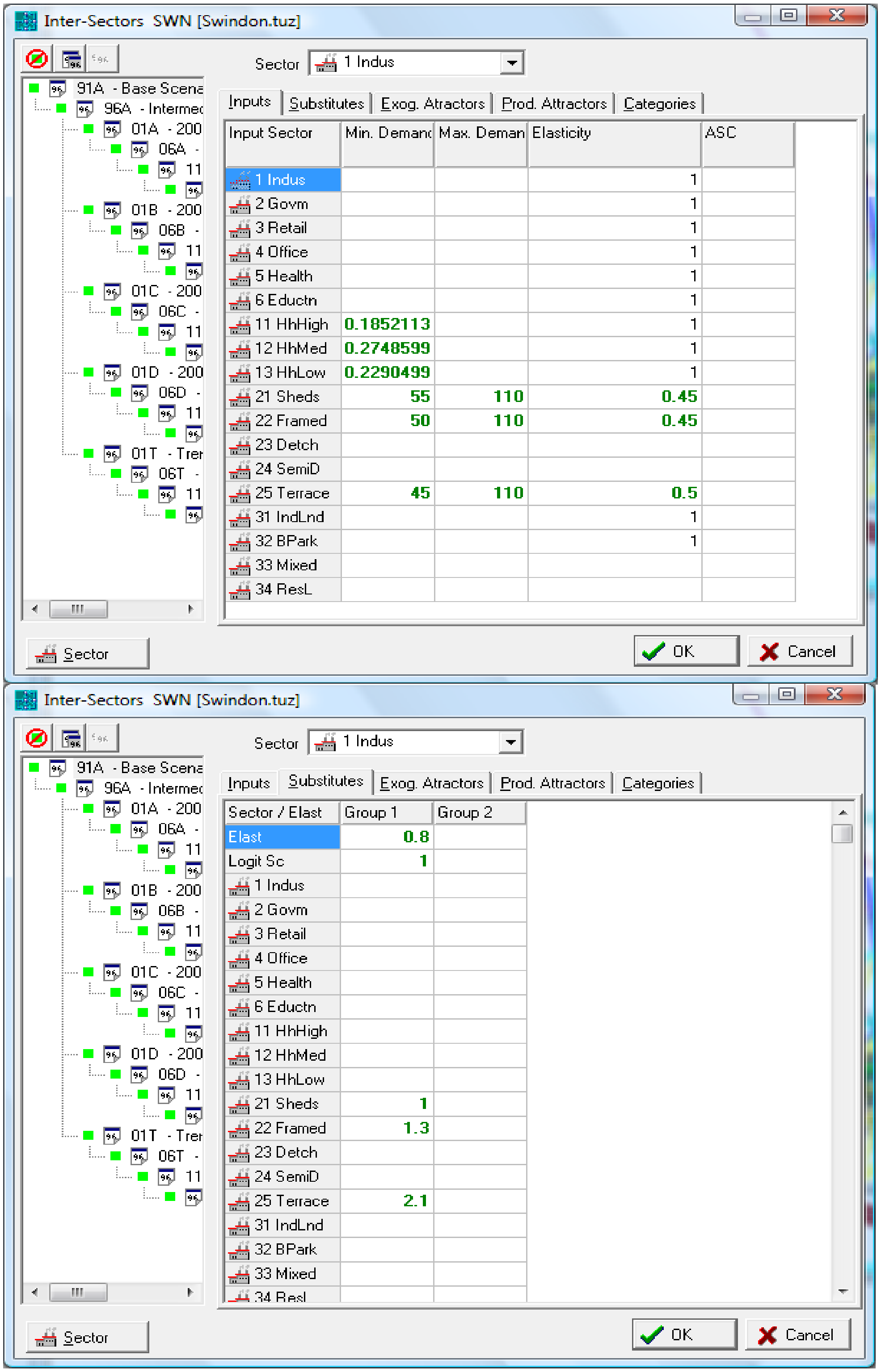
These relationships are specified in the Land Use -> Intersector menu, combining the Inputs and Substitutes tabs, as shown in Figure 20. The example shows Sector 1 Industrial jobs. Each job consumes 0.1852113 households of high income, 0.2748599 households of medium income and 0.2290499 households of low income. Additonally each job in the industrial sector will consume floorspace of several types as *substitutes*. The Math Manual describes the form of the elastic demand functions, together with the logit model that is used to distribute demand over possible types of land. The following table summarizes this for the given example, that is industrial employment consuming floorspace:

Floorspace type	Minimum demand	Maximum demand	Penalty
Sheds	55	110	0.45
Framed	50	110	0.45
Detch			
SemiD			
Terrace	45	110	0.5

When an industrial job consumes Sheds it will consume at least 55 m^2 per job and up to 110 m^2. In this example industrial jobs may also consume Framed and Terraces. The penalty factor multiplies expenditure, so that smaller values mean a positive preference. In this case industrial jobs prefer sheds and framed buildings over terraces. Note that they cannot consume detached and semidetached houses. Similar specifications are made for every sector.

The penalty factors may be any positive value and they do not have to add up to one. It may well be that not all possible floorspace types are present in every zone. In the example above it could be that in a specific zone, such as an industrial estate, there are no terraces. In this case the model will distribute consumption among the remaining types sheds and framed.

Figure 20: The Land Use -> Intersectors window menu to specify inputs



3.6 Transport data

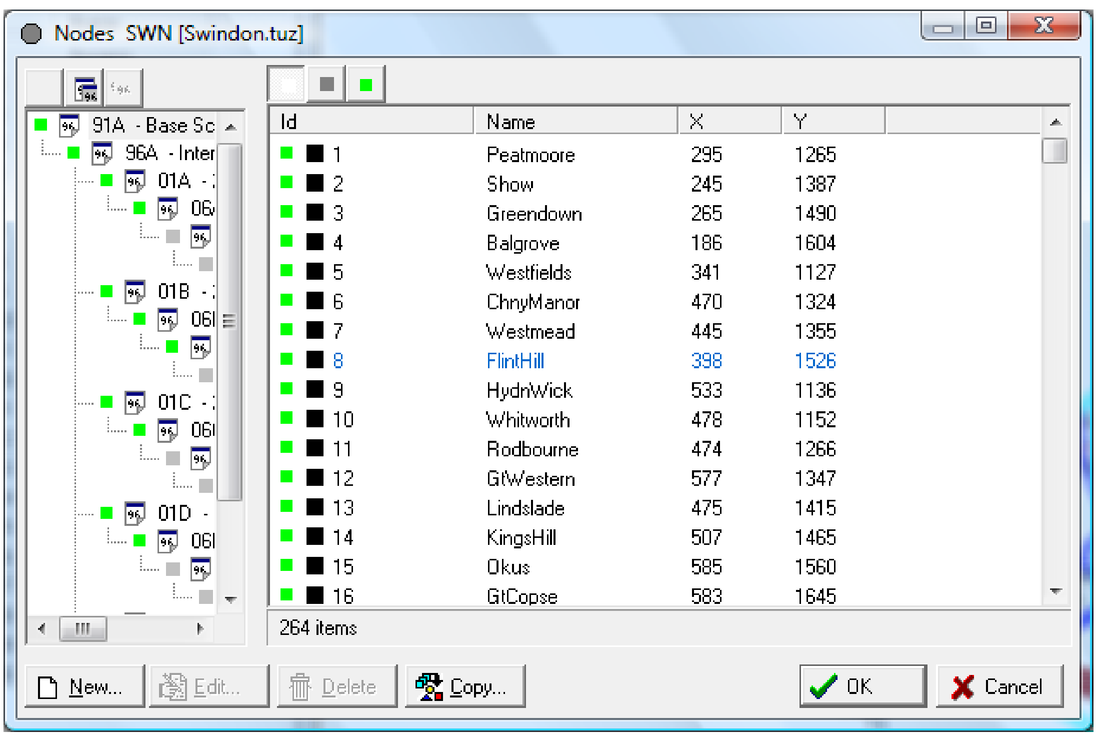
Transport network: nodes, links and routes

As was mentioned, the transport network is made of nodes and directional links. Nodes are specified in the Transport -> Nodes menu, as shown in Figure 21. Each node is given an identifying number, optional names and description and XY coordinates. As was mentioned, in this application non-geographical coordinates were used and values are in tens of meters. Nowadays most applications will be in UTM geographical coordinates in meters.

Like zones, nodes are not scenario-dependent. If a node is moved or deleted, it applies to all scenarios. There are, however, nodes that are used in a scenario and nodes that are not. A node is defined as not-used if no link uses it. This is shown in the list with a green square if used, gray square if not used.

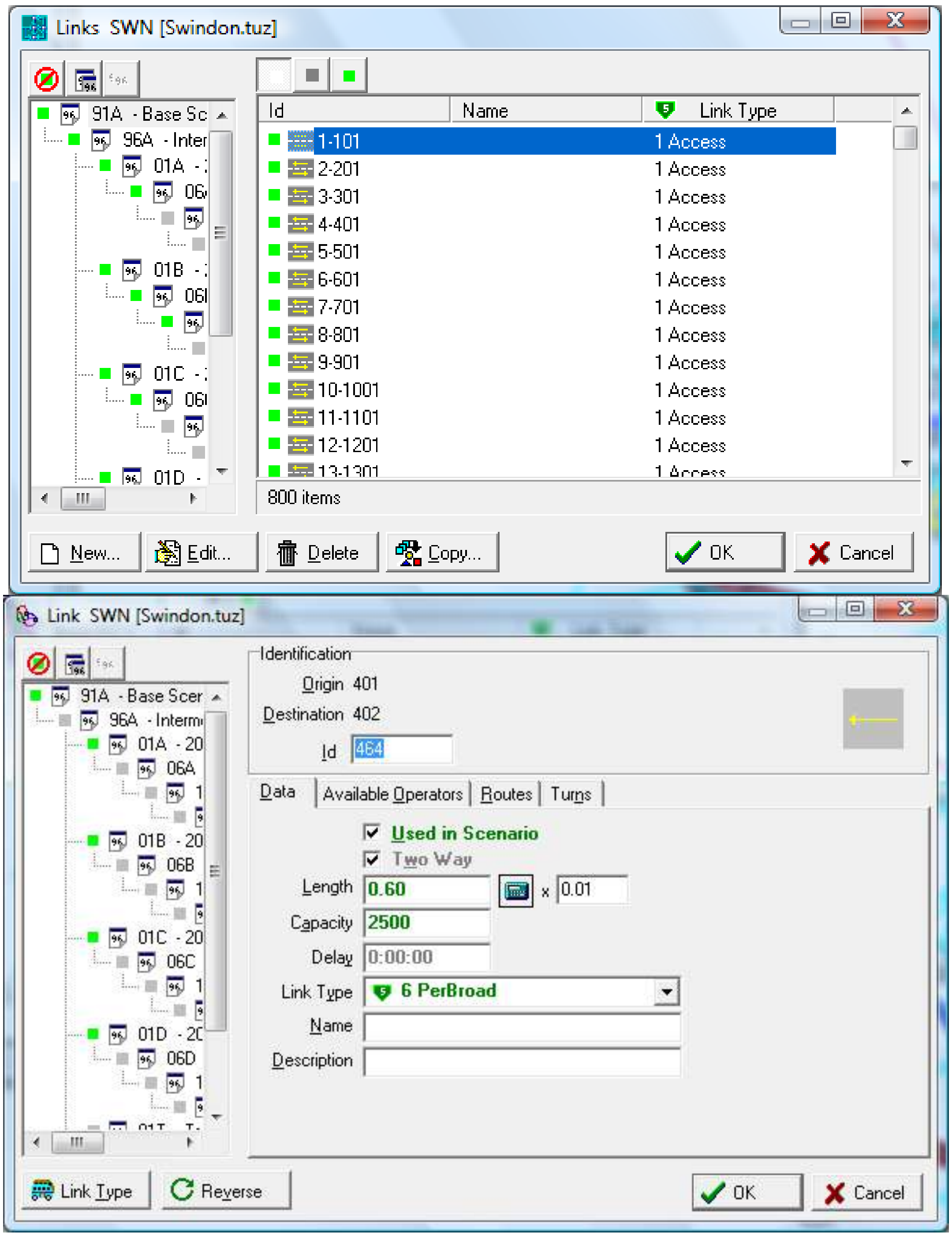
Data may be entered to the database by typing them in. However, in many applications the list of nodes may be quite large, with several thousand nodes. Also the data may be obtained from a GIS database in an automatic fashion. The interface provides a special facility to import a list of nodes with corresponding coordinates in the menu Project -> Import Network.

Figure 21: The Transport -> Nodes menu window



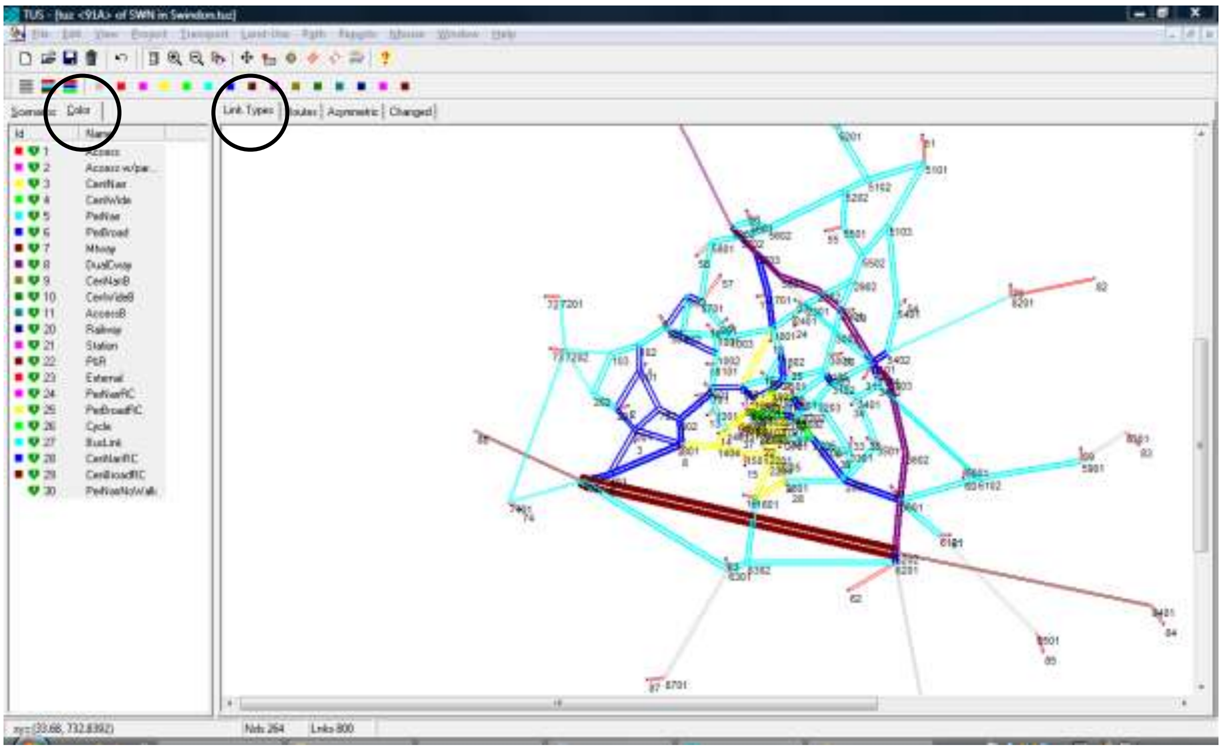
Nodes are connected by links. The list of links is displayed in menu Transport -> Links, as shown in Figure 22. A double-click on any link in the list displays the characteristics of the link, as shown in the bottom half of the figure. In this case it is a link of type 'Peripheral Broad'. Length is 0.6 Km and the capacity is 2500 standard vehicles per hour.

Figure 22: The Transport -> Links menu window



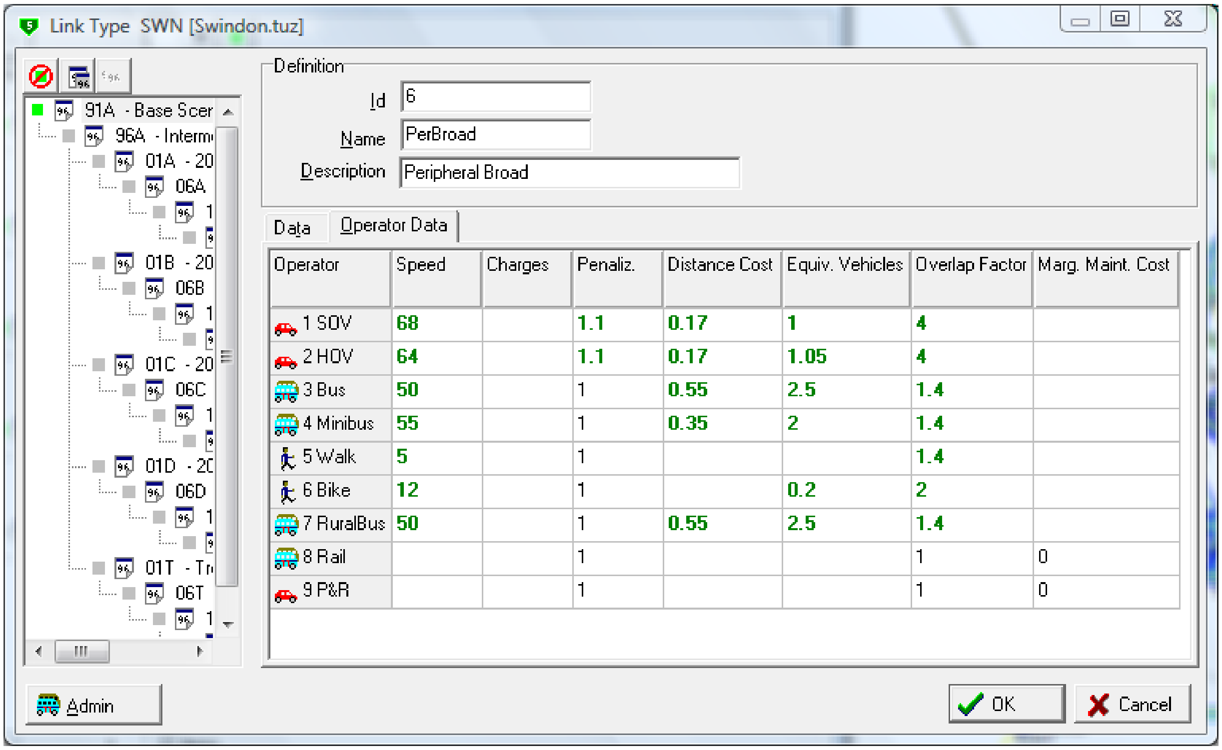
The network view shown in Figure 23 displays all links with a colour code. To get this view make sure the Link Types tab is selected on the right panel and Color is selected in the left panel. Colours may be changed at will. The thickness of each link is proportional to the capacity, and the scale may be changed in menu View -> Options.

Figure 23: Network view showing link types and capacities



Select the Transport -> Link Types menu and choose the Operator Data tab to see the characteristics assigned to each operator in each link type, as shown in Figure 24. In this example link type 6 Peripheral Broad was selected. The complete list of operators is presented and the first column shows the maximum operating speed of each one, also called *free-flow speed*. For instance SOV cars may go up to 68 Km/hour, HOV cars at 64, buses at 50 and so on. Operators with no speed mean that they cannot travel along links of this type, as is the case of Rail and P&R in the example. The column Charges is where tolls or any other is specified, not in this example. Penalizing Factor multiplies the value of time of all users travelling along links of this type. Distance Cost is the operating cost of vehicles per unit of distance. Equivalent Vehicles is a parameter that multiplies the number of vehicles in the link to get standard or *equivalent vehicles*. It is also called *PCU* (passenger car units) in the literature. For example, a bus is equivalent to 2.5 equivalent units, while the SOV car has been taken as the unit with a factor of 1. Overlapping Factor multiplies the value of time at path search (see the Math Manual for a full description of this process). A high value means that the program will try that this link is not repeated along paths. Marginal Maintenance Cost is not used in this application.

Figure 24: The Transport -> Link Type menu showing Operator Data



Finally public transport routes are defined in menu Transport -> Routes shown in Figure 25. In all there are 43 routes, but no all of them are used in the base year scenario. Note that some routes are presented with a green square to denote that they are used in this scenario, no square if they are not used, and a red square if the route is used but the program thinks there might be something wrong or at least suspicious about this route that is worth checking.

If any route in the list is selected, another window showing data is displayed. In the figure route 306 is presented. It belongs to operator 3 Bus and has a frequency of 6 buses per hour. The 'Used' box is checked as well as the 'Follows Schedule' box. The latter means that this route has a timetable that users know, so that they will wait a fixed minimum amount of time as specified in Transport -> Operators.

Select the *Routes* tab to get a network view of public transport routes, as shown in Figure 26. In this example all bus routes were given a blue colour. Walk was given a light blue colour and bike was given yellow. Cars were not assigned any colour. Because all buses were given the same colour, the network view displays the sum of all routes. The bandwidth is proportional to the capacity of routes. Assign a single colour to a specific route to see its itinerary. It is possible to double-click on any of the routes in the left panel to display the corresponding Transport -> Routes window.

Figure 25: The Transport -> Routes menu window

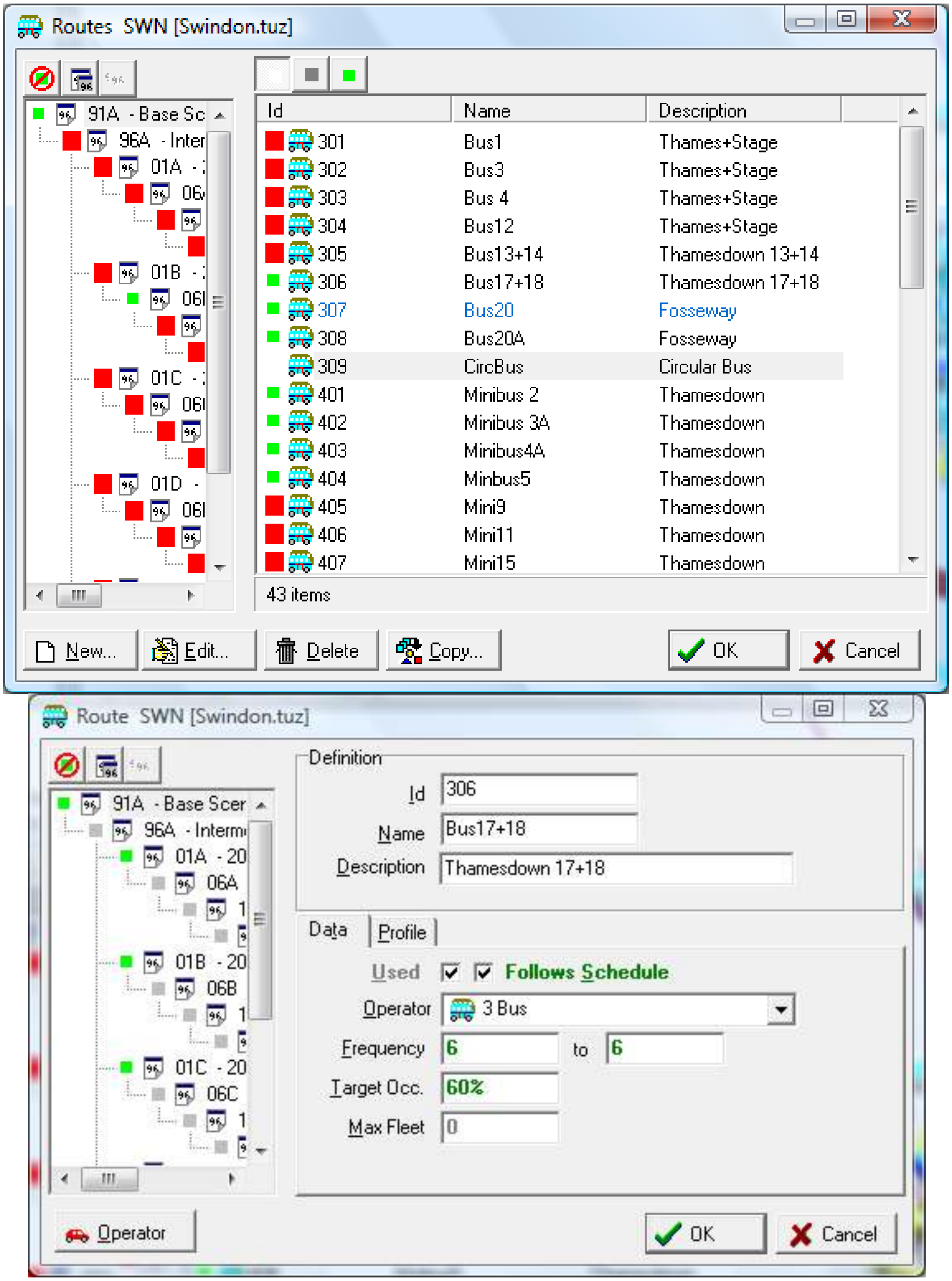
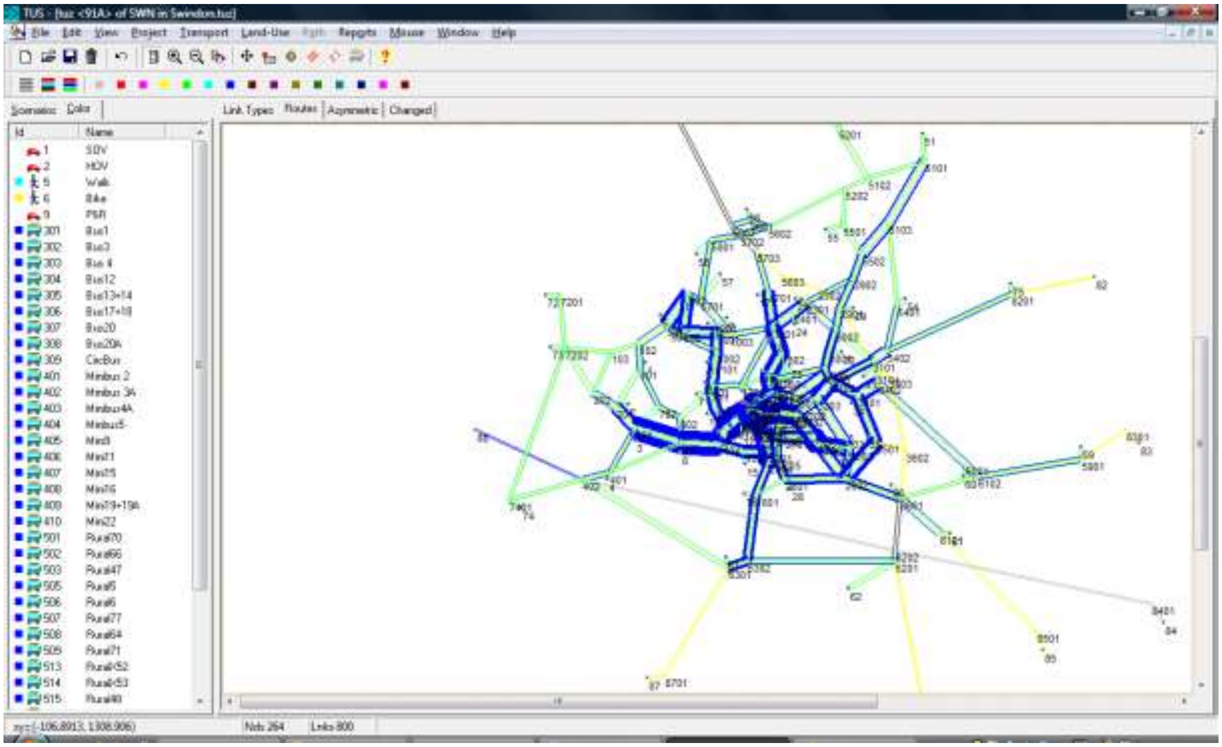


Figure 26: Network view showing public transport routes and capacities



4 Running and adjusting the base scenario

This chapter describes the way in which the base scenario is run and reports about the results that are obtained. Also the way in which the model is adjusted to calibrate the model against data is discussed.

The base scenario was defined as 1991 and the three-letter code was set to 91A.

4.1 Running the base scenario

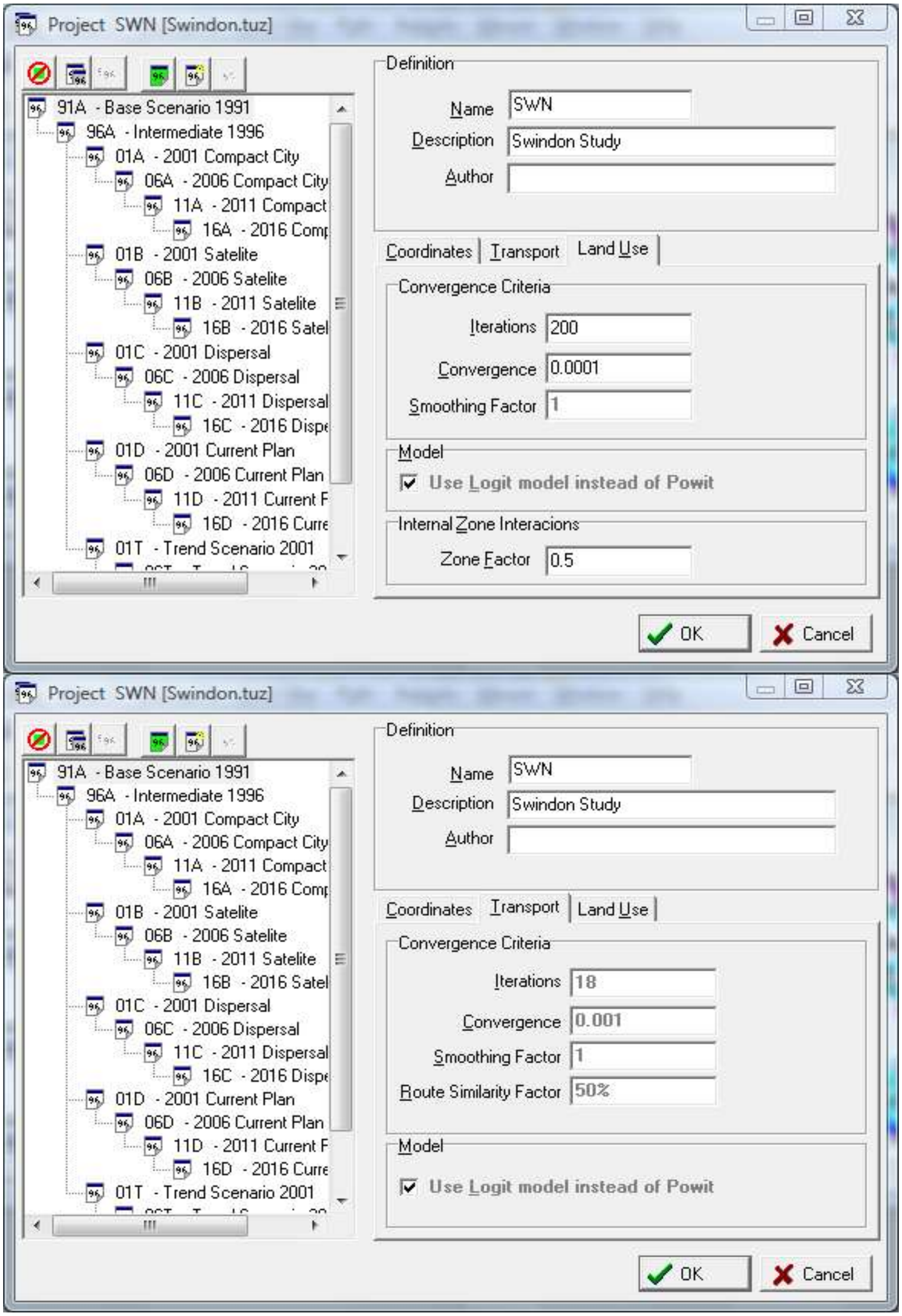
The TRANUS interface provides a special menu to run the model programs. See the *TUS Manual* for more details about running scenarios. The procedure is quite simple, as will be seen below. When one or more programs are run, the interface automatically performs the following functions:

- creates a folder to hold all scenario-related data (in this case the folder will be 91A) that hangs from the application folder
- generates a set of data files, most in the scenario folder but also s few in the application folder
- runs the corresponding programs that in turn generate a number of files in the scenario folder to hold all results

The Project -> Run menu

Before running the programs, check some options in menu Project -> Options, as shown in Figure 28. The Land use tab shows that the land use model will be run for up to 200 iterations (unless it converges before), and the convergence target is set to 0.0001. The transport model will run for up to 18 iterations with a convergence criterion of 0.001. In both cases a *smoothing factor* of 1 is specified, which means that the values of each iteration are averaged with those of the previous iteration in equal proportions.

Figure 27: Menu Project -> for land use and transport

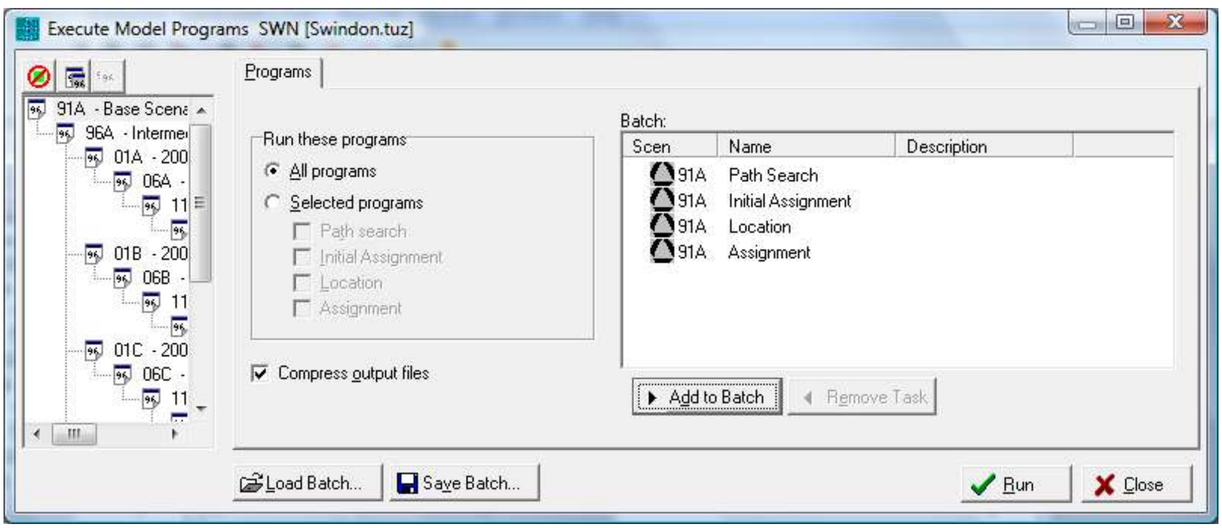


To run the models for the base scenario simply select the Project -> Run menu. Make sure the 91A scenario is selected in the left panel. The menu offers two basic choices: all programs, or selected programs. In this case we are interested in running all programs. After this choice press the *Add to Batch* button, and a list of the programs that will be run appears in the right panel. The list of programs is as follows:

- Path search: runs program PASOS, the multimodal path search procedure
- Initial assignment: runs a single iteration of program TRANS, the transport assignment model, and then runs COST, the cost adjustment program
- Location: runs program LCAL, the Land Use model used for the base year scenario, and then runs FLUJ, the flows adjustment program
- Assignment: runs all iterations of program TRANS, and then runs COST again

As may be seen, the interface knows that you want to run the base scenario, because it is the one at the top of the scenario tree, and selects the programs accordingly. Next press the *Run* button. A black window is presented with messages reporting the progress of the programs. Some error or warning messages will also appear. Once all programs have run, you may save all the information in the screen by selecting it, Ctrl+C to copy and Ctrl+V to paste it in any program such as Word or NotePad. Running all programs should only take a few minutes.

Figure 28: The Project -> Run menu window



Program PASOS will display the following messages:

```
P A S O S :  PATH SEARCH BY MODE
READING PARAMETERS AND DATA
VERIFYING REPEATED LINKS...
Total number of links in the network:
      472        2737
PATH SEARCH BY MODE
  ADY   Mod    1 (100%)  a=( 0%)      )
  PAS   Mod   1  Orig      89(100%) h=( 3%)
Run time:    0.101 mins
NORMAL END OF P A S O S
```

The program is reporting that it found 472 links in the base scenario network, that combined with transit routes and other operators makes a multimodal network of 2737 links. ADY is the procedure to build the *dual network*, and the message is reporting that it is using less than 1% of the capacity of the program (a= 0%). It then builds the paths for all origins and uses 3% of the model capacity. The program took 0.1 mins to run on a 2.2 GHz Dual Core.

The Initial Assignment screen does not contain much information, just a progress report.

The Location screen is much more interesting, with a table for each iteration. Convergence of the model is evaluated on a sector-by-sector basis. Because 200 iterations were made, only the last table is shown here for iteration 200:

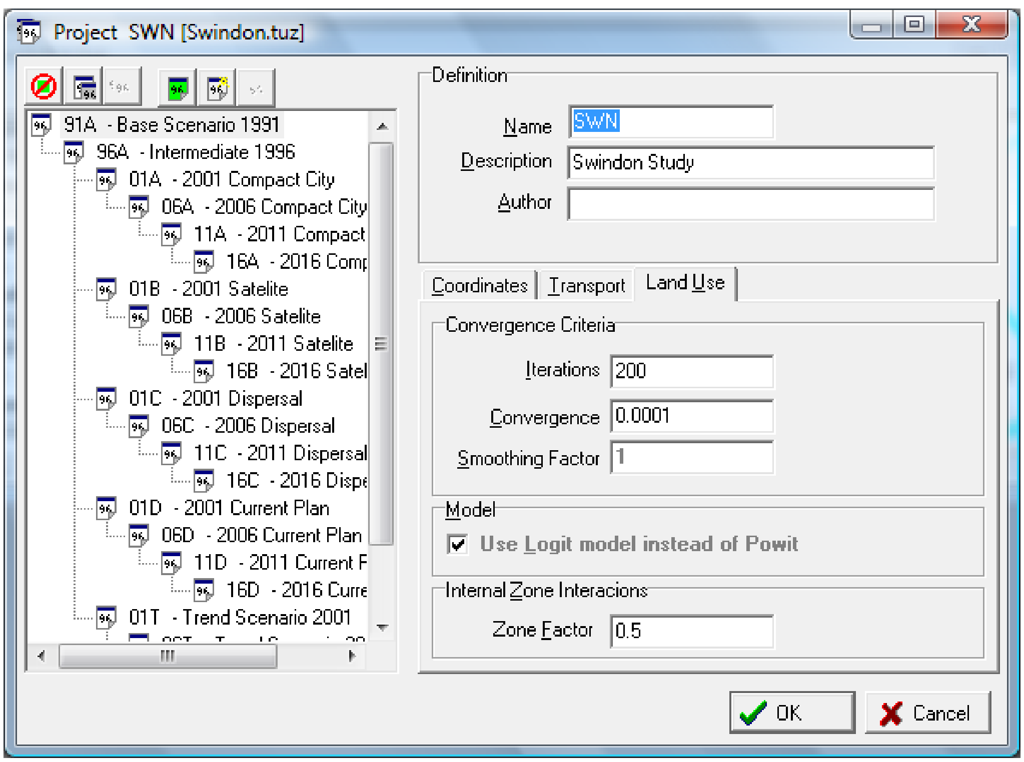
Convergence indicators

Sector	ConvPric	Zon	ConvProd	Zon	ExogProd	InducProd
1 Indus	0.000013	18	0.000000	0	43615.	0.
2 Govm	0.000007	37	0.000000	0	4062.	0.
3 Retail	0.000001	52	0.000000	15	0.	25642.
4 Office	0.000001	32	0.000000	23	0.	23086.
5 Health	0.000001	75	0.000000	19	0.	3118.
6 Eductn	0.000001	71	0.000000	30	0.	7004.
11 HhHigh	0.000001	59	0.000000	38	0.	19730.
12 HhMed	0.000001	75	0.000000	71	0.	29280.
13 HhLow	0.000001	53	0.000000	74	0.	24400.
21 Sheds	- 0.000121	23	-0.000135	23	0.	1403691.
22 Framed	-0.000134	23	0.000516	18	0.	1205309.
23 Detch	0.000009	38	0.000003	54	0.	1996788.
24 SemiD	-0.000002	37	-0.000004	38	0.	2186582.
25 Terrace	0.000010	6	-0.000007	38	0.	4173464.
31 IndLnd	0.000273	12	-0.000139	23	0.	583.
32 BPark	0.000263	12	0.000024	35	0.	95.
33 Mixed	- 0.000105	38	0.000396	18	0.	190.
34 ResL	-0.000091	38	-0.000009	37	0.	3556.

The model evaluates two convergence indicators: convergence of prices (ConvPric) and convergence of production. In the example, sector 1 Industry shows a convergence of 0.000013 (0.0013%) in prices. The model takes the worst case, that is, the zone in which the price changed the most with respect to the previous iteration, and this took place in zone 18. Production did not vary, because Industry is a totally exogenous sector, so that production does not vary. Two additional columns show exogenous production and induced production accumulated up to this iteration. Because (again) sector 1 is totally exogenous, only exogenous production must be shown, in this case 43615 jobs.

At the end there is a message saying *"Last iteration without convergence"*. This is because iteration 200 was reached before the convergence criterion was fully met. These parameters are specified in menu Project -> Optons -> Land Use, as shown in Figure 29. However, achieved convergence is quite good, so that it was not thought necessary to increase the number of iterations.

Figure 29: The Project -> Options -> Land Use menu window



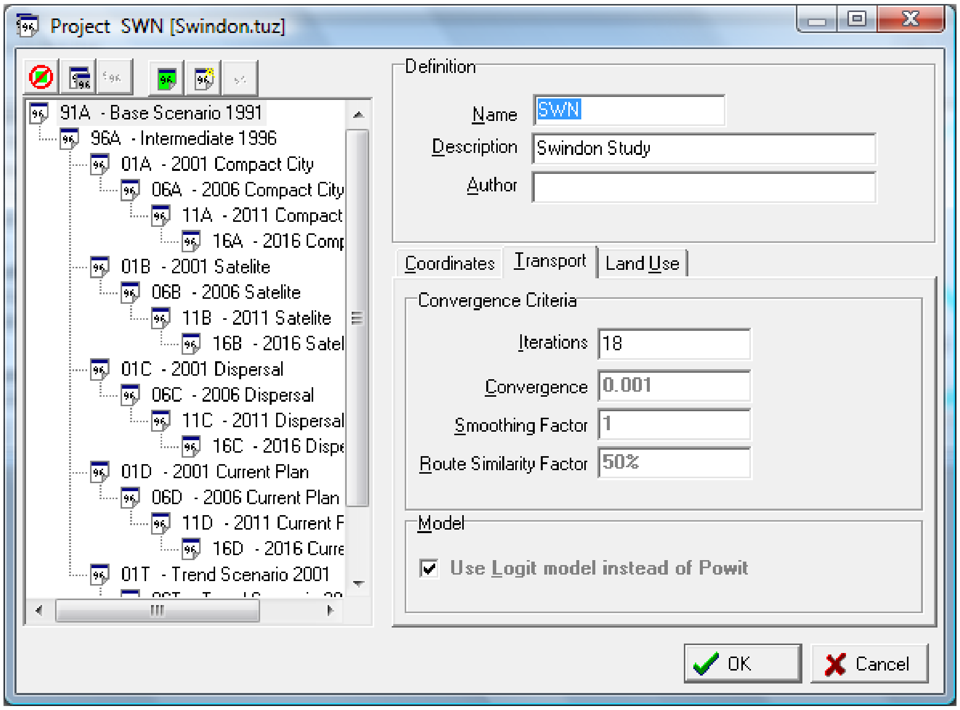
Next the Transformation of Flows procedure was performed by running program FLUJ automatically, displaying a progress report only.

The (Final) Assignment screen also reports results for every iteration, as follows:

Iter	Categ	Origin	ConvObj	ConvFlows	Worst	ConvSpeed	Worst
1	6	65	0.0010000	F ********	(0 0)	V 0.41855	(2102 2101)
2	6	65	0.0010000	F 0.56633	(6301 402)	V 0.46569	(701 601)
3	6	65	0.0010000	F 0.34746	(402 6301)	V 0.47645	(701 601)
4	6	65	0.0010000	F 0.26442	(201 101)	V 0.46644	(701 601)
5	6	65	0.0010000	F 0.22323	(201 101)	V 0.41205	(701 601)
6	6	65	0.0010000	F 0.20525	(1201 1202)	V 0.25622	(701 601)
7	6	65	0.0010000	F 0.10881	(15 1501)	V 0.17188	(601 1201)
8	6	65	0.0010000	F 0.06650	(15 1501)	V 0.04902	(1902 1202)
9	6	65	0.0010000	F 0.02592	(601 1201)	V 0.01834	(701 601)
10	6	65	0.0010000	F 0.01704	(3701 1403)	V 0.01333	(601 1201)
11	6	65	0.0010000	F 0.02813	(15 1501)	V 0.00821	(701 601)
12	6	65	0.0010000	F 0.01053	(7 701)	V 0.00956	(701 601)
13	6	65	0.0010000	F 0.00862	(7 701)	V 0.00523	(701 601)
14	6	65	0.0010000	F 0.01620	(15 1501)	V 0.00274	(1404 801)
15	6	65	0.0010000	F 0.00335	(15 1501)	V 0.00122	(1404 801)
16	6	65	0.0010000	F 0.00832	(15 1501)	V 0.00136	(1501 1404)
17	6	65	0.0010000	F 0.00357	(12 1201)	V 0.00062	(702 301)
18	6	65	0.0010000	F 0.00161	(15 1501)	V 0.00046	(1404 801)

The transport model evaluates convergence with two indicators: convergence in flows and convergence in speeds, again showing the worst case, that is, the link that varied the most. In the first iteration it is not possible to evaluate the variation in flows, because there is no previous iteration flows to compare. Speed can be compared, because at the end of iteration 1 there might be congestion slowing down the vehicles. In this example, the worst case of iteration 1 happened in 2102-2101 that varied 41%. Note that the convergence criterion is always shown as 0.001. The program reached iteration 18 without fully converging, since flows show an indicator of 0.161% as worst case in link 15-1501, that is a little bit greater than the convergence criterion. Worst case in speeds happened in link 1404-801 with a variation of 0.0046% with respect to the previous iteration, well bellow the convergence criterion. These parameters are specified in the Project -> Options -> Transport menu, as shown in Figure 30.

Figure 30: The Project -> Options -> Transport menu window

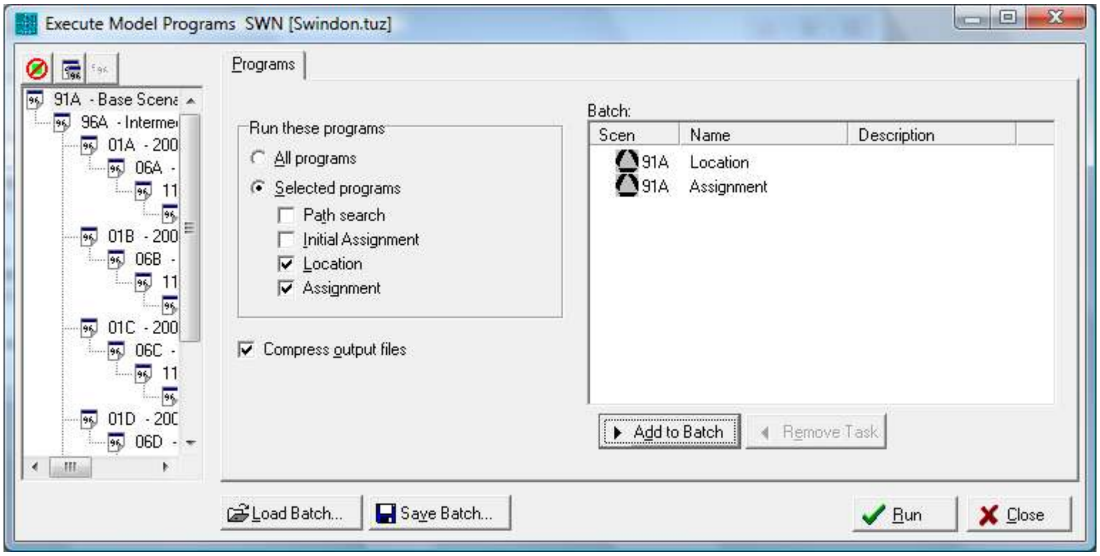


This ends the sequence of programs. Note that the land use model ran with transport costs and disutilities that were calculated with the ‘initial run’ of the transport model, based on free-flow speeds. Once the land-use model ran, the transport assignment model was applied, this time with flows from the land use model, giving rise to *congested* transport costs and disutilities. Because these values affect the location of activities and land use, it is necessary to re-run location and assignment. This is done by selecting the Project -> Run menu again, specifying additional runs, as shown in Figure 31. This time the option *Selected Programs* is chosen to check on Location and Assignment, since there is no need to run Path Search again nor Initial Assignment. Note that running Initial Assignment again is equivalent to starting from scratch.

In theory land use and transport should be run many times to achieve equilibrium. It is not straightforward to assess when such equilibrium has been reached without considerable work. In practice it is safe to say that a couple of spins is enough. For the purpose of this guide we shall repeat the process only once.

Once the second run has been completed, the next step is to find out what the results look like. Did the model behave properly? Was data properly reproduced? These are the issues addressed in the following sections.

Figure 31: The Project -> Run menu to perform additional runs



4.2 Land use results

There are several programs that read the results of the models and present them in readable table-like fashion. In the case of land-use results, the main program to obtain results is called IMPLOC. Read the Programs Manual to get instructions to run this program. The land use model, however, automatically generates a file called ***locaton_indicators_91A.csv***. This is a comma-separated-values text file that is easy to read with any spreadsheet program such as Excel, as shown in Figure 32.

Note that the file present numbers with a dot as decimal delimiter. Make sure that Excel assumes this also (if not use Windows' Control Panel to set a dot as delimiter and a comma as separator).

The file contains a heading and then a table with values for each sector and zone, in this case sector 1 Industrial employment. The main columns of data are:

Scen	the scenario code (in this case *91A*)
Sector	the economic sector (in this case *1 Indus*)
Zone	the zone each row refers to
TotProd	Total production, the sum of possible exogenous and induced production
TotDem	Total demand, the sum of possible exogenous and induced demand
ProdCost	Production Cost
Price	Price
MinRes	Minimum restriction
MaxRes	Maximum restriction

Adjust Price adjusting factor

Note that scientific notation is used throughout, but it is easy to change to a more familiar format in the spreadsheet. In this case Industrial employment is totally exogenous, that is, all production is exogenous and no other sector demands it. Consequently all production is in the column TotProd and TotDem is always zero. Note that with this format it is easy to produce *Dynamic Tables* in Excel and other spreadsheets.

Production Cost and Price must be equal, because this is an unconstrained sector. These values have been calculated by the model as it works through the input-output procedure. It is the sum of whatever this sector has consumed, in this case population, floorspace and land. MinRes and MaxRes are always zero because no restrictions have been imposed. The price adjustment factor (see the *Math Manual*) adds or subtracts a a certain amount to the price in order to approach simulated induced production to data values. The values are presented as a percentage of the price. In the case of an exogenous sector like this one, there is nothing to adjust.

Figure 32: Land use results displayed in a spreadsheet

	A	B	C	D	E	F	G	H	I	J
1	Scen	Sector	Zone	TotProd	TotDem	ProdCost	Price	MinRes	MaxRes	Adjust
2	91A	1 Indus	1 Peatmoore	1.10E+01	0.00E+00	1.28E+03	1.28E+03	0.00E+00	9.00E+09	0.00E+00
3	91A	1 Indus	2 Show	9.80E+01	0.00E+00	1.28E+03	1.28E+03	0.00E+00	9.00E+09	0.00E+00
4	91A	1 Indus	3 Greendow	1.13E+03	0.00E+00	1.27E+03	1.27E+03	0.00E+00	9.00E+09	0.00E+00
5	91A	1 Indus	4 Balgrove	2.02E+03	0.00E+00	1.28E+03	1.28E+03	0.00E+00	9.00E+09	0.00E+00
6	91A	1 Indus	5 Westfields	5.49E+02	0.00E+00	1.23E+03	1.23E+03	0.00E+00	9.00E+09	0.00E+00
7	91A	1 Indus	6 ChnyManc	3.04E+03	0.00E+00	1.27E+03	1.27E+03	0.00E+00	9.00E+09	0.00E+00
8	91A	1 Indus	7 Westmeac	3.58E+03	0.00E+00	1.27E+03	1.27E+03	0.00E+00	9.00E+09	0.00E+00
9	91A	1 Indus	8 FlintHill	2.04E+02	0.00E+00	1.27E+03	1.27E+03	0.00E+00	9.00E+09	0.00E+00
10	91A	1 Indus	9 HydnWick	1.50E+01	0.00E+00	1.26E+03	1.26E+03	0.00E+00	9.00E+09	0.00E+00
11	91A	1 Indus	10 Whitwort	5.15E+02	0.00E+00	1.26E+03	1.26E+03	0.00E+00	9.00E+09	0.00E+00
12	91A	1 Indus	11 Rodbourr	1.08E+02	0.00E+00	1.29E+03	1.29E+03	0.00E+00	9.00E+09	0.00E+00
13	91A	1 Indus	12 GtWester	2.96E+02	0.00E+00	1.33E+03	1.33E+03	0.00E+00	9.00E+09	0.00E+00
14	91A	1 Indus	13 Lindslade	1.71E+02	0.00E+00	1.28E+03	1.28E+03	0.00E+00	9.00E+09	0.00E+00
15	91A	1 Indus	14 KingsHill	9.63E+02	0.00E+00	1.26E+03	1.26E+03	0.00E+00	9.00E+09	0.00E+00
16	91A	1 Indus	15 Okus	1.41E+02	0.00E+00	1.32E+03	1.32E+03	0.00E+00	9.00E+09	0.00E+00
17	91A	1 Indus	16 GtCopse	1.60E+01	0.00E+00	1.26E+03	1.26E+03	0.00E+00	9.00E+09	0.00E+00
18	91A	1 Indus	17 Penhill	4.20E+01	0.00E+00	1.27E+03	1.27E+03	0.00E+00	9.00E+09	0.00E+00

Figure 33 shows the results for Sector 3 Retail employment, an induced sector further down the table, with the scientific notation changed to a number format with no decimal places, and the first row frozen to show the name of the columns. Because the production in this sector is consumed by other sectors, values are present in both TotProd and TotDem. In the example, 78 jobs were produced in zone 1. Demand for retail jobs in that zone is bigger, 174. This is a transportable sector, so that the 78 jobs produced in zone 1 may have been consumed partly in zone 1 and partly in many other zones. Because it is an unconstrained sector ProdCost and Price are the same. In zone 1 the cost of producing one job is £ 1,269. MinRes is zero and MaxRes is a very large number, which means that there are no restrictions. The adjustment factor is -66.54 in zone one, which means that the price was reduced by 66% in order to achieve the production of 78 jobs.

Figure 33: Land Use results, showing an induced sector

	A	B	C	D	E	F	G	H	I	J	K
1	Scen	Sector	Zone	TotProd	TotDem	ProdCost	Price	MinRes	MaxRes	Adjust	
132	91A	3 Retail	1 Peatmoore	78	174	1,269	1,269	-	8,999,999,488	-66.54	
133	91A	3 Retail	2 Show	80	772	1,277	1,277	-	8,999,999,488	-45.58	
134	91A	3 Retail	3 Greendow	2,903	1,297	1,230	1,230	-	8,999,999,488	-60.87	
135	91A	3 Retail	4 Balgrove	1,041	204	1,229	1,229	-	8,999,999,488	-30.49	
136	91A	3 Retail	5 Westfields	1,042	903	1,202	1,202	-	8,999,999,488	-61.35	
137	91A	3 Retail	6 ChnyManc	277	55	1,250	1,250	-	8,999,999,488	2.98	
138	91A	3 Retail	7 Westmeac	463	289	1,221	1,221	-	8,999,999,488	1.29	
139	91A	3 Retail	8 FlintHill	96	768	1,254	1,254	-	8,999,999,488	-44.20	
140	91A	3 Retail	9 HydnWick	63	495	1,256	1,256	-	8,999,999,488	-66.69	
141	91A	3 Retail	10 Whitwort	126	682	1,253	1,253	-	8,999,999,488	-25.93	
142	91A	3 Retail	11 Rodbourr	118	422	1,285	1,285	-	8,999,999,488	-59.09	
143	91A	3 Retail	12 GtWester	180	115	1,354	1,354	-	8,999,999,488	-52.74	
144	91A	3 Retail	13 Lindslade	173	351	1,259	1,259	-	8,999,999,488	-51.19	
145	91A	3 Retail	14 KingsHill	1,802	549	1,220	1,220	-	8,999,999,488	-41.40	
146	91A	3 Retail	15 Okus	85	266	1,267	1,267	-	8,999,999,488	-1.44	
147	91A	3 Retail	16 GtCopse	-	220	1,265	1,265	-	8,999,999,488	-	
148	91A	3 Retail	17 Penhill	56	804	1,268	1,268	-	8,999,999,488	-27.10	
149	91A	3 Retail	18 Pinehurst	145	679	1,295	1,295	-	8,999,999,488	-45.05	

Finally Figure 34 shows a non-transportable sector 23 Detached Houses. The main difference is that production and demand must be the same, since houses must be produced and consumed in the same place. Again here ProdCost and Price are the same, even if it is a constrained sector. This is because it is the base year, since they may become quite different in future scenarios. Columns MinRes and MaxRes show the minimum and maximum constraints that were entered in Land Use -> Economic Data. These should be as close as possible as production values. In the case of zone 1 the difference was minimized with and adjustment factor of 38.11% of the price.

Figure 34: Land-use results in Excel, showing a non-transportable sector

	A	B	C	D	E	F	G	H	I	J	K
1	Scen	Sector	Zone	TotProd	TotDem	ProdCost	Price	MinRes	MaxRes	Adjust	
717	91A	23 Detch	1 Peatmoore	18,672	18,672	8	8	18,672	18,672	-38.11	
718	91A	23 Detch	2 Show	105,225	105,225	7	7	105,225	105,225	-30.40	
719	91A	23 Detch	3 Greendow	151,661	151,661	7	7	151,662	151,662	-34.78	
720	91A	23 Detch	4 Balgrove	13,687	13,687	7	7	13,687	13,687	-59.78	
721	91A	23 Detch	5 Westfields	76,118	76,118	6	6	76,118	76,118	-29.41	
722	91A	23 Detch	6 ChnyManc	-	-	7	7	-	-	-	
723	91A	23 Detch	7 Westmeac	10,312	10,312	6	6	10,312	10,312	-60.35	
724	91A	23 Detch	8 FlintHill	94,464	94,464	7	7	94,464	94,464	-33.04	
725	91A	23 Detch	9 HydnWick	67,677	67,677	7	7	67,677	67,677	-28.81	
726	91A	23 Detch	10 Whitwort	27,368	27,368	8	8	27,368	27,368	-49.52	
727	91A	23 Detch	11 Rodbourr	7,593	7,593	9	9	7,593	7,593	-51.56	
728	91A	23 Detch	12 GtWester	1,822	1,822	7	7	1,822	1,822	-62.22	
729	91A	23 Detch	13 Lindslade	7,743	7,743	7	7	7,743	7,743	-39.87	
730	91A	23 Detch	14 KingsHill	1,540	1,540	8	8	1,540	1,540	-67.20	
731	91A	23 Detch	15 Okus	13,946	13,946	8	8	13,946	13,946	-43.47	
732	91A	23 Detch	16 GtCopse	28,826	28,826	7	7	28,826	28,826	-31.48	
733	91A	23 Detch	17 Penhill	12,342	12,342	7	7	12,342	12,342	-45.68	
734	91A	23 Detch	18 Pinehurst	9,108	9,108	8	8	9,108	9,108	-50.11	
735	91A	23 Detch	19 GorseHill	6,822	6,822	8	8	6,822	6,822	-56.79	

4.3 Transport results

There are three ways of viewing transport results. The first one is similar to that described in the preceding section, that is, by simply opening files that are generated automatically. The second form is to run programs that generate text-based reports. The third way is to use the same interface TUS to display transport results graphically in the form of thematic maps.

Two files are generated automatically:

> ***transport_indicators_91A.csv***, and
>
> ***route_profile_91A.csv***

Text reports may be obtained with three programs (see Programs Manual):

> IMPTRA presents a menu with several options to produce link-based results or indicators with a variety of formats.
>
> MATS presents a menu with options to produce matrices of several types, such as trip matrices, costs, disutilities, and many others. This program is also used to present land use matrices.
>
> MATESP also presents a menu with options to produce 'special matrices', such as O-D matrices that use a link or an operator, matrices of transfers, and others.

The resulting file transport_indicators_91A.csv may be opened in Excel just like in the previous example, since it is a text file with values separated by commas. The first row contains the headings of each data column with global indicators of the transport system for the whole study area. As in the previous case, Dynamic Tables are easily built from the basic data table. The data table contains the following columns:

Scenario

Table

Object

Subobject

Value

Figure 35 shows the first part of the data table, corresponding to a table called Trips by cat/model. The object in this case corresponds to transport categories such as 1 HWHigh (home-work trips by high-income population). The subobject in this case is the only mode in the system: Passengers. The first row indicates that this category makes 84,313 daily trips. These represent door-to-door trips, so that if there are transfers with several boardings along the way, they are still counted as one trip.

Figure 35: Transport indicators data table

	A	B	C	D	E	F
1	Scenario	Table	Object	SubObject	Value	
2	91A	Trips by cat/mode	1 HWHigh	1 Passengs	84,313	
3	91A	Trips by cat/mode	2 HWMed	1 Passengs	114,069	
4	91A	Trips by cat/mode	3 HWLow	1 Passengs	85,705	
5	91A	Trips by cat/mode	4 Serv	1 Passengs	100,670	
6	91A	Trips by cat/mode	5 Educ	1 Passengs	95,317	
7	91A	Trips by cat/mode	6 External	1 Passengs	172,315	
8	91A	Supressed by cat	1 HWHigh	All	38	
9	91A	Supressed by cat	2 HWMed	All	31	

From this table, another table with a nicer format may be produced by making simple references or using the Dynamic Table utility in Excel.

Further down the file general statistics by transport categories are found, as shown in Figure 36. The indicators include distance travelled, monetary cost, and travel time. In this example category 1 Home to work high income travel a total of 673,921 Km (if we divide this by the number of trips an average trip length of 8.04 Km results). Note that there are external trips in a separate category in order to avoid distortions to the indicators.

Figure 36: Statistics by transport category

	A	B	C	D	E
1	Scenario	Table	Object	SubObject	Value
14	91A	Distance by cat	1 HWHigh	All	673,921
15	91A	Distance by cat	2 HWMed	All	843,697
16	91A	Distance by cat	3 HWLow	All	631,226
17	91A	Distance by cat	4 Serv	All	750,092
18	91A	Distance by cat	5 Educ	All	722,273
19	91A	Distance by cat	6 External	All	5,995,807
20	91A	Cost by cat	1 HWHigh	All	97,624
21	91A	Cost by cat	2 HWMed	All	110,598
22	91A	Cost by cat	3 HWLow	All	71,012
23	91A	Cost by cat	4 Serv	All	98,216
24	91A	Cost by cat	5 Educ	All	90,037
25	91A	Cost by cat	6 External	All	753,088
26	91A	TravTime by cat	1 HWHigh	All	23,328
27	91A	TravTime by cat	2 HWMed	All	34,365
28	91A	TravTime by cat	3 HWLow	All	30,838
29	91A	TravTime by cat	4 Serv	All	31,419
30	91A	TravTime by cat	5 Educ	All	32,649
31	91A	TravTime by cat	6 External	All	114,626

Further down the data table results by operator are presented, as in Figure 37. The first is boardings by operator, such that a trip that involved, say, walking and then boarding a bus will appear both as a bus trip and a walk trip. If we add all boardings we get a total of 841,134 that is larger than the total number of trips by category, 652,387.

Units-Dist represents, in this case, passenger-Km travelled. By far the greatest figures correspond to the two types of cars, but it is interesting to note that there are as many trips and passenger-Km in bike compared to buses. Note that in the base scenario there are no trips by rail and no park-and-ride. These will be introduced in future scenarios.

Energy is, in this application, the amount of fuel consumed in litres. This indicator may be used to calculate emissions. It is clear that cars consume an enormous amount of fuel compared to buses. An interesting exercise is to divide the litres by passengers-Km to get an efficiency indicator that may be viewed also as a pollution indicator.

Further down, Costs are the operating cost of vehicles in daily units, including the cost of fuel, in Sterling pounds. Income is what the operator receives, and revenue is just income-minus-cost. This is only relevant for the buses. Cars shouldn't have any revenues, but because users do not perceive all of the cost (as specified in Transport -> Operators -> Cost) they show up in the table as loosing money.

VehKm is vehicle-Km travelled. In the case of SOV cars, vehicles travel the same as passengers, because the occupancy rate is set to 1.0. In the case of HOV cars passenger-Km are more than twice the vehicle-Km. Dividing these two indicators yields another efficiency indicator. VehHrs is vehicle-hours. Divide VehKm/VehHrs to get average speed.

Figure 37: Statistics by operator

	A	B	C	D	E
1	Scenario	Table	Object	SubObject	Value
44	91A	Boardings by oper	1 SOV	All	251,586
45	91A	Boardings by oper	2 HOV	All	247,941
46	91A	Boardings by oper	3 Bus	All	30,954
47	91A	Boardings by oper	4 Minibus	All	36,564
48	91A	Boardings by oper	5 Walk	All	159,668
49	91A	Boardings by oper	6 Bike	All	68,933
50	91A	Boardings by oper	7 RuralBus	All	45,490
51	91A	Boardings by oper	8 Rail	All	-
52	91A	Boardings by oper	9 P&R	All	-
53	91A	Units-dist by oper	1 SOV	All	3,819,874
54	91A	Units-dist by oper	2 HOV	All	4,652,767
55	91A	Units-dist by oper	3 Bus	All	127,346
56	91A	Units-dist by oper	4 Minibus	All	135,857
57	91A	Units-dist by oper	5 Walk	All	67,024
58	91A	Units-dist by oper	6 Bike	All	446,094
59	91A	Units-dist by oper	7 RuralBus	All	369,446
60	91A	Units-dist by oper	8 Rail	All	-
61	91A	Units-dist by oper	9 P&R	All	-
62	91A	Energy by oper	1 SOV	All	465,561
63	91A	Energy by oper	2 HOV	All	427,466
64	91A	Energy by oper	3 Bus	All	2,739
65	91A	Energy by oper	4 Minibus	All	1,991
66	91A	Energy by oper	5 Walk	All	-

Further down the file there are values with statistics by administrator, as shown in Figure 38. Each administrator may have income from tolls or other charges, and have maintenance costs. In this application the base year only has one administrator: *'County'*, and no maintenance costs were specified. *County* perceives an income from parking charges in some downtown zones (see Transport -> Link Types -> Operator Data for Link Type *2 Access with parking)*.

Figure 38: Statistics by administrator

	A	B	C	D	E
1	Scenario	Table	Object	SubObject	Value
107	91A	Distance by admin	1 County	All	607
108	91A	Distance by admin	2 Railway	All	-
109	91A	Distance by admin	3 P&R	All	-
110	91A	Income by admin	1 County	All	23,323
111	91A	Income by admin	2 Railway	All	-
112	91A	Income by admin	3 P&R	All	-
113	91A	MaintCost by admin	1 County	All	-
114	91A	MaintCost by admin	2 Railway	All	-
115	91A	MaintCost by admin	3 P&R	All	-

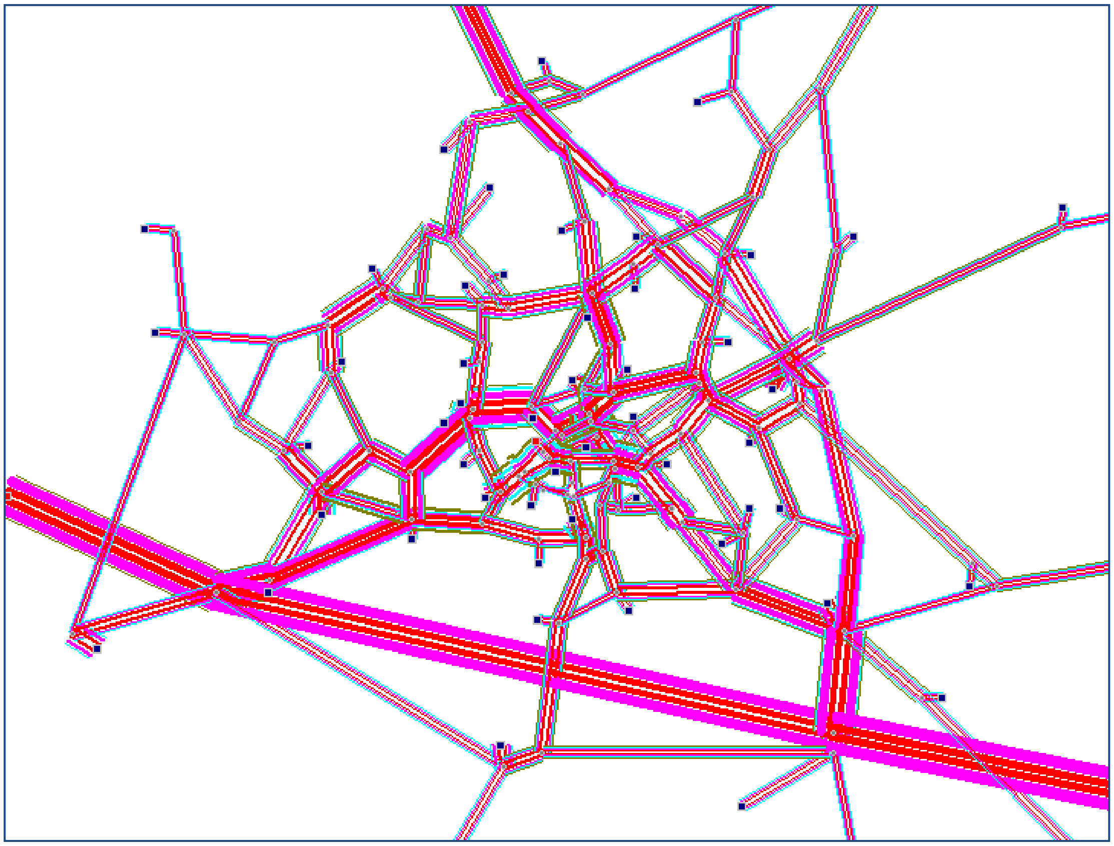
At the end of the file there is a set of tables combining categories and operators. The first of these tables, shown in Figure 39 presents values in terms of boardings. This is useful to see which categories use certain operators the most. For instance, high-income trips home-work make 45,931 trips by SOV car (46%), while low-income home-work trips by SOV are 26,843 (18%). By contrast, high-income make 4.7% of their trips by bike, while low-income make 9.1%. This is because high-income travellers have a high value of time, so that they favour faster modes even if they are more expensive.

Figure 39: Boardings by category and operator

	A	B	C	D	E	F
1	Scenario	Table	Object	SubObject	Value	
116	91A	Boardings by cat/op	1 HWHigh	1 SOV	45,931	
117	91A	Boardings by cat/op	1 HWHigh	2 HOV	26,843	
118	91A	Boardings by cat/op	1 HWHigh	3 Bus	2,139	
119	91A	Boardings by cat/op	1 HWHigh	4 Minibus	3,115	
120	91A	Boardings by cat/op	1 HWHigh	5 Walk	13,979	
121	91A	Boardings by cat/op	1 HWHigh	6 Bike	4,519	
122	91A	Boardings by cat/op	1 HWHigh	7 RuralBus	4,087	
123	91A	Boardings by cat/op	1 HWHigh	8 Rail	-	
124	91A	Boardings by cat/op	1 HWHigh	9 P&R	-	
125	91A	Boardings by cat/op	2 HWMed	1 SOV	45,573	
126	91A	Boardings by cat/op	2 HWMed	2 HOV	38,700	
127	91A	Boardings by cat/op	2 HWMed	3 Bus	6,196	
128	91A	Boardings by cat/op	2 HWMed	4 Minibus	7,503	
129	91A	Boardings by cat/op	2 HWMed	5 Walk	32,793	
130	91A	Boardings by cat/op	2 HWMed	6 Bike	13,284	
131	91A	Boardings by cat/op	2 HWMed	7 RuralBus	8,192	
132	91A	Boardings by cat/op	2 HWMed	8 Rail	-	

To get thematic maps of transport results, use the File ->Open menu in the interface to open the results. Look for the 91A folder and in there open a file called SWN91A.T3S. Once opened, you may set colours and scales to get the appropriate network view. An example is shown below in Figure 40 in terms of demand values, in this case, passengers by operator. SOV cars are red, HOV cars pink, buses green and bikes and pedestrians light blue. The bandwidth is proportional to the number of passengers in each link.

Figure 40: Network view showing demand values (passengers) by operator



4.4 Adjusting floorspace and land demand functions

The Swindon model already went through the calibration process, so that there is no need to adjust anything. However, it is a good exercise to go through some of the main functions that must be estimated and adjusted at the calibration stage of model development. In this section we look at the elastic demand functions that are present in considerable number in the land use model.

When reviewing the model structure, two main types of demand functions were described: elastic and inelastic. The model treats both the same way, defining inelastic functions as elastic functions with elasticity = 0. In the Swindon application, jobs consume residents, and in turn, residents consume jobs. These relationships are represented as inelastic functions, that is, one unit of job of a specific sector will consume a fixed, constant, amount of households of a specific type. By contrast, when activities consume floorspace they do so with an elastic function, that is, with a minimum and a maximum amount and an elasticity parameter with respect to expenditure (see the *Math Manual* for an explanation on this). If the price of a house becomes too expensive, people will react either by changing location or consuming smaller amounts. In turn, in the model of Swindon floorspace consumes land of various types, also with elastic functions. This means that as land becomes expensive, plots of land will get smaller.

In this section we will use two reports generated by program IMPLOC. Run this program from a command window in the application folder, to get a menu like this one:

```
I M P L O C : DISPLAY LOC RESULTS

 Display options:

   [1] All information by sector and zone
   [2] Total production by sector and zone
   [3] Total production by year/policy
   [4] Internal information by sector and zone
   [5] Consumption coefficients by sector
   [6] Total consumption by sector and zone

                              Option ---> 1
```

Option 5 produces a set of tables with consumption coefficients by sector, while Option 6 produces a set of tables with total consumption by sector and zone. You may choose any name for the files. The resulting files may be opened with Excel (tab delimited).

Figure 41 shows two sections of the unit consumption report. The upper view corresponds to sheds. There are only two sectors that consume this type of floorspace, according to the model definition: industrial employment and retail employment. The table shows the amount of floorspace that each unit of activity consumes. In zone 1, one unit of industrial job consumes 79.467 m2 of shed-type floorspace, while a job in the retail sector consumes 115.62 m2. Note that the minimum and maximum consumption, shown in the header of the table, are 55 and 110 m2 for industrial jobs and 40 and 210 m2 for retail. The amounts consumed in zone 1 are, therefore, somewhere in between, depending on elasticity and prices. The price of a unit of sheds floorspace is the same for all activities in zone 1.

The bottom half of the figure shows a section of the table further down, in which activities are consuming semidetached floorspace. In this case retail, office, and the three types of households consume this type of floorspace.

Figure 41: Unit consumption of floorspace with elastic demand functions

A31 | fx 13

	A	B	C	D	E	F
5	Swindon Study		POLITICA:			
6	RESULTS OF THE ACTIVITY LOCATION MODEL					
7	Area Policy	Date/time simulation				
8	SWN 91A	18- 5-2009	14:30 ITER 200			
9						
10	--					
11	Sect 21 Sheds					
12	--					
13						
14	Zon	Indus	Retail			
15	Min	55	40			
16	Max	110	210			
17	Els	0.44999999	0.44999999			
18	--					
19	1	79.4671936	115.625877			
20	2	79.4671936	115.625877			
21	3	67.2504807	77.8651123			
22	4	60.9853134	58.5000648			
23	5	79.4671936	115.625877			
24	6	60.4023476	56.6981659			
25	7	58.7363663	51.5487671			

SWN91A

A31 | fx 13

	A	B	C	D	E	F
208	--					
209	Sect 24 SemiD					
210	--					
211						
212	Zon	Retail	Office	HhHigh	HhMed	HhLow
213	Min	25	24	43	29	27
214	Max	170	150	370	320	300
215	Els	0.5	0.55000001	0.40000001	0.40000001	0.40000001
216	--					
217	1	42.0664711	35.9735718	102.042984	81.5428391	76.2927628
218	2	47.3051834	40.0735588	116.143875	94.0913391	88.0650711
219	3	35.7806854	31.2239819	83.8856049	65.3844376	61.1338501
220	4	38.9593163	33.5987854	93.274147	73.7393799	68.9719925
221	5	37.2280502	32.297718	88.2208862	69.2424469	64.7532196
222	6	57.5792618	48.3837814	142.039017	117.135643	109.683952
223	7	54.5710831	45.9189453	134.653091	110.562843	103.517723
224	8	44.4658928	37.8378143	108.595314	87.3738098	81.7630615
225	9	43.845562	37.3535194	106.917618	85.8808212	80.3624191
226	10	45.8699379	38.9396019	112.353806	90.7185211	84.9008789
227	11	45.6909943	38.7987556	111.87767	90.2948074	84.5033722
228	12	59.1448326	49.6757545	145.828461	120.507896	112.84761

SWN91A

Figure 42 shows the tables that result with Option 6, that is, total consumption. Remember that these are *substituive* consumptions. In each zone activities may choose between alternative floorspace types. Not all types will be available in every zone. In the example, retail would consume 115.62 m2 of sheds per job, if there is any stock available. However, there are no sheds in zone 1, as shown in the table below. The preceding table also showed that a retail job would consume 42.06 m2 of semidetached floorspace. In this case zone 1 does have semidetached floorspace, so that in all retail jobs consume 829.93 m2. There are also other types of floorspace in zone 1 that retail may consume, in addition to semidetached. Look in the table for all types of floorspace that retail jobs consume.

Figure 42: Total consumption with elastic demand functions

RESULTS OF THE ACTIVITY LOCATION MODEL
Area Policy Date/time simulation
SWN 91A 18- 5-2009 14:30 ITER 200

Sect 21 Sheds

Zon	Indus	Retail
1	0	0
2	0	0
3	24684.6738	26163.8535
4	76039.5078	21243.002
5	0	0
6	157149.594	11131.0703
7	130501.625	9126.91504
8	0	0
9	0	0
10	0	0
11	0	0

Sect 24 SemiD

Zon	Retail	Office	HhHigh	HhMed	HhLow
1	829.935852	226.836426	3923.82446	2810.59351	548.802979
2	1025.23889	737.908997	18970.5234	13224.252	2872.04492
3	16784.8164	6213.97559	20833.9414	16645.5137	7595.74854
4	3038.05762	6580.96875	3059.09644	3676.49414	801.384644
5	16863.3594	3253.94385	23336.8105	24056.0195	16160.8887
6	384.406006	449.247437	536.921326	2115.81592	627.603088
7	2702.43066	6811.87891	7214.5249	5719.43115	4549.74219
8	1027.46191	168.952835	9721.49707	13989.5049	7019.55762
9	1722.54077	403.01062	12052.4141	23291.5801	12833.4277
10	2824.07495	1038.70654	10439.2188	33834.1328	36525.7773
11	1667.14111	268.909424	8223.49316	15177.0078	9704.39648
12	1233.04077	207.307343	1726.33557	3278.31787	2524.97583
13	1884.92151	851.126282	6299.82324	9891.23145	6767.89014
14	912.532593	1043.94885	420.071686	1068.05359	929.387573
15	808.800354	3315.17065	11519.333	2118.79175	4646.88525

4.5 Adjusting transport assignment

There are many things to adjust in the transport model. A few of these are described in this section. One of the first elements to consider is the number of trips per category and modal shares.

The number of trips per category is adjusted in the menu Transport -> Category. The resulting table has already been shown in Figure 35, in terms of the total number of trips by category. In this application there is only one mode: *passengers*, but many submodes or *operators*, as was shown in Figure 37. The number of trips depends on the trip generation parameters as shown in Figure 43 below. The figure shows the menu when opened, and then what you get if you select any of the categories. In the example category *2 Medium income home-work trips* is shown. Parameters are minimum trip generation rate = 1, maximum = 2, elasticity is 0.003. During the calibration stage, these values must be adjusted until the correct number of trips is obtained. Elasticity also has an effect on the mean trip length.

Submodal shares are affected by a number of variables, such as travel times, fares, waiting times, values of time, and so on. Each category-operator combination must be adjusted until the correct share is obtained. Once all variables have been entered, there is a set of penalties to represent non-modelled components. The main set is the operators-categories penalty factors, shown in Figure 44, corresponding to the Transport -> Operators menu. The HOV car was selected, and shows that there is a penalty of 1.7. This compares with the SOV car with a penalty of 1. The HOV car is much cheaper than the SOV car, because the cost is being shared by two or more passengers, and it is just a little bit slower (see Link Types). Consequently, if both SOV and HOV have a penalty of 1, all passengers will choose HOV. In practice, however, most people find that HOV cars are not very convenient because some sort of previous arrangement must be made with the other car-sharers, probably including the return trips as well. Also car-sharers must coincide in destination and times of day. Statistics show that only a small proportion of travellers choose HOV, and the proper share was obtained with the 1.7 penalty factor. Note that you may specify specific combinations between operators and categories selecting the ‘categories’ tab. This possibility was not used in this application.

Figure 43: Trip generation parameters in menu Transport -> Categories

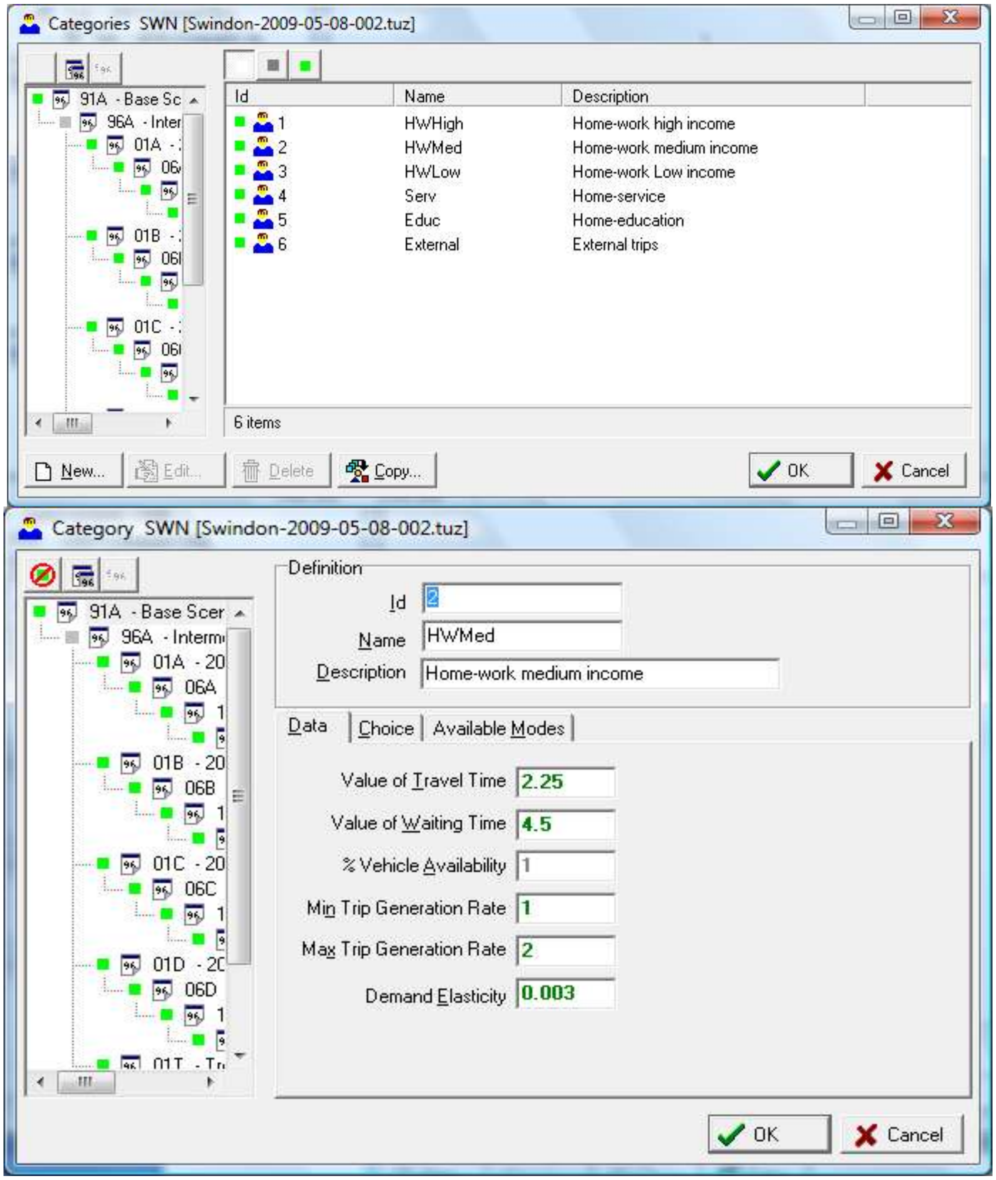
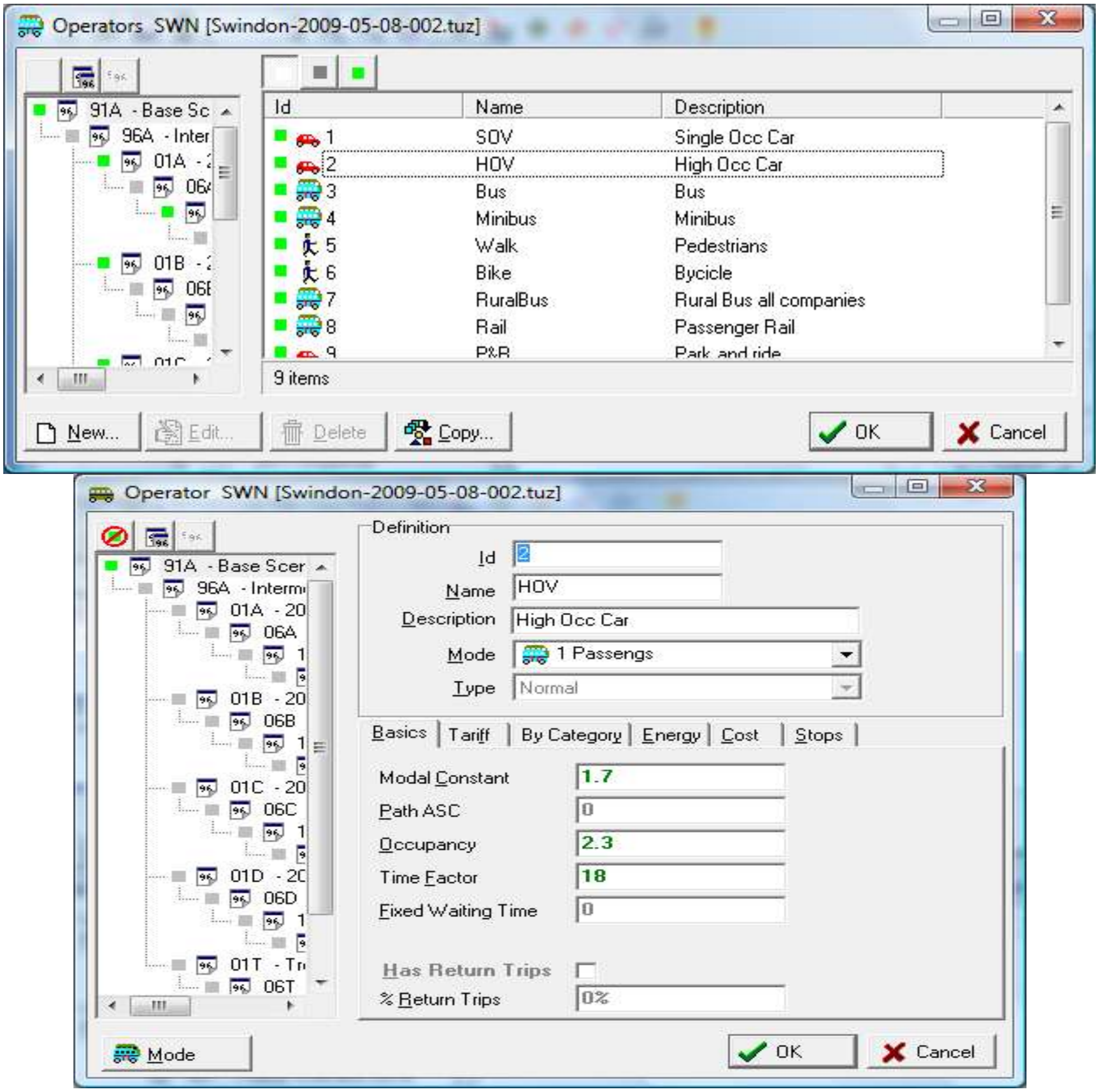


Figure 44: The operators-categories penalties

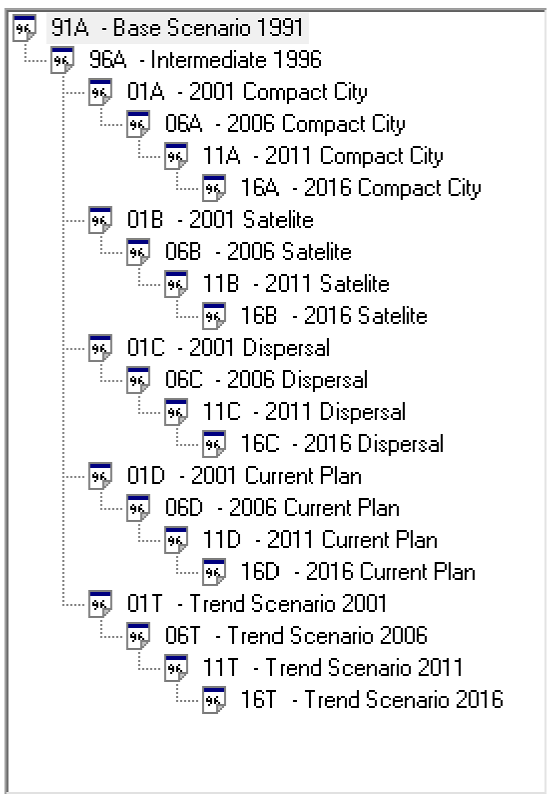


5 The Trend Scenario

This chapter describes the way in which future scenarios are defined, calculated and reported, taking the Trend Scenario as a first example. This scenario goes into the future assuming growth, but maintaining land use and transport policies as they are today, unchanged.

In TRANUS scenarios are defined as a scenario tree, as shown in Figure 45. All scenarios data are stored in the same database, and follow certain 'intelligence'. In this example, the base scenario 91A is followed by an intermediate scenario 96A. This setup was chosen because the study team had data for both periods, so that the dynamics of the model could be tested. The only scenario that 'hangs' from 91A is 96A. Following that there are many branches A, B, C, D and T. In this chapter we concentrate on the latter, called the Trend Scenario, as described. The Trend Scenario branches down as 01T, 06T, 11T and 16T, with a steady five-year interval. Scenarios are defined in the Project -> Options menu. See the *TUS Manual* for a detailed description of how scenarios work.

Figure 45: The scenario tree in the TRANUS database



It is now possible to ‘navigate’ up and down the scenario tree. If there are any changes in the network, they should become visible in the network view. However, the Trend Scenario does not include any changes in the network.

5.1 Defining growth and land-use constraints

Before running future scenarios, they must be defined in the database. As mentioned, the Trend Scenario does not include changes in the transport system, but it does contain some expected changes in land use: growth and land-use constraints.

In this application there are two exogenous sectors: industry and government. In the Trend Scenario growth has been defined for these sectors in terms of a global amount of jobs that will be added. The model will allocate this total amount to all zones based on a simple probabilistic model that you define, as will be shown. It is also possible to assign specific amounts in specific zones, but this has not been done in the Trend Scenario.

The functions that determine the allocation of the global amount to each zone are defined in Land Use -> Intersectors -> Exog Attractors, as shown in Figure 46. Three variables are defined for the growth of Industrial employment: Industrial employment itself, Industrial Land and Business Parks Land, with weights of 0.8, 1 and 0.8. In all cases the values of production are being used, such that it is the production of, say, Industrial Land that is being used as an attractor. In all cases the model will take the *previous year* production. In this example, increments in industrial jobs will be allocated to zones as a function of the number of industrial jobs in the previous scenario and the amount of industrial and Business Park land also in the previous scenario. As will be seen, there are also zonal attractors to consider.

Government jobs were incremented as a simple function of existing government jobs in the previous scenario.

Next, the global amounts and possible zonal attractors are defined in Land Use -> Economic Data, as shown in Figure 47 for Industrial Employment in Scenario 96A. Make sure to select ‘Increments’. As may be seen, the increment in the number of industrial jobs has been set to 3603. In the base scenario 91A all zonal attractors were set to zero. Because in this menu actual increments are specified, the values shown for 96A are the ones that the model will use for the allocation of the increment. For instance, zone 1 has a zonal attractor of 0.8, making it slightly less attractive than zone 7 with a value of 1.4. The units of the attractors are irrelevant; it’s the proportions that matter. See the *Math Manual* for a detailed description of the allocation function.

Go down the pull-down list to check growth for the Government employment sector. In this case the increment in government jobs is 336.

Figure 46: Defining allocation functions for exogenous production

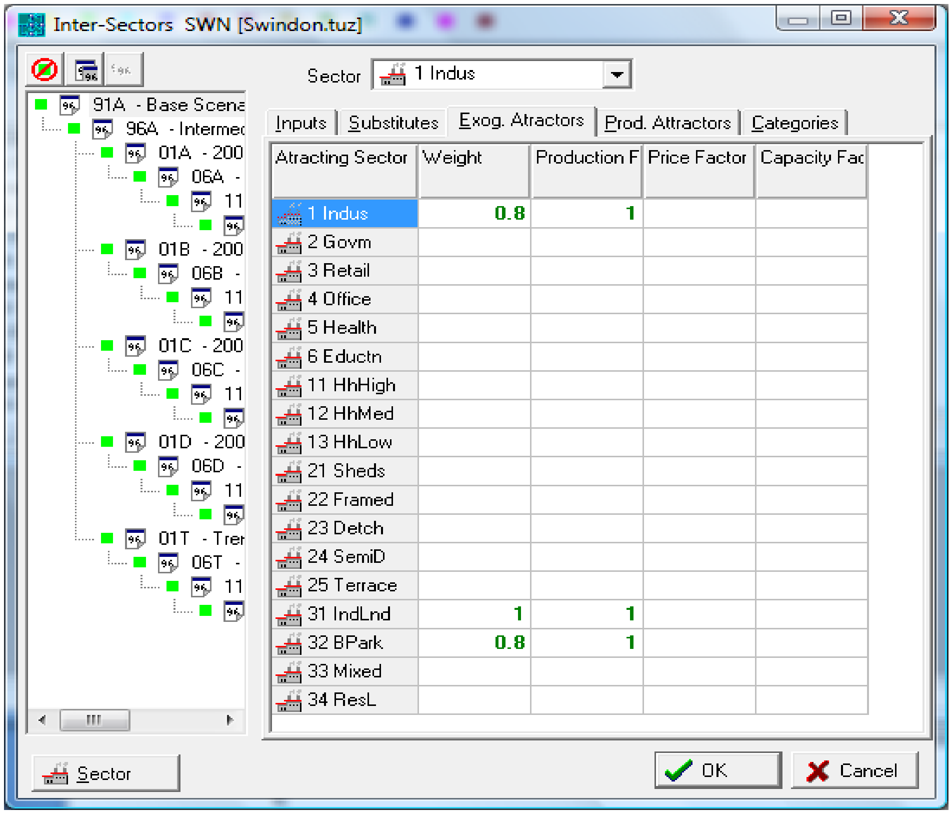
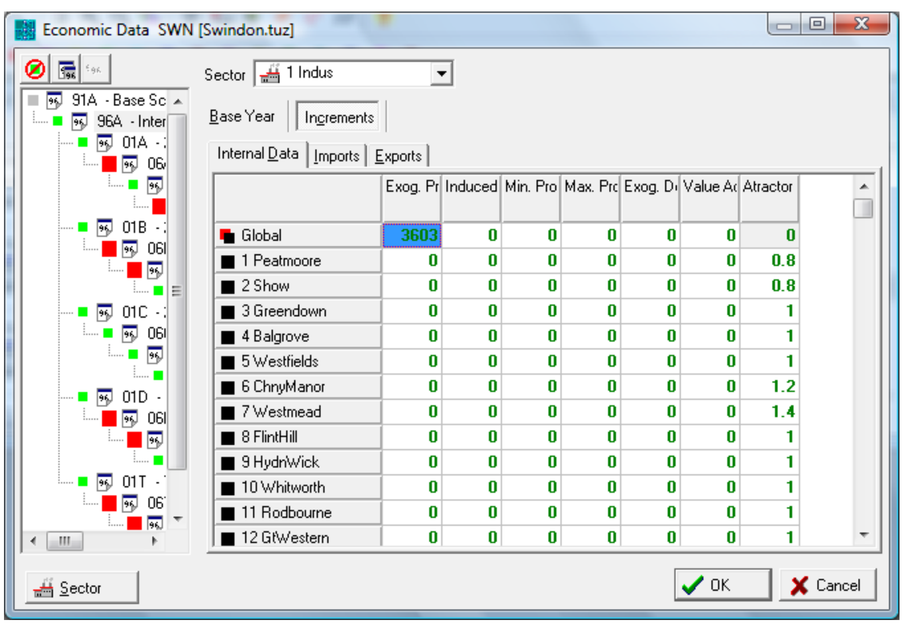


Figure 47: Defining a global increment and zonal attractors for exogenous production



Growth in the exogenous sectors affects all other induced sectors. In 96A there will be more population and more retail jobs and so on. These are determined by the *intersector demand functions* that were described for the base year (see Figure 20). In 1996 and subsequent scenarios, however, intersector demand values were allowed to change. To check this, open the Land Use -> Intersectors -> Inputs menu and navigate around the scenario tree to verify that the values actually change. These changes were introduced to account for some trends that are usually observed in urban areas: mostly that employment will grow faster than population, with annual rates of 1.6 and 1.4 respectively. These are very simplifying assumptions about the future growth in activities.

If activities grow, floorspace and land will also grow, but this may not be possible in all zones. Some zones may have plenty of land available for future development, but others may have run out of available vacant land. In the centre of Swindon there are areas of historical value that cannot be touched. If demand for land grows but there is no real possibility for such growth, then the model assumes that land rents or prices will go up, thus affecting the location of activities.

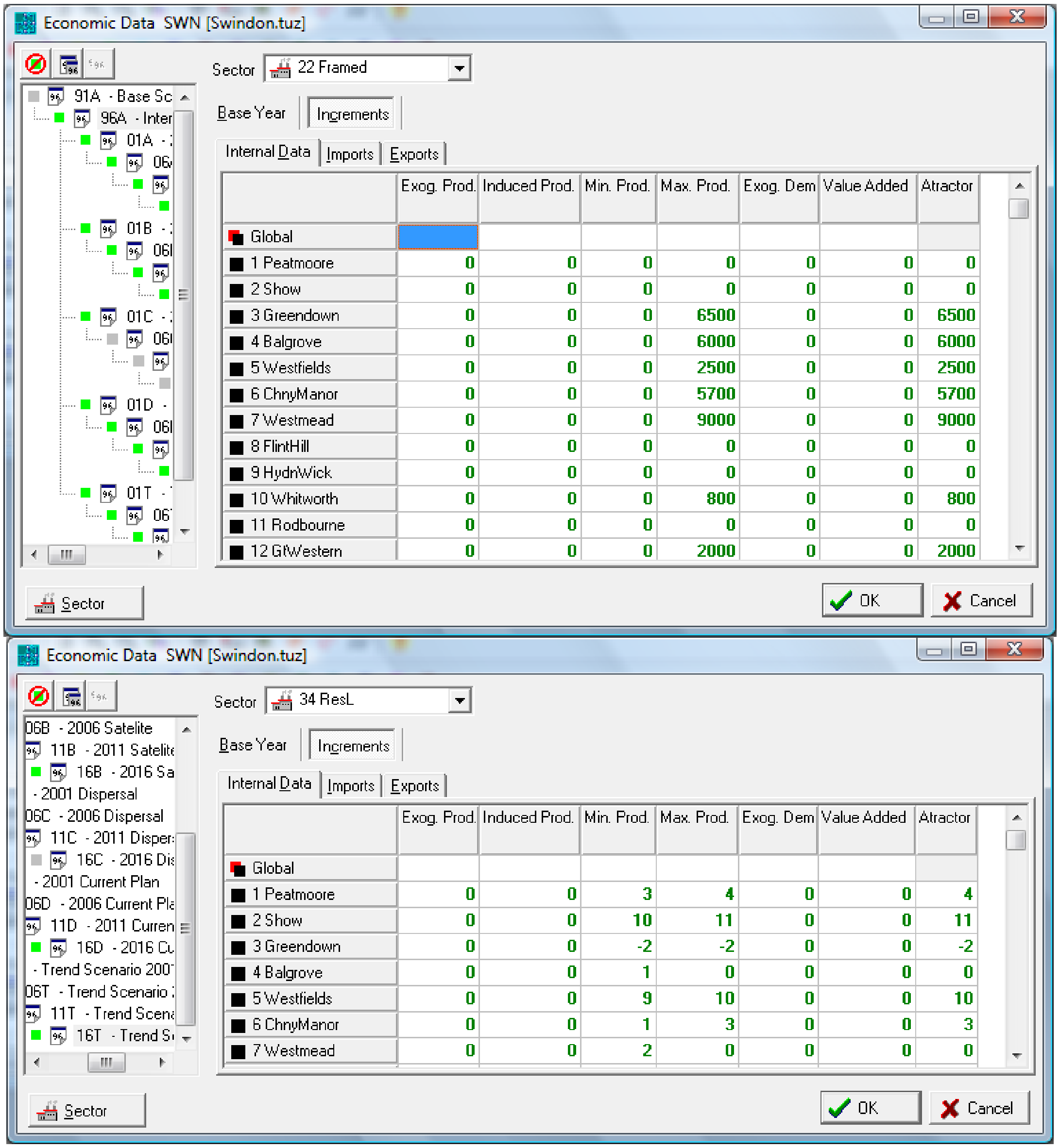
Possible increments are specified in the same Land Use -> Economic Data -> Increments, as shown in Figure 48. Pull down to sector *22 Framed floorspace* and select the 96A scenario. This type of floorspace does not exist in zones 1 and 2, and because the values of *Max. Prod*. are set to zero, they cannot appear in 96A. Framed buildings do exist in zone 3, where there are 64,704 m2 in 91A. Here we are telling the model that this stock of buildings may grow, up to 6,500 m2 more. No minimum value was specified. The increment is also specified for the attractor, since the existing stock was used as an attractor in the base year.

The lower part of the figure shows increments in Residential Land for Scenario 16T. In zone 3 this type of land shows a negative increment in *Max. Prod.* of -2, that is, it was reduced by 2 Hectares with respect to the previous scenario 11T. In this case the *Min Prod* and the *Attractor* were reduced by the same amount. This was done to accommodate other types of land, such as *Mixed Land*. Zone 3 has run out of available land by 2016, so that it cannot grow and prices go up. As a consequence, developers buy residential land (2 Ha in this case), turn it into Mixed land, pull down the houses and raise office buildings (Framed floorspace) in its place. The modeller must make sure that this is only allowed to happen where urban regulations admit it. Note that if 2 Ha are taken away from Residential Land in zone 3, the growth for both the maximum and the minimum must be equal to -2.

When floorspace of a certain type in a specific zone is reduced, we will call it *demolitions*. When land of a certain type in a zone is reduced from, say, residential towards mixed, we call this *redevelopment*.

The spreadsheet *LandUseProjT.xls* holds all data necessary for the calculation of future trend scenarios T, as well as the results.

Figure 48: Specifying increments in the production of floorspace



	Exog. Prod.	Induced Prod.	Min. Prod.	Max. Prod.	Exog. Dem	Value Added	Atractor
Global							
1 Peatmoore	0	0	0	0	0	0	0
2 Show	0	0	0	0	0	0	0
3 Greendown	0	0	0	6500	0	0	6500
4 Balgrove	0	0	0	6000	0	0	6000
5 Westfields	0	0	0	2500	0	0	2500
6 ChnyManor	0	0	0	5700	0	0	5700
7 Westmead	0	0	0	9000	0	0	9000
8 FlintHill	0	0	0	0	0	0	0
9 HydnWick	0	0	0	0	0	0	0
10 Whitworth	0	0	0	800	0	0	800
11 Rodbourne	0	0	0	0	0	0	0
12 GtWestern	0	0	0	2000	0	0	2000

	Exog. Prod.	Induced Prod.	Min. Prod.	Max. Prod.	Exog. Dem	Value Added	Atractor
Global							
1 Peatmoore	0	0	3	4	0	0	4
2 Show	0	0	10	11	0	0	11
3 Greendown	0	0	-2	-2	0	0	-2
4 Balgrove	0	0	1	0	0	0	0
5 Westfields	0	0	9	10	0	0	10
6 ChnyManor	0	0	1	3	0	0	3
7 Westmead	0	0	2	0	0	0	0

5.2 Running the Trend Scenario

Once all data has been put into place, running the Trend Scenario should be quite simple. Use the Project -> Run command, select the scenario, and proceed in the usual way. You may select one scenario at a time or several or all scenarios to run a long batch.

In this example, all data has been set up for all scenarios and adjusted, so that it is safe to run all scenarios in a single batch. When a scenario is being developed, however, it is necessary to run the scenarios one by one. In the case of Scenario 96A, it is possible to run the land use model first. Keep in mind that the land use or location model reads transport costs and disutilities of the previous scenario, that is, from 91A. This means that you may run location 96A without running path search of 96A before. Once location 96A is ready, results must be checked and possibly adjusted. Check prices of land and floorspace and verify in your database if something can be done should prices go up too much in specific zones and land and floorspace types. It may be that the price of, say, residential land in a specific zone has gone up too much and there is more land that may be introduced into the market. Make such adjustments over and over, until you are satisfied that the system is in equilibrium and stable. It is very important that the location model should converge to a considerable extent.

Once location and land use is stable, proceed with path building and assignment. It may be necessary to check the frequency of public transport routes, since demand may have gone beyond the capacity of some services and you may want to increase some frequencies. Once equilibrium has been reached, it is possible to proceed with the next scenario, in this case 01T. Proceed in this fashion until you reach the end of the branch in the scenario tree.

5.3 Getting the results and setting up comparative tables

Land use results

Land use results are obtained in the usual way, as described in the previous chapter. The most interesting tables are generated automatically by the programs in the ***location_indicators_xxx.csv*** files. Results may also be obtained with program IMPTRA, Option 1. The idea is to produce one file per scenario and then compile them together on a workbook to obtain tables and graphs with the evolution of the system. In this demo the workbook ***LandUseProjT.xls*** contains all results and many comparative tables for the Trend Scenario.

Figure 49 shows a section of a table compiled from the land use results, in this case showing sector *1 Agricultural and Industrial employment*, from the base year 1991A to the last period 2016T, including annual growth rates. Note that the workbook contains several sheets called 91A, 96A, 01T, etc., where the results of the automatically generated files ***location_indicators_xxx.csv*** have been copied. For instance, in zone 7 there are 3,576 jobs in 1991, growing up to 5,019 in 2016T.

Many things can be done with these results, depending on the main interest of the study. Figure 50 shows a set of tables showing total consumption of floorspace and land by type and consuming sector in 1991. Similar tables were compiled for all other periods of the Trend Scenario. In this example, sector 1 Industry consumes 1,192,859 m2 of shed-type floorspace, and in turn sheds consume 474 Ha of Industrial Land.

A number of tables, graphs and maps are presented next, all produced with the outputs of the Trend Scenario. Energy use was of particular interest in the study for which this model was built. Floorspace areas by type were multiplied by energy parameters to obtain fuel consumption and, consequently, fuel costs. The maps were produced with MapInfo reading model results readily from the Excel sheets.

Figure 49: Table compiled from the land use model results

Agr+Industry

Zone	1991A	1996A	%	2001T	%	2006T	%	2011T	%	2016T	%
1	11	12	1.8%	13	1.6%	15	2.9%	18	3.7%	22	4.1%
2	98	104	1.2%	115	2.0%	133	3.0%	163	4.2%	200	4.2%
3	1133	1227	1.6%	1366	2.2%	1591	3.1%	1691	1.2%	1691	0.0%
4	2022	2189	1.6%	2436	2.2%	2677	1.9%	2677	0.0%	2677	0.0%
5	549	593	1.6%	659	2.1%	765	3.0%	920	3.8%	1109	3.8%
6	3036	3338	1.9%	3794	2.6%	4296	2.5%	4654	1.6%	4851	0.8%
7	3576	3987	2.2%	4616	3.0%	4918	1.3%	5019	0.4%	5019	0.0%
8	204	220	1.5%	245	2.2%	257	1.0%	262	0.4%	262	0.0%
9	15	16	1.3%	18	2.4%	21	3.1%	23	1.8%	24	0.9%
10	515	556	1.5%	593	1.3%	612	0.6%	612	0.0%	612	0.0%
11	108	117	1.6%	130	2.1%	150	2.9%	166	2.0%	172	0.7%
12	296	320	1.6%	357	2.2%	416	3.1%	502	3.8%	608	3.9%
13	171	188	1.9%	213	2.5%	254	3.6%	316	4.5%	396	4.6%
14	963	1041	1.6%	1158	2.2%	1347	3.1%	1486	2.0%	1517	0.4%
15	141	153	1.6%	163	1.3%	168	0.6%	168	0.0%	168	0.0%
16	16	17	1.2%	19	2.2%	22	3.0%	27	4.2%	32	3.5%
17	42	45	1.4%	50	2.1%	59	3.4%	64	1.6%	67	0.9%

Tables | 91A | 96A | 01T | 06T | 11T | 16T | MapsT

Figure 50: Total consumption of floorspace and land

1991

Total consumption of floorspace by sector

	Sheds	Framed	Detached	SemiDet	Terraced	Total
Industry	1192859	535555			754921	**2483335**
Government		151966				**151966**
Retail	210796	296437		199377	424896	**1131506**
Office		221307		130316	377147	**728771**
HhdsHigh			888288	571508	688803	**2148599**
HhdsMed			783949	738543	1000692	**2523184**
HhdsLow			324563	546839	927002	**1798403**
TOTAL	**1403655**	**1205266**	**1996799**	**2186583**	**4173461**	**10965763**

Total consumption of Land by floorspace type

	IndLand	Bparks	Mixed	ResidnLanc	Total
Sheds	474	59			**534**
Framed	109	36	103		**248**
Detached				1486	**1486**
SemiDet				1018	**1018**
Terraced			87	1053	**1140**
TOTAL	**583**	**95**	**190**	**3557**	**4425**

Tables | 91A | 96A | 01T | 06T | 11T | 16T

Total consumption of floorspace with anual growth rates

	1991	1996	%	2001	%	2006	%	2011	%	2016	%
Sheds	1403655	1494196	1.3%	1602142	1.4%	1735872	1.6%	1907768	1.9%	2079356	1.7%
Framed	1205266	1307582	1.6%	1432856	1.8%	1589262	2.1%	1791768	2.4%	1998731	2.2%
Detached	1996799	2050287	0.5%	2158010	1.0%	2273559	1.0%	2432252	1.4%	2612690	1.4%
SemiDet	2186583	2300434	1.0%	2413824	1.0%	2531566	1.0%	2651778	0.9%	2772455	0.9%
Terraced	4173461	4402066	1.1%	4555783	0.7%	4766583	0.9%	4987840	0.9%	5266182	1.1%
TOTAL	**10965763**	**11554565**	**1.1%**	**12162614**	**1.0%**	**12896842**	**1.2%**	**13771406**	**1.3%**	**14729413**	**1.4%**

Total consumption of land with annual growth rates

	1991	1996	%	2001	%	2006	%	2011	%	2016	%
IndLand	583	614	1.0%	645	1.0%	688	1.3%	744	1.6%	800	1.5%
Bparks	95	109	2.7%	129	3.6%	153	3.5%	182	3.5%	209	2.8%
Mixed	190	206	1.6%	225	1.8%	250	2.1%	284	2.6%	324	2.7%
ResidnLand	3557	3684	0.7%	3836	0.8%	4012	0.9%	4221	1.0%	4454	1.1%
TOTAL	**4425**	**4612**	**0.8%**	**4836**	**1.0%**	**5103**	**1.1%**	**5431**	**1.3%**	**5787**	**1.3%**

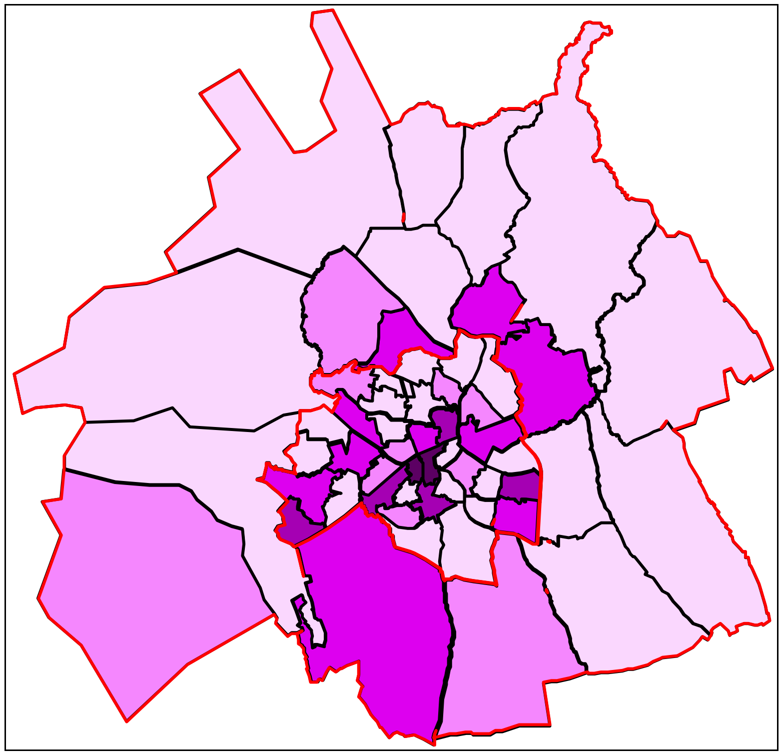
Energy consumption (Millions of KWh/year)

2016	**Sheds**	**Framed**	**Detached**	**SemiDet**	**Terraced**	**Total**
Industry	386.1	229.9	0.0	0.0	217.7	**833.8**
Government	0.0	38.0	0.0	0.0	0.0	**38.0**
Retail	164.8	148.7	0.0	94.3	199.0	**606.7**
Office	0.0	63.1	0.0	29.2	69.2	**161.5**
HhdsHigh	0.0	0.0	627.6	391.3	453.3	**1472.2**
HhdsMed	0.0	0.0	253.8	234.9	317.4	**806.1**
HhdsLow	0.0	0.0	135.1	139.2	187.2	**461.5**
TOTAL	**550.9**	**479.7**	**1016.5**	**888.8**	**1443.9**	**4379.7**

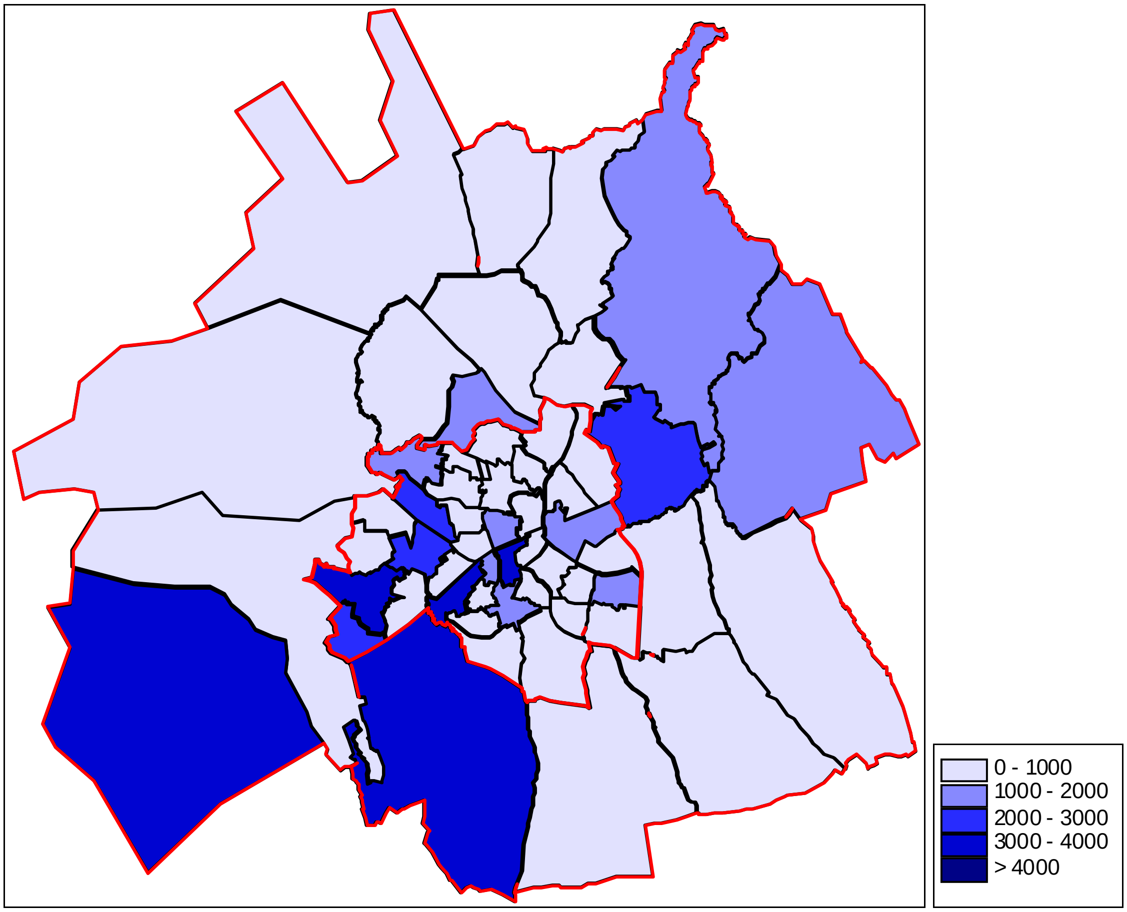
Fuel costs by activity type (millions of £/yr)

Activity	**1996**	**2001**	**2006**	**2011**	**2016**	**Total**
Industry	20.5	21.0	21.6	22.1	22.7	**539.5**
Government	1.4	1.4	1.4	1.4	1.4	**35.4**
Retail	28.8	29.5	30.6	32.1	33.4	**772.5**
Office	5.6	5.6	5.6	5.7	5.7	**141.1**
HhdsHigh	30.6	30.8	31.2	31.7	32.4	**783.4**
HhdsMed	26.2	25.4	24.6	23.8	23.0	**614.8**
HhdsLow	15.6	15.5	15.4	15.4	15.4	**386.6**
TOTAL	**128.7**	**129.1**	**130.4**	**132.3**	**134.1**	**3273.2**

Employment density 2016-T



Employment growth 1991-2016 Trend Scenario



Transport results

In a similar way, tables, graphs and maps may be produced from the results of the model. Use program IMPTRA to generate tables of indicators for each period of the Trend Scenario, or much easier, use the automatically generated file ***transport_indicators_xxx.csv***. All such reports are easy to read with a spreadsheet and turned into comparative tables and graphs. In the case of maps, however, the situation is different in transport compared to land use. This is because standard GIS software, like MapInfo or ArcGIS are easy and flexible to use to produce thematic maps based on polygons, but they are not very good at networks. TransCAD provides many facilities to map transport results, but even then there are limitations and the interchange of information with any transport model, including TRANUS is, to say the least, cumbersome. At the heart of this 'misunderstanding' between transport models and GIS is the fact that networks in transport models are directional, that is, they go from an origin node to a destination node, or maybe both ways. In GIS networks are represented as polylines that have no directionality. Directionality may only be an attribute of an otherwise non-directional geographical object.

For this reason, TRANUS is provided with ample transport-related capabilities in terms of mapping. The interface reads the results of the simulations and represents them in geographical terms, combined with digital background maps with geographical coordinates, and a wide range of options.

Figure 51 shows the kind of tables that may be built. The example shows total daily trips by transport categories and time period for the Trend Scenario, including annual growth rates. Note that growth rates in the number of trips are smaller than the growth in activities. This is due to elasticities in trip generation, because transport demand grows without an equivalent growth in network capacities, thus leading to increased congestion. Note that the workbook contains a sheet for each period, so that many tables may be compiled from them. What follows is a number of tables, graphs and maps that came out of the simulations.

Note that the fuel consumption graph is strongly dominated by HOVs and SOVs, while public transport hardly shows. The table Distribution of vehicle-km by speed class is fundamental to the calculation of greenhouse emissions. Maps are produced directly by the TRANUS interface. The TUS Manual describes the numerous options to adjust, scale and color maps.

Figure 51: Transport-related tables comparing several time-periods of the Trend Scenario

Total daily trips by transport category (linked)

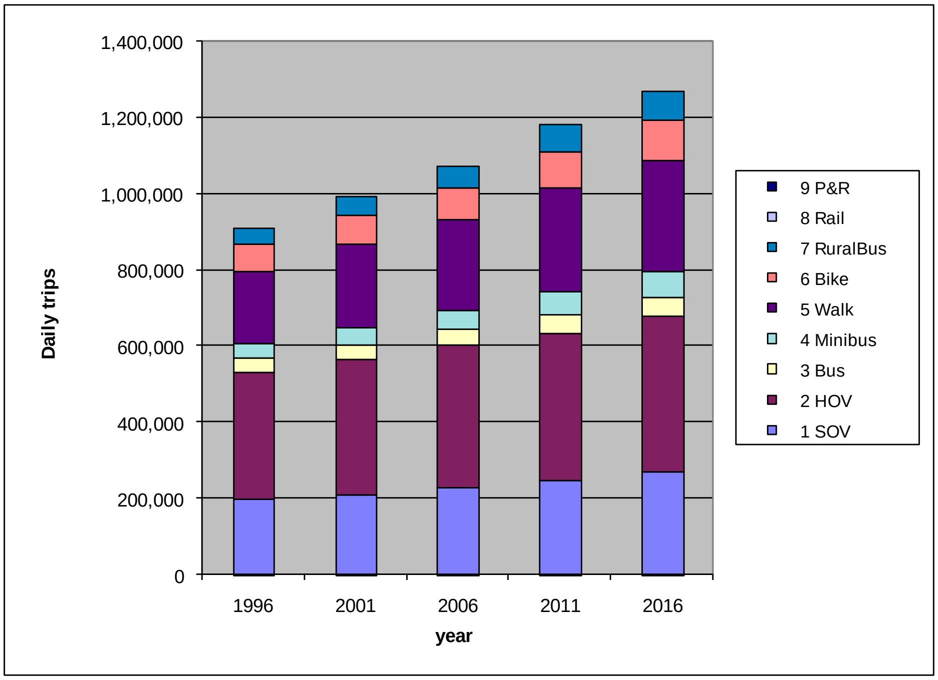
Category	1991A	1996A	%	2001T	%	2006T	%	2011T	%	2016T	%
WorkHhds	84314	90392	1.4%	96935	1.4%	103948	1.4%	111478	1.4%	119553	1.4%
WorkHhds	114048	122263	1.4%	131082	1.4%	140523	1.4%	150649	1.4%	161505	1.4%
WorkHhds	85691	91865	1.4%	98486	1.4%	105580	1.4%	113180	1.4%	121323	1.4%
Service	100662	108977	1.6%	117985	1.6%	127739	1.6%	138305	1.6%	149745	1.6%
Education	95283	103161	1.6%	111693	1.6%	120924	1.6%	130935	1.6%	141786	1.6%
External	172315	184722	1.4%	197990	1.4%	212292	1.4%	227456	1.4%	244687	1.5%
TOTAL	652313	701380	1.5%	754171	1.5%	811005	1.5%	872003	1.5%	938600	1.5%

Tables | 91A | 96A | 01T | 06T | 11T | 16T | Energy | Sheet9

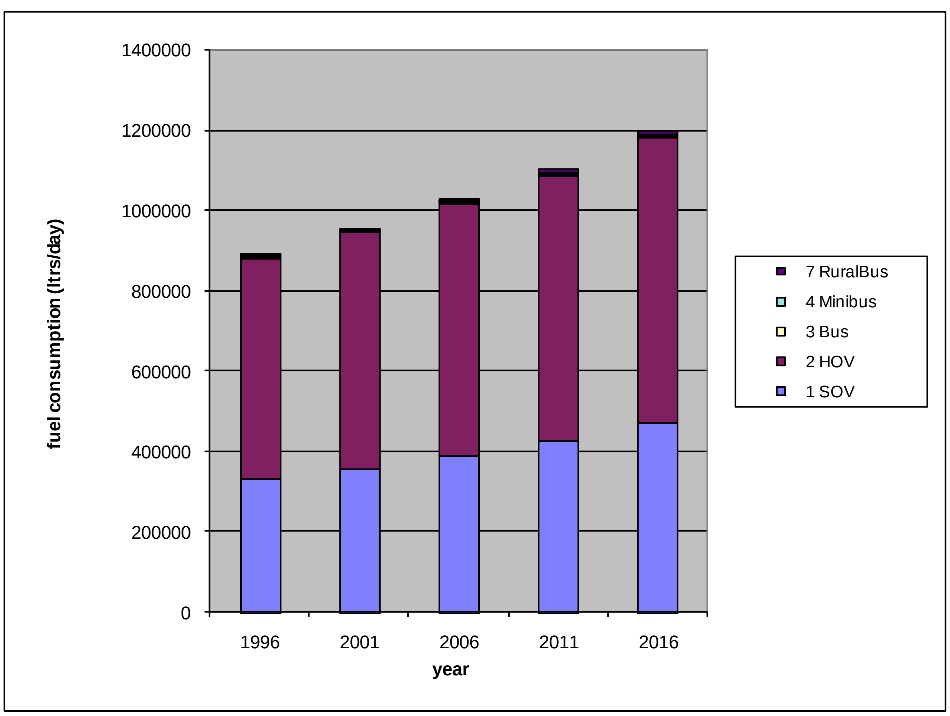
Average travel time (minutes)

Category	1991A	1996[a]	2001T	2006T	2011T	2016T
WorkHhdsHi	15.0	15.6	16.2	16.8	18.0	18.6
WorkHhdsMed	16.2	16.8	17.4	18.0	18.6	19.8
WorkHhdsLo	18.6	19.2	19.8	21.0	21.6	22.8
Service	16.8	17.4	18.0	18.6	19.2	20.4
Education	18.6	18.6	19.8	20.4	21.0	21.6
External	28.8	29.4	29.4	30.0	30.6	30.6
Average	17.23	17.71	18.43	19.14	19.74	20.82

Daily trips by operator for the Trend Scenario



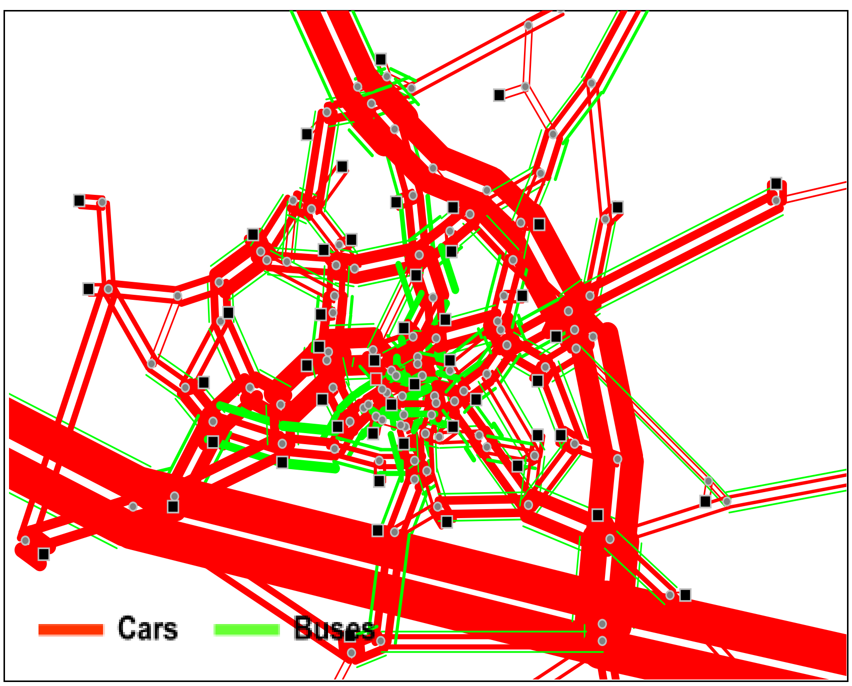
Fuel consumption by transport operator



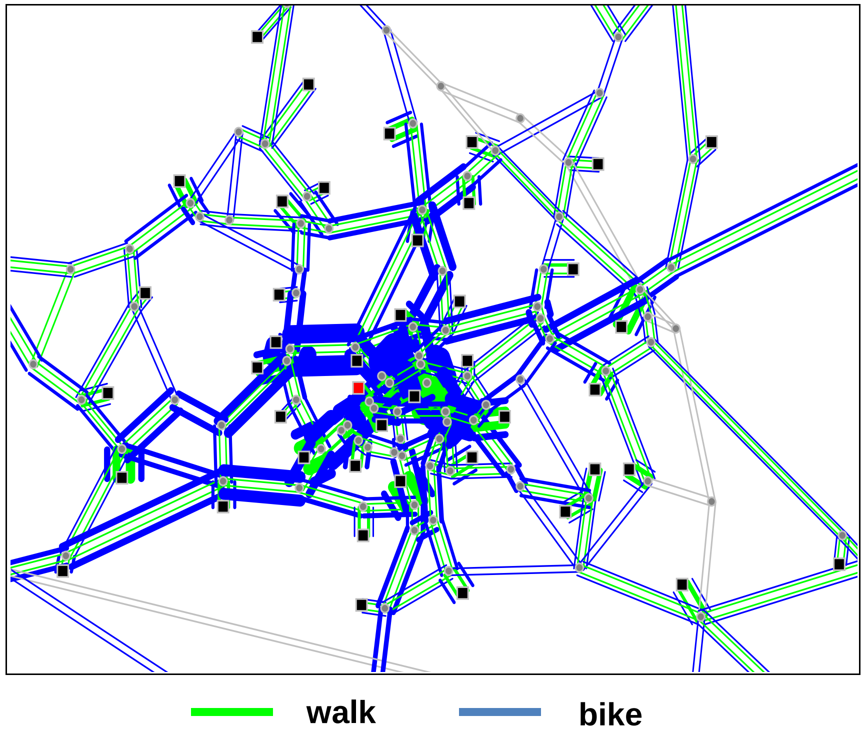
Distribution of vehicle-km by speed class – Trend Scenario

SpeedClass	1991	1996[a]	2001T	2006T	2011T	2016T
0-5	4695	6228	9728	11662	13952	20258
5-10	35350	38209	44563	48582	54885	65903
10-15	41271	48770	52133	86083	105235	126711
15-20	52017	70201	98140	77735	96536	121404
20-25	94482	88152	87449	139254	129836	129822
25-30	107612	143836	170247	150176	148553	124874
30-35	117343	91029	70212	85256	110435	259364
35-40	133533	224136	257323	268337	290577	327496
40-45	692807	663731	686491	741461	810428	748195
45-50	185690	213812	248692	279369	285227	338846
50-55	27700	33122	19224	54312	64543	143120
55-60	53412	46441	101949	125031	100741	210109
60-65	486920	558010	569331	576974	720295	618049
65-70	395130	392297	433144	499784	467342	530728
70-75	65129	135899	189892	204450	178420	223077
75-80	417595	378830	315070	265604	284842	205520
80-85	309066	334462	354642	382428	413418	449867
85-90	1961945	2107091	2254846	2420408	2579593	2787329
Total	5181697	5574256	5963076	6416906	6854858	7430672

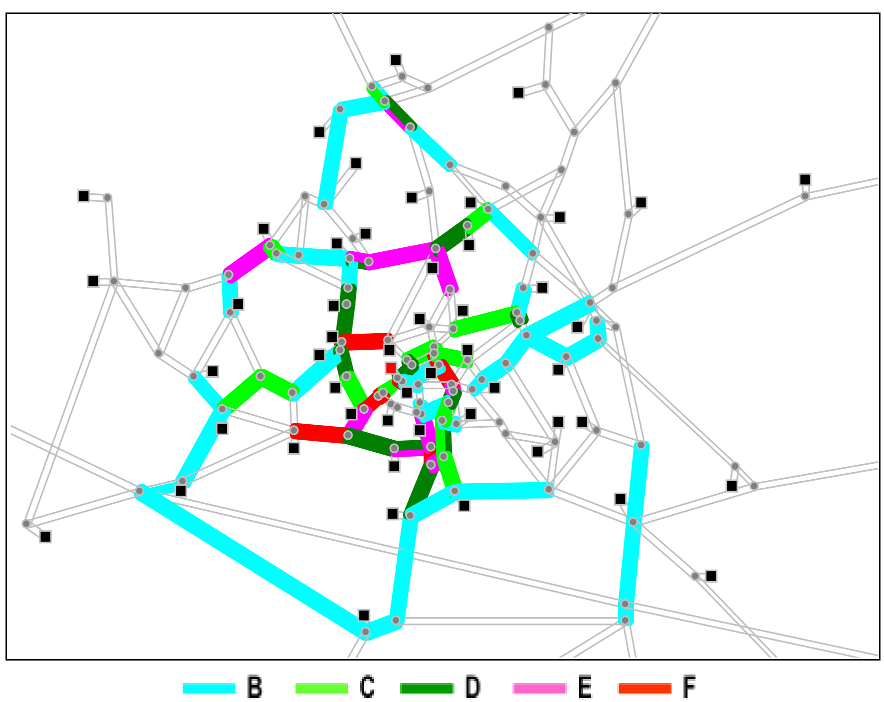
Assigned trips by mode



Assigned trips by mode



Levels of service – Trend Scenario 2016



6 Alternative Scenarios

The Trend Scenario described in the previous chapter serves as a basis to compare alternative scenarios. This is because the Trend Scenario acts as a do-nothing case, or at least as little as possible. In this chapter a number of alternative scenarios are modelled and the results compared to the Trend.

6.1 Description of the alternative scenarios

Four scenarios were developed in detail and modeled, based on the same projections of total growth in households and employment envisaged in the Wiltshire Structure Plan of 1996, and used in the Trend Scenario. Each scenario starts in 1991 and was modeled through five -year intervals, to a horizon of 2016. The model was calibrated to data for 1991 and 1996. Population grows over the period by 32%, from 171,000 to 225,000, and jobs by 19%, from 93,800 to 116,700. Average household size is projected to decrease, from 2.6 persons in 1991 to 2.3 persons in 2016. The study area extends somewhat beyond the Borough of Thamesdown boundaries, to take in some commuter villages in N. Wiltshire and S. Oxfordshire.

The four scenarios may be described as follows:

A: Containment and increased density. This is a *'compact city'* type of scenario in which all new land development is contained, at increased densities, within the existing urban area of Swindon; and development is prohibited on greenfield sites in existing villages or elsewhere in the rural hinterland. These land use policies are combined with a ban on car access to the centre of town, the creation of segregated busways along the main radial roads, and the provision of park-and-ride facilities where these main roads enter the town. A network of cycleways is also introduced.

B: High density dispersal. This is in one sense the inverse of Scenario A. Development of new land is now forbidden in the existing urban area, and is directed instead into a series of existing satellite villages around Swindon. The two scenarios are similar however in that this new development is to be at high densities, and to incorporate industry and services as well as housing, so that the satellites can be more self-sufficient. Use of public transport, cycling and walking is still encouraged. Restrictions are placed on the development of new land elsewhere in the rural hinterland. The accompanying transport policies are similar to scenario A, with a central area car ban, segregated radial bus-lanes and the park-and-ride scheme. They differ in that busways and enhanced bus services are also provided on orbital routes linking the satellites to each other; and some new commuter stations are built on existing railway lines.

C: Limited peripheral expansion. This scenario follows the policies being pursued by the Swindon Borough Council at the time the study was carried out. The greater part of the growth is accommodated within a limited *'town expansion'* area on the north-east edge of the town, where residential development is combined with some industry and services. The scenario has affinities with A, in that the supply of new land is restricted to Swindon itself - albeit extending the edge of the town. A large former industrial site in the town centre is also redeveloped with mixed uses. The expansion area is served by a new orbital road with segregated bus-lanes. A bus-based park-and-ride scheme, priority bus routes, and one new commuter railway station are introduced. The scenario, as modeled, also incorporated the central area car ban as in the other scenarios. The Borough did not envisage this, only restriction of central area car parking.

T: Trend. This is the scenario described in the previous chapter. It was introduced simply for purposes of comparison. The Trend Scenario embodies no explicit land use or transport policies, but simply lets new development go where it wishes. Public transport provision follows demand, and no improvements are made in transport infrastructure.

Specifying land use constraints

Scenarios A, B and C involve strict constraints to future land use and expansion, while T assumes that developers are going to introduce new floorspace and land more or less freely. These policies are represented in the model as values in minimum and maximum constraints in menu Land Use -> Economic Data -> Increments.

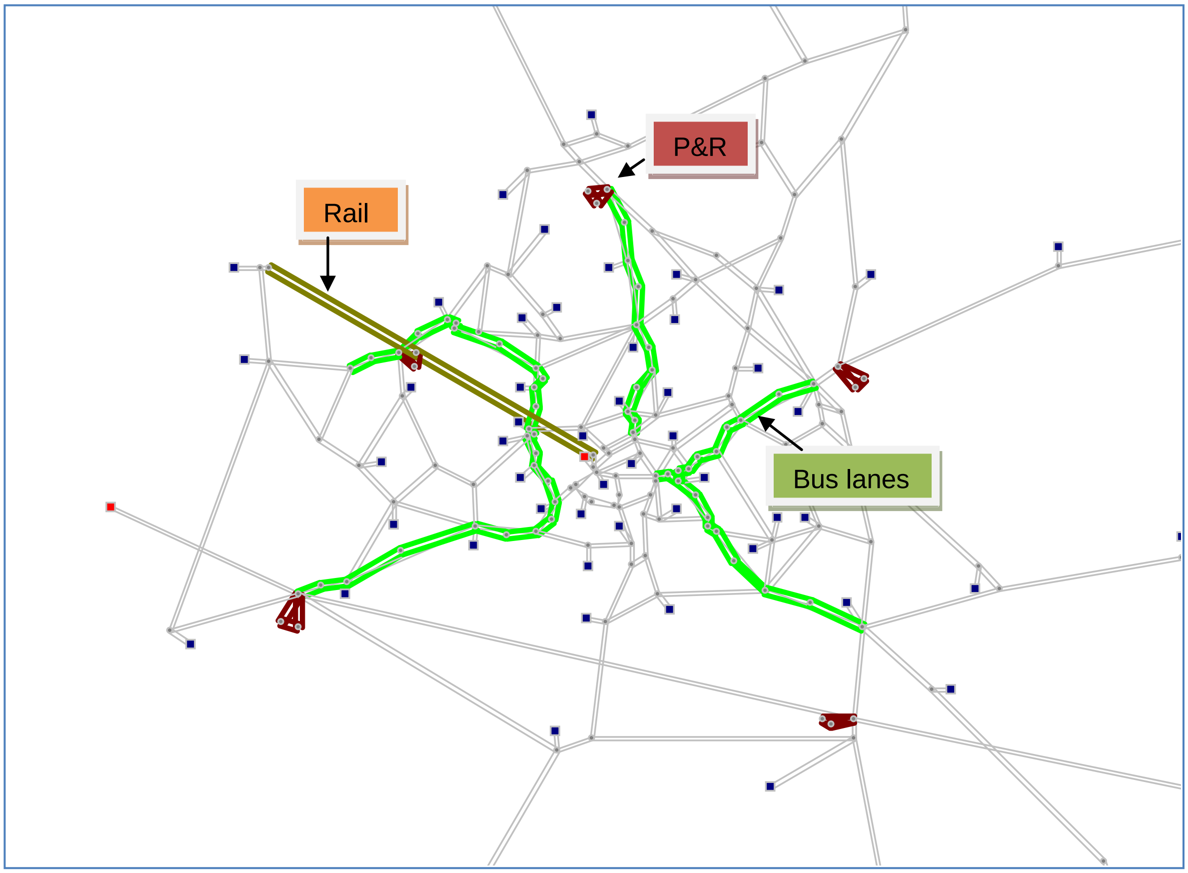
Specifying park-and-ride facilities

As mentioned, the Trend Scenario does not include specific transport projects or policies. Alternative scenarios do have many and of various kinds. Here is a description of how they are introduced to the model. All alternative scenarios have park-and-ride facilities in the periphery where car users may park and then transfer to bus or rail.

To visualize the P&R facilities, chose any of the alternative scenarios in the Link Type network view. Assign colors to link type *20 Railway*, *22 P&R* and *27 Bus Link*. You should get a view like the one shown in Figure 52. *P&R* are represented as little triangles, linked or close to rail and bus links. In this way cars drive into one side of the triangle, transfer to park and ride on another side and come out with a transfer to bus or rail.

The P&R fares are integrated, as was described before. Check the menu Transport -> Transfers to verify that cars are allowed to transfer to the P&R operator, and that from there travelers may transfer to bus or rail. Next look in the menu Transport -> Link Types and select link type *22 P&R*. In the Operator Data tab the following operators have speeds of 5 Km/hr: HOV, SOV, Bike and P&R. This means that travelers may drive into the P&R facility in any of the two car modes or bike and park there.

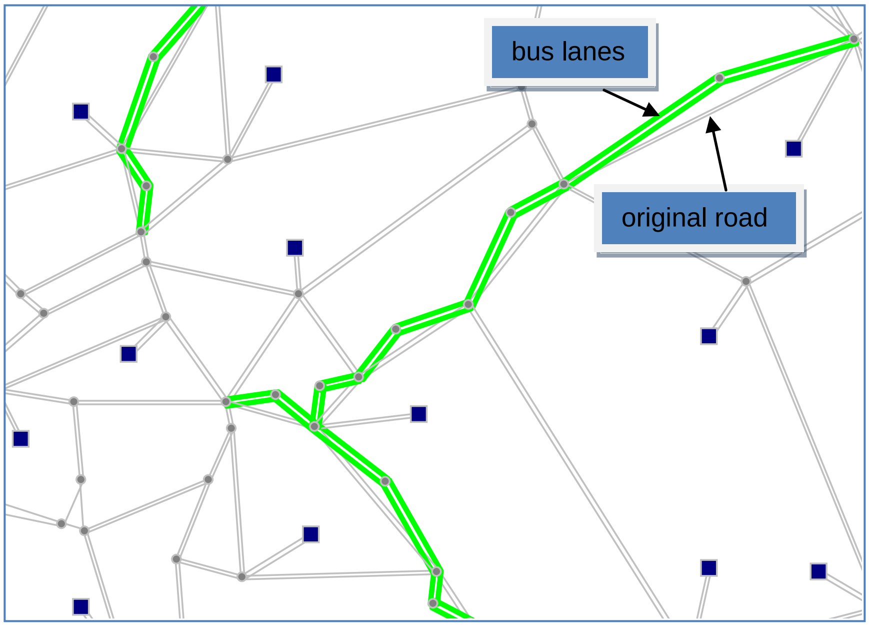
Figure 52: P&R, bus lanes and rail in alternative scenarios



Specifying bus-only lanes

Three bus-only corridors were defined, as shown in Figure 52 above. These were coded as zigzagging links parallel to the roads themselves. A detail is shown in Figure 53. In the network view double-click on any of the bus-only links. You will see that the link type is 27 Bus Link. Click on the Link Type button to display the data related to this link type. In Operator Data you will see that speeds are assigned to all types of buses, but not for HOV and SOV cars. In other words, this type of link may only be used by buses. Bus lanes were given a capacity of 1000. Now click on any of the roads to which the bus lanes are related. It will be seen that such roads have a reduced capacity compared to what they had in the base scenario. This means that the new bus lane was built by extracting capacity from the road.

Figure 53: Coding bus-only lanes



Specifying a new rail line

The idea of this project is to make use of an existing intercity railway and introduce a suburban commuter service. This is simply coded as a straight line connecting the periphery with the city center. This is also seen in Figure 52. In this case not only the link was defined but also a route that runs along the link called *601 GlostRail*. Check the corresponding route and operator data in the routes and operators menus.

Specifying car-ban in the town center

Complementary to P&R, rail and bus-only lanes, cars were banned from the town center. The best way to see how this was coded is as follows. In the Link Type network view assign a color to link types 3 and 4, and another color to link types 9 and 10. Then select the Scenarios tab and navigate back and forth from scenario 96A to 01A. In this way you will see that streets in the town center change colors. Then check the characteristics of these link types and verify that cars may use types 3 and 4, but not 9 or 10.

6.2 Running the scenarios

Running the scenarios is a relatively straightforward matter from an operative point of view. However, there are a number of adjustments that must be made as the simulation process proceeds into the future. The main adjustments are:

- Floorspace and land must be adjusted, increasing supply where necessary and possible, to reflect land availability and the land use policy being simulated.

- Public transport frequencies must be adjusted to accommodate growth in demand, or as new transport systems are introduced in some scenarios, frequencies must be adjusted to adapt each new component.

Unfortunately there is no 'automatic' way of doing these adjustments, although the software does provide a number of facilities. These adjustments have already been made in the database provided.

Running the programs

Actually running the programs is done the same way as described in the previous chapter. Simply use the Project -> Run menu and use the default settings. With the run menu you may run all scenarios and time periods in a single action. In fact this is possible with the provided database, because everything has already been adjusted. When running a scenario for the first time, however, it is necessary to proceed one period at a time. Furthermore, it is necessary to run land use first, make the land use and floorspace adjustments over and over until satisfied, and then proceed with the transport runs and adjustments.

Adjusting land and floorspace

Adjusting land and floorspace is made as described in the previous chapter for the Trend scenario. The procedure is as follows:

- Run a time-period of a scenario without increments in the supply of land or floorspace.
- Analyse the results in ***location_indicators_xxx.csv***, verifying possible increments in prices. If the price of a particular type of land or floorspace increases with respect to the previous period, increase supply if possible.
- If an increment in the supply is not possible, consider transforming one type of floorspace and land for another, such as changing low-density residential land for high-density residential land or industrial for business parks.
- Re-run the model and check the results. Repeat until prices grow at reasonable rates.

It is recommended that you set up a spreadsheet to keep control over the process.

Adjusting public transport frequencies

For each time-period public transport frequencies must be adjusted. The procedure is quite simple. Run transport assignment without any increments in frequencies with respect to the previous period. Inspect file ***route_profile_xxx.csv*** to get the list of routes and check the *critical volume* and *volume/capacity* indicators for each route. If a route has gone beyond capacity, the maximum frequency may be increased. Note that a *maximum fleet* parameter may be activated to avoid unreasonable growth, usually as a result of increased congestion, but this feature has not been used in this modelling exercise.

6.3 Producing comparative tables, graphs and maps

At this point we are interested in producing a set of tables that compare the results of the same variable for different scenarios. The procedure to produce tables of results and indicators for a single scenario, the Trend Scenario, was described in the previous chapter. The same must be applied to each one of the four scenarios that were developed. In the case of land use results, files ***location_indicators_xxx.csv*** are used to produce tables for each scenario/period. The resulting tables are pasted into spreadsheets where they can be compiled into comparative tables. A GIS is then used to produce maps with the results. Similarly, files ***transport_indicators_xxx.csv*** are used produce a set of transport-related indicators tables, and the TRANUS interface is used to produce transport-related maps. What follows is a set of tables, graphs and maps that were produced to analyse the results. Tables and graphs are at an aggregate level for obvious reasons.

The totals of employment and population are the same for all scenarios, but the location varies depending on the land use policy. From the results of the model and using a GIS, a number of maps were produced, as may be seen in the following pages. Even if the totals of population and employment are the same for all scenarios, total consumption of floorspace and land show variations as a result of the land use policies.

Table 3 compiles the total consumption of floorspace by scenario and period in m2. Because consuming activities grow, floorspace also grows, but as the amount of available land varies for each scenario, the amounts consumed also vary. The table shows that the Containment Scenario is the one that grows the least, as expected, and the Trend Scenario grows the most. The differences are, however, not very big. Between A and T is 811 thousand, in the order of 5% of the total stock. Figure 54 shows these results in graph form (Note that the graph is cheating because the y axle begins at 10,000. This was done to emphasize the differences.).

Table 3: Consumption of Floorspace by Scenario (Thousands of m2)

Scenario	1996	2001	2006	2011	2016	16-96
A Containment	11555	12114	12702	13247	13918	2364
B Hinterland	11555	12180	12933	13744	14569	3014
D Peripheral	11555	12149	12798	13508	14220	2666
T Trend	11555	12163	12897	13771	14729	3175

Figure 54: Consumption of Floorspace by Scenario

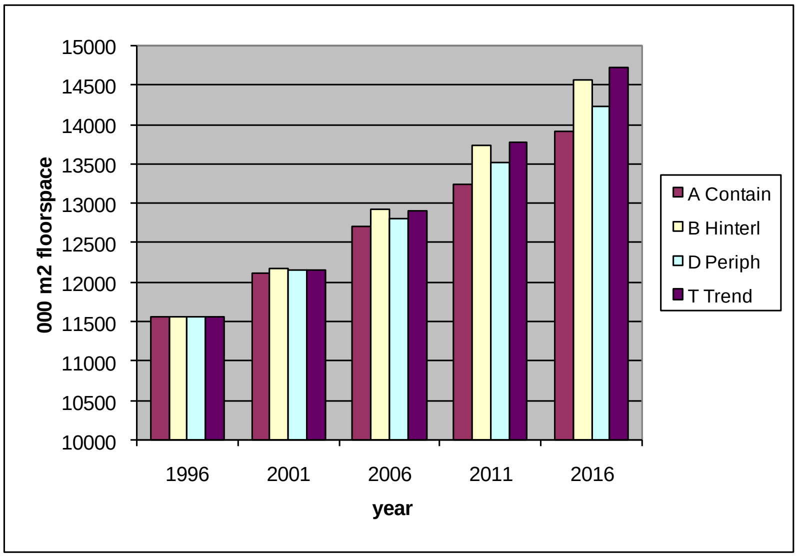
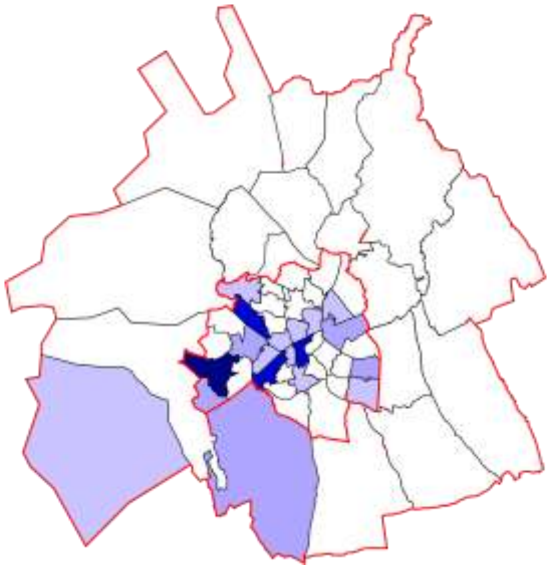
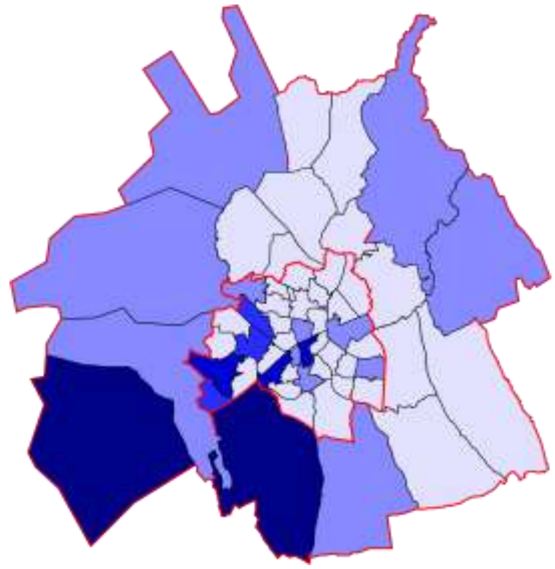


Figure 55 shows a set of four maps, one for each scenario, depicting the difference in total employment for each zone, for the period 1991-2016. As expected, the Containment Scenario concentrates employment growth in the central area of Swindon, as opposed to Trend and Hinterland where growth spreads out. The rest of the maps show consistent results.

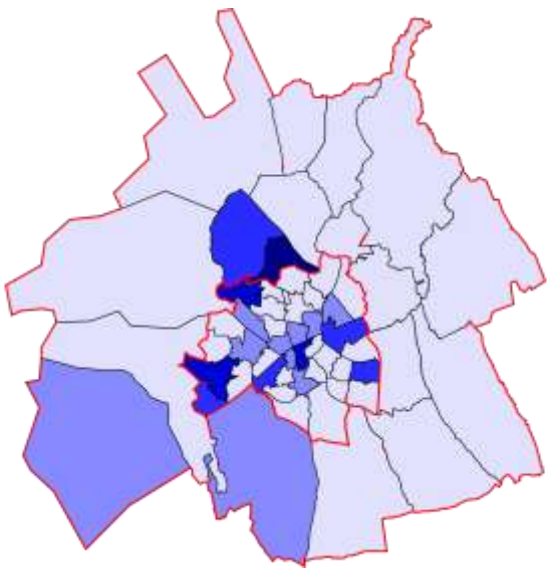
Figure 55: Employment Growth – 1991-2016



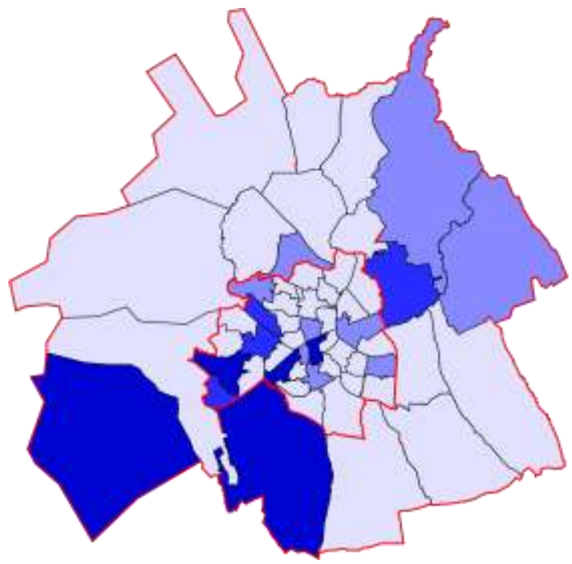
Containment



Hinterland



Peripheral



Trend

Figure 56: Population Growth 1991- 2016

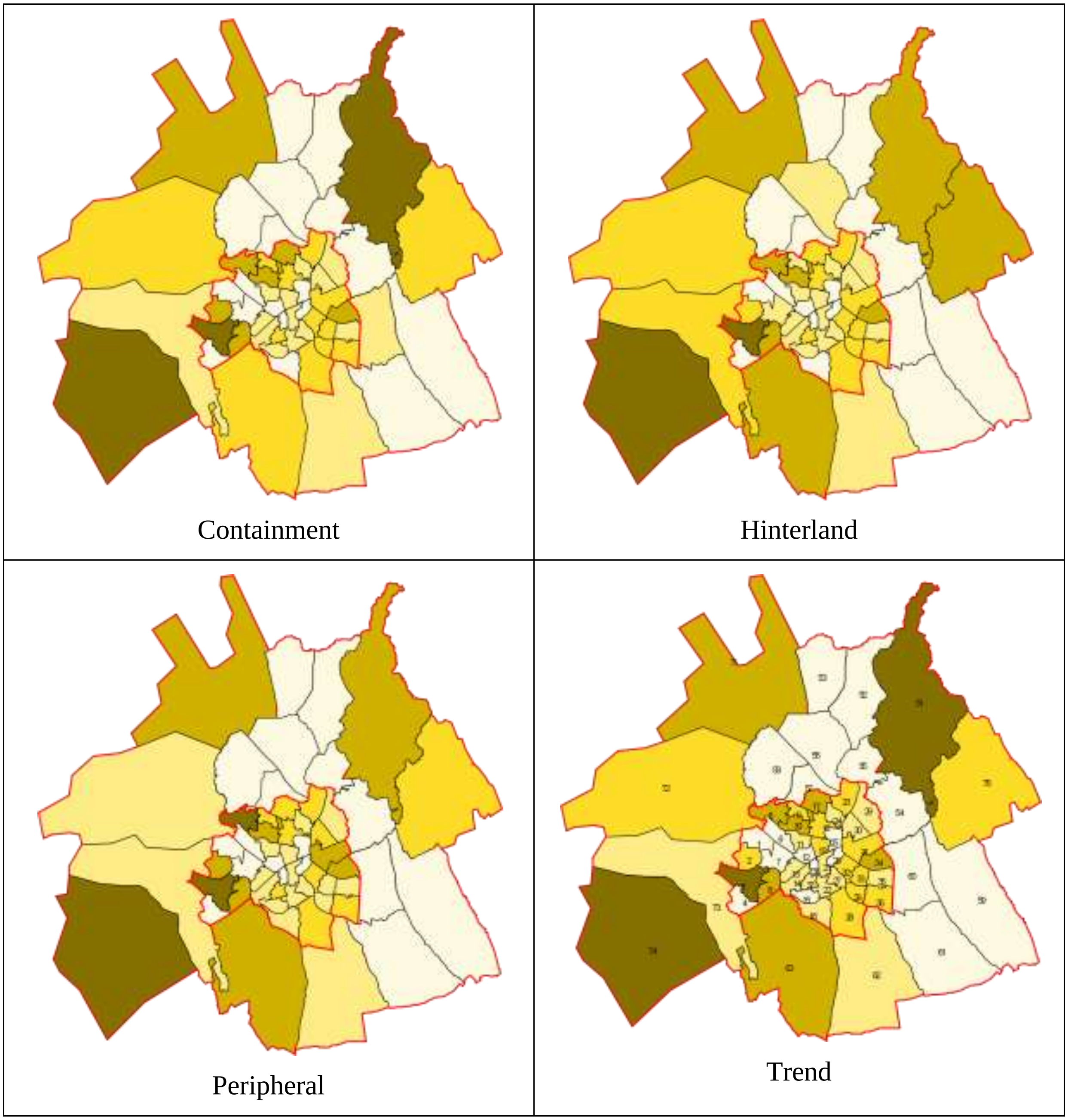


Figure 57: Income distribution - 2016

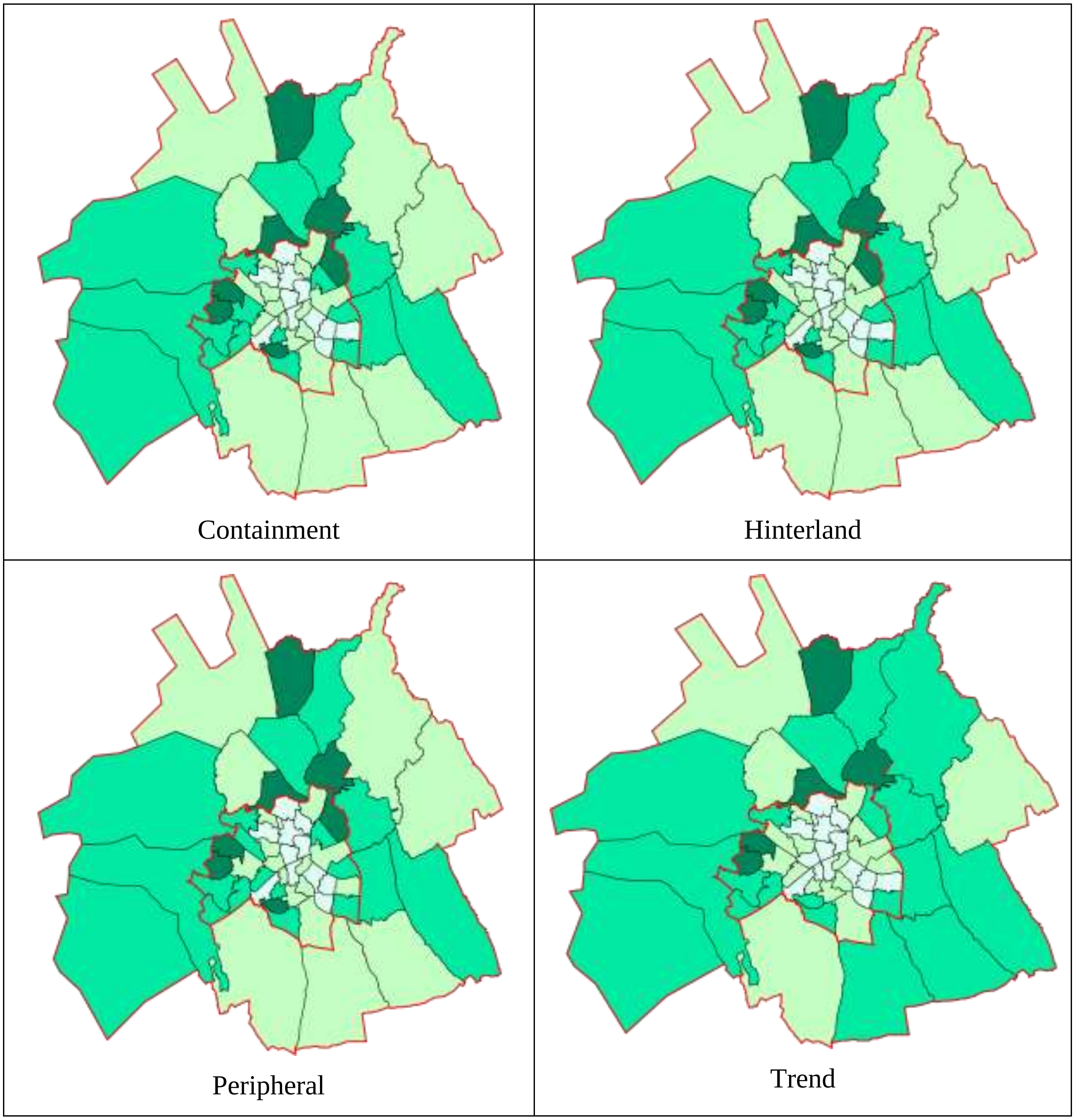


Figure 58: Floorspace Growth 1991 - 2016

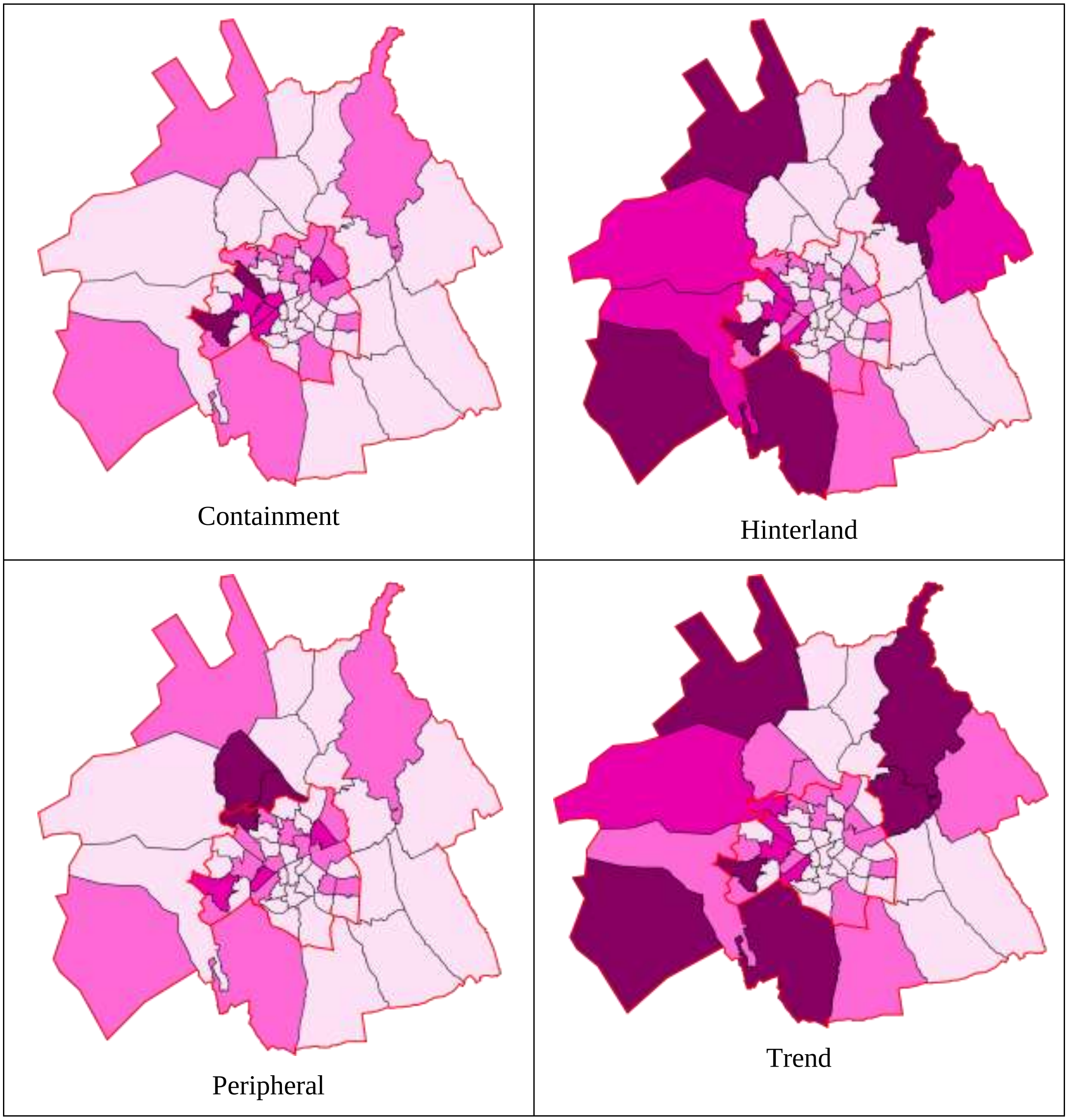


Figure 59: Land Development Growth 1991 - 2016

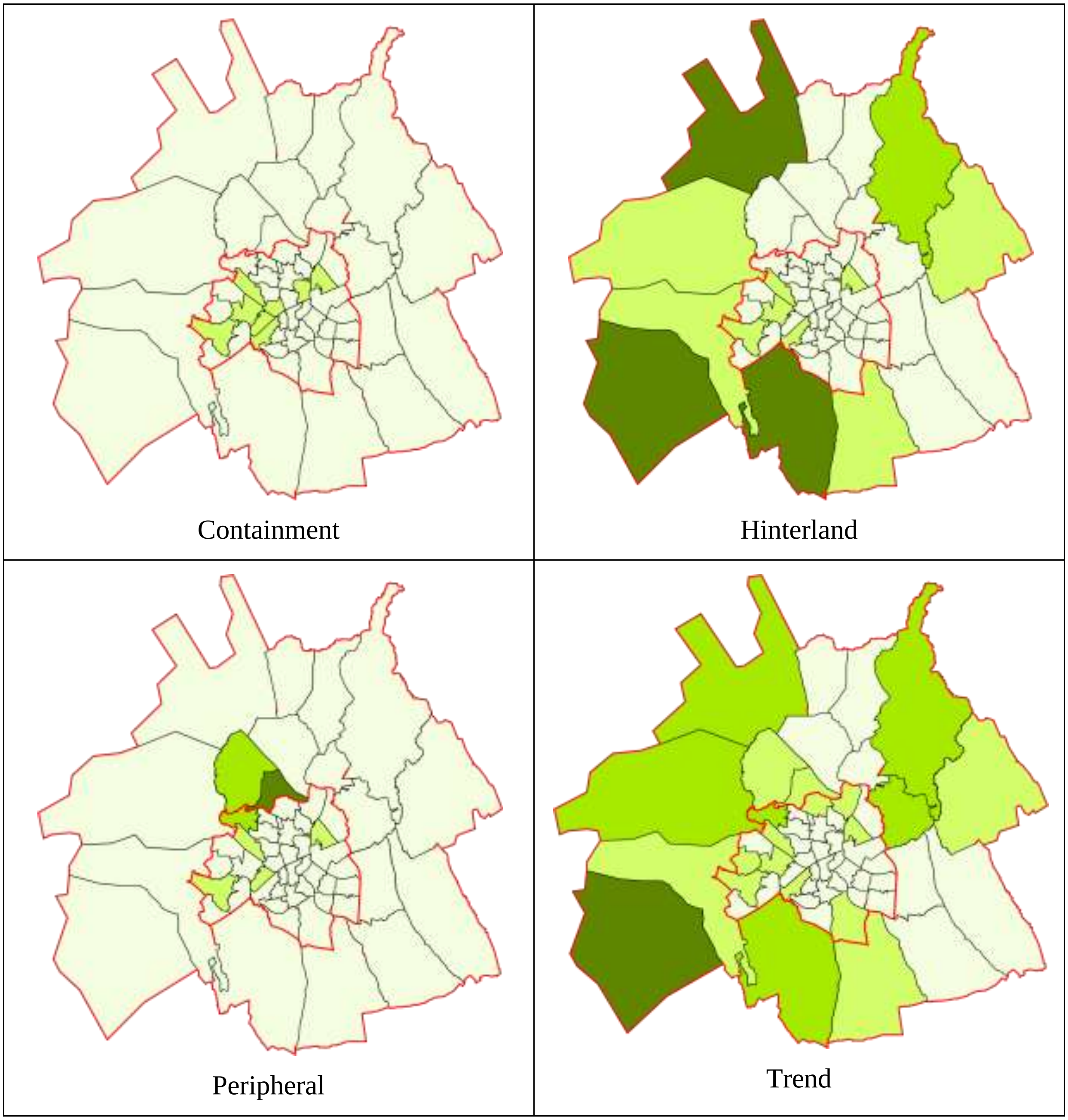


Figure 60: Land Value Index - 2016

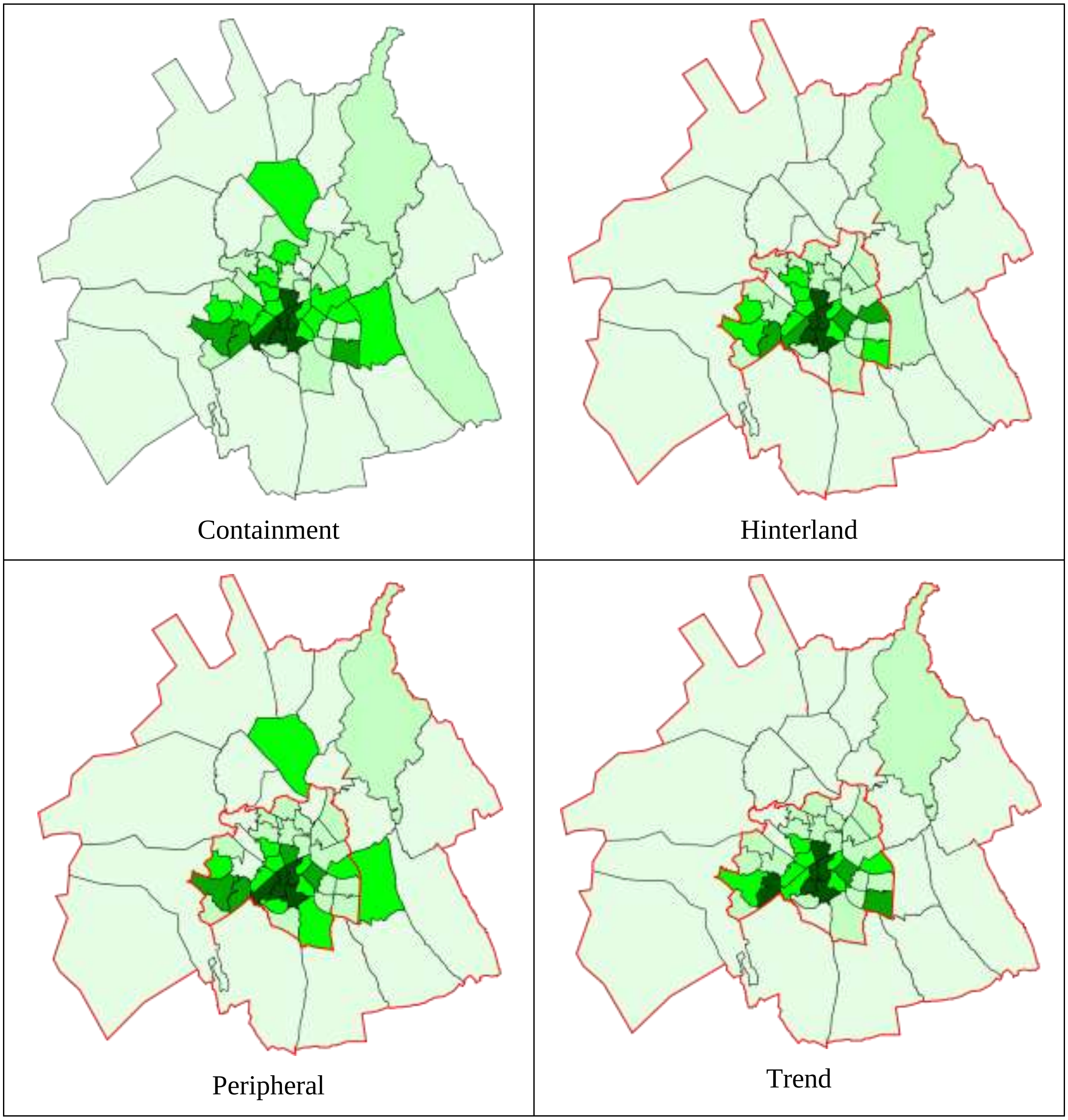


Figure 61: Demolitions 1991 - 2016

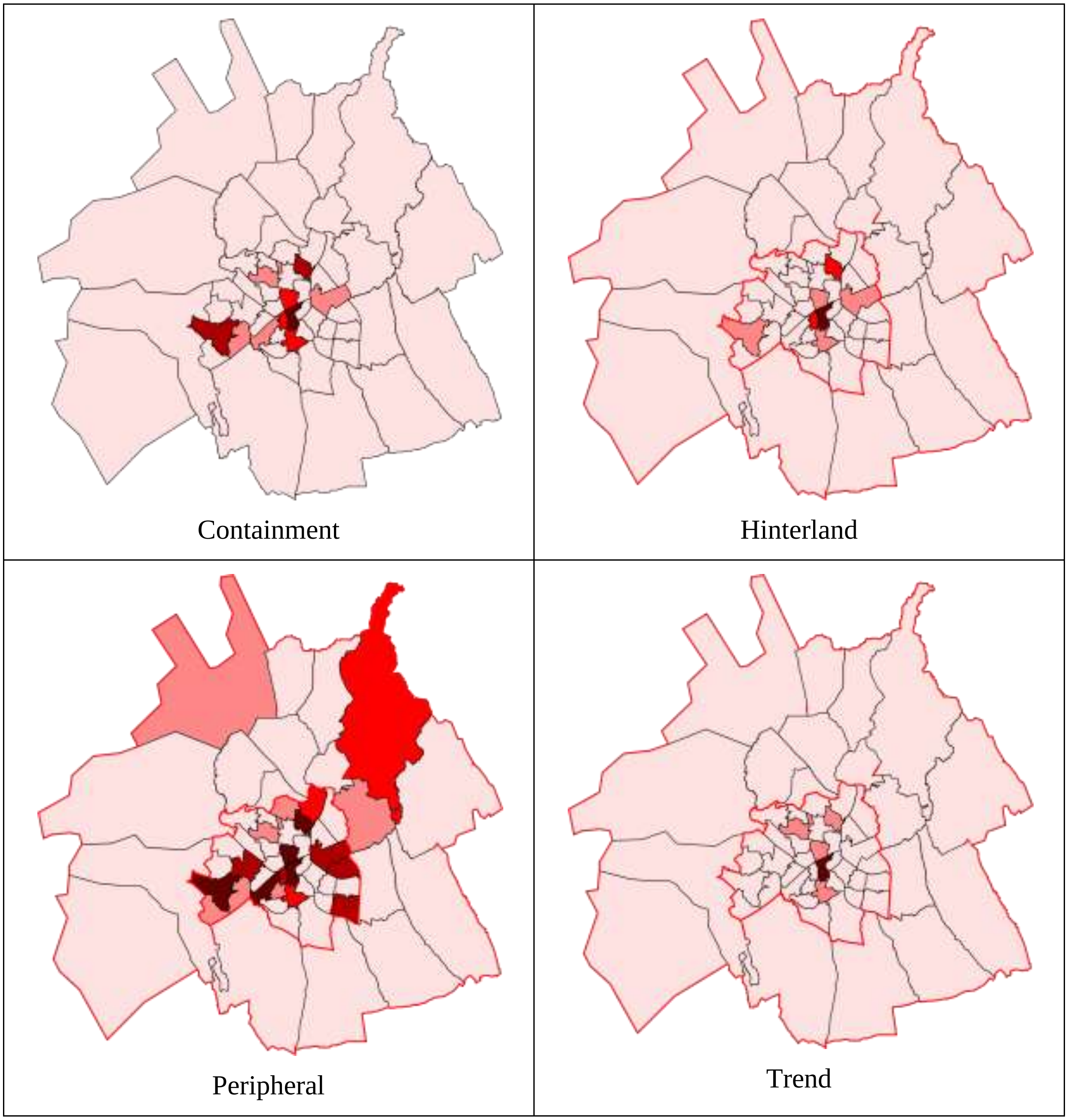
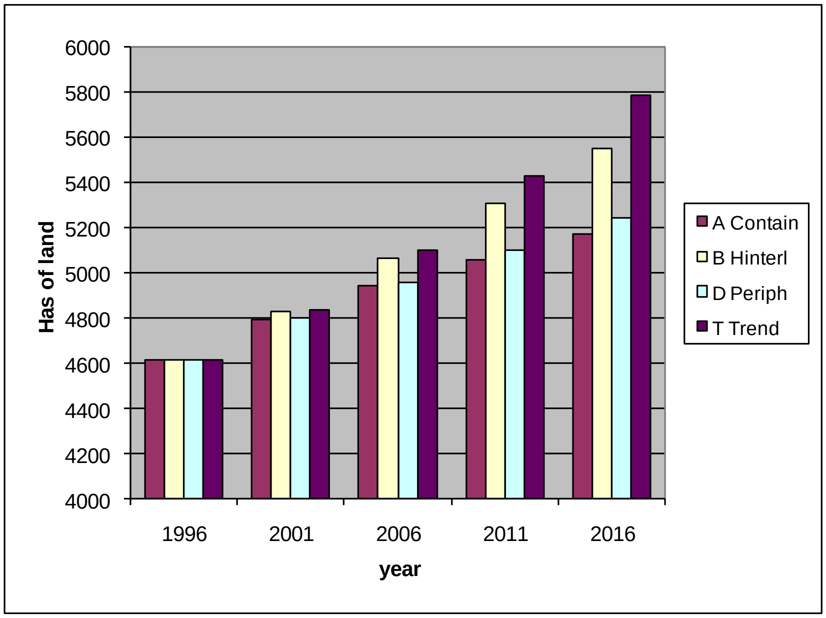


Table 4 and Figure 62 show the consumption of land by scenario and period in Ha. Again the Containment Scenario shows the least growth in consumption and the Trend shows the most, with a difference of 615 Ha, representing more that 10% of the total stock. This is because activities find it easier to reduce plot sizes compared to reducing actual floorspace consumption.

Table 4: Consumption of Land by Scenario (Has)

Scenario	1996	2001	2006	2011	2016	16-96
A Containment	4612	4793	4944	5058	5173	561
B Hinterland	4612	4832	5064	5306	5549	937
D Peripheral	4612	4801	4954	5102	5243	631
T Trend	4612	4836	5103	5431	5787	1176

Figure 62: Consumption of Land by Scenario



The research team was able to estimate fuel consumption per square meter of floorspace by type based on an extensive study of the built stock in Britain. These values were applied to the results above to get millions of kWh/year. These were in turn multiplied by the price of energy to get fuel costs in millions of £ per year. In this case the difference between the Trend and Containment scenarios is in the order of 86 million £ per year representing 12.8% of the total. As may be seen, fuel cost savings are greater than the reduction in floorspace consumption. This is because the amounts of m2 are less in the Containment Scenario compared to the Trend. Building types also vary, with a greater proportion of framed buildings, terraces and flats that consume less energy per m2 compared to sheds and detached houses.

Figure 63: Consumption of Floorspace Energy by Scenario (Millions of kWh/year)

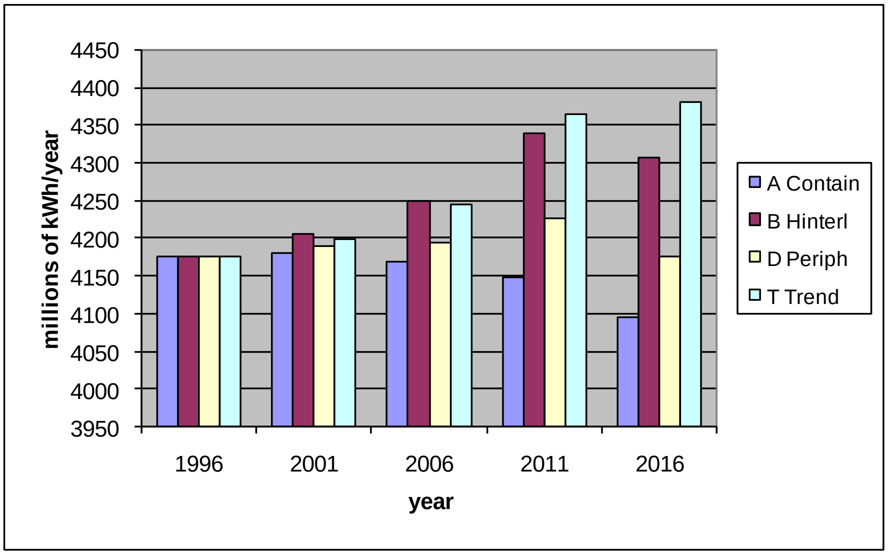
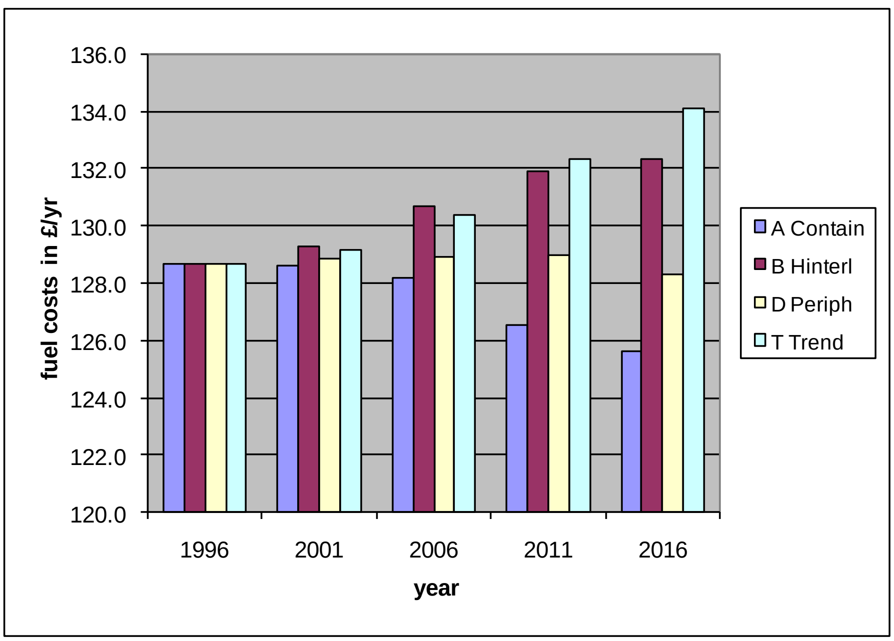


Figure 64: Fuel costs of buildings (millions of £/yr)



Some interesting transport-related tables and graphs follow.

Table 5: % passenger-Km in public transport

Scenario	1996	2001	2006	2011	2016
A Containment	6.4%	13.1%	13.4%	13.7%	13.9%
B Hinterland	6.4%	13.5%	14.3%	15.2%	15.7%
D Peripheral	6.4%	12.9%	13.0%	13.3%	13.5%
T Trend	6.4%	7.0%	7.2%	8.3%	8.4%

Table 6: % passenger-Km in non-motorized modes

Scenario	1996	2001	2006	2011	2016
A Containment	4.1%	8.6%	8.5%	8.5%	8.6%
B Hinterland	4.1%	8.5%	8.3%	8.5%	8.7%
D Peripheral	4.1%	8.5%	8.1%	8.1%	8.1%
T Trend	4.1%	4.2%	4.4%	4.5%	4.7%

Table 7: Park&Ride trips

Scenario	1996	2001	2006	2011	2016
A Containment	0	39825	46635	49917	53065
B Hinterland	0	37637	43929	50100	55654
D Peripheral	0	37911	46021	49044	52389
T Trend	0	0	0	0	0

Figure 65: Total operating cost savings (thousands per year)

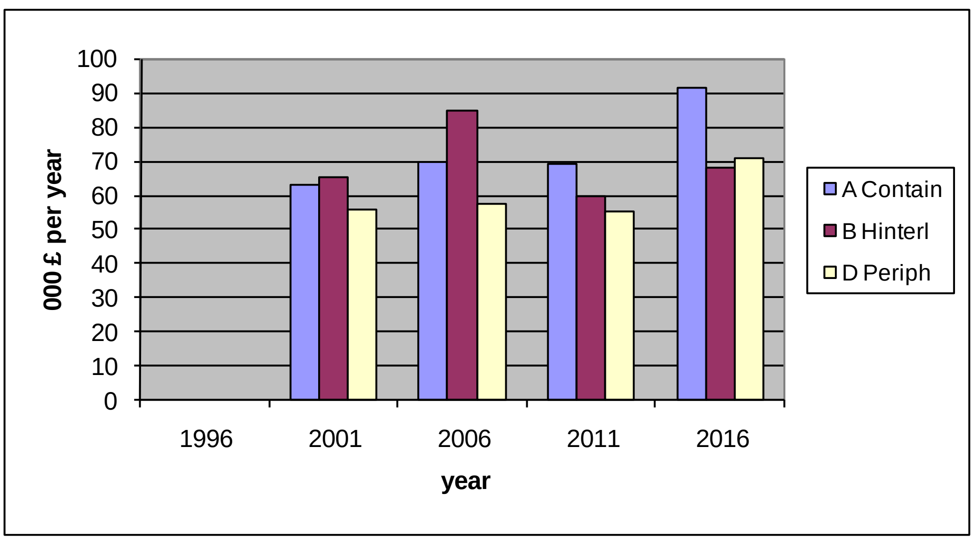


Figure 66: Total fuel consumption

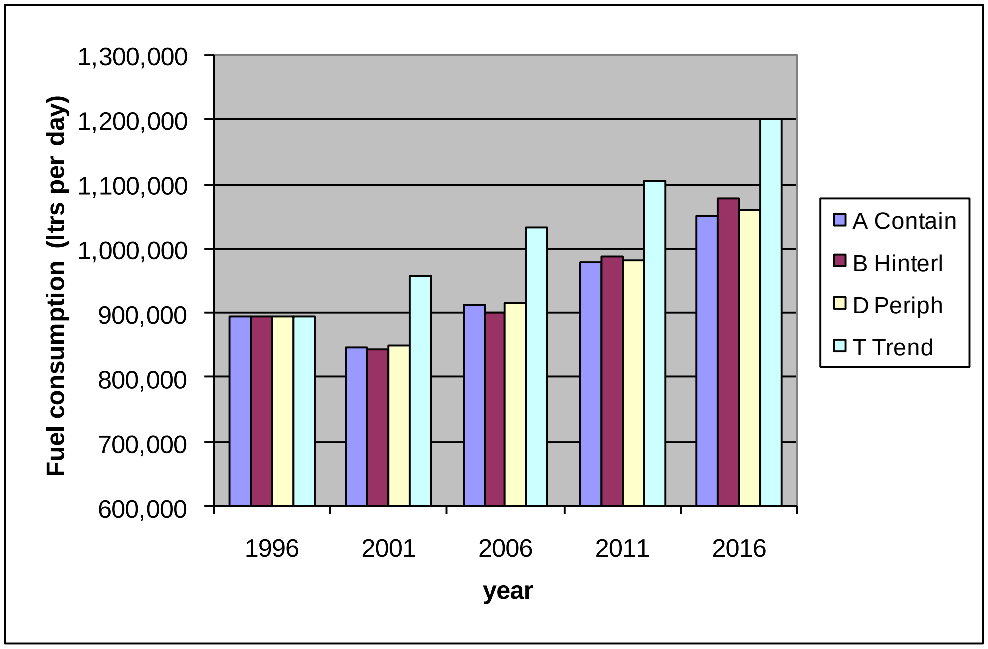


Figure 67: Distribution of vehicle-km by speed class -2016

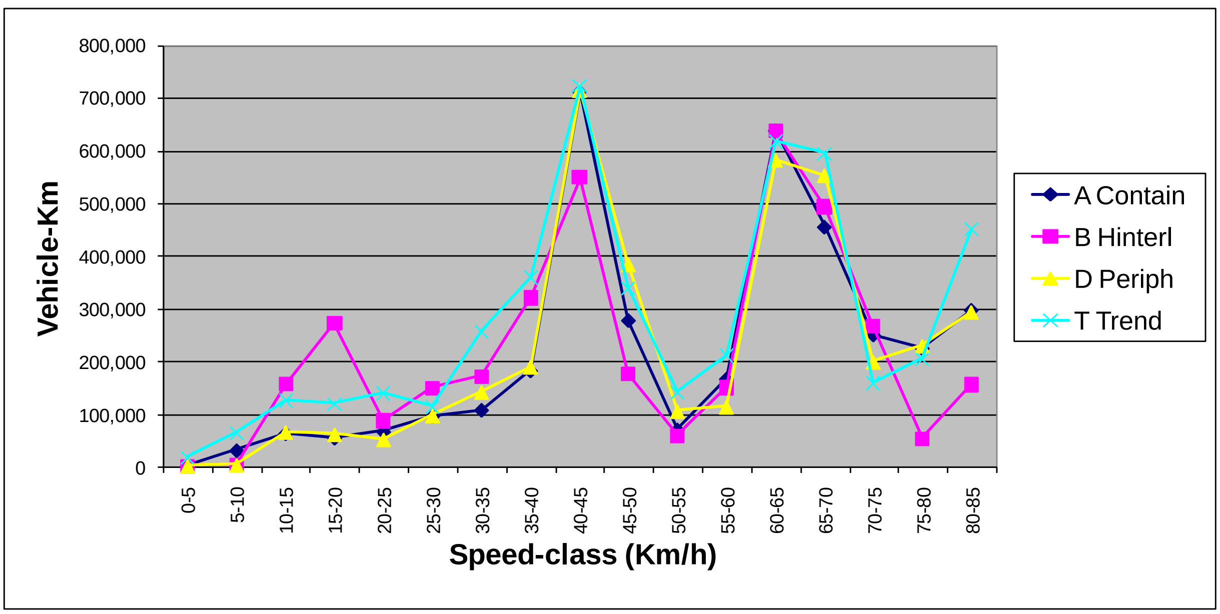
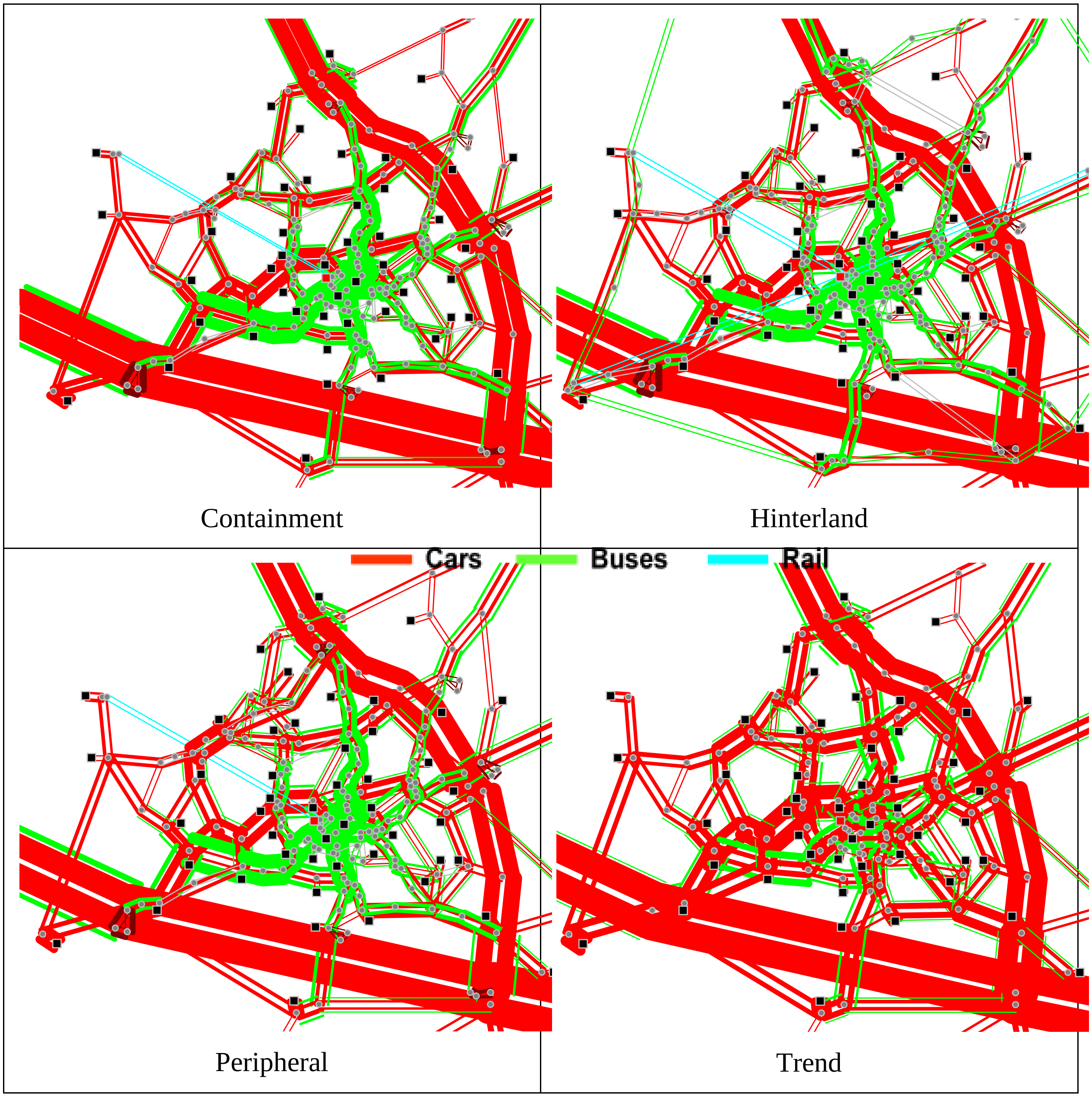


Figure 68: Assigned trips - 2016



7 Final remarks about the results

Although the main purpose of this guide is to help run the model of Swindon, reproduce the results and describe how to produce reports and analyse them, it is worthwhile to sum up some important conclusions and remarks about these results. Here we shall discuss each scenario in turn and then put together some general remarks.

7.1 Scenario A: Containment and increased density

Land use results

Scenario A specifies that new land for development is made available only within the existing urban area of Swindon. The implementation of this policy is shown clearly in the map of Land Development Growth 1991-2016 in Figure 59. Employment growth over the period is largely confined to this same area, although there is also growth in some peripheral rural zones to the south-west. (This is made possible by increases in density on already-developed land. There is no new land take in these zones.).

Commercial and industrial activities are in competition with residential uses for land and floorspace in Swindon, a competition in which the former are able to outbid the latter. As a result, although population does grow within Swindon itself, it actually grows faster in the outer rural zones. These peripheral housing developments are shown by the map of Floorspace Growth 1991-2016 in Figure 58. The increases in floorspace in the south and west are partly due to employment growth as we have seen, but the increase to the north of the town, and some to the south, is largely residential. The biggest land use changes between 1991 and 2016 in this scenario are within Swindon itself, but there are high rates of change in land use in the rural hinterland, especially in the zone containing Highworth to the north-east. Because of the limits on land supply, the Containment Scenario results in high floorspace densities in the urban area, and high land values associated with those high densities. The map of Demolitions in Figure 61 shows that these are confined to Swindon itself. The growth in floorspace in the hinterland zones is thus entirely achieved by increased densities within parcels of land which were already developed in 1991.

The growth of housing outside Swindon is one of the most significant findings for this scenario. Proponents of a 'compact city' approach argue that redirecting development towards existing urban centres will result in a lively mixture of commercial with residential uses, and shorter journeys from home to work and from home to services. The results for this Containment Scenario raise a warning that, unless special measures are taken to keep housing within city centers, there is a danger that restrictions on land supply in peripheral or hinterland areas may, paradoxically, serve to drive housing out of town. Commercial and industrial growth must go somewhere, and if it can only go on central urban sites, this will raise land prices and rents, and may force housing to go elsewhere.

Transport results

So far as overall travel patterns are concerned, the Containment Scenario has the effect of doubling the trips made by public transport, over the period from 1991 to 2016. Even so, this proportion is still only 14%, i.e. about one trip in seven. The greater part of the shift to public transport occurs immediately on the introduction of the car ban and the park-and-ride scheme, between 1996 and 2001. The map of Assigned trips in 2016 shows the city centre free of cars, as the scenario specifies. The only motorized trips in the centre are now by bus. Non-motorized journeys, i.e. cycling and walking, are more than doubled from 4% to over 8% of all trips, again as a result of the central area car ban.

There are a series of consequences for overall travel statistics. The average trip length is more or less unchanged. This is because some shorter trips in centre due to higher densities, are compensated by longer ones outside, going round the city centre by car, or coming in from peripheral housing developments. The average trip cost falls slightly, because of the shifts in mode to walking, cycling and public transport, including use of the park-and-ride scheme (even though parking charges are assumed to be included in the bus fares). Average travel time increases over the entire period, because of the shifts to slower modes. When modal shift is examined in more detail, it becomes clear that the major changes are from cars carrying several occupants, to public transport and non-motorized modes.

The implication of these results is that it is the middle-income groups who are mostly making the shifts in mode away from the car. The lower income groups travel more by public transport, bicycle or on foot in the first place. Meanwhile the higher income groups are not attracted by the park-and-ride option, and are not greatly deterred by the central area car ban, and carry on driving regardless. This is shown by an increase in fuel use by cars with single occupants in the Containment Scenario, because these are being used to make longer, more circuitous journeys around the town centre. There is also the fact of higher-income housing being pushed out to rural zones outside Swindon, as already mentioned.

7.2 Scenario B: Hinterland, high density dispersal

Land use results

In this scenario, new employment and services are exported to a number of existing villages in the hinterland of Swindon: Cricklade, Broad Blunsden, Highworth and Shrivenham to the north; Purton, the Lydiards and Wootton Bassett to the west; Wroughton and Chiseldon to the south. New housing follows these jobs and services. Meanwhile new development is severely restricted in Swindon itself. The effects of these constraints are clearly visible in the maps of Land Development Growth and Floorspace Growth. New land gets developed by 2016 in most of the rural zones, especially to the south-west and north-west.

The map of Employment Growth confirms this picture. It shows growth in most of the hinterland zones, especially strong to the south-west around Wroughton and Wootton Bassett, which are both well-placed for access from the M4 motorway. There is some increase in employment in Swindon itself, on land already developed in 1991, but this is not as marked as in the Containment Scenario, as expected. Growth in population follows employment, as housing moves to the sub-centres. The resulting pattern of population growth in the hinterland is not greatly different from that which occurs in the Containment Scenario for the reasons explained above. Floorspace densities and land values are somewhat lower generally than in the Containment Scenario, because the supply of land is greater. There are fewer redevelopments and conversions, for the same reason.

Transport results

Some of the transport policies embodied in this scenario are the same as for Scenario A: the central area car ban, the radial park-and-ride scheme. The biggest difference lies in the creation of orbital routes linking the satellites, with bus services running along segregated bus-lanes. The result is the largest shift to public transport of all scenarios, up to nearly 16% of all trips (one in six). Trips along the orbital bus routes can be seen (as green bands) in the map of *Assigned Trips 2016*. Use of the park-and-ride scheme is slightly increased compared to the Containment Scenario, as a result of the residential population being more widely spread into the hinterland. Meanwhile the shift of trips to walking and cycling is similar to Scenario A (up from 4% to nearly 9%) since this is largely brought about by the central area car ban in both cases.

As for average trip cost in 2016, it is also similar to the Containment Scenario. Average trip length and travel time are very slightly greater, because of the dispersion of employment and population over a wider area. But this effect is not very marked.

A further difference in transport policies in this scenario was the introduction of four new suburban stations on the existing railway lines. These however have negligible effects on traffic patterns, and the numbers of users are very small. This is perhaps because the stations are few in number and not in places where demand would be highest.

7.3 Scenario C: Peripheral - limited peripheral expansion

Land use results

New land for residential development is made available, in this scenario, only in an area on the north-west edge of Swindon. Some industrial and commercial growth is also allowed in this area, as well as on one large former industrial site in the town centre. Otherwise development in the hinterland is severely controlled. The map of *Land Development Growth* illustrates these constraints. There are some broad similarities with the Containment Scenario in the resulting land use patterns - although in different zones - as a result of the supply of land being greatly restricted in both cases.

Employment grows most sharply in the designated north-western area, as would be expected, but it also grows in Swindon itself, and in other parts of the hinterland especially those same zones to the south-west which grow strongly in the Hinterland scenario. Floorspace growth follows a similar pattern, with additional residential development occurring (through increased densities on land already developed) in the rural zones to the north of the town, beyond the designated growth area. This is again comparable with the Containment Scenario. In both scenarios the limits on the supply of land mean that some housing is driven out into the countryside. The growth of population in two northern rural zones in particular - those containing Highworth and Cricklade - results in especially high rates of redevelopment and conversion.

Transport results

A new orbital road, with special bus-lanes, is built in this scenario to serve the north-western expansion area. A park-and-ride scheme is also introduced, plus some other segregated and priority bus routes. There is a ban on cars in the town centre as in both previous scenarios. The consequence is again a shift to public transport, from 6% of trips in 1996 to 13.5% in 2016 - very nearly as large a change as in the Containment Scenario. The park-and-ride scheme attracts almost the same number of riders in the two scenarios.

The scenario introduces one new suburban station with associated car parking, but the effects of this on modal shift are even smaller than in the Hinterland Scenario with its four stations.

7.4 Scenario T: Trend

Land use and transport results

There are no constraints on amounts of land available for development, and no new traffic management policies or public transport initiatives, in this scenario. It is not intended to be realistic in itself, but is introduced simply to serve as a 'do-nothing' benchmark against which the previous three scenarios can be compared for their effects. As might be expected, there is growth in newly developed land, and new floorspace, both in Swindon itself and in the surrounding rural zones (although the latter not as marked as in the Hinterland Scenario). Because land is freely available in many zones, there are few changes in land use, and little redevelopment. Land values and densities remain lower than in other scenarios. Population growth in the rural areas is greater than in the Hinterland Scenario, and is broadly comparable with the Constrained Scenario. This is because middle and higher income groups are seeking more land and larger houses in the outlying villages – a process whose effects are visible in the map of *Income Distribution*.

The results for traffic patterns are that use of public transport increases hardly at all (from 6% of trips to 7%). There is practically no shift to cycling or walking. All this has the effect that the average trip cost is significantly higher in the Trend Scenario than all others. Average travel time is also the highest of all, by a small margin. This is because, although a higher proportion of trips are by car, new development is very spread out, and more importantly the cars cause congestion, hence travel times deteriorate. Because the model simulates all-day traffic flows, the predicted effects of congestion are not especially serious in any of the scenarios, even the Trend. Simulation of peak-hour flows would doubtless show a different picture.

7.5 Comparative performance of all four scenarios

Land use, floorspace and energy in buildings

We are now in a position to make some quantitative comparisons of the overall performance of all four scenarios. Scenarios Constrained and Peripheral take the smallest areas of extra land - 560 and 630 hectares respectively - as would be expected from their inherent constraints on new development. The Hinterland Scenario takes 940 hectares, and the Trend Scenario, which places no restrictions at all on development, takes 1050 hectares. A similar ranking of scenarios gives total consumption of floorspace over the same period. Again the Constrained and Peripheral consume the least, the Hinterland and the Trend the most. (The Hinterland Scenario actually consumes more new floorspace than the Trend). The differences are not however so marked as for land, because of greater elasticities in land consumption.

These differences in consumption of land and floorspace have some impact, in turn, on the use of energy in buildings. A general improvement in the energy efficiency of buildings was assumed at the same rate for all scenarios. This serves to offset part of the growth in energy use which occurs otherwise simply through increases in total floor area. Total energy use in the Hinterland and Trend Scenarios still goes up over the period to 2016. In the Peripheral Scenario it rises and then falls again. In the Constrained Scenario it falls throughout. By the end year 2016, total energy use per annum is 4.5% lower in the Constrained Scenario than in the Trend, and in Peripheral it is 3% lower. These results translate into similar percentage savings in energy costs per annum.

Notice that these comparative results have nothing to do with any technical improvements in the fabric or servicing systems of buildings, which are assumed to be the same in all cases. They result wholly from changes in built forms, of two kinds. First, in those scenarios where land is in short supply and densities rise, the same activities occupy less floor area (smaller houses, less office floorspace per employee etc). Second, the higher densities have the additional effect that the same activities tend to locate in more compact forms with a lower ratio of surface to volume: residential in terrace or semi-detached rather than detached, other activities in multi-storey framed buildings in preference to single-storey sheds.

The most marked reductions in fuel consumption, in the Constrained and Peripheral scenarios, are shown by middle-income households, a proportion of which have moved by 2016 into smaller houses of more energy-efficient types. The high income households meanwhile are able to continue to afford larger detached houses. The low income households are already in small energy-efficient dwellings in 1996.

Transport mode and energy in transport

There is little difference between the scenarios in the predicted total number of trips in 2016 - of the order of 4.5% between the highest and lowest. The main differences are rather in modes of transport. To recapitulate: all three scenarios result in greater use of public transport compared to the Trend, by between 6.5 and 8%, as a result of the combination of central area car ban and park-and-ride. These scenarios have between 3% and 4% more trips by cycling and walking than in the Trend, because of the car ban.

The Containment and Peripheral scenarios produce savings of around 13% over the Trend by the year 2016. In the Hinterland Scenario the savings are lower, around 11%, because of trips being on average slightly longer. The pattern of vehicle fuel consumption in 2016 is still absolutely dominated by cars, which account typically for 98% of the total. Fuel savings in the Constrained and Peripheral scenarios occur, as mentioned earlier, as a result of some users of cars with several occupants shifting to other modes. In the Constrained Scenario, fuel use by single occupant cars actually increases, because of households in the relevant groups moving outside of Swindon, and because circuitous routes are being taken around the area of the car ban.

7.6 Overall conclusions

To an extent these results must be peculiar to Swindon. It would be dangerous, without more work, to claim any general validity, even for other towns of similar size, since these might differ greatly from Swindon in densities, the extent of undeveloped central area land, and other significant characteristics. The results do seem to indicate nevertheless that for Swindon, and possibly for other comparable towns:

1) The effects of land use changes by themselves, for towns of this order of size, in reducing car travel or encouraging modal shift to public transport, cycling or walking, are small.
2) The combination of a central area car ban with a comprehensive park-and-ride network, using segregated bus lanes, can shift up to 8% of trips from cars to other modes, and to save up to 13% in total annual fuel use in transport.
3) These modal shifts are of almost the same magnitude for a land use policy which directs new development to satellite villages around the town, as for land use policies which contain new development either within, or on the edge of the town.
4) A policy of containing new development within or adjacent to the existing urban area - i.e. a 'compact city' approach - can, by restricting the supply of available land, have the effect of raising densities and land values in these zones. Industrial and commercial uses then drive out housing, which cannot compete, to rural areas outside the town. Thus two of the explicit aims of the 'compact city', to encourage mixed uses in town centers, and to bring jobs and services closer to houses, are subverted.
5) On the other hand, this same restriction on the supply of land, and the resulting increases in density, mean that activities occupy less floorspace, in more compact building types, and the total use of energy in buildings is reduced, by these built form effects alone. (Their impact is not however large, of the order of 3% or 4% of total fuel consumption.)
6) It is changes in behavior by middle-income groups, from less efficient to more efficient house types, and from car travel to other modes, which bring about the greater part of these savings in fuel use in both buildings and transport. The scope for savings by low-income groups is small to start off. High-income groups can afford to meet the costs of increasing their use of cars, and of continuing to occupy larger detached houses.

From a methodological point of view, it is quite clear that only integrated land use and transport models can produce this sort of results. In this case, since we are demonstrating a specific model, TRANUS, it is hoped that the reader, after going through the exercise in detail, is convinced of the advantages of this methodology over common practice, such as ‘expert analysis’ and maybe conventional transport-only models. Real cities are far too complex, so that powerful analytical tools like this sort of model is required.