META-SYNTHESIS APPROACH TO EXPLORING CONSTRUCTING COMPREHENSIVE TRANSPORTATION SYSTEM IN CHINA *

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Abstract

In this paper, meta-synthesis system approach (MSA) is applied to a consulting project on exploring constructing comprehensive transportation system in China. Firstly, brief introduction about the concept of comprehensive transportation is given to indicate that comprehensive transportation is an open complex giant system, which thus MSA is applied to exploring its constructing in China. A group argumentation environment (GAE) is applied to facilitate group divergent thinking process about what the concerned topics are in the project and acquire qualitative hypotheses for meta-synthetic system modeling. A multi-agent system model is constructed to analyze competitive relations of passenger transport between railway and highway as a demonstration of modeling by rule, one of 6 strategies of meta-synthetic system modeling. An evaluation support system is developed to integrate a variety of indicators and their related measure methods by a framework of input-output-outcome of comprehensive transportation to facilitate consultants to monitor current state of operation and management of transport system and generate alternatives of a set of indicators to evaluate efficiency or effectiveness of the whole system or its elements on demand.

Keywords: Meta-synthesis, multi-agent system, simulation, transportation, group argumentation, evaluation support system

1. Introduction

Transportation is a basic and indispensable element in social economic development. Great achievements have been reached in transportation in China since the adoption of reform and opening policy in 1978. To meet the continuously increasing demands from the socioeconomic development for a harmony and

*This work was supported by National Natural Science Foundation of China under Grant No.79990583, 70221001 and Chinese Academy of Engineering. The original version was presented at the Congress of the IFSR2005.

well-off living society, a national integrative transportation system instead of separate planning by individual transport mode has been under consideration to deal with old and emerging problems in current national transportation framework (Dong 2002). A variety of relevant research have been undertaking. A consulting project is also launched by Department of Engineering and Management, Chinese Academy of Engineering, whose goal is not to draw conclusions but to undertake an idea generation process for wide and scientific visions about comprehensive transportation system construction in China by effectively utilizing intellectual resources. One of sub projects (Subproject II) in this project is oriented to theories, directions and methods about the comprehensive transportation system construction, which is expected to provide guidelines and coordination for other practical research work. The participants of Subproject II with diverse disciplines held many formal/informal discussions to exchange opinions and defined the pathway toward the sub-project goals. Among those discussions, the concept of so-called comprehensive transportation system, which is obviously totally different from an aggregation of independent transport systems, is a hot topic.

In this paper, brief introduction about the concept of comprehensive transportation is firstly given where to indicate that comprehensive transportation is an open complex giant system. Then instead of technical economic studies, meta-synthesis approach is applied in the consulting project, as demonstrated by computerized support for confident hypothesis generation about comprehensive transportation development and meta-synthetic modeling based on those assumptions. Concretely, a multi-agent system model is developed for passenger transport simulation to help analyze competitive relations between railway and highway.

Efficiency and effectiveness are two basic measures about system performance and there are a lot of relevant indicators about the transportation and socioeconomic development of the nation. An integrative evaluation support system is then developed to integrate a variety of indicators by a framework of input - output - outcome of the concerned system, as together with qualitative and quantitative measuring or scoring methods about those indicators.

The aim of the paper is to show how to acquire a systemic vision toward comprehensive transportation development by meta-synthesis approach, where computerized support tools are applied for different purposes. The research contents belong to Subproject II. In next section, basic ideas of meta-synthesis approach to issue of constructing comprehensive transportation system are addressed.

2. Comprehensive Transportation System and Meta-synthesis Approach to Its Construction

Currently 5 available transport ways, railway, highway, airway, waterway and pipelines in China, are independently managed by different government departments with their own strategic goals. Take railways, the leading role in China transportation, for example 8 north-to-south and 8 east-to-west trunk lines will be implemented and nation-wide corridors and networks for large capacity passenger and cargo transportation will be constructed by the end of 2010. On the other hand, construction of expressway is at quick development stage. In some areas, the competition between railway and highway is so intense that exposes problems in structure of whole transportation infrastructure. Actually each transport system is a complex system itself. Both traditional and emerging problems, such as structure conflicts, bring uncertainties toward the development of each transport mode, let alone the construction of comprehensive transportation, which is expected to be an integrative system of 5 transport ways. Here the concept of comprehensive transportation system is discussed briefly.

2.1 Comprehensive Transportation System is an Open Complex Giant System

Comprehensive or integrative transportation system has been studied since 1940s in western countries. USA, previous USSR and Japan have proposed similar concepts. In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) was approved to develop a national intermodal transportation system that is "economically efficient, environmentally sound, provides the foundation for the nation to compete in the global economy and will move people and goods in an energy efficient manner" and its reauthorization as NEXTEA (National Economic Crossroad Transportation Efficiency Act) was approved in 1997 which emphasizes use of intelligent transportation systems (ITS) with existing infrastructure and sets 9 core elements as "putting safety first, rebuilding America, increasing investment through innovative financial tools, ensuring global competitiveness, improving access to jobs and training, protecting the environment, improving transportation through technology, strengthening urban communities and serving rural America". Intermodal is emphasized in transport system development. European Union also formulated development strategy in 1997 and started trans-European transport network project to connect and interoperate national networks.

It is regarded that integrated transportation is firstly proposed by Japanese in their economic planning in 1955. A Comprehensive Transportation Institute was founded in China in 1959 while system thinking and theories about comprehensive transportation system have been under development around the mid of 1980s. The basic drive for such kind of thinking or planning comes from high speed economic development. Currently, concepts such as intermodalism, balanced transportation, integrated transportation and multimodal transportation reflect different foci toward minimizing cost and maximizing efficiency of transportation while emphasizing quality and service at the same time (Dong, et al. 2003). Unlike the widely used "integrated transportation" in western countries, the term of comprehensive transportation is used more in China. Integrated transportation is regarded to indicate seamless or continuous connection between different transport modes while comprehensive transport indicates a feasible and optimized structure, investment and utilization of transport ways in China (Li 2005). Recently, intensive research and practice about comprehensive transportation driven by economy growth are undertaken while most studies still concern one transport mode and transporting process (Hu & Qian 2004). The consulting project initiated by Chinese Academy of Engineering is expected to exhibit a systemic vision about a comprehensive transportation system with preliminary feasible analysis and provide advices toward future system development. Systemic studies have been then undertaken while firstly a consensus is expected toward the concept of comprehensive transportation system, which is regarded beyond aggregation of 5 separate transport systems.

A comprehensive transportation system is composed of three elements, a) transportation infrastructure (networks and connecting systems with adequate equipments); b) production system (i.e. to fulfill transport task); and c) organizing and coordinating system (Dong 2002). As a matter of fact, the system by each transport mode is also composed of those three elements, while more complexities emerge with increasing scale and interaction as 5 systems are restructured into an integrated one, which is regarded as an open complex giant system (OCGS).

Originally defined by Qian, Yu and Dai (1990), the concept of OCGS refers to one kind of system, where the quantity of subsystems is extremely large, the subsystems have hierarchical structure and complex interrelations within them, and the exchange of energy, material and information are open to outside, self-adaptive and evolutionary. OCGS is the most complex and difficultly handled system**.**

As to comprehensive transportation, lots of different modeling work have been done toward different topics and issues about different transport ways under different purposes. Research on multi-modal or intermodal transportation modeling has also been done where a combination of at least 2 transport ways is studied. How to build an integrated transportation system is a big issue due to different perspectives by different domain experts and decision-makers who are affected by their knowledge scopes and own departmental interests. A system of systems (SOS) is supposed to be an OCGS. Then the comprehensive transportation system is thought to be an OCGS. Traditional reductionism or analytical methods do not work well with OCGS problems where meta-synthesis system approach is applied.

2.2 Meta-Synthesis Approach and a Working Flowchart

Meta-synthesis approach (MSA) is specially proposed for solving OCGS problems (Qian, Yu & Dai 1990, Qian 2001, Wang et al. 1996). The essential idea of MSA can be simplified as "confident hypothesizing, rigorous validating", i.e. quantitative knowledge arises from qualitative understanding, which reflects the process of knowing and doing in epistemology. The approach expects "to unite organically the expert group, data, all sorts of information, and the computer technology, and to unite scientific theory of various disciplines and human experience and knowledge" for both proposing hypothesis and quantitative validating. Later the concept of Hall of Workshop for Meta-Synthetic Engineering (HWMSE) is proposed as MSA practicing platform which is expected to utilize breaking advances in information technologies while the active roles of human beings are greatly emphasized during human-machine collaboration, which is beyond traditional decision support systems (DSS) where machine plays active roles.

Over 10-year research of the approach by practice in several projects on socioeconomic problem, military system, etc. enabled rapid progress on MSA studies in recent years along with the tremendous achievements in networking technologies and more concerns in complexity research (Gu & Tang 2003). Currently, more research is on how to implement meta-synthesis at three levels, information, knowledge and wisdom. Mainly, there are three kinds of meta-synthesis, i) qualitative meta-synthesis; ii) qualitative - quantitative meta-synthesis; iii) meta-synthesis from qualitative hypothesis to quantitative validation (Yu & Tu 2002). Qualitative meta-synthesis produces assumptions or hypotheses about the unstructured problems, i.e. to expose some qualitative relations or structures of the concerned problems. A variety of computerized tools, such as group support systems (GSS), creativity support systems, could be used to support idea generation which is the origin for qualitative meta-synthesis. The second kind of meta-synthesis denotes to conduct quantitative analysis based on assumptions drawn from qualitative meta-synthesis. This kind of work is what system analysts and system engineering people do in their daily work and have already been studied widely and deeply, and supported by most DSS and expert systems in AI field (Wierzbicki, Makowski & Wessel 2000). The third kind of meta-synthesis is to validate the results from the second one. If it works, solution toward the original unstructured problem is gained. If not, new perspectives need to be explored by three kinds of meta-synthesis for another problem structuring and solving process.

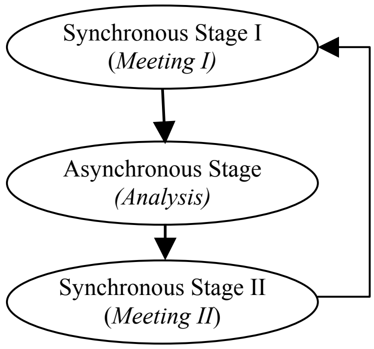

Figure 1 Working process of MSA

Gu and Tang (2005) gave a group working process of MSA in correspondence with three kinds of meta-synthesis as shown in Figure 1.

Activities at synchronous or asynchronous stages are relatively differentiated under time pressure. Most discussions held in the consulting project belong to activities in Synchronous Stage I where to generate hypotheses for meta-synthetic modeling at Asynchronous Stage.

2.3 Meta-Synthetic System Modeling

According to meta-synthetic modeling strategies referred in Gu and Tang (2005), 6 categories of modeling activities may be undertaken for different facets of comprehensive transportation system in Subproject II.

I. Modeling by mechanism, such as econometric models to predict the whole year operation of national economy or specific economic zone, input-output models for demand forecast of transportation capacity, etc.
II. Modeling by analogy. For example, for strategic planning of national transportation

system, it is obviously useful to consider the situations of other countries, such as USA and Japan as their per capita incomes were over 1000 US dollars. Case based reasoning is also an advanced technique.

III. Modeling by data, such as various statistic models may be developed to forecast transport or economy growth so as to predict demand of cargo transport, etc.

IV. Modeling by learning, such as those knowledge discovery and data-mining models. Modeling by learning is still based on data, while it emphasizes a higher level work to expose hidden knowledge embedded in large amount of data. Human involvement is also emphasized to absorb experts' knowledge for improvement of modeling process. Neural network models belong to this category and could also be used in forecasting.

V. Modeling by rule. This category refers to multi-agent system (MAS) simulations which have offered an interesting methodological issue and an innovative tool for specifying and validating individual behavioral models that are believed to be the origin of emergent social and organizational phenomena during the last decade. Given different rules about individual (agent) behaviors, the behaviors of macro system which is consisted of collective agents may be changing. Such kind of rule-based modeling may serve as a means to test some assumptions, design and examine what will be happened.

VI. Modeling by evolutionary scenario, such as evolutionary models, which may be helpful to investigate and explore the complexity, such as chaos and fractal, in transportation and economy.

Above modeling activities may be under assumptions given by qualitative meta-synthesis. The main research foci of Subproject II may include system modeling in consideration of sustainable development, defense and security of the nation, applications and development of new technologies, etc., structure optimization for efficient resources allocation toward constructing the comprehensive transportation system and technical steps, etc. Different from other research, Tang (2004) discussed some basic ideas about applying MSA to the project. In next section, our developed computerized tool is applied to support group brainstorming for new ideas about comprehensive transportation, which is then justified by quantitative validation. Section 4 introduces modeling by rule about passenger transport analysis as a demonstration at the asynchronous stage.

3. Group Argumentation for Qualitative Hypothesis about Comprehensive Transportation System

Subproject II actually includes 3 kinds of people, system researchers, management researchers and representatives (analysts) from 3 major transport modes, railway, highway and airway. Initially, many discussions had been held concerning how to undertake the theoretical research, to which direction, even the definition of comprehensive transportation system and possible problems. Such kind of opinion exchanges facilitates participants to generate many original diverse ideas and take a systemic view toward what kind of a comprehensive transportation system is appropriate for the national development and move outward into a variety of perspectives for further studies. Here one kind of creativity support system *Group Argumentation Environment* (GAE) is used to analyze those discussion process, which may show the effectiveness of computerized support for tacit knowledge transfer. As to introduction and details of GAE, please refer to Tang & Liu (2002, 2004).

For better understanding, here we use the first group meeting held on October 10, 2002 for demonstration. All opinions are summarized into 51 utterances contributed by five participants, whose ID used in GAE is *yzliu, wyang, lihong, ybyang* and *huo* respectively.

Figure 2 shows the visualized structure of whole discussion based on keywords contributed by participants. From that map, we suppose that concerns of four participants (*yzliu, wyang, lihong,* and *ybyang*) are closer while the ideas of *huo*'s are much different from others', since *huo* situates far away from the other 4 participants. The 2-dimensional correspondence mapping is based on dual scaling method.

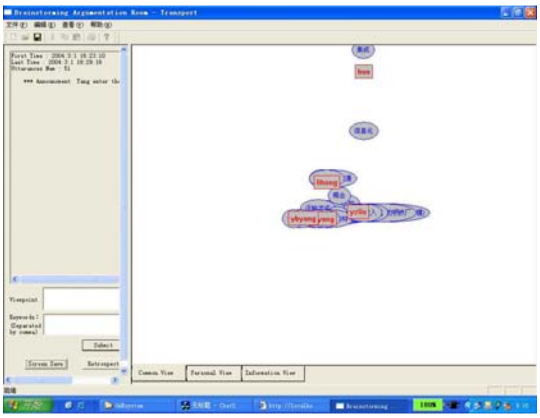

Figure 2 Visualized global opinions by keywords by GAE

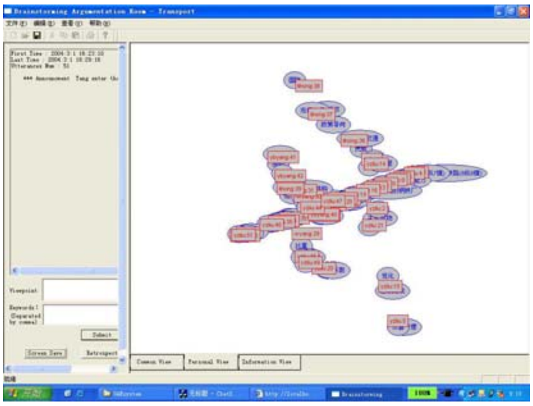

Figure 3 Visualized opinions at personalized viewer

Figure 3 shows a visualized utterances' structure based on utterances' submission sequence. User *yzliu* contributed 30 utterances, and was the most influential participant during that discussion. Those visualized maps as shown based on relations of keyword-user or utterance-user are expected to stimulate participants' further thinking about the discussing topics and expand the group thinking space.

The example is not an on-line case. For later reviewers, retrospective viewer in GAE can help participants and others to review the whole process by a variety of alternatives. Figure 4 displays the group thinking structure based on first 40 utterances, while User *huo* has not submitted any utterances; concerns of User *wyang* and *ybyang* are closer, whatever may not be supported by spatial relations existed only among three participants *wyang, lihong,* and *ybyang*, as shown in Figure 5. Such kind of analysis may help to detect micro-community among the participants and then serve as references for selection of appropriate participants in avoid of groupthink during group idea generation process later.

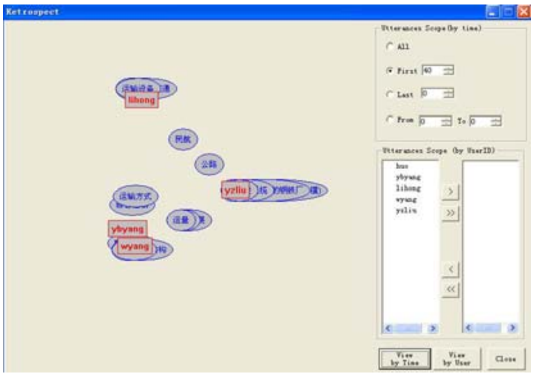

Figure 4 Retrospective view by time (first 40 utterances)

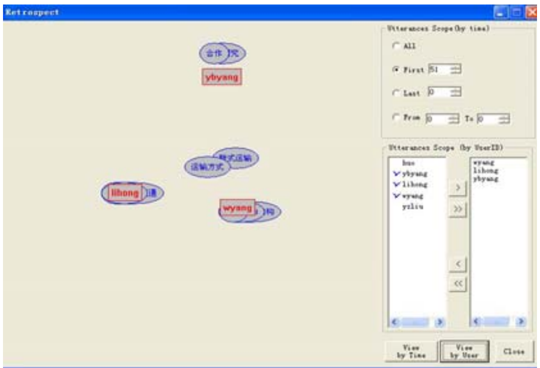

Figure 5 Retrospective view by selected participants

Besides procedural support for group argumentation, GAE also fulfills information processing for outcome analysis, one of which is clustering of all utterances into affinity groups based on the spatial map about utterance-user. Figure 6 shows the affinity list in part as the whole utterance set is categorized into 26 cells via a 16×16 segmentation of the spatial map. The utterances fall into one cell are regarded as one cluster. Automatic affinity diagramming could be regarded as a rough clustering about participants' opinions during the brainstorming session. Further processing by human experts could be taken to acquire more reasonable clusters, such as combining some neighbor cells. For example, those utterances within the adjacent Cell [row=10, col=6] and Cell [row=10, col=7] reflect participants' emphasizing concerns on key factors in comprehensive transportation and macro economy and then could be grouped into one cluster. Such kind of further processing by human experts based on automatic affinity diagramming also exhibits the ideas of man-machine interaction while human plays principal roles emphasized by meta-synthesis approach.

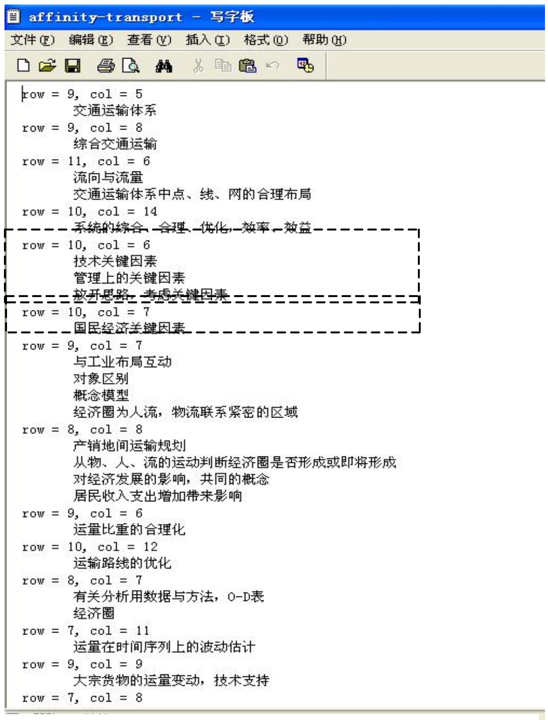

Figure 6 Affinity list

Group discussions had been taken many times which were very helpful to fix the limited goals with limited resources in humans, money and information available for Subproject II. Later the main foci were concentrated on the enhancement of efficiency and effectiveness of comprehensive transport system and detailed tasks were made clear together with a working plan. Most of the further quantitative modeling and analytical work belongs to Type I, II and III (Liu 2004). Modeling by rule (Type V) is regarded to provide a different perspective from technical economic analysis and demonstrated here by a multi-agent system (MAS) simulation model to analyze competitive relations of passenger transport between railway and highway in next section.

4. Multi-Agent System for Passenger Transport Simulation

As an important part of comprehensive transportation system, passenger transport is currently fulfilled via four modes, railway, highway, airway and waterway, in China. In recent years, the competition between railway and highway in passenger transport becomes more and more intense. Limited rationality in human behaviors brings uncertainties and increases complexity to practical passenger transport systems. Instead of qualitative descriptions about the competitive relations between two modes, here a MAS model is developed to analyze how different factors of each transport system affect passengers' selection of travel means by the StarLogo MAS platform developed by MIT (downloaded at http://education.mit.edu/starlogo/).

Passengers' selection of vehicles is affected by many factors, which can be classified into internal and external factors by view of transportation system. External factors may refer to passengers' incomes, industry structure, urbanization, etc. Internal factors are relevant to characteristics of the transport mode and here viewed by 5 indicators, safety, comfort, convenience, speediness and economy (cost), for passenger transport. For simplification, only impacts of internal factors are considered.

Table 1 Groups of agents (Passengers)

Group	Income (RMB *yuan*)	Percentage (%)	Income growth rate (%)
1	≥5000	5	5
2	3000-5000	15	10
3	1000-3000	40	20
4	500-1000	25	10
5	<500	15	5

Table 2 Value of indicators for transport modes

	safety	comfort	conveni-ence	speedi-ness	economy
railway	4	4	3	4	3
highway	4	3	4	4	3

4.1 Modeling Passenger Transport

The only agent (passengers) is categorized into 5 groups by level of incomes as shown in Table 1. Those figures are given by estimation, not from practical investigation. Here we concentrate on modeling itself.

The behaviors of each agent and system are defined as follows.

1) Motivitation of traveling. Each agent owns *energy* to afford his traveling. Here *energy* of an agent is defined as 20% of his income. When his *energy* reaches a certain point, the agent has a possibility for a trip. Traveling will be at a cost of *energy*. As *energy* is less than the minimum cost for a trip, agent stops traveling.

2) Scores for vehicles. Each transport mode has its advantage and disadvantage in passenger transport. Table 2 gives general benchmark for railway and highway.

Table 3 Weights of indicators for different groups

Income Level	safety	comfort	convenience	speediness	economy
1	3	5	2	4	1
2	5	4	1	3	2
3	2	4	5	1	3
4	3	2	1	5	4
5	4	1	3	2	5

Table 4 Acting rules of an agent

#	Rule	Priority
1	IF *energy* < MIN(P_r, P_h) THEN stop traveling	2
2	IFMIN(P_r, P_h) < *energy* < MAX(P_r, P_h) THEN select vehicle with lower price	3
3	IF *energy* > MAX(P_r, P_h) AND $T_{ir} > T_{ih}$ THEN select railway	4
4	IF *energy* > MAX(P_r, P_h) AND $T_{ir} < T_{ih}$ THEN select highway	4
5	IF *energy* > MAX(P_r, P_h) AND $T_{ir} = T_{ih}$ THEN select vehicle with lower price	4
6	IF *capacity* of both modes are full THEN stop traveling	1
7	IF *capacity* of one and only one mode is available THEN select that mode	3

(P_r and P_h denote prices for railway and highway respectively.)

Those values come from evaluation of 5 transport modes based on statistics and expert evaluations. Some indicators, such as *economy* and *speediness* can also be calculated by Equations (1) and (2).

Cost = *INT* (K_1*distance/price + 0.5) (1)

Speediness = *INT* (K_2 * speed + 0.5) (2)

where K_1 and K_2 are coefficients, here K_1=0.5, K_2 = 1/30, *INT* denotes the function to convert a decimal number to an integer value.

However, different groups of agents have their own preferences to vehicles due to different levels of incomes. Table 3 lists the subjective weights for 5 factors at different income levels.

Agent at each income level selects one vehicle based on the total scores calculated by $T_{im} = \sum_{j=1}^{5}(W_{ij} \times I_{mj})$, where $i = 1,2,3,4,5;$ m denotes transport mode (r-railway, h-highway), W_{ij} is subjective weight for indicator j by group i, I_{mj} denotes the points of indicator j for transport mode m, T_{im} is the total subjective score for transport mode m by group i (income level). $T_{ir} > T_{ih}$ means the agent prefers railway.

(3) Rules for Vehicle Selection. Agent selects vehicle according to the available *capacity* of transport modes, his preferences and *energy*. Table 4 lists rules about agent behaviors.

Figure 7 shows the working flow of the MAS simulation which is based on three assumptions: (i) the income of agent increases with time at different growth rates for different income levels; (ii) both income and energy of agent are assigned once at each step of simulation (referring a period of time); (iii) agent consumes his energy as much as possible at each step.

4.2 Simulation Experiments

Four tests are taken to observe how different factors of transportation systems affect behaviors of passengers, (i) transport price change; (ii) transport speed change; (iii) safety improvement; and (iv) capacity adjustment. The distance of traveling is 1200km. Due to limitations of the capacity of StarLogo, the maximum number of agents is set to 200.

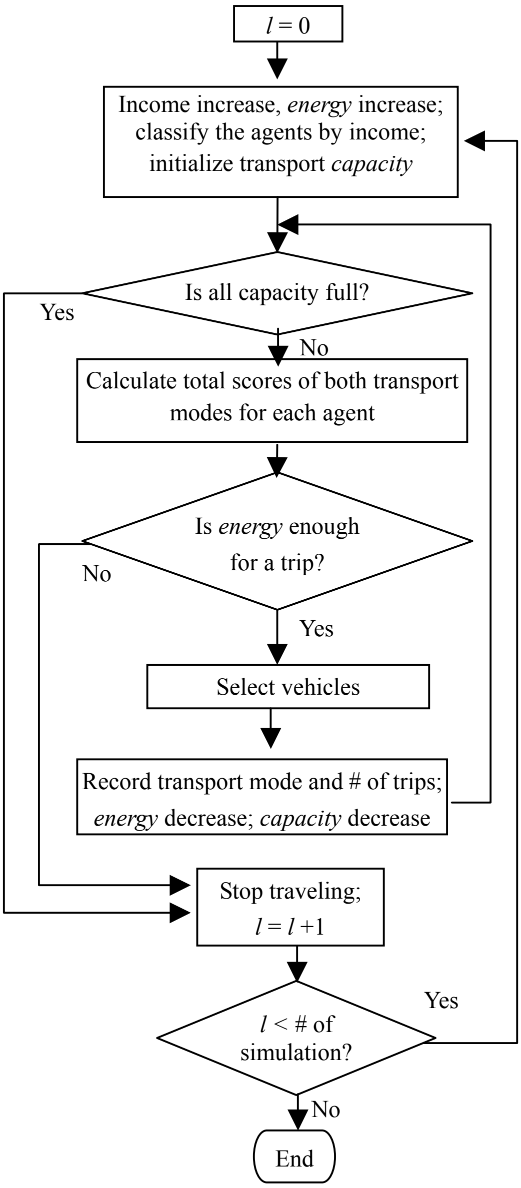

Figure 7 Working flow of MAS simulation

Figures 8-11 show the performance of both transport modes by different conditions respectively. As test condition state 1 was changed to 2, the price of highway dropped from 180 to 120 which increased the value of economy of highway to 5 from 3, then both passenger traffic and income of highway increased quickly while those of railway dropped as shown in Figure 9(a & b), which reflects most people prefer more economical vehicles.

From test condition state 2 to 3, as train speed increased from 120 km/hr to 180 km/hr (value of speediness increased from 4 to 6) as well as safety was improved (4 to 6), railway passenger traffic increased again. The traffic amounts of both modes were closer. For experiment 4, the limitation of capacity of railway drove people travel by highway.

Those experiments exhibit the competition of passenger transport between railway and highway. Given different rules about agent behaviors, the performances of both transport modes will be changing. Some qualitative results may be drawn from qualitative hypothesis (rules) by simulations which are really beyond those qualitative discussions on competition relations between two transport modes and may be useful for policy making on resources allocation, transport pricing, and capacity adjustment of transportation system, etc. On the other hand, there are lots of improvements worth endeavors toward the MAS model. Neither the differences between business traveling and private trips nor the reciprocal impacts between agents are considered in this research (Nie & Tang 2004).

Table 5 Simulation experiments design

	Transport mode	safety	comfort	convenience	speediness	economy	Price (yuan)	Speed (km/h）	capacity
1	railway	4	4	3	4	3	180	120	No limit
	highway	4	3	4	4	3	180	120	No limit
2	railway	4	4	3	4	3	180	120	No limit
	highway	4	3	4	4	5	120	120	No limit
3	railway	6	4	3	6	3	180	180	No limit
	highway	4	3	4	4	5	120	120	No limit
4	railway	6	4	3	6	3	180	180	100
	highway	4	3	4	4	5	120	120	No limit

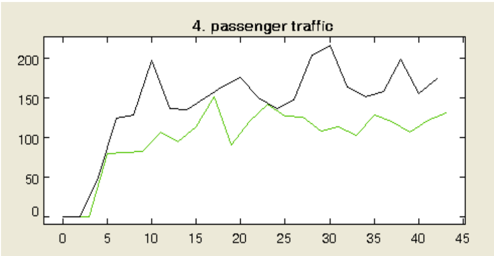

Figure 8a Passenger transport for railway (solid line) and highway (dashed line) (Test 1)

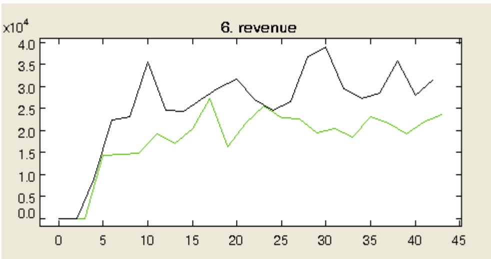

Figure 8b Incomes of transport systems (Test 1)

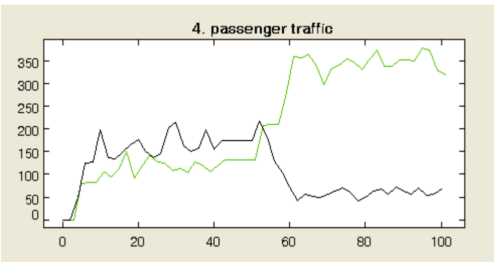

Figure 9a Passenger transport (Test 2)

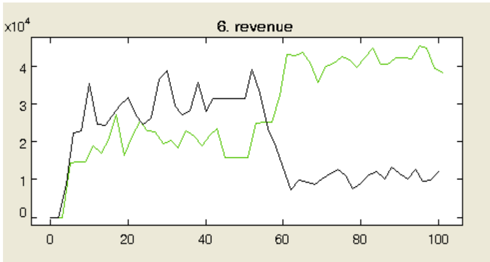

Figure 9b Incomes of transport systems (Test 2)

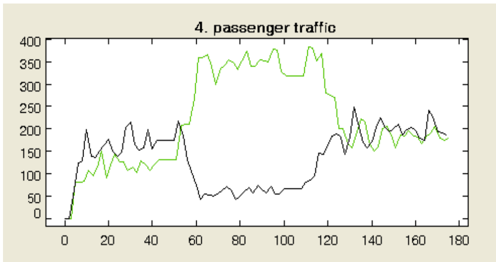

Figure 10a Passenger traffic (Test 3)

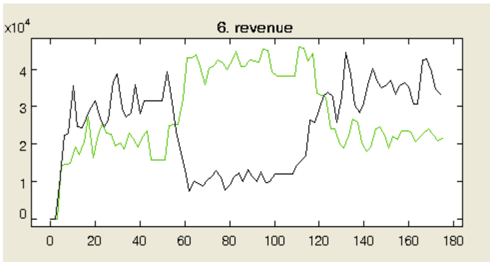

Figure 10b Incomes of transport systems (Test 3)

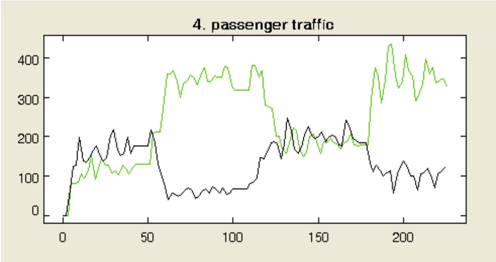

Figure 11a Passenger traffic (Test 4)

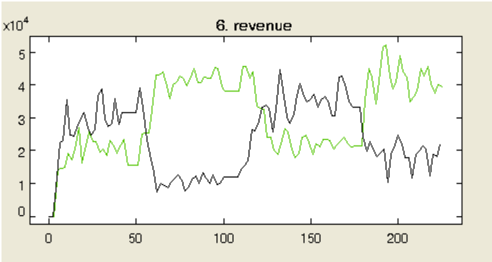

Figure 11b Incomes of transport systems (Test 4)

Till now, the practice of meta-synthesis approach to the concerned problems in the consulting project is addressed. Most quantitative work in Subproject II is about transport forecasting and measuring of both efficiency and effectiveness of comprehensive transportation system. Actually there have been a lot of indices toward basic operation, efficiency and effectiveness of each transport mode and the intermodal system. To help domain people, consultants and even decision-makers to understand more of those indices, how to measure them and how to combine them for an appropriate evaluation alternative for specified purposes, next depicts the idea of an evaluation support system.

5. Evaluation Support System

Efficiency and effectiveness are the most basic indicators about a system performance. Efficiency is a measure of how well the organization is able to manage resources and produce *outputs*. It includes a focus on optimizing all resources (*inputs*) and producing *outputs* at the lowest cost, while effectiveness is a measure of *outcomes*. There are many indicators about input, output and outcome of a transportation system. Here a framework of input-output-outcome is adopted to classify those indicators. Classification can also be based on other technical economic indicators of transport modes.

5.1 Integrative Index Framework for Assessment of System Performance

Either input-output-outcome framework or others serve as a means for indicators management.

For input layer, there are indicators as human resources, money, and materials invested into transportation system construction and operation, such as number of staff and employed workers in transport services, fixed assets investment by state-owned economy, length of railways in operation, etc.

For output layer, total passenger or freight traffic, total turnover of passenger and freight traffic for railway, highway, airway and waterway are common indicators.

For outcome layer, different indicators such as job created or supported (directly and indirectly), tons of pollution, etc. can show the positive or negative effects of transportation system operation. Actually, the core objectives of NEXTEA imply indicators of outcome.

5.2 The Evaluation Process and Evaluation Case Base

Above depicts a logic framework to store specific indicators. In our study, as many as indicators have been collected, especially those indicators used abroad, to provide appropriate reference for domain people in evaluating transport system or its element. Instead completely objective, the evaluation was usually a subjective process. Preferences of the owners will affect the result. The results of evaluation about strategic planning efforts may affect policy making and healthy development of the sector. In reality, relevant indices are selected from the framework to constitute the specific evaluation index alternative for the specific tasks. One set of indices is impossible to be feasible to any cases. Here imply two concepts, index base (IB) and evaluation index solution. The framework is actually an index base whose contents can be changed. For specific evaluation tasks, specific indices will be selected from IB to establish specified conceptual scenarios which could be regarded as evaluation index alternatives or solutions to evaluation tasks. Such kind of ideas had already been used to commercial information system (Gu, et al. 1998) and multimedia communication networks (Yue, Gu & Tang 2004).

The selection process may undergo interactively. The solution not only refers to an array of indices but also includes the measures and valuation methods about those indices. Different evaluation tasks may result different index solutions, which construct an index alternative base or case base. The detailed process may be as follows:

(a) Choose similar index alternative from alternative base according to the evaluation tasks. If no proper alternative in the base is found, select indices directly from index base to form new scenarios and search for new solutions or select closely similar alternative for modification. Repeat until form an evaluation alternative.
(b) If not statisfied with the alternative, ask for domain expert to provide indicators or alternatives.
(c) Give the name, method of evaluation, operational definition of those newly added indicators.
(d) Reassign weights of those items at the same levels where new items added.
(e) Confirm the evaluation index alternative. If satisfied with the scenario, a solution is reached and also stored in the alternative base. If not, go to (a).
(f) Acquire scores for indices from a checklist where lists all selected indices, their measures and valuation methods. The users are required to give a score for qualitative index. Run relevant computation module to value quantitative index.
(g) Choose one method of integrative evaluation to produce a synthetic result. More methods can be in trial for comparison.
(h) Before exit, confirm if new indices have been stored into index base. If do not exit, go back Step (a).

The working process (a) to (g) is an iterative process to find an appropriate solution for performance evaluation of the transport system or its elements where the preferences of the users can be reflected by the evaluation alternative and the final evaluation result. Furthermore, the measures and valuation process of different indices also reflect users' subjective judgment. The process to scenario establishment is modeling for imagines (scenarios of the concerned by the human beings), instead for insights of systems, which are hardly and possibly modeled in human activity issues.

5.3 Evaluation Methods

The evaluation methods may be used in two ways, individual evaluation and comprehensive evaluation. For former case, we just select all indices for evaluation, then value for each index and exhibit the results. For the latter which is usually in the case of more than two indices, we undertake integration or synthesis of individual evaluations. A variety of evaluation methods are usually applied, such as comprehensive scoring approach, order number approach, ideal point methods, analytical hierarchy process (AHP) and data envelopment analysis (DEA), etc. Specific software toolbox may be used for some evaluation methods.

5.4 Computerized Support Tool

A computerized support tool including Index Base, Method Base, Case base (alternative base) and interface is implemented using Java and Microsoft Access. The tool will not only facilitate the evaluation of practical cases, but also provide a useful aid to compare evaluation methods, understand users' desires and improve the index framework.

Figure 12 shows the logical working process of evaluation support system. Administrator undertakes maintenance work about index base, alternative base and method base. Domain experts contribute indicators and valuing methods which could be regarded as a way of knowledge transfer and sharing during the evaluation process. Figure 13 shows the interface of the implementation.

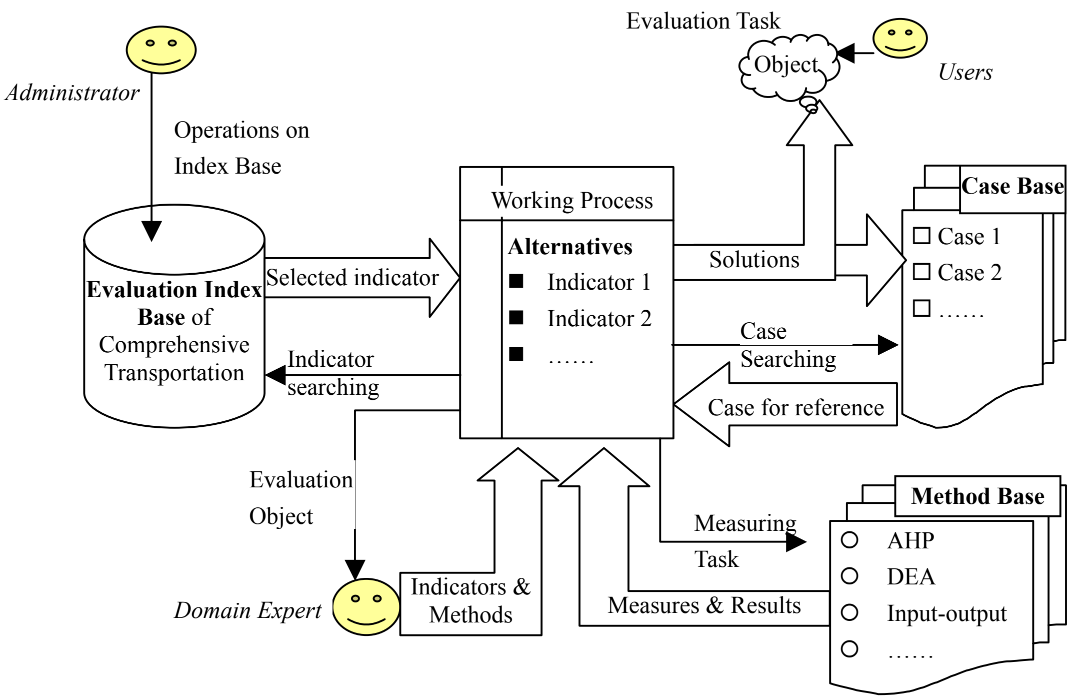

Figure 12 Framework of evaluation support system

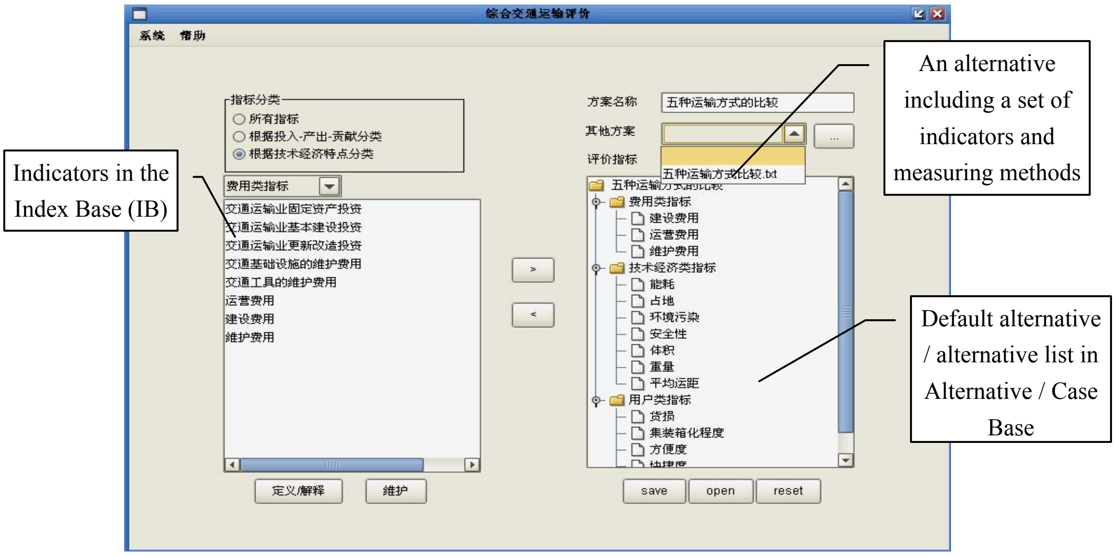

Figure 13 Evaluation support system: indicators selection and case base

The evaluation support tool may be regarded as a part of machine system, domain consultants belong to human expert system, and index base, alternative base (case base) and method base can also be regarded as knowledge elements for in the evaluation process. Then the working process of implementation of practical evaluation about comprehensive transportation system or its element can also be regarded as activities happened in HWMSE, where qualitative intelligence (from domain experts and users) and quantitative intelligence (evaluation support tool) are combined in the evaluating process.

6. Concluding Remarks

In this paper, the practice of meta-synthesis system approach to a consulting research project on exploring constructing comprehensive transportation system in China is addressed. The group discussions among project participants with diverse disciplines, knowledge structures and departmental interests bring both uncertainties and rich ideas toward project implementation. Our developed creativity support tool, Group Argumentation Environment, is then applied to help analyze procedure and outcome of group argumentation. Visualized analysis provided by GAE transforms qualitative knowledge into a series of 2-dimensional maps, which help the participants to understand others' opinions easier, find common interests, stimulate further thinking, knowledge sharing and ideas generation, expose more uncertain factors and acquire intuition or even insight toward the unstructured issues.

It is still of different views toward the definition of comprehensive transportation system, which is beyond the aggregation of 5 separate transport modes and therefore regarded as an open complex giant system. Thus meta-synthesis approach is applied for synthesis of a variety of perspectives or a systemic scenario for modeling. Here 6 categories of modeling strategies for comprehensive transportation system modeling are indicated while basic ideas of modeling by rule for passenger transport are demonstrated.

The simulation of MAS model for passenger traffic depicts the system performance of individual transport mode given different system conditions and individual behaviors, which shows more reasonable explanations than only qualitative discussions about competitive relations of passenger traffic between railway and highway. Endeavors are needed for model improvements in consideration of more practical situations.

With accumulated indicators toward the assessment of transportation systems, an integrative evaluation support system is then developed to integrate a variety of indicators and their related measure methods by a framework of input-output-outcome of the concerned system.

What we are concerned here is to provide one kind of concept and demonstrations for complex problem solving by meta-synthesis approach. Such kind of work aims to provide different perspectives for a systemic scenario toward transportation planning research in China.

Acknowledgements

Professor Yuanzhang LIU, as the principal investigator of Subproject II, is greatly thankful for his encourages in this study fulfilled during September of 2002 to April of 2004.

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