Remote Sensing Change Analysis Methodology to Support Traffic Monitoring Programs

Sponsored by
National Consortium on Remote Sensing in Transportation for Infrastructure
University of California, Santa Barbara
and
the Iowa Department of Transportation

CTRE

Center for Transportation Research and Education

Iowa State University

Final Report • July 2003

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CTRE Project 02-114		

4. Title and Subtitle	5. Report Date
Remote Sensing Change Analysis Methodology to Support Traffic Monitoring Programs	July 2003
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
Reginald R. Souleyrette, Shauna L. Hallmark, Molly M. O'Brien, Sitansu B. Pattnaik, and Zachary N. Hans	
9. Performing Organization Name and Address	**10. Work Unit No. (TRAIS)**
Center for Transportation Research and Education Iowa State University 2901 South Loop Drive, Suite 3100 Ames, IA 50010-8632	**11. Contract or Grant No.**
12. Sponsoring Organization Name and Address	**13. Type of Report and Period Covered**
Iowa Department of Transportation 800 Lincoln Way Ames, IA 50010 National Consortium on Remote Sensing in Transportation for Infrastructure University of California, Santa Barbara	Final Report **14. Sponsoring Agency Code**
15. Supplementary Notes	

16. Abstract

The Federal Highway Administration mandates that states collect traffic count information at specified intervals to meet the needs of the Highway Performance Monitoring System (HPMS). A manual land use change detection method was employed to determine the effects of land use change on traffic for Black Hawk County, Iowa, from 1994 to 2002. Results from land use change detection could enable redirecting traffic count activities and related data management resources to areas that are experiencing the greatest changes in land use and related traffic volume. Including a manual land use change detection process in the Iowa Department of Transportation's traffic count program has the potential to improve efficiency by focusing monitoring activities in areas more likely to experience significant increase in traffic.

17. Key Words	18. Distribution Statement
data collection, manual land use change detection method, traffic counts, traffic monitoring	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	17	NA

Remote Sensing Change Analysis Methodology to Support Traffic Monitoring Programs

Principal Investigator
Reginald R. Souleyrette
Professor, Department of Civil, Construction, and Environmental Engineering
Associate Director for Transportation Planning and Information Systems,
Center for Transportation Research and Education
Iowa State University

Co-Principal Investigator
Shauna L. Hallmark
Assistant Professor, Department of Civil, Construction, and Environmental Engineering
Transportation Engineer, Center for Transportation Research and Education
Iowa State University

Research Assistants
Molly M. O'Brien and Sitansu B. Pattnaik
Center for Transportation Research and Education, Iowa State University

Research Engineer
Zachary N. Hans
Center for Transportation Research and Education, Iowa State University

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its research management agreement with the
Center for Transportation Research and Education.

Center for Transportation Research and Education
Iowa State University
2901 South Loop Drive, Suite 3100
Ames, IA 50010-8632
Phone: 515-294-8103
Fax: 515-294-0467
www.ctre.iastate.edu

Final Report • July 2003

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

The authors appreciate the support of the Iowa Department of Transportation Offices of Transportation Data (Peggi Knight, Phil Meraz, and Ron Bunting) and Research Management (Sandra Larson and Steve Kadolph), the U.S. Department of Transportation Research and Special Programs Administration (K.T. Thiramulai), and the National Consortium for Remote Sensing in Transportation, Infrastructure (University of California, Santa Barbara/Val Noronha). The authors are responsible for errors or omissions and findings and views expressed do not necessarily represent those of the agencies listed above.

INTRODUCTION

The Federal Highway Administration (FHWA) mandates that states collect traffic count information at specified intervals to meet the needs of the Highway Performance Monitoring System (HPMS). Each state may have its own method of implementation to satisfy the minimum federal requirements. In the state of Iowa, approximately 9,000 mechanical counts and 1,000 manual counts are collected every year. These counts collect two types of data: traffic volume counts and vehicle classification. Besides meeting federal requirements, traffic-monitoring data are used for determining pavement performance assessment, transportation planning, bridge performance assessment, safety analysis, etc. Garder (1999) indicates that “with the movement towards design-build highway projects and warranties on performance, accurate measurement of vehicular movement is required to ascertain if the roadway has met or exceeded the design requirements.” According to Zhao and Chung (2001), estimation of the average annual daily traffic (AADT) is extremely important because it provides information for planning of new road construction, determination of roadway geometry, congestion management, pavement design, and safety considerations. Without precise AADT data, analysts cannot accurately predict vehicle miles traveled (VMT), compliance with the 1990 Clean Air Act Amendment, or provide truthful reports of AADT to the FHWA.

In the absence of budgetary constraints, each road segment could be continuously monitored to determine AADT, vehicle mix by type, and gross weight. Obviously, only a small subset of all road segments is monitored continuously to produce annual characteristics of traffic flow (Iowa Department of Transportation [Iowa DOT] 2002). Other roads are sampled and monitored on a short-term basis. From the monitoring information obtained, volumes and vehicle classification for other road segments are extrapolated, potentially resulting in significant error (Zhao and Chung 2001). Knowing where to sample is important in allocating resources and staying abreast of changing travel patterns. We are particularly interested in counting roadway segments near areas of significant changes in land use. However, in-the-field tracking of land use change on a statewide basis is expensive and time consuming, and relying on reports from hundreds of local agencies may seriously lag the traffic monitoring process itself.

Remote sensing has the potential to identify change over large areas in a more cost effective way. Change detection, a common application of remote sensing for environmental assessment, can identify regions that have undergone development during an analysis period of interest, and potentially be correlated to changes in traffic generation and distribution.

Results of land use change detection could enable redirecting traffic count activities and related data management resources to areas that are experiencing the greatest changes in land use and related traffic volume. Conversely, areas where land use changes are static or changes are statistically insignificant over time could be counted less frequently. Less costly methods might be employed to generate traffic estimates for locations with little land use change.

TRAFFIC MONITORING

General

There are generally two types of traffic counts: portable short-duration counts and permanent continuous counts. For either method, the number and location of counts must be selected. For short-term counts, the number of sites is statistically selected to achieve desired precision, and count station locations are based on transportation network characteristics. After short-term counts are taken, expansion factors must be generated. These factors are needed to extrapolate short-duration traffic counts into estimates of AADT. They are also required for the remaining roads to determine the AADT based on permanent and short-duration traffic counts at the sample locations. These factors are necessary to generate representative values for day of week, month, and road type. Validation is the last step in the data analysis process, wherein the results produced from the adjustment factors are compared with control data (Office of Highway Policy Information 2003).

The *Traffic Monitoring Guide* (TMG), published by the FHWA, is the key reference and standard for traffic monitoring initiatives in most states. The TMG includes recommendations for implementation of portable short duration counts and permanent continuous counts. The TMG also provides specific recommendations on the number, extent, and duration of monitoring efforts.

Iowa DOT's Traffic Monitoring Procedure

The state of Iowa has approximately 130 permanent traffic count positions at various locations around the state. The state is divided into four zones, as shown in Figure 1, to facilitate collection of data on a four-year rotation, originally predicated on the need to support the no-longer-required "quadrennial needs assessment." Each year, a quarter of the state is selected for collection of temporary traffic counts. Traffic counts are conducted for all primary roads in the selected quadrant and all secondary roads in half of the quadrant's counties. Therefore, secondary (county owned and maintained) roads are counted only once every eight years. While road segments are counted on a regular cycle, changes in land use as well as infrastructure development can greatly affect traffic patterns in intervening years. Therefore, some roads should be counted more often than once every four or eight years. To compensate, the current Iowa DOT procedure allows out-of-turn counting. State, county, and city officials provide locations where substantial change has occurred and make recommendations on prioritizing counts. However, this procedure is subject to interpretation and only "significant" changes in land use and network are considered.

Traffic studies are conducted with mechanical and manual traffic counts. Mechanical counts are performed using portable automatic traffic controllers for periods of 24 to 48 hours. Manual counts are directly entered into a computer, and are conducted in two time periods of four hours each or three consecutive eight-hour periods.

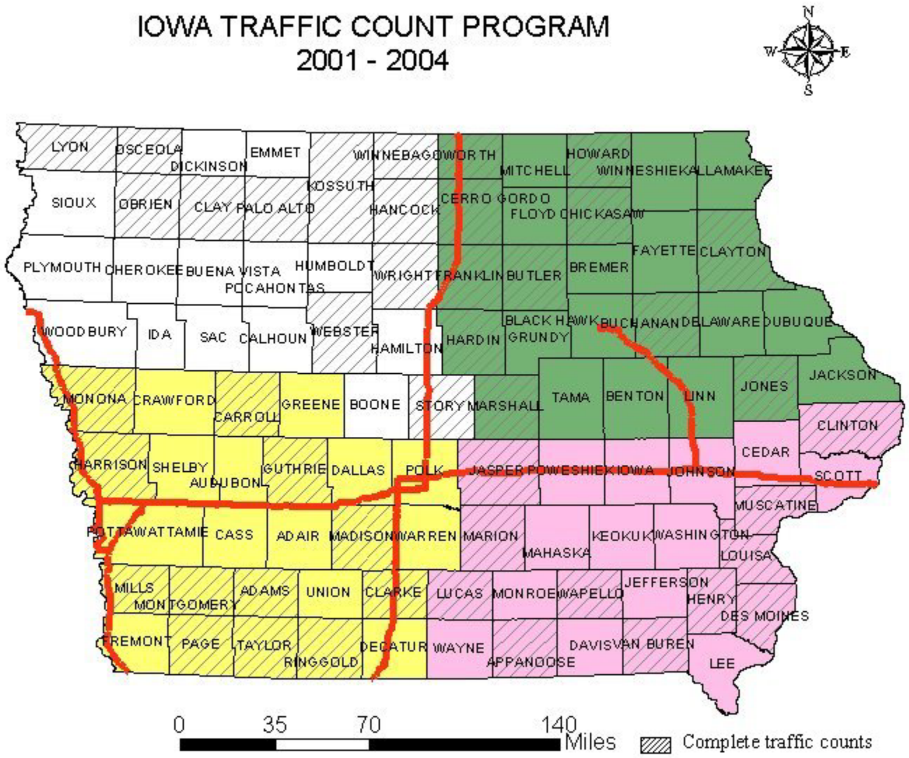


Figure 1. Map of Iowa Depicting the Four Counting Zones (Source: Iowa DOT Office of Transportation Data)

METHODOLOGY

Two methods were investigated to detect land use changes affecting traffic over a period of interest: semi-automated (image classification) and manual (geographic information systems [GIS]). Preliminary image classification testing was performed for the Maquoketa, Iowa area, due to availability of data. During the project period, statewide color infrared imagery became available, and preliminary manual GIS assessment was conducted for Black Hawk County, Iowa (more representative of urban/rural mix). The automated method was also tested for a portion of Black Hawk County.

Data Availability

Remote sensing data are available at many spatial and spectral resolutions. An example is the U.S. Geological Survey (USGS) Landsat series. However, Landsat data sets have limited utility in local land use analysis due to low spatial resolution. However, as they are available over time, they can be useful in understanding changes at a regional level.

A more common form of remotely sensed data is the aerial photograph, often available at project, city, county, or statewide scope. Now, satellite imagery of high spatial resolution (up to

0.6 meters) is becoming widely available. For many areas, spatial resolution of available aerial photographs is better than available satellite imagery. Clearly, statewide analysis requires statewide data. Automated methods require consistent imagery (over time and space), while manual interpretation is more flexible, allowing an analyst to use "best available" data for an area, and is perhaps better suited to the current state of availability of data. Both methods would require timely temporal data (data for the study period of interest), which turns out to be probably the most serious limitation of the current project. For example, only two statewide datasets exist—a USGS DOQQ one-meter panchromatic series (vintage ranges from 1992 to 1996 in various parts of the state) and a 2002 color infrared one-meter series. Only the 2002 series covers the state in more-or-less the same time period. However, aerial photography and satellite imagery are becoming increasingly available and affordable.

Introduction to Automated Change Detection

Initially, to develop a cost-effective process, an automated method of land use change detection was explored. The procedure would use software to identify the areas where the land use has changed and the manner in which it has changed. In automated land use change detection, two steps are taken to determine land use change for a study area: image differencing and post classification comparison.

The image differencing procedure involves pixel level operation wherein radiance values in the imagery from the after period is subtracted from that of the before period. The changes in the radiance values are grouped to detect the areas with appreciable change, and results are quite sensitive to determination of the threshold values for change.

In post classification comparison, imagery from each dataset is independently classified as land use change or "error" by using "manual" classification (spectral ranges are manually set). Next, land use types are compared across the time period to determine the magnitude and type of change.

Imagery for Automated Change Detection Analysis

Due to availability of data, the analysis period selected for the city of Maquoketa was between 1992 and 2002. Panchromatic aerial photographs for the area were available from the USGS (1992) and Aerial Service, Incorporated (2002). The Iowa DOT GIMS road database was also used for the study. The imagery from 1992 had a spatial resolution of 1 meter and the 2002 data set had a spatial resolution of 0.3 meters (one foot).

Procedure for Automated Change Detection

First an image differencing change detection method was applied to identify the land use changes near the city of Maquoketa during the analysis period. Next, the post classification comparison procedure was applied. This was accomplished by initially classifying the aerial photographs into five land use classes: thick vegetation, cultivated land, dense residential, sparse residential, and water bodies. Image differencing was then applied to establish the regions with land use change, by type.

Following are the steps used in the investigation of an automated process:

Step 1: Identifying the Area for Analysis

To limit the areal extent of processing required, we propose taking advantage of the fact that most development occurs adjacent to existing or new roads. Prior to running the change detection algorithm, road vectors can be buffered in GIS, and aerial images clipped to reduce their size. In the Maquoketa databases, the registration of the road and before/after imagery was approximately10 meters. It is suggested that the buffer size be set to include the maximum registration error plus 30 meters, as it was anticipated that most development would be within 30 meters of the nearest road. By ignoring change outside the buffered area of existing roads, the computations are faster, but more importantly, an analyst conducting manual identification of change can proceed through the database at a much faster rate.

Step 2: Change Detection

The imagery is next manually classified to identify fully developed areas, by assigning breakpoints derived from the spectral grouping observed in their respective histograms (this is the "manual" classification process). Image differencing is then performed for post-classification comparison of these classified images. Sample results are shown in Figure 2. The regions in blue are locations of potential new development and the red regions denote developed areas that are unchanged over the analysis time frame. While the method correctly identified the development of some roads and buildings, obvious errors exist. The figure shows some of these errors, which are in all likelihood variations in crops between image years.

Step 3: Identifying New Roads

In steps 1 and 2, areas indicating potential new development are identified. These steps assist the analyst in determining areas of actual and significant development; GIS and remote sensing can help to identify the spatial location of new road segments. New roads adjoining areas identified as potentially built-up or changed would indicate a high likelihood of interest to traffic planners. The process for identifying new road segments could range from simple attribute queries in a roads database, to spatial subtracting of two vector road databases from different dates, to complex centerline extraction from aerial or satellite imagery. For example, new lanes or major resurfacing such as a change in the actual structural rating all could indicate that activities are occurring of significance. Of course, if a recent road database and an older road database include unique attribute identifiers, one can simply query out the new roads. In Maquoketa, two vector road databases were available. One vector road database was from 1992 and the other from 2002. The two databases were compared spatially to find differences. Because the two databases did not overlay exactly, the older database was conflated or rubber-sheeted to the new one before differencing. Resulting "existing roads" were then buffered to create "existing road areas" (see Figure 3). The "new roads" were identified after subtracting the buffer of existing roads from the latest road database.

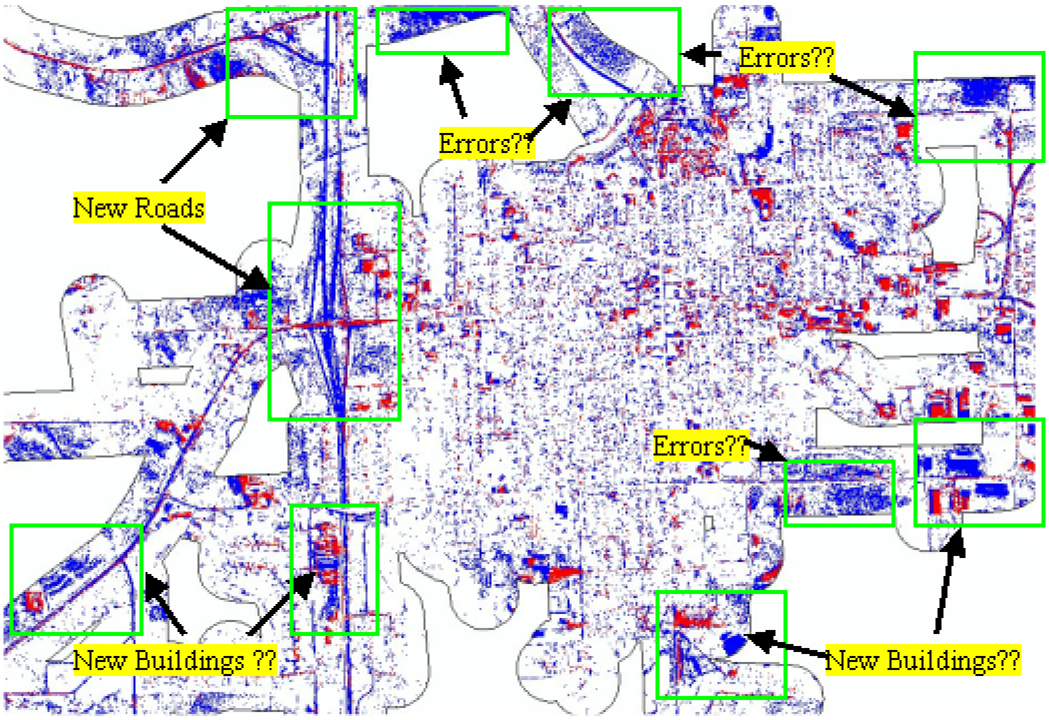


Figure 2. Results of Change Detection (blue, new; red, unchanged)

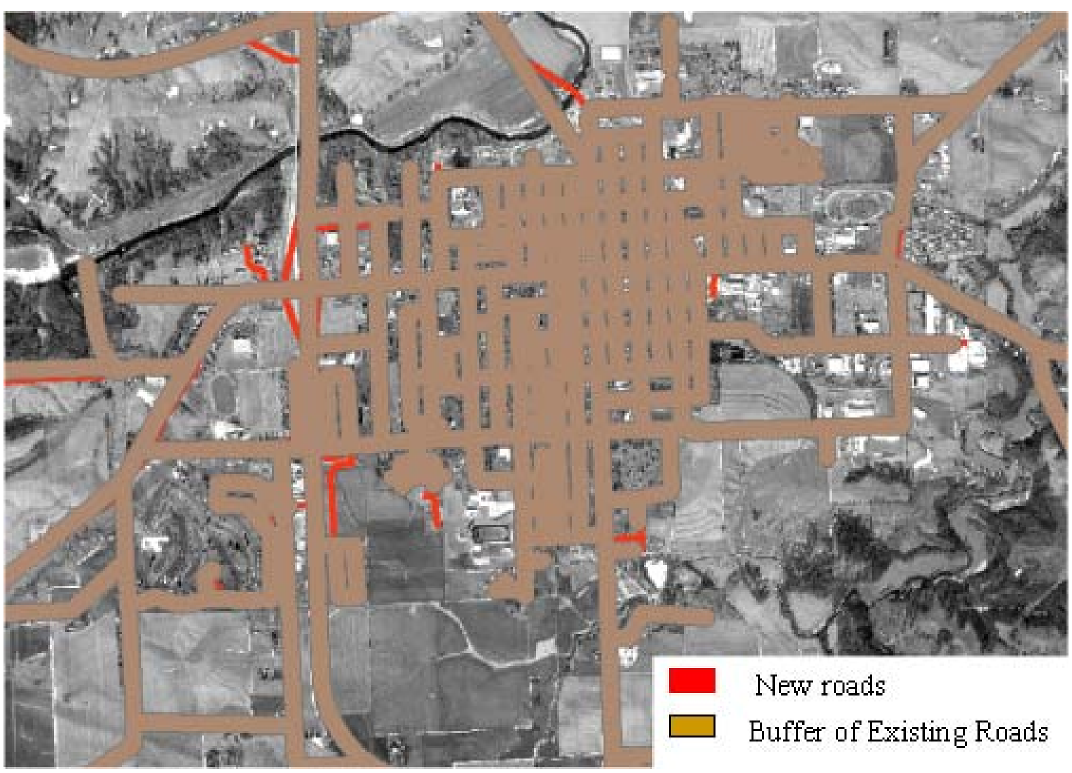


Figure 3: Identifying New Roads (The newer roads built in the analysis period [red] include errors due to large mismatch in the road networks.)

Step 4: Identifying Areas of Development

Potential sites with land use change were identified as shown in Figure 2. These sites are potential regions for focusing traffic monitoring efforts. Potential developing areas that abut new roads are especially promising perhaps deserving of more focused attention. The regions with verified land use change can be flagged and traffic count locations can be established. Recent aerial photos of the area can then be examined manually by focusing only on these areas classified as potentially developing. However, the process of automatically identifying "significant" change areas could be quite subjective and difficult given the results as indicated in Figure 2.

Step 5: Correlation with Traffic

While providing some indication of areas that could be studied further or examined for change, the preliminary results did not provide a simple, accurate and automated way to identify land use change that could be used to focus traffic counting efforts (low spectral resolution of the available imagery resulted in the selection of impure training pixels for supervised classification). Even though the initial comparison is automated, the analyst still has to manually identify the change in land use in corresponding images after comparing the regions, a time consuming process. Early results clearly indicate the need for a more refined automated process, a semi-automated process whereby automated methods may be useful in selecting areas for manual change detection, or suggest a totally manual image classification process.

Limitations of Automated Change Detection

There are several limitations associated with the automated method of land use change detection. These limitations include missing large or small developments that do not occur within the suggested buffer distance, detecting land use change that does not affect traffic (crops), or detecting areas that are not land use change at all. The methodology may miss large or small developments that do not occur within the suggested buffer distance. Most small development occurs in close proximity to roads. However, some larger developments with high traffic generation occur on large tracts of land and may be setback from the adjoining road. These developments may be connected to the road by small, two-lane, private service roads. High traffic generators that may be set back from the highway may include factories, hotels, or office parks. These high traffic generators will be large in size and mode; therefore, detectable on lower resolution imagery using either automated change detection or manual techniques. It is suggested that the change detection process be repeated for the areas that were originally omitted because of their location outside the buffers using imagery with larger pixel size. While the area to be examined would be much larger, smaller viewing scales could be used to move through large areas of imagery in an efficient manner without missing the larger developments. It is suggested that an adequate viewing scale for identifying these facilities would be 1:24,000 (1:12,000 is better), with aerial photos resampled to 10-meter pixel (5-meter may be better.)

Since the methodology is based on detecting land use change through the difference in spectral histograms, some areas that did not experience land use change may be identified as areas with land use change. For example, rural areas where crops are rotated from corn to wheat will show up as an area of land use change. All of these areas would need to be manually examined to determine whether or not land use change took place.

Although this method of land use change detection is referred to as an automated method, it is clearly not totally automated. In order to conduct land use change analysis, an individual would need to work with extensive data sets, buffer around roads, and closely monitor the results to determine whether land use change actually took place over the study period. Not only is this process labor intensive, there is still a possibility that areas with land use change will be missed because they fall outside the buffer area or the new changed area falls within the same spectral histogram category as the previous land use.

Time Estimate, Automated Process

If the automatic method were to be performed on an area, the operator would then need to correct errors. A program written as part of this project developed using ArcObjects and Visual Basic can facilitate this. It allows a user to eliminate areas not considered to be experiencing land use change. Using the program, it is estimated that it would take approximately 15 minutes for a user to complete 920 acres (1.44 square miles) in an urban setting and 10 minutes for 920 acres (1.44 square miles) in a rural setting. Of Iowa's 56,271 square miles, 1.9 percent is urban area (Iowa DOT 2003). Consequently, it could take over 6,000 person hours to perform error correction once the automated method is complete. This is three person years and, as will be seen below, is much longer than the amount of time that would be required by a totally manual interpretation process. There is a potential to mitigate the amount of time. Better software could be used to damp out spectral differences that don't matter. There is the potential for additional bands to be used to identify surfaced such as asphalt/concrete. However, these software and spectrally rich data sets are not expected to be available in the study areas for some time to come.

Introduction to Manual Change Detection

After considering the limitations of the automated land use change detection process, a manual method of determining land use change was explored. Detection for determining change in land use is based on identifying regions that have undergone growth and development during the analysis period. This procedure allows an individual to visually identify the areas where the land use has changed and the manner in which it has changed.

Imagery for Manual Change Detection Analysis

An analysis period of 1994–2002 was selected for Black Hawk County, Iowa. Panchromatic aerial photographs for the area from 1994 were available from the USGS. Color Infrared aerial photographs from 2002 were available from the Iowa DOT. These images had spatial resolutions of 1 meter. Iowa DOT road databases for 1994 and 2002 were used in the change detection study.

Procedure for Manual Change Detection

A manual image differencing change detection method was applied to identify the land use changes in Black Hawk County, Iowa. This was accomplished by first obtaining imagery from the beginning and ending year of the analysis period. These images were overlaid on top of each other in a GIS software package, and compared to determine changes in land use. Polygons were drawn around areas with land use change, and rated based on the intensity of change. These polygons were then compared to road databases corresponding to the study period.

Step 1: Identifying Areas of Change

In order to simplify the process of determining what areas need to be inspected for change, and what areas have already been inspected, a grid was created for the study area. Each grid cell encompasses a 376-acre area, and is labeled based on the 1994 and 2002 aerial photos associated with it and the location of the grid cell within that particular aerial photo. This is depicted in Figure 4. The grid cell size is an arbitrary size and was based on an acceptable viewing area for denoting change.

After the grids were created, each 376-acre area was examined for change. This was accomplished by inspecting the 1994 and 2002 aerial photographs. Polygons were drawn around areas of change. Figure 5 demonstrates this process.

Step 2: Quantifying Number of Trips Generated from Land Use Change

Since different land use change will produce different effects on roadway traffic, the land use change was quantified based on the intensity of development. The Institute for Transportation Engineers trip generation rates were used to determine the number of trips per acre generated by new land use developments.

- A value of 1 was assigned to rural development such as a farmhouse. It was assumed this land use change generates 30 trips per acre.
- A value of 2 was assigned to neighborhood developments. It was assumed this land use change generates 50 trips per acre.
- A value of 3 was assigned to high density housing such as apartment complexes. It was assumed this land use change generates 150 trips per acre.
- A value of 4 was assigned to areas believed to produce significant traffic impacts such as industry, schools, and malls. It was assumed this land use change generates 150 trips per acre.
- New roads were assigned a value of 5. It was assumed this land use change generates 150 trips per acre. This value was assigned due to the time difference between the time the aerial photo was flown and the traffic counts taken.

In order to determine the approximate number of trips produced from land use change, the appropriate number of trips generated per acre was multiplied by the polygon size. Then a total number of trips generated from land use change were determined for all 40 grid cells (9024 acres each).

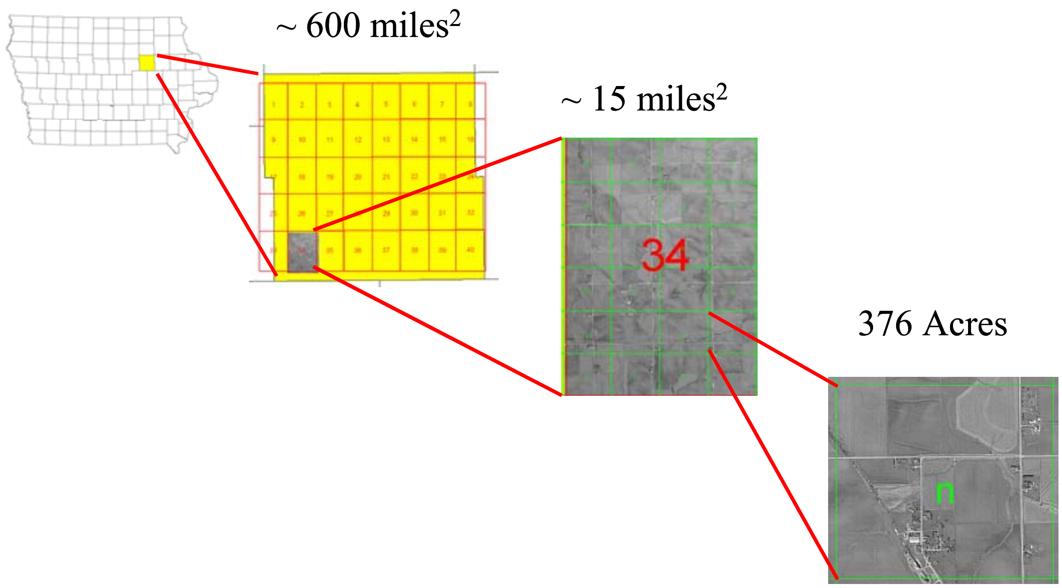


Figure 4. Black Hawk County Analysis Area

Figure 5. Identifying Change Manually

Step 3: Vehicle Miles Traveled

Iowa DOT road databases were utilized to obtain the AADT values for each road in the study area. Road databases from 1994 and 2002 were utilized to correspond with the imagery from the study area. Since road segments did not break at each grid; the road databases were intersected with the grid layer. VMTs for 1994 and 2002 were determined for 40 (9024 acre) grid cells.

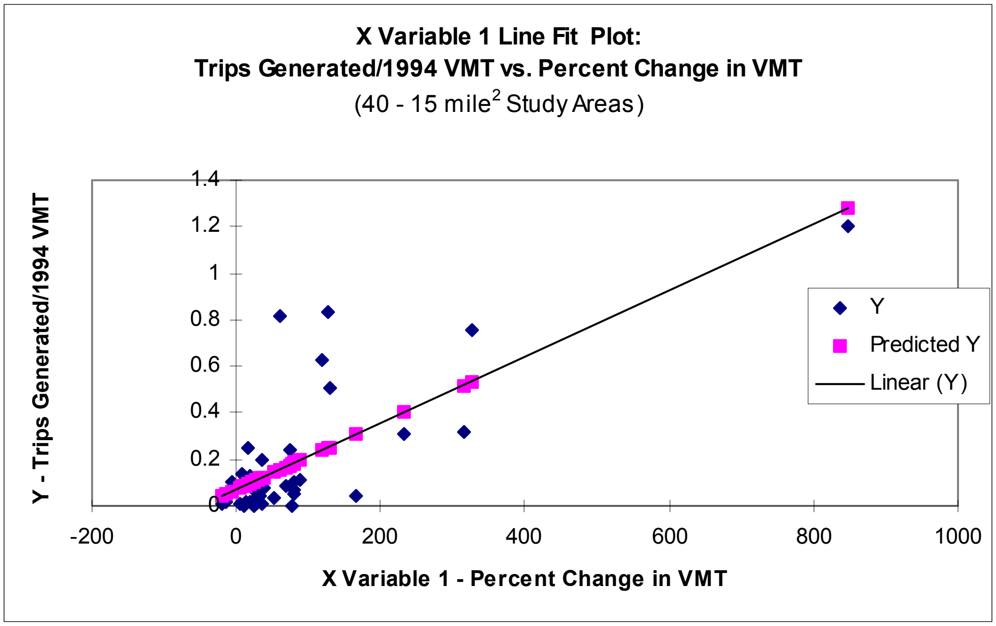
Step 4: Creating Correlations

Several different ways to correlate land use change and increase in VMT were explored. The initial results produced two very promising methods. The first method involved analyzing trips generated divided by 1994 VMT vs. percent change in VMT. This produced an R^2 value of 0.55, but when further examined this high R^2 value was due to and extreme outlier. When the extreme outlier was eliminated, the R^2 value decreased to 0.32 (R^2 decreased as the outlier was much larger in magnitude than other data points, skewing the distribution and violating the assumption of normally distributed errors). These results are outlined in Figure 6.

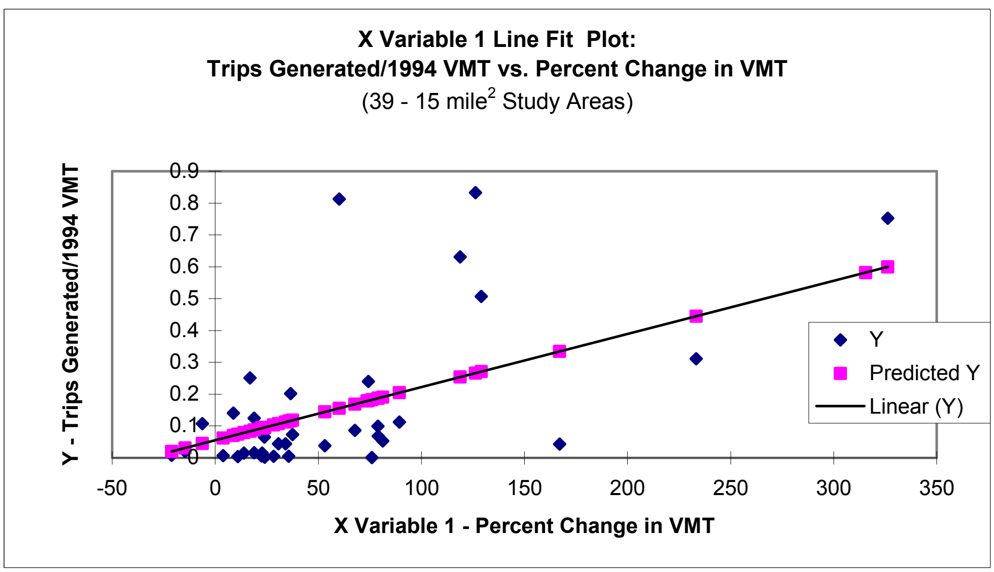
The other method of correlation was trips generated vs. absolute change in VMT. This produced an R^2 value of 0.48. There was an extreme outlier in this analysis, and when removed, the R^2 value increased to 0.74, refer to Figure 7. The exact cause of the outlier is uncertain, but could be due to the fact that land use change was detected, but trips were not yet being generated in the area, thus having little effect on the VMT for the grid cell.

Time Estimate, Manual Process

Areas that are more densely populated require a longer analysis time than rural areas. According to the 2000 census, there are 56,271 square miles in the state of Iowa. Of these 56,271 square miles, 1.9 percent is urban area (Iowa DOT 2003). It takes approximately 5 minutes to manually detect change for a 376 acre area in urban or densely populated areas, while it only takes approximately 1 minute or less to manually detect change in rural, less densely populated areas. This means that manual change detection could be completed for the entire state is 1,715 person hours (less than one person year). The amount of time required to detect land use change in Iowa could greatly be reduced if rural areas are examined with a larger grid sizes. Students or entry-level employees could be hired to complete manual change detection for roughly \$10,000–\$20,000 a year. This estimate does not include supervisor time, data acquisition, storage space, and equipment cost. See Figure 8.

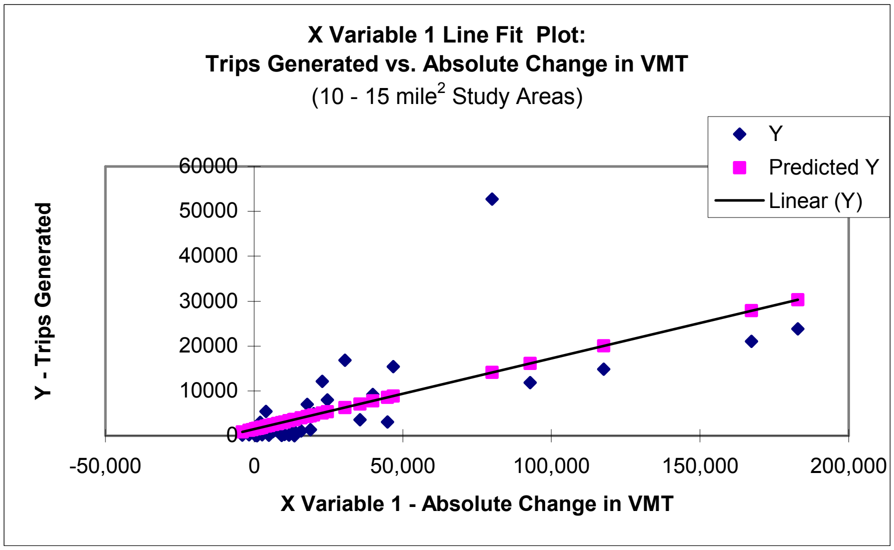


Regression Statistics	
Multiple R	0.74
R Square	0.55
Adjusted R Square	0.54
Standard Error	0.19
Observations	40

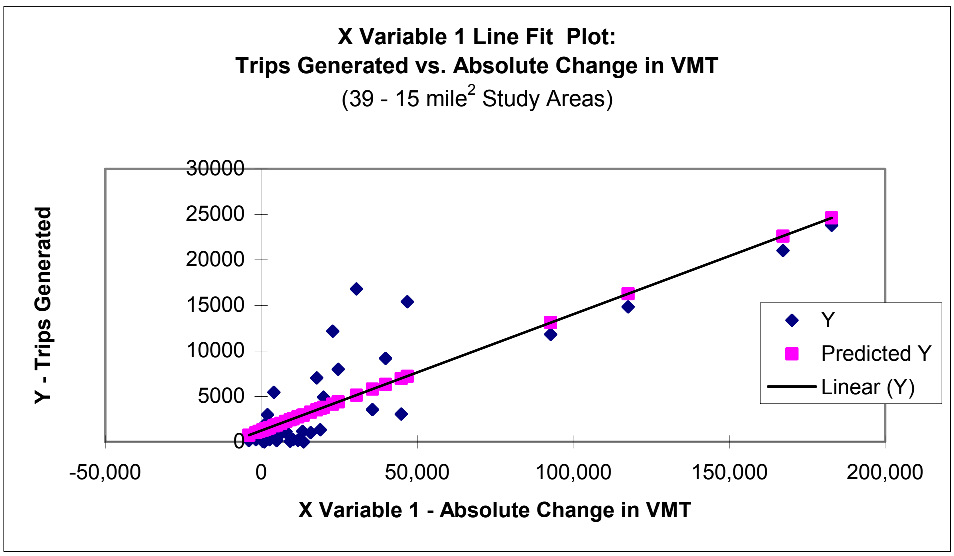


Regression Statistics	
Multiple R	0.57
R Square	0.32
Adjusted R Square	0.31
Standard Error	0.19
Observations	39

Figure 6. Trips Generated Divided by 1994 VMT vs. Percent Change in VMT



Regression Statistics	
Multiple R	0.69
R Square	0.48
Adjusted R Square	0.46
Standard Error	7254.37
Observations	40



Regression Statistics	
Multiple R	0.86
R Square	0.74
Adjusted R Square	0.73
Standard Error	3311.69
Observations	39

Figure 7. Trips Generated vs. Absolute Change in VMT

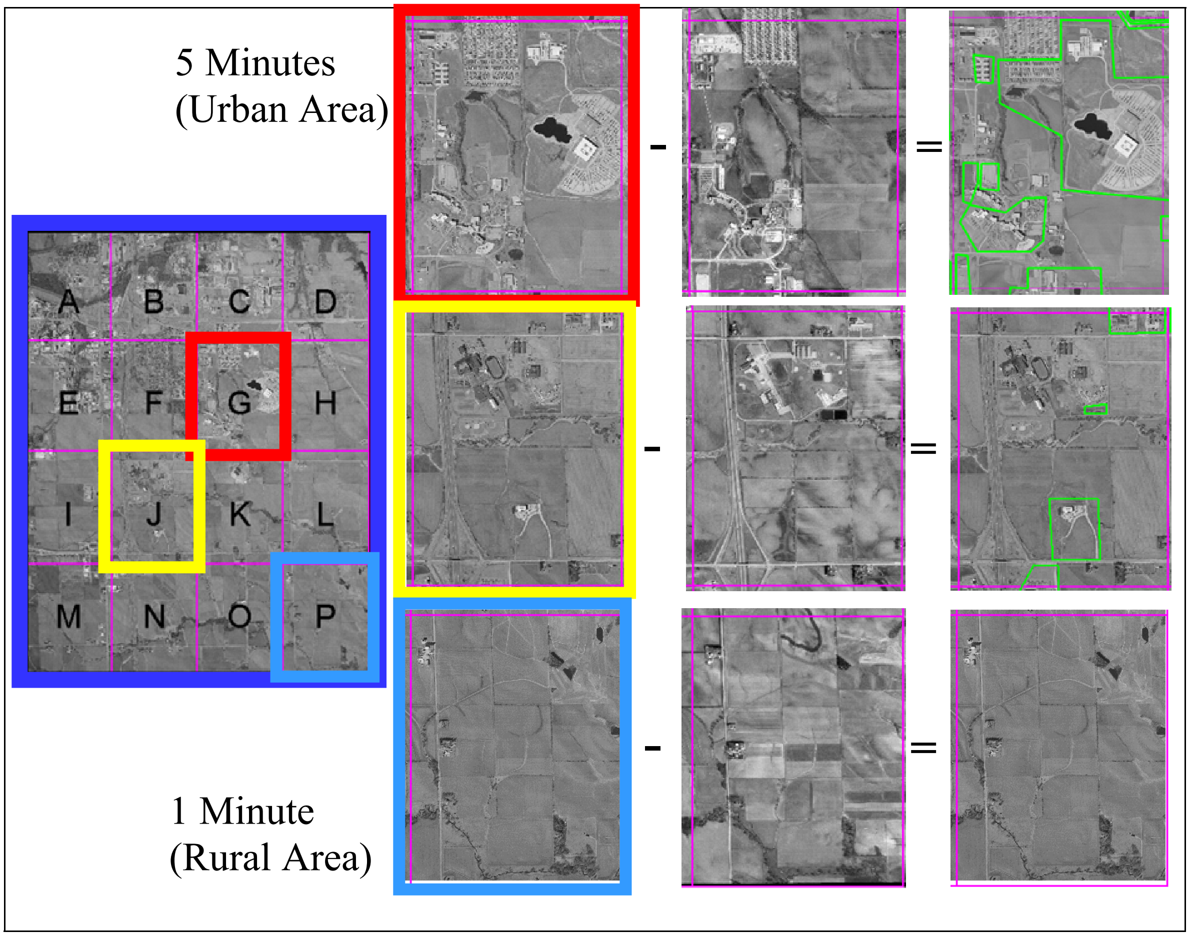


Figure 8. Time Estimates for Detecting Land Use Change (376 Acre Sections)

Limitations of Manual Change Detection

There are several limitations associated with the manual method of land use change detection. These limitations include human error, technology changes or advances, monotony, and working with large files.

The obvious limitation of the manual method of land use change detection is human error. Human error can occur at several different levels during the process. A large number of errors can occur because the employee does not detect land use change. If land use change goes unnoticed by the technician, trips generated from this land use change will go unnoticed in the analysis. The opposite of this can also be true. An employee might draw a polygon around an area that did not change. Another human error that can occur in the process involves assigning the wrong intensity to the polygon drawn around the land use change. This error will result in a higher or lower trips generated value to be assigned to a particular polygon. One way to reduce human error is to have a supervisor review the files before processing them.

In addition to human error, over time there are technology changes that might limit the output or ability of the employee to detect land use change. For example, in this study, all of the 2002 color infrared images had to be converted to black and white prior to examining areas for land use change. Although this is not a complicated process, it takes time to complete. This time will quickly add up when color infrared images for an entire state must be converted to black and white. Additionally, image resolution plays a large role in the speed and accuracy of the employee to determine land use change. Images with poor spatial resolution are blurry and at times it is difficult to determine if land use change took place during the study period.

Finally, this process requires employees to work with and create large files and is monotonous. Since the process is monotonous, it might be difficult to hire and retain employees to work on this project. Since the files are large, they might slow down the process or overload server space.

Suggestions for Future Research

There are supplementary resources beyond the aerial photo based land use change detection that could be useful in future investigations. These include the following:

- City or county zoning maps could be used in conjunction with construction permits to help determine where possible future growth will occur. This would only be possible in the areas of the state that are not rural.
- Historical traffic count data at representative urban and rural locations can provide information about the relative trends in traffic counts from one counting cycle to the next.
- The U.S. Census Bureau data could be useful to identify demographic changes in roadways adjacent to land use change. However, there is a 2 to 3 year data lag and data are collected every 10 years.
- Economic development and employment data could be useful to identify new industrial and retail sites that generate and attract vehicles. For example, new sales tax permits could be used to help indicate areas of land use change.

Also, other steps can be taken to enhance results:

- Main roads such as interstates, highways, and major arterials could be eliminated from the VMT calculations because AADT experienced on these roads is not directly related to land use change, whereas the AADT on collector and local roads is directly related to adjacent land use.
- In this analysis, retail, industry, and office buildings were grouped together to simplify analysis. In the future, these development types could be grouped separately and the number of trips generated per acre would be more representative of the exact land use type. This could possibly produce even higher R^2 values.
- A more comprehensive method of determining the affects of land use change on increases in VMT would be to use a gravity model to model traffic patterns in surrounding areas. It is believed this will increase the correlation coefficient and better direct efforts to identify focused areas for traffic monitoring.

CONCLUSIONS AND RECOMMENDATIONS

Currently, some traffic counts are performed on the same cycle even though there may be negligible change development or traffic. As expected, the results indicate that changes in land use have a high correlation with changes in traffic volume and distribution patterns in the road network. Once areas of land use change and number of trips generated have been determined, analysts can determine where land use change will have impact on the system. Focusing traffic counts at changing areas has the potential to reduce the amount of manual count locations across the state and by concentrating on those locations that are experiencing large changes in traffic, better AADTs should result.

Two different methods of change detection were explored: an automated method and a manual method. Although the automated method uses automated image differencing and post-classification comparison, it requires extensive manual input to find “potential” areas of change. On the other hand, the manual method for land use change detection can be accomplished with less possibility of missing areas of change. The manual method proved to be very reliable in predicting absolute change in VMT based on trips generated.

By including the manual land use change detection process in traffic count program management, the quality and timeliness of traffic count data could potentially be increased. While the methodology described herein does not allow for perfect tracking of traffic change areas (only 50 percent of the variability in VMT was predicted), the process may be used to reduce the number of counts in relatively static areas, saving these resources or potentially shifting these resources to target growth areas. In “non-changing” areas, it is recommended that a smaller set of counts still be maintained for quality assurance purposes, at least until the methodology can be improved and further validated.

REFERENCES

Gardner, M.P. 1999. *Highway Traffic Monitoring*. Committee on Highway Traffic Monitoring; Transportation Research Board, National Research Council, Washington, D.C.

Iowa Department of Transportation. 2002. *Iowa's Monitoring Program*. Systems Monitoring Section, Iowa Department of Transportation, Ames, Iowa.

Iowa Department of Transportation. 2003. *Trans Facts*. April 2003. http://www.dot.state.ia.us/dot overview/transportationfacts.htm.

Office of Highway Policy Information, Federal Highway Administration, U.S. Department of Transportation. *Traffic Monitoring Guide*. March 2003. http://www.fhwa.dot.gov/ohim/tmguide/.

Zhao, Fang, and Soon Chung. 2001. Estimation of Annual Average Daily Traffic in a Florida County Using GIS and Regression. *Transportation Research Record,* No. 1769, pp. 113–122.