□ 論　文 □

TranDASS : GIS와 전문가 시스템을 응용한 교통계획 Package

TranDASS : A Transportation Planning Machine Equipped with GIS and Expert System

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目　次

국 문 요 약

본고의 목적은 기존의 교통계획 모형이 가지는 제반 문제점을 GIS와 전문가체계를 교통계획과정에 통합함으로서 얻을 수 있는 편익을 살펴보는데 있다. GIS의 통합에서는 GIS network data를 교통계획모형의 network data로 변환하는 작업이 중추적인바 본고에서는 GIS의 위상학적 data체계를 변환시킬 수 있는 방안이 제시되었으며, 전문가 시스템의 통합은 복잡한 교통계획 모형의 사용에 있어서 사용자와 대화를 통한 모형입력의 자동화와 교통계획과정에서 생겨나는 애매모호한 여러판단작업(judgmental issues)의 효율적 처리를 통해서 전체적인 교통계획과정을 쉽고 편리하게 하는 측면에서 검토되었다. 또한 양자의 통합을 계기로 전반적 계획과정에 feed back기능을 부여함으로써 종래의 순차적인 모형에서 발생하는 문제점을 극복하려는 시도도 해 보았다. TranDASS(Transportation Decision Aid and Support System)라는 PC상의 구현을 통해서 상기의 통합이 이루어졌으며 기존의 교통계획모형의 문제점을 해소하면서 특정도시 및 지역에 장·단기적 교통계획의 수립을 용이하게 할 것으로 보인다.

1. Introduction

A zone-based sequential modeling approach to travel demand forecasting assumes that travelers choose a destination, a mode, and routes sequentially, mostly in that order. Therefore, in estimating travel demand, four stages of demand analysis-trip generation, trip distribution, mode choice, and trip assignment-have been assumed to represent travel maker's choice behaviors. Although it is true that different sequences can be postulated for the trip-making process, the above sequence is common in practice and has been implemented in the widely distributed computer-aided transportation planning system referred to as the Urban Transportation Planning Systems (UTPS) (Ben-Akiva and Lerman 1987).

While the UTPS-type modeling package has been used in helping make transportation investment or planning decisions in most of the planning agencies throughout the world, it has many theoretical and practical limitations. Theoretical limitations are well described in Stopher and Meyburg(1975) and Kim(1990), and they can be boiled down to the following practical limitations:

Aggregation Issue In the conventional zone-based model, a centroid is assigned to each zone to represent the characteristics of the transportation study area. By modeling an area as a single node, bias is introduced in the description of the socio-economic characteristics of the area. This bias may ignore the spatial variations of key attributes within zones, such that they exceed the variance between zones, leading to a false conclusion due to overly aggregate data.

No Feedback Issue The sequential process of defining each zone as a node prior to the trip generation stage can be affected by even slight changes in zone boundaries. These changes in zone boundaries can produce different results in distribution, mode choice, and assignment. An iterative process that combines delineating zonal boundaries, network buliding and travel forecasting is needed to solve some of the problems associated with the sequential process.

User-Unfriendliness The input generation of transportation demand modeling requires the modeler to be familiar with the modeling package being used. It is very time-consuming to master the whole manual, such as the TRANPLAN or EMME/2 manuals, in order to use the packages correctly and efficiently. Interpretation of the model output generally involves printing the whole or partial output, or retrieving voluminous output into a text editor to review the numerical results[1].

Labor-Intensiveness The following key steps in the modeling process are very time-consuming and burdensome:

- transportation network generation(network coding and node-link data preparation)
- socio-economic data preparation based on de-

lineated traffic analysis zone(TAZ).

Transportation planners have to prepare maps to describe study areas and actual transportation networks. As O'Neil(1991) states, network generation requires extensive data collection and integration efforts. Furthermore, generated networks are frequently modified to reflect changes such as : changes in study area boundaries, changes in zone delineation due to the land use change, modified networks(link shape and node location change) for testing alternative network scenarios, and link attribute(e. g., capacity and speed limit) changes. However, data acquisition is expensive. Even when sufficient and relevant data is already available, the cost of converting data into a usable form can be substantial. Each of these factors contributes to the labor-intensive character of this process.

Retaining the four-step sequential trip making behaviors, this paper demonstrates how the integration of GIS and ES technologies can help to solve the problems listed above by combining the ARC/INFO Geographic Information Systems(GIS), and Expert System(ES), and Transportation Planning package called TRANPLAN. This paper addresses the follwoing questions : (1) how can a GIS model be linked to a transportation planning model?, (2) how can ES facilitate transportation planning process by generating an input for a transportation planning model and by providing a user-friendly interface? (3) how can both GIS and ES contribute to incorporating feedback mechanism in the sequential transportation planning process?, and (4) how can an integrated system work as a decision aid tool?

[1]Recently, graphic support routines have been added to the existing UTPS-type transportation demand modeling packages such as MINUTP and TRANPLAN. In the MINUTP, NETVUE exist as components for viewing and editing transportation networks. NIS(Network Information System) exists as a separate graphic display and editing transportation networks. NIS(Network Information System)exists as a separate graphic display and editing system for TRANPLAN. However, most probably EMME/2 can be considered as the first interactive graphic-based turnkey system for modeling the transportation planning process.

2. The Applicability of GIS and Expert System to the Transportation Planning Process

Recent developments in computer software technology have helped create some useful computer-aided systems that can be used in transportation planning process. Table 1 shows the characteristics of software that have been used in solving transportation problems.

Computer graphics have been an important aid in the analysis and interpretation of data and provide substantial assistance in the description, analysis and design phases of a diverse transportation projects (Schneider 1984). More recently, CAD and GIS have been used in areas such as pavement and accident managements. While both GIS and CAD are dealing with spatial objects graphically, GIS is different from CAD in that it has the ability to create new information (See Dueker 1987, Antenucci et al. 1991, Lewis 1990 for more information.)

2.1 GIS and Transportation Systems Modeling

Transportation planning involves a great deal of information on features that are geographically distributed over a study area. It utilizes socio-economic data such as population and employment statistics collected for spatially homogeneous areas to estimate trip production and attraction(Simkowitz 1989).

Data collected for network development is a spatial component comprised of a set of modes and links. Based on the similarity of spatial data used in transportation system modeling and geographic information systems, GIS could be used to manage data and information needed for transportation network development. In addition, GIS allows many elements of the spatially distributed transportation database to be linked to the graphical display.

However, as noted earlier, the database function of GIS has been mostly used for descriptive type problems, such as pavement and accident management systems. Even though GIS can perform spatial analysis and network operations that are not available in CAD-type software, not all modeling activities of transportation planning process can be achieved. Therefore, it seems more reasonable to combine the transportation systems modeling(not to mention TP models) and GIS than to try to obtain solutions only within GIS.

Tabel 1 : Comparison of Recent Software Developments

Software Type	Function	Unit
Spreadsheet	store and manipulate numbers	number/cell
Database	structure numbers and words into records	record
CAD/CAM	input and manipulate drawings	spatial object
GIS	structure and join drawings and rocords into intelligent maps	topological spatial object
ES	reason with rules and facts	rule/fact

2.2 The Role of GIS in Transportation Planning Process

Some GIS functions can be incorporated into the transportation planning modeling process to solve the problems inherited in the UTPS-type transportation planning models. These functions are : (1) *a database integrating function* porviding appropriate data in the zone delineation and trip generation stages, (2) *a network topology-generating function* to provide the basic node-link scheme and necessary attribute data, (3) *a spatial analyst function* to perform spatial search and query(such as the routing and allocation of transportation supply centers), and (4) *a display device* for presenting nonspatial data in graphics form.

GIS, as database integrator, can manage and manipulate spatially oriented data structures, such as parcel-based data in a study area, leading to resolve the issues of user-unfriendliness the conventional TP models. As spatial analyst, GIS may overcome the aggregate nature of TP model structure that ignores spatial variations, by allowing the generation of different schemes of TAZs. In addition, GIS as output interpreter can summarize large amounts of numerical data into single pictures that "tell a thousand words." The role of GIS as network topology generator may reduce the number of labor-intensive tasks in transportation network data construction. The arc-node topology of a digital map in vector GIS can be a basis for transportation node-link data construction.

In establishing the supportive role of GIS, it is very important to reduce the inherent topological differences between the two systems, especially differences between the GIS topology and transportation network topology. Once the one-to-one mapping of transportation network elements and spatial elements in GIS have been established, it is easy to transfer the data of each system back and forth between the two systems. This will be further discussed in Section 3.1

2.3 The Applicability of Expert Systems to TP Process

Expert systems, developed as a branch of artificial intelligence (AI), have been successfully utilized in the fields of medicine, chemistry, engineering, and military applications. In essence, ES attempts to incorporate the judgment, experience, rules of thumb, and intuition of human experts into the problem solving process(Kim, Wiggins, and Wright 1990).

Table 2 : The Characteristics of Transportation Planning Model, ES, and GIS

Dimension	TP Model	Expert System	GIS
Focus	Travel Behavior Simulation	Expertise Transfer	Spatial Operation
Manipulation	Numerical	Symbolic	Numerical Graphical
Impetus	Effectiveness	Efficiency Expediency	Effectiveness
Input Data	Processed data Model	Facts and Rules	Location and Attribute Data
Process Type	Data Analysis OR-type Modelling	Inferencing Reasoning	Spatial Modeling
Output Type	Optimal Solution	Acceptable Solution or Advice	Composite Overlay of Maps

The most popular use of ES is its application to "diagnostic" problems. The main reason why the transportation plannng field has lagged behind in the use of ES is that transportation planning problems are planning and design problems, not diagnostic. However, there are a lot of judgmental issues in the TP process such as modeling sequnces from trip generation to assignment, model selection, and model parameter selection. User-inputs provided to ES throgh a user-interface could produce and those judgments if the expertise of transportation planners are stored in the if-then production rulebase.

In this paper, there are four areas for the application of ES in TP process. They are : (1) user-interface construction, (2) the input generation of transportation planning model, (3) the classification of spatial basic units that will be aggregated for serving TAZs, and (4) feedback mechanism construction, which forces the iterative process throughout the four stages of transportation planning process until satisfactory results are obtained.

3. Integration of A TP Model, A GIS, and An Expert System

Table 2 shows the characteristics of transportation planning models, GIS and ES. Interest in combining different systems arises from the assumption that the full-blown integrated information and modeling system incorporating both spatial and nonspatial information systems will provide more efficient and reliable results by overcoming the problems identified earlier.

Coupling the independent systems is a practical solution that complements each system's advantages. The benefits of this strategy are that while each system retains its identity and does what it is designed to do the best, the system also gains the advantages of the cooperation with the partner system. On the other hand, integration results in a new class of combined systems that consist of more than three different individual systems. In this case, the comprehensive system incorporates DBMS (Data Base Management System), GIS, ES, and transportation planning models. Integrated information systems are developed to recognize that each different information system has its own unique ability to solve problems of a specific data type, requiring that an interface be built to facilitate the interchange of different data types among systems.

Table 3: Handling of Network Data in GIS and TP Model

TP Model	GIS
Single purpose	Multi-purpose
Model-driven	Data-driven
Abstract context	Geographic context
Single topology (link-node)	Many topologies (point, arc, polygon, network)
Link-node structures	Chain structures
Sort-indexed	Spatially-indexed

In the integration of ES, GIS, and TP models to solve problems of transportation planning models, data compatibility and communication issues are crucial to facilitating the data transfer smong the systems. For example, in classifying a parcel's land-use type, the ES output is a symbolic code assigned to the parcel, which is not directly recognizable by GIS. In a similar way, the GIS database file must be converted to a form that the TP models can use, such as the ASCII format or vice versa.

3.1 Network Discrepancy Between GIS and TP Models

Table 3 shows the fundamental differences between transportation planning models and GIS in the handling of network data(Lewis and Fletcher 1992). Gaps between the two are expected since each system was developed for its own specific purpose. In combining the two systems, the topological gap of the data structures between the two systems should be resolved in order for a combined system to work to overcome the problems of TP models mentioned before.

Patterson (1990) recognizes the linkage gap between GIS and TP models and provides three situations(shown in Figure 1), in which one-to-one correspondence in networks betwwen the two systems is not always possible. Specifically, it is difficult to identify the links in the transportation networks that correspond to particular links in the GIS networks.

As shown in Figure 1, transportation networks are usually simplified versions of the real street network encompassing only interstates, arterials and major collectors. This results in one-to-many correspondence with a more comprehensive GIS network. The second problem he identified is that some transportation models treat intersections and divided highways as a pair of one-way links, whereas many GIS street networks (including TIGER and DIME[2]) do not. This results in a many-to-one correspondence between the two networks. The last problem is the inconsistency between the two networks. Several links in GIS will not have consistent directions with respect to each other, although taken together they correspond to a single link in the transportation network. These problems are common if a planner is working in the United States because standard digital map data is becoming more and more important in the application. If the planner is not in the US, these problems are not always present.

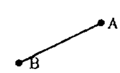
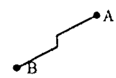
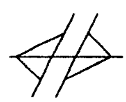
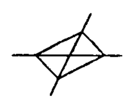
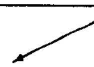
Problems	TP Model	GIS
Simplified Incomplete Network		
Multiple Links for Intersection		
Inconsistent Arc Direction		

Figure 1 : Network Discrepancies Between TP Model and GIS

There is another problem associated with GIS and transportation planning model linkage, in addition to those pointed out by Patterson(1990), Even after those problems have been solved, the distinction of 'zone node'

[2] Stands for Topologically Integrated Geographic Encoding and Referencing and Dual Independent Map Encoding, respectively.

(where trips originate and end) and 'intersection node' (where two or more links meet together) should be made in order for GIS networks to be effectively used as transportation networks, to provide network data to transportation planning models. Therefore, this distinction gives rise to a question of how to directly use the topology of vector GIS in the transportation network, and how to construct a communication channel between the two. The following section focuses on specific software and will explain more about this topology difference and the conversion process.

3.2 The Topology of A GIS and A TP Model Network Structure

In this paper, pc ARC/INFO and TRANPLAN have been chosen as GIS software and transportation planning model packages for the discussion of the GIS and TP model linkage. In orer to circumvent the three problems Patterson(1990) identified in the previous section, all physical transportation networks(national roads and wxpressways) have been digitized using a real map of 1,100,000:1 scale in the proposed case study[3] of Korea.

Arc-node topology created in ARC/INFO cannot be directly used as a node-link scheme in the TRANPLAN network. The main reasons why arc-node topology is directly incompatible with the node-link scheme are:

- **TRANPLAN,** as is the case with other TP package, requires each zonal node to be numbered from 1 to n(if there are n TAZ's), whereas the intersection nodes can be numbered without such restrictions.
- **There is no distinction between zonal node and intersection node in the GIS topology. In addition, it is difficult to change the arc-node topology in such a way that zone nodes should be numbered from 1 to n and other nodes, for example, from(n+1) to m, where m is last node satisfying such relationship as (n+1)<m.**

Some people may propose that the arc-node topology can be modified to coordinayte with the TP model. The nodes generated during the digitization process, however, are not easy to change using commands available in ARC/INFO modules. Furthermore, it is useless to couple GIS and TRANPLAN if every network change in GIS should require the manual change of the arc-node topology. Since this is the case, a topology conversion algorighm should be developed not only to accommodate the topological difference between GIS and TP model topology but also to automate the conversion of GIS arc-node topology into the TP model's node-link topology on a real-time basis.

3.3 Transportation Network Generation Using Topological Connectivity: A Topology Conversion Algorithm

The main thrust of the topology conversion is to provide the capability to develop a trans-

[3]Even though the actual digitizing and topology building are not simple tasks, having a digital version of a map, as a fundamental basis of transportation studies, will be worthwhile if it can aid TP modeling process in an efficient way.

portation network structure and attach attribute data to this structure such that the requirements of the chosen transportation planning model is satisfied. Recent efforts for this kind of research have focused on reconciling existing digital transportation networks with existing digital cartographic databases(Patterson 1990). However, numerous problems caused by the nature of transportation networks of the conventional transportation planning model and digital encoding practices of topographic database limit the success of this approach.

The topology conversion algorithm proposed in this paper first selects the zone nodes from all nodes in the coverage created in the digitization process based on special values assigned to User-ID for each 'zonal arc'(which correspond to links that connect zone node and intersection nodes.

As shown in Figure 2, whatever node is connected to a zone centroid(assumed to be chosen before the digitization process) will be selected in Phase I, based on the are User-ID set bigger than θ, during the digitization process to differentiate plain arc and zonal arc(A zonal arc may be defined in such a way that the User-ID value of the arc exceed θ[4].). Intersection nodes are updated using the formulas in the box.

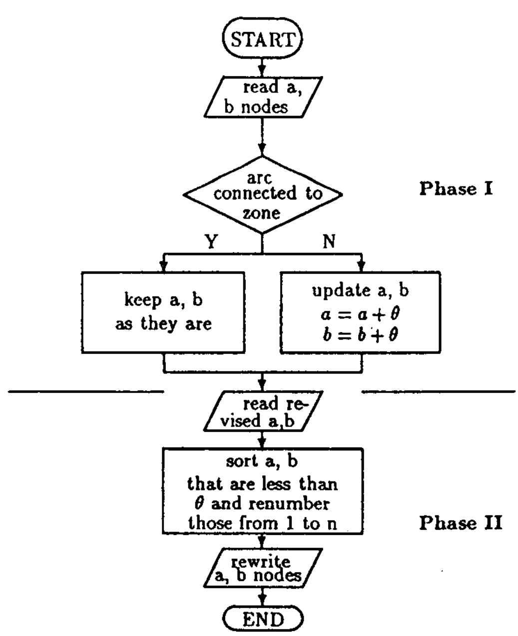
The selected nodes in Phase I will be sorted and renumbered from 1 to n in Phase II to create a compatible form for TRANPLAN. The converted and rewritten arc-node topology will be the basic input for TP model's network generation module and it will be combined with attribute data such as the capacity and speed of links based on the User-ID value of each arc.

[4] In the case study, θ value of 3000 has been used, since TRANPLAN in DOS(Disk Operating System) version can handle up to 3000 zones.

3.4 Issues of Generating Traffic Analysis Zones with GIS

As indicated in Introduction, the sequential process of defining a traffic analysis zone scheme prior to trip generation is very fragile since a slight change in the zoning scheme impacts the results of the four-step modeling process. In practice, however, zone design procedures are mainly based on considerations of convenience and the existence of readily available data

Figure 2: General Flow of the Topology Conversion Algorithm



rather than on the criteria mentioned above. Furthermore, in most transportation studies, the choice of zones and the results have seldom been investigated, even when the data are sufficient.

In the integration of the TP model with a GIS in the context of the generation of traffic analysis zones, the GIS can be a spatial processor, equipped with spatial algorithms, to extract a set of traffic zones, satisfying the rules listed above. This operation requires an integration of several data layers, such as population, land-use, and other geographic barriers like streams.

To perform this spatial processing, a raster-or grid-based GIS is better suited because raster-based GISs facilitate database design and the analysis of multiple polygon overlays (O'Neil 1991). However, vector-based GISs are much more appropriate for many linear featured transportation applications. Therefore, a GIS with raster-to-vector conversion capabilities may be required to effectively integrate TP models with GIS in the context of traffic analysis zone delineation.

Another problem, even after using GIS for extracting spatial block groups, is that the extracted zones satisfying the above zone delineation criteria are not always spatially contiguous. Therefore, given the scale setting, a method of spatial aggregation should be sought that produces both spatially contiguous and homogeneous block groups, so that the automated development of the traffic analysis zone scheme is always warranted in the integration.

In this paper (TranDASS experiment), zoning for the generation of TAZs are based on the calculated similarity indices and the topologies representing the adjacency among parcels [5]. GIS not only provides topological information of adjacency, but integrates zonal database-socioeconomic data such as population, the number of cars, and etc.-for inputting the aggregated sum of agglomerated TAZs' socioeconomic data into TP model of trip generation. For more details regarding this issues, refer to Choi (1992).

3.5 The Role of Knowledge Base in Integration

The knowledge base of the integrated systems in this paper contains three types of knowledge: (1) knowledge about generating the TRANPLAN input, (2) knowledge of classifying the fine-grained GIS parcel into a certain type[6], and (3) knowledge about forcing the feedback behavior.

The major role of the ES module is to generate the input of the TP model to be run by TRANPLAN package. The input generation is accomplished using dialogues between the user and the system, and the input contains the syntax of all the necessary TRANPLAN job control language and related parameters. The following is an example of the rules used in the input generation knowledge (TLD, in the followidng rules, means trip length distribu-

[5]132 parcels, which is county-based classification of the total South Korean penninsula, have been used as the spatial basic units.

[6]This knowledge is needed for identifying the land-use type of the fine-grained parcels. In turns, this land-use type will be one of the inputs for the hierarchical cluster analysis to derive a zone scheme.

tion):

IF (distribution method = Gravity) AND (TLD = known)
THEN (get the TLD file and insert it in the current input)

IF (distribution method = Gravity) AND (TLD = unknown)
  THEN
    IF (OD is available)
    THEN (calculate skim and calibrate the Gravity model
          and feed the output to the current input)
  ELSE
    (print "Can not use Gravity model! Try another!")
ENDIF

Classification rules for assigning a code (land-use) to each parcel were derived by applying a machine-learning program called ID3 (Interactive Dichotomizer 3, see Quinlan 1979) to produce generalizations based on examples. ID3 generates a decision-tree-type rules that classify a case into a category (It is very useful for the construction of a classification rulebase.)and each branch of the decision tree can be translated into production rules such as:

IF (Land Use = Residential) AND (Employment < 4000)
THEN (Parcel-type = 3)

Parcel-type values generated using the rules above will be converted to numerical values and they will be used as one of the inputs of the similarity calculation and parcel regrouping routine, which generates the zone delineation scheme of the study area.

Finally, knowledge about forcing the feedback requires more exact rules which determine the need for feedback based on calculated statistics[7]. These rules look like the following.

IF (chi-square > 20000) AND (assignment technique = equilibrim)
THEN (generate new TAZs and run again!)

IF (chi-square < 20000) AND (chi-square > 10000) AND (used assignment
    technique = equilibrium)
THEN (generate network with at least county roads and run again)

As demonstrated in the above examples, the conclusion of a rule can be a single value or the performance of another external program module. Furthermore, this type of rules can be modified frequently based on user's need, and it is very easy to update rules since in expert systems the rulebase is seperated from control mechanism.

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[7]For example, as a measure of assignment result reliability, chi-square may be calculated using

$$\chi^2 = \Sigma\left[\frac{(V_o - V_e)^2}{V_e}\right]_l$$

where l is a set containing all links in the study area and V_o and V_e are observed (ground count) and expected (model output) volumes, respectively.

4. TranDASS: A Combined System

TranDASS (Transportation planning Decision Aid Supporting System) is a combined system integrating TP models, GIS, and ES that aims to solve the problems of the conventional TP process identified previously.

4.1 Purpose of TranDASS

TranDASS is a prototype of an integrated transportation system for an interactive and user-friendly desktop transportation planning. The purpose of developing TranDASS is to demonstrate the feasibility of combining GIS with TP models using the algorithm developed to convert ARC/INFO coverage topology into TRANPLAN link-node network topology. TranDASS is an improved TP model by incorporating a feedback mechanism, and providing a user-friendly and menu-driven modeling interface.

4.2 TranDASS: System Components and Structure

TranDASS is constructed based on the Decision Support System(DSS) concept as shown in Figure 3. The components of TranDASS include data and model bases, GIS, ES, and data conversion routiness written in FORTRAN. The expert system governs the input generation for TRANPLAN and optimal zone boundary configurations with GIS parcel-based data[8].

GIS provides an important service to the integrated system as a front-end of the model base and database, by generating the appropriate data needed by TP models, and by redisplaying the calculated TP model outputs. The topology conversion routine converts the dumped ASCII format of the ARC/INFO topology into a TRANPLAN link-node topology. The link attribute manager has been set up as an independent system to support the TRANPLAN operation. Thus, two options are possible in TranDASSS to manage link attribute data: one allows GIS to manage the whole arc data and to convert it to the TRANPLAN format, the other allows GIS to generate only an arc-node topology for the TRANPLAN node-link scheme, to which all the link attribute data will be combind later. In this paper, the second method was used.

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[8]The basic flow of zone configuration routine is as follows.

1. ES classifies the type of the parcel-based polygon based on attributes.
2. Hierarchical cluster analysis or parcel regrouping routine based on the calculated similarities, which is written in FORTRAN, will be used to agglomerate the entire parcels into n relatively homogeneous geographical units that will be used as TAZ.
3. GIS will agglomerate parcels into n TAZ based on the output of the cluster analysis and calculate the socio-economic data for each TAZ.

Figure 3: Schematic Structure of TranDASS

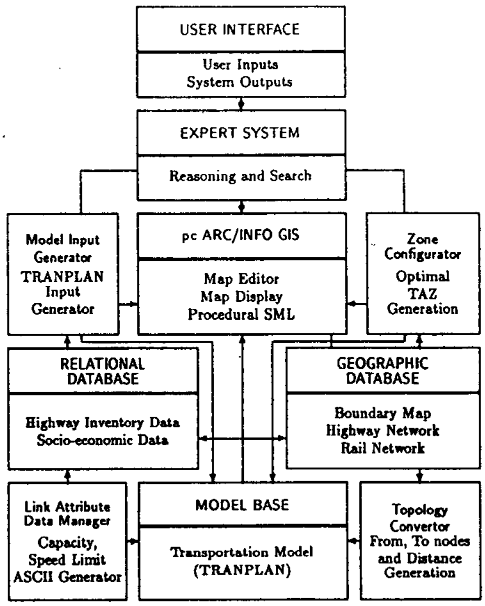
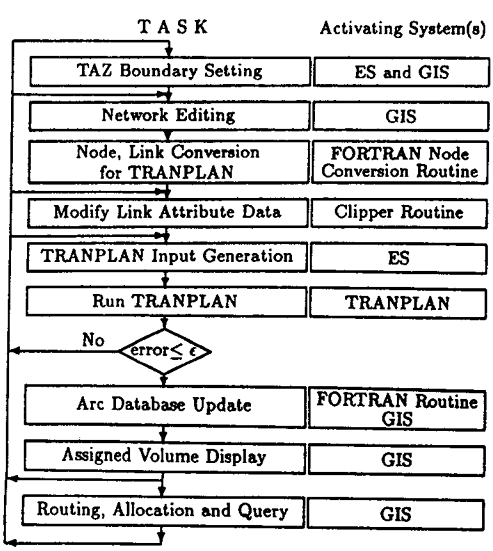


Figure 4: Typical Task Sequence of TranDASS



4.3 Typical System Operation

The typical task sequence of TranDASS is shown in Figure 4. TAZ boundary setting module determines efficient sizes and numbers for TAZs. Each zone's socio-economic statistics will be calculated in GIS and the results will be stored in the database for the next trip generation stage. The modified GIS topology, due to the network editing, will be the input to the topology conversion routine which generates new TRANPLAN node-link topology automatically. The link attribute routine, developed using the Clipper database language, can update the link attribute database[9]. By joining the location data (nodes and link distances) and attribute data, such as the capacity and speed limit of a road, a file containing the complete link data will be generated. It will be combned together with the TRANPLAN input generated by the ES module. As soon as the

[9]There are two reasons for the development of attribute management medules in the TranDASS application. In developing highway or transit networks, the user is required to provide each data entry at specific column positions. For example, the origin node should be typed in between column 1 and column 5, the destination node between 5 to 10, and so on. So, any error in the data entry will generate lots of error messages and will be very cumbersome to locate and correct.

The other reason is to expedite the link data preparation stage. Managing the link attribute data separately and combining it with the converted node-link (location) data is much faster than managing each attribute within GIS. This type of separation is possible because each line element can be managed with its User-ID remaining constants.

TRANPLAN input has been generated, the running of TRANPLAN will follow. After the TRANPLAN session is over, the assigned network volumes will be compared with the actual ground counts and chi-square statistics will be calculated. If the chi-square value is not less than the convergence value specified by the user in ES routine, the whole sequential process (from delineating zone boundaries or changes in link attributes to assignment) will be executed iteratively until results are satisfactory.

4.4 System Implementation

TranDASS has been implemented using IBM PC-compatible 386 and 486 machines, equipped with a math coprocessor and a color graphics card (at least VGA-Video Graphic Adapter). Executing TranDASS requires pc ARC/INFO 3.4D GIS software, TRANPLAN TP modeling package and GURU ES shell language as its backbone. Interfacing routines for proper data exchange, including the topology conversion algorithm, have been developed using Microsoft FORTRAN. Like the grahics operations, all routines involve extensive calculations and conditional branching. Therefore, faster computers are prefereed and some peripherals such as a wide screen and a color printer or plotter are desirable for running TranDASS efficiently.

5. Conclusion and Future Research

In TranDASS, GIS has been adopted as a database integrator, display device for TP model output, and topology generator for direct application to the TP model's network topology through the use of a conversion algorithm. ES supports the entire TP modeling task in four ways: (1) by automating the generation of the TRANPLAN syntax using the heuristic rules, (2) by enhancing the user-friendliness with a user-interface, and (3) by classifying the GIS parcel into a specific type, and (4) by providing a feedback mechanism based on exact rules.

Linking GIS and ES to TP models can not only enhance the user-friendliness and but also partially eliminate other inherent problems associated with aggregation and no-feedback. It will also save a lot of time by automating the conversion process of the GIS topology to transportation network topology.

From the experience of developing TranDASS, it is believed that the intelligent interface provided by the ES for the modeling tasks can assist planners to employ TP models more easily and effectively. In addition, the interactive, real-time decision support can aid the decision-making activities by quickly generating diverse scenarios and enabling decision-makers to select a better alternative.

The application-oriented approach in this study is quite different from the approach taken by developers of generalized GIS systems, who have applied GIS capabilities to

TP[10].The generalized systems are relatively expensive, require powerful computers, and involve command structures which are not generally familiar to transportation planners. In addition, some drawbacks such as no-feedback still remain unresolved.

In contrast, an application-oriented approach, such as the TranDASS described here, can not only overcome the TP model's theoretical limitations by incorporating the feedback mechanism supported by GIS, ES, and the interface routines written in FORTRAN, but also enhance the effectiveness of the conventional four-step TP process. At the same time, all the important GIS functions can be utilized within the TP framework.

There will be a greater potential for integrating GIS, ES, and the conventional TP models if ES can help GIS handle data more efficiently. However, substantial time and resources will be required to explore this potential fully. Thus, in order to develop a system which can be used in a field-level works(such as planning agencies), substantial time and resources will be required to fully explore this potential. However, improvements in computer software and hardware will likely to continue to increase the potential benefits of making these connections.

References

1. Antenucci, J.C. et al. 1991. *Geographic Information Systems; A Guide to Technology.* Van Nostrand Reinhold. New York, NY.

2. Ben-Akiva, M. and Lerman, S.R. 1987. *Discrete Choice Analysis: Theory and Application to Travel Demand.* The MIT Press. Boston. MA.

3. Choi, Keechoo. 1992. *The Implementation of an Integrated Transportation Planning Model with GIS and Expert Systems for Interactive Transportation Planning,* University of Illinois at Urbana-Champaign, Urbana, IL.

4. Dueker, K.J. 1987. Geographic Information Systems and Computer-Aided Mapping. *Journal of the American Planners Association* Summer:384-390.

5. Kim, T.J. 1990. *Advanced Transport and Spatial Systems Models: Application to Korea.* Springer-Verlag. New-York, NY.

6. Kim, T.J., Wiggins, L.L, and Wright, J.R. 1990, (eds). *Expert Systems: Applications to Urban Planning.* Springer-Verlag. New York, Ny.

7. Lewis, S. 1990. Use of Geographical Information Systems in Transportation Modelling. *ITE Journal* 60: 34-38.

8. Lewis, S. and Fletcher, D. 1992. *Data-The GIS Foundation.* Presented at the PreConference Workshop on Geographic Information Systems for Transportation Symposium. Portland, OR.

9. O'Neil, W.A. 1991. Developing Optimal Transportation Analysis Zones Using GIS. *ITE Journal* 61: 33-36.

10. Patterson, P.E. 1990. An Evaluation of the Capabilities and Intergration of Aggregate Transportation Demand Models with GIS Technologies. *Proceedings of the 1990 Annual Con-*

[10]The typical example of this type of GIS is TransCAD, in which the conventional four-stage TP process is incorporated within GIS. However, only limited options in each stage are available, e.g., in generation ITE rate method, in distribution gravity model, in mode choice logit model, etc.

ference of the Urban and Regional Information Systems Association: 330-342. Boston, MA.

11. Quinlan, J. R. 1979. Discovering Rules by Induction from Large Collection of Examples. In *Expert System in Microelectronic Age*, eds. D. Michie. Edinburgh: Edinburgh University Press.

12. Schneider, J.B. 1984. A Review of a Decade of Applications of Computer Graphics Software in the Transportation Field. *Computer, Environment and Urban Systems* 9: 1-20.

13. Simkowitz, H.J. 1989. GIS in Transportation Planning and Operation. *Public Works* July: 62-67.

14. Stopher, P. and Meyburg, A. 1975. *Urban Transportation Planning and Modelling*, Lexington Book Co., Lexington, MA.