Remote Sensing Change Analysis Methodology to Support Traffic Monitoring Programs: Phase 2

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16. Abstract

The Center for Transportation Research and Education (CTRE) issued a report in July 2003, based on a sample study of the application of remote sensed image land use change detection to the methodology of traffic monitoring in Blackhawk County, Iowa. In summary, the results indicated a strong correlation and a statistically significant regression coefficient between the identification of built-up land use change areas from remote sensed data and corresponding changes in traffic patterns, expressed as vehicle miles traveled (VMT).

Based on these results, the Iowa Department of Transportation (Iowa DOT) requested that CTRE expand the study area to five counties in the southwest quadrant of the state. These counties are scheduled for traffic counts in 2004, and the Iowa DOT desired the data to 1) evaluate the current methodology used to place the devices; 2) potentially influence the placement of traffic counting devices in areas of high built-up land use change; and 3) determine if opportunities exist to reduce the frequency and/or density of monitoring activity in lower trafficked rural areas of the state.

This project is focused on the practical application of built-up land use change data for placement of traffic count data recording devices in five southwest Iowa counties.

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REMOTE SENSING CHANGE ANALYSIS METHODOLOGY TO SUPPORT TRAFFIC MONITORING PROGRAMS: PHASE 2

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INTRODUCTION

Background

The Center for Transportation Research and Education (CTRE) issued a report in July 2003, based on a sample study of the application of remote sensed image land use change detection to the methodology of traffic monitoring in Blackhawk County, Iowa. In summary, the results indicated a strong correlation and a statistically significant regression coefficient between the identification of built-up land use change areas from remote sensed data and corresponding changes in traffic patterns, expressed as vehicle miles traveled (VMT).

Based on these results, the Iowa Department of Transportation (Iowa DOT) requested that CTRE expand the study area to five counties in the southwest quadrant of the state. These counties are scheduled for traffic counts in 2004, and the Iowa DOT desired the data to 1) evaluate the current methodology used to place the devices; 2) potentially influence the placement of traffic counting devices in areas of high built-up land use change; and 3) determine if opportunities exist to reduce the frequency and/or density of monitoring activity in lower trafficked rural areas of the state.

This project is focused on the practical application of built-up land use change data for placement of traffic count data recording devices in five southwest Iowa counties.

Research Objectives

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 tailor its methods of implementation to satisfy minimum federal requirements.

Average Annual Daily Traffic (AADT) is the common metric used to develop estimates of traffic flow density, often extrapolated to VMT. In the absence of budgetary constraints, each road segment could be continuously monitored to determine AADT, vehicle mix by type, and gross weight. As a practical matter, a subset of roads are monitored continuously to produce annual characteristics of traffic flow, which in combination with limited duration sample counts of other road segments, are extrapolated to the entire road network.

Of particular interest are road networks near areas of significant land use change, as well as roadway segments in rural areas with very static land use patterns. Field tracking and reporting of land use change on a statewide basis is expensive and time consuming and relying on reports from hundreds of local agencies may seriously delay the traffic monitoring process itself.

Temporal analysis of remote sensed imagery has the potential to identify land use change over large areas in a more consistent and efficacious manner. Change detection, a common application of remote sensing for environmental analyses, can identify regions that have been transformed to built-up development during an analysis period, with potential correlation to changed traffic generation and distribution. Areas exhibiting little or no land use change over long periods are also identifiable via these methods.

The results could enable redirecting traffic count activities and related data management resources to areas that have experienced 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 and/or with fewer counting devices.

TRAFFIC MONITORING

Requirements

The Traffic Monitoring Guide (TMG), published by the FWHA, recommends, as a general rule, *"that each roadway segment be counted at least once every six years." "Coverage counts are needed to ensure that adequate geographic coverage exists for all roads under the jurisdiction of the state highway authority. In general, roadway sections that experience high rates of growth require more frequent data collection than those that do not experience growth. Therefore, roads near growing urban centers and expanding recreational sites tend to need more frequent counting than roads in predominately rural areas where volumes have changed little in the last ten years."*

"Finally, not all count locations should be counted on a six-year basis. Some count locations need to be counted more often. Other roads have such stable traffic volumes, that counts can be performed even less frequently."

Iowa DOT Traffic Monitoring Program

The capture, management, and dissemination of traffic monitoring data in Iowa are costly as well as labor intensive. Each year, the Iowa DOT performs approximately 9,000 mechanical counts and 1,000 manual counts for traffic volume, turn movements, and vehicle classification. These data are factored and interpolated to the entire road network in Iowa, with traffic count values attached to each road segment (e.g. loosely speaking, a segment is a section of roadway between two consecutive intersections, although segments can be longer or shorter, with bridge structures, railway crossings, political boundaries, and other structures and termini serving as break points). Such data are used to assess pavement and bridge performance, generate safety statistics, develop transportation plans, allocate highway funds, plan for roadway maintenance, renewal, and reconstruction, evaluate design compliance, comply with clean air laws, report to the FHWA, and for other special purposes and studies.

The current traffic counting process involves monitoring a sample of Iowa road segments for traffic counts. Counts are performed during a 24 to 48 hour period on this sample and are factored based on data from approximately 130 permanent traffic count devices (automated traffic recorders) placed around the state. This enables adjustment for time of day, day of week, seasonality, commute patterns, geography, and other factors that impact methods for annualizing the data. From this information, a further process involves the interpolation of these sampled annualized counts to all road segments in the state.

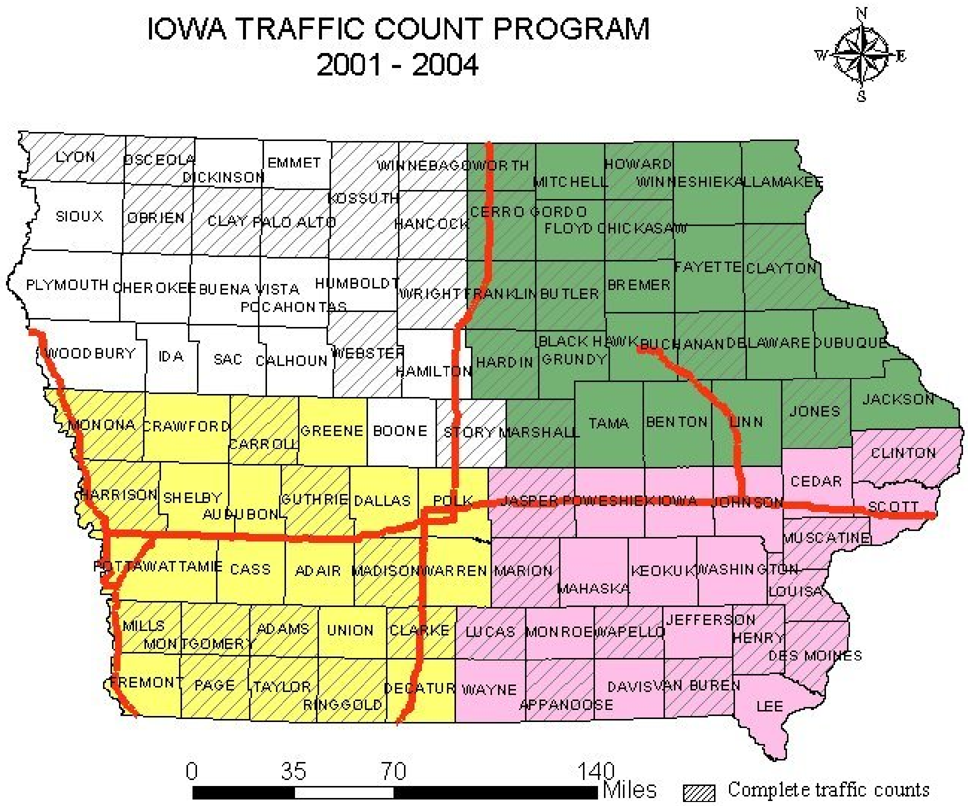


Figure 1. Map of Iowa traffic counting zones and frequencies, 2001 to 2004
Source: Iowa DOT office transportation data

Because the volume of potential sample locations is large, the Iowa DOT divides the state into four quadrant zones using a cycle count program. Within each zone, all primary routes (principal arterials) are sample counted once every four years in each county; secondary and local roads (minor arterials, collectors, locals) are sample counted every eight years on a cycle that alternates between approximately half of the counties in each zone. All counties with large urban areas have complete sample counts every four years.

Again, quoting from the TMG: *"The basic statewide traffic data collection coverage program includes the collection of volume and classification data for the HPMS. The HPMS is a combination of complete coverage (universe) for the National Highway System (NHS) and other principal arterials, and a structured sample of roadway sections for the remaining functional systems excluding the rural minor collectors and locals."*

Iowa's program substantially adheres to FWHA recommendations and HPMS requirements. Selected large urban areas have sample counts performed even more frequently than required, especially for high growth or volatile locales. In fact, Iowa DOT may be over-counting in some areas of the state, given the depopulation of predominately rural counties, which exhibit continuing trends of very low or no built-up land use change, as well as decreasing built-up land use intensity.

RESEARCH METHODOLOGY

Analysis Methods

Two basic methods were developed and used during the Blackhawk project to detect land use changes affecting traffic over a period of interest: 1) a “semi-automated” method that employed image classification and comparison, and 2) a “manual” visual inspection method for detecting built-up land use change supported by GIS technology[1]. This project was performed using the manual method.

The semi-automated method employed image-processing software to detect image differences and facilitate a post-classification comparison. The procedure evaluated radiance values from the image pixels and mathematically determined the differences between temporally different images of identical geographic extents. Results were grouped to facilitate analysis of the areas with measurable and significant change. In post-classification, imagery from each data set was independently classified as “actual” land use change, or by manual visual inspection, spectral ranges were adjusted by human intervention.

Unfortunately, the semi-automated method tends to create large numbers of “false positive” land use change candidates. The process converts identified raster change values to vector polygon change areas. Although many of the candidate polygons can be summarily eliminated based on small extents, many others required manual inspection to determine the validity of the semi-automated selection process. Those identified as false positives required intervention to eliminate them from further analysis. Evaluation of the time required to perform this post-processing data preparation, versus simply performing a manual inspection of the before and after imagery via visual comparison, suggested that the manual approach would be more reliable and equally fast.

It is likely that the semi-automated method could be enhanced to address some of its deficiencies, and like so many other automated processes, it depends on the quality and precision of the data it uses as input. The only Iowa statewide imagery available in both before and after epochs that had an approximate match to the cycles of traffic monitoring were not of the same spectral or temporal quality. Only two statewide image data sets exist, a USGS DOQQ one-meter panchromatic series (vintage ranges from 1988 to 1998) and a 2002 color infrared (CIR) one-meter series. To facilitate spectral comparison via the semi-automated method, the CIR images were converted to panchromatic equivalent intensity-hue-saturation (I-H-S) formats. The resulting loss in fidelity likely impacted the quality of the pixel change comparison.

[1] To reconfirm the validity of the manual method originally tested in Blackhawk County, the method was retested on Scott County (a county where aerial imagery and data collection dates, 1994 and 2002, also closely coincided). Test results indicated that the manual method produced projected VMT increase in analysis grids that correlated well (R squared of 0.68) with DOT AADT estimates.

Image Data

The range in image years for the USGS DOQQ panchromatic aerial photographs was significant. The map shown in Figure 2 below illustrates the disparity in image acquisition dates, especially for the western half of the state.

However, as noted earlier, these are the only statewide "before" images available for comparison to the "after" CIR images. The absence of contemporaneous DOQQ data within counties presents challenges in performing valid comparisons of before and after land use change detection, especially when alignment with corresponding cycles of traffic count activities is desired. In addition to before and after image data, GIS datasets were obtained and used for Iowa counties and for the Iowa DOT road network, with corresponding traffic count (AADT) data associated to road segments.

Study Area

The Iowa DOT selected five counties in the southwest quadrant of the state for the expanded follow-up study. Those counties were Adair, Dallas, Guthrie, Madison, and Warren. They are scheduled for traffic monitoring counts during 2004. Dallas and Warren counties are experiencing significant suburban growth contiguous to the Des Moines metropolitan area, with resulting conversion of agricultural land to built-up use. Madison also exhibits these characteristics, but less so. Adair and Guthrie counties are predominately rural, with comparatively small amounts of land conversion to urban uses.

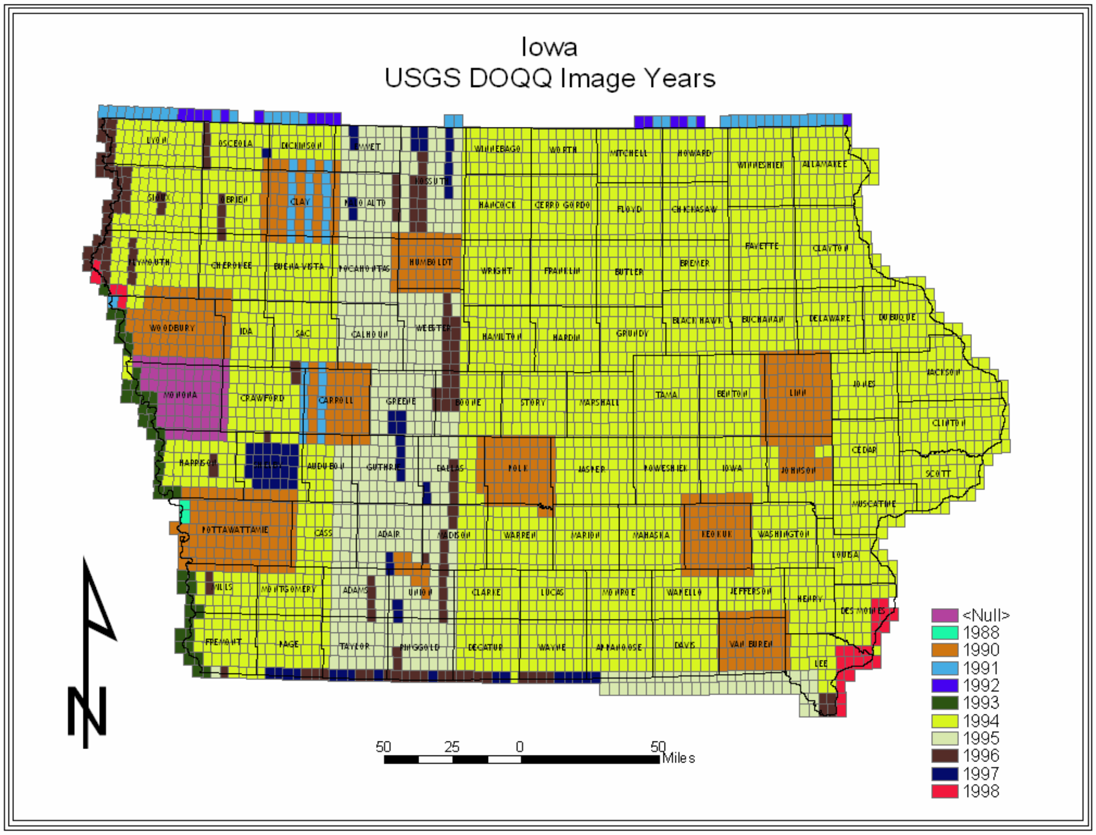


Figure 2. Map of Iowa USGS DOQQ image acquisition years

Technology and Tools

Given the choice of the manual method of land use change detection, ArcGIS (ESRI), a geographic information system (GIS) tool, was the primary technology employed. Imagine (ERDAS) was used for image data preparation.

Manual Inspection Procedure

A mosaic of the quadrangle images was created on a county-wide extent, and they were transformed to a common projection and grid (UTM Zone 15N). The USGS DOQQ was the "before" image and the Iowa CIR was the "after" image. These data, along with county political boundaries and roads network data from the Iowa DOT, were loaded into ArcGIS.

Using an add-in tool called "Fishnet," each county was draped with two grid layers. The first was a 5 x 5 overview grid (the ogrid) and each of these grids was further subdivided into 25 analysis grids (the agrid). Fishnet allows the specification of origin X and Y coordinates, map extent, cell size, number of rows and columns, and projection.

A personal geodatabase was created in ArcGIS to store the feature dataset for the change detection digitizing work. This enabled both the automatic computation of the polygon shape area in the attribute table, as well as the definition of domain attributes for classifying the type of land use change (e.g. agricultural, commercial, industrial, residential, etc.)

Finally, a custom visual basic application (VBA) was used to enable rapid navigation to a specified ogrid and one of its constituent agrids. When the GIS operator was finished inspecting and digitizing a land use change polygon based on visual inspection of the before and after images, he/she needed only to key enter the next agrid id or new ogrid, if needed, into the VBA dialog box to automatically pan to the next geographic expanse. This permitted a systematic review of the entire geographic expanse of the county at a consistent level of resolution and geographic extent.

Figure 3 provides an example of the use of the VBA custom tool to perform change detection at the ogrid and agrid level. The far southwest ogrid for Dallas County is selected for change detection analysis in this example.

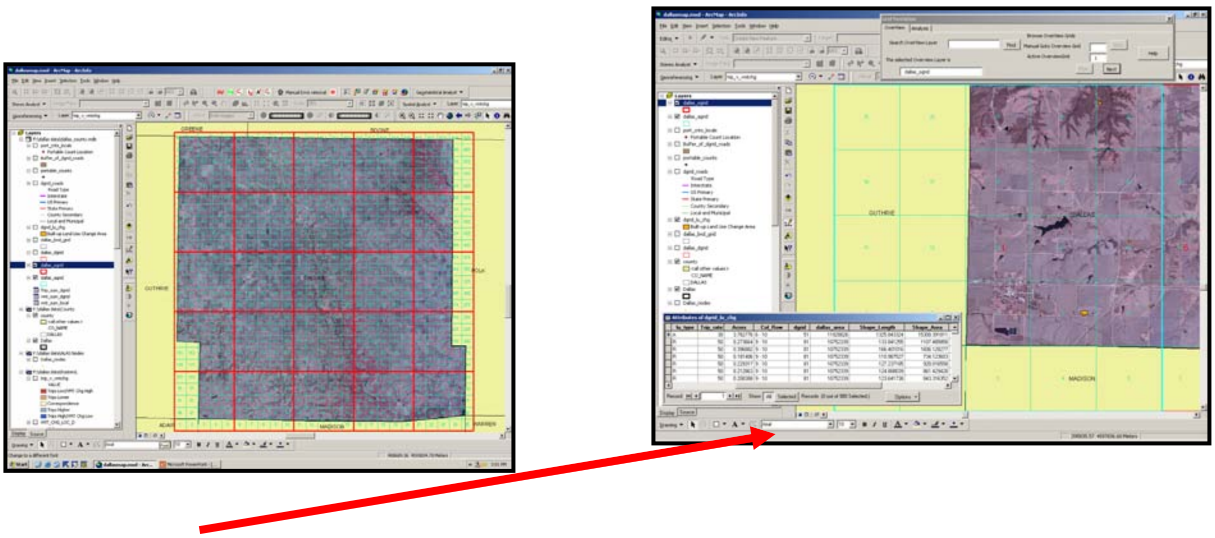
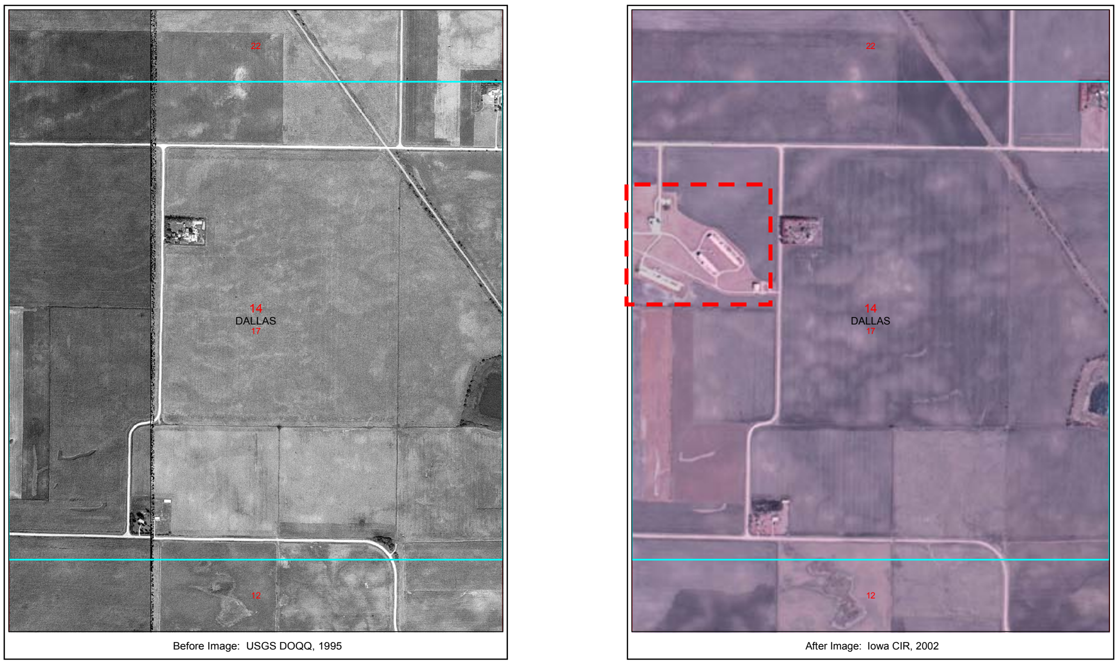


Figure 3. Change detection using ArcGIS and custom VBA tool

Detected built-up land use change was outlined by digitizing a polygon shape around its boundary. Since different land use change will produce different impacts on roadway traffic, the land use change was quantified based on the type of development. Parcel acreage was computed and the type of land-use change activity was assigned to one of the following categories:

1. Rural development/agricultural uses (30 trips per acre).
2. Low density residential (50 trips per acre).
3. High density residential (150 trips per acre).
4. Commercial and Industrial (150 trips per acre).

These trip rates were developed from the *Transportation Planning Handbook—Trip Generation, 6th ed.*, Institute of Transportation Engineers, Washington, D.C., 1997. Figure 4 provides an example of land use change detection:



Before After

Figure 4. Example before and after imagery with identified land use change

To enable comparison of the trip production data to a known traffic baseline, the "local" VMT was computed and a ratio was developed of new trips generated to local VMT. Local VMT was determined by excluding arterial roads, which are much more affected by external or through trips that are not possible to estimate from only local land use change.

A new set of 5,000 meter square grids was created using Fishnet, whose size approximated the 3 x 3 mile extents used by the Iowa DOT for traffic monitoring planning and analysis. These new grids were intersected with both the land use change polygons and the local road segments entirely within each grid cell. The area of the intersected land use change polygons was calculated as well as the length of the intersected road segments by grid cell. The total number of daily trips for each land use polygon was then calculated using appropriate trips rates for the corresponding land use types. The daily VMT for each road segment was calculated by multiplying the most recent AADT and corresponding road segment length. Using these values, the new daily trips and total daily local VMT were determined for each grid cell.

Limitations of Manual Change Detection

Visual inspection of imagery for built-up land use change is a tedious process that depends on human attention to detailed photographic inspection over relatively long time periods. As a result, it is subject to both errors of commission and omission. The errors of commission include misidentification of the type of land use change and digitizing the parcel boundaries inaccurately. Since trip generation values depend on both the type and extent of the change activity, this can contribute to significant error. Errors of omission likely are of greater concern. In this regard, fatigue can contribute to missing change areas completely.

For routine application of the manual method for detecting land use change, at least three key quality control measures should be employed:

- On-going supervisory review of the results of the change detection work.
- Quality assurance metrics should be developed and implemented to routinely evaluate adherence to acceptable error levels and their potential impact on the data.
- Periodic rotation of photographic inspection work responsibility should be employed to ensure that "fresh" eyes are performing the change detection work.

Another limitation of this methodology is that land-use intensity can change without any visual cues available that would enable detection on imagery. Probably the best example of this phenomenon is an industrial site that has experienced significantly changed employment or even abandonment. Generally, there will be no obvious change in the before and after images; however, changes in traffic volume on the surrounding road network could be significant. Supplemental data could be acquired, such as retail tax receipts and/or employment data, and geo-referenced, to facilitate identification of and correction for this type of anomaly. This study did not attempt to incorporate such data.

Another source of potential error is the spectral quality of the images. Although this was not a frequently encountered issue for this study, such error was occasionally noted. Examples include shadows that distorted objects as well as mosaic edge matching, where rubber sheeting the DOQQ images created "noise" in the pixel data that obscured or distorted the image.

RESEARCH RESULTS

Temporal Limitations on Analysis

Likely the largest contributor to errors in change detection are the temporal limitations imposed by the multiple image acquisition dates of the DOQQ photographs, and their lack of correspondence with the timing of the cycle traffic counts in the selected five counties. This was not the case in the Blackhawk study, where the "before" image dates were of the same epoch and the relationship to VMT change (e.g. traffic generation) was demonstrated. The graphic in Figure 5 shows the case for Dallas County, which is similar to the other four counties selected for this study.

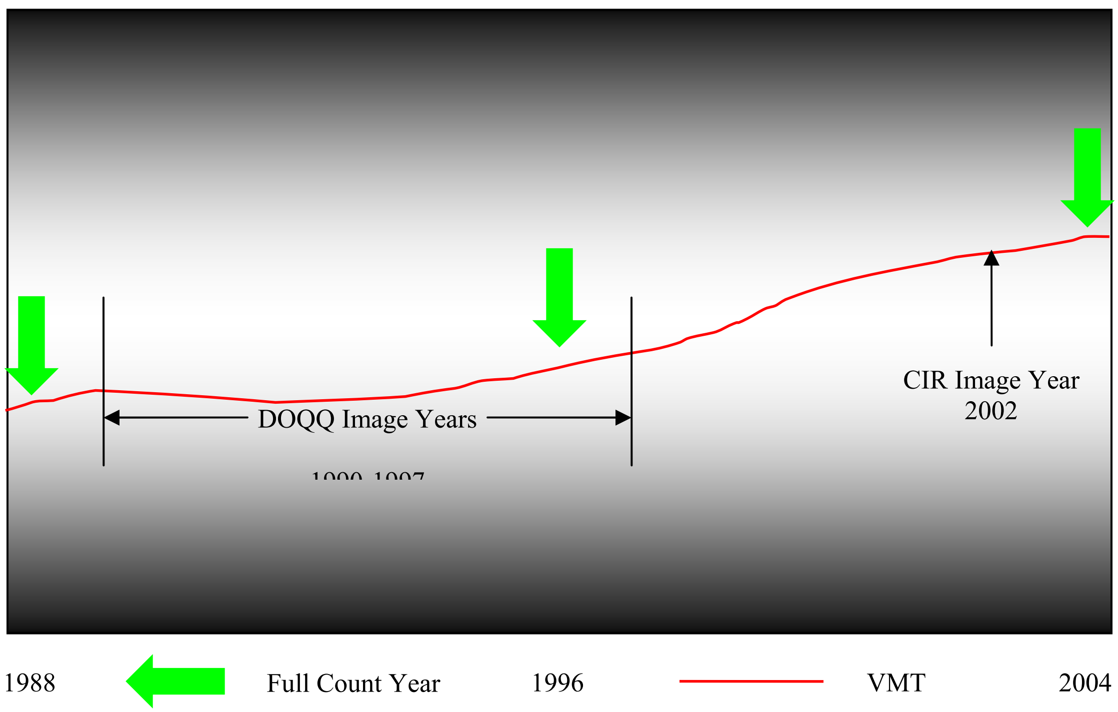


Figure 5. Dallas County image and traffic count years

As a result, the same statistical correlation between new trips generated from land use change and corresponding VMT change between the count years could not be demonstrated in Dallas County. Any future practical use of imagery to detect land use change in support of traffic monitoring should employ photographs whose vintage corresponds to the traffic counting cycle.

Study Area Maps

Given the counting frequency requirements for the national HPMS, the placement of counting devices and the corresponding detection of built-up land use, change for the five counties in this study showed high correspondence. In urban and suburban areas of high growth, with corresponding changes in traffic volume and distribution, the Iowa DOT is performing traffic monitoring consistent with the mandates and recommendations of the FWHA.

Decisions regarding the placement of devices on rural collector and local roads are made by the experience and judgment of the people who plan and conduct the counts, since FWHA and state guidelines do not specify nor require a methodology for such relatively low trafficked roads. Generally, based on knowledge of the device positions during the prior count cycles, devices are moved to nearby locations in order to achieve reasonable geographic coverage across a set of counting cycles. Some locations may be repeated for purposes of longitudinal comparison. Others may be identified based on information provided by county engineers or other local government officials.

Figure 6 shows the results of mapping the detected built-up land use change for Dallas County. The number of new trips approximated from the detected land use change has been normalized by local VMT values in each grid cell. Although, as expected, areas of high suburban growth demonstrate darker green (higher intensity land use and traffic relative to other cells), there are similar patterns in other parts of the county that are not urban or suburban.

Normalized by Local VMT

These cells tend to occur along rural arterial corridors, likely supporting commute patterns driven by economic activities within Des Moines and its surrounding suburban communities. Conversely, there are a large number of cells which demonstrate static land use change, even when normalized by local VMT. These areas could be candidates for less frequent, or less densely placed, counts.

With the built-up land use change data layer, the Iowa DOT can perhaps make more informed decisions about where to focus the placement of devices in order to capture higher growth traffic change activity along and near particular roadway corridors. The built-up land use change layers for Dallas County and the four other counties in the study group were provided to the Iowa DOT in formats compatible with their electronic mapping, design, and planning tools.

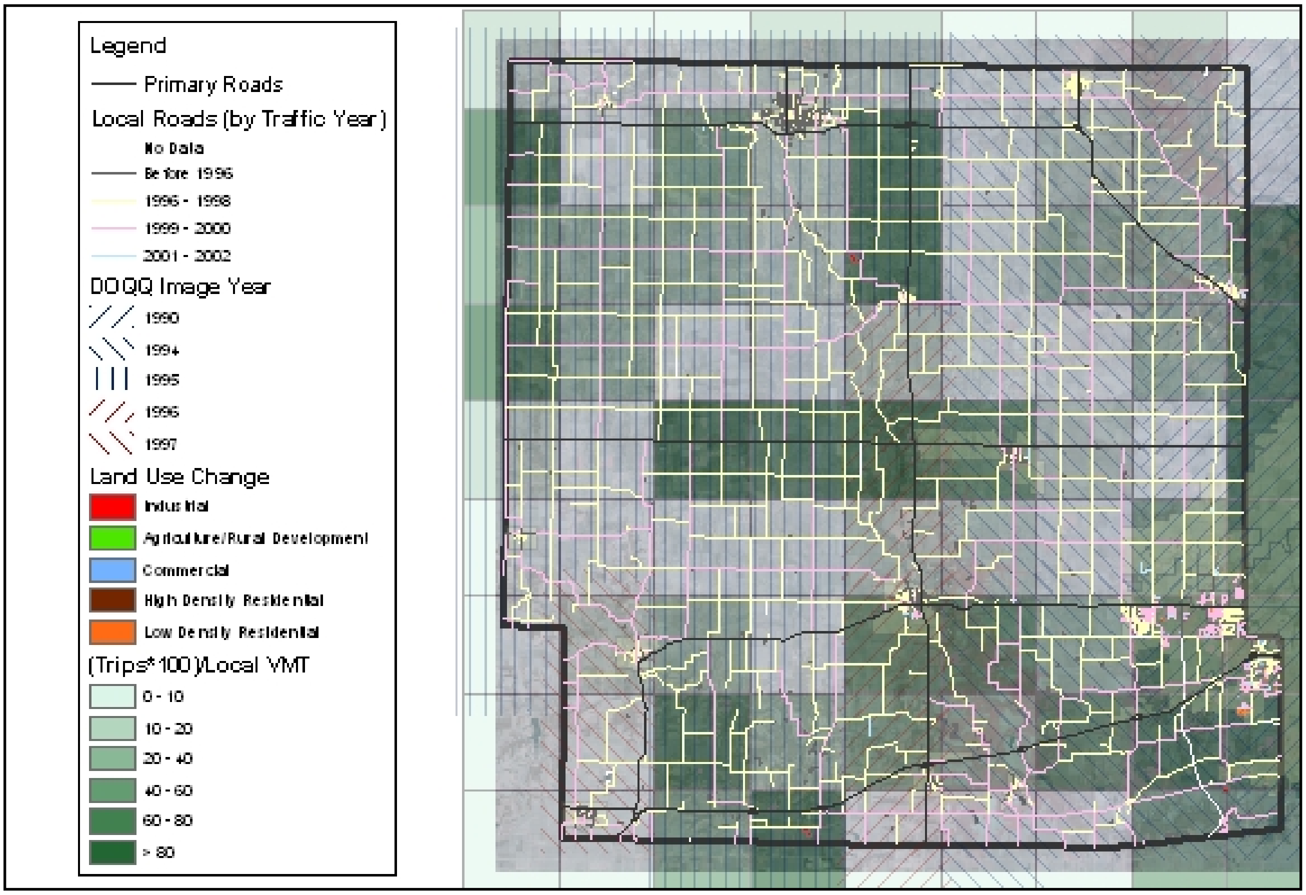


Figure 6. Dallas County map of trip generation from built-up land use change

Use by Iowa DOT

Currently, the Iowa DOT Office of Transportation Data is conducting temporary traffic counts in the five county pilot areas. These counts will be processed (cleaned up, analyzed, and factored) to produce updated AADT values. This process will be completed by Spring 2005, when results will be compared with cellular estimates produced in this study. This validation process will establish the confidence DOT analysts may have in using the procedures to help plan and optimize future count programs.

Collateral Uses of Change Detection Analysis

The acquisition of statewide imagery, and the inspection of such imagery for built-up land use change, can be an expensive undertaking, although imagery, both satellite and aerial, is becoming more available and less costly. To spread such costs over more uses is desirable. The acquisition of the Iowa CIR aerial photography is a good example of collaboration between government and non-government agencies for this purpose.

In this project, sample inspection was performed for other than built-up land use change, particularly for changes in the natural environment, but also for other types of "static" features that are human-made. Examples of each follow:

Changes in the natural environment included:

- New drainage waterways and impoundments
- Terracing of landscapes for erosion control in tilled agricultural fields
- Change in the course of natural waterways, including accretion of land and reliction of water.
- Removal of timbered areas for development and agricultural uses.

Static human-made features included:

- Abandoned railway lines
- Farm tiles
- Sewage lagoons and ponds
- Recreation and other human-made trails.

OPPORTUNITIES TO IMPROVE CHANGE DETECTION METHODS

Potential for use of other Spatial and Spectral Resolutions

Due to the availability of USGS DOQQ Panchromatic and Color Infrared aerial data for Iowa, this study was limited to use of one-meter imagery. However, other spatial and spectral data resolutions may present opportunities for improving the cost, efficiency, or effectiveness of the change detection process. Of particular interest are lower spectral resolution imagery, such as Landsat (to lower costs and speed processing), and higher resolution satellite or aerial photography (to allow better identification and classification of land use to generate trips). Figure 7 represents the quality of image available from Landsat (15 meter Pan image available every 16 days since 1979), compared to the one meter resolution used in the project. The figure is scaled to represent the resolution an analyst would see when analyzing grids of approximately one square mile on the computer display (the analyst would see a larger extent in full screen mode, but the resolution would be about the same).

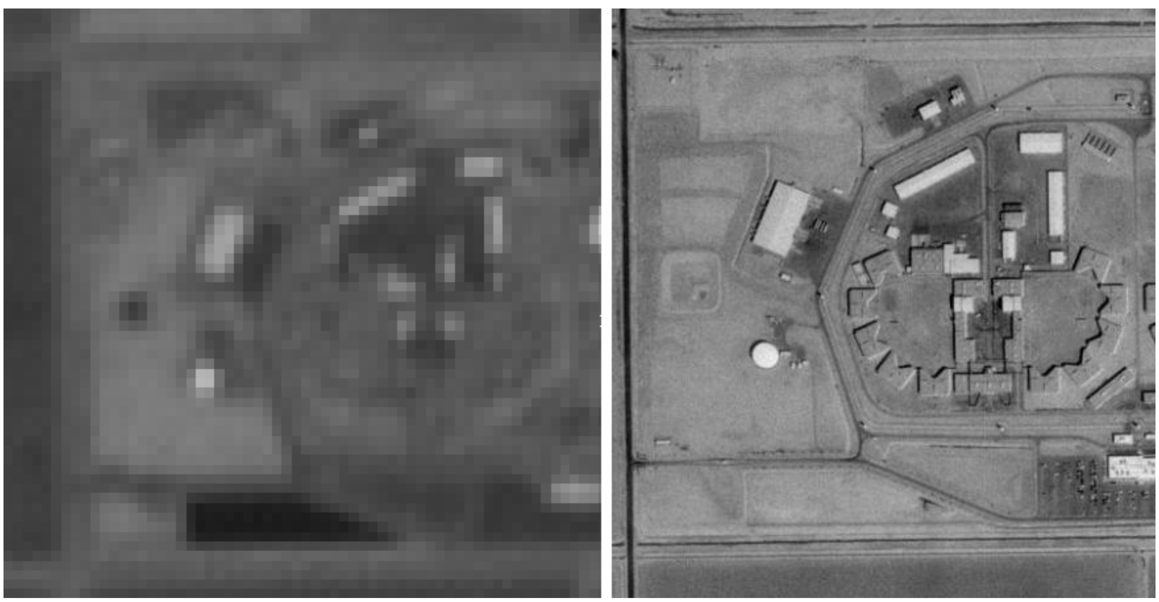


Figure 7. Landsat 15m vs. DOQQ 1m panchromatic

It is questionable that manual change detection would be effective using 15m imagery (let alone classification). However, there may be merit in exploring automated (supervised) change detection using the Landsat imagery, if image registration, radiometric intensity and cloud cover concerns could be worked out. And, while other Landsat bands (color, near infrared and thermal infrared) are available at lower spatial resolution (30 and 60 meter), incorporation of the enhanced spectral quality would likely benefit automated or manual change detection procedures. However, this exploration was beyond the scope of the current project.

Higher resolution (spectral and spatial) images are available for limited areas of the state. To indicate the potential improvement in identification or classification of development, Figure 8 shows four resolutions of imagery for the same geographic extent (1 foot natural color, 2 foot color infrared, 1 meter color infrared, and 1 meter panchromatic.) It is interesting to note that for the extent of an analysis grid (about one square mile), each pixel on the computer display represents about 2 meters on the ground. Therefore, each image is degraded to 2 meters unless the analyst zooms in. In this project, the analyst rarely zoomed in to identify or classify features, so enhanced spatial resolution imagery would serve little purpose. However, in the opinion of the analyst, color or infrared would help in both detection and classification. If the size of the analysis grid was reduced to 800 feet square to make full use of one foot image resolution, Figure 9 shows the difference in resolution that would be experienced. However, smaller analysis grids would increase processing time, perhaps by a factor of 30 or more.

Figure 8. Difference in spectral resolution for one square mile analysis grids

Figure 9. Difference in spatial resolution for 800 foot analysis grids

Availability, Effectiveness, and Cost of Imagery

In general, imagery is becoming less expensive and more widely available. It is hoped that the CIR imagery could be updated on a five-year schedule. Satellites now provide a level of detail previously available only by aerial survey. For example, Quickbird imagery is now available at 0.60 meter resolution (Panchromatic) and 2.4 meter resolution (color). This resolution is better than the resolution used in this study and better than that required for change detection for traffic monitoring planning. However, cost and availability remains a limitation, particularly if the cost of acquisition is born solely for this purpose. For example, the total cost of updating the CIR imagery for one quarter of the State would be about $400,000. Satellite imagery may be purchased for about $75 per square mile[2] (depending upon rectification costs, and other processing

[2] Space Imaging (Ikonos) ad in Jan/Feb 2004 issue of Earth Imaging Journal

fees). Obtaining imagery for one quarter of the state would be cost prohibitive (over $1 million) for all but the largest, multi-use projects. And while scale economies would certainly reduce costs, tasking satellites to cover the entire state on cloud-free days could take years, and it would be difficult if not impossible to coordinate with appropriate periods of the traffic count program. A lower cost (but higher effort) approach would be to assemble aerial and satellite imagery collected for other purposes (e.g., county assessor or engineering programs). However, this collection would require dozens (if not hundreds) of agreements, large amounts of computer space and processing time to assemble into consistent formats, and still suffer from the periodicity problem.

Landsat data are possibly the most economical for the proposed program. It would take about 4-5 Landsat scenes to cover one quadrant of the State. Total cost would therefore range from about $600 to $3,000 annually. However, as noted above, it is unclear whether the Landsat data would be of sufficient resolution to reliably estimate land use change for traffic planning. More research is needed in this area.

Perhaps the best chance of obtaining cost-effective and timely imagery would be the CIR update program. However, this image source would be most useful if the period of traffic counting were changed to five years, lagging the availability of new imagery by one year to allow for processing time. Counting the entire state at once, however, is also cost-prohibitive and does not fit the availability of Iowa DOT Transportation Data resources (e.g., count employees would not be needed four of five years.)

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

The Blackhawk and Scott County studies suggested a strong correlation between trips generated from land use change detected from imagery and resulting traffic patterns. However, this correlation could not be replicated in the five counties in southwest Iowa where the temporal correspondence between image dates and traffic count data was poor. A more accurate application of the methods described in this study would therefore require that the timing of traffic cycle counts be coordinated with image acquisition dates. As imagery becomes more available and less costly over time, and is available in geographic extents which correspond to the traffic count cycles, such constraints would be minimized or eliminated.

Manual methods of visual inspection to detect land use change are tedious and monotonous; however, they would not often be performed, and given appropriate quality control measures, could be implemented in support of this and other applications. If the results of implementation of such a program match expectations, then further investment in a more automated solution could further reduce the cost of land use change detection activity. The efficacy of this investment would be further extended by imagery of improved spectral and temporal quality, which would likely make the automated image processing more reliable and less prone to produce errors requiring human intervention.

Given the requirements of the FWHA for traffic monitoring, and the current Iowa DOT procedures for traffic counting device placement, it appears that areas of urban and suburban growth in Iowa are monitored in a manner consistent both with federal requirements and the concomitant need for such data for state and local transportation planning, design, and operations management. However, the analyses developed from this study suggest that there are large areas of rural Iowa that could be physically counted less often than is the current practice. Fewer devices could potentially be placed and counts performed less often, by adopting statistical methods of AADT development, which could be validated with periodic on-the-ground counts. This would enable reducing the overall cost of the traffic monitoring program or potentially redirecting such resources to urban and suburban areas of the state where traffic volumes and mix are more volatile and demanding of more frequent on-the-ground monitoring.

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