September 25, 2001

Neal R. Hawkins
MOVITE President
Howard R. Green Company Consulting Engineers
4685 Merle Hay Rd., Ste. 106
Des Moines, IA 50322-1966

RE: Revised Standardized Section Charter

Dear Mr. Hawkins:

The Executive Director of the Institute of Transportation Engineers, on September 24, 2001, has officially approved the standardized section charter that was proposed and approved at the District 4 board meeting on June 20, 2001. With this approval, each of the four sections within District 4 will have the same standard language in their charter.

I am attaching a signed copy of the MOVITE Charter for your records and will also email you a digital copy. Please distribute this revised charter to all appropriate persons on your executive board.

Thank you for your assistance in accomplishing this goal.

Sincerely,

Bruce L. Wacker
2001 District 4 Secretary

cc: Thomas W. Brahms, Institute Executive Director
Thomas E. Campbell, District 4 Administrator
Earl E. Newman, District 4 Director
Steven D. Hofener, MOVITE Section Administrator

Institute of Transportation Engineers
2001 District 4 Board of Directors

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Traffic Engineering Division
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(417) 864-1983 Fax
earl_newman@ci.springfield.mo.us

Thursday 10/4

8:00-8:45am	Registration, continental breakfast
8:45-9:15am	**Welcome**
	Tom Welch, MOVITE Fall Meeting Program Chair, Iowa DOT
	Mark Wandro, Director, Iowa DOT
	Jenny Grote ITE Int'l VP / Earl Newman ITE Dist. 4 Director
	Tom Maze, Howard R. Green Company
9:15-10:15am	**Context sensitive design**
	Tim Neuman, Chief Highway Engineer, CH2MHill
10:45-12:00	**Issues, techniques, and new ideas in roadway safety**
	Tom Welch, Iowa DOT - Iowa Safety Programs - TSIP, TEAP, SMS
	Dr. Reg Soulerette, Iowa State University - Systematic Identification of High Accident Locations
	Tom Welch/Chad Smith, Iowa DOT - Left Turn Phasing Debate on Prot Only, Prot/Perm, Perm Only-Open Group Discussion
10:45-12:00	**Learning from access management**
	Dave Plazak, CTRE - Access management: impacts and business vitality and real estate
	Howard Preston, Howard R Green Company - Safety Implications of Access Management
	Dan Holderness, City of Coralville - Highway 6 Fifth Lane Roadway Improvement in Coralville, Iowa
12:00-1:15pm	Lunch and MOVITE Business Meeting
1:30-3:00pm	**Growth and all its challenges**
	Tom Kane, Des Moines MPO - Des Moines MPO's perspective on Growth
	Tom Stout, Stanley Associates - Single Point Urban Interchange Design on I-35
	Matt Tondl, HDR - West Dodge Street Grade Separation Project, Omaha
1:30-3:00pm	**Unique Arterial Roadway Design Projects**
	Bill Cary, Shive Hattery -10th Avenue Roadway and Railroad Bridge Reconstruction, Waverly
	Will Sharp, HDR - US 20 Corridor Project, Dubuque
	Tom Ryan, MoDOT - Creeve Corp Lake Bridge Project
3:30-5:00pm	**Experience, applications, results: Roundabouts to durable pavement markings**
	Kurtis Younkin, Iowa DOT - What's New in the World of Pavement Markings?
	Dr Schnell, The University of Iowa - Enhancing Pavement Marking Visibility for Older Drivers
	Alonzo Linan, City of Olathe, KS - Installation of Roundabouts within the City of Olathe
3:30-5:00pm	**Accomodating trucks on the transportation network**
	Scott Weiser, Iowa Motor Truck Association - The Trucking Perspective
	Bill Stone, MoDOT - I-35 Trade Corridor Project
	Erin Flanigan, TranSystems - Multi State C- Vision
6:00pm - 7:00pm	Social Hour and MOVITE 50th Anniversary Salute
7:00pm - 9:00pm	Dinner and Murder Mystery

Friday 10/5

7:30am - 8:30am	MOVITE Breakfast
8:30-10:00am	**Major interstate reconstruction projects**
	Tom Ryan, MoDOT - I-64 Major Reconstruction Project, St. Louis
	Marty Sankey / Sverdrup Team - I-235 Reconstruction Traffic Management Plan Update
	Tracey Roberts, Iowa DOT (District 4) - I-29/80 Reconstruction Overview, Council Bluffs
10:15-12:00	**Keynote Presentations**
	Mark Ward, John Deere - International Freight Logistics
	FHWA - Human Factors Research and Traffic Engineering Applications
	Earl Newman, City of Springfield, MO - Closing Comments

Dan Fuchs, Brown Traffic, demonstrates proper golf form while his team looks on.

Howard Preston, presents a Traffic Safety Fundamentals Workshop on Wednesday.

When this team tees off, even the wildlife runs for cover. (Jon Resler, Ken Morris, Hal Hofener, Todd Butler)

2001 MOVITE 50th Anniversary Fall Meeting—Ames, Iowa

The 2001 Fall Meeting was held in Ames, IA on October 3-5. The fall meeting commemorated the past fifty years of MOVITE and celebrated the future of the organization. The meeting was a combination of many things this year, fun, education, reflection, celebration, and as always friendship.

The meeting kicked off on Wednesday with a Traffic Safety Fundamentals workshop. After the workshop 36 daring souls were granted beautiful weather, and the opportunity to lose their balls in the rough at Veenker Golf Course in Ames. The big feature of this years golf tournament was a Hole-In-One opportunity to win a new Buick Century sponsored by Brown Traffic Products, Inc. One innocent by-stander was quoted as saying "The only safe place on this course with your group is near the hole." This was especially true on the hole-in-one opportunity.

The MOVITE Board met Wednesday evening with Int'l ITE Vice-President Jenny Grote and District IV ITE Director Earl Newman participating.

Thursday morning was kicked off by Master of Ceremonies Tom Welch from the Iowa DOT and the learning and information exchange began. The agenda included a variety of topics and perspectives on such issues as Context Sensitive Design, Roundabouts, Growth, and Freight. Prior to the opening of the morning events a Past-President's Breakfast was held at the conference center.

During the Thursday Business meeting a number of honors and awards were given as follows:

Gary Fox—Melvin B. Meyer Transp Professional of the Year
Pat McCoy—MOVITE Education Professional of the Year
Michael Piernicky—Young Transp Professional of the Year
Mark Lutjeharms—Transportation Achievement Award, and
Iowa State University—MOVITE Student Chapter of the Year.

The Thursday night banquet featured a murder mystery taking place throughout dinner. "Livening" up the engagement was a social/cocktail hour sponsored by a number of MOVITE member companies. The drinks and appetizers created a wonderful social setting to reflect on the days events and the video presentation showing the MOVITE Presidents over the last 50 years.

The information continued on Friday with another great line-up of presenters and topics. The meeting was closed after Earl Newman reflected on the history of the organization and presented a challenge for the membership to work toward an even better future for MOVITE and the transportation industry.

Members of the Murder Mystery try to convince the crowd of their innocence.

All-in-all, more than 125 people attended the events throughout the three days and if any of them walked away without more friends, more information, and more memories, they must of went to the wrong conference.

Pat McCoy, U of N, presented Education Professional of the Year Award by Kyle Anderson

Gary Fox, City of Des Moines, is presented the Professional of the Year Award by Neal Hawkins

Past presidents assemble for a group photo on Friday morning.

Jan Kibbe Student Scholarship

for Study in

Traffic/Transportation Engineering

Submitted by:

Rebecca L. Burdick

Transportation engineering is a highly visible discipline of civil engineering. Millions of people travel our nation's roadways each and every day. Doing so may make the average American feel as though they are a transportation expert, but over the past few years I have learned that this is far from the truth.

How hard can it be to design a road? New roads are constantly being designed; certainly each new project can be built by using a carbon copy of an old project. Fortunately this is not the case otherwise transportation would be a rather monotonous field. I've learned through my education and work experience that no matter how routine a project may appear, there is always at least one situation that presents a challenge in completing the project. These unique challenges are what make transportation engineering an exciting field.

What I have enjoyed most about transportation is how initially it seems so simple. But when you take a chance to look deeper and learn more about planning, traffic operations, and roadway design, you realize that there are many complexities within these subsets of transportation engineering. In my introductory highway engineering class I remember being amazed at all of the calculations and consideration that went into designing what appeared to be an ordinary stretch of highway. As I delved further into this area with my next highway engineering class, I had the opportunity to redesign a stretch of existing highway. From this single experience, I learned so much more about the inner workings of a design project. Although there were many calculations that had to be made, our group learned that engineering isn't simply about the numbers. It's also about making sure that several options are explored and that the best alternative is chosen according to the needs of the client. I have found the same to be true in my planning and traffic courses. Math is crucial to transportation engineering, but often there is software available to compute the numbers if you can supply the input data. Therefore, some of the most important functions of a transportation engineer are to decide if the information makes sense, and how to use this information to find the best solution to the problem at hand.

That is the part of engineering that I have come to enjoy most. I started off as a civil engineering major my freshman year simply because I had always enjoyed math and science and I had always been a "numbers person." As a graduating senior with more educational and work experience, I have come to realize that I ultimately hope to progress to a position in which I will make more managerial decisions instead of just computing the numbers. I know that like every other recent engineering graduate I will start out on the technical side of the profession, but my utmost desire is to become a manager and deal with the business side of engineering.

I have had two internships, both in the field of traffic engineering, that have confirmed my interest in transportation. I enjoyed my transportation and my environmental courses at the University so I felt I should obtain real-world experience in each of those fields to find out if I'd like working in these fields on a day to day basis. In my first internship, I worked for the City of Omaha in the Traffic Engineering Division of Public Works. I appreciated the opportunity to become more familiar with some of the policies and new programs that the city had proposed. For my next internship, however, I intended to gain experience in environmental engineering. I found a few leads, but meanwhile a transportation opportunity with HWS Consulting Group came along and I decided to take it. While there I learned several software packages and that knowledge has proven quite useful this year. In fact, I learned so much about traffic engineering and planning that one of my classes last semester was almost entirely a review of the things I had learned over the summer at HWS. This internship was certainly one of the deciding factors for my decision to attend graduate school in the field of transportation engineering.

I have always intended to pursue my master's degree, but up until this year I had planned to get my degree in business. Since I would like to work my way up to management, I felt that an MBA would be the best degree for the management career path. I thought that the most affordable way to accomplish this goal would be to take night classes while working full-time during the day. I have heard from several people that this is a tough and lengthy way to get your degree, but I was determined that I could do it. This year, however, I found out that I could get my master's in transportation in a very short timeframe. Even though I had made a promise to myself that I'd go back to school, I began to realize that once I graduated and I was out in the real world making real money, it would be difficult to go back to school. I decided that it could be too mentally and physically taxing to attend night classes after putting in a full day of work. Consequently, I began to look into the idea of graduate study in the field of transportation. I found that I could easily earn my master's degree in approximately one year and a half if I started working on it immediately after I received my undergraduate degree. Once I looked at the types of classes I'd be taking, I was convinced this was the way to go. Transportation Ergonomics, Transportation Planning and Economics, and Transportation Safety Engineering were just a few courses that sparked my interest.

By working toward a master's degree in transportation, I will have the opportunity to conduct research that I wasn't able to explore as an undergraduate student. I will also be able to work more closely with faculty and learn more from them than I would by simply having them as professors. I am eagerly awaiting the chance to learn more about everything from roadway design to intelligent transportation systems in the next few terms of my academic career. This additional knowledge will further prepare me for an exciting and successful career in transportation engineering.

Adopted 2001 MOVITE Budget

September 28, 2000

INCOME:

		2000 To Date	2000 Adopted	2001 Proposed
1	Dues and Penalties	$3,225.80	$2,800.00	$3,000.00
2	Meetings	--	$2,000.00	$3,000.00
3	Interest	--	$250.00	$250.00
4	Journal Advertising	$5,001.00	$4,000.00	$7,000.00
5	District IV Reimbursement	$2,007.06	$500.00	$500.00
6	Income from Reserves	--	$3,325.00	$2,175.00
7	Scholarship	$720.00	$700.00	$700.00
	TOTAL INCOME=>	**$10,953.86**	**$13,575.00**	**$16,625.00**

EXPENSES:

		2000 To Date	2000 Adopted	2001 Proposed
1	Postage	$574.30	$1,300.00	$1,300.00
2	Stationery and Labels	$35.60	$200.00	$200.00
3	Journal Printing	$1,445.01	$4,000.00	$4,500.00
4	~~Handbook~~	~~--~~	~~$500.00~~	--
5	Officer's Handbook	--	$50.00	$50.00
6	Meeting Guide	--	$50.00	$50.00
6A	50th Anniversary Meeting Advance	--	--	$1,000.00
7	Meeting Advances	$2,000.00	$2,000.00	$2,000.00
8	Past President's Plaque & Pin	--	$125.00	$125.00
9	Award Plaques (3 total)	$182.07	$300.00	$300.00
10	Student Award Travel and Certificate	$800.00	$800.00	$1,050.00
11	Student Chapter Award & Plaque	--	$100.00	$200.00
12	Student Chapter Start-up	--	$250.00	$250.00
13	Miscellaneous	$200.52	$200.00	$200.00
~~13A~~	~~Miscellaneous Steve Hofener ITE VP Elec.~~	~~$1,250.00~~		
14	President's ITE Meeting Expenses	--	$1,500.00	$1,500.00
15	Contribution to MOVITE Scholarship Fund	--	--	--
16	MOVITE Membership / Affiliate Training	--	--	$1,500.00
17	Contribution to District IV Meeting Expenses	--	--	--
~~18~~	~~MOVITE Membership Training~~	--	--	--
19	Web Page	$365.00	$1,500.00	$200.00
20	Scholarship pmt to ITE	--	$700.00	$700.00
21	Officer's Planning Meeting			$1,500.00
	TOTAL EXPENSES=>	**$6,852.50**	**$13,575.00**	**$16,625.00**

SUMMARY FOR CHECKING ACCOUNT:

Initial Balance	$ 12,199.28
Total Income	$10,953.86
Total Expenses	$6,852.50
Net Over Period	$4,101.36
BALANCE=>	**$16,300.64**

SCHOLARSHIP FUND (ITE):

Initial Balance	$35,518.09
MOVITE Contributions	$0.00
Interest	$3,331.74
Realized Gain (Loss)	$0.00
Unrealized Gain (Loss)	($4,585.81)
Scholarship Distributions	$0.00
BALANCE=>	**$34,264.02**

CELEBRATION

FALL 2001 — IOWA

MOVITE

Spring Meeting 2001

St. Louis, Missouri

Wednesday April 25

IMSA Training - Work Zone 8:00 to 4:30
Room 209 Transportation Information Center
Lunch Provided — 8 Hour Session — $170 Fee

Adaptive Traffic Signal Systems 8:00 to Noon
Room 207 Transportation Information Center
4 Hour Session—No Fee

St. Louis Regional Transportation Facilities
2 Hour Tours— at 10 am and 1:30 pm– No fee

Social Mixer Marriott Hotel 5:30 to 7:30 pm

MOVITE Board Meeting 6:30 to ??

Thursday April 26

Breakfast—Marriott Hotel 7 to 8:15 am

Track A—Urban Design Issues—Room 207

Micro-Modeling Roundabouts -- 8:30 to 9:15
Shawn Leight, Sverdrup Civil, Inc.

Pedestrian and Bike Program - 9:15 to 10:00
Larry Welty, Missouri DOT

Break— Vendor Area 10:00 to 10:30
Rooms 213 & 214

Springfield Access Management 10:30 to 11:15
Dr. Jim Gattis, University of Arkansas

MOVITE Luncheon Meeting—11:30 to 1:00
Marriott Hotel

Route 367—Lewis & Clark / Lindbergh
Exploring the Options—1:00 to 1:45
Trueblood, Rolle & Kinzel, HDR Engr.

Urban Design Considerations—Lighting,
Signing, Landscaping, etc. 1:45 to 2:30
Doug Mann, HNTB

Break— Vendor Area 2:30 to 3:00
Rooms 213 & 214

I-270 @ I-170 Innovative Methods of
Construction Staging —3:00 to 3:45
Todd Welz, Sverdrup Civil, Inc.

Challenges of Seismic Retrofitting Bridges
3:45 to 4:30 Mark Capron, Sverdrup Civil, Inc.

Conference Banquet 6:00 to 8:00
Presentation on Lambert Airfield Expansion

Thursday April 26

Track B—Advanced Technologies Issues
Room 209

Little Rock—ATMS 8:30 to 9:15
Jay Wynn, Mathews & Associates and Bill
Henry, City of Little Rock

Red Light Running 9:15 to 10:00
Debbie Walker, Nestor , Inc.

Kansas City Scout Project 10:30 to 11:15
Sabin Yanez, Missouri DOT

MO. Statewide ITS Plan 1:00 to 1:45
Erin Flanigan, Transystems and
Rick Bennett, MoDOT

Traffic Management Plan Reconstruction
I-235 Corridor Des Moines, Iowa 1:45 to 2:30
Tom Darnold, Sverdrup Civil, Inc.

St. Louis Signal System 3:00 to 3:45
Bob Budd, Traffic Systems Solutions and Rich
Schmidt, Crawford, Bunte and Brammeier

Metro Networks, ISP - 3:45 to 4:30
Joan Ravier, Westwood One / Metro Networks

Friday April 27

Track A—Urban Design Issues—Room 207

The **New I-64 Corridor—** 8:30 to 9:15
Mary Cay O'Malley, HNTB

Midwest High Speed Rail Initiative -
9:15 to 10:00 — Jack Hynes, MoDOT

Break— Vendor Area 10:00 to 10:30
Rooms 213 & 214

St. Louis Regional Multi-Modal Facility
10:30 to 11:15– John McCarthy and Donald
Karban, Sverdrup Civil Inc.

Track B—Advanced Technologies Issues
Room 209

Regional Light Rail — Metro Link
8:30 to 9:15 — Bill Grogan, St. Clair County
Transit District

Flooding Conditions Notification Research
9:15 to 10:00 — Ed Boselly, Weather
Solution Group

Gateway Guide Program 10:30 to 11:15
Teresa Krenning, MoDOT

Final Wrap-up—Neal Hawkins 11:15 to 11:30

“TRANSPORTATION PROFESSIONAL OF THE YEAR AWARD”
Nomination of
Gary L. Fox, P.E.

City Traffic Engineer
City of Des Moines, Iowa

It is my pleasure to nominate Gary L. Fox for the “Melvin B. Meyer Transportation Professional of the Year Award.” Gary Fox has made a significant career-long contribution to the improvement of transportation systems and the transportation profession, dedicating his entire career of 28 years to public service with the Iowa Department of Transportation and then to the City of Des Moines. During his career he has exhibited the highest standards of professional integrity and excellence in improving the transportation system to enhance the safety and mobility of the traveling public.

Gary was born and raised in the State of Kansas and received his Bachelor of Science degree in Civil Engineering (1972) and his Master of Science degree in Transportation Engineering (1973) from Kansas State University. Gary then began his career with the Iowa Department of Transportation as an Engineer-In-Training (1972-1974). In 1974 Gary was named as an Accident Surveillance Engineer, a position he held until he left the Iowa DOT to accept a position with the City of Des Moines in 1979.

At the City of Des Moines, Gary was a Principal Civil Engineer from 1979 to 1982. In 1983, he was named as Assistant Director of Traffic and Transportation for the City of Des Moines, a position he held until 1997. At that time he became City Traffic Engineer a position he currently holds.

Gary is a licensed professional engineer in the states of Kansas and Iowa. He has maintained a career-long involvement in professional organizations and actively participates in these organizations, sharing ideas with other professionals from all over the country. He is a member of the Institute of Transportation Engineers; a member of the American Society of Civil Engineers; American Public Works Association; International Municipal Signal Association; and International Parking Institute. Gary served as President of the Iowa Section ASCE in 1989. He has held all of MOVITE’s officer positions, serving as President in 1994 and was an officer in District IV the following year.

I have never met anyone with as much zeal in protecting the public and using their talents to develop on-the-street engineering solutions as Gary. Gary is someone people go to during difficult times. A few examples from the City of Des Moines follow:

Downtown events (bike races, parades, block parties, etc) during all times of the day. There have been many times when I have seen Gary out working with the Police with an event well after midnight.
Relationship with Police Department – I have had Officers tell me “the reason this event didn’t end up in catastrophe was due to Gary’s professionalism”.
City Wide Events - Drake Relays and Marathons, Des Moines Grand Prix, Des Moines Airshow, Floods of 1993, Safety Improvements City-Wide, Downtown Parking, Downtown Traffic Signal System, City wide fiber optic backbone, and the list goes on.

Gary is a relationship builder and when he gives his word it is solid. His love for our profession is evident in everything he does. Those lucky enough to be around him are given the chance to never stop learning and will be challenged to apply both the art and science of our profession.

Gary and his wife Mary Jo have three sons Andy, Danny, and Robbie. Both Andy and Danny were National merit finalists and obtained their degrees at Iowa State University.

It is very fitting that someone who has dedicated as much time to our MOVITE Chapter as Gary be the recipient of the newly named Melvin B. Meyer MOVITE Transportation Professional of the Year Award here on this 50th Year milestone.

If additional information is needed, I will be happy to provide it.

Respectfully submitted,

Neal R. Hawkins
Senior Project Manager
Howard R. Green Company

Missouri Valley Section
Institute of Transportation Engineers
2001 Technical Research Scholarship Competition

Application Form

Deadline February 1, 2001

PLEASE TYPE OR PRINT CLEARLY

First Name: ___________________ Middle Initial:_____ Last Name:________________________

Preferred mailing address (for the period in May 2001; this will be the address used to notify you of the status of the application)

Street/P.O. Box: ____

City:_________________________ State: ______________ Zip Code:___________

Daytime Phone:____________________ Evening Phone: ___________________

Indicate the university you are currently attending:

University: _________________________ Department: ______________________

Degree Program:___________________ Expected Graduation Date: _________

Advisor:___________________________ Research Completion Date: ___________

Current course work in traffic/transportation engineering or related field.

_________________________________ _________________________________

_________________________________ _________________________________

Description of technical research project and your role or proposed role in the project that will serve as the basis for your research scholarship request (attach additional sheet(s) if necessary).

____

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____

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(continued on reverse side)

I certify that the technical research project will be prepared by me and will be the result of my important responsibility and that the information provided on this form is true and correct:

Signature: ________________________________ Date: ______________________
(Student)

I certify that the aforementioned technical research program meets the requirements of the award and that the graduate or doctorate student making application for the technical research scholarship will have important responsibility in the study described in the submitted scope, and that this graduate or doctorate student is currently enrolled in a program which is related to transportation and/or traffic engineering.

Signature: ________________________________ Date: ______________________
(Faculty Advisor)

Signature: ________________________________ Date: ______________________
(Supervisor) *(if applicable)*

Submit research scope, abstract and this application form to:

Mike Gorman, P.E.
2001 MOVITE Vice-President
HWS Consulting Group, Inc.
10844 Old Mill Road, Suite 1
Omaha, NE 68144-2651

Vehicle Detection Systems Evaluation for Fully Actuated Intersections

2001 MOVITE Competition
Young Transportation Professional of the Year Award

Submitted by:

Michael C. Piernicky, E.I.

January 30, 2001

Abstract

Traffic engineers are given choices when deciding upon what systems to install for the operation of fully actuated intersections. Among the different choices for the detection of vehicles are pneumatic tubes, magnetic, infrared, ultrasonic, radar, photoelectric, inductive loop detectors and video image processing systems (VIPS). The decision on the type of vehicle detection system to install would ideally be based on research that shows one system to superior to the others for a given list of criteria. The use of inductive loops has been the standard since the 1970's. Currently, the use of VIPS is receiving a significant amount of attention because of the advancements of technologies in that area.

The objective of this research is to examine and compare the operational efficiency of a fully actuated intersection while operated under three different vehicle detection methods. The three systems to be evaluated are: 1) Inductive loop vehicle detection, 2) VIPS and 3) A Hybrid system incorporating both inductive loops and VIPS. More specifically the systems were to be evaluated given the parameters and constraints currently found in field installations.

The objective was achieved by accomplishing the following tasks. First, a field study was conducted to acquire data. From that data, a control delay evaluation, a capacity analysis and a computer simulation were completed so the results could be compared. Examination of the analyses, indicated that there is no statistical difference between delays and vehicle stops for the vehicle detection methods within the examined traffic volumes. Further examination suggests that the detection zone configuration has a greater impact on intersection operation than does the vehicle detection method.

Acknowledgments

The author wishes to thank Dr. Patrick McCoy for the guidance and insights provided throughout this project. Special recognition is also due to Mark Garrett, Larry Jochum and Jim Huff from the City of Lincoln Traffic Engineering Division, for without their assistance none of this research would have been possible. Also, the help provided by Matt Kruse is greatly appreciated.

Finally, and most importantly, I am dedicating this work to my parents Michael E. and Mary Piernicky, who have made this all possible.

Table of Contents

Objective

The use of inductive loops for intersection operation has been the industry standard, with the loop installation occurring within or below the pavement surface on each intersection approach. The installation method and the detector positioning exposes the detectors to factors that affect the reliability and operation of the system. The most significant of these factors include, extreme environmental conditions (i.e. temperature, moisture, etc.), repetitive vehicle loadings and pavement movement. The maintenance of these systems is expensive and disruptive to traffic flow. These limitations and challenges have fueled the search for viable, cost effective alternative detection methods.

One system that has emerged as a possible alternative to inductive loop systems is video image processing systems (VIPS). VIPS typically employ the use of video camera(s), computer processing systems and software and output interfaces to standard traffic signal controllers. Video detection systems have advantages over traditional inductive loop detectors as well as their own unique set of challenges and limitations. Advantages of the video systems are the ability to easily change the placement detection zones, maintenance that does not require the closing of traffic lanes and the ability to integrate into traffic management centers for visual surveillance. Challenges that VIPS encounter are vehicle occlusion and detection zone placement issues due to camera field of view and vantage point limitations. The placement of detection zones and the accuracy and reliability of those zones affect the efficiency of intersection operation. Therefore, the limitations of the inductive loop systems and video image processing systems affect the efficiency of intersection operation where semi-actuated or fully actuated traffic control systems are used.

The objective of this research is to examine and compare the operational efficiency of a fully actuated intersection while operated under three different vehicle detection methods. The three systems to be evaluated are: 1) inductive loop vehicle detection, 2) VIPS and 3) a hybrid system incorporating both inductive loops and VIPS. The systems were evaluated according to the procedure for estimation of control delay as detailed in the Chapter 9 Appendix of the 1998 Highway Capacity Manual. Furthermore, the estimated delay was compared with the theoretical delay as calculated by the Highway Capacity Software (HCS) and the delay estimated by a NETSIM simulation.

The research for the evaluation of intersection efficiency under different vehicle detection methods was done as a pilot project for the City of Lincoln, Nebraska.

Previous Research

The development and deployment of the video detection systems has been well documented. The general consensus of the research is that video detection, if correctly set up, performs as well as traditional loop detection (within a couple of percent for the detection of traffic volumes). The majority of the published research, however, has focused on freeway operations, volume data collection and the detection of incidents. Most of the research on intersection control has been of mixed results. Some initial research completed by Chatziioanou at Cal Poly State University has shown certain video detection systems to be up to 99% accurate in vehicle counts at intersections. There is also research that has found that the video detection systems are inaccurate if improperly set up or if environmental conditions are unusual. High winds and fog are two examples of environmental conditions that cause the video detection systems to malfunction. For the case of wind, the video detection systems have a tendency to over count vehicles due to the movement of the camera. Fog on the other hand causes vehicles to be missed because the camera cannot see through it. It should be noted that the majority of the intersection research that has been published deals with the counting of vehicle volumes. This gap in available research of intersection control by video detection systems leaves significant questions that are left to be answered. The efficiency of intersection operation has been an area of interest that needs further research. Specifically, the efficiency of the intersection under different vehicle detection methods given the conditions and/or the limitations experienced at a particular intersection. There is currently research that is being completed by the University of California at Berkeley that examines the use of video detection for intersection operation. The UCAB study will be an evaluation of video detection, however, the scope of the project will not include a comparative evaluation between the use of traditional inductive loop and the video detection. This area of need is the intent of this research.

Research Approach

The objective was achieved by accomplishing the following tasks. First, a field study was conducted to acquire data for the control delay evaluation, the HCS evaluation and the simulation input data. The data gathering included the collection of four hours of video data from the study intersection for each of the three detection methods on either a Tuesday, Wednesday or Thursday. Furthermore, video recordings of the individual cycle lengths and phase splits were taken for all of the time periods recorded of the intersection approaches. From the video, the hours of 9:00 a.m. to 10:00 a.m. and 11:30 a.m. to 12:30 p.m. each day were analyzed for the following information: 1) volumes, 2) turning movements, 3) vehicle stops, 4) control delay, 5) cycle lengths, 6) green splits 7) percent max-out for each phase and 8) no incidents. Following, the data collection from the approximately 75 hours of video tape, results for control delay and vehicle stops were tested statistically and compared. Furthermore, the data reduced from the video tape was used as input for a Highway Capacity Manual (HCM) delay analysis and the creation of NETSIM simulation model. Using the results from the field study and the computer analyses, the use of different vehicle detection methods can be compared upon the basis of operational efficiency and other criteria.

Area Description

The intersection of 27th and Superior Streets is located in north central Lincoln, Nebraska. Early discussions of the project identified this intersection as an ideal study site (See Figure 1). It was determined it would be an ideal location based on the existence of both a video and a loop detection systems. Another feature of the intersection is its location along a developing corridor in the Lincoln area. The area surrounding 27th and Superior is best described as commercial in nature. Businesses and restaurants line both sides of all four approaches to the intersection.

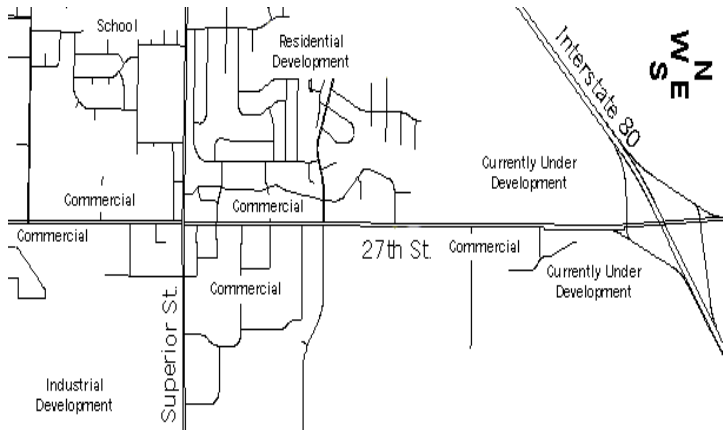

Figure 1

When the intersection of 27th and Superior Street was reconstructed, exclusive or shared right-turn lanes, exclusive left-turn lanes and multiple through lanes were provided. Figure 2 shows the layout of the intersection and the movement phases.

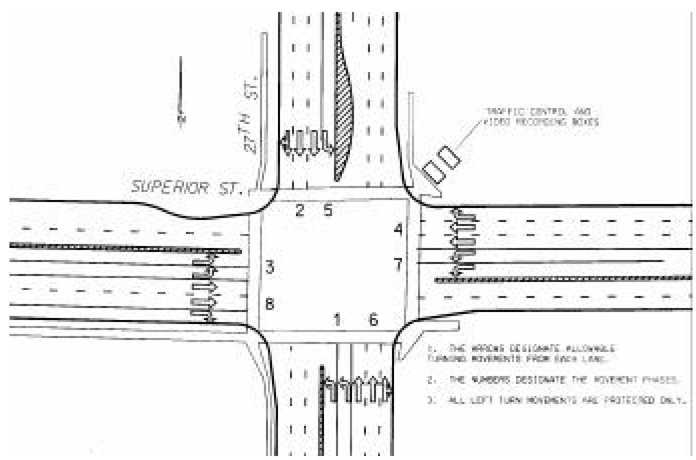

Figure 2

Signal System and Operation

The intersection of 27th and Superior Street is currently being operated as an isolated, fully actuated intersection. It is being operated in this manner because of the high traffic volumes present from different directions. The actuated system has three alternative detection methods that can be used. These systems are inductive loop detection, VIPS and a hybrid system. The inductive loop system uses coiled wire typically placed below the pavement to detect vehicles. The VIPS exclusively uses video cameras placed above the intersection to detect vehicles. The hybrid system uses video detection for the detection zones at the stop line (presence mode) and the first set of advance detection (presence mode) and traditional inductive loop detectors for the second set of advance detectors (pulse mode). The City of Lincoln currently uses a hybrid system for because the inductive loops act as a fail-safe system in the event that the video detection system completely fails. The positioning, size and other information about the detectors and detector layouts for each system can be seen in Table 1.

The vehicle detection systems examined in this research operated with a combination of traffic control system settings. The video and hybrid detection systems had a passage time set on the controller for each of the detection zones set to the specifications in Table 2. The loop detection system similarly had passage times set for all of the detectors. The loop detection system also had extensions of 1.0 sec placed on the first set of advance detection loops back from the stop line in the through lanes.

Data Collection

Data Collection Equipment

The field data was provided by the City of Lincoln Traffic Engineering Department, and video recording equipment that utilized the video detection system cameras located at the intersection. The cameras recording north, south and westbound traffic, were mounted on the top of street lights luminares. The eastbound camera was mounted on a 10 foot pole attached to the mast arm.

The recording equipment consisted of five video-recording machines. Four of the machines were wired into the camera relays of the VIPS system at the intersection showing each of the four intersection approaches. These four recording machines were placed in a second traffic control cabinet that was positioned next to the existing unit on the northeast corner of the intersection. The fifth camera was located at the City of Lincoln Street and Traffic Operations office. The fifth camera was recording the Monarch Traffic Control Software output screen for the traffic controller at the intersection of 27^{th} and Superior Streets. From that screen, the video recorded the length of each cycle, the length of each phase and the percent of time that each phase maxed out.

Table 1-Vehicle Detector Locations

Detector Descriptions (Location/Length)[(2), (3)]	Hybrid Model[(1)]	Loop Model[(1),(6)]	Video Model[(1)]
Northbound Left Turn Bay Detection			
Stop Line Detection[(5)]	20/20	0/39	20/20
First Advance Detection	246/15	234/12	246/15
Northbound Through/Right Detection			
Stop Line Detection[(5)]	20/15	27/12	20/15
First Advance Detection	246/15	234/12	246/15
Second Advance Detection	334/12[(4)]	334/12	None
Southbound Left Turn Bay Detection			
Stop Line Detection[(5)]	20/20	0/39	20/20
First Advance Detection	246/15	None	246/15
Southbound Through/Right Detection			
Stop Line Detection[(5)]	20/15	27/12	20/15
First Advance Detection	246/15	234/12	246/15
Second Advance Detection	334/12[(4)]	334/12	None
Eastbound Left Turn Bay Detection			
Stop Line Detection[(5)]	20/20	0/39	20/20
First Advance Detection	246/15	214/12	246/15
Eastbound Through Detection			
Stop Line Detection[(5)]	20/15	27/12	20/15
First Advance Detection	246/15	214/12	246/15
Second Advance Detection	304/12[(4)]	304/12	None
Eastbound Right Detection			
Stop Line Detection[(5)]	20/15	0/12	20/15
Westbound Left Turn Bay Detection			
Stop Line Detection[(5)]	20/20	0/39	20/20
First Advance Detection	246/15	214/12	246/15
Westbound Through Detection			
Stop Line Detection[(5)]	20/15	27/12	20/15
First Advance Detection	246/15	214/12	246/15
Second Advance Detection	304/12[(4)]	304/12	None
Westbound Right Detection			
Stop Line Detection[(5)]	20/15	0/12	20/15

(1) All units in feet.
(2) The first values for all detectors represent the distance from the stop line.
(3) The length value represents the length of the detection zone.
(4) The Hybrid model detectors are all video except for the second advance detection zones.
(5) All stop line detection operates in presence mode.
(6) All detector extensions are zero except the first advance thru detectors of the loop model (1.0 sec.).

Table 2 - 27th and Superior St. Signal Control Timings

Setting	Phase Timings (sec)							
	1-NBL	2-SBT	3-EBL	4-WBT	5-SBL	6-NBT	7-WBL	8-WBT
Min. Green Time	5	8	5	8	5	8	5	8
Passage Time	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.6
Max Green Time	15	30	15	25	15	30	15	25
Yellow Interval	3.0	4.8	3.0	4.8	3.0	4.8	3.0	4.8
All Red Interval	2.6	1.2	2.7	1.4	2.6	1.2	2.7	1.4
Walk Display	0	5	0	5	0	5	0	5
Pedestrian Clearance	0	21	0	25	0	21	0	25
Extension Time*	0	1	0	1	0	1	0	1

* - Placed on loop system first advance through detectors only

Data Collection Procedure

A plan for the collection of data using the recording system was formulated to facilitate the acquisition of traffic characteristics needed for the comparison of the field study, the HCS analysis and the NETSIM model.

The five recording units were setup so that the recording of the four approaches and the traffic controller signal timings could be synchronized. Video recording was done from the hours of 9:00 AM until 1:00 PM on three different mid-week days, one day for each of the vehicle detection systems. The hours of 9:00 AM until 1:00 PM were selected because of the varied traffic flow, off-peak and midday-peak traffic. This choice of recording time was determined to be the optimum period because it would allow for the comparison of the detection systems while operating under fully actuated conditions with a wide range of traffic volumes. The AM or PM peak periods were not chosen for the research here due to the high volumes present at the intersection that effectively causes the operation of the intersection to behave similar to a pretimed signal as all phases would be maxed out. The video data for the four-hour period was reduced to the same two hours from each day (9 AM to 10 AM and 11:30 AM thru 12:30 PM). These hours were chosen because incidents (stalled cars blocking lanes, multiple emergency vehicles, etc.) that influenced the traffic flow significantly occurred during the other two hours of videotape. The data was then separated into 15-minute intervals so the variation in the traffic volumes could be noted and incorporated into the analysis.

Data Reduction

The traffic characteristic data taken from the videotapes were aggregated into 15-minute intervals so that the variations in the traffic flow could be incorporated into the three analyses and the number of representative data points could be increased. This approach also allows for the difference between off-peak and peak periods to be examined. The specific data collected were turning movements volumes, stops, delays, cycle/phase lengths and max outs. Additional information on traffic characteristics are included in the following sections.

Two measures of performance were initially selected for comparison purposes. These measures were: 1) control delay and 2) vehicle stops. Both measures were extracted from the videotape recorded as part of the field study at 27^{th} and Superior Streets. The data collections were completed by performing a control delay estimation procedure detailed in Chapter 9 of the 1998 HCM. There are a number of different measures of effectiveness (MOE's) that could have been selected. These measures include average speed, moving time, queue time, as well as control delay and vehicle stops. Control delay and vehicle stops were selected because they are well defined and generally accepted as MOE's. Another reason is all three evaluation methods directly measure delay and two of the three measure stops. The HCS analysis does not include an estimate for the number of vehicle stops. Furthermore, their collection from the videotapes was relatively easy with the exception of the large number of hours required to collect and reduce the data.

Level of service (LOS), which is a measuring scale of delay, is defined as a measure of driver discomfort, frustration, fuel consumption and lost travel time. Delay is due to a number of factors relating to control, geometrics, traffic and incidents. Control delay is specifically the portion of delay due to the control of the facility. Control delay consists of initial deceleration delay, queue move-up time, stopped delay and final acceleration delay. It should be noted that the measure of intersection delay has changed since the 1994 Highway Capacity Manual (HCM), which used stopped delay as its measure of intersection level of service. The stopped delay is only a portion of control delay.

Vehicle stops can be simply defined as the stopping of a vehicle while traveling through an intersection. The percentage of vehicle stops is indicative of the signal offset quality if the system is coordinated and of the efficiency of a detection system if the system is an isolated fully actuated signal.

HCS Analysis Overview

An intersection capacity analysis was conducted to evaluate the operational characteristics of 27th and Superior Street. The Highway Capacity Software (HCS) was used for this analysis. The HCS is a program that replicates the methodology for analyzing signalized intersections found in Chapter 9 of the 1994 Highway Capacity Manual. The results of the analysis were compared to results from the field study and the NETSIM simulation. The HCS was selected for comparison because of its wide spread use for the analysis of intersections by professional traffic engineers.

It should be noted that Release 3 of the software was available at the time of analysis but was undergoing several patches to the software. Therefore, Release 2.1f was used for the analysis. Furthermore, the Release 2.1f uses the 1994 Highway Capacity Manual methodology for estimating delay, which calculates stopped-time delay. This measure of stopped-time delay is approximately 76% of the total control delay, which is the delay the 1998 HCM uses to evaluate the operation of signalized intersections. The total control delay can be approximated by multiplying the stopped-time delay values given by the HCS 2.1f by a factor of 1.3. This method of approximation for total control delay will be used when comparing the result of the three analysis methods.

HCS Input Data

The analysis of a fully actuated intersection requires several inputs for the software to accurately calculate delay. The data listed in Table 3 are required by the HCS program to analyze the intersection. The acquisition of the data for the HCS analysis came from three sources. The first of these was the City of Lincoln intersection layout design of the intersection (Figure 2). From the layout the lane geometries and the widths were taken and input into the program. The second source of information, traffic volumes, were recorded using the video detection cameras at the intersection. Lastly, the traffic control timings were extracted from the recording of the Monarch Traffic Control system at the City of Lincoln Traffic Engineering Department.

Table 3 - HCS Input Data

Number of Lanes Traffic Volumes Peak Hour Factor Lane Widths Grade Percentage of Heavy Vehicles Parking Lanes Bus Stops	Pedestrians Traffic Arrival Type Right Turns on Red Lost Times Phase Green Times Phase Yellow + All Red Times Phasing Phase Sequencing

It should be noted that the communication system that transmitted data to the Street and Traffic Operations Center was somewhat suspect. The phase length, cycle length and max-out data were unavailable because the communication link was lost for intervals scattered throughout the eight analysis periods.

HCS Limitations

The Highway Capacity software has three main limitations that affect the analysis of actuated intersections. The first of these limitations is the inability of the software to model the use of an eight-phase control sequence. Variable phasing sequences cannot be modeled. The HCS requires the user to define a fixed phasing sequence that will not always occur under fully actuated control. The second short coming of the software is the requirement of fixed phase lengths and a constant cycle length. The advantage of an actuated controller is the ability to vary the phase and cycle lengths in response to traffic demand on the approach in the absence of traffic to other approaches. The inability of the HCS to “gap out” a phase is a limitation of the software that will add to the amount of delay that is observed in the results. The last limitation to the software is the previously discussed use of stopped-time delay from the 1994 HCM, instead of control delay to evaluate signalized intersections.

For the purposes of analysis, information uncovered by other sections of this research was used to help reduce the limitations of the HCS. An analysis of variance was conducted on the regression models to test if they were significantly different than one another. This ANOVA was completed using the Statgraphics 3.1 Software. The field study and NETSIM analysis found that there is no significant difference between any of the models for total control delay. Because there was no significant difference in the data at the 95% confidence level, the data was combined so that the sample size was larger. This new larger data pool was analyzed for average phase and cycle lengths that would be used for input into the software. By using the average signal timings the HCS would hopefully give a better overall picture of the intersection operation.

HCS Analysis Output Data

The analysis output data consists of average stopped-time delay estimates for each of the lane-groups and the intersection as a whole. The output also includes a Level of Service analysis (LOS) that is derived from the average amount of delay experienced by vehicles at the intersection. This output of delay time is in seconds per vehicle, to compare it to the field study and the NETSIM outputs will have to be multiplied by the number of vehicles using the intersection during that analysis period. This resulting value in seconds is the total stopped-time delay for the intersection. The conversion to control delay found in other research is a multiplier of 1.3. This final value is a reasonable approximation that can be compared with the results of the field study and the NETSIM simulation.

Modeling Overview

The NETSIM simulation of 27th and Superior Street can be used to evaluate different vehicle detection systems based on operational efficiency of the intersection as measured by MOE's. NETSIM is a microscopic stochastic simulation model that uses an interval-based methodology. Each vehicle modeled is a distinct object which is moved every second, and every variable control device is updated every interval. The reason NETSIM was selected over other traffic models was the flexibility and high detail of detection zone configurations that it can model.

The initial input files for the NETSIM simulation were created with the ITRAF 2.7 program. ITRAF 2.7 is a windows based editor that transforms graphical and other data into a text file that is used by NETSIM. The resulting text file was then edited by hand to more accurately represent the detection zones for each of the three detection setups. This was necessary because the ITRAF software only allowed the definition of 10 detection zones per approach, and the approaches being modeled required a greater number of detectors. Editing the text file manually allows for a maximum of 40 detectors on an approach link. This complete text input file is then used to run the simulation.

The simulation period was 2 hours of time, broken down into 15-minute intervals so that the variation of traffic volumes in the validation data can be accurately represented. The simulation output is in two main files. The first is a text file containing all input variables, standard simulation values and output MOE's. The second is a graphical representation file that can be run by the TRAFVU program.

The output MOE's of delay and stops were then used to compare the results of the NETSIM modeling with the field study and the HCS results.

Model Input Data

The computer modeling of a full actuated intersection requires many data inputs for the software to accurately represent real-world conditions. The data listed in Table 4 are required by the NETSIM program to model the intersection. The majority of the data requirements are taken from the field, exceptions to this are the random number seeds, simulation output intervals and the run time.

Two changes were made to the model as the result of limitations of the software. The two changes that were made due to software limitations were, changed extension timings and the use of yellow lock functions to simulate a soft recall function. The software limitation for extension times was a minimum of 1.1 seconds. The field setting for extensions was 1.0 seconds. The second limitation of the software was the inability to model a soft recall setting. The use of locking memory detectors while the phase is yellow or red, referred to a yellow lock by the software, was used to simulate the soft call setting. The limitations were made know to the City of Lincoln traffic engineer and after careful consideration were judged to be insignificant to the results as the differences in the outputs would be minor.

The only differences between the three models occur with changes to the detection zones. There are three variables that were changed to model the differences between the detection methods, location, operation mode of the detectors (presence vs. pulse) and detector extension timings. Table 1 earlier in the report shows the detection zone specifics for each of the computer models.

Table 4 - NETSIM Input Data

Approach Lengths	Phase Designations
Number of Through Lanes	Phasing Sequence
Number of Left-Turn Lanes	Phase Flags
Number of Right-Turn Lanes	Last Car Passage
Left-Turn Bay Lengths	Max Recall
Right-Turn Bay Lengths	Min Recall
Lane Widths	Rest in Red
Lane Alignment	Dual Entry
Traffic Movement (for each lane)	Red Lock
Approach Discharge Headways	Yellow Lock
Approach Startup Loss Times	Conditional Service
Stop Line Setback	Simultaneous Gap
Approach Free-Flow Speeds	Pedestrian Recall
Traffic Volumes by Movement	Rest in Walk
Approach Percentages of Heavy Vehicles	Overlaps
Detector Locations	Lag Phasing
Detector Lengths	Extensible Initial Interval
Detector Extensions	Phase Timings
Detector Phase References	Walk Time
Detector Modes (Presence/Pulse)	Don't Walk Time
Approach Grades	Max Phase Length
Right-Turn on Red	Min Green
Approach Sight Distances	Vehicle Carry-Over Times
Random Number Sees	Yellow Times
Simulation Output Intervals	Red Clearance Times
Simulation Run Time	

Model Output Data

The model output data includes several measures to evaluate operational efficiency of an intersection. The data is placed in a single text file that separates data for each of the intersection approaches and into the individual movements. Table 5 shows a selected number of MOE's that are included in the data output file. From the list below the MOE's of vehicle delay time and percentage stops were selected for comparison purposes with the field study and the HCS analysis.

Table 5 - Simulation Output MOE's

Vehicle Trips	Percentage Stops
Vehicle Miles	Average Speed
Vehicle Move Time	Queue Lengths
Vehicle Delay Time	Trip Time per Mile
Vehicle Total Time	Fuel Consumption
Vehicle Queue Time	Vehicle Emissions

Control Delay Study Results

The field analysis, intersection capacity analysis and the NETSIM analysis provided information on the delay experienced at the intersection. It should be noted that each of the three analyses calculated delay using a different technique.

Field Study Analysis

The field study examined the total control delay at the intersection level, the intersection approach level and on an individual lane group basis. Each of the detection methods was tested for statistical significance using a comparison of regression lines test in Statgraphics 3.1. The analysis designated the volume as the independent variable for each test and the control delay as the dependent variable. It should be noted that the models were tested on an intersection basis, an approach specific basis and for each of the 8 lane-groups. For each of the analyses the delay and volume for that specific test were used. The statistical testing assumed the hybrid system to be the base condition with which to compare the other detection systems for differences in the regression models of total intersection volume. The P-values for the 13 statistical tests are listed in Table 6 (Loop and Video since the Hybrid system was considered the base model). The statistical analyses showed no statistical difference between the regression lines of any of the vehicle detection systems for a 95 percent confidence level.

Table 6 - Comparison of Regression Models P-Values for Total Control Delay

Analysis Level	Loop	Video
Intersection	0.0509	0.5339
NB Approach	0.0826	0.1594
SB Approach	0.2376	0.8171
WB Approach	0.4486	0.5017
EB Approach	0.1212	0.7774
NB Approach Left	0.4361	0.9285
NB Approach Thru&Right	0.2111	0.0776
SB Approach Left	0.4714	0.9487
SB Approach Thru&Right	0.7521	0.7683
WB Approach Left	0.6849	0.6977
WB Approach Thru&Right	0.3715	0.5999
EB Approach Left	0.6175	0.1793
EB Approach Thru&Right	0.4786	0.8569

It should be noted that all of the R^2 values of the fitted models are above 0.96. The R^2 value measures the amount of the variation in the data explained by the regression equation. The relationships modeled in Figure 3 shows a direct relationship between the volume of traffic and the control delay observed. This relationship is logical; the total control delay increases proportionally to the traffic volume, as volume increases.

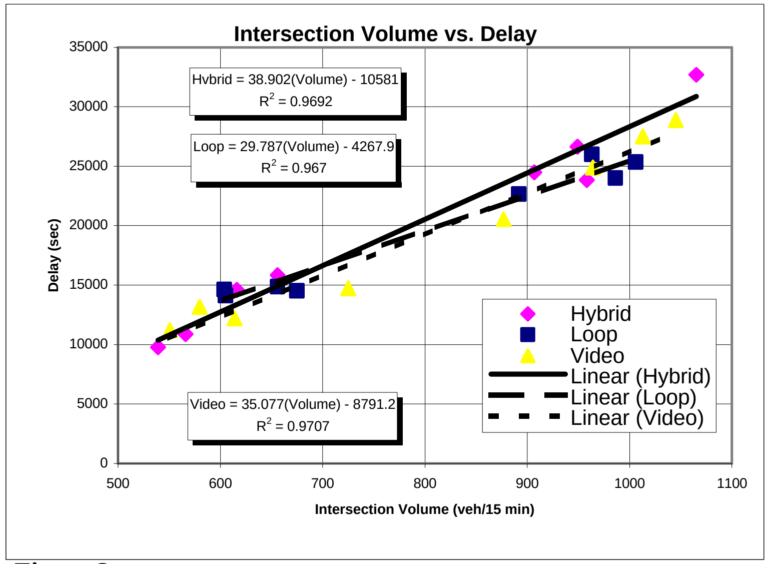

Figure 3

HCM Analysis

The results of the intersection capacity analysis using the HCS are very similar to the field analysis findings. The three detection systems were evaluated similar to the field study, in that an analysis of variance of the regression models was completed. The intersection, approach or lane group volume was used for the independent variable and the corresponding control delay was used as the dependent variable. Figure 4 shows a plot of the HCS output data of the estimation of total control delay for the three different detection methods.

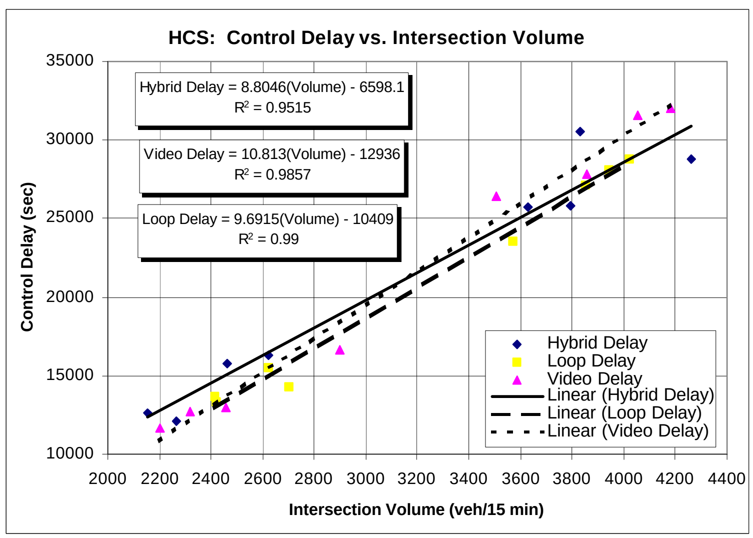

Figure 4

The data shows plotted shows a direct relationship between the intersection volume and the amount of control delay that is experienced by the vehicles traveling through the intersection. The plot of the HCS results is a theoretical estimation of the delay experienced at the intersection according to the methodology found in the HCM . This theoretical estimation is valuable in that it can be compared to the field study to gain an understanding of how reasonable the results of the field study are. The field study results appear to be reasonable given the similarity to the theoretical estimation of control delay from the HCS.

NETSIM Analysis

The results of the NETSIM analysis of delay followed the field analysis findings also. The three detection systems were evaluated similar to the field study. An analysis of variance for the regression models was used to test for significant differences between the detection methods. Again the hybrid method was used as the baseline detection method to which the others were compared. Figure 5 shows a plot of the NETSIM output data of delay or the three different detection methods. Similar to the field study and the HCS analysis, a direct relationship between the total control delay and the intersection volume is seen. It should be noted that the volume range that the NETSIM models were run over is greater than that of the field study or the HCS analysis. When the initial modeling outputs were analyzed it was noted that they were similar to the field and HCS analyses and that they were very linear in nature. It was determined that the computer model was a reasonable approximation of the field and HCS models. The volumes were above and below those observed, to see if the direct relationship between total control delay and intersection volume would stay constant outside of the volumes experienced in the other analyses. The plots of the NETSIM models would suggest that the direct relationship holds for intersection volumes between 200 and approximately 1600 vehicles per 15 minute period or 800 to 6400 vehicles per hour.

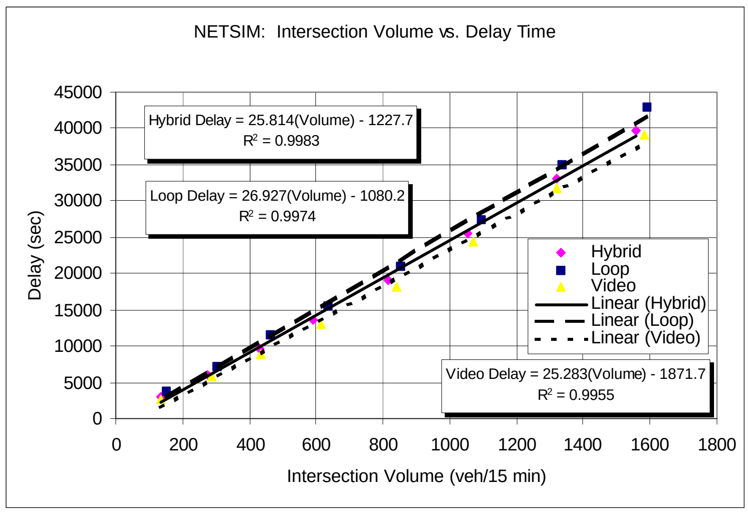

Figure 5

Comparison of Analyses

The three evaluation techniques, field study, intersection capacity analysis and NETSIM simulation, were then compared to one another. The comparison of the different analysis methods was conducted to examine the results of three different estimates of control delay. The comparison of the field control delay to the theoretical and simulated estimates of delay allowed the data to be examined to see if the estimates of field control delay were reasonable. Because there was no statistical difference between the three detection methods for the field study, capacity and the NETSIM analyses, the data points for each were combined into a single model for each analysis method to increase the sample size. Each of the analysis sets (24 data points each) were plotted and regressed linearly. The plot of this can be seen in Figure 6. The plot clearly shows the three analysis methods are similar in their estimates of control delay for the range of traffic volumes shown.

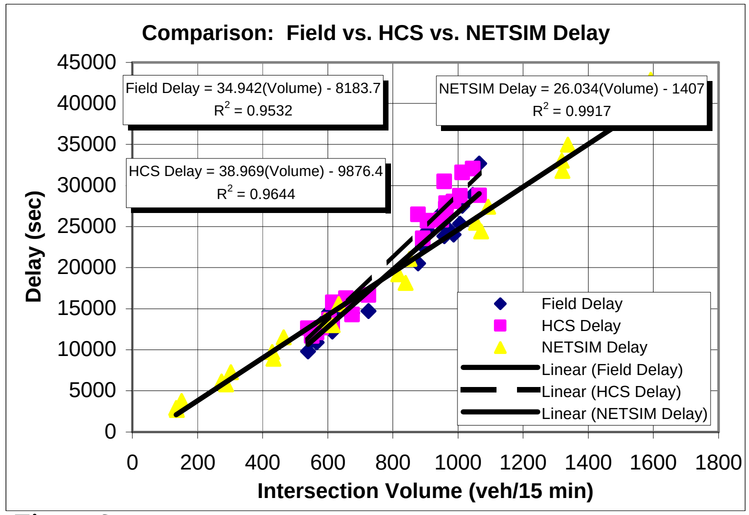

Figure 6

The comparison of the three methods was further examined. A fundamental relationship exists between the total intersection volume and the delay. At an intersection volume of zero, the corresponding delay must also be zero. The NETSIM analysis is a stochastic simulation. It follows that if an infinite number of analysis runs with an infinite number of random number seeds were analyzed, the regression line would pass through the origin point on the plot of delay versus total intersection volume. Figure 7 shows a plot of delay versus total intersection volume with the regression lines forced through the origin. It should be noted that although the three models are statistically different than one another, yet they are close enough to show the existence of a general direct relationship between the amount of control delay experienced and the intersection traffic volume.

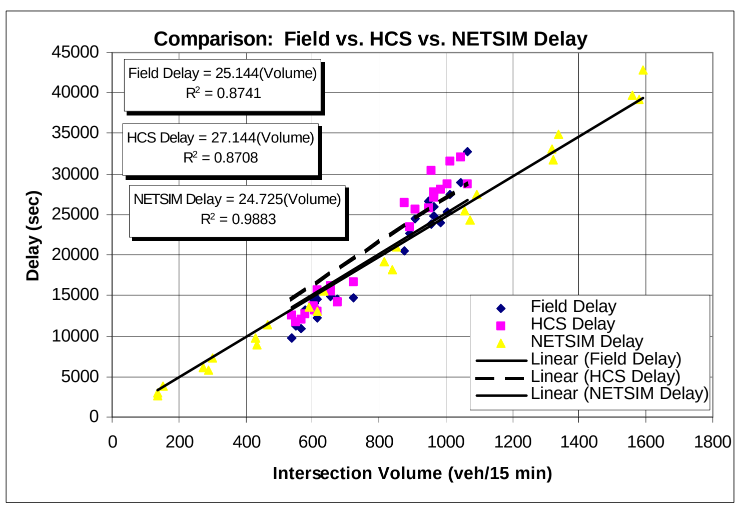

Figure 7

The differences between the three detection methods could be reduced by further research. The differences in the NETSIM simulation could be corrected to more closely match the field study values if a calibration of the computer model was completed. The HCS estimation of delay is based on the research done by Reilly, et. al. and is also hindered by limitations of the program discussed earlier in this research (fixed phasing sequence).

Vehicle Stops Results

The field analysis and the NETSIM analysis both provided information on the number of vehicle stops for comparison. The field analysis provided the number of vehicles in each lane group that stopped during each analysis period (15 min). The NETISM output however provided the percentages of each individual movement. These movement percentages were combined into lane groups matching those in the field analysis. Then the weighted averages of the NETSIM vehicle stops were compared to the output from the field analysis.

Field Study Analysis

The field study examined the independent variable of vehicle stops at the intersection level, the intersection approach level and on an individual lane group basis. Each of the detection methods was tested using the comparison of regression lines test for statistical significance using Statgraphics 3.1. The statistical testing assumed the hybrid system to be the base condition with which to compare the other detection systems for differences. Table 7 shows the P-values for the different analyses.

Table 7 - Comparison of Regression Models P-Values for Total Vehicle Stops

Analysis Level	Loop	Video
Intersection	0.5235	0.4064
NB Approach	0.7419	0.2476
SB Approach	0.7944	0.5757
WB Approach	0.6502	0.5187
EB Approach	0.7347	0.4049
NB Approach Left	0.9012	0.7333
NB Approach Thru&Right	0.8253	0.1863
SB Approach Left	0.6314	0.7831
SB Approach Thru&Right	0.8925	0.5913
WB Approach Left	0.0474	0.2634
WB Approach Thru&Right	0.1514	0.3226
EB Approach Left	0.1612	0.7524
EB Approach Thru&Right	0.6199	0.4364

The statistical analyses showed no statistical difference between any of the vehicle detection systems for a 90 percent confidence level. A plot of the intersection data, regression lines and equations, by system, can be seen in Figure 8. It should be further noted that twelve of the thirteen different analyses (intersection, 4 approaches, 8 lane groups) completed were not statistically different at a 95 percent confidence level. The Westbound left turn analysis shows the loop detection method to be statistically different than the other two at the 95 percent level confidence level. The difference is probably caused by a narrow range of volumes that were observed for this particular lane group. A second possible explanation for the statistical difference is the proximity of a traffic signal approximately 1000 feet to the north. This traffic signal has the ability to alter the vehicle arrival pattern, which for analysis purposes is assumed to be uniform and random. It should be noted that all of the R^2 values for the fitted models are above 0.98. The R^2 value measures the amount of the variation in the data that is explained by the regression equation. The relationships modeled in Figure 8 show a direct relationship between the volume of traffic and the total vehicle stops observed. This relationship is logical, the total vehicle stops increase proportionally to the traffic volume, as volume increases.

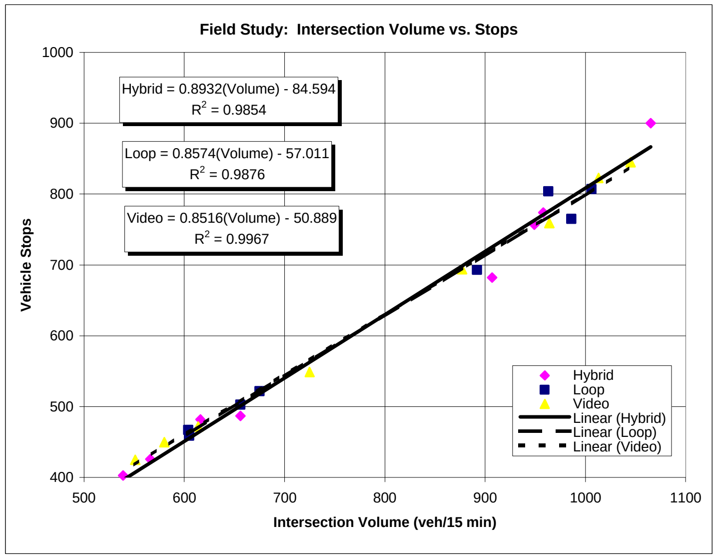

Figure 8

NETSIM Analysis

The results of the NETSIM analysis followed very closely the field analysis findings. The three detection systems were evaluated similar to the field study where the dependent variable of vehicle stops was examined in relation to the independent variable of intersection volume. Figure 9

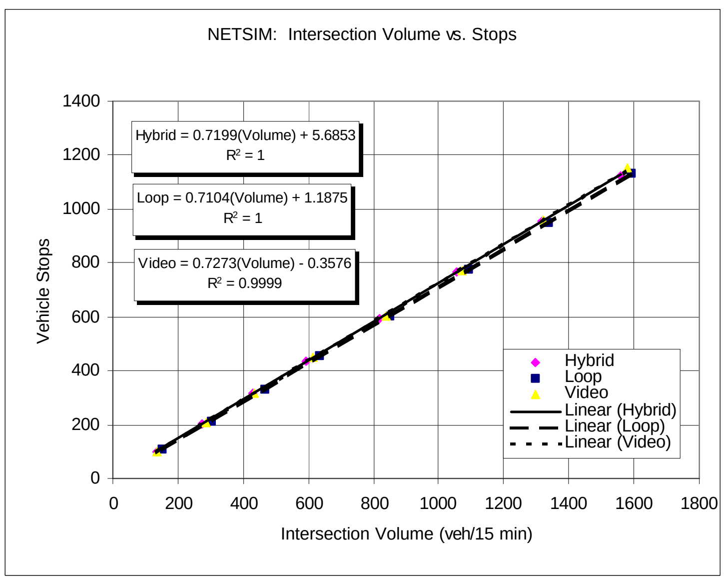

Figure 9

shows a plot of the NETSIM output data of vehicle stops for the three different detection methods.

Similar to previously mentioned data analyses the number of vehicle stops follows a direct relationship with the intersection volume. The regressions models explain almost all of the variation in the data given by the computer simulation. This can be seen in the R^2 values all being above 0.9999. This linear relationship with an extremely high value for the R^2 should be expected, as NETSIM is a stochastic model. Similar to the control delay analysis the intersection volume range experienced during the field study. Upon this further examination of traffic volumes it was found that the relationship between intersection volume and the total number of vehicle stops remains constant between the volumes of approximately 175 to 1600 vehicles per hour.

Comparison of Analyses

The two evaluation techniques, field study and NETSIM simulation, were then compared to one another. Because there was no statistical difference between the three detection methods for both the field study and the NETSIM analysis, the data points for each were combined into a single model for each analysis method to increase the sample size. Each of the analysis sets (24 data points each) were plotted and regressed linearly. The plot of this can be seen in Figure 10.

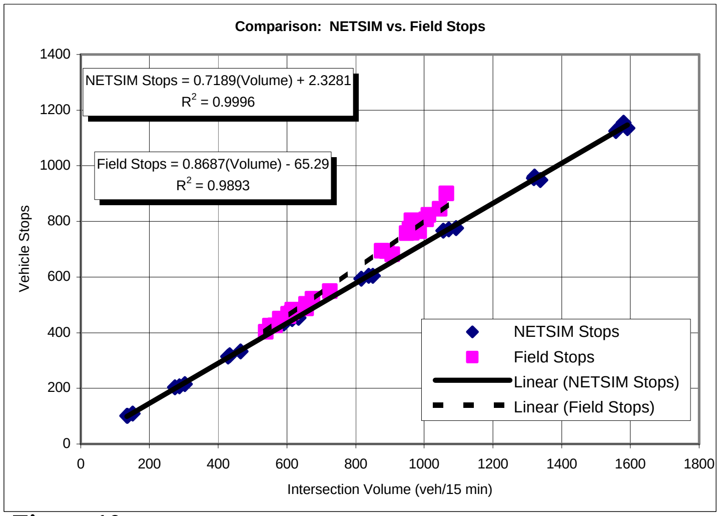

Figure 10

The comparison of the two methods was further examined. A fundamental relationship exists between the total intersection volume and the number of vehicle stops. At an intersection volume of zero, the corresponding number of vehicle stops must also be zero. The NETSIM analysis is a stochastic simulation. It follows that if an infinite number of analysis runs with an infinite number of random number seeds were analyzed the regression line would pass through the origin point on the plot of vehicle stops versus total intersection volume. Figure 11 (Next Page) shows a plot of vehicle stops versus total intersection volume with the regression lines forced through the origin. There is no statistical difference between the two analysis models when the regression lines are forced through the origin.

Further Research

It should be noted that further research was done examining the relationship of cycle length and percentage maxout to volume and detection method. The results from those sections proved to be possibly significant yet, inconclusive at this point and require more research to be completed. A complete description of the items mentioned specifically in this paper and those not mentioned, can be found in their entirety as part of the original masters thesis located in the library system at the University of Nebraska-Lincoln.

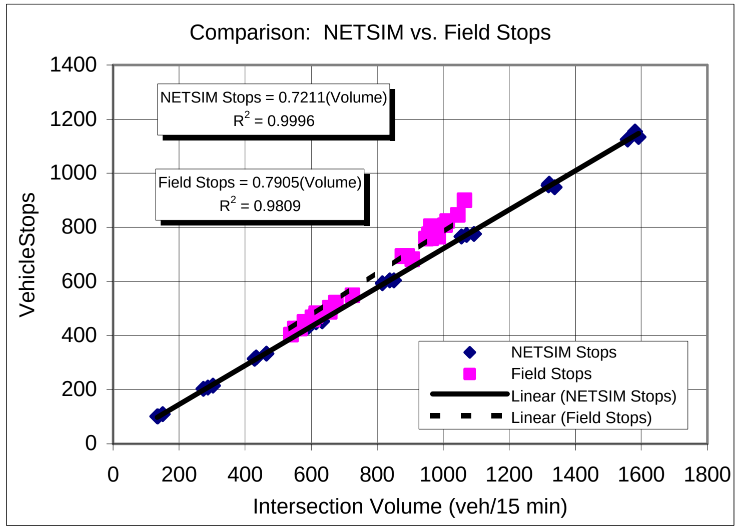

Figure 11

Recommendations and Conclusions

The research presented here was done in an effort to examine the efficiency of different vehicle detection methods for the operation of a fully actuated intersection. To accomplish this task the following things were done. A field study of an intersection was completed with the outcome MOE's of control delay, vehicle stops, average cycle lengths and the determination of max-out percentage. Second, an intersection capacity analysis was conducted using the HCS Release 2.1f. From the HCS analysis and research conducted by Reilly, et.al. an approximation of theoretical control delay was formulated so that it could be compared to the actual conditions in the field and the computer simulation. Finally, a computer simulation model was created using NETSIM. From the NETSIM simulation, an estimate of delay and vehicle stops was acquired for comparison to the other analysis techniques. The findings of the research are as follows:

- The results of the field study were supported by the outputs of a computer simulation and the theoretical analysis of delay using the 1994 HCM methodology and previous research.
- There is no statistical difference between the three detection methods, inductive loops, video detection and a hybrid system, for the criteria of control delay or vehicle stops. The data also shows the need for more research in the area that will expand on this research so this data can be extended to other intersections with different lane configurations and signal timing parameters than those examined here.

- The examination of phase lengths, cycle lengths and percentage of max-out phases showed that there was a significant difference between the hybrid detection system and the other two. The hybrid system had a high average cycle length and max-out percentage at lower intersection volumes. The findings for the cycle length and phase volumes should be looked at with skepticism due to the low cycle samples that fifty percent of the data experienced. Assuming the data is correct, a possible explanation for the difference in the hybrid system could be the result of having a larger number of vehicle detection zones than the other detection methods. This increase number of detection zones increases the chances that the green will be extended by vehicles on an approach. The field study however showed no differences in the control delay and vehicle stops measurements. This could be explained by the number of vehicles that incur extra delay or stop, being relatively equal to the number of vehicles that were able to traverse the intersection with out delay or stopping. To prove any of these possible explanations for the results of the cycle length and max-out percentage analyses further research outside the scope of this project would have to be conducted. The elimination of all advance detection in right turn only lanes will reduce the number times that the green time is extended, therefore reducing the overall average cycle length and max-out percentage. The providing of dilemma zone protection also reduces the efficiency of an intersection. The result of removing the back advance detection on the thru lanes would be the same as removing the advance detection in the right-turn lane but the ability to provide dilemma zone protection to the through phases would be sacrificed.
- The research would suggest that there is no significant difference between the three detection systems evaluated. This however is coupled with the need for further research concerning the placement and number of detection zones and their affect on the operational characteristics of an actuated intersection. Furthermore, additional research should be conducted to examine the effect of vehicle detection methods at different types of intersections (both operationally, and geometrically). The ability to extend the results of this research to other conditions would be valuable in that a more thorough understanding of vehicle detection would be attained in addition to hopefully reducing delay and vehicle stops that the motoring public experiences.

movite

Missouri Valley Section - Institute of Transportation Engineers

October 16, 2000

Tom Brahms
The Millennium Fund
Institute of Transportation Engineers
525 School St. S.W., Suite 410
Washington, D.C. 20024-2797 USA

Dear Mr. Brahms:

As President of the Missouri Valley Section of the Institute of Transportation Engineers, it gives me great pleasure to submit a check for the amount of $1,000 as a contribution to the new ITE Headquarters Office for the year 2000.

The executive board approved this expenditure at our annual fall meeting. We therefore request that the name of our section be engraved as a Silver Contributor on the Millennium Fund Contributors' Wall that will be prominently displayed in the new ITE Headquarters Office.

I am proud of the leadership role our section has demonstrated by making this noteworthy contribution. I also challenge all other sections within District IV and the remaining districts to support ITE in this endeavor.

Please list the name of our section as "The Missouri Valley Section (MOVITE)".

Sincerely,

Bruce L. Wacker
MOVITE President

cc: Executive Board
Journal Editor
Web Page Administrator