Modeling Automated Highway System
Guideway Operations

by
Eric J. Siess

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Civil Engineering

APPROVED:

______________________________
Donald R. Drew, Ph.D., Chairman

______________________________  _____________________________
Wei H. Lin, Ph.D.                     Antonio A. Trani, Ph.D.

December, 1997
Blacksburg, Virginia
Modeling Automated Highway System
Guideway Operations

by

Eric J. Siess

Donald R. Drew, Chairman
Department of Civil Engineering

(ABSTRACT)

The purpose of this research is to explore the operational characteristics of a Maglev-based Automated Highway System and how it would interact with freeway operations. The extension of traditional traffic flow phenomenon, including weaving, merging, and stopping distance, into the automated system is looked at. These are also extended into platoon operations and their effect on such properties as gap control and ultimately the capacity of such a system. The ability to incorporate an AHS system into the existing Interstate Highway System is investigated. This includes placing the magways in the right-of-way of the highway system and interfacing the AHS with the existing freeways. A model is developed and run to simulate the assignment of traffic between the freeway and the guideway links. Both operational concepts of user equilibrium and system optimal conditions are explored, and equations are found to estimate the amount of traffic which can be found on the links based on the total traffic volume.
Acknowledgments

I would like to extend my sincere gratitude to Dr. Donald Drew for serving as my advisor and helping me through both the development of this thesis and my academic career at Virginia Tech. Thanks also goes to Dr. Antonio Trani and Dr. Wei Lin for not only serving as members of my committee, but for providing support and assistance whenever needed. Additional thanks to Dr. Trani for the insight and guidance he has provided me through the past several years.

A very special thanks goes to my parents, Gail and Joseph Siess, and my sister, Kerri, for their unflagging support throughout the many years of academic work at Virginia Tech. None of the accomplishments I have achieved would have been possible without them. All of my achievements belong not just to me, but also to them.

Thank you to my roommates, John Sozio and Ben Hall, who I could always count on providing a distraction or lending an ear when I needed it most. Additional thanks to John for being a great friend through it all from the very beginning.

Thanks to my friend Roger Bodnar, who showed me exactly what the thesis experience was all about before I began mine. Also thanks for the support and interest through it all.

Additional thanks to my close friends Fay Barrett, Cheryl Britton, Erin Moore, Mike Caro, Matt Dovie, Ben Sturtevant, and Kit Schkloven for providing the interest and support needed to complete my thesis and just for being someone I could count on when I needed to.

Thanks to the Via family for providing the endowment which provided the funds for my graduate education. Without your support the last year and a half would not have been possible.
Finally, thanks to all my fellow graduate students in the Transportation Division for providing encouragement and support towards the completion of this thesis and my graduate degree.
# Table of Contents

Acknowledgments ................................................................................................................ iii
Table of Contents .............................................................................................................. v
List of Figures................................................................................................................ vi
1 Introduction ..................................................................................................................... 1
  1.1 Today’s Transportation Dilemma ............................................................................... 1
  1.2 ITS – A Potential Solution ...................................................................................... 3
  1.3 ITS Categories ......................................................................................................... 4
2 Literature Review ............................................................................................................. 7
  2.1 Introduction .............................................................................................................. 7
  2.2 AHS Demonstration .............................................................................................. 7
  2.3 AHS Operational Concepts ................................................................................. 10
  2.4 Potential AHS Benefits ....................................................................................... 13
3 The Automated Highway System ................................................................................. 18
  3.1 AHS Architecture ............................................................................................... 18
  3.2 AHS Schematics ................................................................................................. 20
  3.3 AHS Operations ................................................................................................... 29
4 Platooning on the AHS ................................................................................................. 35
  4.1 Introduction .......................................................................................................... 35
  4.2 Platoon Stability ................................................................................................... 35
  4.3 Interplatoon Spacing ......................................................................................... 41
  4.4 Guideway Volume-Speed Relationships ......................................................... 44
  4.5 Moving Queues .................................................................................................. 47
  4.6 Merging and Weaving ....................................................................................... 50
  4.7 Guideway – Freeway Interface .......................................................................... 62
5 Network Analysis .......................................................................................................... 67
  5.1 Introduction .......................................................................................................... 67
  5.2 Trip Distribution ................................................................................................. 68
  5.3 Traffic Assignment .............................................................................................. 72
6 Summary, Conclusions and Recommendations ......................................................... 92
  6.1 Summary .............................................................................................................. 92
  6.2 Conclusions .......................................................................................................... 93
  6.3 Recommendations for Future Research ............................................................. 96
7 References..................................................................................................................... 98
Appendix A ..................................................................................................................... 100
Vita .............................................................................................................................. 125
List of Figures

Figure 3-1 – AHS Maglev Levitation, Propulsion and Guidance ........................................... 21
Figure 3-2 – AHS Guideways and Freeway Roadways .......................................................... 23
Figure 3-3 – Guideway-Freeway Interchange ....................................................................... 24
Figure 3-4 – Guideway-Guideway Interchange .................................................................... 25
Figure 3-5 – Conditions For a Vehicle on AHS Maglev ....................................................... 27
Figure 3-6 – Horizontal Curve Relationships on AHS Magway ............................................. 28
Figure 3-7 – Vehicle Kinematics of Safe-Following Distance ............................................. 31
Figure 4-1 – Velocity, Space, Headway-Time Relationships ................................................ 38
Figure 4-2 – Guideway Traffic Stream Dynamics ................................................................. 43
Figure 4-3 – Guideway Speed-Volume Relationship ............................................................ 45
Figure 4-4 – Guideway Speed-Volume Relationship ............................................................ 46
Figure 4-5 – Platoon Size for Various Parameter Values ...................................................... 49
Figure 4-6 – Ideal Gap for Controlled Merge ..................................................................... 53
Figure 4-7 – Guideway Ramp Capacity versus Guideway Volume ....................................... 59
Figure 4-8 – Weaving Capacities Based on Multiple Entries ............................................... 61
Figure 4-9 – Weaving Capacities Based on Weaving Ratio ................................................. 63
Figure 4-10 – Guideway Weaving Area .............................................................................. 64
Figure 4-11 – Ramp Queue Lengths .................................................................................... 66
Figure 5-1 – Trip Distribution Analysis .............................................................................. 69
Figure 5-2 – Volume Ratio versus Length of Trip ............................................................... 71
Figure 5-3 – Relationship Between Volume Ratio and Length of Trip .................................. 73
Figure 5-4 – Sample AHS Network ..................................................................................... 76
Figure 5-5 – Traffic Assignment of Cars Under User Equilibrium Conditions ..................... 79
Figure 5-6 – Traffic Assignment of Trucks Under User Equilibrium Conditions ................. 80
Figure 5-7 – Freeway Traffic Volume as a Function of the Total Traffic Volume
   For Cars Under User Equilibrium Conditions ................................................................. 83
Figure 5-8 – Freeway Traffic Volume as a Function of the Total Traffic Volume
   For Trucks Under User Equilibrium Conditions ............................................................. 84
Figure 5-9 – Traffic Assignment of Cars Under System Optimal Conditions ....................... 86
Figure 5-10 – Traffic Assignment of Trucks Under System Optimal Conditions .................. 87
Figure 5-11 – Freeway Traffic Volume as a Function of the Total Traffic Volume
   For Cars Under System Optimal Conditions ................................................................... 89
Figure 5-12 – Freeway Traffic Volume as a Function of the Total Traffic Volume
   For Trucks Under System Optimal Conditions ............................................................. 90
Figure A-1 – Regression Line for Guideway Volume versus Total Volume for
   Cars Under User Equilibrium Conditions ...................................................................... 101
Figure A-2 – Regression Line for Guideway Volume versus Total Volume for
   Cars Under User Equilibrium Conditions ...................................................................... 102
Figure A-3 – Regression Line for Guideway Volume versus Total Volume for
   Cars Under User Equilibrium Conditions ...................................................................... 103