

## CHAPTER 7

### SUMMARY AND DISCUSSION

#### 7.1 Search for Perspective

Transportation is both our slave and master. Civilized man literally cannot live without it and seemingly can't live with it. It is half of the world longest love-hate relationship. It is part of us; there is no escaping from it. We need to move about and exchange the products of our labors. In doing so we necessarily become involved in transportation, either actively - as drivers, riders, shippers, and workers, or passively – as pedestrians, receivers of deliveries, and consumers. Even if we chose to remain at rest in one place, imposed upon us are its benefits in the form of wider choice of goods and lower prices, and its impacts ranging from the noise of aircraft to the nausea and frustration of traffic. Transportation, more than any other industry, has always been in the public mind, the target of its criticism, and the recipient of over-simplified plans for its improvement.

Past civilization and cultures have always sought milestones as benchmarks upon which to gauge progress, accomplishments and well-being, as to set goals for the future. Typically a new year or a new decade has been the instrument. Every hundred years the milestone is provided by a new century; every thousand years by a new millennium. The greater the length of time between milestones, the greater the search for context and perspective. The coming millennium is a time to look back, to look around, to look ahead, and to look beyond.

In moving into the 19<sup>th</sup> Century, had James Watt not invented the steam engine technology, the industrial revolution in Europe would not have been inspired. Had Henry Ford not invented the automobile, or had Wright Brothers not invented the airplane, American economy and society would have developed differently, presumably in more inactive and more agonizing ways. The 19<sup>th</sup>-Century American life style would have

been much different from how it was, had they not faced the challenges with creativity and courage.

The development of transportation during this century has been dominated by the internal combustion engine, which, because of its high power to weight ratio and because the energy in form of petroleum fuel, was so readily available, and conferred a freedom of movement unknown to previous modes. The century is noteworthy for the liberation of transportation from fixed facilities, notably the development of air transportation, and the ubiquitous use of pneumatic tires on roads varying from unmarked lanes to freeways.

The United States committed itself to an incredible capital investment in the 1960s by constructing the interstate system and undertaking the construction of many other roadways. The economic climate that permitted such an ambitious construction program was indeed unique and was not to exist again until the present time. The costs and benefits associated with such an enormous transportation system go well beyond initial capital investments.

Cost-wise, transportation systems in general and the interstate system in particular require continuing maintenance and rehabilitation. Benefit-wise, we learn that highway transportation is the critical underpinning upon which the industrial and technological complex of the U.S. is based. Virtually every aspect of the U.S. economy can be directly tied to highways. With the resulting increase in standard of living coupled with population growth, the freedom afforded by the motor vehicle and the airplane began to result in congestion, which is particularly marked in our cities and our airports.

If the 1980s was the decade of supply-side economics, the 1990s and beyond should be the age of supply-side highway transportation design. The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) was passed to advance U.S. transportation technology and expertise through a worldwide initiative called ITS. Theoretically each area of ITS includes a range of modern communication, computer and control technologies to aid in reducing congestion, enhancing mobility, improving safety, maximizing transportation facility efficiency, promoting economic productivity, maximizing energy resource usage and minimizing environmental impact. Within the

labyrinth of ISTEA, in general, and ITS, in particular, lurks the opportunity for an innovative infrastructure initiative to balance environmental preservation and economic growth so as to achieve sustainable development. But this can only happen if the “demand” obsessed segment of the bureaucracy will allow the best ideas to see the light of application.

At the moment, the transportation sector is again confronting a major challenge. To be able to compete with the transportation needs of the 21<sup>st</sup> Century is an important issue that would contribute to the direction and quality of improvement of the society. Focusing on the supply side, expansion of existing transportation facilities alone will not be an effective remedy to the problem. It requires an absolute innovative technology to serve the overflowing demand in the next century. Magnetic levitation transportation is proposed to be the technology that fulfills such an objective.

## **7.2 Purpose, Premise and Approach**

This dissertation was undertaken to articulate a conception of a transportation system called AHS Maglev which is a synergistic combination of AHS and high speed magnetic levitation technology, and to assess its potential as the foundation for a strategic vision of the next revolution in transportation. Due to limited time and resources, it is recognized that this modest effort will inevitably raise more questions than it answers. Indeed, the number of questions to be answered in formulating a forward policy for such an innovative, comprehensive high-speed ground transportation system is so great that only a very massive study could produce any real quantification.

The key word is innovative. Urban transportation – both intraurban and interurban – has become a major issue due to social and technical evolution, to urban growth and the nuisances of existing transportation systems. Innovation seems to be the only way out.

Governments have achieved very little in recent years in the field of transportation because of a number of basic conflicts between users and internal nuisances, between

operators and dwellers, between collective and individual transports, between economy and quality of life, between technical progress and exploitation. Moreover, urban development is a constantly changing system. A transportation system that is installed early enough can guide and control urban growth. The present accumulation of unsolved problems regarding transportation is a typical deadlock, not the first to be encountered throughout society's evolution. It stems from the fact that we are trying to solve the coming 21<sup>st</sup> Century transportation problems with the technical solutions of the 1950s when every aspect of the 1950 situation has dramatically changed.

To help define this strategic vision, a Decision Support System (DSS) approach described in Chapter 3 was utilized. Let us abandon for the time-being the idiosyncrasies of the transportation phenomenon in order to see how the DSS works in the industrial world: first, the need is identified which should become a market after a decade or two necessary for product development; within the need a specific gap is located and the operating qualities or architecture necessary. To sum up, the study of transportation needs for the next millennium leads to a system comprising individual dual-mode vehicles, traveling at low speeds on urban streets and integrated into high-speed platoons on intercity guideway.

The strategic vision described in this dissertation is based on basic premises. The first premise is that motor vehicle transportation is not sustainable in its present form and the second premise is that government must attack the transportation problem in the same manner that it does problems in other infrastructure sectors such as national defense, water supply and distribution, environmental protection, etc. This is at odds with current conventional wisdom. Those currently shaping ITS and, in the United States, ISTEA have embraced two premises that will surely render ITS an invisible revolution: (1) the need to wean American society from its 20<sup>th</sup> Century love affair with the automobile and (2) the assumption that development of the transportation system for the 21<sup>st</sup> Century can be accomplished with \$200 billion over the next 20 years with 80% of the costs borne by the private sector and 20% by the public sector. Clearly, under present policy ITS is not a transportation infrastructure improvement program; at best it is an attempt for improvement in the conditions of travel. For many, the appeal of ATIS and ATMS lies in

their relative ease of implementation, low cost and low risk. However, it should not be forgotten that the benefits to be expected are equally modest.

The third premise is that the direction of causality is from transportation to development, not the reverse. Contrary to this, the planning community tells us that the first and most important step is to imagine how the towns of the 21<sup>st</sup> Century will develop and then try to determine what the transportation needs will be at the time. This is asinine because we know that each time a population is offered a personalized and flexible transportation means such as the automobile, it chooses it immediately as the basic system. As we enter the new millennium, such a reaction will be worldwide based on the increasing standard of living.

The fourth premises is that the automobile is here to stay. The appeal of the automobile lies in the notion of the “personal sphere” described by the psychologist. The theory is that the human being resents all interference within a sphere of one meter around him, but greatly appreciate a freedom of behavior, of choice and of interest in and from this sphere.

Taken collectively, these first four premises describe a solution space that matches the characteristics of AHS Maglev. The fifth premise is that the existing Interstate Highway System and other freeways are the only practical resource for housing and feeding the AHS Maglev guideways. The sixth premise is that all the elements of AHS Maglev are within the current technological state of the art. For example, high-temperature superconductivity which is the basis of magnetic levitation is an enhancing, not an enabling technology.

The challenge as we enter the new millennium is to develop an integrated system of transportation to provide an improved quality of service consistent with anticipated travel demands within the nation’s economic capabilities and compatible with the requirements of the sustainable development of the country.

This research offers background of the history of magnetic levitation development and information about maglev system currently in use throughout the world. The concept

of maglev technology in transit systems has been adapted into a private transportation mode. Along with reforming the transportation network, reshaping accessibility, and creating compatible cities, we have developed a blueprint for controlling development in the guideway corridor to achieve the elusive goal of successful coordination of the land use transportation system.

### **7.3 Overcoming Congestion with AHS Maglev**

The application of Maglev technology would have been ineffectual, unless economic factors had been proven positively. Thus, the first issue that has been investigated is the economic feasibility. This research has proved that utilization of the proposed Maglev technology is economically feasible. Based on predicted traffic growth in the next 100 years, comparison of user benefit cost ratio indicates considerable advantage of the Maglev alternative over an alternative of expansion of the existing freeway network, which fully depends on 20<sup>th</sup>-century technology. Furthermore, the benefits to nonusers, measured from gross national product, population, and per capita income are proved to be in favor of the Maglev alternative.

The main growth of travel, especially in the U.S. will continue by road and air. AHS Maglev would alleviate airport congestion by greatly reducing short and medium range of flights as reported in Chapter 4.

The growing congestion of highways will pose even greater problems because while traffic demand is increasing exponentially (fueled by the exponential growth of both population and income); highway capacity increases linearly one lane at a time. The important factor then is the capacity of a route provided by a given investment. Highway capacity is determined from simple Newtonian dynamics provided certain assumptions are accepted as being necessary for safety. If a vehicle must be separated from its predecessor so that it can stop at any time without colliding, then a single lane can handle about 2,000 vehicles per hour (1,200 to 1,600 trucks or 1,800 to 2,400 cars) at a moderate

speed. This of course, compromises passing and lane changing, because passing requires that faster lanes are not themselves loaded to capacity.

The penalizing effect of braking distance can, however, be reduced by magnetically coupling vehicles together into platoons. The optimum speed is that at which the spacing of platoons becomes equal to their lengths (Chapter 5). Depending on the safety regime used a single lane guideway can have a possible capacity of more than 24,000 vehicles per hour, equivalent to twelve traditional freeway lanes. It is reasonable to assume, as in Chapter 4 that a double guideway in each direction can carry more traffic than twelve freeway lanes at a lower capital expenditure. The user benefit-cost ratio for the AHS Maglev Alternative (8 lanes) is one and one half that of the Traditional Freeway Expansion Alternative (36 lanes). However, the user BCR does not begin to tell the story because of the full effect of the difference in speeds between AHS Maglev (Alternative 3) and traditional freeways (Alternative 2) does not manifest itself. The areas between the curves denoting the two alternatives for nonuser benefit analysis in Figure 4.17 are a quantitative measure of the difference in nonuser benefits, a much more comprehensive measure of effectiveness. For example, the cumulative difference in GNPs between Alternatives 2 and 3 over the 100-year period between 2000 and 2100 amounts to about 150 trillion dollars. Compare this to the total cost of building Alternative 3 which is 2.2 trillion dollars.

The Maglev network operation is first illustrated in the form of macroscopic traffic characteristics. From a macroscopic point of view, vehicles are taken as groups and their characteristics within a group are assumed to be the same. Platooning and safe following distances indicate trade-offs between safety and capacity. Safe following distances are investigated from three regimes of combinations of deceleration rates between the leading and the following platoons. The results show that high-speed operation is possible if we can avoid sudden stops, while lower speed operation will greatly decrease headway and increase capacity in case such breakdowns are inevitable. The number of vehicles in a platoon also has great influence on the guideway capacity. A larger platoon definitely increases the guideway capacity. However, the ability to form a platoon varied inversely with the operating speed.

Network assignment is performed based on the principal of user equilibrium. Separately operated, cars and trucks are separately assigned to the network. The policy on the minimum number of links required to travel on the guideway affects the network capacity. The more links traveled, the larger the capacity on the guideway. Nonetheless, to force vehicles to traverse many links also reduces the accessibility of the network to adjacent zones.

One of the objectives of this research is the comparison of two-lane guideways with one-lane guideways. Siess [38] based his analysis on one-lane guideways. His “possible capacity” analysis is based on a very liberal safety regime. However, more seriously, since there is only one lane, his assumption that merging vehicles would occupy the spacing between platoons violates the very lenient safety regime assumption that he employed.

#### **7.4 Preserving Stream Stability**

The challenge facing the traffic researcher is the translation of the traffic problem situation comprising drivers, vehicles, control devices and, in this case, guideway elements, into a set of mathematical relationships that reproduces their behavior – a model. The organization and classification of traffic models affords a way of approaching the research of a completely new transportation system. Addressing guideway congestion depends on modeling the macroscopic properties of guideway traffic. The effect of the motion or the headway of one vehicle on another vehicle is referred to as the local, or microscopic, properties of traffic. This is the approach followed in Chapter 6. The macroscopic approach of Chapter 5 is particularly appropriate for steady-state phenomenon of flow and hence best describes operational efficiency. The microscopic approach of Chapter 6 best describe the stability in vehicular interactions, so important in guideway safety.

Automatic vehicle headway control is a complicated process involving a variety of factors – human, mechanical, environmental and guideway. All of these factors affect

the properties of the control system greatly. AHS Maglev is far more complicated to model because in addition to longitudinal control (propulsion), there are the simultaneous problems of suspension (vertical control) and guidance (lateral control). The three-dimensional control model required starts with the classical concept of equation of motion – a differential equation stating the law by which a particle (in this case, a vehicle) moves.

The development of AHS technologies can be divided into the following stages: analytical modeling, simulation, field test, and deployment. Research on the technologies associated with automated highway operation has been conducted for many years. Various automatic headway control models have been proposed based on a variety of control strategies. The complex nature of these models and the effects caused by different external factors result in a thorough model testing and evaluation prior to the automatic control systems deployment.

Following this procedure, the basic three dimensional control equation was formulated using system dynamics so as to permit both analytical and simulation treatment. Longitudinal control required extension of the basic equation of motion since vehicles along the longitudinal axis are not always magnetically coupled. In contrast, vehicles are continually subjected to magnetic levitation (vertical axis) and magnetic guidance (lateral axis). Therefore, the longitudinal portion of the equation of motion was broken down into three components: (1) the magnetic coupling component, (2) the car-following component, and (3) the car-maneuvering component.

In the simulation, a vehicle is modeled to possess speed, and an ability to accelerate with particular values. Ranges of magnetic constants have been assigned to control the high-speed vehicles in desired position laterally and vertically. From applied car maneuvering models, a set of stepwise control rules has been established in a longitudinal control scheme as a train of four vehicles is tested. The use of car maneuvering is believed to mark an original contribution to longitudinal control.

The vehicle is modeled to operate in both tangent and curvature paths to establish a pattern of acceleration and deceleration. The curvature path characteristics are

designed to be consistently integrated into the existing freeway network. The effects of changes in speeds and acceleration on changes in lateral and vertical position during the motion on a curve are considered in depth.

Any high-speed ground transportation to be considered for the next millennium must allow a programmed diversion of individual vehicles at interchanges and a programmed re-entry of vehicles into the main flow. In both cases, passenger accelerations must be maintained at an acceptable level, and the injection of vehicles into available slots must be achieved successfully.

This problem is addressed using the freeway merging experience as a point of departure. Freeway merging is a probabilistic phenomenon involving a distribution of ramp arrivals, distribution of freeway gaps, distribution of waiting times for ramp vehicles in a position to merge, and even the distribution of driver reaction times and vehicular accelerating capabilities. After the merge, a certain percentage of the ramp vehicles will move to other lanes, during successive incremental sections of the freeway. This appears to be of the nature of a Markov process, which is subject to fluctuations before the stationary process, or steady state, is reached. In the vicinity of the merging area, shock waves are produced in the outside lane, spreading to the other lanes. The quantitative description of this effect is best described by the utilization of the deterministic approach.

Merging and weaving are the other two maneuvers that greatly effect guideway capacity. The application of deterministic and random queuing theories is applied to study the upper and lower bounds of the mainstream and weaving traffic capacities. Applying finite capacity queuing theory, ramp capacity is determined based on the reliability to prevent overflowing queues and traffic diversion.

## **7.5 Recommendations for Further Study**

This research is heavily focused from a perspective of civil engineering. Although it includes supporting subject matters relating electrical engineering,

economics, and urban planning and policies, there are still several relevant issues to be investigated to fulfill implementation of maglev technology. Ensuing studies that could be conducted involve:

1. Detailed land use and architectural aspects: Right-of-way required in network construction should be further studied in detail. This includes right-of-way required in curves, ramps, and other non-basic sections. Good architectural design is also preferred for city beautification.
2. The possibilities of applying fuzzy logic into the control scheme: It is believed that the application of neural network and a few fuzzy rules could raise the efficiency of operating systems [82]. Letting the control system reasoning the input information could help eliminate discontinuities between phases of three-dimensional control law.
3. Vehicle properties: The vehicle has to be carefully designed to possess particular physical and aerodynamic properties to be able to operate at the desired manner. Also, the interactions between vehicles purely based on aerodynamic principle such as air resistance and effects of wake vortex should be investigated in depth.
4. Designs of guideways and other infrastructure facilities: In order to put the maglev system in use, the cooperation between electrical and superconductivity technologies is required. Not only will good design enable system operation, but also minimizing energy consumption.
5. Environmental impact: Moving into the 21<sup>st</sup> Century, the environmental impact is always a major concern for all projects. In addition to being a zero-emission system, maglev operation could have a major impact on the environment, namely noise pollution and the loss of habitats.
6. Emergency response: Since no system is absolutely reliable, the emergency response in the case of the system breakdowns has to be well planned. The reduction in capacity and diversion of traffic should be understood.

7. City Planning: The land use functions (i.e., residential, commercial, industrial and other zones) in a magway town and areas along the corridor has to be allocated harmoniously to traffic planning. The proper city zoning would greatly contribute to network assignment and delay reduction.

## **7.6 The Future of High Speed Transportation**

Highway transportation has lagged railway transportation based on speed. The maximum speed achieved on highways has barely changed over the past 50 years, while the maximum speed of passenger trains has tripled. It was in the sixties, that high-speed rail projects began to take shape, first in Japan with the Shinkansen trains, then in Europe. France became the leader in the 1970s with its TGV (Tren la Gran Vitesse) program. Her lead was extended in 1989 with the 300 km/hr TGV Atlantic Route. Now high-speed services are already operating successfully in Japan, France, Germany, Italy Spain and Sweden, with destinations in Switzerland also being served. “Eurostar” trains run international service between Great Britain, France, and Belgium, and “Thalys” service will operate on the Paris-Brussels-Cologne-Amsterdam networks. Projects are being studied in several other regions of the world, more specifically in Korean, China, Taiwan, the United States, Canada and Australia.

Transrapid International, a joint venture of AEG Daimler-Benz Industries, Siemens AG, and Thyssen Industrie AG Henschel, has driven the two-decade development of magnetic levitation technology in Germany. The Transrapid is the first superspeed maglev technology in the world, which is ready and available for application. This was certified in 1991 by independent appraisers and experts of the German Federal Railways, the same people who developed the ICE, one of the most modern high speed rail system in the world.

More than any other system, the Transrapid embodies the qualities of low life cycle cost, high availability and low environmental impact. Due to its ability to climb steep grades (10%) and transit tight curves (2825 m at 400 km/h), the Transrapid

guideway can be sensibly integrated into every landscape. Expensive cuttings retaining walls and tunnels can thereby minimized if not eliminated entirely.

The German Government cleared all the legislative hurdles for the first Transrapid route between Berlin and Hamburg. The Transrapid will enter operation in 2005 and hover straight into the center of both metropolitan areas. Even with three intermediate stops, the nearly 300 km long route from Berlin to Hamburg will take less than an hour, with its tremendous acceleration, the Transrapid reaches 300 km/h in less than 5 km. The planned 10-15 minutes schedule interval will allow more than 40,000 people per day to efficiently travel between Germany's two largest cities.

Exciting as these developments on the railway are, their impact upon the total transport pattern is likely to be limited and it is probable that the conventional railway will remain an important minority carrier. The main growth of traffic will continue by road and air. Highway transportation can learn from the advances in railway transportation, particularly in the possibilities of surface, wheel-less guided transport. The countries which adopt the most imaginative approaches and which provide appropriate facilities for engineers both academic and industrial to innovate and conduct trials, are likely, not only to have transport systems ahead of those in the rest of the world, but also to have salable techniques and hardware which the others will be obliged to buy if they wish to catch up.

The universities have a responsibility here, insofar as fundamental studies are concerned and there is a healthy interest in all aspects of transportation. In the 1960s American universities accepted this challenge and the results were fantastic. Most of the great University Transportation Research Centers emerged and grew along with the Interstate Highway Systems that they both studied and helped to implement.

The decade of the 1960s was the golden age of traffic research driven by the need to perfect and understand freeways, an innovation in highway transportation. Something called traffic flow theory emerged in the attempt of understanding how the fundamental characteristics of the driver, the vehicle, and the road interact to create "traffic" as we know it. The goal of a unified theory of traffic flow was never realized, but a body of

theory, data, and models was created that provided a foundation for traffic research over the past thirty years. In this dissertation, this body of theory has been utilized to define a new transportation system that could usher in a renaissance in traffic research.