A PROBLEM STRUCTURING MODEL FOR ANALYSING TRANSPORT AND ENVIRONMENT INTERACTIONS

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Abstract

This study proposes a decision support system module for analyzing impacts of transportation policies on environment. The main issues of the contemporary transport models include the specification of the nature. For a sustainable transportation system, the extent of the relationships between transport and the environment has to be considered. For this purpose a two-stage problem structuring model is developed. Initially, experts' opinions are structured by using a cognitive map to determine the relationships between transportation and environmental concepts. After that, a structural equation model is constructed based on the cognitive map in order to quantify the relations between transportation and environmental externalities. World Development Indicators of World Bank are utilized for this purpose.

Keywords: Transportation, environment, cognitive maps, structural equation modeling

1. Introduction

In the new millennium, one of the most challenging problems is how to assess, build and maintain a sustainable economy that will allow the human society to enjoy a sufficiently high standard of living without destroying its natural and biological support resources. Sustainable development (SD) has become an essential question of international environment policy, at least since the summit of the United Nations in Rio 1992. The concept of sustainability, combines the needs of present and future generations, and takes the interdependencies of economic activities and ecological status into account (Phillis and Andriantiantsaholiniaina, 2001).

The rise in worldwide trade and the increasing interaction between countries previously separated by trade barriers have spurred a significant increase in transportation flows at all geographical levels. This has caused a wide variety of environmental externalities, ranging from ecological footprint problems to global pollution. The 1990s were characterized by a realization of global environmental issues, namely the impacts of carbon dioxide emissions on the greenhouse effect. The World Bank expects that if current trends continue, CO_2 emissions caused by transport will significantly increase by the year 2010 (Veen-Groot and Nijkamp, 1999). CO_2 emissions are 1% higher than that of 1990 and the fossil fuels are the main sources of emissions in rich countries and emergent economies (Worldbank, 2007). It is now generally agreed that a global climate change is occurring. It also appears that the poorer countries stand to suffer most as a consequence of this change, with estimated costs in the range of 5% to 9% of gross domestic product (GDP) especially for developing countries. It is also estimated that the transport sector is responsible for about 25% of emissions of the gases contributing to global warming in industrial countries, but only about one-half of this amount is observed in developing country cities (World Bank, 2002). Especially, road pollution contributes significantly to urban air pollution in many countries.

From the point of view of the feasibility of providing growth in road capacity parallel to the predicted growth in traffic as well in terms of impact on the environment and society, current trends in transportation appear to be unsustainable. To resolve the problem, each country has to work out its own transportation policies in accordance with its geographical and political conditions.

European Union (EU) countries have recently admitted that their transport policies are unsustainable and their transport problems are even expected to worsen due to the fact that worldwide automobile ownership tripled between 1970 and 2000, and the movement of goods is projected to increase by 50% by 2010. In the white paper titled European transport policy for 2010: time to decide (ETP, 2000), EU countries have accepted the importance of having a balanced, sustainable and integrated transportation system. In fact, until 1998, in many EU countries such as Germany and United Kingdom, the basic strategy of transportation was based on "predict and provide" approach. However, such a strategy results with a disproportionate growth of road transportation and leads to unsustainable, unbalanced transportation system. The white paper titled "A New Deal for Transport: Better for Everyone" (DETR, 1998) underlines the inadequacy of this approach and emphasizes the importance of a pragmatic multi-modalism.

Similar problems can be seen in an even more dramatic way in Turkey. The Turkish transport network has not followed a planned growth strategy, mainly due to political factors. None of the transportation master plans developed so far in Turkey have succeeded to integrate the transport modes in order to provide a balanced, multimodal system. As a result, currently, the share of highways reached 92% in freight transportation, and 95% in passenger transportation. Turkey's 9th development plan (2007-2013) underlines that even though considerable productivity increases have been obtained as a result of structural reforms realized in many areas and the macroeconomic stability achieved in recent years, the competitiveness of Turkey has not been sufficiently improved. One of the main reasons is accepted to be the inadequacy in the quality of transportation infrastructure (Ulengin et al., 2007).

Incorporation of environmental issues within an urban transport strategy requires the identification of the main factors that contribute to the environmental pollution in a transportation system. Therefore, it does not make sense to study transport issues separately. There is a widespread acceptance that integration decisions across transport, land use planning and environment policy is crucial for sustainable development.

This study proposes a problem structuring model that shows the relationship between transportation and environment and their effect on the health of the society. In the second section, a literature survey on the researches conducted on transport and environment interaction is provided. The theoretical explanations and the application of the proposed two-stage methodology are presented in details in the third section. Finally conclusions and further suggestions are given.

2. Literature Survey

The report of ECMT-OECD project on Implementing Sustainable Urban Travel Policies (ECMT, 2001) underline that planning for transport, land-use and environment can no longer be treated in isolation one from the other. Geerlings and Stead (2003), provide a review of European policy documents and research activities and underline that relatively little European research has been carried out on the issue of policy integration, particularly in relation to transport, land use planning and environment policies. European Transport White Paper (CEC, 2001) highlights the need to integrate environmental considerations into transport policies, although the way of realizing this integration remains unclear.

Fiksel (2006) provides an overview of the current approaches for modeling and management of complex economic, ecological and social systems and underlines the inexistence of modeling and decision-making approaches that will help to understand the full implication of alternative choices and their relative attractiveness in terms of enhancing system resilience for the study of sustainable systems. The STEEDS project, which is a computer-based Decision Support System (DSS) in the context of transport-energy-environment interactions, has been developed and validated. The DSS is developed to evaluate future policy and technology options for the European transport system. However, the DSS consists of transport demand model, vehicle stock model, energy emissions model, lifecycle analysis model and environmental impact models (Brand et al, 2002). Therefore, it includes several domain specific models linked together. The causal relations among all the variables of the system are not considered.

Ulengin et al. (2007) provides an integrated decision support system designed to allow formulation of aggregate and long-term scenarios (countrywide, regional or global). It provides a system approach and analyses the interrelation among the transportation variables, socioeconomic and demographic variables using causal map approach and then uses neural network and Bayesian causal map to analyze the impact of different scenarios on the transportation of passenger and freight demand in the future. The developed model is used to guide the transportation policy makers in their future strategic decisions; to facilitate analysis of the possible consequences of a specific policy on changing the share of transportation modes for both passenger and freight transportation; to highlight in detail the causal relationships among variables that are considered relevant in the transportation system analyzed and finally to show the impact of a change in any variable on the whole system. However, environment and transportation interactions are not taken into account.

Tsamboulas and Mikroudis (2006) proposes a DSS, TRANSPOL, specifically developed for the transport policy sector, to provide policy support information which can be generated in-house. It provides a medium for bringing together all kinds of transport models and databases, making them available to a wider audience in a user-friendly environment. However, the environmental impacts of different transport policies are not considered.

Arampatzis et al (2004) develop a DSS integrated in a geographical information system for the analysis of different policies. The objective of the tool is to assist transport administrators enhance the efficiency of the transportation supply while improving environmental and energy indicators. However, it is developed for urban transportation and it does not allow a macro perspective.

Literature analysis shows that an important research priority for the study of sustainable systems is the development of modeling and decision-making approaches from the systems perspective. Multiple models that reflect different system interpretations or shareholder perspective should be explored. As the need for a systems approach becomes more apparent, the deficiencies of existing models are also revealed. Integrated assessment of sustainable systems cannot be accomplished by simply linking together a collection of domain-specific models. To assess the interactions among interdependent systems require new tools to capture the behaviors and dynamic relationships that characterize complex systems. This study proposed a problem structuring model to analyze the transport and environment interactions and their effect on health of the society.

3. The Proposed Methodology

The proposed methodology is composed of two main stages to analyze the transport and environment interactions and their impact on the health of the society. At the first stage of the proposed model, the specification of the nature and extent of the relationships between transport, environment, and health is considered. Cognitive maps are used for this purpose in order to reveal the experts' judgments. In the next stage, the quantification of the relations that are specified in the first stage is realized using Structural Equation Modeling (SEM) technique. The framework of the proposed model is given in Figure 1.

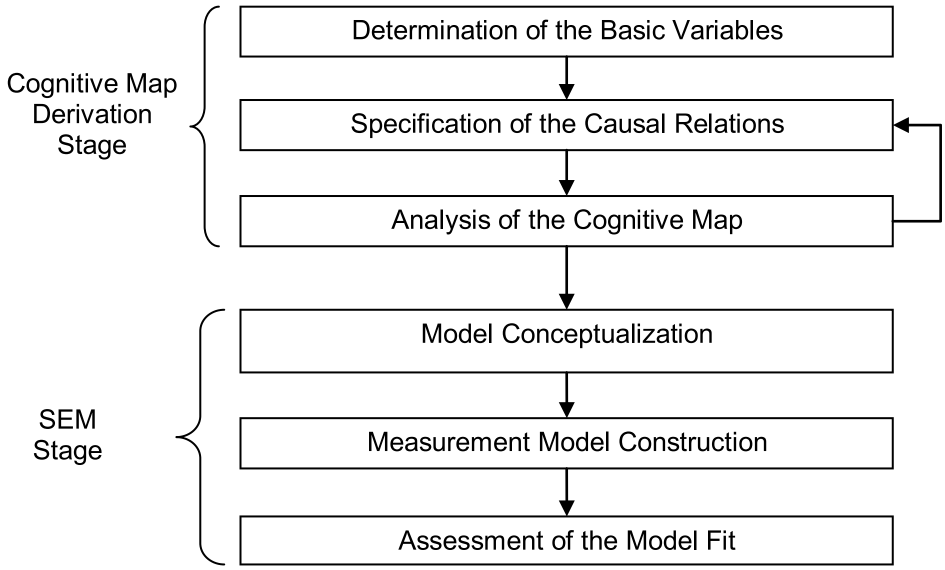

Figure 1. Flowchart of the proposed methodology

3.1. Cognitive Map of the System

The first step of the proposed model is the development of the cognitive map of the sustainable transportation system. Cognitive mapping is a qualitative technique designed to identify the cause and effect as well as to explain causal links (Onsel Sahin et.al., 2006). A cognitive map represents an individual's stated beliefs concerning a particular domain at a specific point in time (Eden, 1990). It is a representation of thinking about a problem that follows from the process of mapping (Eden, 2004). As stated by Eden (2004), cognitive maps are not simply 'word and arrow' diagrams, or influence diagrams or a 'mind-map'. Mapping processes often lead to the later development of influence diagrams as a lead in to system dynamics simulation modeling. Cognitive mapping have been used in a variety of areas such as strategic change, environmental, joint venture formation, software operations support exercise and entrepreneurship.

The cognitive maps are useful in describing deterministic decision problems (Önsel Sahin et.al., 2006). They analyze causal assertions of people to provide a qualitative interpretation of the concepts representing a decision problem. Cognitive maps represent domain knowledge more descriptively than other models, such as regression or structural equations. They provide a prescriptive framework for decision making and allow predictions in case of interventions (Nodkarni and Shenoy, 2001). Sometimes, cognitive maps are known as cause maps, particularly when they are constructed by a group, and so cannot claim to be related to an individual cognition. However, the formalisms for cause maps will be the same as those for cognitive maps (Eden, 2004).

In this paper, the basic reason of using cognitive maps is based on the fact that, in a world of incomplete data, individuals nonetheless make causal inferences that allow interpretation. Interactively generated maps that focus on causal relationships are attractive decision aids. That allows the decision maker to focus on action (Huff, 1990).

For this purpose, in the first stage of the proposed methodology the cognitive map of the system is derived for knowledge acquisition and problem structuring. Initially, the determination of the basic variables is done and than the causal relations is specified followed by analysis of the cognitive map.

A cognitive map is the representation of thinking about a problem that follows the process of mapping (Eden, 2004). The maps are a network of nodes. Due to the fact that they represent domain knowledge more descriptively than other models, such as regression or structural equations, they are more useful decision tools (Nadkarni and Shenoy, 2001). There are three components of a causal map: the nodes representing causal concepts, the links representing causal connections among causal concepts, and strengths representing the causal value of a causal connection. In this paper Decision Explorer (Banxia Software, 1996) is used as a supporting tool to elicit, store, and handle the complexity revealed by the experts.

3.1.1. Determination of the Basic Variables

Different methods are used to construct the causal maps, depending on the purpose and the theory guiding the research. In this study, Axelrod's sense of mapping proves suitable (Axelrod, 1976). Mapping in Axelrod's sense is designed to be a systematic, reliable way of measuring and analyzing the structure of an argument, not just its separate parts. The purpose of this type of unstructured approach is to inductively explore a new or unfamiliar domain by posing questions regarding the concepts relevant to the decision (Nadkarni and Shenoy, 2004). The unstructured approach thus yields a richer understanding of the processes that individuals engage in decision-making as well as helping gather important insights into the general knowledge that individuals have regarding the domain being evaluated.

In this study, in order to obtain a mutually exclusive and selectively exhaustive list of basic variables of the causal map, initially, a literature survey is realized and then interviews are conducted with transportation and environment experts who are encouraged to identify concepts that might be relevant to the transportation-environment interaction. In this attempt to reveal the basic variables, a consensus is reached on 25 variables (Table 1).

Table 1 Variables and their Definitions

Air pollutants: Air pollutants includes Carbon dioxide, Sulfur, and Nitrogen emissions. The state of a country's technology and pollution controls is an important determinant of particulate matter concentrations.	**Road infrastructure:** Total road network covers motorways, highways, main or national roads, secondary or regional roads, and all other roads in a country.
Clean Technology: Biofuel production is an important indicator of clean technology for transportation systems	**Rural population:** Rural population is calculated as the difference between the total population and the urban population.
Emission limits for the vehicles: Emission limits are determined by the government policies in order to control the air pollutant emissions of the vehicles	**Speed limits:** Speed limits are determined by the government policies
Economical Welfare: Gross domestic product (GDP) and gross national income (GNP) as well as their per capita values are the well-known indicators of the economical welfare of a country.	**Transportation mode-airways:** Passengers carried by airways, and goods hauled by airways are used as indicators of transportation mode airways.
Education: Literacy and enrollment levels of a country are the indicators of education. Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown.	**Transportation mode-highway:** Passengers carried by highways, goods hauled by highways, and length of paved road are used as indicators of transportation mode highway.
Energy use: Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport	**Transportation mode-maritime lines:** Port traffic, passengers carried by maritime, and goods hauled by maritime are used as indicators of transportation mode maritime.
Health expenditure: Total health expenditure is the sum of public and private health expenditure. Health expenditure per capita can also be used as an additional indicator	**Transportation mode-railways:** Rail lines, passengers carried by railways, and goods hauled by railways are used as indicators of transportation mode railway.
Life expectancy at birth: Life expectancy at birth is the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.	**Urban population:** Urban population is the midyear population of areas defined as urban in each country and reported to the United Nations
Mass transportation: Mass transportation includes bus and rail transportation of passengers (especially for urban area).	**Investment to airways:** Investments done by both government and private sector to maintenance and infrastructure of airway transportation
Noise: Noise generated by transportation vehicles measured in decibels.	**Investment to highway:** Investments done by both government and private sector to maintenance and infrastructure of highway transportation
Number of Vehicles: It is the number of road vehicles including cars, buses, trucks etc.	**Investment to maritime lines:** Investments done by both government and private sector to maintenance and infrastructure of maritime transportation
Oil prices: Pump price for diesel fuel is the indicator for the oil price	**Investment to railways:** Investments done by both government and private sector to maintenance and infrastructure of railway transportation

Organic water pollutant: Emissions of organic water pollutants are measured in terms of biochemical oxygen demand, which refers to the amount of oxygen that bacteria in water will consume in breaking down waste.	**Investment to railways:** Investments done by both government and private sector to maintenance and infrastructure of railway transportation

*Revealed from World Development Indicators (2006)

3.1.2. Specification of the Causal Relations

Once variables related to the problem of interest are specified, a second interview is held with the experts to reveal the key causal relationships within the system. The experts are asked to compare the variables that were determined in the previous stage in a pair-wise matrix and to specify whether a positive (+), negative (-) or no relation (0) exists between each pair of variables. Then an aggregation of the individual maps has been conducted. In fact, several researchers have investigated the idea of eliciting aggregated group maps (Langfield-Smith and Wirth, 1992). One possibility is to form an "average map" by calculating the average relationship between similar elements within the individual maps. In our research, the group map was initially aggregated from these individual matrices as suggested by Langfield-Smith (1992). However, since the strength of the relationships was not asked to individuals, instead of taking the averages, the conflicted views about the type (negative/positive or no relation) of the causal relations were solved by the use of majority rule as suggested by Roberts (1976). The duplication of routes was again solved by majority rule. Whenever two of the three experts indicated that there was a route between two variables, an arrow was drawn indicating that there was a route between these variables. The resulting pairwise comparison matrix is given in Table 2.

Table 2 The Relationship Matrix of the Variables

ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1 Air pollutants								1	-1																				
2 Clean Technology	-1					-1		-1	1		-1			-1															
3 Emission limits for the vehicles	1					1																							
4 Economical Welfare		1			1	1		1	1	-1		1			1	-1		1	1	1	1	1	1	1	1				
5 Education		1						1																					
6 Energy use	1												1	1															
7 Government subvention to unleaded gasoline	-1																												
8 Health expenditure									1																				
9 Life expectancy at birth																1							1						
10 Mass transportation	-1					-1					-1	-1			1				1	-1		1							
11 Noise																													
12 Number of Vehicles	1					1				-1	1			1	1				1	1		-1			1				
13 Oil prices				-1		-1				1								-1	1	-1		1							
14 Organic water pollutant																													
15 Road infrastructure												1		1					1	1									
16 Rural population						1		1				1						1	1	1	1	1							
17 Speed limits	1					1																							
18 Transportation mode: airways	1					1					1																		
19 Transportation mode: highway - Bus	1					1				1	1	1			1							-1			1				
20 Transportation mode: highway - car	1					1				-1	1	1			1				-1			-1			1				
21 Transportation mode: Maritime lines	1					1				1		-1		1					-1	-1									
22 Transportation mode: railways	1					1				1	-1	-1							-1	-1									
23 Urban population						1		1		1		1						1	1	1	1	1							
24 Use of Two-wheelers	-1					-1					-1	1		-1											1				
25 Vehicle and parts manufacture				1		1						1																	
26 Investment to airways																		1											
27 Investment to highway																			1	1									
28 Investment to maritime lines																					1								
29 investment to railways																						1							

The causal map of this matrix is drawn using Decision Explorer (Banxia Software, 1996) as given in Figure 2.

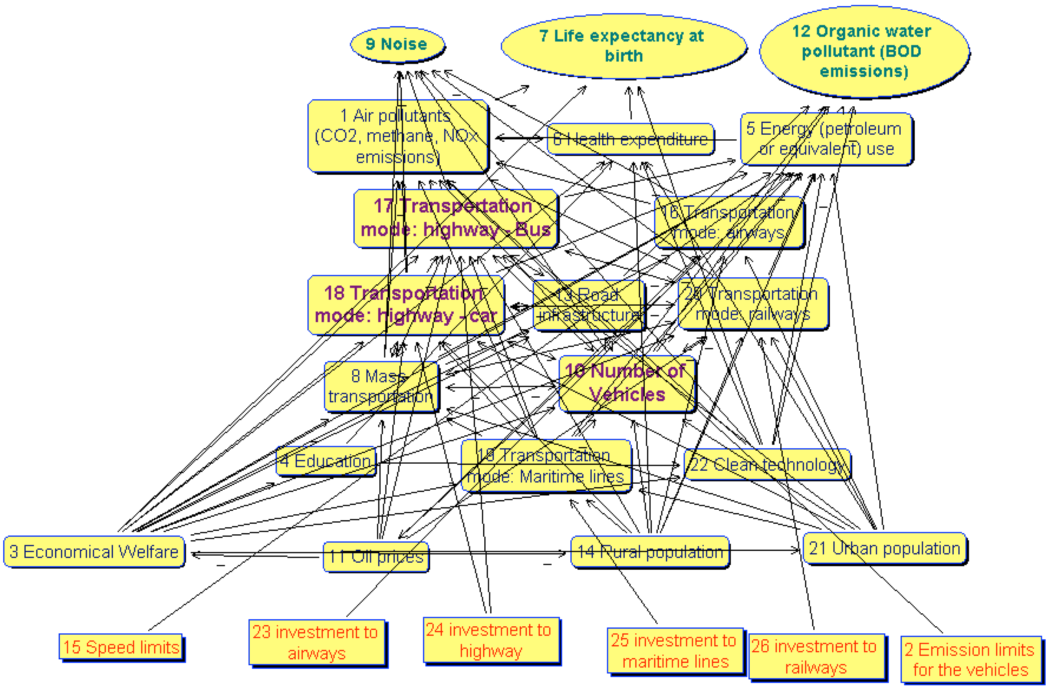

Figure 2 Causal Map of the Sustainable Transport System

3.1.3. Analysis of the Causal Map

Domain Analysis

The basis for the analyses of the causal maps comes from the theory of directed graphs. The analysis can take place by representing a cognitive map as an nxn adjacency matrix A, where n is the number of elements in the corresponding cognitive map. It has as its entry, the value of the direct causal relationship from concept variable i to concept variable j. If the strength of relations are not taken into account, A is a signed binary matrix and a_{ij} can take the values of 1, 0 or -1 (a_{ij} = 1 if positive relationship from i to j is present in the cognitive map; a_{ij} = -1, if a negative relationship and a_{ij} = 0, if no relationship). Raising the adjacency matrix A to the k^{th} power gives the total effect matrix T. In the total effect matrix, the indirect effect of all paths of length k from i to j can be seen. In other words, all direct and indirect relationships between elements, can be calculated from the direct effects matrix by letting

$$T=\sum_{k=1}^{n-1} A^k$$

The presence of a non-zero value in a cell of T indicates that a direct or indirect relationship exists between the relevant elements within the cognitive map. In the adjacency matrix A, the row sum of the absolute values of the element of row i gives the outdegree (od) of concept i, that is the number of concepts perceived to be affected directly by concept i. Similarly, the column sum of the absolute values of the elements of column i gives the indegree (id) of concept -the number of concepts perceived to affect concept i directly-. The sum of od and id for i gives the total degree (td), which is a useful measure to find out the cognitive centrality of the concept. The centrality of the variables can be effectively calculated by the domain analysis of the Decision Explorer (Banxia Software, 1996).

Decision Explorer showed that the most central variables are “number of vehicles” “transportation mode: highway-bus” and “transportation mode: highway-car” concepts having 18 as centrality value, which means that the sum of incoming to and outgoing from that variable is 18. These concepts can be named as key issues of the model since they are the most densely linked concepts.

As can be observed from the map and the relationship matrix, experts accept 25 variables (driving forces) as the basic indicators of a sustainable transport system. On the other hand, the analysis of the aggregated cognitive map shows the existence of many loops due to the existence of a high number of variables. The existence of loops is an indicator of the dynamic structure of the map (Eden and

Ackermann, 1998). However, due to the fact that the loops will influence the validity of all the analysis that can be made using the maps, they have to be treated with great caution.

Head and Tail Analysis

Besides domain analysis; determining head and tail concepts of the map is another well known analysis type that can be conducted in a causal map. Head and tail analysis are conducted in order to determine the concepts that can be named as goal and policy variables of the model. Head concepts have no outgoing links indicating that they are influenced by other concepts of the models. A map with relatively large number of "head" indicates multiple and possibly conflicting objectives (Eden et al., 1992). On the contrary, the tail concepts have no incoming links meaning that they influence the remaining concepts of the model. Besides a “tail” is a node having no incoming arrow. So in fact, tail nodes can easily be thought as policy variables. In the related cognitive map, 3 head and 7 tail nodes are specified. The head nodes are “noise” “life expectancy at birth” and “organic water pollutant” nodes while the tail nodes are “government subvention to unleaded gasoline”, “speed limits”, “emission limits for the vehicles”, “investment to airways”, “investment to highways”, ““investment to maritime lines” and “investment to railways”.

Givens–Means–Ends Analysis

Another analysis of cognitive maps is Givens–Means–Ends (GME) analysis (Tegarden and Sheetz, 2003). In GME analysis, the inflow per outflow ratio is calculated for each of the variable and according to these ratios, the variables are categorized under 3 classes: variables having more outflows than inflows (ratio < 1) are named as “givens”; variables having more inflows than outflows (ratio >1) are named as “ends” and variables having approximately same number of outflows and inflows (ratio $\cong 1$) are named as “means”. Viewing the categories from givens to ends shows the direction of the causality in a cognitive map. Moreover, the hierarchical structure that may not be determined in some cases according to head-tail analysis can also be represented with GME analysis. “Ends” can be thought as goals of the structure since they are mostly influenced by the other variables while “givens” can be regarded as strategies since they mostly influence the “means” and “ends”.

The hierarchical structure of the map is important in the sense that it provides information about the emerging characteristics of the map (Eden, 2004). The node that appears in the center of a map is usually significantly central to the construal of the problem or issue being depicted.

GME analysis is also conducted on the related cognitive map and the hierarchical structure (Figure 2) is developed according to the ratios derived from this analysis.

Cluster Analysis

Additionally cluster analysis can also be conducted in the analysis process of a cognitive map. A typical use of cluster analysis is to split a large model into related sections to produce an overview of the model (Özen and Ulengin, 2001). These clusters can be named as "islands of materials" (Eden, 2004). The detection of each cluster as a separate map allows an exploration of the content of each island to identify themes that describe each cluster. Generally, a map is not in the form of islands or a single ''unbreakable'' cluster but rather connected clusters of nodes. In this case the identification of clusters that break the map into a system of interrelated themes becomes worthwhile.

Finally a cluster analysis is conducted by using Decision Explorer. Two clusters including 12 and 14 variables have been identified as can be seen in Figure 3 and Figure 4.

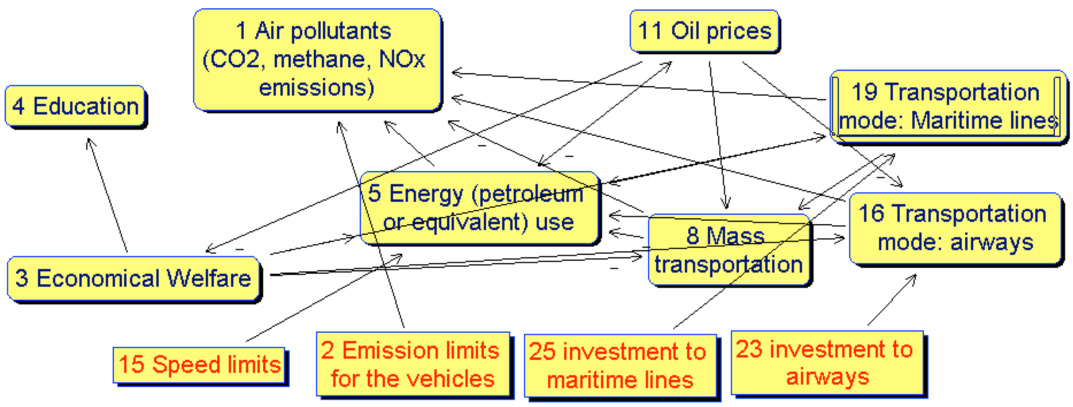

Figure 3 First Cluster of the Cognitive Map

Clusters can be compared with each other in means of complexity. This is a simple analysis that is based on a ratio of links to nodes in the map (Eden et al, 1992). According to this ratio, the second cluster can be said to be more complex (complexity ratio= 132/14=9.42) when compared to cluster 1 (complexity ratio=94/12=7.83). Besides, the second cluster includes all of the three key issues of the map as well as the goal variables.

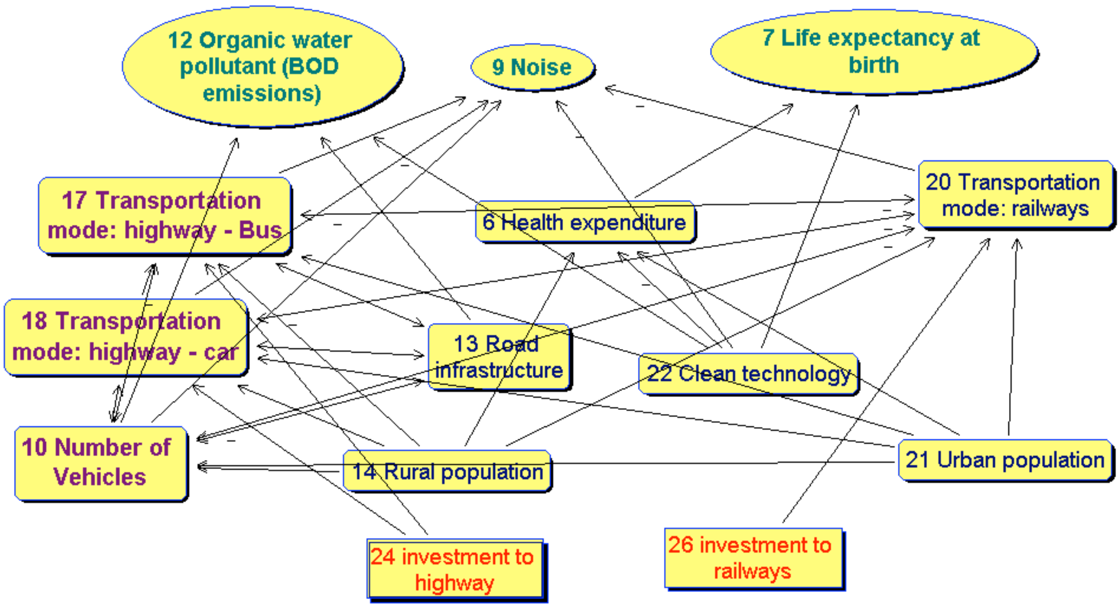

Figure 4 Second Cluster of the Cognitive Map

3.2. Structural Equation Model of the System

Structural Equation Modeling (SEM) uses various types of models to depict the relationships among observed variables, with the same basic goal of providing a quantitative test of a theoretical model. Various theoretical models can be tested in SEM that hypothesizes how sets of variables define constructs and how these constructs are related to each other. Constructs are not easily observed and regarded as the latent variables of the model. Latent variables can be classified as independent (ksi) variables and dependent (eta) variables. The measurable indicators of constructs are called observed (manifest) variables. Of course, there are error terms associated with these observed variables.

SEM models essentially combine path models and confirmatory factor models incorporating both latent and observed variables. The early development of SEM models was due to Jöreskog (1973), Keesling (1972), and Wiley (1973). This approach was initially known as the JKW model, but became known as the linear structural relations (LISREL) with the development of the first software program, LISREL, in 1973.

For the particular application the causal map derived in the previous stage is used as the input for the SEM. The relations of the causal map are directly used to specify the initial relations between independent and dependent latent variables of the system.

3.2.1 Model Conceptualization

In the proposed methodology the first step of SEM is the model conceptualization. Model conceptualization is concerned with deriving the latent variables from the cognitive map results and the development of theory-based hypotheses to serve as the guide for linking the latent variables to each other. At this stage input (Ksi) and output (Eta) variables are also specified.

The latent variables of the SEM model are specified according to the results of causal map analysis. Based on the cognitive map results the head nodes are found to be “life expectancy at birth”, “organic water pollutants”, and “noise”. That’s why health (related to first variable) and environment (related to second and third variable) are specified as the output latent variables of the SEM model. On the other hand among the policy variables found through tail analysis, investment in transport modes (airways, highway, and railway) are added as input latents to the SEM model with generalized name of “Airways”, “Highway”, and “Railway”. Additionally according to the cluster analysis result, “economical welfare” and “population” are noticed to be tails of each cluster. That is why, they are also selected as input latent variables. Cluster analysis also shows that energy use is one of the important variables which affect and also affected from the other variables. Therefore it is defined as the latent variable in the SEM model.

The conceptual model revealed from the cognitive map is also confirmed by the fact that the aim of the proposed model is to investigate the impact of transportation on environment and health. The latents related to transportation are defined as Ksi variables while the ones related to environment and health as Eta variables.

The relations between the latent variables as well as the relations between the latent and the manifest variables are identified using the causal map. The manifest variables indicating similar concepts are used to estimate the related latent variables.

The conceptual model derived from the causal map, according to the suggestions of the experts, is given in Figure 5. As can be noticed the conceptual model does not include all the variables of the causal map but only the latent variables; i.e. the variables that are not directly observed but are rather inferred from other variables that are observed and directly measured. The latent variables at the left part of the figure are the inputs and those at the right are outputs. The figure shows that the airway, highway and railway transportation as well as population have an impact on energy use. Energy use in turn, together with the economical power has an impact on environmental pollution. An increase in energy use is expected to result with an increase in environmental pollution. However, the impact of the economy is slightly complicated: when the economy of a country is improved, environmental pollution may increase as a result of the increase in the economical activities. However the increase of the economic power is also expected to increase the concern of people for the environment pollution. Finally it is also expected that if the pollution increases the health of the society will deteriorate.

The hypothesis about the relationship among the input and output variables are derived based the previous explanations according the causal map. They are summarized in Table 3 and Figure 5.

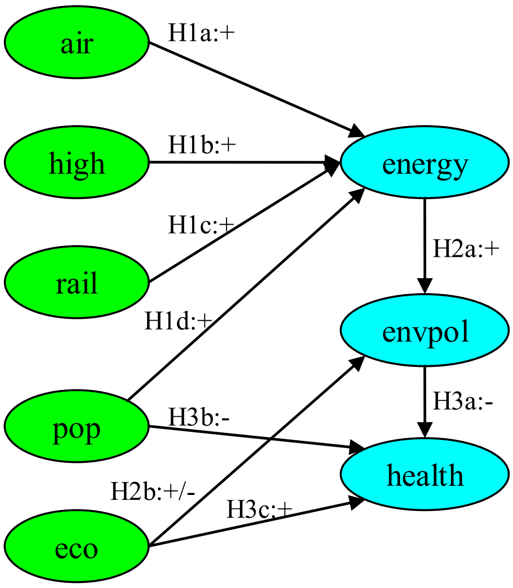

Figure 5. Conceptual Model of Latent Variables and the Hypothesis

Table 3 The Proposed Hypothesis for the relationship among the latent variables

Hypothesis	Explanation
H1a	A higher level of air transportation leads to a higher level of energy use
H1b	A higher level of highway transportation leads to a higher level of energy use
H1c	A higher level of rail transportation leads to a higher level of energy use
H1d	A higher level of population leads to a higher level of energy use
H2a	A higher level of energy use leads to higher level of environmental pollution
H2b	A higher level of economical power leads to changes in environmental pollution (the sign of the relationship is not precise)
H3a	A higher level of environmental pollution leads to a lower health level
H3b	A higher level of population leads to a lower health level
H3c	A higher level of economical power leads to a higher health level

3.2.2. Construction of the Measurement Model

After the model conceptualization, the second step in SEM is the construction of the measurement model. In order to construct a path diagram that represents the substantive hypotheses and measurement scheme, corresponding indicators of the latent variables have to be specified. A measurement model consists of observed indicators, which serve for respective measurement instruments of latent variables. Prior to the test of the hypothesized relationship among latents, the measurement model must hold. If any indicators do not measure its underlying latent and or are not reliable, the model must be modified before it can be structurally tested. There are two different ways used by researchers to evaluate a measurement model's validity: a test to measure each latent separately; and a test for all measures together (Cheng, 2001). In the proposed methodology the first method is preferred because of the manifest variables as well as the test of their validity are made simultaneously. Therefore the specification of manifest variables is made in two steps: (1) a set of indicators is employed for a latent variable (2) the reliability and validity of the measures are assessed. If the assessed set of indicators is valid then they are selected as the manifest variables of the latent; otherwise another set of indicators are tried. These steps are processed for all latent variables until the full measurement model is constructed.

In the analysis initially, the variables from the World Economic Indicators (WDI) of the World Bank (World Bank, 2005) are evaluated to find those that may be suitable to measure the latent variables of the model. Table 5 shows the variables thought initially to be appropriate manifest variables and those that are finally accepted to measure appropriately the related latent variables used in the research. First of all, all appropriate variables are selected from the list of WDI. Then the variables that have not efficient data are eliminated. In order to construct a robust measurement model different sets of variables are tested for each latent variable. To modify a measure, a variable has to be rejected if it cannot measure the underlying latent. The measure of each latent is tested separately in order to evaluate measurement models validity. To give an idea the analysis of the different sets of variables to select the best measurement model of the environmental pollution is given in Table 4. Initially among the 8 canditate indicators, "metan emissions" and "NOx emissions" are eliminated due to the inadequate number of available data (approximately %75 of data is not available for both indicators).

Then the first trial is realized by including all possible indicators of environmental pollution, this resulted with root mean square error of approximation (RMSEA) is 0.166. All of the coefficients of the indicators are positive except “CO2 emissions” therefore CO2 is excluded from the set. On the second trial, RMSEA value is 0.107, that should be decreased. In order to get a better result all possible sets of 4 members are tried (trial #3-7). Consequently the best set of indicators is obtained by excluding “Adjusted savings: Net forest depletion” (trial#6).

Table 4. Selecting the best measurement model for environment pollution

	Selected Indicators							
Trial #	AS_PART	AS_NFD	CO2	AS_CO2	PM10	BOD	**RMSEA**	**Action**
1	√	√	√	√	√	√	0.166	“CO2” is excluded due to its negative coeficient
2	√	√		√	√	√	0.107	In order to decrease RMSEA value, all possible combinations of 4 member sets are tried
3	√	√		√	√		0.159	
4	√	√		√		√	0.110	
5	√	√			√	√	0.092	
6	√			√	√	√	0.000	Determined as the best set of indicators
7		√		√	√	√	0.150	

Table 5 The Latents and their Manifest Variables

Latent	Appropriate Manifest Variables	Selected Manifest Variables
Environmental Pollution (envpol)	NOx emissions, Adjusted savings: particulate emission damage (AS_PART), Metan emissions Adjusted savings: net forest depletion (AS_NFD), CO2 Emissions (CO2), Adjusted savings: CO2 Damage (AS_CO2), PM10, country level (PM10), Organic water pollutants (BOD)	Adjusted Savings: CO2 Damage (AS_CO2) Adjusted Savings: Particulate emission damage (AS_PART) Organic water pollutants (BOD) PM10, country level (PM10)
Energy use (energy)	Fuel imports, Emmission limit, GDP per unit of energy use, Energy imports, Energy production, Oil price, Adjusted savings: Energy depletion, Energy use, Energy us eper capita Electric power consumption, Electric power consumption,	Adjusted Savings: Energy use (AS_ENERGY) Energy use per Capita (ENRGY _USE) GDP per unit of energy use (GDP_EN)
Health of the	Mortality caused by road traffic injuries,	Healt expenditure per capita

society (health)	Healt expenditure per capita, Death rate, Life expentancy at birth, Health expenditure per capita	(HEALTH_E) Death rate (DEATH) Life expentancy at birth (LIFE_EXP)
Transportation mode: airways (air)	Air Trans: Registered carrier departures, Private investment in transport, Number of passenger on airways, Amount of Freight on airways, Oil price, Investmen to airways	Number of passenger on Airways (P_AIR) Amount of Freight on airways (F_AIR) Air Trans: Registered carrier departures (RCD_AIR)
Transportation mode: Highway (high)	Road Paved, Private investment in transport, Road traffic, Number of vehicles, Oil price, Roads Total network, Amount of Freight on highway, Investment to highway, Number of passenger on Highway	Number of vehicles (VEHICLE) Road Paved (R_PAVED) Roads Total network (R_NET)
Transportation mode: Railways (rail)	Investment to railways, Oil price, Number of passenger on railway, Amount of Freight on railway, Private investment in transport, Railways total route	Number of passenger on railway (P_RAIL) Amount of Freight on railway (F_RAIL) Railways total route (R_RAIL)
Population (pop)	Population density, Urban population (% of total), Population, Population ages 15-64 (% of total), Population growth, Birth rate, crude, Urban population - gross, population 15-64 - gross	Population (POPUL) Urban population – gross(UPOPX) Population 15-64 – gross (P1564X)
Economical Welfare (eco)	Export of goods and services, GDP per capita, GNI per capita, GNI, Current account balance, Oil price, Industry, value added USD, Industry, value added % of GDP, Gross national expenditure, Final consumption expenditure, import + export of goods and services, Imports of goods and services, Export of goods and services, GDP Growth	Import + export (IM_EX) Gross Domestic Product per capita (GDP_CAP) Gross National Income (GNI)

The path diagram of the final conceptual model obtained as a result of these iterations is given in Figure 6.

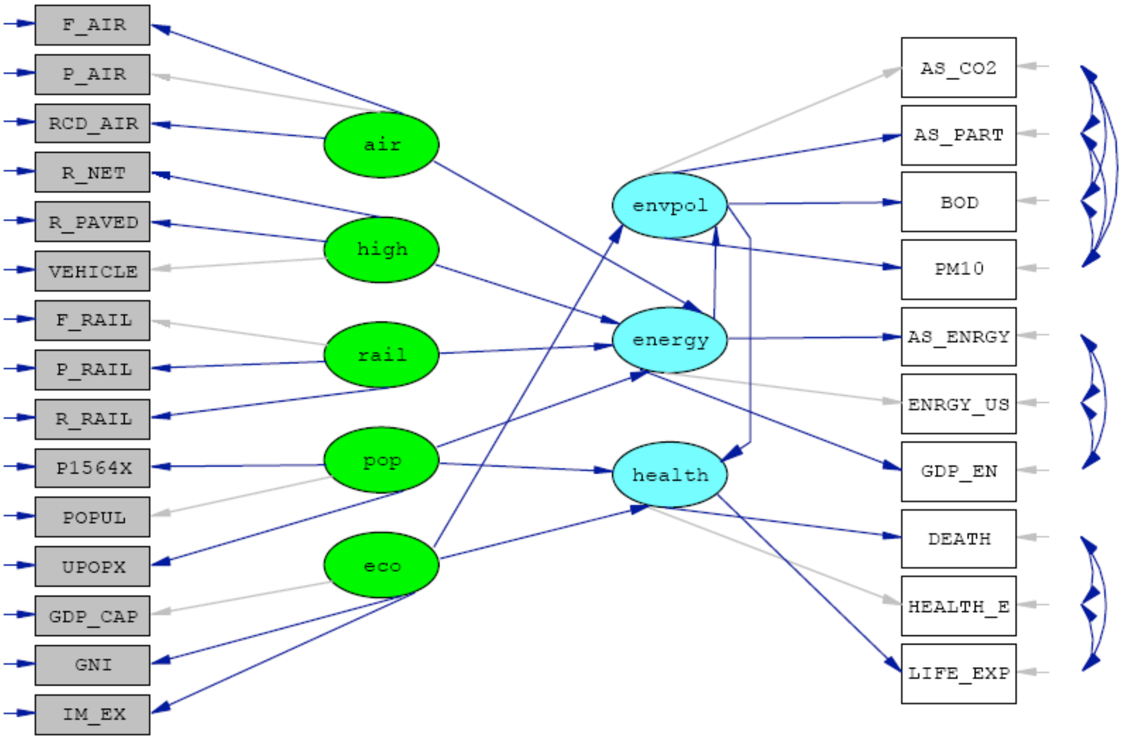

Figure 6 The path diagram of the conceptual model

3.2.3. Assessment of the Model Fit

In the third step, the assessment of the model fit is checked. For this purpose initially, the parameter estimates are obtained. The software (LISREL program) attempts to generate an implied (i.e. model-based) covariance matrix that is equivalent to the observed (i.e. actual) covariance matrix. Furthermore, the significance tests are performed indicating whether the obtained parameters are significantly different from zero. When the covariance matrix implied by the model is equivalent to the covariance matrix of the observed data, it can be said that the model fits the data. Various fit indices provided by the LISREL program allow evaluating the quality and soundness of the measurement and structural parts of the model in terms of supporting the operationalizations and theory-based hypotheses. Subsequently a necessity for a model modification is investigated in the light of the results obtained in assessment of model fit.

In order to identify the model the available data for the specified variables are gathered. Records of the data table are the values of variables for a year of a country. Inbalanced panel data of countries in a year is used in the model Records of the data table are the yearly values of variables for a country. For this purpose the yearly data (1990 – 2002) of 42 countries are used. If the data of a country for a year is not available it is not used. As a result 344 records are taken into account. Then standardization is made within each country data.

The parameter estimates and goodness of fit of the structural model are examined using LISREL 8.54. LISREL syntax was used to specify the commands for LISREL analysis (Joreskog and Sorbom, 1996). Goodness of fit indexes for the model (Chi-Square = 1111.86 [p=0,000], df=251, RMSEA=0.100) has a moderate fit to the data that attains a significant Chi-Square statistic. For RMSEA, values less than 0.05 are indicative of good fit, between 0.05 and under 0.08 of reasonable fit, between 0.08 and 0.10 of mediocre fit and > 0.10 of poor fit (Diamantopoulos and Siguaw, 2000). For the proposed model RMSEA is 0.100 which suggests a mediocre fit. The basic reason of this is that the model is not based on a survey but on an unbalanced panel yearly data of different countries.

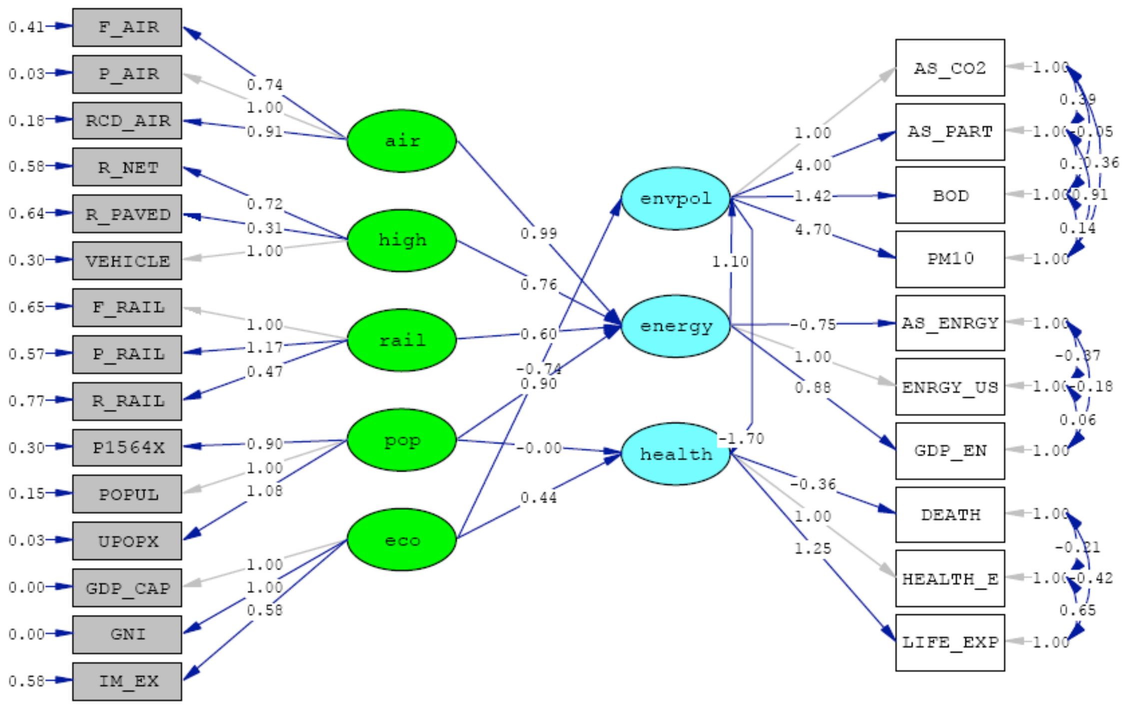

Figure 7. Estimates of the model parameters

According to the model results, all the proposed hypothesis are found significant at %1 confidence level except H3b (relation between population and health) (see Figure 7 and Table 6). According to the experts' opinion, the population has a positive impact on the health of the society however the

Unstructured Equation Model does not find this relation significant. This shows that the population does not have a direct impact on the health of the society.

Table 6. Result of the model

Hypothesis	Estimate	T-value
H1a	0.99	18.05*
H1b	0.76	9.54*
H1c	0.60	4.26*
H1d	0.90	16.68*
H2a	1.10	10.79*
H2b	-0.74	-10.71*
H3a	-1.70	-3.34*
H3b	0.00	0.02
H3c	0.44	8.27*
*significant at 0.01 level		

According to the model findings the airway transportation (0.99) has the highest positive impact on energy use. This is followed by population increase (0.90), highway transportation (0.76) and railway transportation (0.60). The increase in energy use in turn, increases the environmental pollution. On the other hand, the economic power has direct negative effect on the environment pollution although it has an indirect positive impact through transportation modes and energy use. This means that when the economic power of a country increases environmental concern of its citizen's increases that leads a decrease in environmental pollution. However this does not change the fact that the developed countries having high level of economic power will have a high level of energy and transportation use and does have a negative contribution to the environment.

The results also show that environmental pollution has a significant effect (-1.70) on the health of the society.

4. Conclusion and Further Suggestions

This study proposes a decision support system module to analyze the impacts of transportation policies on the environmental issues. In the proposed method, initially, a model of transportation-environment and energy interaction is structured using a cognitive mapping technique. The cognitive map derived in this first stage is used as the input for the SEM. The relations of the cognitive map are directly used to specify the initial relations between independent and dependent latent variables of the system. In the second stage, SEM is used to confirm the relations represented by the cognitive map and to quantify those relationships. The parameter estimation, the assessment of model fit, and the model modification is conducted on SEM.

According to the model findings, airway has the highest impact on energy use, this in turn, indirectly influences the increases in environmental pollution. In fact, this is in parallel with the recently increased attention of the environmental group to the impact of airways. Traditionally, the focus on the air pollution by the environmental groups in the 1980s was to a large extent directed at industrial processes and energy generation. Later, transport and, particularly the motor car came into the firing line with lead in petrol, diesel emissions and NO_x being seen in the part of the equation. Now this has all changed. A number of environmental groups have produced material depicting air travel as being a significant factor in the air pollution equation, now, and certainly tomorrow (Mans, 2000). As a result policy makers should find solutions to environmental impact of aviation in terms of both noise and aircraft engine emissions. In fact European commission recently incorporated in air transport into their existing emissions, trading, and scheme, although currently only CO_2 is included (Morrel, 2007).

Similarly the importance of the role the highway on the environmental pollution continues to be one of the dominant factors.

In summary it can be seen from the model findings that the transportation activities contribute directly, indirectly and cumulatively to environmental problems. In some cases, they may be dominant factors, while in others their role is marginal and difficult to establish. On the other hand, while their concern for environmental pollution is increased, the wealthy populations are found to have more transportation and energy use than a less wealthy one, therefore they have an indirect positive impact on environment pollution. Actions must be taken to alleviate and mitigate environmental externalities linked to transportation in a way where those contributions bear the consequences of their activities.

Developed as such, this proposed model is expected to evaluate the impacts of different transportation policies on environment. By this way, the authorities will consider the proposed solutions as a result of a detailed analysis that highlights all the important dimensions. The proposed model recognizes the need to look at the transportation, environment and energy problems as a whole, not in separate components. In this way, each affecting and affected variable is considered in relation to its impact on the whole system.

As a further suggestion, scenario and policy analysis should be conducted in order to help the policy makers find the appropriate policies to alleviate and mitigate environmental externalities linked to transportation. Scenario planning puts forward a number of different alternative futures, each of which is possible, and focuses less on predicting outcomes than on understanding the forces that may eventually compel an outcome. The scenarios will provide a detailed picture of all the possible futures that may be encountered and in making use of them. It will also be possible to see the possible transitions and the resulting changes that will occur in the Turkish transportation system. By using the proposed TDSS, a dynamic scenario analysis opportunity can be made possible for the Turkish policy makers in their attempt to reduce uncertainties and specify a direction to pursue in the future.

After conducting the scenario analysis, the policy variables that are derived based on different scenarios can be used as inputs to a multicriteria group decision making model. In fact, the costs of environmental externalities can be considered from economic, social and environment dimensions. Using such a model, a finite number of policy alternatives can be evaluated according to conflicting objectives and taking into consideration the different perspectives of the shareholders.

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