Appendix A1: Land Use Model Methodology

Top-down Approach to obtain Employment and Demographic Projections for the Maryland Statewide Transportation Model

1 INTRODUCTION

This section describes the methodology to obtain economic and land use (employment and demographic) projections needed for the Maryland State-wide Transportation Model (MSTM). In general there are three separate steps in the approach.

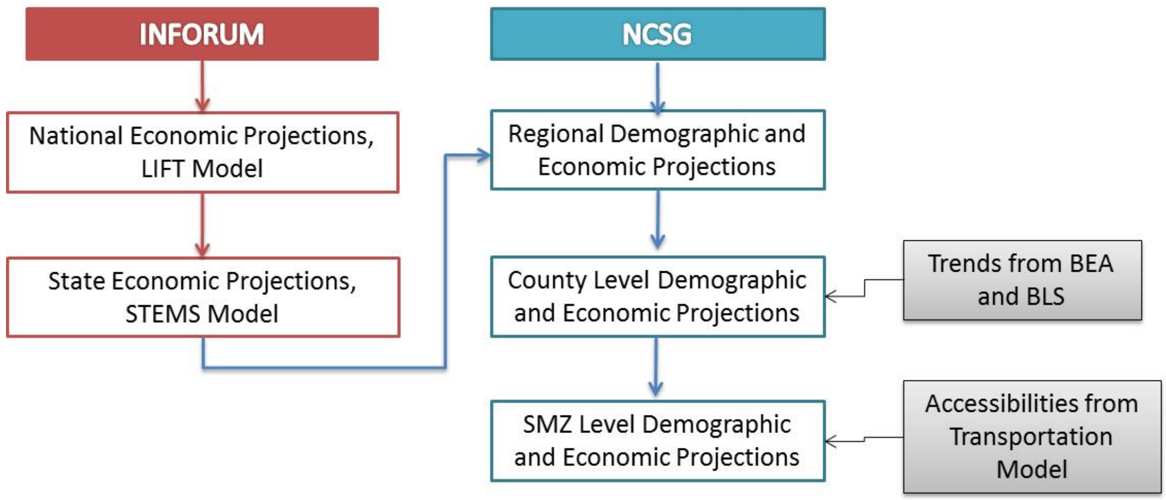
First, national and regional economic forecasts are generated from an econometric model.

Second, the econometric model results are disaggregated to the county level for those counties included in the person and truck travel modeling area (the middle tier of the State-wide Travel Demand Model), relying on econometric relationships estimated from historic data.

Third, these county level projections are further disaggregated to state-wide modeling zones (SMZs) using a spatial allocation model.

The three stages of employment and demographic projection technique is presented in Figure A-1. Each of these three steps is explained in the following sections. In addition, summary of the methodology and linkages with the transportation model is discussed in the conclusion section.

Figure A- 1: Schematic of the Employment and Population Projections



2 National and State Projections

The national and state level forecasts are obtained from a Computable General Equilibrium (CGE) Model, which combines an inter-industry (input output) formulation with extensive use of econometric techniques. The specific model is the Long-term Inter-Industry Forecasting Tool (LIFT), developed by INFORUM, an economic research center at the University of Maryland. LIFT provides the capacity to analyze the impact of macro economic variables such as interest rates, exchange rates, trade policies and unemployment on various plausible futures. The schematic of the LIFT is presented in Figure 2. The outputs generated from this model are employment and production across 97 sectors of the national economy.

The demand/production block of LIFT uses econometric equations to predict the behavior of final demand (consumption, investment, imports, exports, government) at a detailed level. Then, the detailed predictions for demand are used in input-output production identity to generate gross output (total revenue adjusted for inflation). LIFT's approach to projecting industry prices is similar. Behavioral equations estimate each value-added component (e.g., compensation, profits, interest, rent, indirect taxes) for each industry. Value added per unit of output is then combined with the prices of intermediate goods and services with the input-output price identity to form an indicator for industry prices. Prices by industry are also dependent on measures of slack in each industry, and, in some cases, international prices. Thus, income and prices are directly related and are consistent. In turn, relative price terms and income flows are included as independent variables in the regression equations for final demand, creating a simultaneity between final demand and value-added.

The results from the LIFT model are then input into the State Employment Modeling System (STEMS), also developed by INFORUM. By considering basic and non-basic sector employment types and personal income, STEMS allocates the national forecasts to states. The employment and gross state product sectoral detail of the outputs from the STEMS model is presented in Table A-1. STEMS works mostly in a top-down fashion, using employment growth in industries at the national level to derive employment growth at the state level. However, industries are along a spectrum of 'basic' and 'non-basic'. Basic industries are considered to have a national market, and so are driven entirely by the forecast by the INFORUM LIFT model of growth of employment at the national level of the same industry. Non-basic industries are considered to have a purely local market, and are driven by the estimates of personal income in that state, which is generated endogenously by STEMS. Most industries fall somewhere in between. For example, if a certain industry is assigned a basic coefficient of 0.8, this means that its growth is determined 80% by national industry growth, and 20% by state personal income growth. The resulting state forecasts provide the benchmark projections for the county-level disaggregation and population projections as described in the next section.

Figure A-2: Schematic of LIFT Model

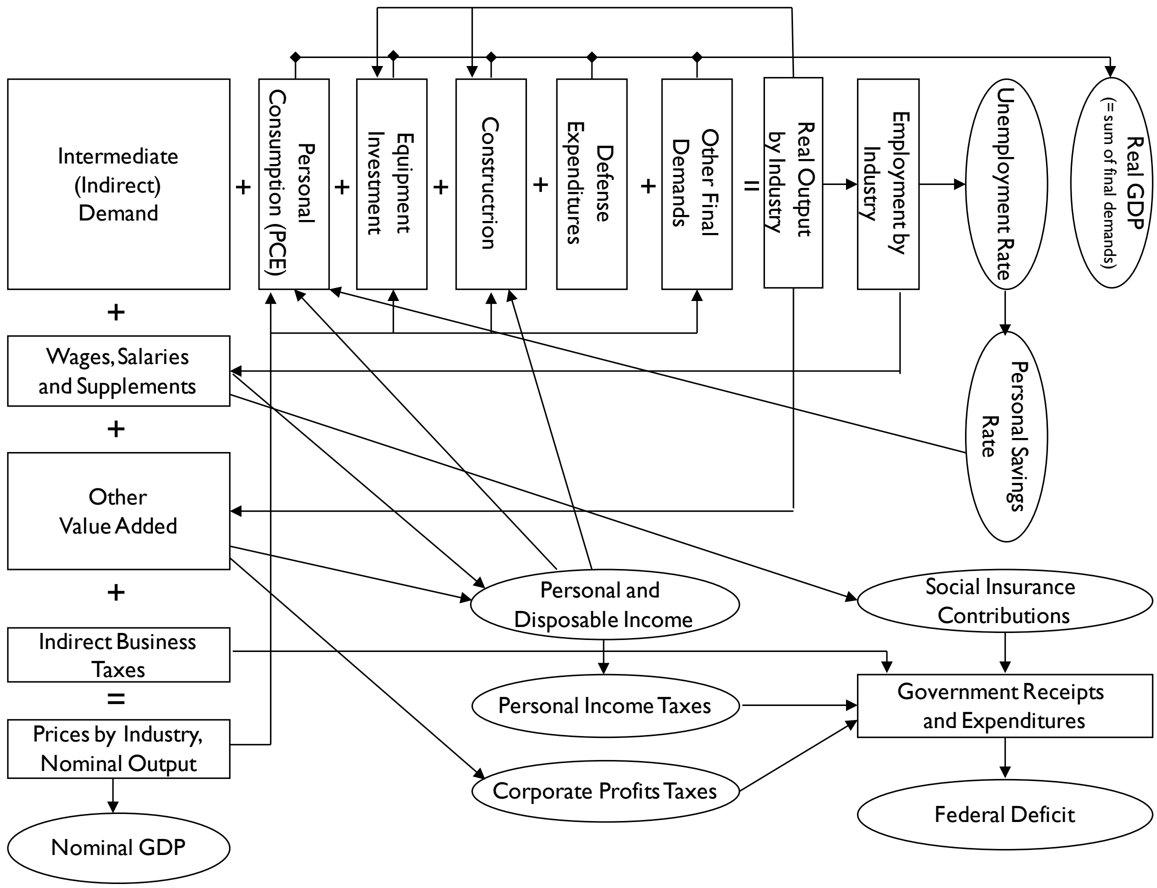


Table A-1: Sectoral Detail Ouput from Inforum's STEMS model

Sl.	Sector
1	Farms
2	Forestry, fishing, and related activities
3	Oil and gas extraction
4	Mining, except oil and gas
5	Support activities for mining
6	Utilities
7	Construction
8	Food and beverage and tobacco products
9	Textile mills and textile product mills
10	Apparel and leather and allied products
11	Wood products
12	Paper products
13	Printing and related support activities
14	Petroleum and coal products
15	Chemical products
16	Plastics and rubber products
17	Nonmetallic mineral products
18	Primary metals
19	Fabricated metal products
20	Machinery
21	Computer and electronic products
22	Electrical equipment, appliances, and components
23	Motor vehicles, bodies and trailers, and parts
24	Other transportation equipment
25	Furniture and related products
26	Miscellaneous manufacturing
27	Wholesale trade
28	Retail trade
29	Air transportation
30	Rail transportation
31	Water transportation
32	Truck transportation
33	Transit and ground passenger transportation
34	Pipeline transportation
35	Other transportation and support activities
36	Warehousing and storage
37	Publishing industries (includes software)
38	Motion picture and sound recording industries
39	Broadcasting and telecommunications
40	Information and data processing services
41	Federal Reserve banks, credit intermediation, and related
42	Securities, commodity contracts, and investments
43	Insurance carriers and related activities
44	Funds, trusts, and other financial vehicles
45	Real estate
46	Rental and leasing services and lessors of intabgible assets
47	Legal services
48	Miscellaneous professional, scientific and technical services
49	Computer systems design and related services
50	Management of companies and enterprises
51	Administrative and support services
52	Waste management and remediation services

Table 1: Sectoral Detail Ouput from Inforum's STEMS model (*Contd.*)

Sl.	Sector
53	Educational services

54	Ambulatory health care services
55	Hospitals and nursing and residential care facilities
56	Social assistance
57	Performing arts, spectator sports, and museums
58	Amusements, gambling, and recreation industries
59	Accommodation
60	Food services and drinking places
61	Other services, except government
62	Federal civilian employees
63	Federal military employees
64	State government employees
65	Local government employees

3 Regional and County Projections

The state-level projections obtained are then allocated to various nested disaggregate geographies (regions, then counties) are broken down into employment profiles for four regions, and demographic forecasts for these regions are developed. The regions and the counties that comprise them are described in that are further disaggregated into county level employment projections. The methodology to obtain projections at the county level is described in Figure A-3 and is explained in the following subsections.

3.1 Regional Projections

Three of the four regions will consist of multiple metropolitan areas (MSAs), plus a number of bordering counties in two cases. A proper region-to-county allocation process must cover entire metropolitan districts due to interaction among their components, but the study area for the scenario project cuts across MSA boundaries in several cases. Hence the four regions will include nine counties in addition to the 64 counties comprising the study area.

The translation of state employment forecasts into regional forecasts assumes that all long-term trends at the regional level are economically driven. Historical employment data is obtained for the 76 jurisdictions of interest and assembled into employment profiles for the 14 or 15 region-related zones. Then each zone's employment in each industry is linked statistically to industry employment in the relevant state. Usually the linkage is fitted to observations of the zone's share of state employment. The forecasting process consists of extrapolating these relationships into the future and applying them to the state forecasts.

3.2 COUNTY PROJECTIONS

The Maryland Statewide Transportation Model requires projections at a lower level geography than provided by the projections at the state level developed by the Inforum STEMS model. In order to facilitate this need a disaggregation and projection method was developed to provide county level projections of employment, population and households. The disaggregation model uses historical average weighted "share-of-change" data to create projections from 2010 to 2060.

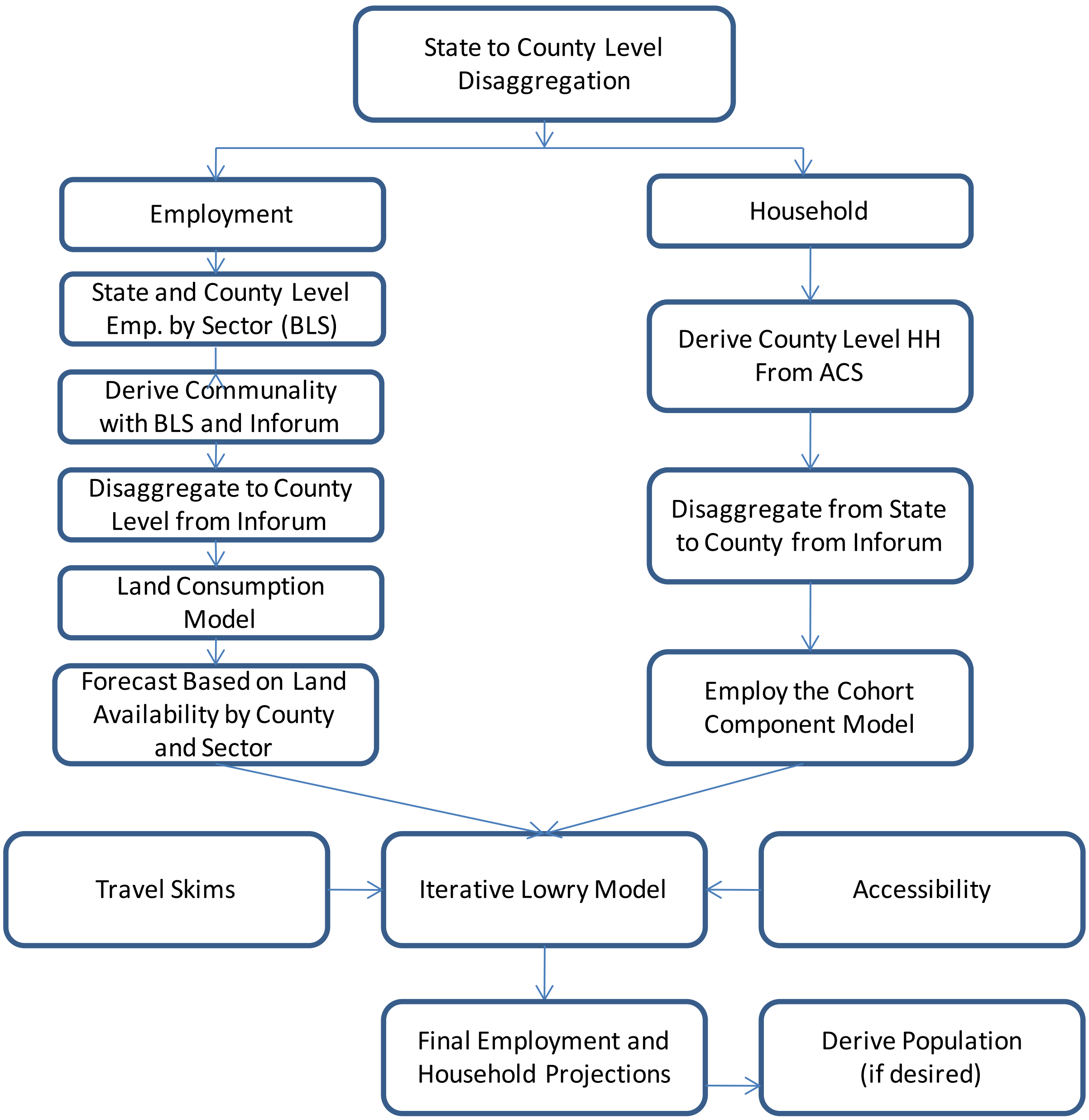
The disaggregation and projection process begins with the input of historic employment data from the Bureau of Labor Statistics' (BLS) Quarterly Census of Employment and Wages. Employment data at the county level is used to calculate share of employment of each county in the baseline years 2000, 2005 and 2009. The ratio of employment for each county is then extrapolated for five year periods beginning in 2010 and ending in 2060 using an exponential smoothing method. Employment data from 101 BLS sub-sectors for the same period are then reconciled with 65 STEMS industries disaggregated to match the BLS sub-sectors. This process simply employs a straight average of the two employment ratios. The purpose of this method is to properly allocate future STEMS projections based on the historic difference in BLS data and STEMS projections. Based on these previous ratios from 2000, 2005 and 2009 projection for the ratios until 2060 is extrapolated using OLS regression. The final disaggregation process takes the aggregate STEMS total employment number for each five year projection cycle and allocates it by county and sub-sector based on the ratios developed in the previous steps.

The disaggregated projections represent baseline data. Once the initial disaggregation is complete the allocation of sub-sector employment is further modified. This step uses historic developable land data to calculate the amount of land consumed for each unit of a particular employment sub-sector. The data is then fed into the allocation model to set upper limits on the allocation of employment to each sector. For example, if historic employment data indicates that crop related employment has grown by 10 units in the first projection cycle, 5 units in the second and only two units in the third cycle, and 100 units of land were consumed for each unit of growth, the model will restrict allocation of this employment type based on the downward trend and the reduction in available land for that sub-sector. In some cases this may mean that employment in a particular sub-sector no longer exists by 2060. By using an iterative consumption method a county's land-use regulations are implicitly incorporated into the projection method without the need the set these rules manually. This also allows for setting county specific and sub-sector parameters for use in scenario testing. In conjunction with the sub-sector related allocation method, county employment ratios are also iteratively adjusted based on a gravity model. The gravity model uses historic, current and projection data to calculate employment levels in each county and incorporates feedback from the population model to adjust county employment disaggregation ratios based on the size and distance of employment and population centers. When these two methods are combined the model is able to disaggregate and project county and sub-sector employment levels based on the maximum likelihood of real future growth.

The projection and disaggregation of county level population data begins in much the same way as the employment method. Historic population data is input from the 2000 census and 2005/2010 American Community Survey (ACS) population estimates. (Note: some population data from the 2010 census is already available with more to be released by March of 2011 this data will be used to update the model as it becomes available.) The ratios derived from the census are used to reconcile ratios from past STEMS projections and disaggregate future projections. Once a baseline population is created until 2060 the baseline data is entered into a cohort-component model which projects population based on historic birth, death and migration rates for each county. The two projections are for best fit based on historic trends and the results with the best statistics are fed back into the employment model. Employment locations are then used in a gravity model to reallocate population. Both the employment and population models are then run iteratively until they converge.

The final model process allocates population to households. This process resembles the employment and population methods as household information is drawn from the census, ACS and STEMS projections. Ratios are derived from this data and then projected to 2060. Using STEMS state level household projections households are allocated to the county level to create the baseline household projection. The baseline projections are then reallocated using population data and historic land consumption per household data used create upper limits on households. The final step of the model replaces population in the employment feedback loop and the two models are again run to convergence. Population is then reallocated based on household projections and the final projections are ready for aggregation based on the model the data will be input to.

Figure A-3: Schematic of Regional and County Level Projections



SMZ Level Projections

Once these county level projections in various sectors and demographic categories are available, a simple Lowry type allocation model is assumed to disaggregate them to the SMZ level. Since this allocation method is simple and widely used it also provides a method for allocating official projections of the Counties and the State. The county totals of socio-economic data (household, employment) are exogenous to this modeling process. A detailed description of the socio-economic data is presented in Table A-2.

Table A-2: Socio-economic data descriptions

Socio-economic Variable	Categories	Definition
HH		Total number of households
	INC_{00-20}	Total number of households with income level less than $20,000 per year
	INC_{20-40}	Total number of households with income level ranging between $20,000 to $40,000 per year
	INC_{40-60}	Total number of households with income level ranging between $40,000 to $60,000 per year
	INC_{60-100}	Total number of households with income level ranging between $60,000 to $100,000 per year
	INC_{100+}	Total number of households with income level higher than $100,000 per year
EMP		Total Employment
	IND	Total industrial employment
	RET	Total retail employment
	OFF	Total office employment
	OTH	Total other employment

The methodology adapted is presented below:

$$hh_i^l = HH^l * \frac{\sum_{j=1}^{n}\sum_{k=1}^{4}\left(emp_j^k \big/ tt\_emp_{ij}^{\beta_k} \right)}{\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{4}\left(emp_j^k \big/ tt\_emp_{ij}^{\beta_k} \right)} \quad (1)$$

$$emp_i^k = E^k \times \frac{\sum_{j=1}^{n}\sum_{l=1}^{5}\left(hh_j^l \big/ tt\_hh^l{}_{ij}^{\beta_l} \right)}{\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{l=1}^{5}\left(hh_j^l \big/ tt\_hh^l{}_{ij}^{\beta_l} \right)} \quad (2)$$

where,

$$HH^l = \sum_{i=1}^{n} hh_i^l \quad (3)$$

$$E^k = \sum_{i=1}^{n} emp_i^k \quad (4)$$

Total number of households for a specific income category in a SMZ is determined by equation (1). The basic employment is assumed to be the industrial employment and serves as the input to equation 1. The basic employment is allocated on the basis of existing proportion of the SMZ's basic employment to the County's total basic employment. These SMZ basic employments drive the allocation of households in various categories and the other non basic employment. Equation (2) represents the employment for each category in a SMZ. Equation (3) and (4) are definitional equality constraints to ensure that the sum of households and employment for all SMZs is equal to that of the county. The notations used in the formulation are presented in Table A-3. The travel times are the composite travel times for each income category household and are determined based on network conditions in the previous time period. For all categories of employment, the middle household income category's composite travel times are used. The corresponding friction factors for each sector (household and employment) are calibrated for the base year by minimizing the difference between observed and predicted values for the household and employment categories for all SMZs in the county. The minimization is performed by simulated annealing.

Table A-3: Variable Descriptions

Variable	Definition
n	Total number of SMZs
l	Income category ($INC_{00\text{-}20}$, $INC_{20\text{-}40}$, $INC_{40\text{-}60}$, $INC_{60\text{-}100}$, and INC_{100+})
k	Employment category (IND, RET, OFF, and OTH)
j	SMZ (Destination)
i	SMZ (Origin)
hh_i^l	Total number of household of income category *l* in SMZ *i*
HH^l	Total number of households of income category l in a county
emp_j^k	Total employment of category *k* attracted to SMZ *j*
$tt\_emp_{ij}^{\beta_k}$	Shortest path travel time for employment category k travelling from SMZ *i* to *j*
E^k	Total employment in a county by category *k*
$tt\_hh^l{}_{ij}^{\beta_l}$	Shortest path travel time for household by income level l travelling from SMZ *i* to *j*
emp_i^k	Total employment
β_k	Friction factor for employment category *k*
β_l	Friction factor for household type *l*
hh_j^l	Total number of household of income category *l* in SMZ *j*

A step by step description of the calibration algorithm can be viewed as following:

Step-1: Determine the shortest path travel times and initialize the friction factors for base year by household type and income category. Initialize non basic employment categories and household types in all SMZs to 0.

Step-2: Determine the household by income category from the county control total and the proportions derived from the travel impedances of basic employment (industrial).

Step-3: Determine a specific type of non-basic employment using the county control total and the proportions derived from travel impedances of households of income category.

Step-4: Go to step-2 and obtain a new set of households, repeat step-3 to obtain new set of non basic employment.

Step-5: Repeat step-2 through step-4 till convergence is achieved.

Step-6: Sum the square of the differences between observed values in each SMZ and model predicted values for all categories. Modify the friction factors and run Step 1- Step 5 till an optimal minimum is achieved.

4 CONCLUSIONS

The national and state projections are derived from the LIFT and STEM models. Predictive equations are utilized to determine county level projections. Further, a Lowry type allocation model is applied to derive projections at the SMZ level. This document described the methodology of the proposed interactions and linkage between the economic projections and the input requirement for transportation model. This modeling framework allows for construction of scenarios that are varied in scales (from trade balances to major restructuring of transport). The model is capable of incorporating changes in the scenarios both temporally and spatially.