Feasibility of Using Remote Sensing to Monitor Truck Rest Area Availability and Utilization

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Abstract

The shortage of truck parking spaces in public rest areas and at privately owned truck stops has recently been recognized as a serious problem, with implications for driver fatigue and highway safety. This paper reviews the type of data required for determining truck parking space utilization at rest areas and the various conventional methods adopted for data collections in past studies. It addresses the limitations of the conventional data collection methods and explores the potential applications of remote sensing for monitoring the parking space requirements at rest areas.

Introduction

There is growing concern about the adequacy of truck rest areas along the interstate highways. The issues of driver fatigue and safety have become critical, as the available parking spaces are often inadequate to accommodate the requirements. Studies have been carried out and are being conducted by many states to ascertain rest area requirements. The Federal Highway Administration (FHWA) acknowledges that there is a nationwide scarcity of rest areas on interstate highways.

A study published by FHWA in 1996 [1] estimated a current total nationwide shortfall of 28,400 truck parking spaces at public rest areas. The shortfall is projected to reach about 36,000 spaces over the next 5 years. The average current national truck parking space shortfall per rest area is 21. Most commercial drivers, motor carriers, and private truck stop operators acknowledge that there are shortages at some locations at certain times.

Trucks heavily use rest areas on interstate highways, particularly during the late evening and early morning hours. Many rest areas and truck stops were built early in the interstate program to a design that typically provided about 35 diagonal parking spaces for cars and 12 parallel spaces for trucks. Because commercial drivers have difficulty maneuvering into and out of such spaces they are not reluctant to occupy more than one parallel space, hence 12 spaces may contain only 6 to 8 trucks at any one time [2].

In spite of expansion of parking capacity and provisions for improved truck parking in some areas, most rest areas on the primary system of highways now lack sufficient truck parking spaces. Consequently, overflow parking of trucks occurs on shoulders of entrance and exit ramps, and on travel lane shoulders. There is a perception that commercial drivers who cannot find space at rest areas tend to park on entrance and exit ramps at nearby interchanges. In addition to damaging shoulders and adjacent highway appurtenances, this practice reduces the available pavement width and sight distance, creating traffic safety hazards. Another issue being debated is how truck drivers can remain informed about the availability of parking spaces. Some of the interesting suggestions that are emerging are use of intelligent transportation systems, such as computerized highway information signs, to offer real-time information about parking spaces available ahead.

Public Rest Areas and Private Truck Stops

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There are important distinctions between public and private rest areas. Public rest areas are those rest stops that are funded by federal and state governments. However the federal funding is available only for construction, modernization, and expansion of rest areas. There is no provision of federal funding for the maintenance of these public rest areas. Public rest areas on the interstate highway system provide parking for all kinds of vehicles. In most of the public rest areas vending machines are offered for food and beverages purchases. There is a general feeling among truck drivers that the public rest areas are for short stays. They offer only bathroom services, and the enclosed areas have landscaping that can make security a problem. There is often a time limit imposed by the governing state on the time spent at public rest areas [4].

Private truck stops are constructed and managed by private owners. These private truck stops are located close to interchanges and, in addition to truck parking space, they provide services such as fuel, showers, restaurants and sleeping quarters. Private truck rest areas are preferred especially for long periods of rest. Private truck stops impose no time limits. The differences in services provided determines the driver's decision where to stop and for how long.

The public and private rest areas appear to serve different functions and meet different needs. Still it is possible that some of the shortfall at public rest areas might be satisfied by private truck stops.

Adequacy of Parking Areas

Adequacy of rest area parking is one of the most critical issues today and has gained national importance. To understand the gravity of the problem a study was carried out by the FHWA in 1996. According to this study, more than 90% of drivers interviewed agreed that there is a shortage of truck parking at public rest areas. The shortages of parking spaces are more predominant for long-term or overnight parking. The report also points out that 80% of rest areas were full or overflowing, with few legal spaces available, between midnight and early morning. It also found that more than 50% of truck stops are filled to capacity 20 nights per months or more [1].

Possible safety impacts are of great concern. More than 80% of drivers interviewed in the study indicated that at least once a week they drive beyond the point where they feel "safe and alert" because they can't find parking. More than 30% agreed that lack of parking spaces caused them to drive beyond hours-of-service limits at least once a week [1].

The study reported that approximately 52,000 truck parking spaces are necessary in public rest areas along interstate highways to satisfy demand. The number of current truck parking spaces available is estimated at 24,700. The total current shortfall in truck parking spaces nationwide is estimated to total about 28,000 spaces [1].

The study also projected an average of 167,000 trucks to be parked at private truck stops on any given night. The survey indicated about one third of truck stop operators plan to expand their parking facilities over the next three years. This will increase the projected parking capacity from the current 185,000 to more than 213,000 [1]. This suggests that some of the current shortfall at public rest areas might be satisfied in the near future by private expansion efforts.

According to the National Association of Truck Stop Operators (NATSO) its members offer more than 250,000 parking spaces nationwide. This is more than the FHWA survey because the latter only counts facilities along interstate highways. Since 1996, 10,000 spaces have been added and there will be further addition of 20,000 to 30,000 in the next few years [1].

Various states have carried out studies to assess truck parking requirements [5]. The majority of these studies were carried out through direct observation, interviews, and surveys. Most of these studies conclude there is scarcity of parking along the interstate highways. Based on the finding of the studies and within the framework of federal laws, which prohibit commercial use of interstate rights of way, many states attempted to resolve parking issues in innovative ways. Examples include the New York and California Departments of Transportation.

Data Collection Methods

The primary data requirement for monitoring the availability and utilization of parking spaces at rest areas and rest stops can be categorized into the following three major areas.

1. Inventory of State Facilities and Policies.

The inventory of highway rest area facilities includes the following data elements:

- *Rest area identification:* state rest-area identification number and name by which it is known.
- *Site location:* county, district, route number, travel direction, milepost number and distance from intersecting road.
- *Physical characteristics:* number of car and truck parking spaces, type of truck spaces (parallel, diagonal, pull-through), width and length of truck spaces, number of spaces designated for buses, recreational vehicles and handicapped parking.
- *Facilities available:* amenities offered, e.g., an attendant, snack machines, food service, picnic tables, telephones, restrooms, RV dumps, lighted parking, security.
- *Usage patterns:* demand for truck parking during day and nighttime hours and whether this use is seasonal. These data are rarely available, necessitating direct observation of current conditions.
- *Traffic statistics:* ADT for the current year as well as that projected for future years; one-way traffic passing in front of the rest area; percentage of trucks; any figures on traffic entering the rest area.

2. Direct Observation of Rest Areas Use

Direct observation of rest areas is necessary to identify shortfalls in capacity. The steps involved in implementing such a survey are as follows:

- *Select trucking corridors:* Priority corridors are determined by factors such as volume of long distance truck traffic, activities across a number of observation sites along the corridor, both public and private truck rest facilities, and a good mix of trucks by type.
- *Select individual sites:* Site should be selected with corridor selection criteria and also to provide good access by observer teams.
- *Measure demand and capacity:* To measure demand and capacity it is necessary to carry out direct observation of truck rest stops during the peak periods of use, typically over a five-day period. The observations are made every half hour from 10 am to 6 a.m. at each site from Sunday to Friday. Observers record the number of trucks parked in various spaces including unauthorized places and on the rest area ramps. Observer teams should also count truck traffic for 15 minutes once an hour. This figure is then multiplied by four to estimate hourly traffic. The counting can be done manually or using electronic or mechanical counters.

3. Target Group Surveys

The target group survey collects data through interviewing truck drivers, motor carrier executives, and truck stop operators. These surveys aim at gathering information on the needs, habits, attitudes, opinions and preferences of the respondents. The truck driver surveys are often conducted at public and private rest stops along the same corridors where the direct observations are conducted.

Limitations of Data Collection

Limitations – Direct Observation

- Traffic count data are collected either manually or using electronic traffic metering devices. This requires substantial trained manpower and equipment.
- It is essential to make observations and traffic counts at each site simultaneously. This requires multiple trained observers.
- Direct observation survey methods inherently involve risk for observer teams, as the members of the team need to observe and record truck movements and parking activities.
- The accuracy of manual traffic counts and observations are always questionable and susceptible to errors.
- Implementation of simultaneous surveys at various site locations to study corridor operations requires multiple observer teams.

Other Limitations

- There is no provision for getting real-time data on availability of parking spaces using conventional methods of data collection, particularly over wide areas.
- The data collected by conventional methods need to be processed using statistical tools and software to get relevant information on availability of spaces at particular instances, which is time consuming and arduous.
- The FHWA national inventory of truck parking included only public rest areas and did not include parking provided by the large number of privately owned truck stops.
- The review of information sources on supply and demand for truck parking at privately owned truck stops carried out by TRI and Apogee for FHWA indicated that detailed information was available on the location of these facilities, the services they provide and general size of their truck parking areas. There is no information available from these sources on the actual number of existing parking spaces or the usage of these spaces [1].

Remote Sensing Applications to Traffic Flow

Remote sensing is proving very useful for broad range of applications. The entire electromagnetic spectrum, particularly the wavelength region from ultraviolet through microwave, has practical applications. Availability of data for inaccessible areas and repetitive coverage are advantages of aircraft and satellite imagery.

It has been demonstrated that air photo interpretation can assist in traffic and parking studies. Traditional on the ground vehicle counts show the number of vehicles passing a few selected points over a period of time. An aerial photograph shows the distribution of vehicles over space at an instant of time. Vehicle density and areas of congestion can be evaluated by viewing such photographs. Average vehicle speed can be determined when the photographic scale and the time interval between exposures of overlapping photographs are known. The number and spatial distribution of vehicles parked in open-air lots and on streets can be inventoried from aerial photographs.

Remotely sensed data allow the user to inventory, monitor, and analyze large tracts of land. The integration of remotely sensed imagery with geographical information systems has expanded environmental analysis, particularly in the area of urban development. The spatial resolution and geometric accuracies of today's imagery are enabling new applications and extending the capabilities of existing applications [9]. The high spectral resolutions and high signal to noise ratios of the emerging hyperspectral sensors, together with the imaging radars and laser systems now available, will revolutionize the remote sensing capabilities of the transportation world.

Platforms

A spectral imaging system is a combination of a supporting collection platform and a spectral imaging scanner. The collection platform can be either airborne or spaceborne. The type of collection platform used is dependent on the mission, sensor size, power consumption, and data collection volume. Airborne platforms range from light aircraft to high-altitude research aircraft. A satellite platform typically contains the power source, altitude control devices, satellite orientation sensors, communication equipment, receive and downlink antennas, and image scanner. Table 1 compares airborne and satellite platforms.

Airborne systems can operate over an even greater range of the electromagnetic spectrum than satellite systems because the scanner can collect more spectral information at lower altitudes. It can also fly under the clouds, which might block signals to satellite sensors. Compared to the satellite sensors, airborne systems achieve higher spatial resolutions. Airborne collection parameters are more flexible than satellite collection parameters. The airborne platform is also responsive to changing priorities and is easily relocated.

Though airborne collection at lower altitudes improves spatial resolution, it limits the size of the area covered. Larger areas require multiple flight lines for coverage. Mosaicking of multiple flight lines is usually required to obtain coverage of a large area of interest.

Table 1. Airborne vs. Satellite Imagery

Characteristics	Airborne	Satellite
Altitude	Low up to 30,0000 meters	High above 175 km
Swath width	Narrow (Many strips to cover large area)	Wide (Single strips cover large area)
Resolution	Can be varied to meet requirements	Fixed by Satellite orbit
Illumination	Variable over large areas (Non-sun synchronous)	Constant over large areas (Sun synchronous)
Revisit	Frequent/Flexible	Fixed by orbit – days
Geographic Responsiveness	Relocated	Fixed by orbit – days
Flight path	Variable user defined	Fixed by orbit
Access	Intrusive	Non-intrusive

Source: Multispectral Imagery Guide [7]

Remote Sensing Spectral Ranges

Spectrum information can be categorized as panchromatic, multispectral, hyperspectral, or ultraspectral. Each category has a range of spectral bands associated with it. A spectral band defines a specific portion of the electromagnetic spectrum. A panchromatic sensor, for example, records data in a single spectrum band and produces the familiar black and white (shades of gray) image. A multispectral sensor may have two or more relatively wide bands; a hyperspectral sensor may have hundreds of relatively narrow contiguous bands; and an ultraspectral sensor may have thousands of very narrow contiguous bands. A larger number of bands within a given spectral range results in a smaller bandwidth and a higher spectral resolution for each band.

Multispectral

Multispectral sensors collect data in relatively wide spectral bands that are typically measured in micrometers. Most multispectral collectors today have fewer than 70 bands. Multispectral aircraft sensors have been built with 4, 16, 32, and up to 64 spectral bands. Current operational multispectral satellite sensors have fewer than 10 bands. The Landsat Thematic Mapper™ has seven, and the SPOT spectral sensor has three unique bands. These spectral bands were selected to collect in specifically defined parts of the electromagnetic spectrum and optimize collection for certain categories of information most evident in those bands. Multispectral images in many respects resemble color photographs. Multispectral bands in the near infrared (NIR) region and short-wave infrared (SWIR) region are used to discriminate features that are not visible to the human eye. [7] The Terra Modis multispectral sensor, which has a scientific mission, has 36 spectral bands.

The primary factors affecting the ability to visually distinguish and measure objects are the size of the objects, resolution of the imaging system, and contrast between object and background. Multispectral data offer the advantage over panchromatic imagery of enhancing features with color.

A significant advantage of multispectral imagery is the ability to detect important differences between materials by combining two or more spectral bands. Within a single band, different materials may appear the same, but by selecting proper band combinations, various materials may be contrasted against their background by using color.

Hyperspectral Imagery

Hyperspectral sensors detect, collect, and record data in relatively narrow bands. The increased number of sensor bands and the resulting narrower bandwidth provide higher spectral resolution and the opportunity to identify unique spectral patterns or signatures that are not apparent on wider-band multispectral imagery. Bandwidths of hyperspectral sensors are usually measured in nanometers (nm). The significant increase in the number of hyperspectral bands has prompted development of totally different methods of analysis from those traditionally used for multispectral imagery. Identification relies on unique spectral signatures rather than on literal interpretation. Hyperspectral imagery enables us to extract a very detailed reflectance spectrum for every pixel in the image. These reflectance spectra can be used to discriminate different materials, as most surface materials have characteristic spectral features at distinct wavelengths.

Hyperspectral is an emerging powerful technology. Airborne sensors already exist in the civil and commercial communities. NASA has the Airborne Visible/Infrared Imaging Spectrometer (AVARIS) with 224 spectral bands. The government sponsored Hyperspectral Digital Imagery Collection Experiment (HYDICE) sensor has 210 bands. In the commercial community, the Compact Airborne Spectrographic Imager (CASI), built by ITRES of Canada, has 288 bands. The Daedalus MIVIS has 128 bands, and the Digital Airborne Imaging Spectrometer (DAIS 7915) built by the Geophysical Environmental Research Corporation has 79 bands [8].

Hyperspectral data enable the user to use a remote sensing approach to do what was formerly limited to laboratory research or expensive site surveys. Hyperspectral technology is well suited to those applications requiring the detection of optically unresolved subpixel-size objects in an image. The technology is an excellent complement to the large investment in image processing by adding quantitative physical information to each pixel in a scene, thereby adding an entirely new dimension for object location, classification, and identification. Applications of this technology are many. Novel applications can range from precision agriculture applications, such as early detection of crop infestation, to medical applications, such as functional mapping of the brain and early detection of cancer (hyperspectral biopsy), to mine detection, and to search and rescue operations among many other novel applications [8].

Hyperspectral Data Processing

Hyperspectral sensors record large volumes of data over relatively short distances. Due to the nature and volume of hyperspectral data, different processing strategies have to be applied. Conventional multispectral processing relies on the production of color composites from three bands of data, an approach that is not suitable for hyperspectral data.

In order to utilize the high spectral information content in hyperspectral imagery, the data has to be processed using a spectral-interpretation approach. In performing detection and identification applications, it is widely recognized that it is the background, rather than the object, which limits our ability to perform detection and identification missions. The background includes the effects of the environment in which the object is located. A good understanding of background and object spectral signatures and their dynamic behavior in realistic environments is essential to the exploitation of space-based hyperspectral imagery to support applications in a real-time mode. To achieve this level of understanding, the user has to address atmospheric effects, atmospheric back-out corrections, autonomous intelligent processing, spectral signature database usage, sub-pixel mixing retrieval techniques, scene generation models, and other spectral research topics. Probably the most vital component in all of this is a good spectral signature library.

Hyperspectral Imagery for Truck Rest Area Monitoring

The authors are currently conducting research to determine if hyperspectral imagery technology can be applied for monitoring truck rest area parking space availability and utilization. As described earlier the shortages of parking spaces at truck rest areas and fatigue and safety issues associated with inadequate parking spaces are topics of great concern. A possible approach to the truck rest area parking problem is more effective monitoring of rest area parking spaces.

Monitoring the parking spaces essentially requires collecting data on site location, parking spaces, vehicle counts, usage patterns, and parking characteristics. Most of these data are collected by conventional methods such as manual counting of traffic. These methods are not automated and provide no real time data for analysis. In this backdrop hyperspectral imagery could play a vital role in improving data collection and timeliness.

Identifying objects in a scene can be accompanied by performing simultaneous imaging of the scene at multiple frequencies from a space based or airborne remote sensor and examining the clues provided by the signatures of the objects. Hyperspectral sensors which acquire or have access to many hundreds of spectral channels are well suited for this purpose. It is essential to create a library of spectral signatures of objects. Such a library will help identify the objects in the remotely sensed imagery. A spectral signature database is intended to serve as the spectral user's starting point and ready reference. The present topographic database and spectral signature database are inadequate.

Hyperspectral imagery can be useful for monitoring the rest areas in the following ways:

- To locate and identify rest areas
- To identify the number of vehicles parked in rest areas
- To classify the vehicle parked
- To identify vehicles parked on ramps and shoulders
- To characterize rest area condition

A further possible extension of this technology is providing real time information to truckers. Information on vehicles parked and availability of parking spaces can be delivered to truck drivers in advance by integrating hyperspectral technology with intelligent transportation system techniques.

Research Issues

Hyperspectral imagery may have potential for innovative quantitative observation of truck rest area parking. It may provide accurate information and timeliness in data acquisition and processing. However, this technology requires sophisticated processing and availability of images. Hence the cost issues associated with these data and processing requirements needs critical attention.

REFERENCES

1. *Commercial Driver Rest and Parking Requirements: Making Space for Safety*, Report FHWA-MC-96-0010, FHWA, U.S. Department of Transportation, May 1996.
2. *Commercial Driver Rest and Parking Requirements: Making Space for Safety*, Appendix C – How to Determine Commercial Drivers' Requirements For Parking at Rest Areas, FHWA-MC-96-0010, FHWA, U.S. Department of Transportation, May 1996.
3. Robert E. L. Davis, Commercial Driver Rest and Parking Requirements: Making Space for Safety, *Transportation Research Record,* No. 1595, pg 46-50,1997.
4. Cover Story, *RoadSTAR*, September 1999.

5. *Commercial Vehicle Parking,* CTRE Management Project 99-56, Iowa State University, December 1999.
6. Personal Communication with Prof. Nick Garber, Virginia Transportation Research Council, Charlottesville, VA, August 2000.
7. *Multispectral Imagery Reference Guide*, LOGICON Geodynamics, Inc. Fairfax, Virginia, 1997.
8. Richard Gomez,Key issues of Hyperspectral Sensing Technology Applications, *American Institute of Aeronautics and Astronautics and Astronautics Journal*, AIAA-99-4563, 1999.
9. Thomas M. Lillisand, Ralf W. Kiefer, *Remote Sensing and Interpretation, 3rd Edition*, John Wiley & Sons, Inc., 1994.