CHAPTER 1

INTRODUCTION

1.1 Background

Most transportation technologies currently in use are mature, indeed. The concept of railroad trains with flanged-wheel cars pulled by a locomotive is over 160 years old. The concept of the automobile, a road vehicle with four wheels, compliant tires, seats for two to six people, and powered by an internal combustion engine, is over 100 years old. The airplane was invented 95 years ago. Today the computer-controlled revolution is just beginning. Its ultimate impact on the movement of persons and goods within an innovative transportation paradigm could be quite profound.

A fantastic vision of the future of automobile in which cars drove themselves, while their drivers relaxed, was introduced to the public in the General Motors' Pavilion at the 1939 World's Fair. Since then, a great deal of research in the area of the automatic control of individual rubber-tired vehicles has been conducted on both theoretical [1] and experimental [2] bases, and prototype equipment has been developed [3] and operationally tested [4].

Between the 1960s and 1980s, automated highway technology was explored at Ohio State University under the sponsorship of the Bureau of Public Roads (now the Federal Highway Administration). Other efforts, such as Automated Guideway Transit (AGT) and Personal Rapid Transit (PRT), under the sponsorship of the Urban Mass Transportation Administration (now the Federal Transit Administration) also contributed to advances in automated highway technology.

In 1986, the California Department of Transportation and the University of California's Institute of Transportation Studies initiated the PATH to address, through advanced technology, California's growing need for increased highway capacity to relieve congestion. In 1988, Mobility 2000 was formed to develop a national program on the development of automated highway technology, which eventually evolved into Intelligent Transportation Systems (ITS). Mobility 2000 was the organizational precursor to ITS America, of which AASHTO was a founding member.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), signed by President George Bush on December 18, 1991, formalized a concept known as Intelligent Transportation Systems (ITS) as the new national paradigm. The goal of ITS is to use advanced technologies to improve the operating efficiency of the transportation network. Efforts in ITS can be classified into the six categories identified in the ISTEA legislation: (1) ATMS - Advanced Traffic Management Systems, (2) ATIS - Advanced Traffic Information Systems, (3) APTS - Advanced Public Transportation Systems, (4) CVO - Commercial Vehicle Operations, (5) ARTS - Advanced Rural Transportation Systems, and (6) AVCS - Advanced Vehicle Control Systems.

AVCS can be classified into three levels depending on the ways in which its two unique features, perceptual enhancement and automated controls, are combined. Level 1 is the autonomous driver-vehicle system limited to the incorporation of sensors to augment human eyes and ears. Level 2 is the cooperative driver-vehicle system with technological aids that assume some of the driving tasks. Level 3 is the Automated Highway System (AHS), handling all driving tasks on dedicated highways.

AHS is one of three AVCS categories; Maglev is a technology associated with the operation of high speed trains on specially designed guideways. Under AHS Maglev, cars and trucks would replace trains on fully automated guideways. Magnetically levitated vehicles are designed for high speed transport. Simply put, these are train-like vehicles equipped with a magnet system that is propelled above a track that also contains a magnet system. Depending on the system, the magnets either repel or attract to levitate the vehicle.

The passage of the ISTEA served as a primary stimulus for ITS development, and the AHS development in particular, since it both provided the specific goal of an automated highway system demonstration in 1997 and resources to its accomplishment. The National Automated Highway System Consortium (NAHSC) was established in 1994 to combine private and public sector efforts for AHS development. The Consortium is comprised of 10 “core participants” including Bechtel, California Department of Transportation, Carnegie Mellon University, Delco Electronics, General Motors, Hughes, Lockheed Martin, Parsons Brinckerhoff, and the University of California (PATH) Program in partnership with the U.S. Department of Transportation, Federal Highway Administration. In addition, more than 100 associate participants are working with the program, including Virginia Tech [5].

In October 1993, Virginia Tech was named one of the three ITS Research Centers of Excellence in the United States by the Federal Highway Administration. In 1995, Virginia Tech became part of a consortium to develop a “smart highway” to test ITS technologies, in general, and AHS concepts, in particular. On May 16, 1997, a contract for the first section of the “smart highway” was awarded. In December 1997 a second consortium including Lockheed-Martin, American Maglev Technology, Inc., Virginia Power, and Virginia Tech announced the intention of building a test guideway for magnetically levitated and propelled high speed vehicles in the median of the “smart highway”. In November 1998, Virginia Tech withdrew from this consortium.

The concept of magnetic levitation (Maglev) vehicles is currently deployed in several places. In the past 20 years, the German and Japanese Governments have spent billions of dollars in demonstrating the application of Maglev to High Speed Rail (HSR). An EDS (Electro-dynamic) repulsion system is being developed by the Japanese National Railway on its 4-mile test track at the Miyazaki Maglev Test Center. An EMS (Electro-magnetic) attraction system is being developed in several places, the most advanced of which is the German “Transrapid” System. The implementation costs in these two cases are projected to be $36 million/mile by the Japanese and $28 million/mile by the Germans. The German “Transrapid” System will enter operation between Berlin and Hamburg in 2005.

Today, the United States Department of Transportation, in cooperation with NASA, is again looking into the feasibility of a Maglev transportation system. Both Germany and Japan are currently running extensive testing on full-scale Maglev systems. The United States, while far behind in its application for train travel, is positioned to pioneer its application to providing the guidance and propulsion for cars on AHS guideways.

1.2 Problem Description

Air transportation is losing favor for short trips over land. Travelers have to bear with long waits involved with taking off and landing. Excessive delays are common due to air traffic congestion and bad weather conditions. The locations of most airports outside city limits generate additional trips and travel time to reach final destinationsAirplane tickets are relatively expensive, especially for trips between two small towns which are practically monopolized by one or two airlines. Moreover, growth in the number of air trips means increases in noise and air pollution.

In the crowded world of the next century with high demand for travel, high speed ground transportation will replace aircraft as the preferred mode for short journeys. It is essentially a good alternative for trips of 50 to 1000 km, considering speed of 400 to 500 km/hr [6]. To achieve such high speeds and put this innovative mode of ground transportation into a reasonably competitive position, the technological solutions of this century would not suffice. Innovative changes to established practice must be made before something new is introduced. This paper deals with the innovations, which may produce transportation at lower cost to users and non-users. They are not small, incremental changes; contemporary transportation problems and issues require imaginative innovations. We believe that they will involve changes in both the driver-vehicle interface and the vehicle-roadway interface. The former will be accomplished through automation of part or all of the guidance function over part or all of surface trips. The latter will be effected by reducing the role of wheeled propulsion with its large and expansive power requirements. Speeds in excess of 300 miles per hour inhibit the use of conventional vehicles because of the large material stresses produced. To this end, a number of researchers throughout the world are investigating the applicability of magnetic levitation and linear motor technologies. In place of the driver-controlled wheeled vehicles currently used for the line-haul portion of a journey, we propose computer-controlled "ground airplanes" operating on guideways.

In August 1988, Professor Drew of Virginia Tech was commissioned by the Taiwanese Ministry of Communication to evaluate a proposal by the Japanese National Railroad to develop high-speed magnetically levitated train service between Taipei and Kaohsiung, Taiwan's two largest cities located at opposite ends of the island some two hundred miles apart. Drew concluded that Maglev trains on an automobile-oriented, mobility-driven island were impractical and recommended that if this 21st Century concept was to be seriously considered it should be motor vehicle oriented, perhaps Maglev buses on a guideway [7].

In 1989, Drew wrote a proposal describing a motor vehicle application of Maglev for the Virginia Tech University Center of Transportation Research (UCTR). Because of the lateral guidance problems associated with retrofitting existing highway facilities as automated highway systems, Drew proposed Maglev guideways or "Magways." In 1991, a presentation was made to Westinghouse [8].

It must be appreciated that the automobile is a major feature of contemporary society, our way of life, our travel habits, and our economies. Therefore, rather than try to supplant the auto or diminish its usefulness, we need a transportation system that will enhance the use of automobiles, but in a sensible manner. The automobile is a popular form of mechanized transportation because it is comfortable, flexible, immediately available to the owner, and provides door-to-door service for many travel needs. AHS is an automated transportation concept that complements and augments the individual vehicle. AHS maintains the desirable features of the automobile and improves upon many of the negative aspects. Political and user acceptance of the AHS depends on the ability to provide positive benefits in the areas of capacity, safety, energy, level of service, and environmental and community impacts.

1.3 Purpose and Broad Objectives

The purpose of this research is to develop a strategic vision of AHS/Maglev, a ubiquitous land transportation system for the 21st Century that would fulfill the ITS legacy as the new transportation paradigm, and to explore its impacts and implications. Specific goals of this "ideal" transportation system are:

(1) To provide fast, safe, comfortable, and reliable door-to-door transportation.

(2) To alleviate congestion of the air corridors and airports by virtually eliminating the need for commercial flights under 500 miles in length.

(3) To significantly reduce resource consumption and pollution generation.

(4) To harness a region's economic potential by increasing the diversity of economic opportunities, and by aiding the orderly assimilation of population increases.

Broad objectives are to assess AHS Maglev using a Decision Support System (DSS) instrumentality based on the system dynamics methodology so as:

(1) To develop a concept of operations that could serve as a framework for national AHS architecture;

(2) To illustrate how the proposed system would interface with the existing transportation system; and

(3) To develop scenarios for implementation as a supply-side approach to sustainable development.

This research will focus on some specific objectives, which include

(1) Developing vertical, lateral, and longitudinal vehicle control models.

(2) A comparison of one-lane and two-lane guideways considering:

- Safety regimes.
- Merging operations.
- Safety, capacity and speed tradeoffs.
- Benefit-cost model.

(3) Schematic and geometric design of the guideway to fit into median of 80 mph design speed freeways.

1.4 Plan of Research

In order to accomplish the objectives of the research, several elements of traffic theory are relevant. These elements can be divided into two parts: microscopic and macroscopic characteristics. The microscopic study of AHS/Maglev includes the vehicle specifications, position control schemes and merging procedures. The macroscopic study involves platooning, capacity analysis, traffic assignment, and a consideration of the environmental aspects of Maglev. A simulation model using the system dynamics methodology can be utilized to duplicate several policies for AHS/Maglev. The application of these policies will be illustrated using system dynamics software, DYNAMO [9].

It is necessary to establish an automated position control scheme throughout the guidance of magnetic levitation system. A special type of aerodynamically designed vehicles equipped with magnets can be propelled, controlled and guided by magnetic forces on the guideway. The vertical, lateral and longitudinal position of a Maglev vehicle must be precisely allocated in each small period of time for the vehicle to be fully automated. All of the schemes relate to vehicle specifications, desired position, speed and acceleration. DYNAMO will simulate scenarios to study the effect of the external forces and the control of magnetic levitation forces in all three axes.

Since a Maglev vehicle would be operated like a ground airplane, the vertical position control scheme will play a significant roll in the process of taking off. A high speed is required to generate a sufficient lift force to elevate the vehicle above the guideway. In order to reach that level, the vehicle must also possess applicable physical and aerodynamic properties. After the vehicle reaches a desired level, the elevation must be maintained along the journey. Two important external forces interfere with the desired operation: the centrifugal force and wind force. The first, which is more critical, occurs when a vehicle enters a curve with a high speed. A strong centrifugal force generated in a horizontal axis will cause a vehicle to drop along the Y-axis to the superelevated curve of the guideway. The speed of the vehicle together with the magnetic propulsive force must be adjusted to maintain a safe cushion between the vehicle and the guideway surface. The second force is a minor factor but still can raise both acceleration and jerk to an unacceptable level. A damping magnetic force must also be adjusted to eliminate these effects.

Correspondingly, a lateral position control scheme must also be established to eliminate the effect of the lateral external forces acting on the vehicle. These forces include the aforementioned centrifugal force and wind factor. We can allow more space for centrifugal and wind forces to push the vehicle off the centerline. However, the changes of speed and acceleration are the major concerns in the consideration of ride comfort and safety.

A longitudinal control concept will be established in such a manner as to minimize the headway between two successive vehicles while maintaining high-speeds and safe operation. Some global rules must be incorporated to control interactions in positions, speeds, and accelerations among all the vehicles in the system. Several conventional car-following models will be taken into account and incorporated in the simulation model. The longitudinal concept should enhance guideway capacity while reducing the travel time for individual users.

Weaving and merging must be considered. Statistical methods and queuing theory will be applied to explain the interactions between the freeway roadways and Magways. Ramp capacities will be determined based on an ideal merge. Policies must be established so as to synthesize the merging vehicles with the mainstream traffic with minimal interruption.

After completing all the tasks, the capacity analysis and traffic assignment will be performed. Several traffic network combinations and policies will be tested to obtain the best operation and accessibility. This will be completed by way of an economic sensitivity analysis. Urban modules and Magway allocation must be planned together so as to obtain the “best fit” without overloading either. A conventional urban transportation planning framework will be used to achieve the equilibrium state between traffic facilities and corridor land use.