TRANUS User Guide

TRANUS: Integrated Land Use and Transport Modeling System

Contributors:

Tomás de la Barra

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Table of contents

1 Introduction and purpose of this guide

The modeling system TRANUS may be applied to a wide variety of cities or regions at different scales and for different purposes. The system was designed with such a variety of applications in mind. As a result, a very flexible software was developed to provide users with a tool that may be adapted to any spatial economic system. This flexibility, however, carries the need for a guide to help the user in the building of an application. The purpose of this guide is to provide useful advice and information about the multiple possibilities provided by the models on many subjects, in order to build an application as easy as possible.

The are a number of documents that complement this guide, all of them available from the TRANUS site, such as:

- **Mathematical and Algorithmic Description.** This document presents and detailed and exhaustive description of the mathematical formulation of the models. Every effort has been made to keep full consistency between this document and the programs. Many users have contributed in this respect.

- **TRANUS User Interface Guide.** The interface is the main tool for the use of the model, so that this guide provides lots of infomation on how to use the models.

- **Guide to the Application of TRANUS to Swindon.** This guide provides a detailed description of the application of the model to a specific town.

- **Tutorials.** This is a very useful document for those that want to get started with the TRANUS system, on the basis of simple step-by-step step examples.

This user guide brings together many contributions from users in many parts of the world. Hopefully this guide should become a dynamic document in constant growth and change. Everyone is most welcome to participate. We have also brought together many comments from the TRANUS forum.

You will notice that there are lots of empty chapters that will be completed through time.

2 Software installation

The installation of the TRANUS system is very simple. The site www.tranus.com indicates where and how to download two typical Windows 'installers': tranus_xxx.exe and tus_xxx.exe, where xxx indicates the version. They may be installed in any order. By default the installers create a folder *c:tranus*, but the user may change this at will.

3 Creating a new application from scratch

There are many ways to start a new TRANUS application. Here we will review a few:

- Sketching a new application. In which you just create a network by creating nodes and links in a very approximate way with arbitrary geo-coordinates.

- Using a more precise geo-coordinate base so that the model matches real coordinates such as UTM

- Importing networks

3.1 Sketching a new application

Once you have installed the programs, you are ready to begin an application. You may open an existing application, such as the tutorial examples or the model of Swindon. In many cases, however, you will want to start a new application from scratch.

When you open the TRANUS interface, you see a blank window with menus and buttons like this one:
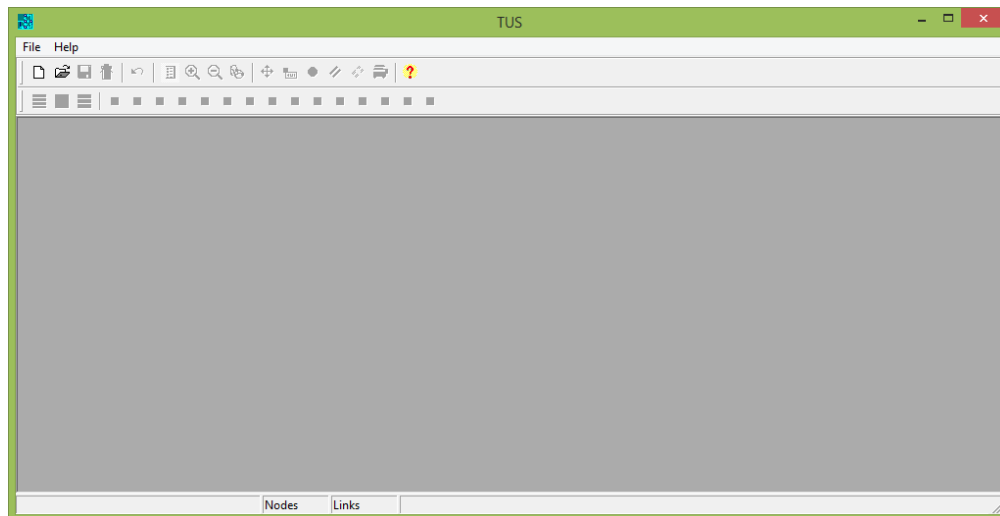
The only menu that you see is *File*. You begin by selectin *File* and then *New*. This action generates a *network view* a *scenario tree*, and a number of menus, as follows:
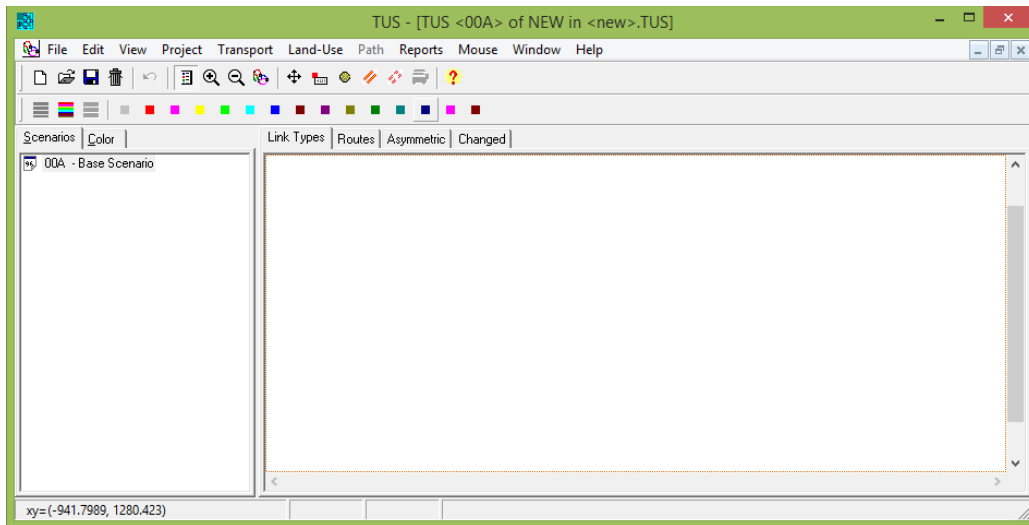
The single scenario that is created is called 00A. In menú *Project-options* you may change this. Asume you want your base year to be 2013. Then you want your base scenario to be called 13ª (always three characters). By default you study area is coded as NEW, and you posible want something more meaninful like LON for London or BSL for Brusssels. To change the name of the scenario, select it and then click on the Green tool on top called Edit Scenario.
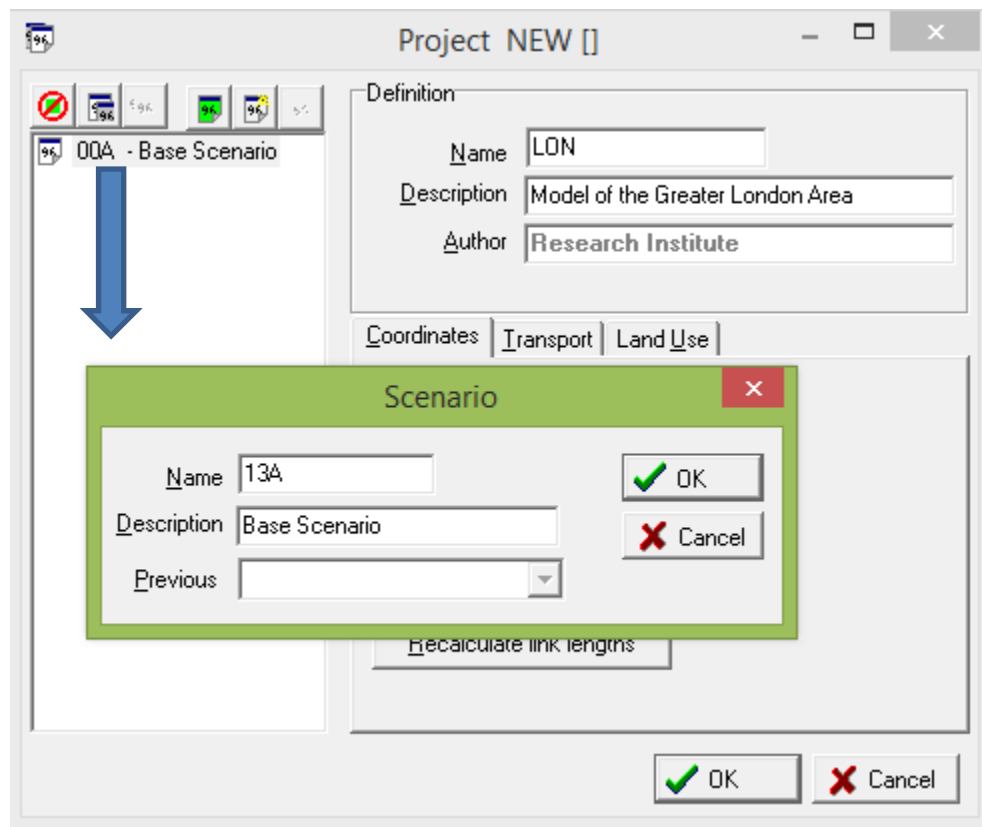
We now want to sketch a simple network. To do this we create nodes. The problem with creating new nodes is that they are not displayed (visible) unless they are connected by links. The only way to see them is in the Changed view of the network. Then choose the Create Node tool at the top

and double-click anywhere on the screen. To see the nodes better, you may select menu *View Options*. There you can make nodes bigger and you can label them with numbers.

This is how the View Options – Nodes window looks like:
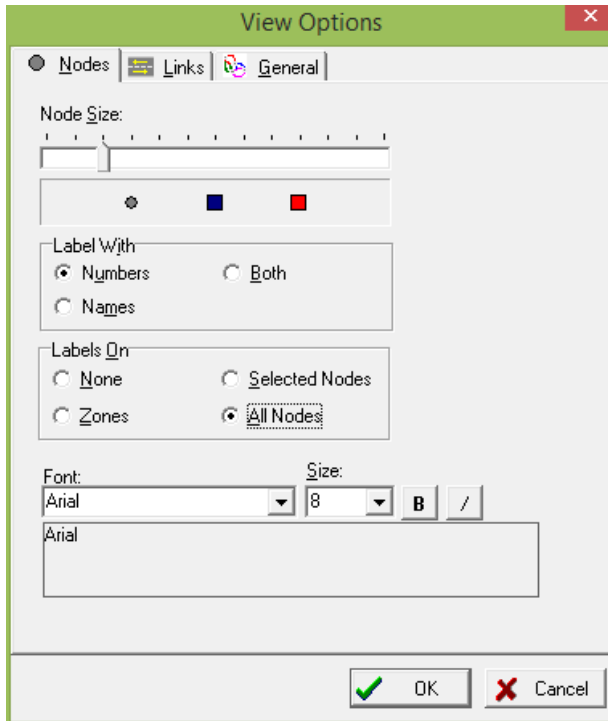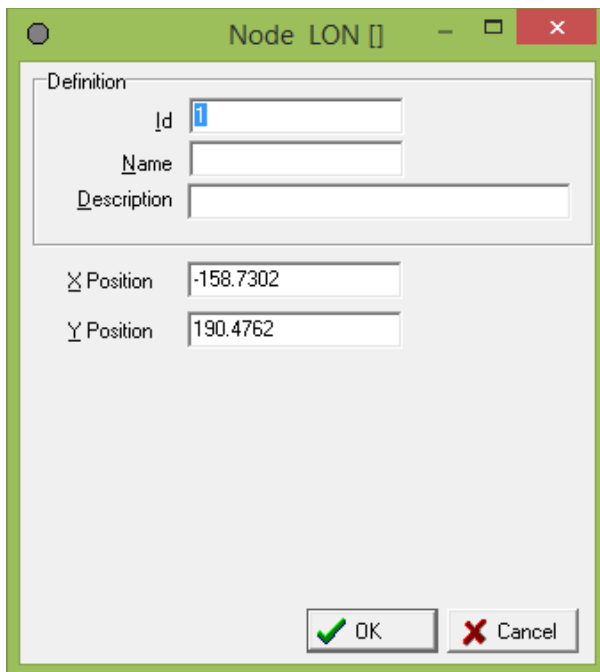
Move the Node Size ruler to the right to make them look bigger. Then select Label With Numbers All Nodes.

Slide the mouse over the network editing tools to see what each one does. You will notice that

This is the Create Node tool. Select it and then double-click anywhere on the screen. A node window will pop-up, suggesting a node number and a pair of coordinates. Because in this simple case we are not dealing with geographical coordinates, they can be anything. You can, of course, replace them with real geo-coordinates, an in this way the whole map will be at a specific scale.

After OK the network view will look like:
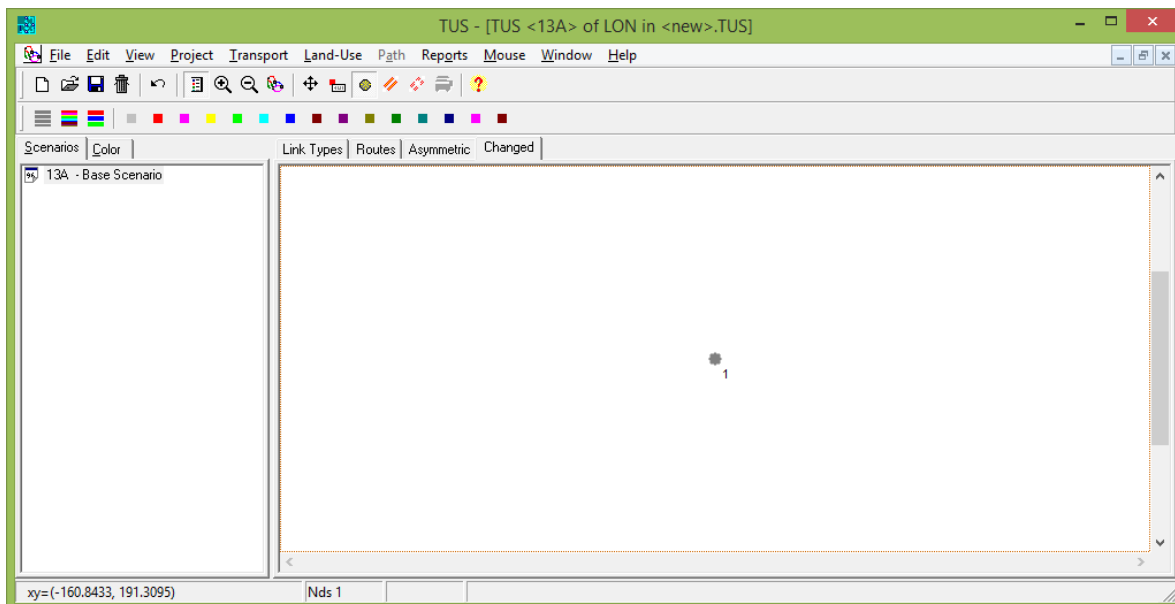
Congratulations! You have created your first node in TRANUS. We now proceed to create several nodes in lots of places. At the end it might look as follows:

6
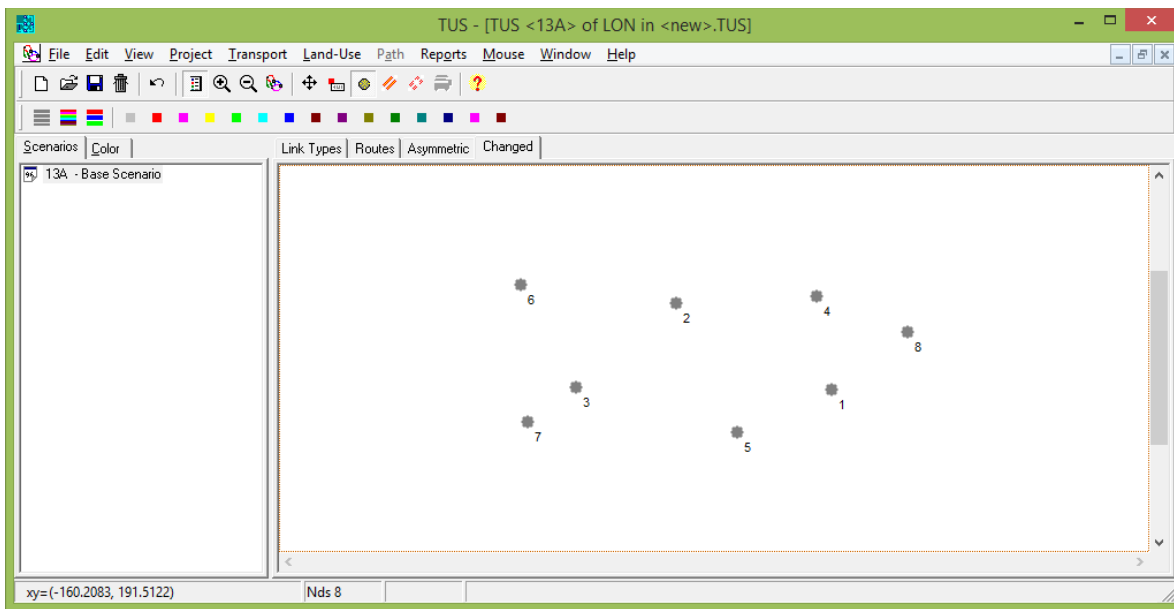
We are now ready to create links connecting these nodes. Links belong to specific link types, so that it is good practice to create link types before you create any links. You may, however, create links first and assign link types afterwards.

To create link types we choose menu Transport – Link Types. The list will be empty, so you start by clicking on the *New* button. This will in turn trigger a new window where you specify the characteristics of the new link type.
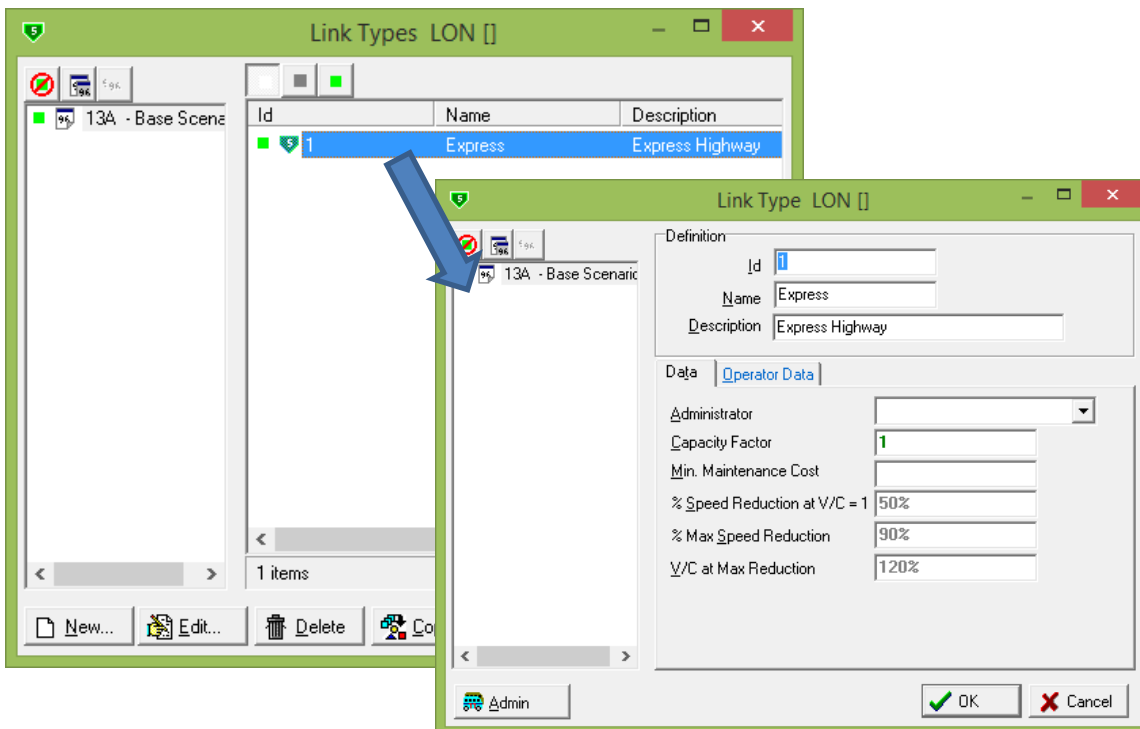
For the time being we cannot define much because we don't have *Operators* or *Administrators*. Just make sure that the *Capacity Factor* is 1.0 or more. You may continue defining link types, such

7

as arterial and local. Each time you create a new link type, a code number is automatically assigned, but you can change it at will.

We now go back to the network to create links. Select the Create Link tool.
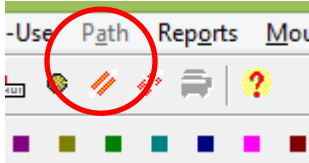
Move the cursor and place it over a node that you want to be the origin node of the link. You will notice that the cursor changes. Click once and then move the cursor over another node that you want to be the destination node of the link, and click again. A window will pop-up so that you may specify the characteristics of the link you are creating:
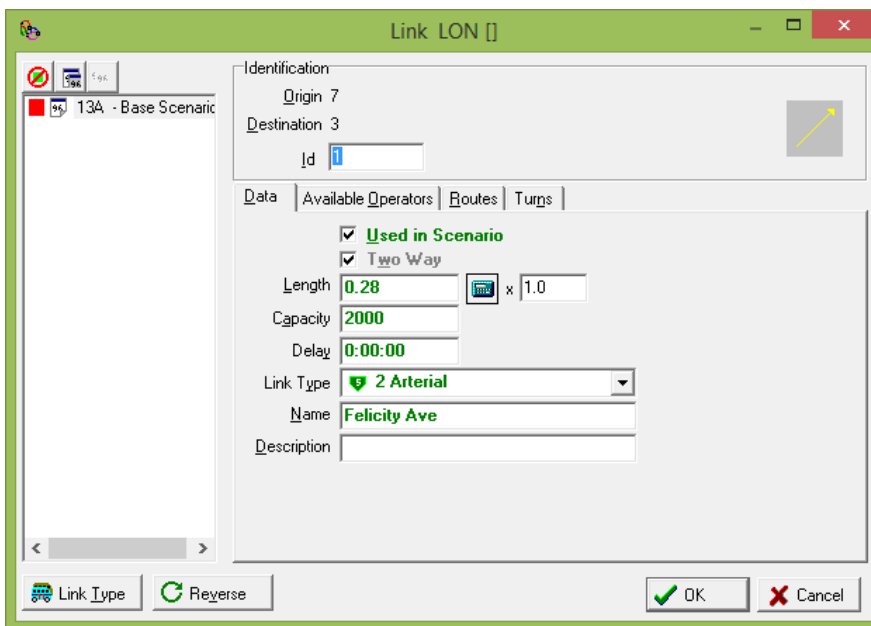
In this example we have created a link from node 7 to node 3 with the following characteristics:

- Capacity of 2000

- In the Link Type pull-down we have chosen link type 2 Arterial

- We have indicated a name

- The length field has been created automatically, calculated from the coordinates of the two nodes. In this simple example coordinates are meaningless, so that the length may also be meaningless. You may put in a specific length, but we will leave it like this for the time being.

- The *Two Way* checkbox is selected by default, so that a two-way road will be created. You can un-check this box if you want a one-way street.

- The little yellow arrow at the top right indicates that the link 7-3 goes upwards

Note that there is a red square on the scenario tree, indicating that there is something wrong with this new link. This is because this new link is not connected to any other link. This will be corrected as we complete the network. The network view should look like this:
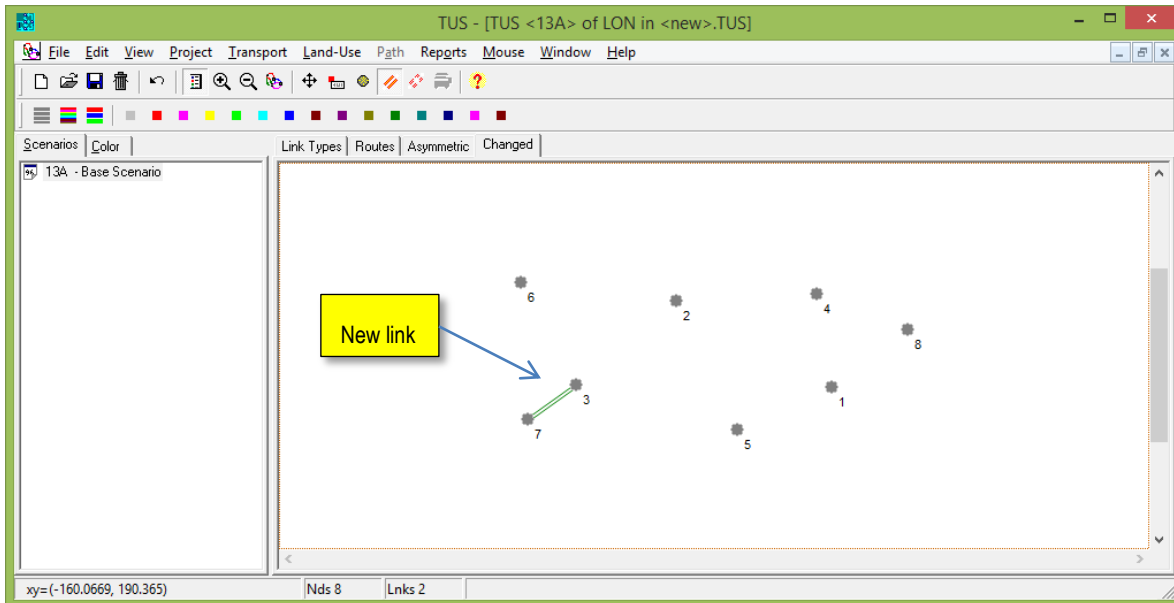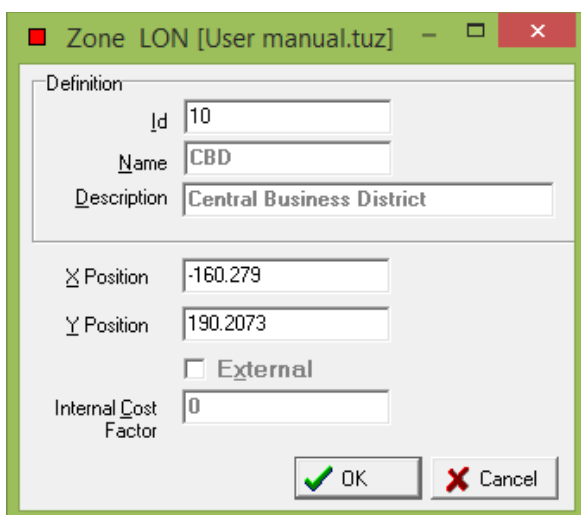
Next we proceed to create more links. When creating a new link it is possible to click on the origin node, then as many intermediate clicks to represent a curvy road, until you finally click on the destination node. This is what we have done in the example for link 3-5. At the end the network will look like this:
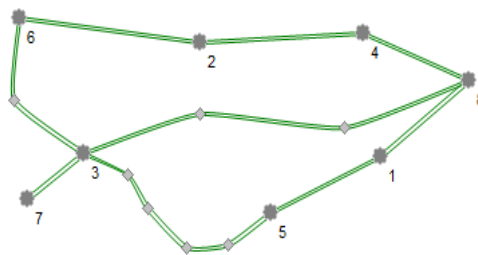
We now go back to the *Link Type view* of the network, and select colors in the scenario view. The list of link types that you created should show. You may assign color to each link type by selecting a link type in the list and then clicking on a color from the palette. You mat refine the view in the View-Options menu on the links tag. The Width Factor adjusts the width of links as a function of the capacity. We selected a factor of 1000. This is the view of the network that you get:
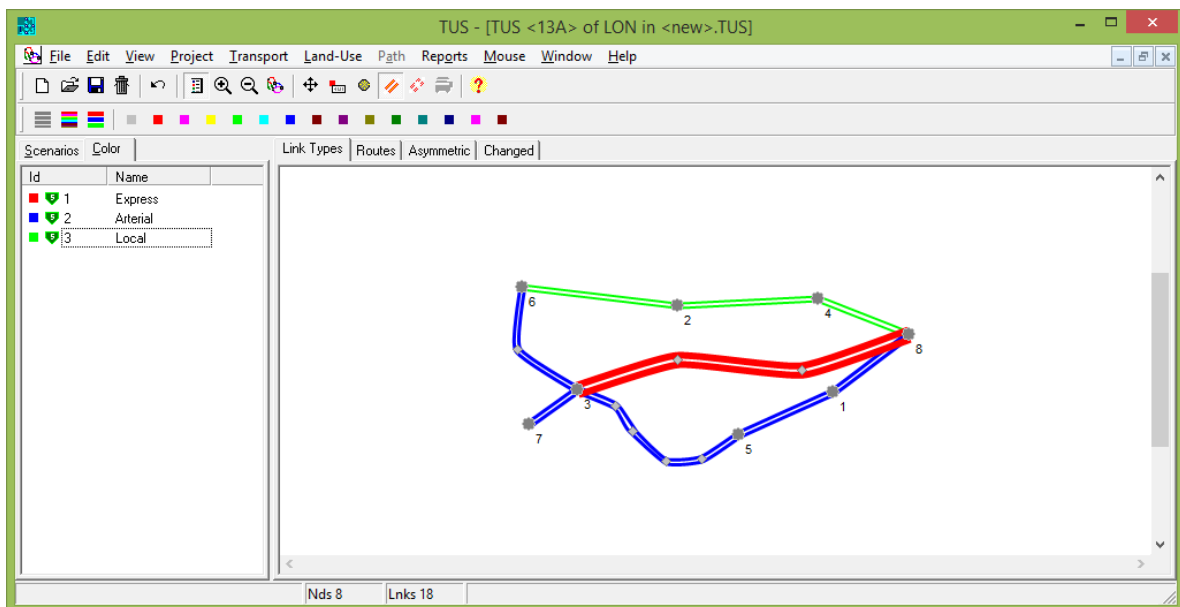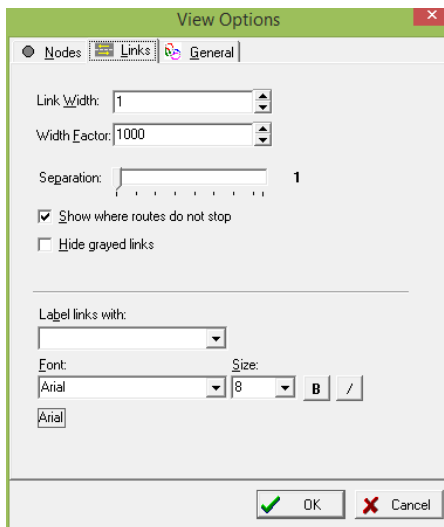
We will now create three centroids. We first create a new link type called Zone Connector. Select the Create Node tool that was used before, but this time Ctrl+Click at the point where you want to locate the centroid. The cursor will change from a circle to a square. With this a new window pops-up as follows, where you may specify a name:

Continue like this to create the other two centroids. Next, select the *Create Link* tool and connect each centroid to the network, specifying the new Zone Connector link type. It is convenient to specify a capacity of 'INF' to the model that the capacity is undetermined, or infinitely large. At the end you should get a view like this one:
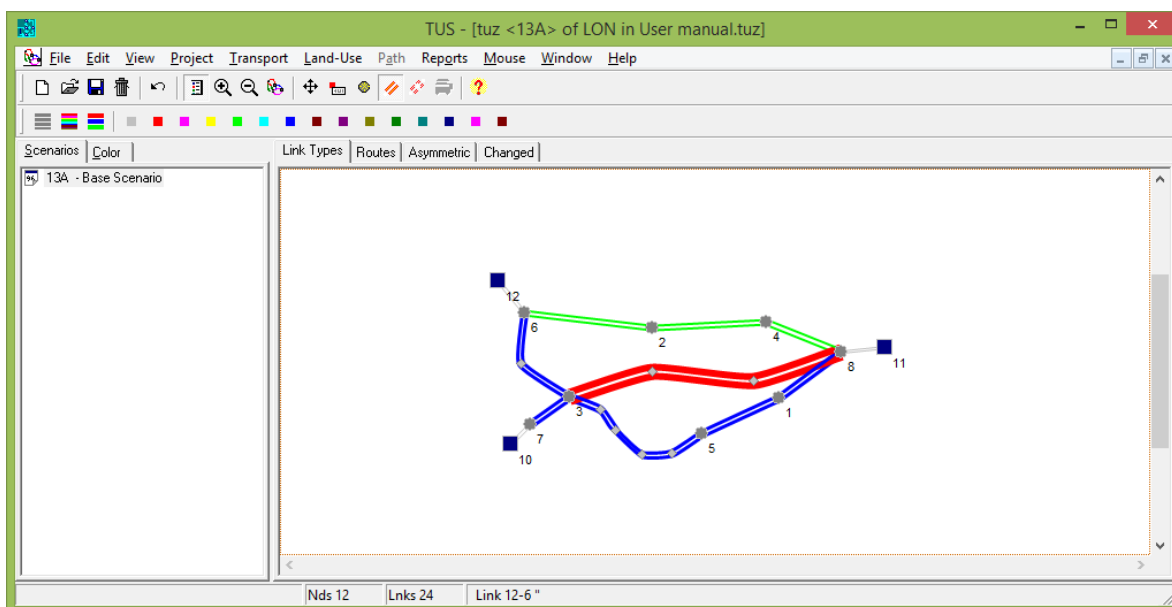
Congratulations! You have successfully coded your first network in TRANUS.

3.2 Using a geo-coordinate base

The network you may have coded in the previous section has no precise geographical references. In most projects, however, you want each node in the right position, and you want curvy links to mimic real roads as much as possible. To achieve this, before you do anything you may import a geo-referenced street file as a background file.

To do this, use menu *View – Background Files*. The following window is displayed:
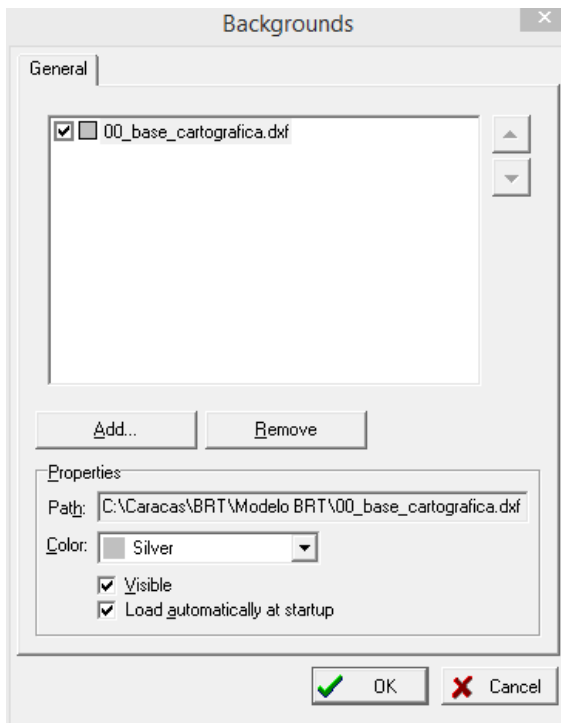
Pressing *Add…* lets you look in your PC files for a .dxf file. This file must have been created beforehand and must correspond to the standard Autocad DXF version 12 text format. Such files may be created straight from Autocad, or by many GIS programs (eg MapInfo). The above menu allows you to select a color (silver usually works fine), and you may check the *Load automatically at startup* box. The latter means that each time you open the TRANUS application file, the .dxf file is also loaded.

With the OK button the background file gets displayed. Id the file is large, it may take a few seconds to load. And then voilà:
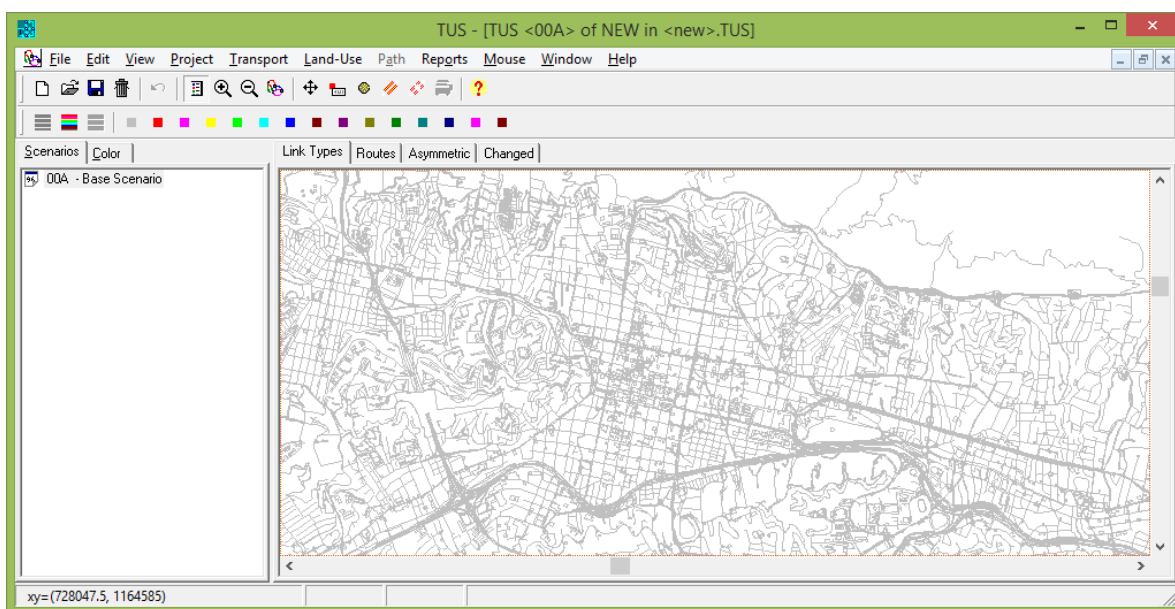
There is now a street map in your window with geographical coordinates. You are now able to use the network editing tools to code the model network on top of this, so that the nodes and centroids and links all get geographical coordinates. At the end you get something like this:
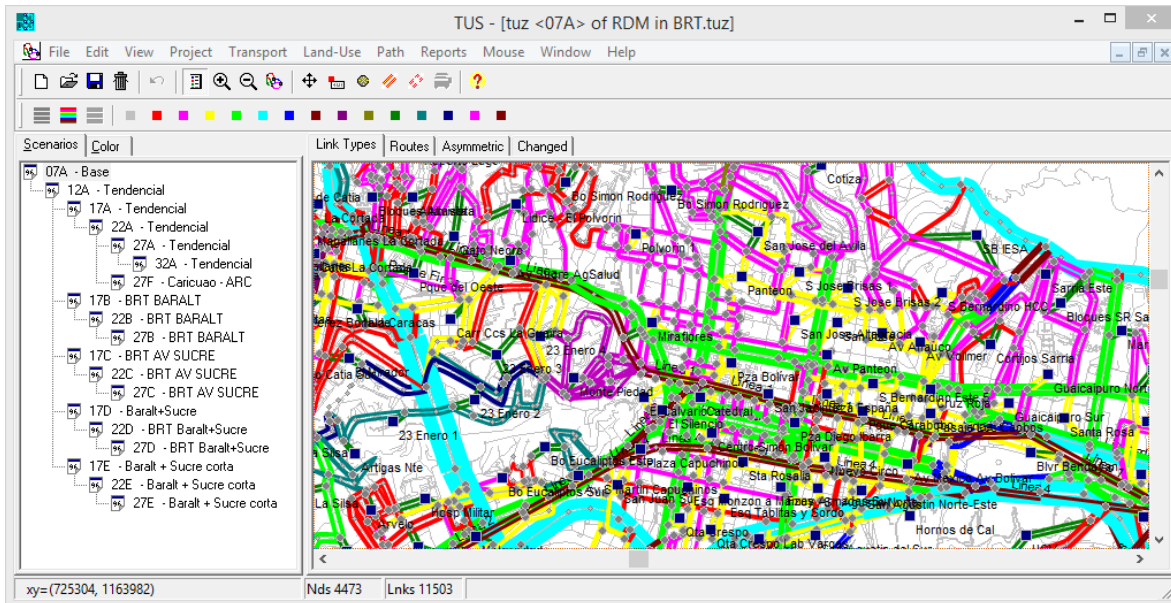
3.3 Importing networks

Another way of coding a model network is to import from another model or a GIS. This is done with the Import/Export utility. A set of comma-delimited files with specific formats is used to import a network. The files follow a sequential logic. For instance, if you want to import a bus route, the sequence of links that the route follows must exist. If you want to import links, the origin and destination nodes must exist. If they don't exist, then the program generates them automatically with (sometimes dangerous) default values. Consequently, it is good practice to follow the sequential logic strictly.

The comma-separated data files are text files that may be created with any text editor or Excel. They have a first record with titles separated by commas, and an unlimited number of data records also separated by commas. The following is the list of files and their content:

Nodes file

The name of the file is *anything.nodes*. One record for each node with the following comma separated fields:

Node Id, X Coordinate, Y Coordinate, Zone Indicator, 'Name', 'Description'

- ▪ **Node Id** is a unique node identification number, a positive integer

- ▪ **X and Y** coordinates of the node (any coordinate system)

- ▪ **Zone Indicator** can take one of three values: 1 if the node is an internal zone; 2 for external zones and 0 for any other node

- ▪ **Name and Description** are optional text fields

Links file

The name of the file is *anything.links*. One record for each link with the following fields:

Link Id, Origin, Destination, Direction, Link Type, Distance, Capacity, 'Name', 'Description'

- **Link Id** is an identifying number of the link

- **Origin** and **Destination** are the Node Id of the nodes that define the link

- **Direction** has one of two values: 1 for one-way links, 2 for two-way links (*)

- **Link Type** is the code or Id number of the link type to which the link belongs (**)

- **Distance** of the link or link length

- **Capacity** of the link in traffic units, normally in standard vehicles per hour or PCU (***)

- Optional name and description as text fields

(*) A two-way link may be coded as two separate one-way links.

(**) Link type = 0 if the link is not used in the scenario

(***) An undefined or infinite capacity is coded as -1.

Routes definition file

This file contains a list of all routes in the network with basic characteristics. A separate file described below contains the itineraries of the routes, that is, the set of links in which the route provides a service. The name of the file is *anything.opers*. The file contains a record for each route, with the following comma separated fields:

Route Id, 'Name', 'Description', Operator, MinFreq, MaxFreq, TargOcc, MaxFleet, Sched

- **Route Id** is an identifying number of the route

- **Name** and **Description** are optional text fields

- **Operator** is the Id number of the operator to which the route belongs

- **MinFreq** and **MaxFreq** define a frequency range from minimum to maximum, usually in terms of number of services per hour

- **TargOcc,** is a parameter that regulates the function that moves the frequency from MinFreq to MaxFreq, usually 0.7

- **MaxFleet,** sets a maximum to the fleet of the route. This is important when heavy congestion takes place, since if speed is reduced, the fleet required to keep the frequency must increase.

- **Sched,** indicates if the route follows a schedule (=1) or not (=0). If the route follows a schedule, then waiting time is equal to the minimum waiting time of the route. If it does not, waiting time is the minimum + half the frequency.

Routes assignments to links or itineraries file

The default name of the file is *anything.routes*. For each route, the file contains a record for each link to which the route is assigned. The file has the following comma separated fields:

Origin, Destination, Route ID, Use

- **Origin** and **Destination** are the node Ids of the of the link the route is assigned to

- **Route Id** is the code of the route in the database

- **Use** is an integer with two possible values: 1 if the route uses the link but cannot stop in it; 2 if the route passes and stops.

Turns file

Contains records to describe possible turn delays or prohibitions in the network. The default name of the file is that of the proyect with extension 'turns' (Project.turns). The file has the following comma-separated fields:

From, Thru, To, Delay

From, Thru, To are the node Ids that identify the turn

Delay is the delay time (if the turn is prohibited, delay = 'INF')

When importing a complete or partial list, consider the following:

- If the list of nodes, links, or routes contains repetitions, that is, records with the same Id number or the same origin and destination numbers, the data of the last occurrence prevails.

- If the list contains an entity (node, link, etc.) that already exists in the Tranus database, the new version being imported replaces the previous one.

- If the list of links contains origin and/or destination Ids that have not been defined previously in the Tranus database to which the data is being imported, they are created with blank names and descriptions and with X=Y=0.

- If the list contains an operator Id that has not been previously defined in the Tranus database, the operator is created with default parameters.

- If the list of routes assignments contains node Ids that have not been previously defined in the database, they are generated with blank names and descriptions and X=Y=0. If the list contains a Route Id that has not been previously defined, it is generated with default parameters and assigned to a new operator.

For the above reasons it is recommended that files are imported in the correct sequence: nodes, links, routes definitions and routes assignments. The lists may be total or partial, and the process of importing the network may be repeated as many times as necessary.

Example of a node file:

```
Id,           X,              Y,Zone,name          ,description
    1,630675.785720862,288154.87025823, 1,ARRAS      ,ZE Artois-Ternois
    2,620557.694331025,311924.239064873, 1,BETHUNE    ,ZE Bèthune-Bruay
    3,547389.638846477,336782.278339217, 1,BOULOGNE SUR MER,ZE Boulonnais
    4,565203.828131204,359779.38854208, 1,CALAIS     ,ZE Calaisis
    5,663966.362618009,273508.480564613, 1,CAMBRAI    ,ZE Cambrésis
    6,652721.057794273,297148.282221281, 1,DOUAI      ,ZE Douaisis
    7,602228.424052828,371288.656508809, 1,DUNKERQUE  ,ZE Dunkerque
    8,614356.351985915,336718.339259375, 1,HAZEBROUCK,ZE Flandre-Lys
    9,633997.884532511,303547.083407994, 1,LENS       ,ZE Lens-Hénin
   10,650542.211599031,325686.260201784, 1,LILLE      ,ZE Lille
   11,716350.481116557,287633.517269533, 1,MAUBEUGE   ,ZE Sambre-Avesnois
   12,554001.720225652,310436.48260798, 1,MONTREUIL  ,ZE Berk-Montreuil
   13,659813.411130523,332409.393485988, 1,ROUBAIX    ,ZE Roubaix-Tourcoing
   14,595326.677381982,338766.675412778, 1,SAINT OMER,ZE Saint-Omer
   15,658467.589039763,336335.198388596, 1,TOURCOING ,ZE Roubaix-Tourcoing
   16,683358.029085202,295453.408968767, 1,VALENCIENNES,ZE Valensiennois
```

Example of a links file:

```
Link Id,Origin Id,Destination Id, Dir, Link-Type Id,  Distance, Capacity,name        ,description
28912587,    1, 4135,  1,   12,      0.4,     -1,      ,
28912386,    1,659199,  1,   12,      0.5,     -1,      ,
    9397,    1,659200,  1,   12,      0.5,     -1,      ,
28912389,    1,659208,  1,   12,      0.5,     -1,      ,
    9050,    2, 1943,  1,   12,      0.5,     -1,      ,
28912441,    2, 2031,  1,   12,      0.5,     -1,      ,
28912443,    2, 4066,  1,   12,      0.5,     -1,      ,
28912431,    3, 3051,  1,   12,      0.5,     -1,      ,
28912427,    3, 4106,  1,   12,      0.5,     -1,      ,
28910622,    3, 4107,  1,   12,      0.5,     -1,      ,
28912421,    3,659609,  1,   12,      0.5,     -1,      ,
28912433,    4, 4080,  1,   12,      0.5,     -1,      ,
28912431,    4,659379,  1,   12,      0.5,     -1,      ,
28912409,    4,659383,  1,   12,      0.5,     -1,      ,
28912407,    4,659411,  1,   12,      0.5,     -1,      ,
28912475,    5, 3612,  1,   12,      0.5,     -1,      ,
```

Example of an opers file:

```
      Id, Name          , Desc                        ,   Oper,  MinFreq,  MaxFreq,  TargOcc, MaxFleet, Sched
      20, TER AUTOCAR    , Douai-Ostricourt/Douai-Lens ,     3,     0.2,      0.2,      0.7,       0, 1
      21, BCD 12         , Boulogne Ville-Calais        ,     3,    0.75,   0.8125,      0.7,       0, 1
      23, TER AUTOCAR 14-1, Arras-St Pol/Ternoise       ,     3,    0.43,     0.43,      0.7,       0, 1
      26, TER AUTOCAR 15, St Pol/Ternoise-Béthune       ,     3,     0.1,   0.1875,      0.7,       0, 1
      27, TER AUTOCAR 16-1, Valenciennes-Lille Flandres ,     3,   0.125,    0.125,      0.7,       0, 1
      28, TER AUTOCAR 16-2, Jeumont-Aulnoye Aymeries    ,     3,  0.1875,   0.1875,      0.7,       0, 1
      29, TER AUTOCAR 17, Anor-Aulnoye Aymeries         ,     3,     0.1,    0.125,      0.7,       0, 1
      30, TER AUTOCAR 19, Lourches-Somain               ,     3,     0.1,      0.1,      0.7,       0, 1
      31, TER AUTOCAR 20, Cambrai-Valenciennes          ,     3,  0.3125,   0.5625,      0.7,       0, 1
      33, TER AUTOCAR 22, Busigny-Cambrai               ,     3,     0.1,      0.1,      0.7,       0, 1
      34, TER AUTOCAR 23, Lens-Sainghin                 ,     3,  0.1875,   0.1875,      0.7,       0, 1
      36, BUS DOUAI 2    ,                              ,     2,       4,        4,      0.7,       0, 1
      38, BUS DOUAI 3    ,                              ,     2,       3,        3,      0.7,       0, 1
      39, BUS DOUAI 4    ,                              ,     2,       3,        4,      0.7,       0, 1
      40, BUS DOUAI 5    ,                              ,     2,       2,        2,      0.7,       0, 1
      41, BUS DOUAI 6    ,                              ,     2,       3,        3,      0.7,       0, 1
```

Example of a routes file:

```
  From,     To,  Route, Code (0=not Used,1=Passes,2= Stops)
659260,   1950,    20,    2
  1950,   1951,    20,    2
  1951,659268,    20,    1
659268,   1952,    20,    1
  1952,   4161,    20,    2
  4161,659332,    20,    2
659332,   4163,    20,    2
  4163,   4162,    20,    2
  4162,   1953,    20,    2
  1953,   1954,    20,    1
  1954,   1955,    20,    2
  1955,   4160,    20,    2
  4160,   1956,    20,    1
  1956,   4159,    20,    2
  4159,658804,    20,    2
658804,   4143,    20,    2
```

Example of a turns file:

```
From, Thru, To, Delay
658964, 658974, 658971, INF
658974, 658964, 658971, INF
```

3.4 Importing a network from a GIS

4 Designing the application

In this chapter we discuss the important issue of the design of the model application. TRANUS has a very flexible design. It is the modeler that actually defines the structure of the model, that is, the main components and their relationships.

4.1 Integrated or transport-only application

The first question in designing a model is whether it is going to be a fully integrated land use and transport model or if it is going to be a transport-only application. TRANUS allows both. The following figure illustrates the difference between them.
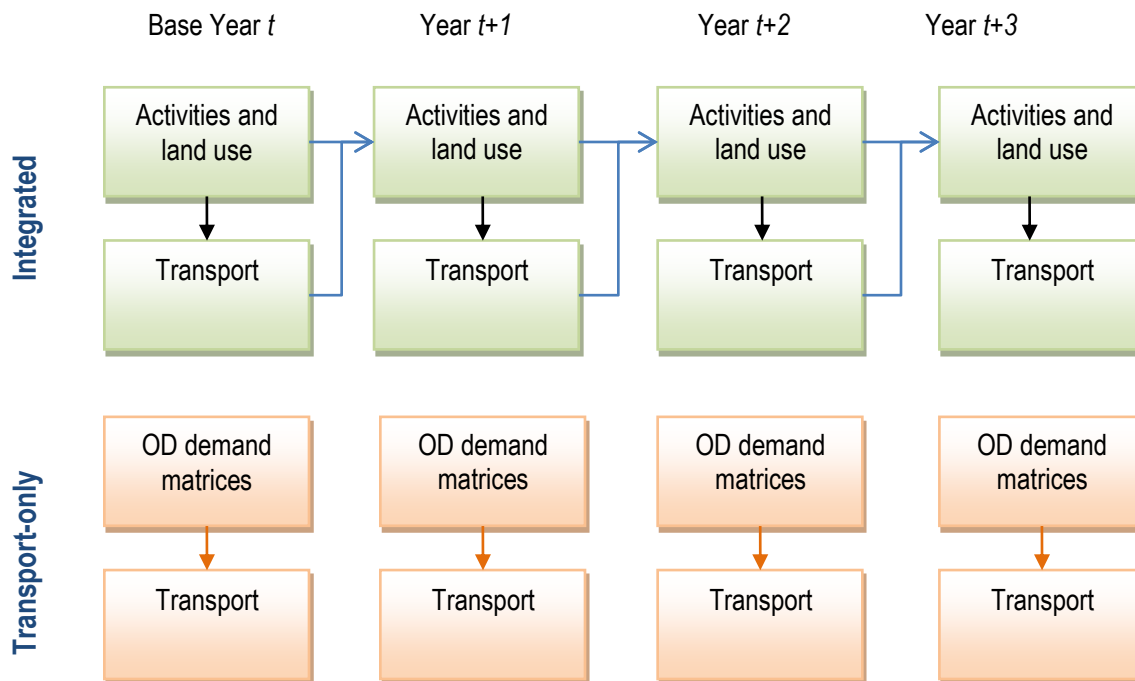
A fully integrated application has many advantages. Transport demand is calculated on the basis of the spatial interaction between activities, so that the results are consistent with information on the location of households, of firms, services, and land use. Travel, whether of people or goods, is explained on the basis of the economic activities that give rise to travel demand. In turn activities interact with the land market. Similarly, transport is a fundamental component in the location of activities. As a result, the use of an integrated application is a guarantee of sound results. Furthermore, it is the basis for long-term projections (20 to 30 years).

A transport-only application may be easier to implement, since there is no need to collect data on activities and land use. Also, the calibration of the location and land use model requires a significant effort, as will be seen later. This is why when a quick study is required and little resources are available, then a transport-only application may be the only way out.

Note that there is an important difference in the way time periods are related. In the integrated scheme, in each time period the location of activities affects the transport system. In turn, the transport system affects the location of activities, but in a following period. Also the location of activities in one period affects the next one. This is indicated with arrows in the diagram. This means that there is a dynamic structure between location and transport, in which each period is affected by the previous one, and generates inputs for the next period. This also means that the models must be run in a specific sequence. In the transport-only scheme each time period is completely independent from the rest, and the models may be run in any sequence.

In order to run the transport model without land use, however, a set of origin-destination trip matrices must be provided, certainly not a trivial matter. In large scale models, such as regional or national, it is not too difficult to estimate origin-destination trip matrices from road-side interviews. The transport model is then used to complete and correct the estimates against traffic counts. This process is made easier because the networks are relatively simple, offering not too many travel options. In several countries such origin-destination estimates are readily available.

An urban or metropolitan area is quite a different matter. The network is extremely dense, with many options and a fine mesh of possibilities. This turns road-side interviews worthless, except perhaps for regional access highways. But the possibility of building a set of origin-destination matrices from road-side interviews is definitely off. This is why researchers have turned to home interviews, asking for the origins and destinations of trips.

Home interviews, however, suffer from a fundamental sampling problem. Such surveys are based on 0.5% to 1% samples. For a city of 3 million, this means that the survey will be in the order of 20 thousand. If the study area is divided into, say, 600 zones, and you want demand by 3 socioeconomic categories of travelers, and 3 trip purposes, and 2 modes, then our survey of 20 thousand households should fill in 600 x 600 x 3 x 3 x 2 = 6.48 million cells, clearly an impossible task. Sampling theory will say that the error is undetermined. Needless to say, home-based surveys are very expensive.

In the traditional four-step modeling structure, trip matrices are estimated with the combination of the trip generation step with the trip distribution step, and this remains a possibility in TRANUS. You may use this method externally in a spreadsheet, taking the matrices of travel disutilities calculated by the transport model of TRANUS. Later on in this guide the way in which you enter the resulting trip matrices into the model will be explained.

Usually trip generation models relate trip productions or origins with the number of households or people in each zone of certain socioeconomic types, and relate trip attractions to jobs and services. Then trip distribution builds the trip matrices by combining trip productions and attractions with travel disutilities. You can do precisely this with the land use model and automate the process. After all, you need more or less the same information.

Under such circumstances, the land use model, integrated with the transport model, is a definite solution. The idea is that a small survey is carried out to estimate some basic parameters, and then the land use model is calibrated, providing the inputs to the transport model. The transport model

is further adjusted against traffic counts and thus you get your final origin-destination matrices. These are synthetic, simulated matrices that are the closest estimate we can have. The land use model is the best way to estimate travel demand into the future.

The following points may be concluded from this analysis:

a) Make an integrated land-use and transport model application whenever possible. It will always be better than a transport-only application.

b) In urban/metropolitan applications, insist on an integrated scheme, unless you really believe that you have reliable origin-destination matrices <u>and</u> you are not interested in medium-long term projections.

c) For regional applications with low-density networks, it is possible to build a transport-only application based on road-side interviews adjusted against traffic count.

4.2 Zoning

The study area must be divided into zones, an important decision to be made at the beginning of a study. The number of zones has many effects on the modeling process. It is a common belief that lots of zones make a better model. This is not necessarily true, since a lot depends on the quality of the information. The error in smaller zones is larger than in big zones. Some variables are more reliable than others. For instance, population is reasonably accurate for small zones because it usually comes from census data. Employment by zone is far less reliable, and the number of trip origins and trip ends is even less.

A large number of zones has some other implications. Running time increases exponentially, although this is less and less of a problem with the increase in computer power. RAM and disc space ceased to be a problem. Nowadays the biggest problem arises when the modeler has to analyze the outputs of the model, checking for possible errors or inconsistencies, a time-consuming task that also grows exponentially with the number of zones.

Another element to consider is the fact that the transport model in TRANUS is multimodal, multipath and probabilistic. This is superior to the user equilibrium paradigm in many ways, and one of the advantages is that it requires fewer zones, that is, it can produce realistic results with larger zones. Consider the example in the Figure below. The top diagram shows two large zones connected by three paths a, b and c. If the network is not heavily congested, a user-equilibrium assignment model will assign all traffic to path a, leaving b and c empty. This is probably not the case in relatively dense urban areas with activities scattered all over the zones. Because the results are not realistic, user-equilibrium modelers have to define much smaller zones like the second example below. The probabilistic assignment model in TRANUS does not have this problem, because even if the network is not congested it will spread traffic on the three paths available. This is why many transport analysts believe that a good model application must have many many zones, and are hard to convince that TRANUS can do a good job with fewer zones.

Simple network to illustrate the problem of few zones in user-equilibrium assignment models
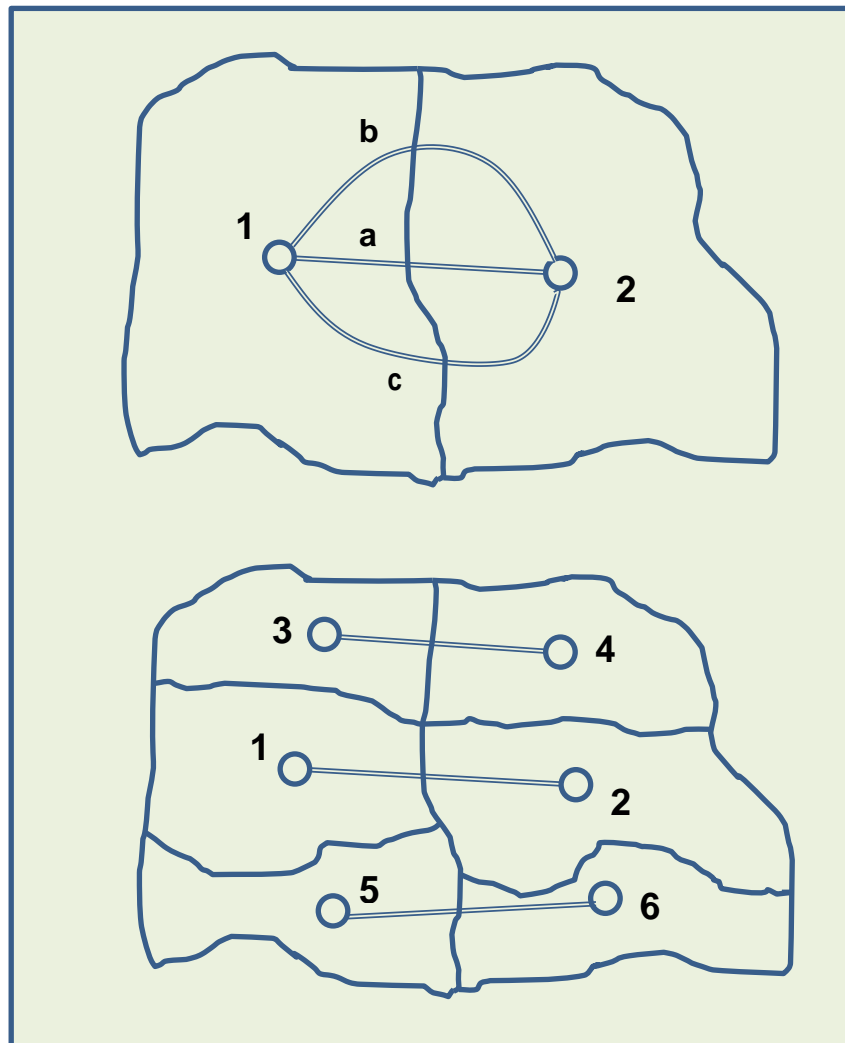
There is no fixed rule about how many zones a model should have, since a lot depends on the density of the area and also on the purpose of the study. An urban model will typically have in the order of 100 zones per million inhabitants, more if the area is dense, less when activities are sparsely located. Naturally zones will be smaller in the center and bigger in the periphery. In a regional application, where the network is simple and the interest is in intercity trips, zones may just represent whole cities and towns.

Zones don't have to cover the whole territory and might have islands (such as satellite towns) and lakes (such as big parks).

Zones may have any combination of activities within them. For instance, you may have a zone with a residential estate, an industrial area and a big shopping center. The land use model has no

problem in dealing with such diversity. What is required, though, is than all parts of the zone are *homogeneous with respect to transport*, that is, they share the same transport facilities.

The following diagram illustrates this. There are two villages, one connected to the network with a big highway, and another with a minor road. In a) this is represented with one zone and the fact that one zone is better connected, is lost. In b) we have two zones, making a better representation of reality.
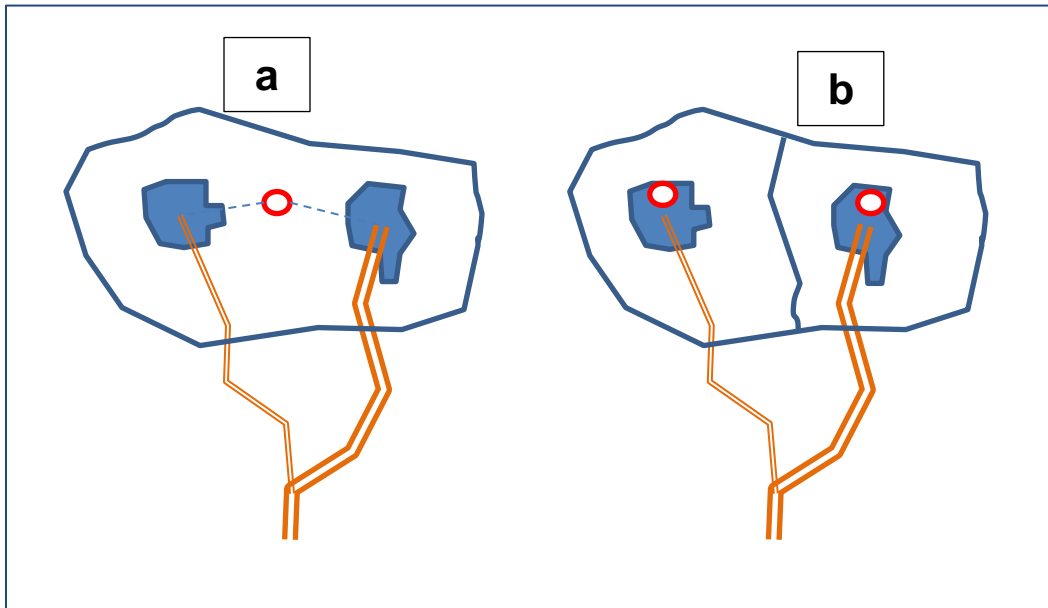
The model also distinguishes between *internal* and *external* zones. The activity model makes a very important distinction, because external zones are used to represent imports and exports. Imports are represented as production that takes place outside the study area and is brought into the study area through external zones. Production assigned to an external zone does not generate induced production in other sectors and zones: the production/consumption chain ends there. By contrast, exports are exogenous demands in external zones that must be satisfied by internal production. In other words, this is where the internal production/consumption chain begins.

External zones are optional. The way in which external zones are defined in the software is explained later on.

4.3 Socioeconomic sectors and transport categories

In the activity and land use model, the economy is divided into *socioeconomic sectors* of various types. In the transport model, demand may be divided into *transport categories*. In an integrated application sectors and categories are combined.

4.3.1 Socioeconomic sectors

In TRANUS the basic concepts of the input-output model have been generalized and extended. The term '*sectors*' is much broader than in the traditional model, because it allows the representation of the various productive sectors of the economy (agriculture, manufacturing, mining, government, etc.), factors of production (capital, land, labor), as well as groups of population, land, buildings, and so on, that make up the spatial-economic system. The number and type of sectors are defined according to the requirements of each application, as well as the most convenient units in which they are represented. This makes it possible to adapt the model to urban or regional applications, and to local cultural peculiarities. In the TRANUS graphical interface, sectors are defined in menu Land Use – Sectors.

Types of sectors

A first distinction must be made between transportable and non-transportable sectors. The main difference is that transportable sectors may be consumed in places different from where they are produced. The demand for coal by a steel industry, for instance, may be satisfied by coal mines located in other regions, and transported from the production zone to the consumption zone. Labor in a certain sector of a city may be provided by residents that live in other places, thus generating flows of people.

The most typical example of non-transportable sectors is land and buildings. The main characteristic is that these sectors must be produced and consumed in the same place. Houses, factories, office buildings and shopping malls cannot be transported. Only activities and products may be transported.

As a consequence, transportable sectors generate flows of people or goods, and these flows may generate demand for travel. Such flows require transport services or facilities, thus imposing transport costs to the productive system. By contrast, non-transportable sectors do not generate flows and do not require transport services.

The model identifies a transportable sector when the production distribution parameter > 0.

Another important distinction is made between exogenous and induced sectors:

- **Exogenous Sector** when all of its production is exogenous, that is, is demanded outside the economic system being modeled. The model identifies such sectors because it finds that in the intersector relations, no other sector is consuming it. Thus, an exogenous sector does not generate flows.

- **Transportable Induced Sector** where all or part of the production is consumed by other sectors. Such sectors generate flows.

- **Non-transportable Induced Sector** in which consuming sectors are in the same zone of production, because the production of these sectors cannot be transported. Consequently they do not generate flows.

An induced sector may have part of its production induced by other sectors, and part exogenous. The following table summarizes the types of sectors:

Type of sector	Description	¿Who demands it?	¿Generates flows?	Distribution parameter
Exogenous	Demand is entirely outside the economic system	No other sector	no	= 0
Induced transportable	Demand for this production is totally or partially within the economic system	Other sectors	yes	> 0
Inducido non-transportable	Demand for this production is totally or partially within the economic system	Other sectors	no	= 0

It is also possible to define sectors that do not consume anything and are not consumed by any other sector. They are just there to serve as an attractor to other sectors.

4.3.2   Intersector relationships

Sectors must be linked together through demand functions and attractors. Demand functions may be elastic or inelastic (coefficients). To the model, all demand functions are elastic, only that some have an elasticity = 0. Here we deal with demand functions. This must be defined at a design stage of the modeling process.

A simple case

Let us begin with the simplest structure: a Lowry model. We define three sectors: basic employment, population and service employment. Basic employment is an exogenous sector that consumes population. Population in turn consumes services, and services also consume population. Assume that there are 1,000 jobs in the basic sector, 1,500 in the service sector and population is 7,250. This means that there are 2,500 jobs in total, which gives a ratio of 2.9 persons/job. The ratio of service jobs per person would be approximately 0.207. This may be expressed in terms of an input-output table as follows:

Sectors	Basic Employment	Population	Service Employment
Basic Employment			
Population	2.9		2.9
Service Employment		0.207	

Columns represent consuming sectors and rows represent producing sectors. For instance, each basic employment consumes 2.9 persons, and so on.

To represent this in the model, we first define the sectors in the Land Use-Sectors menu:

We have defined the three sectors. Note that the parameter 'Elasticity' that represents the logit dispersion parameter for the distribution of production is 0.0 for Basic Employment, 0.8 for Population and 1.2 for Service Employment. This is because Basic is and exogenous sector, while the others are induced transportable.

The intersector windows would look like this:
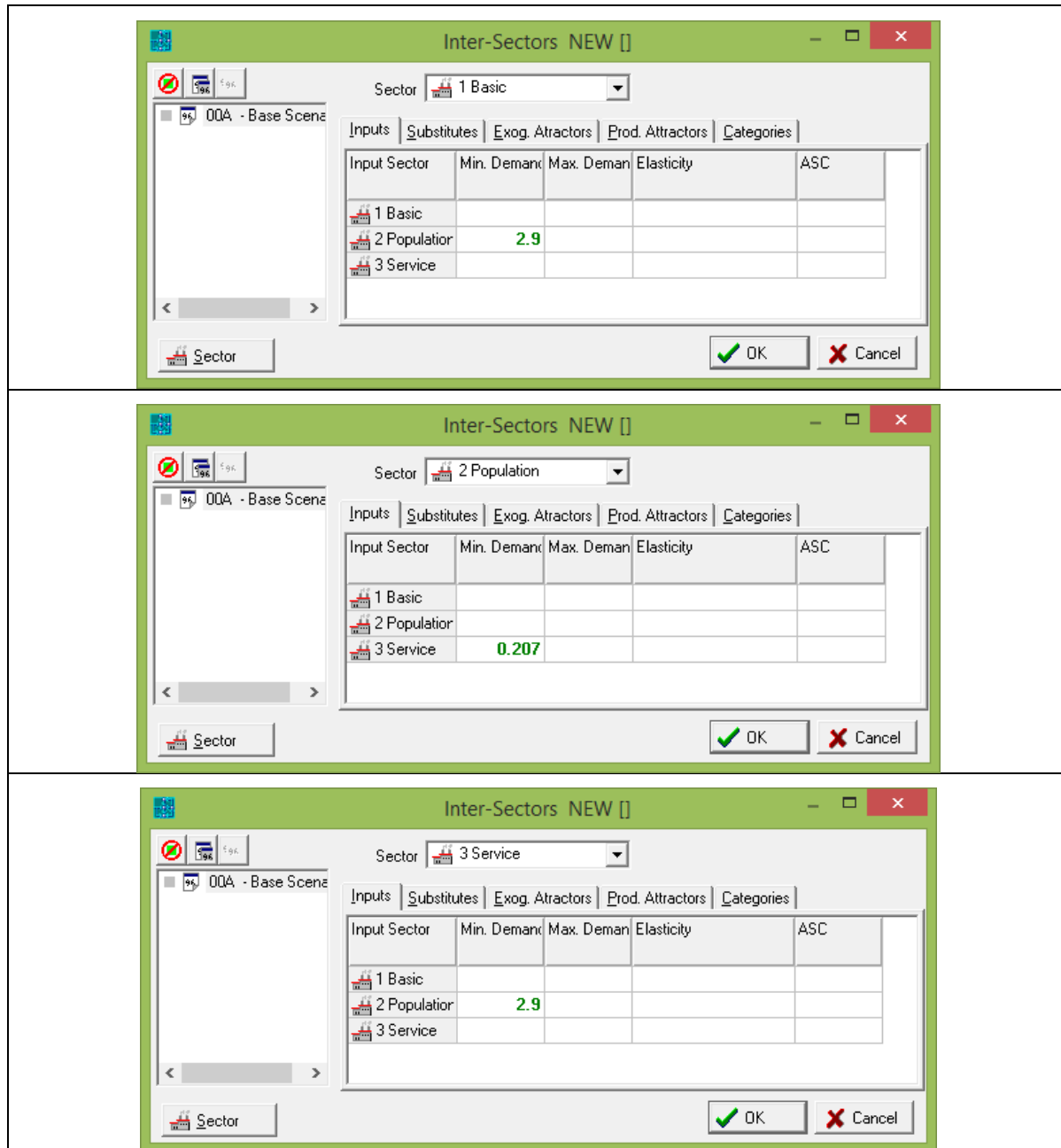
Because the demand for population and services is inelastic, it is only necessary to specify Minimum Demand. The program assumes that if Max Demand and Elasticity is zero, then the

function is inelastic. Finally the Land Use-Economic Data windows, assuming we have four zones and a spatial distribution of production, would look like this:

The sum of production over all zones matches the original totals. Note that in the case of Basic Employment the figures are under the column 'Exogenous Production', while population and service employment are under 'Base Production' (should be 'Induced Production'). If the model is ran, the starting point will be the exogenous production of basic employment. Applying the demand coefficients, the model calculates the induced production of population and service employment.
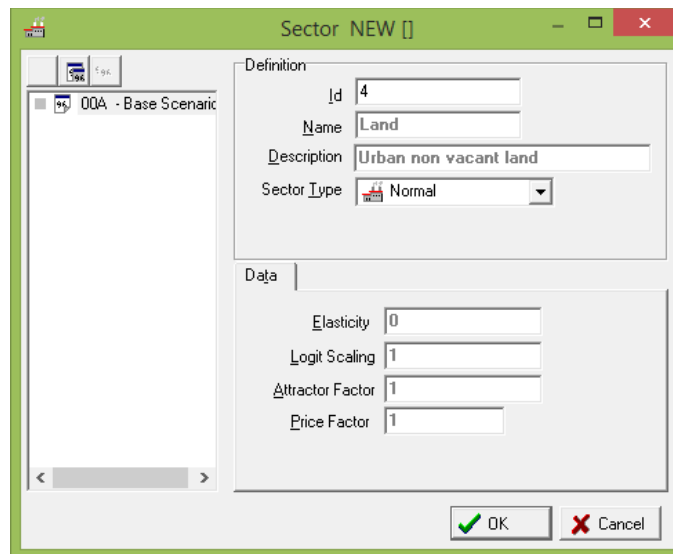
For the spatial distribution of induced production, however, an attractor function must be defined. Because the attractor multiplies the utility function, it cannot be zero. The easiest way to define an attractor for the distribution of induced production is to specify that each sector attracts itself. This is indicated in the Intersector menu – Production Attractors. We only need to specify these for the induced sectors population and service employment.
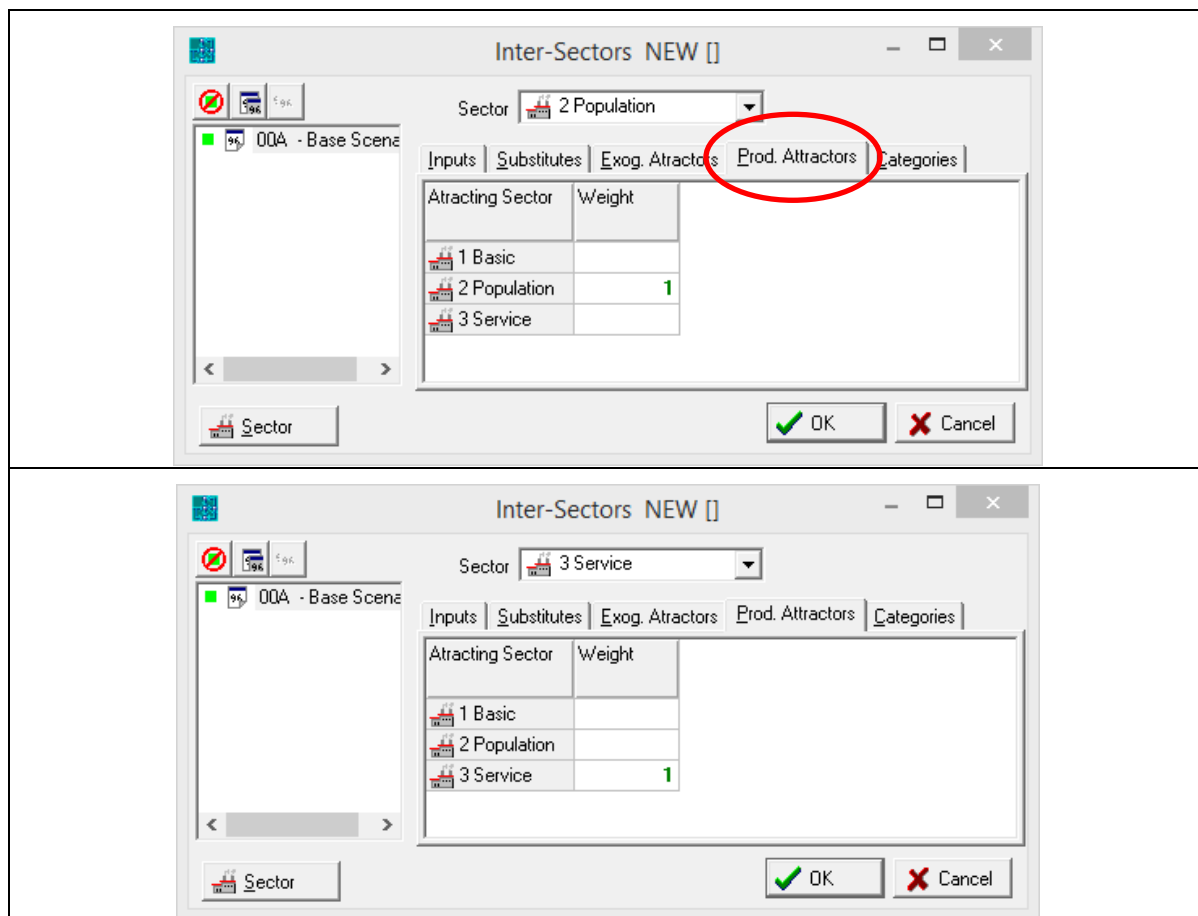
Introducing a non-transportable sector

We can add to this model a non-transportable sector such as land, and we can specify that activities consume land with elastic demand functions. The sector definition window for land would be:
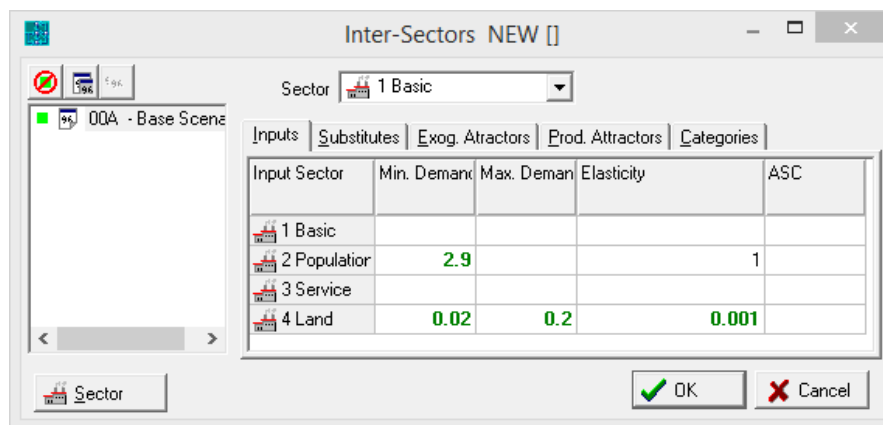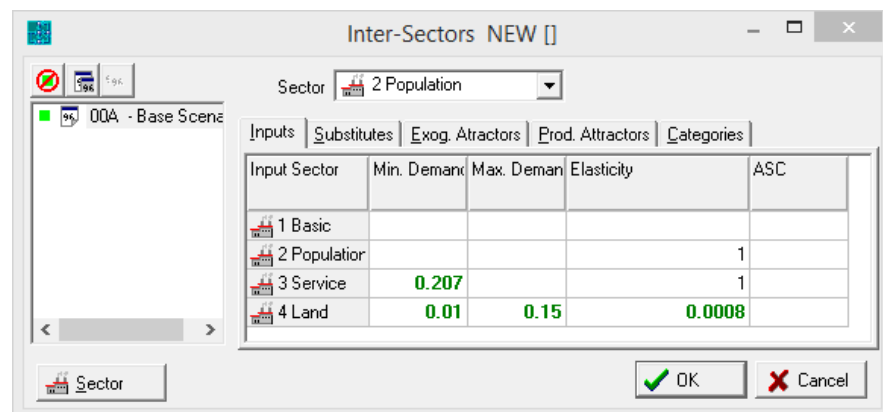
Because land is non-transportable, the 'Elasticity' parameter must be zero. The intersector window for land consuming sectors would look as follows:

For instance, service employment consumes a minimum of 0.008 hectares of land, a maximum of 0.12 with elasticity 0.0015. Depending on the price, consumption per job will be somewhere in between the maximum and minimum. The Inputs window for land is empty, because does not consume anything. Because land is not transportable, there is no spatial distribution and consequently it does not need an attractor.

The elastic demand functions range from the maximum when the price is zero to the minimum when the price is very high. With the data described above, the three demand functions for each consuming sector are as follows:
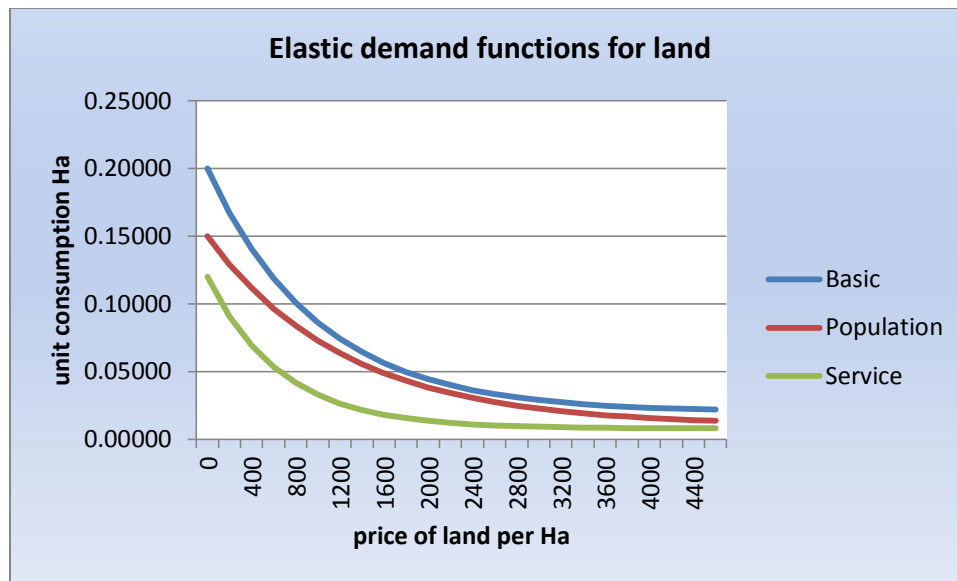
Finally the Economic Data window for land could look like this:

In this example in zone 1 there are 31.6 hectares of land at a price of 4000. The model doesn't know really the units in which land and prices are represented. The model user may choose whatever units seem most appropriate, provided it is consistent throughout. If land is in hectares, then the price must be $$$ <u>per</u> hectare. Land may be in hectares, m2, acres, etc. Note that in the table the amount of land in each zone is under Base Prod because it is an induced sector. The values are repeated under Min Prod and Max Prod because this sector is constrained. The price goes under the Base Price column, and is repeated under Value Added to help in the convergence of the model.

Using Excel and Solver to fine-tune the demand coefficients

Here is a short note on how to use Excel and Solver to fine-tune the inelastic demand coefficients. The first thing to say is that the totals of production in each sector depend on the accuracy of the intersector demand coefficients. A small difference in a sixth decimal may result in a difference of a few hundred people in a particular socioeconomic group, and this, in turn, may make convergence more difficult.

It could also be that the data that we have is not very accurate. For example, the distribution of population by socioeconomic group is only an approximation with few decimal points. Also, when population is split into socioeconomic categories, we have to relate each category to a particular service sector like retail. All we have is the total number of people in each socioeconomic group, and the total number of retail jobs. If we divide total retail jobs by the sum of total population, we may get an accurate coefficient. But we know that high-income population spend more in shopping, and thus generate more retail jobs compared to low-income population. You may even have a survey that estimates that high-income spend twice as much. You want to adjust the coefficients to reflect this, but obviously when you put everything into the model you don't get the correct totals. Also, a small difference in retail will results in another difference in consuming sectors, so that the error spreads out throughout the chain.

To solve this, the best thing to do is to put totals of production for each sector and the coefficients in a spreadsheet in a convenient form. Consider the following example:

	Sector 1	Sector 2	Sector 3	Sector 4	Calculated totals	Difference
Sector 1			a(1,3)	a(1,4)	X1'	Δ1=X1-X1'
Sector 2			a(2,3)	a(2,4)	X2'	Δ2=X2-X2'
Sector 3	a(3,1)	a(3,2)	a(3,3)		X3'	Δ3=X3-X3'
Sector 4	a(4,1)	a(4,2)	a(4,3)		X4'	Δ4=X4-X4'
Known totals	X1	X2	X3	X4		

Again, columns represent consuming sectors and rows represent producing sectors. Sector 3 consumes Sector 1 with a coefficient of a(1,3). In other words, each unit of Sector 3 consumes a(1,3) units of Sector 1. If we multiply the total production of Sector 3 by a(1,3) we get total production of Sector 1 induced by Sector 3. But Sector 4 also consumes Sector 1, with a coefficient of a(1,4). At the end total production of Sector 1 will be:

$$X1' = X3 * a(1,3) + X4 * a(1,4)$$

But we know that the production of Sector 1 is X1. Because the coefficients a(1,3) and a(1,4) are not necessarily accurate, the calculated totals might not be precisely equal to known totals. The difference could be Δ1=X1-X1' a positive or negative value.

To make Δ1=0 we recommend using the Solver utility that comes with Excel (make sure you have it installed). The main window of Solver has one place called *Set Target*. This is where we select the cell where Δ1 is. We then specify that we want this value to be 0.0. Next Solver has another place called *By changing cells* where you select the cells that contain a(1,3) and a(1,4). You might want

to specify as restrictions that the resulting values of a() should be positive. When you press the button *Solve* you get the adjusted values of a(). You can then copy and paste these values into the Inter Sectors window in TRANUS.

4.3.3   Substitutions

What we have seen above are direct production-consumption relationships, in which A consumes B and B consumes C and so on. Substitutions represent a more complex relationship, because it represents a case in which A may choose between consuming B, C or D for the same purpose. Because we are representing an aggregate case, we say that A will distribute its consumption among B, C and D in certain proportions. The result is a logit-type distribution with utility functions. We call this *substitutions*, because B, C and D are substitutive production with respect to the consumption of A. If, say, the production of C becomes more expensive, then A may choose to consume less of C and more of B and D.

In most cases substitutions are used to represent land markets. A household may consume high-density residential land, low-density residential land or mixed land. To represent this in the model, substitutes must be declared. In the previous example, instead of having a single type of land, we introduce 3 types: industrial, mixed and residential. We will assume that basic and service employment may consume industrial and mixed, while population may consume mixed and residential. In this case the Sectors windows will look like this:
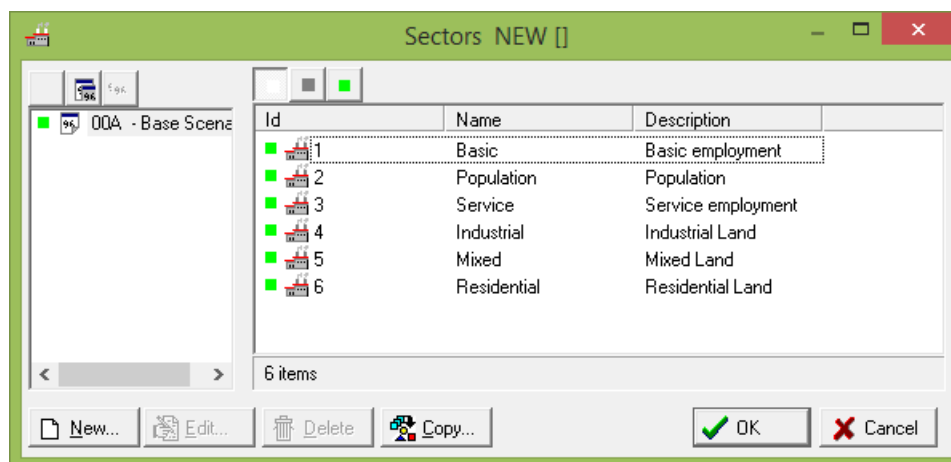
Next we add the demand functions to each land-consuming sector and define the substitutions in the Intersector windows:

In the case of service employment, for instance, a unit job may consume a minimum amount of 0.008 industrial land with a maximum of 0.12 and an elasticity of 0.0015. In the Substitutes tag, the Elasticity parameter corresponds to the logit model used to calculate de choice probabilities (1.1). The parameters associated with each land sector correspond to penalties, with Industrial = 1.5, Mixed = 1 and Residential = 1.8. This means that service jobs prefer mixed land, then industrial land and residential land as the least liked.

The Economic Data window must incorporate the data for the three types of land, that is, quantities and prices in every zone.

Possible configurations

The model that we specified above may be represented in a diagram:
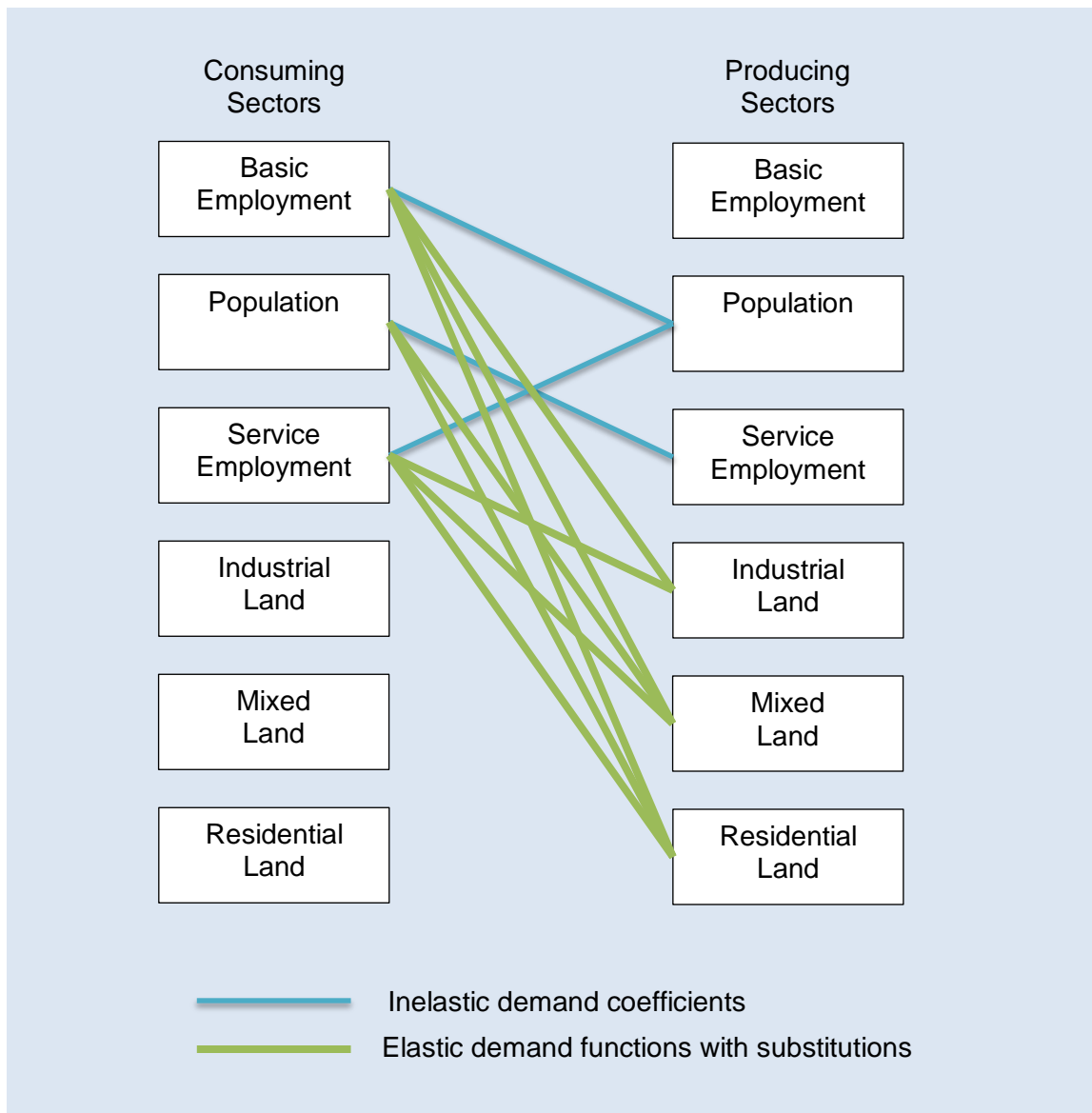
The above scheme would be a typical urban model. Most applications split population into at least three socioeconomic groups, and the service sector in three or four types. In these schemes, activities are consuming land directly, with elasticities and substitutions. In the model of Swindon (see the fully documented model in www.tranus.com) Floorspace categories were introduced in between activities and land. Households of several types, consume floorspace such as detached, semidetached, terraces and flats. In turn, each floorspace type consumes land of several types, such as mixed, low-density residential, high-density residential, and so on. In fact, the model allows for the representation of quite complex real estate systems.

In regional applications tend to follow the classical input-output scheme, in which production is divided into sectors such as agriculture, mining, manufacturing, private services, and so on. Imports and exports are explicitly represented. Production may be represented in money terms, or physical units (Tons). Then employment of several types may be generated from the producing sectors, and in turn, employment may consume population. Land may be incorporated for the representation of agriculture and forestry. Examples of these applications will be seen later on.

4.3.4   Production attractors

4.3.5   Transport categories

4.3.6   Relationship between sectors and categories

4.4 Modes, operators and routes

4.5 Link types and administrators

4.6 Public transport routes

4.7 Coding the multimodal transport network

4.8 Integrated tariffs

4.9 Exogenous trips

5 Calibration

5.1 Path building

5.2 Initial assignment

5.3 Intersector coefficients

5.4 Elastic demand functions

5.5 Distribution of production

5.6 Trip generation functions

5.7 Adjusting modal split and assignment

6 Projections

6.1 Definition of scenarios

6.2 Macroeconomic projections

6.3 Projecting transport variables

6.4 Running scenarios and reporting results

7 Evaluation

7.1 The evaluation procedure in TRANUS

7.2 Users' benefits

7.3 Benefits to producers

7.4 Table of costs and benefits: B/C, TIR y VAN

7.5 Emissions