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INTELLIGENT TRANSPORTATION SYSTEMS FOR
COMMERCIAL VEHICLE OPERATIONS:
A CASE STUDY IN TURKEY

by

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ABSTRACT

INTELLIGENT TRANSPORTATION SYSTEMS FOR COMMERCIAL VEHICLE OPERATIONS: A CASE STUDY IN TURKEY

Intelligent Transportation Systems for Commercial Vehicle Operations (ITS/CVO) is the application of advanced information technologies to commercial vehicle operations. This study aims to analyze the feasibility of this new technology and management strategy, which is referred to as Intelligent Transportation Systems, for solving some of the problems of the motor carrier industry and commercial vehicle operations.

To analyze the benefits and to see the feasibility of ITS/CVO technology, a Turkish transportation company has been examined on a case study. Data have been collected about various operational aspects of the company before and after the installation of a new ITS/CVO technology: a mobile communication system and an automatic vehicle location system. The before and after study concerning statistical comparison of fleet efficiency criteria, seems to indicate that installation of ITS/CVO technology provided an increase in efficiency of fleet operations. Trip frequencies, annual kilometers per vehicle, and revenues increased and trip times, trip costs, and empty kilometers decreased significantly. Furthermore, the system introduced has been found to be economically feasible. However, it seems that the number of accidents may increase as a result of the increased productivity of the fleet and therefore measures should to be taken for alleviating this negative aspect.

ÖZET

TİCARİ ARAÇ OPERASYONLARINDA AKILLI TAŞIMA SİSTEMLERİ: TÜRKİYE'DEN ÖRNEK BİR İNCELEME

Ticari Araç Operasyonları için Akıllı Taşıma Sistemleri (ATS/TAO) gelişmiş bilgi teknolojilerinin ticari araç operasyonlarına uygulanmasıdır. Bu çalışma, yeni bir teknoloji ve aynı zamanda yönetimsel bir strateji olarak Akıllı Taşıma Sistemleri'nin, motorlu taşıyıcılar ve Ticari Araç Operasyonları ile ilgili bazı problemlerin çözümünde kullanılmasının uygulanabilirliğini araştırmayı amaçlamaktadır.

Faydaları ve ATS/TAO teknolojisinin uygulanabilirliğini belirlemek üzere bir Uluslararası Taşımacılık Türk Şirketi örnek olarak incelenmiştir. Şirketin çeşitli operasyonel verileri, Mobil İletişim ve Otomatik Araç Konumlandırma Sistemleri'nden oluşan ATS/TAO teknolojilerinin kullanımından önceki ve sonraki değerler açısından istatistiksel olarak incelenmiştir. Filo verimlilik kriterlerinin istatistiksel karşılaştırılmasına dayanan bu çalışma, ATS/TAO teknolojilerinin filo operasyonlarındaki verimliliği arttırdığını göstermektedir. Sefer sıklıkları, araç başına yıllık kilometreler ve gelirler artarken, sefer süreleri, sefer maliyetleri ve boş kilometreler belirgin bir şekilde azalmıştır. Ayrıca, sistem ekonomik açıdan da uygulanabilir olarak nitelendirilmiştir. Ancak, filo verimliliğinin artırılması, kaza oranlarında artışa sebep olabileceğinden, bu olumsuz etkiyi hafifletebilecek çeşitli önlemlerin alınması zorunludur.

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LIST OF SYMBOLS / ABBREVIATIONS

A	Uniform repayment
B/C	Benefit / cost
C	Initial Cost
E	Empty kilometer
H_0	Null hypothesis
ITSC	ITS / CVO costs
I_E	Export idle time
I_I	Import idle time
i	Interest rate
L^N	Vehicle kilometer at the instant of n^{th} loading operation
LU_E	Export loading / unloading time
LU_I	Import loading / unloading time
M	Number of months
m	Number of terms
N	Number of trips for a period of M months
n	Sample size
n_a	Sample size after ITS/CVO
n_b	Sample size before ITS/CVO
n_C	Number of complete trips
n_E	Number of export trips
n_I	Number of import trips
n_V	Number of vehicles
R	Empty kilometer per cent
S	Salvage value
T	Total kilometer
TC	Total costs
TF	Trip frequency
TR	Total revenues
T_E	Export transit time
T_I	Import transit time

t_c	Complete trip time
t_E	Export trip time
t_I	Import trip time
U^N	Vehicle kilometer at the instant of n^{th} unloading operation
X_a	Expected values after ITS/CVO
X_b	Expected values before ITS/CVO
z	Test Value
δ	Coefficient of variation
μ	Mean value
μ_a	Mean values after ITS/CVO
μ_b	Mean values before ITS/CVO
α	Confidence interval
σ	Standard deviation
σ_a	Standard deviation after ITS/CVO
σ_b	Standard deviation before ITS/CVO
APTS	Advanced public transportation systems
AVLS	Automatic vehicle location systems
CCTV	Closed circuit television
CDMA	Code division multiple access
COV	Coefficient of variation
CPS	Cellular phone systems
CVISN	Commercial vehicle information systems network
CVO	Commercial vehicle operations
DSRC	Dedicated short range communications
EDI	Electronic data interchange
ETC	Electronic toll collection
EUTELSAT	European telecommunications satellite organization
GPS	Global positioning system
GSM	Global system for mobile communications
HAR	Highway advisory radio
IBC	International border clearance

IDE	Interagency data exchange
IRP	International registration plan
ITS	Intelligent transportation systems
ITS / CVO	Intelligent transportation systems for commercial vehicle operations
LEO	Lower earth orbit
LMS	Location and monitoring service
LORAN	Long range navigational systems
LTL	Less than truckload
MCS	Mobile communication systems
MSS	Mobile satellite systems
NPW	Net present worth
OBC	Onboard computers
PC	Personal computer
RF	Radio frequency
SMR	Specialized mobile radio
SCRS	Single country registration system
TDMA	Time division multiple access
TDOA	Time difference of arrivals
TIS	Traveler information systems
TL	Truckload
USD	United States Dollars
VHF	Very high frequency
WIM	Weigh in motion

1. INTRODUCTION

This study aims to determine the feasibility of a new technology and management strategy, which is referred to as Intelligent Transportation Systems, for solving some of the problems of the motor carrier industry and commercial vehicle operations.

In order to fulfill this general goal, the following objectives are aimed :

- To do a thorough literature review on Intelligent Transportation Systems (ITS) in general, and its applications in Commercial Vehicle Operations (CVO) in particular;
- To test the feasibility of a particular ITS / CVO technology in a transportation company as a case study;
- To collect the necessary data and perform the needed analyses for the fulfillment of the second objective;
- To prepare the guidelines for the application of other ITS / CVO technologies, using the knowledge and experience gained from the three objectives above;
- To provide a basis for future ITS research and development projects to be organized by Turkish transportation authorities or universities.

In the rest of this study, first, a comprehensive literature review is presented. In chapter two, ITS are introduced including various related technologies and applications. In chapter three, ITS, especially designed and implemented in order to fulfill the requirements of the commercial vehicle operators are explained in detail. In the fourth chapter, fleet management issues, problems and relevant technologies are discussed.

In order to examine the effect of ITS / CVO fleet management technologies on commercial vehicle operations, an international transportation Turkish Company was selected for a case study. In chapter five, various parameters such as trip times, trip kilometers, and accidents of the company have been statistically compared before and after the installation of some ITS / CVO systems. In the same chapter, also an economic analysis has been made by using costs and benefits of the system. Finally, conclusions and recommendations have been presented in chapter six.

2. INTELLIGENT TRANSPORTATION SYSTEMS

Road transportation gained a continuously increasing share in all modes of transportation in the last five decades. The opening of national borders for international trade caused more traffic on highways. Many of the transportation problems arise from the lack of timely and accurate information and appropriate coordination among people operating the system. With this increase of road traffic, many problems such as accidents, capacity limitations, traffic congestion, impact on environment, reduced productivity, excessive operations costs, travel time delays, reduced mobility, travel stress, and inaccessibility, became problems occurring everyday in our transportation systems, which affect the commercial vehicles operations.

2.1. Introduction to ITS

Intelligent Transportation Systems represent the next step in the evolution of the transportation systems. ITS are designed to identify, analyze, test, and implement new and existing information, communication and control technologies and services aimed at improving safety, increasing efficiency, and cutting transportation costs in the movement of people and goods [1].

ITS activities began in the United States during 1960's in the form of research and development, but ITS related activities has decreased because of the difficulties in funding and gasoline shortage in the 1970's. In early 1980's, California created an Office of New Technology (ONT) within the Division of Transportation Planning. Also, in 1986, a program called Partners for Advanced Transit and Highways (PATH) was created at the University of California, Berkeley, which was intended to increase public awareness of using advanced transportation technologies. In 1988, a more permanent body called Mobility 2000 was formed. Mobility 2000 envisioned opportunities in improving the transportation systems performance throughout the use of advanced technologies. In 1990, Intelligent Vehicle and Highway Society (IVHS) was incorporated in Washington, D.C. as a non-profit educational and scientific organization. In 1991, U.S. Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA) and officially recognized ITS

as a needed national program. TEA-21 is the new Transportation Efficiency Act passed by the U.S. Congress. In 1994, ITS America, ERTICO, and Japan established the first ITS World Congress. Other active members of the Congress include ITS Australia, Canada, and Korea. The Congress has met every year since 1994, for sharing the ITS related issues and research efforts.

In Europe, ITS research and development activities began in 1970's. European Road Transport Telematics Implementation Coordination (ERTICO) is the European ITS Program coordination and advisory body corresponding to ITS America. The most popular ITS Programs in Europe are PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety) and DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe). PROMETHEUS was launched in 1986 by European car companies inspired by EUREKA (European Research Coordination Agency). DRIVE was established in 1989 by Commission of European Community (CEC) and focused on research and development activities involving the infrastructure component of ITS.

The key principle of ITS is to promote a technically integrated and internationally coordinated transportation system across the world [1]. For this purpose research on ITS technologies are supported by various state institutions and private companies. Engineers, planners, transit experts, scientists, scholars, doctors, lawyers, and other public officials actively work in ITS studies. Because of this active participation, ITS programs have been matured on distinct program areas such as intelligent infrastructure and intelligent vehicle. Intelligent infrastructure tries to satisfy the transportation needs of metropolitan and rural areas and intelligent vehicles complement the ITS infrastructure by focusing on safety and information systems for cars, trucks, buses, and trains.

2.2. Benefits of ITS

ITS improve transportation system operations, by increasing efficiency, safety, productivity, energy savings and environmental quality. ITS offer new approaches to reduce or postpone construction needs by increasing capacity per lane or reducing the number of needed vehicles to handle the same job [1]. Furthermore, with the contribution

of information technology in transportation systems, ITS provide better information to assist people involved in the system in making better and coordinated decisions.

Major benefits of ITS are observed in accidents, commercial vehicle operations, rescue response time, travel delays, rerouting, cost reduction, and fuel usage [2]. For example, ITS collect and transmit information on traffic conditions for travelers before and during their trips. Alerted to hazards and delays, travelers can change their plans to minimize inconvenience and additional strain on the system. In addition, ITS decrease congestion by reducing the number of traffic incidents, clearing them more quickly when they occur, rerouting traffic flow around them, and automatically collecting tolls. They also improve the productivity of commercial fleets by using global positioning systems, computer-aided dispatch, or weigh-in-motion systems that speed vehicles associated with international commerce. Moreover, they assist drivers in reaching a desired destination with navigation systems enhanced with route guidance.

As an example of benefits of ITS, the ramp metering / freeway management system in Seattle, showed a 38 per cent reduction in accident rates, although speeds increased up to 20 per cent. Another example is the Automated Traffic Control Program in Los Angeles. This system resulted in 13 per cent decrease in fuel consumption, 14 per cent decrease in emissions, 41 per cent reduction in vehicle stops, 18 per cent reduction in travel time, 16 per cent increase in average speed, and 44 per cent decrease in delay [2].

ITS benefits are expected to increase with increasing implementation of ITS technologies, increasing power of information technologies, land and time value, and traffic volume. ITS costs are expected to decrease with rapid cost reduction of computer hardware and software, and reduction of communications costs and new technology development. Since ITS is focused on transportation system operations, its role may appear to be provision of near-term measures in solving transportation problems, however, in order to have maximum impact, ITS must be planned, developed and implemented in accordance with long and medium term measures [2].

2.3. Technical Infrastructure of ITS

The integration of the many technologies requires that all ITS technologies work in conformity with each other. For full appreciation and appropriate application of ITS, understanding the system architecture is important. System architecture is a framework for interoperability and integration among all ITS functions. It provides rules to be used from the very beginning of ITS implementation. It also provides short-term benefits, saving time and money in the development of an ITS project; and provide long-term benefits through interoperability, increased competition, future expendability, lower costs, and increased system integration. Figure 2.1. is an example ITS architecture for National application of ITS.

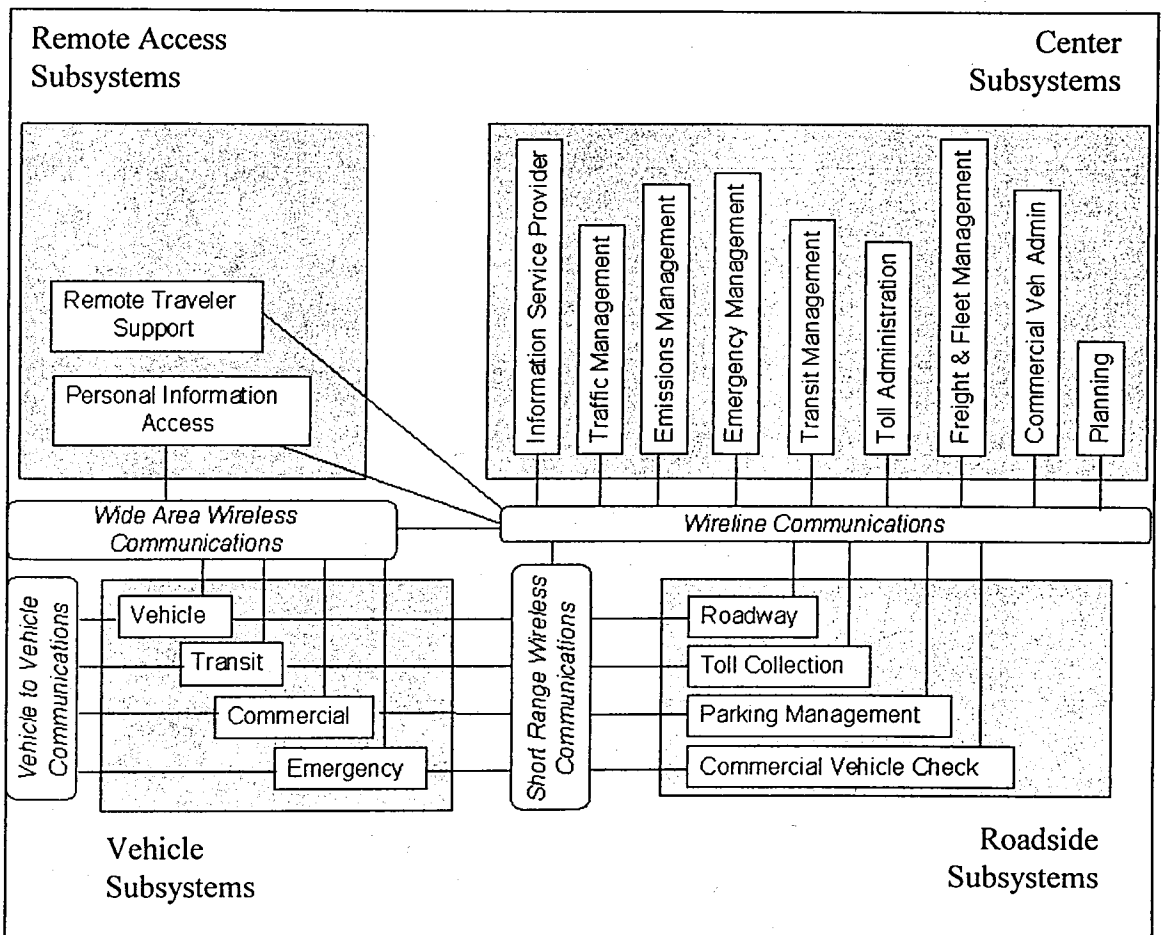


Figure 2.1. ITS Architecture [2]

System architecture is needed at national, regional and operational level. The national architecture provides a national framework for ITS integration and interoperability

throughout the nation, and provides a basis for building regional architectures. The regional architecture defines the functions that must be performed by components or subsystems.

2.4. Organizational Infrastructure of ITS

Institutional arrangements are more challenging in ITS implementation than technical issues. Transportation professionals need to overcome the institutional barriers, establish the national and regional organizational frameworks for ITS which will bring together the key players for the implementation of ITS. The effective institutional arrangements include both the public sector and private sector since the road infrastructure and traffic safety are the responsibilities of the public agencies and the vehicles and information technologies are developed, manufactured and mostly operated by the private sector companies. The private sector role includes partnerships on research and development projects, fully commercial operation of ITS services, or private operation of public services under contract or franchise. Public/private partnerships is a positive way of making progress on implementation of ITS and should encourage a joint interest with a clear division of responsibility between the two sectors [3].

2.5. ITS Technologies

ITS integrate advanced technologies to increase the safety and efficiency of the surface transportation system [4]. The adaptation of these technologies to transportation system requires the knowledge from many engineering fields such as civil, electrical, mechanical, and industrial.

Major ITS technologies are information processing, communications, sensors, electronics, and computers. These technologies are used in databases, software, networks, Internet, sensors, dedicated short range communications, automatic signing, bar codes, smart cards, global positioning systems, dead reckoning, onboard computers, electronic data interchanges, cellular phones, and pagers. ITS technologies may be divided into four sub-functions of data acquisition, data transmission, data processing, and data utilization.

2.5.1. Data Acquisition Technologies

A prerequisite for many ITS services is the collection of timely and accurate information about traffic and road conditions.

Some ITS technologies used in data acquisition are as follows:

- **Loop Detectors:** Signals collected from loop detectors placed on the highway or other sensors and transmitted to the traffic center, when used in conjunction with computer software, can do incident detection and alert the center operator about the likelihood of an incident occurrence. Traffic sensors may be installed on overhead gantries, therefore less disturbing to traffic flow during their installation and maintenance and can accurately measure the dimensions of the passing vehicle, headway between them, vehicle speeds and other information needed for traffic management.
- **Live Video Images:** They are used to help the traffic center operator monitor complicated traffic situations and make appropriate decisions. Visual images from closed circuit television are obtained by the traffic management center to complement the data acquired from traffic detectors.
- **Image Processing:** This is one of the latest technologies to be applied to traffic detection. Images acquired by closed circuit television cameras can be processed to obtain the vehicle presence, speed, lane occupancy, and lane flow rate.
- **Automatic Vehicle Location:** Location information of the vehicles is very important and automatic vehicle location systems such as GPS, GSS, and LEO are used for determining exact vehicle locations.
- **Sensors:** They are used for determining absolute and relative position of the vehicle, and for internal functions used in vehicle units. Relative sensors provide measurements of distance from the vehicle in front, gap closing rate between vehicles, and detection of obstacles on the roadway. Sonic and ultrasonic [4] sensors are also used, especially for detecting people and objects in the back of the vehicle as it backs up.

2.5.2. Data Transmission Technologies

There are two categories of technologies for transmitting information: fixed terminals and mobile terminals. Fixed terminals include regular telephones, radios, television, desktop computers, fax machines, kiosks, and changeable message signs. Mobile terminals include car radios, special mobile radios, cellular telephones, laptop computers, pagers, and hand-held digital devices.

Some ITS technologies used in data transmission are as follows:

- **Teletext:** Traffic information is broadcast with the use of teletext to transmit brief traffic reports superimposed onto the television signals [3]. Also new traffic information services have been made available through interactive telecommunications.
- **Traffic Maps:** These maps are color coded to indicate congestion and incidents, have become available through computer access to Internet.
- **Car Radios:** They receive traffic relevant broadcasts. However, the broadcast information covers a large area. In order to provide traffic information at the time and location where needed, highway advisory radio (HAR) [5] is used, and also FM band is used for text display on car radios.
- **Cellular Systems:** Data communications via analog cellular systems are made feasible by wireless data communication techniques such as the global system for mobile communications (GSM).
- **Dedicated Short Range Communications (DSRC):** Beacons provide mobile communications between the vehicle and the road infrastructure. The information transmitted by DSRC through beacons can also be location relevant or location selective. ITS services based primarily on DSRC include CVO, parking management, and route guidance.

2.5.3. Data Processing and Utilization Technologies

After traffic information is obtained simultaneously at the traffic or transportation management center, there is a need to process all the data, verify their accuracy, omit

conflicting information, and combine them into a consistent set of traffic data before they are distributed and / or used for traffic control purposes. This process is known as traffic data fusion [1].

Some ITS technologies used in data processing and utilization are as follows:

- **Color Coding:** Within the traffic management center, traffic information is conveyed to the operators on a large display board, supplemented by multiple CCTV monitors that can be switched to any camera in the field. Color coding is used on the traffic display board to indicate the degree of congestion or occurrence of incidents. Operators at the traffic management center also maintain voice communications with operators in other centers, which is important during emergency situations, because timely, accurate, and interactive information is required for coordinated rescue operations.
- **Digital Maps:** Two types of digital maps are raster-encoded maps and vector-encoded maps [3]. The former is video images of paper maps and used mainly for display purposes such as for vehicle tracking in fleet management. Vector-encoded maps require less memory, easier to manipulate by zooming, suppression of details, and expansion of attributes. Digital maps are used in navigation and route guidance. For navigation, the vehicle location determined from GPS and other complementary means are displayed as icons superimposed on the digital map. For route guidance purposes, the digital map needs to include such attributes of road segments as distance, travel time according to speed limits, time of the day and turn restrictions.

2.6. ITS Applications

ITS applications are technology independent. Each application may be provided by more than one alternative technology and some may be provided even without ITS technology [2].

Some ITS applications are as follows:

- **Route Guidance and Navigation:** These systems make it possible for drivers to choose the best route to a particular destination and minimize travel time and improve driver convenience through dispersion of traffic flow. The information is provided on demand and include the level of traffic congestion on each route, travel times, traffic restriction information, and parking space availability.
- **Traffic Control:** This system utilizes an optimal signal control [3] not only in areas where the traffic congestion situation is worsening, but also throughout the highway network as a whole. In addition, this system provides drivers with route guidance by means of an in-vehicle device and variable message signs. Urban Traffic Control is a total system including traffic sensors, adaptive traffic signal controls, variable message signs, ramp metering, and communication between field equipment and the traffic control center. Information and control centers include traffic display panels, CCTV monitors, computer hardware and software to assist information analysis and decision making by traffic operators, and communication with information providers and other control centers for transit operation, and emergency management.
- **Automated Vehicle Operation:** This system is based on automatically controlled driving assistance functions, by applying control over the brakes and accelerator, and steering wheel depending on the travel environment in the immediate area. Automated vehicle operation systems make it possible to travel safely at a safe speed, by keeping a proper distance from/to other vehicles. They can also reduce driver workload and prevent traffic accidents.
- **Commercial Vehicle Preclearance:** This system includes applications for passage permits for each special service vehicle and electronic processing of office work, conversion into a database, the information on routes where passage is requested, and information on the actual passage route chosen by vehicles requesting passage [2]. The system also includes automatic vehicle weigh-in-motion to expedite the procedures for obtaining permits for commercial vehicles.
- **Public Transport Management:** The system provides public transport operators with various important traffic conditions data, thereby supporting public transport operations and management.
- **Automatic Emergency Notification:** Automatic emergency notification improves the carrying out of speedy and appropriate first aid activities and road repairs in case of a disaster or accident. According to this system, a vehicle involved in such an incident

automatically transmits an emergency message to notify concerned dispatch centers and emergency stations, and thereby greatly shortens the time for recognizing, locating, and treating a disaster or accident. Emergency notification can be initiated manually by the driver pushing a panic button or automatically through the airbag triggering mechanism.

- Adaptive Traffic Signal Controls: They can create green waves of traffic signals to let a group of vehicles on a major arterial pass through intersections by sensing the speed, presence of platoons upstream from the intersections.
- Ramp Meters: Ramp meters control the rate of vehicle flowing into expressways through varying duration of red lights at the on ramps.
- Electronic Toll Collection: This system enables drivers to pay tolls automatically on a no-cash basis without stopping at toll stations, thereby improving driver convenience and reducing labor costs of toll road operators. Even the non-equipped vehicles benefit since the queues in the manually operated lanes at the toll plaza also get shorter, reducing the time delay in toll payment. Electronic toll collection (ETC) facilitates the implementation of road pricing, resulting in modification of traffic demand in the form of mode, time, and route changes. This system is used also in Turkey on major bridges and highways.
- Safety Enhancement for Vulnerable Road Users: Vehicle-pedestrian accident avoidance creates safe roadside environment, which can be utilized by elderly, handicapped pedestrians or other vulnerable road user. This system provides support for vulnerable road users by prolonging walk signal duration for pedestrians at signalized intersections. Also, when danger is detected in the case of a pedestrian in the path of a vehicle, this system warns the driver of the situation or automatically applies the brakes, thereby preventing collisions involving pedestrians [1].

3. INTELLIGENT TRANSPORTATION SYSTEMS FOR COMMERCIAL VEHICLE OPERATIONS

Commercial Vehicle Operations (CVO) include all the operations associated with moving goods and passengers via commercial vehicles over the highway systems and the activities necessary to regulate the operations including enforcement and safety, credentials administration, fleet and vehicle management, and highway traffic management [1]. CVO is a significant part of the ITS programs. ITS / CVO is the application of intelligent technologies to commercial vehicle operations. Operations involve areas of interaction between public agencies and motor carriers. These interactions are critical for highway safety, carrier productivity, and revenue collection.

3.1. Vision and Mission of ITS / CVO

ITS / CVO vision is based on the idea that, trucks and buses will move safely and freely throughout the world being assisted by technology and ITS / CVO mission is to achieve this vision by using cost-effective methods and technologies to streamline national regulatory enforcement, and motor carrier practices, while increasing levels of safety and productivity for both Governments and carriers, thus improving highway safety for all [1].

3.2. Benefits of ITS / CVO

ITS / CVO improves highway safety by collecting timely and accurate data and reducing frequency and severity of commercial vehicle crashes concentrating roadside safety inspections on high-risk carriers, drivers and vehicles [2]. ITS / CVO simplifies operations and makes the job easier by using available technologies, reduces paperwork which means less bureaucracy, provides quicker roadside inspections, easier license and permit purchasing and streamlines information-based activities. ITS / CVO also provide savings in time, fuel, and maintenance costs efficiency at weigh stations and international border crossings and economic competitiveness by reducing the cost of motor carrier transportation and regulation. Therefore, ITS / CVO reduces accidents, congestion and

costs, improves efficiency, competitiveness, and administrative processes, and increases safety.

3.3. Technical Infrastructure of ITS / CVO

Commercial Vehicle Information Systems and Networks (CVISN) [5] refer to the subset of ITS / CVO that contains the information systems and networks. CVISN architecture is a collection of information systems and communications networks that provide support to CVO. CVISN include information systems owned and operated by Governments, carriers, and other stakeholders. CVISN was originally defined to be a broad term covering all ITS / CVO information systems and networks as noted above. In common usage, CVISN refers to only the information systems and networks being developed as part of the CVISN prototype, pilot, and deployment projects. These are for safety information exchange, credentials administration, and electronic screening. Its objective is to develop technical infrastructure to support widespread ITS / CVO deployment. Expected benefits are more efficient data interchange, ability to improve credentials administration, safety assurance, and enforcement procedures, and reduced administrative burden for regulatory compliance.

CVISN stakeholders are Government agencies, carriers, service providers, professional and trade associations, and local government [2]. Government agencies invest in ITS technology, provide data to each other, establish CVISN information infrastructure, and change processes to allow electronic commerce and paperless vehicles. Carriers participate in CVISN projects, install vehicle transponders, and invest in other technologies when benefit justifies investment. Service providers and manufacturers develop technologies, and provide products and services. Professional and trade associations provide outreach to commercial vehicle professionals, participate in ITS / CVO projects, and provide feedback on proposed changes to business activities. Local government provide leadership, expedite ITS / CVO deployment, develop local architecture and deployment plan, and support system integration.

CVISN architecture embodies key operational concepts of ITS / CVO. Processes are improved through information technology. CVISN provides a common technical

framework and a basis for developing interface standards [2]. It does not specify a particular design for Governments or carriers; it allows them to select from a wide range of options to meet their particular needs.

3.4. ITS / CVO Program Areas

The ITS / CVO programs focus on improving highway safety and motor carrier productivity through the use of technology and the applications address four program areas: Safety assurance, credentials administration, electronic screening, carrier operations.

3.4.1. Safety Assurance

These are programs and services designed to assure the safety of commercial vehicles, drivers, and cargo. They include access to driver, vehicle, and carrier information on inspections and accidents, and automated inspections and reviews. There are onboard, roadside, and deskside safety systems and they are shown in Figure 3.1.

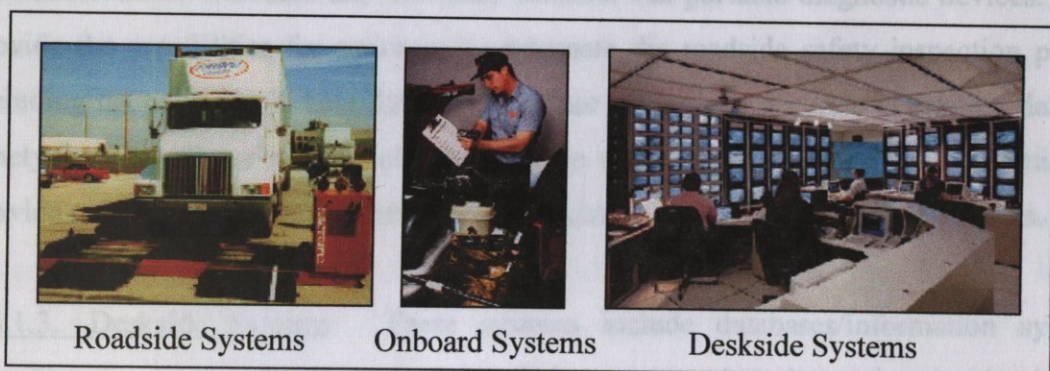


Figure 3.1. Safety assurance systems [2]

3.4.1.1. On-Board Systems. Vehicle safety monitoring systems provide the capability to diagnose critical components of the vehicle and warn the driver of potential dangers. These capabilities use a set of on-board sensors to monitor the vehicle's condition and performance, including steering, braking, acceleration, emissions, fuel economy, and engine performance. Problems are identified using processors on the vehicle. Sensors then provide warnings to the driver, fleet, or roadside inspectors in case of a serious condition.

Driver Safety Monitoring Systems provide the capability to determine the driver's condition and warn the driver of potential dangers. They also include driver sensors to assess the suitability of the driver in terms of fitness and alertness to assume manual control of the vehicle.

On-board Cargo Monitoring Systems provide the capability to monitor cargo safety such that enforcement and hazardous material response teams can be provided with timely and accurate information. These systems include the equipment on board the cargo container such as a communication device and equipment for the processing and storage of cargo material. The system may also include optional sensors for temperature, pressure, load leveling, and acceleration.

All of these systems have the potential to enhance fleet operations by providing measures to be used in evaluation of driver performances.

3.4.1.2. Roadside Systems. These technologies include portable computers, wireless communications, databases and networks, sensors, and portable diagnostic devices. They provide the capabilities for operators to automate the roadside safety inspection process including the use of hand held devices to capture and upload accurate inspection data in a timely fashion. These systems also provide the capability to collect, store, maintain, and provide safety data and access historical safety data of carriers, vehicles, and drivers.

3.4.1.3. Deskside Systems. These systems include databases/information systems, algorithms/analysis, and communications. This process makes electronic prioritization and screening of commercial vehicles possible. For international operations, it is necessary to compile safety data from many nations in order to have a comprehensive picture of an international operation. In Turkey, the national database system is used only for statistical purposes. Data such as inspections, accidents, and compliance reviews for both national and international carrier operations may flow into local databases and may be transmitted electronically to national databases.

A most important use of these data is to make an overall safety assessment of carrier operations and to prioritize these for further enforcement activities. Algorithms that

combine various safety indicators for a carrier are used for this purpose. These algorithms are also used for electronic clearance for prequalification of carriers or roadside clearance of nonprequalified carriers.

Communications include the collection of data, the compilation of data and the transmission of information to the roadside and other users who require the use of modern data communications systems.

3.4.2. Credentials Administration

Components of credentials administration are electronic credentialing, international credentials data and fee exchange, and interagency credentials data exchange. Credentials administration objective is to streamline credentials and tax administration by enabling electronic credentialing and tax filing, providing credentials data to other agencies and enhancing international data and funds exchange [2]. Expected benefits from credentials administration are to move vehicles on the road faster, to improve carrier efficiency in getting new vehicles on the road, to reduce costs for agencies and carriers, to improve access to credential status information for roadside users, and to improve regulatory compliance.

The credentials administration capability area includes all aspects of applying for, reviewing, and granting CVO credentials like national registration, carrier registration, hazardous material permits, titling, paying the associated fees, filing returns on fuel taxes; paying the associated CVO taxes and fees, managing information about credentials and tax payment status, providing information to roadside enforcement and administrative users, and supporting base national agreements and associated fee payment reconciliation.

3.4.2.1. Electronic Credentialing. In many countries, the motor carrier or its agent completes a paper application form and attaches paper copies of all required supporting documents. The paper application is mailed or hand delivered to the government agency. Government agency personnel manually review the application and its attachments. If errors or omissions are found, the officials may call the carrier to correct, or may mail the form back to the carrier for correction / resubmittal. Once the application has been

verified, application data is manually entered into the legacy system. The system calculates the required fees and prints a bill, which is mailed out to the carrier. The carrier, after receiving the bill, mails payment back. The Government manually processes the check, and enters payment data into the legacy system. The system then prints a cab card and the Government mails this back to the carrier. Several weeks or more from the date of original application receipt, the carrier receives the credentials.

The electronic credentialing system performs many of the routine functions that the Governments previously performed. The carrier prepares the application electronically. The automated credentialing system reviews the application for completeness and conformity with national requirements, and submits the application. The automated system calculates the fee upon receipt of the application and immediately notifies the carrier of payment due. The payment can be immediately submitted electronically. The system can issue the credential back to the carrier in minutes rather than weeks. Unfortunately, Electronic Credentialing System does not exist in Turkey yet.

Electronic credentialing is an operational process that uses software under the applicant's control to send credentials applications and fuel tax returns to a government agency, and to get electronic notification of credentials status in return. When feasible, the credential itself is returned electronically. Commercial vehicle operators can apply for and receive credentials electronically. By equipping the vehicle with a tag and using the identifiers retrieved from the tag as indices into infrastructure data, it is possible to reduce or eliminate altogether the need to carry paper permits and other paperwork on the truck.

There are various advantages of using these systems. They increase Governments' application handling capacity without increasing staff and allow Government staff to focus on exceptions rather than the routine. Government's data entry requirements are eliminated and accuracy is improved.

3.4.2.2. International Credentials Data and Fee Exchange. The existing base international agreements are International Registration Plan (IRP) [5], International Fuel Tax Agreement (IFTA) [5], and Single Country Registration System (SCRS) [5]. With these registrations, the applicant files with a base country and that country collects fees for all countries in

which the applicant will operate. The base country agrees to send relevant portion of fees to other countries.

In international registration plan, Government system initiates renewal process by sending renewal reminder to carrier system. Carrier personnel responsible for vehicle registration, check renewal information, updates as needed, and returns to Government system. Government system checks data in received transaction, computes fees due, and sends equivalent of invoice to carrier. Carrier system pays fees to the Government and to carrier's bank. Once fees are processed, Government IRP system issues electronic equivalent of cab card to carrier system, updates vehicle snapshots, and prints physical cab card. Government mailing center mails cab card to carrier. Periodically, the Government system transmits processed applications to the IRP clearinghouse [5], including an accounting of fees received. Monthly, the IRP clearinghouse computes net fees due to / from Governments and informs Governments. Governments check and make corrections. IRP clearinghouse initiates fee transfers according to net due / owed each Government.

3.4.2.3. Interagency Data Exchange. Information sharing within a single agent and across agents using electronic networks is a cornerstone of the ITS / CVO [1]. Interagency data exchange is usually realized using Electronic Data Interchange. EDI [5] is the electronic exchange of business information in a format that permits computer generation and processing of the message. EDI reduces or eliminates paper transactions, promotes automated processing and storing of data. Data are transmitted as text data files, and can be exchanged using almost any communications network and protocol. EDI standards and user implementation guides define the structure and meaning of messages passed between trading partners. A common implementation is to couple existing systems to an EDI translator software package and a commercial network. Information transmitted in EDI transactions is organized to be processed automatically by computers, rather than manually by people. EDI allows automatic message generation, processing and response. The system can preprocess and filter messages according to that user's particular requirements. Already being supported by readily available commercial products, EDI has considerable support and use in the transportation industry.

3.4.3. Electronic Screening

These are programs, services designed to facilitate the verification of size, weight, and credential information, including, automated screening and clearance of commercial vehicles.

Screening, applied to commercial vehicles, is a selection mechanism to make efficient use of limited fixed weigh station and inspection resources [2]. Electronic screening is the application of technology to this process in order to make an informed decision about whether further examination of a vehicle is required. Electronic screening results in improved traffic flow, focused vehicle inspections and achieves the goals of increased safety and reduced operating costs. The Electronic screening capability area provides for screening vehicles that pass a roadside check station based on identifiers read from the transponder, correlated with safety and credentials information from snapshots. Screening factor categories are safety (history, current condition), credentials (tax, fees, permits, licenses, papers), size, and weight (legal limits). Screening factors are recorded with respect to carrier, vehicle, and driver.

3.4.3.1. Weigh in Motion (WIM). Weigh in motion [5] is used to measure approximate axle weights as a vehicle moves across the sensors, and to determine the overall vehicle weight and classification based on the axle weights and spacings. Although not as accurate as a static scale, WIM allows the weight of a vehicle to be estimated for screening purposes, while maintaining traffic flow.

3.4.3.2. Dedicated Short Range Communications (DSRC). DSRC is used to provide data communications between a moving vehicle and the roadside equipment to support the screening process. This is accomplished by means of a transponder mounted in the cab of the vehicle, and a reader and antenna installed at the roadside. DSRC in electronic screening is used for sending carrier / vehicle / driver identifiers, transferring other screening data, previous screening event results, and signalling driver with pull-in decision. Figure 3.2. is an example of DSRC.

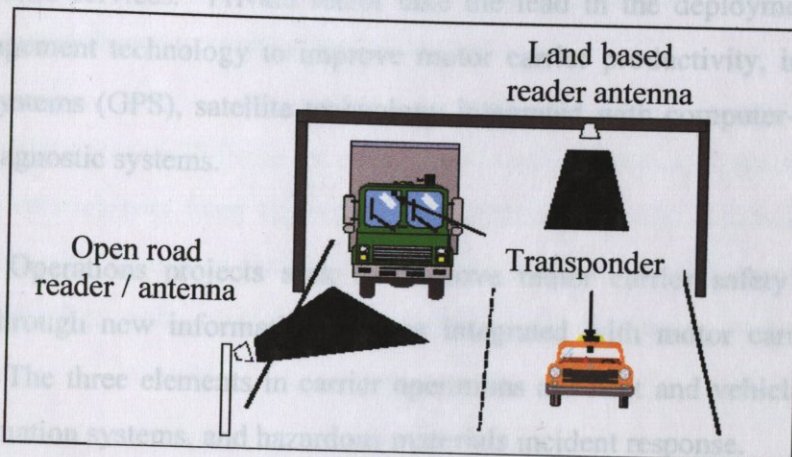


Figure 3.2. Dedicated short range communications [1]

3.4.3.3. International Border Clearance (IBC). IBC [5] integrates CVO with future border crossing processes. Long-term objectives are to provide efficient, safe international trade transportation, CVO safety and credentials screening at the border for all carriers, vehicles, and drivers who want to cross the border for international trade, and to support the agencies responsible for commercial vehicle safety and credentials enforcement.

3.4.4. Carrier Operations

Major carrier operations include business management, credentials management, information management, and fleet management. Business management includes accounting and load information and matching. Credentials management includes filing and receiving credentials, computing and reporting international transportation for fuel taxes, and drivers' hours of service auditing and reporting. Information management deals with data integration and management systems. Fleet management involves routing and dispatching, mobile communications, automatic vehicle location, data collection and maintenance.

ITS / CVO carrier operations is built upon private sector deployment of fleet management systems, and public sector deployment of traffic management systems [1]. In public sector, there are programs and services designed to help manage the flow of commercial vehicles, including, travel information services and hazardous material

incident response services. Private sector take the lead in the deployment of fleet and vehicle management technology to improve motor carrier productivity, including global positioning systems (GPS), satellite technology integrated with computer-aided dispatch, and engine diagnostic systems.

Carrier Operations projects seek to improve motor carrier safety and operating efficiencies through new information sources integrated with motor carrier technology systems [1]. The three elements in carrier operations are fleet and vehicle management, traveler information systems, and hazardous materials incident response.

3.4.4.1. Traveler Information Systems. The objective of this element is to provide motor carriers with information on congestion, incidents, weather, and optimum routing that they need for safe and efficient operations. Most traffic management applications are oriented to passenger cars, although their benefits are available to commercial vehicles as well. Communications are commonly handled directly by police dispatchers, but an increasing number of cities and Governments are building special purpose traffic management centers to coordinate traffic and incident information. Some countries have prepared traffic diversion plans for major incidents, and use HAR, variable message signs, cellular phone, Internet, and other communication means to divert traffic away from the incident area. Additionally, inter-jurisdictional incident information exchange capabilities are under development to enhance notification and alternate routing possibilities. Traveler information systems projects' objectives are to develop operational tests of ITS technologies that provide motor carriers with the information on congestion, incidents, weather, and optimum routing that they need for safe and efficient operations and to streamline Government administrative, regulatory, and enforcement procedures.

3.4.4.2. Hazardous Material Incident Management. Incident management deals with hazardous material monitoring, inventory control, automated reporting, theft recovery, electronic vehicle monitoring, and asset management. It respond provides rapid, accurate information on freight cargo following accidents/spills, information exchange between railroads, intermodal motor carriers, and first responders, and speeds flow of information and notification about hazardous materials incidents. Hazardous materials fleet

management and data monitoring systems are information systems to identify the contents of hazardous materials transported by motor carriers.

Incident Management Projects are activities to enable more rapid detection, response, and clearance of incidents from highways, and efforts to spread information about the incident to encourage drivers to seek alternate routes and reduce traffic queues [1]. Three stages are detection and verification, response and clearance, and recovery and information.

Fleet and Vehicle Management Systems are one of the main subjects of interest in this study and in the next chapter will be discussed in detail.

4. FLEET MANAGEMENT

4.1. Fleet Operating Characteristics

4.1.1. Classification of Carriers

Carriers are classified with respect to their shipment quantities, owners, and annual revenues. Classification of carriers is summarized in Figure 4.1.

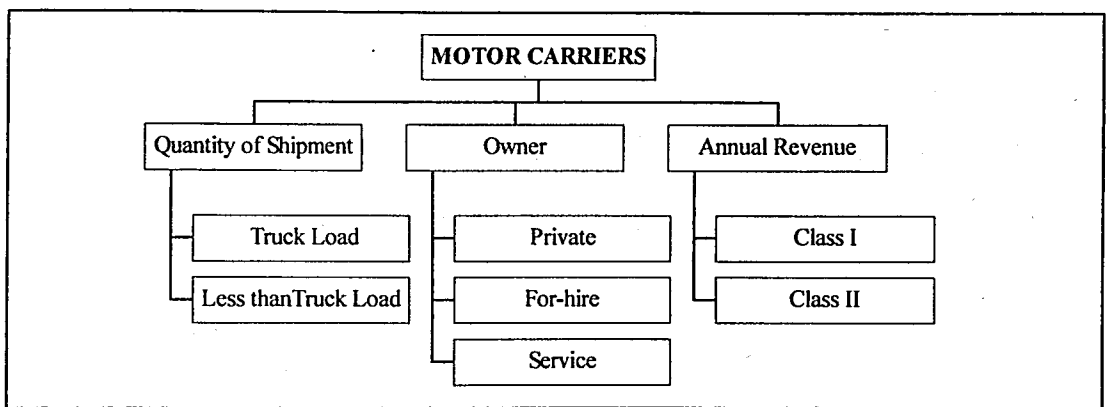


Figure 4.1. Classification of motor carriers

Classification based on the quantity of shipments group carriers as truckload (TL), and less-than-truckload (LTL). Another classification based on owner of the fleet, groups carriers as for-hire, private and service fleet carriers. For-hire truckload (TL) carriers haul general freight and special commodities and they usually have single move from the shipper to the receiver and have irregular schedules determined by the demands of shippers or receivers. For-hire less-than-truckload (LTL) carriers haul general freight and they combine freight from many shippers to achieve cost-effective operations. They have two types of operations. A local pick-up and delivery operation running urban trucks on regular routes from a central terminal, and a line-haul operation running over the road trucks in relays from terminal to terminal. Private truckload (TL) carriers haul special commodities usually between manufacturing plants or from manufacturing plants to warehouses and make short and scheduled moves. Private distribution (LTL) carriers haul general freight and special commodities in short-haul scheduled moves between

warehouses and retail outlets. Service fleets are dedicated equipment like utility company fleets, government vehicles, or fire apparatus operating from a local garage with irregular routes and schedules. Another classification is based on annual revenue. Carriers with revenues more than 1,000,000-USD are called Class I carriers and carriers with revenues less than 1,000,000-USD are called Class II carriers [7].

4.1.2. Classification of Fleets

Fleets are classified with respect to their sizes, operating ranges, routing variability, and time sensitivity of deliveries. Figure 4.2. is a summary of fleet types.

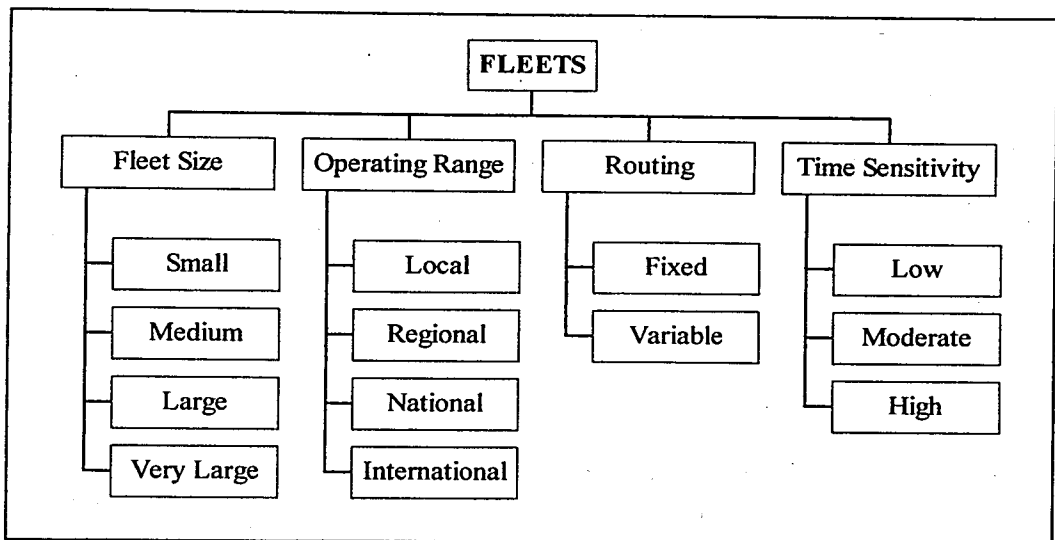


Figure 4.2. Classification of fleets

One classification for fleets is based on fleet size. Fleets are classified as small, medium, large, and very large. The limits of number of units for various fleet sizes are as the following. 1-19 units are small fleet, 20-99 units are medium fleet, 100-499 units are large fleet, and greater than 500 units are very large fleet [7].

In classification based on operating range, the fleets operating within a single city (less than 81 ms) are called local fleets, operating within a single region (from 81 ms to 322 ms) are called regional fleets, and the ones operating across multiple regions and countries (more than 322 ms) are called national or international fleets [7].

Still another classification of fleets is about their routing variability. Fleets operating on the same route everyday, typically having regular pick-up and delivery schedules are called fixed routing fleets. Fleets subject to frequent routing and scheduling changes are called as variable routing fleets.

A final classification of fleets is based on time sensitivity of deliveries, which refers to urgency of a shipment. Low time sensitive fleets are not tied to specified delivery times, and rarely provide next day deliveries. Moderately time sensitive fleets frequently make express deliveries and may, in addition, have narrow time slots within which shipments must be picked-up or delivered. High time sensitive fleets always handle express shipments and must make their pick-ups and deliveries within tight time windows.

4.2. Fleet Management Systems

Fleet and vehicle management systems facilitate safe, timely, and cost-effective movement of goods by allowing fleet managers to gather, process and use information regarding deployment and performance of their trucks, driver availability and performance, available loads and load status, and maintenance scheduling. Figure 4.3. [7] is a summary of fleet management systems.

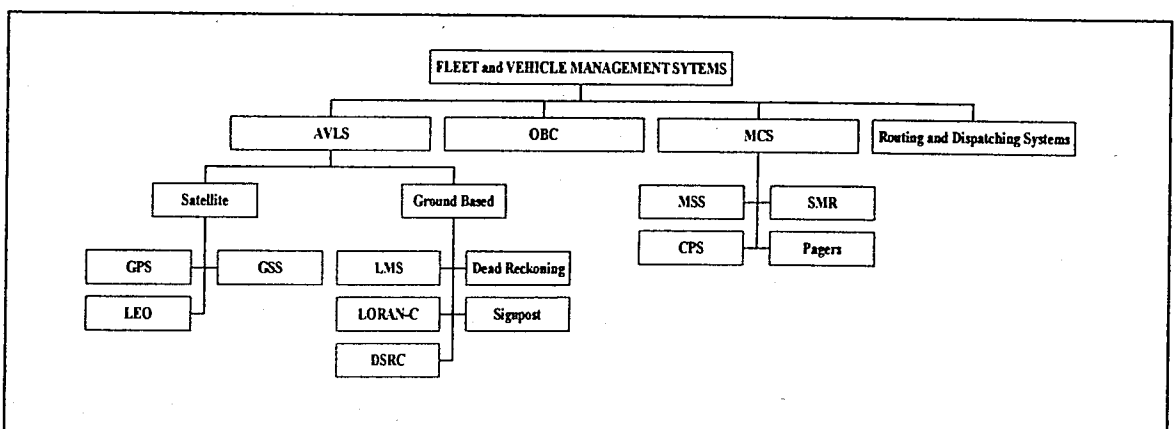


Figure 4.3. Fleet management systems

Fleet and vehicle technologies are Automated vehicle location systems (AVLS), mobile communication systems (MCS), on-board computers (OBC), and routing and dispatching systems.

4.2.1. Automated Vehicle Location Systems (AVLS)

AVLS make it possible to pinpoint the location of a truck. AVLS enables real-time identification of a vehicle location relative to a map and assists with package tracking and real-time routing [8]. When combined with on-board computers and routing and dispatching software, these systems allow dispatchers to track a truck from pick-up to delivery, monitor fleet activities, predict vehicle arrival times, track the progress of time-sensitive shipments precisely, set up back-hauls, make delivery or routing changes and ensure the security of the shipment. Capital costs for AVLS range from 1,000-USD to 3,000-USD per vehicle [4]. There are two basic types of AVLS: Satellite AVLS and ground-based AVLS.

4.2.1.1. Satellite AVLS. These systems offer global coverage and work best when a vehicle is stationary and far from tunnels, tall buildings, and mountains. Advantage of satellite AVLS is their global coverage, but they are less effective in urban areas because navigation signals are reflected and distorted by various structures. Large, national, and TL fleets are primary users of satellite AVL Systems [7]. The three primary satellite AVL Systems are Global positioning systems (GPS), geostationary satellite systems (GSS), and lower-earth orbit (LEO) satellites.

GPS provide one-way communication. Satellites are located 17,500-km above the earth and use time difference of arrival (TDOA) to calculate a truck's position. TDOA measures the time delay of consecutive signals transmitted from a network of satellites (minimum 3). They have accuracy within 30-m [4]. GPS have greater accuracy of speed, location, and direction information and are small, hand-held, and portable, enabling trailer tracking, but do not work indoors and provide only one-way communication from satellites. Terrain interference may occur in dense urban areas. A separate communication system is needed to send location information to a dispatch center. Capital costs for vehicle unit range from 300-USD to 3000-USD per vehicle [4].

GSS orbit at the same rotational speed as earth. Satellites are located 35,800-km above the earth and use time difference of arrival (TDOA) to calculate a truck's position. TDOA measures the time delay of consecutive signals transmitted from two satellites. They have accuracy within 200m [4]. GSS provide two-way communication and do not

require a MCS to transmit location information to the dispatch center but requires powerful transmitters, prohibit the use of hand-held devices and trailer tracking due to power requirements, make the hardware more costly and high buildings can block transmission signals. Capital costs are 150-USD per month per vehicle for leased units and 3500-USD to 4500-USD to buy equipment [4].

LEO Satellites provide two-way communication. Satellites orbit the earth at a height of 640 to 800-km. They use doppler phase shift techniques to locate a truck's position, and have accuracy between 30m and 1000m [4]. LEO satellites also offer two-way data communications and do not require powerful transmitters due to close earth orbit. Hardware is cheaper. Hand-held devices and trailer tracking is possible and effects of terrain interference is not significant, but they are less accurate than GPS, especially when the vehicle is in motion, and two-way communication costs are higher than GSS. Capital costs for vehicle units are less than 1000-USD per vehicle [4].

4.2.1.2. Ground Based AVLS. They differ from satellite systems in that they use ground transmitters or references instead of satellites to determine truck location. Main advantage of ground-based AVLS is their greater reliability in dense urban areas but they require a network of antennas. Short-haul carriers and couriers, that need exact vehicle information in dense urban areas, are the primary users of these systems [7]. The five types of ground-based AVL Systems are location and monitoring systems (LMS), dead reckoning, long range navigational systems (LORAN-C), signposts, and dedicated short-range communications (DSRC).

Location and monitoring service (LMS) provide two-way communication. They use radio frequencies and a network of antennas to locate a truck's position and a control system calculates the location of the vehicle by measuring the signal's time of arrival to various antennas. LMS provide two-way communication and without any transmission interference in urban areas but they require a network of antennas. Workstation software costs about 1500-USD [4]. Vehicle transceivers are less than 500-USD [4].

Dead reckoning uses on-board magnetic compass and wheel odometers to track a truck's distance and direction from a known starting point, and an on-board computer calculates the vehicle location. Dead Reckoning provides accurate determination of

location in dense urban areas and is often coupled with GPS to ensure high accuracy in both rural and urban areas but accuracy varies outside urban areas and often requires another AVL system. Costs are from 1000-USD to 2000-USD per vehicle [4].

LORAN-C calculate a truck's latitude and longitude by measuring the time it takes synchronized radio pulses from two or more ground transmission towers to reach the truck. Long-range navigational systems technology is nearly obsolete and accuracy deteriorates away from the coastline because ground tower coverage is less extensive. The LORAN-C unit, which consists of antenna, receiver, and microprocessor located in truck cab, ranges from 500-USD to 2000-USD per vehicle [4]. It requires additional communication equipment.

Signposts involve the placement of transmitters at fixed locations, typically installed over the roadway on utility poles. As a truck, passes the signpost, it receives the encoded location identifier from the signpost. Signposts do not require sophisticated and expensive technologies but, technology is less advanced, they require installation, tuning, maintenance, and power supply for field-installed transmitters, and limited coverage restricts usefulness to specific routes and gateways.

Dedicated short-range communications (DSRC) include roadside transceivers receiving information from passing vehicles equipped with transponder tags. DSRC do not require sophisticated and expensive technology, but technology is the least advanced. They also require installation, tuning, maintenance, and power supply for field installed transmitters and are useful only at specific locations. Transponder tags cost, ranges from 25-USD to 50-USD [4].

4.2.2. Mobile Communication Systems (MCS)

MCS provide data or voice communication between drivers and dispatchers, also provide communication between carriers and other parties such as intermodal facility operators, clients and intermodal carriers. MCS increase the number of possible pick-up and delivery stops during a given trip because dispatchers and drivers are able to communicate in real-time, improve the accuracy and consistency of data collected from shippers due to on-site data entries, transmit emergency signals / messages to drivers and

dispatchers, and enables dispatchers to locate customer shipments and calculate the estimated time of arrival, delays, and costs for services, but costs of system maintenance and operations are expensive. Costs of systems vary from 50-USD to 4000-USD [4]. These are the most widely used ITS / CVO technologies by LTL carriers, long-haul companies and just-in-time delivery services [7]. These systems allow drivers to communicate with each other, with dispatchers, and with customers. The four types of MCS are mobile satellite services (MSS), specialized mobile radio (SMR), cellular phone systems (CPS), and paging systems.

The standard MSS uses geostationary satellites to relay messages between drivers and dispatchers. Drivers transmit messages to satellites, which relay the message to an earth station. To receive messages, the dispatchers must use a modem to access their messages at the earth station. The reverse sequence is used when dispatchers send messages to drivers. Private companies own most geostationary satellites and to relay messages satellite services must lease space on geostationary satellites. Range of satellite coverage makes MSS superior to both SMR and CPS. Companies can easily track and record communications using text messaging, but they require an expensive hardware to relay messages to satellites, data transmission speeds to and from satellites are slow. They are not able to provide real-time voice communication, and during peak periods, the telephone lines on earth station may become congested. The hardware for a basic system costs between 3000-USD and 4000-USD per truck [4], and includes a transceiver, a dome-shaped antenna, and a display terminal. The dispatcher software for a basic system costs between 2500-USD and 4000-USD per workstation [4]. The basic monthly fee for transmission of a specified number of characters ranges from 30-USD to 60-USD per vehicle [4]. MSS are used primarily by long-haul carriers [7].

A SMR is a two-way communication system similar to MSS except that; messages are transmitted via land-based antennas instead of satellites. Data and voice messages are transmitted between users' handset and a network of land-based antennas using radio bands. A network of telephone lines connects the antennas. Unlike MSS, there is no need to call a central network facility to retrieve messages. Messages are transmitted directly to the dispatcher via telephone and to the driver via radio. SMR transmissions are faster. They provide more efficient voice and fax capabilities, but coverage is sparse in rural regions. An in-vehicle SMR system costs between 1000-USD and 2000-USD [4].

Dispatcher software totals between 2000-USD and 3000-USD and monthly user fees range from 50-USD to 100-USD [4]. Other fees include fleet connections to radio lines up to 1000-USD per month and telephone rates that range from 0.4-USD to 0.8-USD per minute [4]. SMR is used for routine communications such as pick-ups and deliveries and to inform dispatchers of emergency or delays.

CPS are two-way communication systems that messages are transmitted using cellular phones. Voice conversations are transmitted between the user's cellular phone and a ground-based transceiver. The transceiver's effective radius of about 25-km denotes a cell. However, transceivers in urban areas may have an effective radius of less than 8-km [4]. Multiple cells are connected through a central switching station that automatically reroutes calls as trucks move from cell to cell within the system. CPS are useful for short-haul urban trips [7]. They also have high telephone charges and limited coverage. A cellular phone with an auxiliary transmitter, which significantly extends the range of phone, costs approximately 1500-USD per truck. Cellular phone systems without auxiliary transmitters have monthly fees between 30-USD and 40-USD per truck [4]. Voice transmissions average approximately 0.5-USD per minute [4]. Increased range and added flexibility of CPS mostly attract local and regional fleets.

Pagers are mobile communication devices used by dispatchers to send messages to drivers. Dispatchers use pre-coded messages to relay information such as emergencies, routing, revisions, special permit pick-ups, and back haul freight. Dispatchers can also alert resting drivers using a 'sleeper beeper' option. Dispatchers transmit telephone numbers, two-digit codes, and status or full-text messages to drivers. Messages can be transmitted over various radio frequencies. Pagers alert drivers of a message via blinking lights or beeps, and display a 12-number coded message showing first a customer's telephone number and a 2-digit code, which refers to one of up to 99, coded messages. Coded messages make the system ideal for pre-recorded correspondences, but it is not capable of transmitting detailed instructions. Paging systems are the least expensive mobile communication systems, but they lack in extensive two-way communication and they do not have the ability to convey detailed messages. Pagers cost less than 200-USD to purchase; monthly service fees amount to about 20-USD per truck [4]. Paging Systems are mainly used by small, long haul, and fixed route fleets [7]. They are used to transmit

route of each vehicle and shipment information to individual drivers and in emergencies to report delays.

4.2.3. Onboard Computers (OBC)

Onboard computers are mobile data collection, storage, processing devices either vehicle mounted, or portable, often allowing real-time transfer of vehicle, driver, and load information to carrier. They automatically monitor and record information on performance of the vehicle and the driver. More sophisticated units provide keyboard, display screen and have removable memory cartridge. These systems can relay real-time information while in transit to motor carrier terminals via wireless communications. These systems are usually applied to monitor vehicle and load condition and driver performance historically or in real-time, to improve vehicle diagnostics, to track load, and to reduce driver administrative burdens, and staff time-data entry and audits. These systems monitor vehicle performance measures such as speed, fuel consumption, and hours of service. This information is downloaded from the OBC of the vehicle to the dispatch center using mobile communication systems. OBC often are used in conjunction with routing and dispatching systems as well as maintenance scheduling software. OBC provide the following functions. They record registers delivery times, border crossings, and customer signatures for proof-of-delivery, and transmit delivery notification for business transactions. They enable drivers to input records of fuel consumption and hours of service using a keyboard and display screen. They also decipher AVLS transmissions and vehicle location information. OBC track engine idling, braking, shifting, and acceleration patterns, as well as data from diagnostic systems for ancillary equipment and allow drivers to collect vehicle operations data prior to malfunction in order to improve safety performance of vehicles. Trip information is recorded by bar code readers, sensors, electronic signature readings, or driver data entry. OBC use MCS to relay real-time information from the vehicle to the motor carrier dispatch office. They extend vehicle replacement periods and improve fleet safety performance. OBC range from 2000-USD to 3000-USD per unit [4]. These systems and their devices are used primarily by long-haul, TL carriers, just-in-time delivery services, and couriers [7] in order to determine engine performance, vehicle and driver hours-of-service, engine idling and running intervals, arrival and departure times, loading and unloading intervals, driver's driving, shifting and acceleration patterns, maintenance schedules, and trip distances and duration.

4.2.4. Routing and Dispatching Systems

Routing and dispatching systems are used to maximize fleet efficiency and reduce operating costs. They use digital mapping and optimization algorithms to determine the most direct route between origin and destination, or for a series of stops. Routing and dispatching software, also known as computer-aided dispatch, helps select routes that minimize the time and cost of scheduling trucks, and helps assign freight and drivers to trucks. The two major categories of routing and dispatching software are static and dynamic routing and dispatching software. Static routing and dispatching software provides motor carriers with a routing plan for a fleet of vehicles and does not have the capacity to analyze impacts of real-time information such as congestion or incidents. Dynamic routing and dispatching software uses real-time congestion, truck location and shipment volume information to generate route maps, estimate delivery times and distances, and help improve cost estimates. They pick the optimum route given instructions to minimize travel time and fuel costs within performance parameters such as driver hours, equipment, traffic, and warehouse constraints. Main advantages of Routing and Dispatching Systems are improved dispatcher productivity, communication efficiency, and reduced client inventory and labor costs, but they must be coupled with other technologies to be most effective. A basic software package for the dispatch office costs about 3000-USD [4]. The primary users of routing and dispatching software are LTL carriers and package delivery fleets [7]. These systems are used to plan, monitor, and optimize operations such as load consolidation, vehicle routing, dispatching, and back hauling.

4.3. Fleet Management Decision Factors

Commercial vehicle fleet managers rank decision factors in terms of their importance, and gear their fleets' operations toward meeting the top priorities. The factors that are critical to the operation of one fleet may be less important to other carriers. The fleet management decision factors are not mutually exclusive. Indeed, certain objectives are realized by meeting others.

Some of these factors are listed below:

- **Maximizing Revenue per km:** Carriers are especially careful to plan routes and dispatch schedules that minimize total kilometers, minimize kilometers between pick-ups and deliveries, and, where possible, consolidate shipments so that long-distance trips contain as many high-revenue shipments as possible. These carriers are potential candidates for the adoption of automated routing, dispatching, and load planning systems [9].
- **Maximizing Revenue per Trip:** Carriers who seek maximum revenue on a per-trip basis are concerned with many of the same issues as carriers seeking to maximize revenue per kilometer, and may benefit from the same ITS technologies. One important exception is that carriers seeking maximum per trip revenue tend to focus on shipments with the highest total value, regardless of trip distance.
- **Minimizing Empty km:** An important fleet management objective of carriers is to minimize empty kilometers. For these carriers, two factors are important. First, these carriers are concerned with selecting routes and dispatch schedules that sequence pick-ups and deliveries so that trucks do not travel empty. Second, these carriers try to set up a back haul shipment for every outbound shipment. These carriers may benefit from routing and dispatching systems [9]. In addition, because carriers often arrange back haul while vehicles are en-route, these carriers may benefit from mobile communications systems [9] and vehicle location systems.
- **Equipment Availability:** There are three different conditions under which equipment availability becomes important in the decision process of fleet management. First, fleets hauling specialized products such as bulk chemicals often need a particular type of equipment to handle specific shipments. Therefore, these carriers must plan routing and dispatching to insure that specific pieces of equipment are available when and where they are needed. These carriers may benefit from automated vehicle tracking technologies, and from computerized routing and dispatching systems. The second condition under which equipment availability is an important fleet management decision factor involves operating range. The fleets of carriers that handle large volumes of long-distance, line-haul shipments often are dispersed across wide geographic areas. These carriers cannot recall each truck to a centralized dispatch facility after every trip. Consequently, these carriers must plan routing and dispatching to insure that trucks reach their destinations on time. Pick-ups and deliveries often are scheduled en-route for each truck on both the outbound and

return segments of its trip. Carriers with wide geographic operating ranges may benefit from vehicle locating and tracking systems, mobile communications, and computerized routing and dispatching systems. Finally, carriers that operate small fleets often do not have enough trucks to assign each to a single route or shipment. For these carriers, pick-ups and deliveries must be sequenced to allow each truck to handle several shipments on a single run. Mobile communications, computerized routing and dispatching systems may be valuable in helping small carriers to achieve this goal.

- **Maximizing Equipment Utilization:** Trucking companies desire to maximize the use of their trucks as a fleet management decision factor. Carriers seeking maximum equipment utilization try to maintain the smallest fleet necessary to meet their needs. In some cases, shipments may be delayed or rerouted so that they can be combined with other shipments. This requires careful route planning, load building, and dispatching. Companies that try to maximize equipment utilization will benefit from routing and dispatching systems, and many may find onboard computers valuable for monitoring vehicle use.
- **Minimizing Fleet Operating Costs:** The minimization of overall fleet operating costs is an important consideration in fleet management decisions. Fleet operating costs include such items as driver salaries, maintenance costs, and fuel. Companies attempting to minimize costs try to extend the intervals between routine maintenance, to minimize the driver idle time while on the job like waiting at loading and unloading points, and to conserve fuel. For these companies, onboard computers can provide valuable data on truck use, engine performance, driving patterns, and other factors that may help them control their fleet costs.
- **Driver Availability:** Availability of drivers is an important factor in fleet management decisions. Driver availability is influenced by the geographic locations of drivers with respect to shipment origins and destinations, and by drivers' hours-of-service limitations. Trucking companies for whom driver availability is a key fleet management consideration will benefit from the use of onboard computers, for tracking hours of service; vehicle location systems, for monitoring the locations of available drivers; mobile communications, for redirecting available drivers; and routing and dispatching systems, for matching drivers with vehicles and shipments.

- **Backhaul Opportunities:** Fleet management decisions are usually influenced by attempts to secure backhauls for every trip. Backhauls represent free revenue for trucking companies by providing an opportunity to make money from trips the trucks must make, regardless of whether they are empty or full. Often, backhauls are arranged while a truck is already on the outbound portion of its trip. Trucks also may be rerouted on short notice to pick up back hauls. Carriers that actively pursue backhauling can make use of routing and dispatching systems, mobile communications, and vehicle location systems [9].
- **Driver's Hours-of-Service Limitations:** This is also a significant factor in fleet management decisions. For such companies, onboard computers are valuable for collecting and processing hours-of-service data. In addition, routing and dispatching systems can use the hours-of-service data when assigning drivers to vehicles and shipments to insure that drivers do not exceed legal hours-of-service limits.
- **Driver Home Time:** Carriers attempt to minimize extended road trips so that driver is away from home as little as possible. Routing and dispatching systems can help accomplish this goal by coordinating the activities of different vehicles and drivers to minimize the number of extended trips.
- **Importance of Particular Account:** Carriers design their routes and dispatch schedules so that priority is given to meeting the needs of important customers. In many cases, a carrier's operations may be built around meeting the needs of a core group of customers, with other shipments fit in as necessary. Routing and dispatching systems can assist carriers with the design of delivery schedules that give priority to particular customers, while meeting the requirements of other accounts as well.
- **Shipment Origin and Destination:** The origin and destination of each shipment are essential factors in the fleet management decisions of carriers. Shipment origins and destinations are perhaps the most basic element of routing and dispatching decisions. They may dictate the routes, and influence many other factors, from equipment availability to the ability of carriers to acquire backhauls. Routing and dispatching systems are the key ITS technology for carriers who deal with a variety of shipment origins and destinations.
- **Hazardous Material Routing Considerations:** Trucks carrying hazardous materials are restricted to certain routes and travel times. Routing and dispatching systems can allow carriers to maintain as much flexibility as possible in terms of acquiring

backhauls, picking up shipments en-route, minimizing kilometers, and other objectives, while still complying with hazardous materials routing restrictions. Automated vehicle location systems also can assist carriers that have hazardous materials concerns by allowing dispatchers to monitor the location of hazardous shipments en- route.

- **Inventory Management:** Inventory management is a key factor in fleet management decisions, especially for private carriers involved in the total logistics of the companies they serve [10]. These carriers play an essential role in maintaining inventory of products or raw materials, and in transferring inventory between facilities. These carriers must be able to respond rapidly to factory, warehouse, or retail store orders. In addition to benefiting from routing and dispatching systems, carriers involved in inventory management can profit from mobile communication technologies, which allow dispatchers to send routing, scheduling, and inventory information directly to trucks while they are in transit.
- **Pick up and Delivery Times:** Shipment pick up and delivery dates and times influence carriers' fleet management decisions. These include time-sensitive carriers who must make deliveries according to strict time schedules, and carriers that must juggle many different pick-up and delivery times and dates. Carriers for whom delivery times and dates are important fleet management decision factors may benefit from routing and dispatching systems and from mobile communication systems, which allow dispatchers to monitor how closely their trucks are meeting delivery schedules.
- **Size of Shipment:** Shipment size is a critical factor in fleet management decisions. Large shipments can affect the ability of LTL carriers to consolidate loads, and can create load planning and scheduling problems for carriers with small or medium sized fleets. Conversely, small shipments can be problematic for carriers who are trying to maximize equipment utilization if they are forced to dispatch trucks before they are full. This situation could occur if carriers have small shipments that are time sensitive or must be delivered overnight, because the carriers would not be able to delay the dispatch of trucks to allow for the consolidation of several small shipments. Carriers for whom shipment size is an important fleet management factor may benefit from the load planning and dispatching capabilities of ITS routing and dispatching software.

- **Fuel Conservation:** Fuel conservation is an important factor in fleet management decisions. Selecting routes to minimize mileage is one way for carriers to conserve fuel. For this purpose, computerized routing systems are the most useful ITS technology. The greatest fuel efficiency gains come, however, from optimizing the performance of the vehicles. Carriers can use onboard computer systems to monitor both engine performance and the manner in which drivers use the vehicles. Onboard computers can track drivers' acceleration and gear shifting patterns, as well as maximum speeds, to insure that the trucks are being driven as efficiently as possible.

4.4. Problems in Fleet Management

Fleet managers are usually subject to various problems related to the changes in global economic and social balances.

Some of these changes are listed below:

- **Increasing Emphasis on Customer Service:** The pressures and opportunities of the global marketplace force motor carriers to change the way they do business. Many of the changes such as the use of overseas parts suppliers, introduction of the just-in-time manufacturing and distribution systems, and increased emphasis on quality and customer service directly affect motor carrier operations.
- **Competition Pressures:** The second major force shaping the motor carrier industry's fleet management practices is the competition within the trucking industry, which caused restructuring within industry. Sharp competitive pressures force motor carriers to reduce costs in freight rates, motor carrier management, engine and vehicle technology, and labor.
- **Increasing Congestion:** As congestion increases, trucks and cars increasingly compete for the use of a limited available capacity.
- **Regulatory Compliance:** Fleet Managers try to increase the efficiency and reduce the cost of regulatory transactions and vehicle movements by using technology. They want to obtain all credentials in one electronic transaction with a single country and are able to cross national borders without stopping repeatedly for size and weight compliance, verification of credentials and safety status.

- **Labor Pressures:** As the cost of recruiting and retaining drivers rises, the pressure on motor carrier managers to make cost-effective use of their time also increases.
- **Intermodal Freight Operations:** A significant change in transportation is the accelerating integration of truck and rail to provide intermodal freight service. The major force driving the expansion of intermodal freight services is the pressure to cut total transportation costs.
- **Truck Size and Weight:** To make a trip more productive, a motor carrier must generate more revenue per km. The most direct way to do this is to increase truck capacity. This idea creates steady pressure from motor carriers and shippers to increase size and weight limits for trucks, but these efforts are resisted by the governments and railroads.
- Many of the above mentioned problems force fleet managers towards ITS. These problems are valid for most Turkish, European and American transportation companies. After facing these problems, Turkish transportation companies started to use ITS / CVO technologies. Among these companies, OMSAN International Transportation Company is examined in the next chapter as a case study for studying the effectiveness of using some components of ITS / CVO technologies in its operations.

4.5. Fleet Efficiency Criteria

Fleet managers, in order to calculate the efficiency of their fleet operations, develop, modify or use several certain criteria and these criteria are usually used in accordance with the needs and targets of their own fleet. Some of the most used of these criteria are trip times, trip frequencies, kilometers, accidents, and fuel and maintenance costs.

4.5.1. Trip Times

There are two basic types of trips. In this study, a trip from Turkey to Europe is considered as an export trip and a trip from Europe to Turkey is considered as an import trip. A Complete trip is composed of an import and an export trip. The number of complete trips in a certain time interval is the average of the number of export and import trips. A figure explaining the phases of a complete trip time is given below:

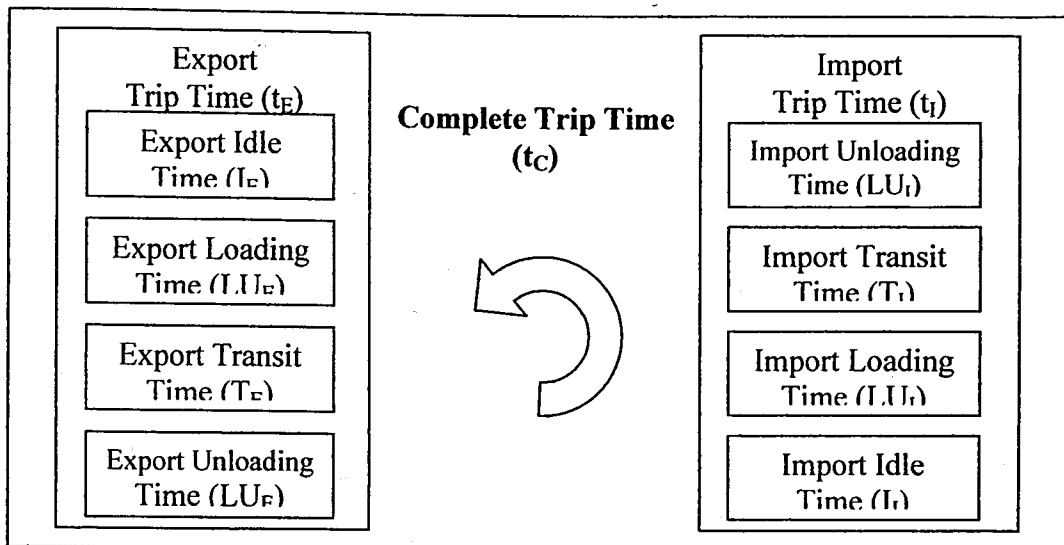


Figure 4.4. Trip times

Number of complete trips are calculated as:

$$\sum n_c = \frac{\sum n_E + \sum n_I}{2} \quad (4.1)$$

where,

n_c : number of complete trips

n_E : number of export trips

n_I : number of import trips

Complete trip time for a vehicle is assumed as the time interval between two consecutive unloading in Turkey. Complete trip time includes export and import trip times both of which are composed of transit time, loading-unloading time and idle time. Transit time is the time interval between a departure and an arrival. Leisure time is the time interval between an unloading and consecutive loading. The export and import trip times, t_E and t_I will be:

$$t_E = I_E + T_E + LU_E \quad (4.2)$$

$$t_I = I_I + T_I + LU_I \quad (4.3)$$

The complete trip time, t_C will be:

$$t_C = t_E + t_I \quad (4.4)$$

4.5.2. Trip Frequencies

Trip Frequency is the number of monthly complete trips per vehicle and is calculated as:

$$TF = \frac{\sum n_C}{M * \sum n_V} \quad (4.5)$$

where,

TF : trip frequency

n_V : number of vehicles

M : number of months

4.5.3. Trip Kilometers

Kilometers given on Figure 4.5. are examined in three parts: empty kilometers, total kilometers, and empty kilometer ratio. L^N and U^N refer to the kilometers of the vehicle at the N^{th} loading and N^{th} unloading points, respectively. Average empty kilometer is the average distance traveled between the last unloading place of the current trip and the first loading place of the next trip. It is calculated as:

$$E = \frac{\sum (L^{N+1} - U^N)}{N} \quad (4.6)$$

where,

E : Average empty kilometer

N : Number of trips

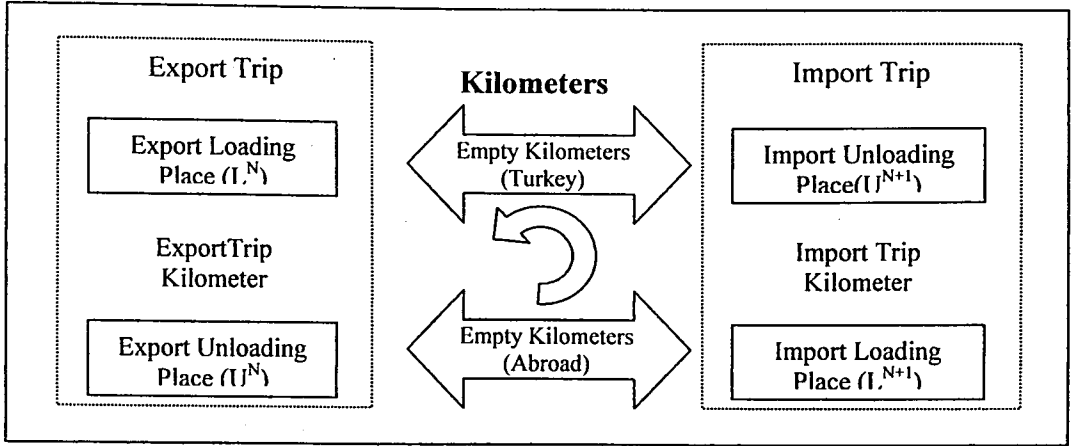


Figure 4.5. Trip kilometers

Average trip kilometer is the average distance traveled between first loading place of the current trip and the first loading place of the next trip. It is calculated as:

$$T = \frac{\sum (L^{N+1} - L^N)}{N} \quad (4.7)$$

where,

T : Total kilometer

N : Number of trips

Empty kilometer ratio is the percentage of total kilometers traveled as empty kilometers and is calculated as:

$$R = \frac{E}{T} * 100 \quad (4.8)$$

where,

R : Empty kilometer per cent

5. A CASE STUDY OF ITS / CVO APPLICATIONS IN TURKISH MOTOR CARRIER INDUSTRY

5.1. Introduction to the Company

This case study has been conducted using data from an international transportation Turkish Company, OMSAN, which is a subsidiary of OYAK. OMSAN started to operate in international road transportation sector in 1982 with 15 trucks and 30 trailers. Today it owns the biggest and youngest road transportation fleet in Turkey. OMSAN road transportation fleet is a very large fleet composed of 600 vehicles carrying shipments in truckload quantities. OMSAN international road transportation fleet composed of 123 Renault trucks having an average age of 3.02 and is the first company to use ITS / CVO in Turkey. These 123 vehicles are all equipped with automatic vehicle location system and mobile communication system. OMSAN is also the first company in the Turkish transportation sector to receive ISO 9002 certificate.

At OMSAN offices, various IBM AS400 systems have been established and these systems have been connected to each other by frame relay connections. There is also a server, which contains the Intranet, firewall, and the web page. This central system is connected to an Internet service provider. OMSAN Information Systems Department has developed the 'e-business project', which provides OMSAN customers with the ability to reach the AS400 systems through a password assigned to them, and see the positions of the vehicles carrying their load in real time. The second phase of this project will enable the customers to generate their orders through Internet.

5.2. Fleet Management Problems of the Company

In the second part of the last decade, OMSAN recognized the need for change in its fleet management practices because, Turkish motor carrier industry has evolved from a highly regulated industry to an extremely competitive one. Profit margins in today's industry are relatively small and the competition within the industry is forcing OMSAN to find ways to reduce operating costs through better vehicle and driver management.

The level of management and technological sophistication in Turkish transportation industry is increasing. In some cases, OMSAN also provide complete logistics services, including transportation, warehousing, scheduling, tagging, and packaging for its clients. These clients do not only evaluate the impacts of ITS on motor carrier operations, but they also evaluate the impact of ITS on their total logistics supply chain. As the industry approaches ITS, there will be more pressure from OMSAN's shippers or customers to demonstrate the cost effectiveness of its operations.

Truck involved fatal accidents have been declining despite an increase in truck-kilometers traveled. Nevertheless, OMSAN trucks are involved in a disproportionately high number of fatal accidents.

It was also considered that several criteria should be used in order to determine the efficiency of operations. Some of these are loading / unloading times, idle times, transit times, trip frequencies, empty kilometers, and total kilometers. These factors were dictating the use of ITS / CVO especially in international operations and OMSAN suggested to use the necessary systems in order to survive in the industry and to protect its leadership position in the sector.

5.3. Description of ITS / CVO Used in the Company

In the last quarter of 1998, OMSAN started to use ITS / CVO for its international road transport fleet. Mobile communication and automatic vehicle location system, called Euteltracs, which is especially designed and developed for the European transportation industry, have been installed at OMSAN facilities and vehicles. The network for this system is provided by the European Telecommunications Satellite Organization (Eutelsat) and Alcatel-Qualcomm supplies the equipment to run the network and provides the terminals.

Two satellites are used for Euteltracs. Both of them are positioned in geostationary orbits at approximately 36,000-km above the surface of the earth and controlled and monitored by Eutelsat in Paris. First satellite is used for mobile communications and the second one is used for vehicle positioning. The center for the system's on-ground

operation is the Euteltracs Hub Station in Paris. The Hub station is the pivotal link between the vehicles, satellites, and the end user. The Hub Station is connected to Satko in Turkey. Satko is the Euteltracs service provider operating for the end users in Turkey.

The fleet dispatcher controls the fleet from his office by using an ordinary PC linked directly to Satko. The PC is fitted with an auto dial up interface and dedicated software, which includes message exchange, mapping, and positioning capabilities. The mobile terminals fitted in the vehicles consists of a 160 characters display unit and a keyboard installed in the cab, a communications unit stored below the seat, and an outdoor unit installed on the cab roof.

Mobile Communication System is a Mobile Satellite System. It offers two-way direct communication up to 2000 characters between dispatcher and driver. Messages are transmitted instantaneously by satellite to individual vehicles, selected group of vehicles, or to the entire fleet. Messages can also be sent by the drivers to the dispatch center. There are also pre-defined macro message options where long standard messages can be transmitted in a special coded format for easier manipulation, and reduced user cost and time.

Automatic Vehicle Location System is a Geostationary Satellite System. It offers automatic hourly and on-demand real-time position reporting service with an accuracy of 200 meters for any point in Europe. Detailed software road maps available to the dispatcher on the PC also provide on-screen vehicle overview and positions of all fleet vehicles relative to any chosen point on the map also showing the vehicle load status.

5.4. Effectiveness of the ITS / CVO Used in the Company

In order to determine the effectiveness of the ITS / CVO system of the company, statistical data of the company concerning the fleet efficiency criteria have been used. The data is gathered from the databases of the company. Since the present ITS / CVO system is installed in the second half of 1998, only the data belonging to the first six months of 1998 and 1999 are examined for comparison. During those time intervals all export trips

from Turkey to Europe and all import trips from Europe to Turkey have been included in the study. Pick up and delivery regions and countries en route are shown in Figure 5.1.

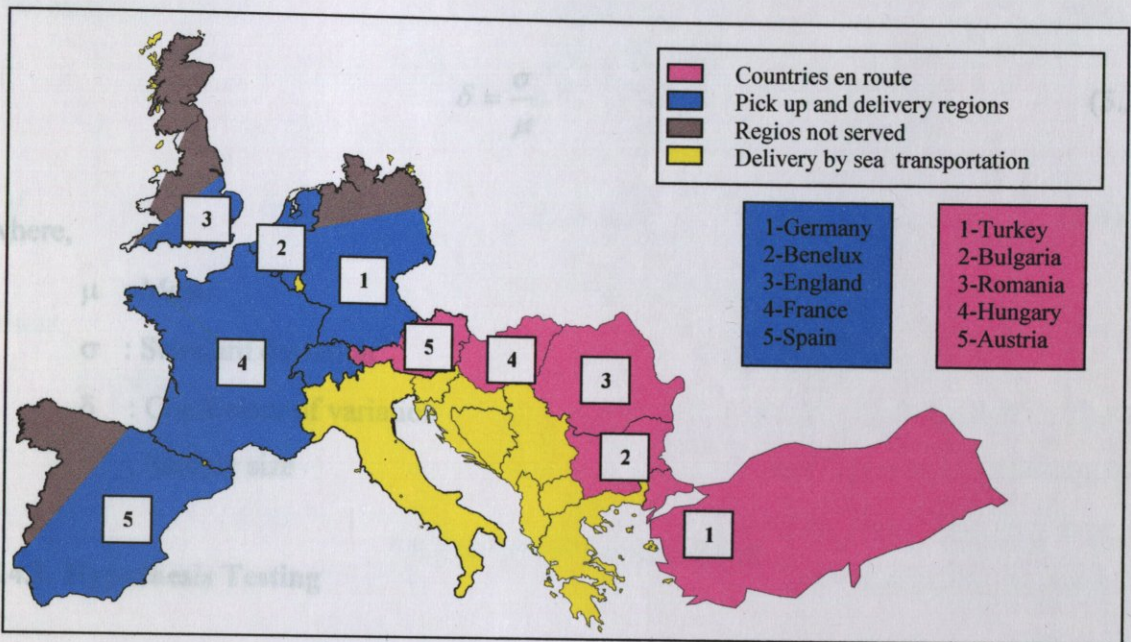


Figure 5.1. Route Map

The number of vehicles used in these operations in 1998 and 1999 are 109 and 96 respectively. The measures of effectiveness used in evaluating the ITS / CVO system included kilometers, trip times, trip frequencies, and accidents. Also an economic analysis has been performed and explained in the following sections.

5.4.1. Statistical Analysis

The mean, variance, and coefficient of variation of each measure such as trip times before and after the Euteltracs system are calculated with formulas (5.1), (5.2), and (5.3), respectively.

$$\mu = \frac{\sum_{i=1}^N X_i}{n} \quad (5.1)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^N (X_i - \mu)^2}{n}} \quad (5.2)$$

$$\delta = \frac{\sigma}{\mu} \quad (5.3)$$

where,

μ : Mean

σ : Standard deviation

δ : Coefficient of variation

n : Sample size

5.4.2. Hypothesis Testing

After determining the mean values and standard deviations of all measures of effectiveness for 1998 and 1999, which include the data before and after the application of Euteltracs system, the mean values of before and after have compared with a typical before and after study as explained below.

The null hypothesis is that, the data of 1998 and 1999 are taken from the same normal population, that the difference in means may be considered as zero as given in equation (5.4). Then, the standard deviation of the difference becomes the expression given in the denominator of equation (5.5). This new distribution is called the normal approximation. When n_a and n_b are both larger than 30, the approximation is acceptable [11]. The test is conducted by computing a z value for use in the standard normal distribution. This is done by taking the observed differences and subtracting the theoretical difference, zero, and dividing by the standard deviation of differences. Then, the probability of a value of z called z_α is obtained from the standard normal distribution table with respect to a certain significance. If the computed value of z falls outside the area determined z_α , the null hypothesis that the means of both cases did not change, is not valid. The null hypothesis has been tested for each parameter with its own significance level. The results of hypothesis testing are given at the end of each table.

$$\text{Null Hypothesis (Ho):} \quad \mu_a = \mu_b \quad (5.4)$$

$$\text{Test statistic z Value:} \quad z = \frac{\bar{X}_a - \bar{X}_b}{\sqrt{\frac{\sigma_a^2}{n_a} + \frac{\sigma_b^2}{n_b}}} \quad (5.5)$$

$$\text{If } z > z_\alpha \text{ then reject } \mu_a = \mu_b \quad (5.6)$$

where,

a : after

b : before

5.5. Statistical Comparisons

Statistical comparisons are based on certain measures of effectiveness about fleet efficiency criteria such as trip times, trip frequencies, trip kilometers, and accidents. The results are explained in the following sections.

5.5.1. Trip Times

Trip time data are examined in three parts. These are transit trip time, idle time and loading / unloading time, respectively.

- **Transit Trip Times:** Transit trip times include export transit time and import transit time. Export and import transit time histograms are shown in Figure 5.2. and 5.3., respectively.

Export transit times are likely to have a normal distribution centered around 6,5 days.

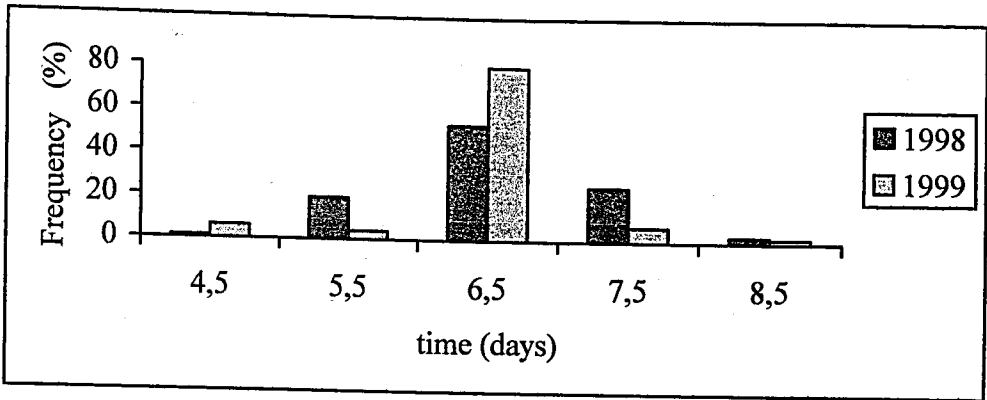


Figure 5.2. Export transit times

In some import trips, the transit trip time is contracted with the customer . These are 'just-in-time' trips and they are centered around four days in Figure 5.3. Other import trips are not time sensitive, therefore, they are centered around 6.5 days. This seems as if two normal distributions are given on the same graph, which results in a higher variance in import transit times as shown in Figure 5.3.

There is one feasible route between Turkey to Europe. This is the route passing through Bulgaria, Romania, Hungary, and Austria, which takes nearly 4 days. In this route, the trucks have to pass Austria by train, and sometimes they wait at borders for hours. Thus, a significant decrease in transit trip times can not be expected from the driving hours. The major reason of improvement in transit times is the drivers' changing habits. Since AVLS traces the vehicles automatically, the drivers waste less time en route.

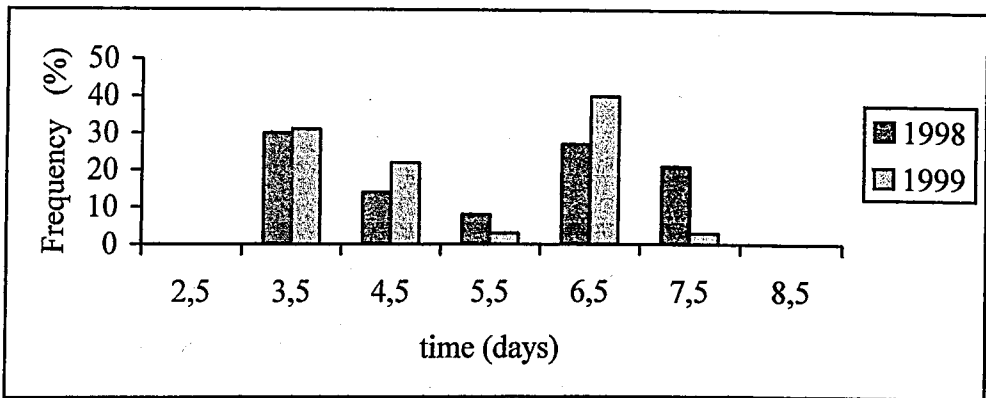


Figure 5.3. Import transit times

The results are shown in Table 5.1. Transit trip times decreased by two to five per cent in 1999 for export and import transit times, respectively, which are relatively small improvements with respect to other parameters, however they are statistically significant.

Table 5.1. Transit trip times

	Export Transit Time (day)		Import Transit Time (day)	
	1998	1999	1998	1999
Population Size	818	803	798	873
Mean	6.71	6.56	5.51	5.22
Standard Deviation	0.52	0.88	1.60	1.23
COV	0.08	0.13	0.29	0.24
% change	-2.2		-5.3	
z value - significance	-4.17 (0.00)		-4.13 (0.00)	

- Idle Times: Export and Import idle time histograms are shown in Figures 5.4. and 5.5., respectively.

Export idle time distributions in 1998 and 1999 are different in terms of skewness. In 1999, export idle times have decreased significantly. Unfortunately, because of the increase in accidents in 1999, idle times related to maintenance and repair times could not be avoided, which disturbed the symmetry of the distribution.

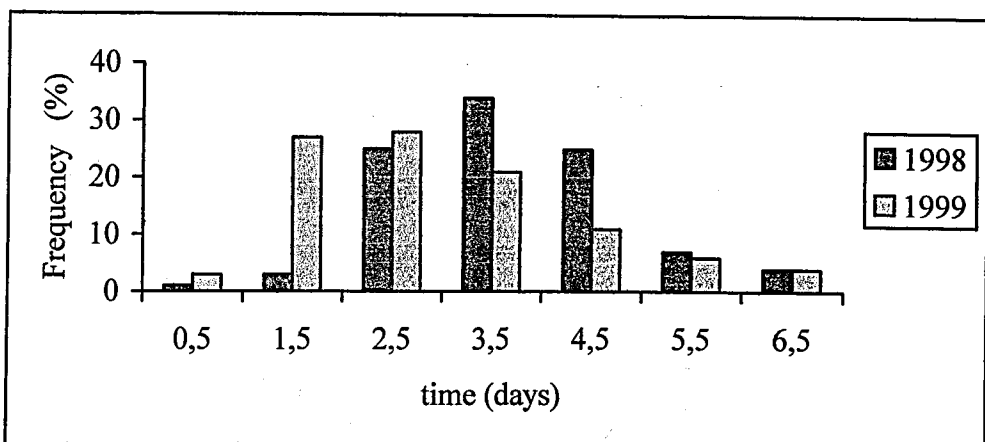


Figure 5.4. Export idle times

The best improvement in trip times was obtained in import idle times. The first reason for this improvement was because the company was unable to track the vehicles in

real time and could only know the exact idle time when the vehicle returned to dispatch office. Figure 5.5. shows a nearly two days improvement in import idle times.

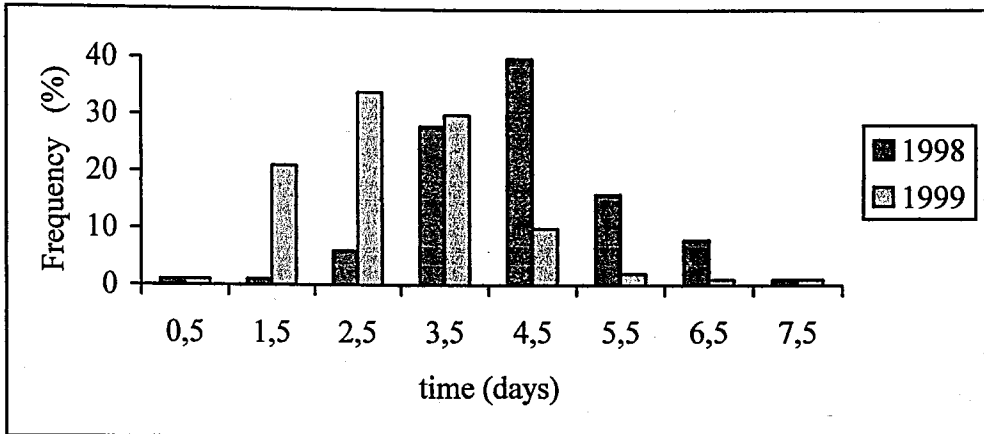


Figure 5.5. Import idle times

The second reason was that, after the installation of ITS / CVO, the marketing department decreased the time for load matching, so the trucks waited less after unloading for their consecutive loading and backhauling opportunities are improved. A third reason is that, when there is a load, dispatchers were able to send there the nearest empty truck, which also decreased the time for the truck to reach its new loading point. For export and import idle times, a greater reduction in import idle time was achieved because of the above mentioned reason and both have decreased significantly as can be seen from the associated z values in Table 5.2.

Table 5.2. Idle times

	Export Idle Time (day)		Import Idle Time (day)	
	1998	1999	1998	1999
Population Size	818	803	798	873
Mean	3.82	2.84	4.46	2.81
Standard Deviation	1.71	1.62	1.15	1.19
COV	0.44	0.57	0.26	0.42
% change	-25.7		-37.0	
z value - significance	-11.85 (0.000)		-28.81 (0.000)	

- Loading / Unloading Times: Export and import loading / unloading time histograms are given in Figures 5.6. and 5.7. Export loading / unloading times have reduced by

0.15 days but the mode of distribution have reduced by almost 0.7 days, which resulted in a change in direction of skewnesses as shown in Figure 5.6.

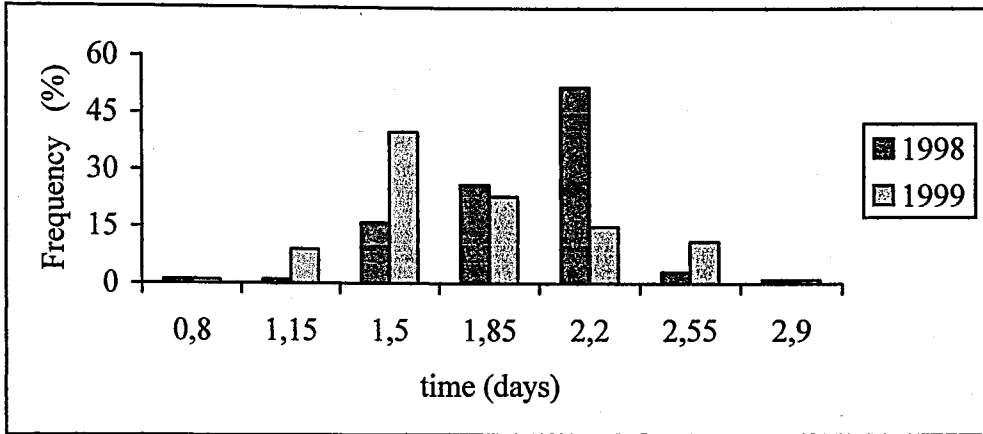


Figure 5.6. Export loading / unloading times

Import loading / unloading times are generally shorter than export loading /unloading operations because of the difficulties in export operations in Turkish Customs Offices.

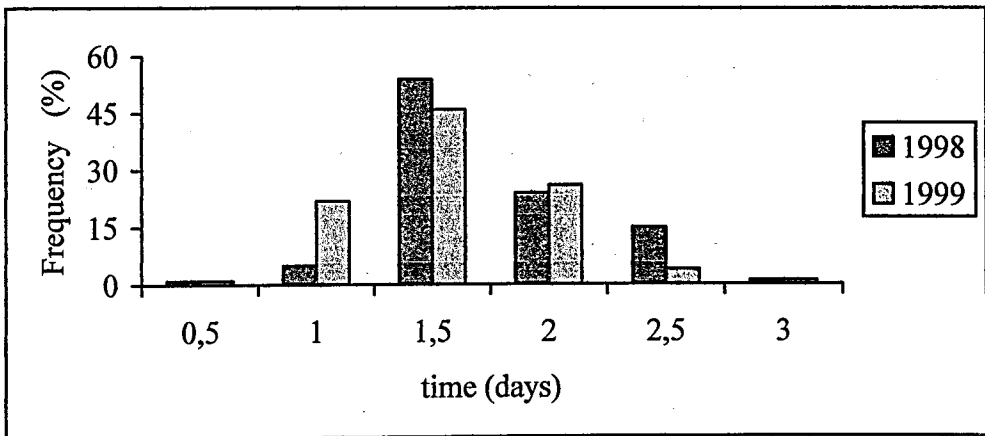


Figure 5.7. Import loading / unloading times

Before ITS / CVO, the drivers were leaving the truck while it was loaded, which resulted mostly in extended loading / unloading times and in case of a damage, it was very difficult to determine whether it has occurred during loading or while in transit. Mobile communication system guaranteed that the driver has accompanied loading and unloading operation. As a result, export and import loading / unloading times have decreased significantly 7 per cent and 22 per cent, respectively as shown in Table 5.3.

Again a greater reduction in import loading / unloading times has been achieved, because if the truck is not unloaded within 48 hours after arrival to the destination point in Turkey, OMSAN has the right to demand a daily fee from the customer. AVLS made it possible for dispatchers to warn the customer about unloading operation.

Table 5.3. Loading / unloading times

	Loading/Unloading Time Export (day)		Loading/Unloading Time Import (day)	
	1998	1999	1998	1999
Population Size	818	803	798	873
Mean	1.94	1.79	1.69	1.31
Standard Deviation	0.41	0.60	0.99	0.55
COV	0.21	0.34	0.58	0.42
% change	-7.7		-22.5	
z value - significance	-5.87 (0.000)		-9.58 (0.000)	

As a result of the above explained reduction in trip time components; the export, import and complete trip times decreased by 10, 20, and 15 per cent, respectively as shown in Table 5.4.

Table 5.4. Export, import, and complete trip times

	Export Trip Time (day)		Import Trip Time (day)		Complete Trip Time (day)	
	1998	1999	1998	1999	1998	1999
Population Size	818	803	798	873	808	838
Mean	12.47	11.19	11.66	9.34	24.13	20.53
Standard Deviation	1.83	1.94	2.21	1.80	2.87	2.65
COV	0.15	0.17	0.19	0.19	0.12	0.13
% change	-10.3		-19.9		-14.9	
z value - significance	-13.66 (0.000)		-23.40 (0.000)		-26.41 (0.000)	

5.5.2. Trip Frequencies

The decrease in trip times resulted in an increase in the number of monthly trips per vehicle. The distribution of trip frequencies are shown in Figure 5.8.

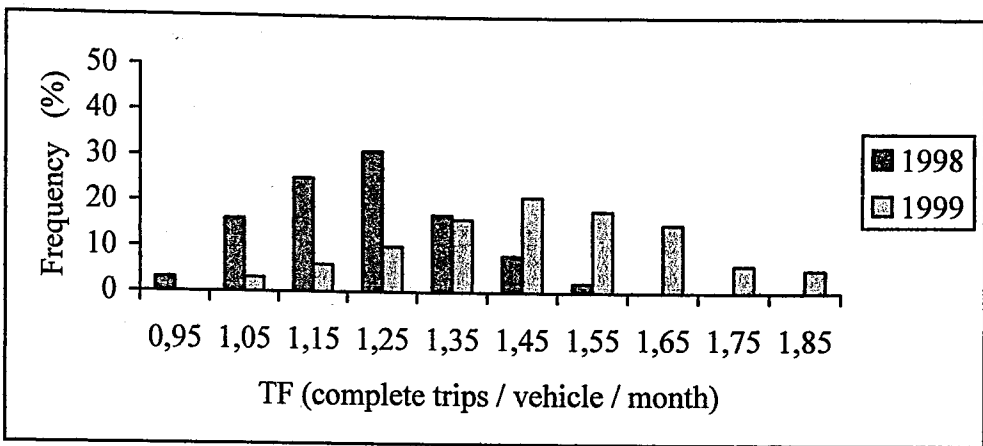


Figure 5.8. Trip frequencies

Trip frequencies increased from 1.24 to 1.46 (n_c / vehicle / month) by 18 per cent. This would also mean, on the average, 5.28 more trips per vehicle per year as shown in Table 5.5.

Table 5.5. Trip frequencies

(complete trips per vehicle per month)	Trip Frequency	
	1998	1999
Population Size	808	838
Mean	1.24	1.46
Standard Deviation	0.12	0.19
COV	0.10	0.13
% change	17.7	
z value - significance	28.19 (0.000)	

5.5.3. Trip Kilometers

- Empty Kilometers: Empty kilometer histograms are given in Figures 5.9. and 5.10.

After ITS / CVO, it was recognized that the empty kilometers in Turkey was mainly as a result of unloading at Bursa and consecutively loading at Denizli, İzmir or Trabzon. In 1999, vehicles unloaded at Bursa are mostly loaded in İstanbul, which resulted in a reduction of empty kilometers in Turkey.

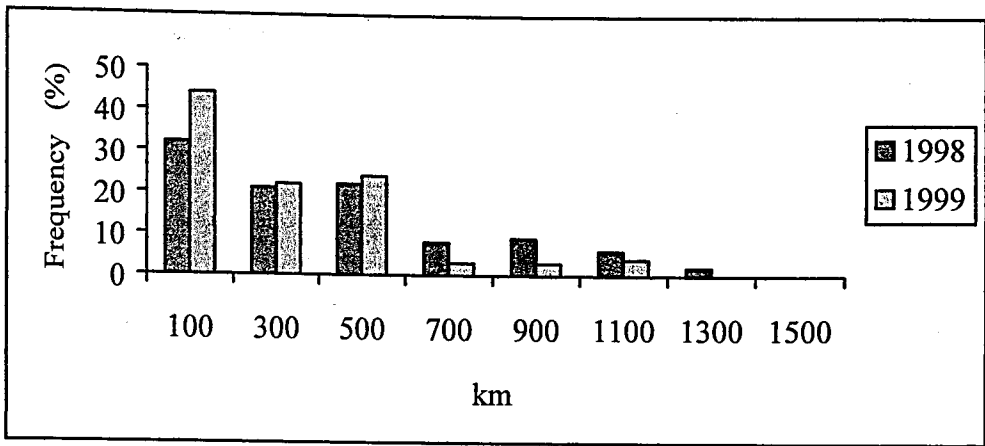


Figure 5.9. Empty kilometers in Turkey

In 1998, 50 per cent of the empty kilometers abroad were because of unloading in Germany and consecutive loading in France because of the imbalance in Turkey's exports and imports. Nevertheless, a significant decrease is achieved from various other locations in Europe.

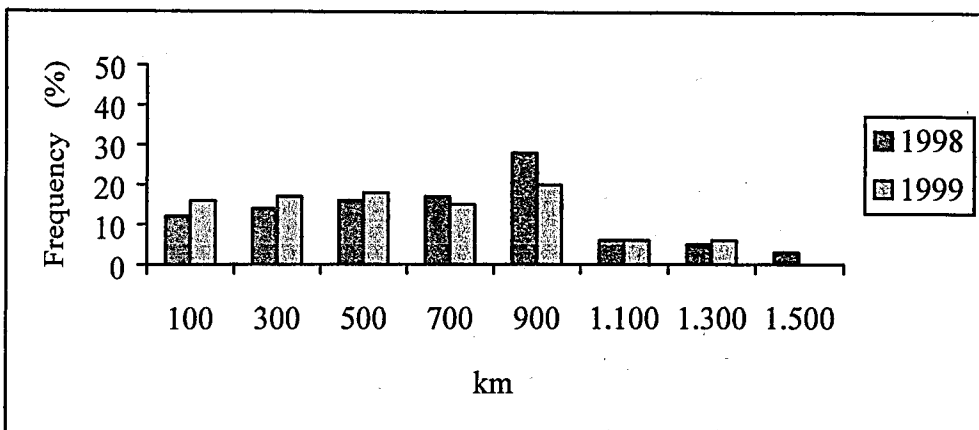


Figure 5.10. Empty kilometers abroad

After the installation of Euteltracs, planning department was able to minimize empty kilometers by optimizing the distance between consecutive unloading and loading points and marketing department maximized the backhauling opportunities. Both of these actions caused empty kilometers to decrease significantly by 24, 9, and 15 per cent in Turkey, abroad and totally, respectively as shown in Table 5.6.

Table 5.6. Empty kilometers

	Empty Kilometers (kms/vehicle/complete trip)					
	Turkey		Abroad		Total	
	1998	1999	1998	1999	1998	1999
Population Size	798	803	818	873	808	838
Mean	434	332	665	605	1099	937
Standard Deviation	300	266	342	362	455	449
COV	0.69	0.80	0.51	0.60	0.42	0.48
% change	-23.5		-9.0		-14.7	
z value - significance	-7.20 (0.000)		-3.50 (0.0)		-7.27 (0.000)	

- Total kilometers: Total kilometers histogram is given in Figure 5.11.

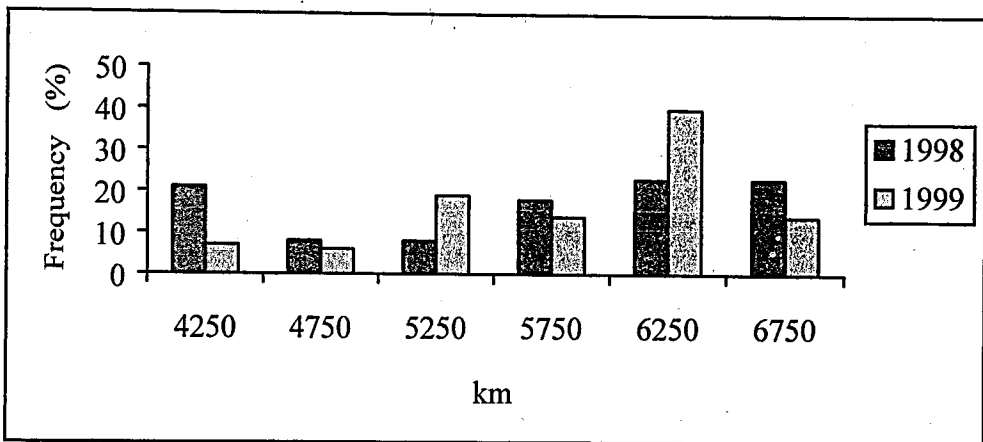


Figure 5.11. Total kilometers

Despite a significant decrease in empty kilometers, total kilometers per trip increased by three per cent, because trips to Spain began in 1999. The average monthly kilometers traveled by each vehicle in 1998 and 1999 are 6966 and 8436 respectively and there was an increase of 21 per cent in the average monthly kilometers per vehicle because of the increase in trip frequencies. The results of analysis are given in Table 5.7.

Table 5.7. Total kilometers

	Total Kilometers (kms/vehicle/ complete trip)	Total Kilometers (kms/vehicle/ complete trip)
	1998	1999
Population Size	808	838
Mean	5638	5799
Standard Deviation	1068	743
COV	0.19	0.13
% change	2.9	
z value - significance	5.00 (0.000)	

- Empty kilometer ratio: It was 19 per cent in 1998 and it reduced to 16 per cent in 1999. The results are shown in Table 5.8.

Table 5.8. Empty kilometer ratio

	Kilometers (kms/vehicle/ complete trip)	Kilometers (kms/vehicle/ complete trip)
	1998	1999
Population Size	808	838
Empty Kilometers	1099	937
Total Kilometers	5638	5799
Empty Kilometer Ratio (%)	19	16
% change		-17

5.5.4. Accidents

Accident analysis is one of the widely used ways of observing safety of fleet operations. In 1998, each vehicle was losing annually 4.24 days [12] because of accidents and in 1999 this value is 6.62 [13], most of these accidents are caused by the pressure of the new system over drivers, and the number of accidents increased significantly more than 50 per cent as shown in Table 5.9.

Table 5.9. Accidents

	Number of Accidents		Number of Accidents / 1,000,000 veh.km	
	1998	1999	1998	1999
Fatal or Injury Accidents	6	9	1.3	1.9
Property Damage Accidents	26	40	5.7	8.2
Total Accidents	32	49	7.0	10.1

The statistical analysis in the previous sections show that ITS / CVO technology improves the efficiency of fleet operations, but safety of operations should also be considered in applications.

5.6. Engineering Economic Analysis

There are three types of costs associated with the economic analysis. These are vehicle utilization costs, ITS / CVO costs, and trip costs. The first two are calculated using the methods described in the following sections and trip cost is taken from the activity reports [14], [15] of the company. The USD interest rate for a six months period will be taken as three per cent, and the service life of investments are considered as five years. These investment are realized by bank credit and they include 10 uniform payments at the end of each six months.

5.6.1. Net Present Worth of an Investment

The net present worth is the method of analysis based on the difference between the present cost and the present salvage value. It is formulated as shown in the following equation.

$$NPW = C - \frac{S}{(1+i)^m} \quad (5.7)$$

In this equation, C is the initial cost of the investment, S is the salvage value after m terms, and i is the interest rate for each term. This equation helps us to calculate the net present worth of an investment after the salvage value is discounted.

5.6.2. Equivalent Uniform Repayment of a Net Present Worth of an Investment

Equivalent uniform repayment analysis is based on getting a credit for the net present worth of an investment and doing the repayment as uniform pieces at the end of each term. The relevant formula is shown as:

$$A = NPW \left[\frac{i(1+i)^m}{(1+i)^m - 1} \right] \quad (5.8)$$

In this equation, A is the uniform repayment to be made at the end of each term, i is the interest rate for each term, and m is the number of terms.

5.6.3. Vehicle Amortization Costs

A vehicle consists of a truck and a trailer. The amortization cost is calculated only for one vehicle and it will be multiplied with the number of vehicles used before and after the installation of ITS / CVO. Vehicle utilization cost is equal to the repayments to be made to the bank for credit based on the net present worth of a vehicle.

Net present worth of a vehicle is calculated in Table 5.10. with equation (5.7). Interest rate is 3 per cent for each six months and it is compounded at each six month. The service life of a vehicle is considered as five years.

Table 5.10. Net present worth of a vehicle

Net Present Worth of a Vehicle					
	C (USD)	S (USD)	i (%)	m*	NPW (USD)
Truck	55.338	11.068	0,03	10	47.103
Trailer	24.195	4.839	0,03	10	20.594
Vehicle	79.533	15.907	0,03	10	67.697

*m = 10, six months period (=5 years)

After determining the NPW of a vehicle, the repayments to the bank for one vehicle is calculated in Table 5.11. with equation (5.8).

Table 5.11. Repayment of credit for one vehicle

Repayment of credit				
	NPW (USD)	i (%)	m	A (USD)
Truck	47.103	0,03	10	5.522
Trailer	20.594	0,03	10	2.414
Vehicle	67.697	0,03	10	7.936

Vehicle amortization costs are calculated in Table 5.12. The repayments to the bank for a vehicle for each six months is equal to the vehicle utilization cost for a vehicle for the

same period, because the service life and repayment periods are both five years. The number of vehicles for 1998 and 1999 are taken as 109 and 96, respectively. Utilization costs are calculated on a total, per trip, and per kilometer basis. In 1999, total vehicle utilization costs decreased, because the number of vehicles used were less than the previous year.

Table 5.12. Vehicle amortization costs

Vehicle Amortization Costs						
Year	Costs per six months (USD)		Costs per trip (USD)		Costs per kilometer (USD)	
	1998	1999	1998	1999	1998	1999
Truck amortization cost	601.888	530.103	372	316	0,132	0,109
Trailer amortization cost	263.153	231.768	163	138	0,058	0,048
Total cost	865.041	761.871	535	455	0,190	0,156

5.6.4. ITS / CVO Costs

ITS/CVO cost, includes utilization cost and regular fee paid to the service provider. ITS/CVO utilization cost is calculated with the same way as the vehicle utilization cost in the previous section and the results are shown in Tables 5.13., 5.14., and 5.15.

The NPW of ITS/CVO unit is equal to the initial investment because after a service life of five years, the salvage value is assumed as zero.

Table 5.13. Net present worth of an ITS/CVO unit

Net Present Worth of an ITS/CVO Unit					
	C (USD)	S (USD)	i (%)	m	NPW (USD)
ITS/CVO	3.000	0	0,03	10	3.000

The repayment of the credit is calculated with the same parameters in the previous section and the results are given in Table 5.14.

Table 5.14. Repayment of credit for one ITS/ CVO unit

Repayment of credit				
	NPW (USD)	i (%)	m	A (USD)
ITS/CVO	3.000	0,03	10	352

ITS/CVO costs for 1998 are zero, because the system is installed in 1999. The ITS/CVO fee is taken from the databases of the company. The results are given in Table 5.15.

Table 5.15. ITS / CVO costs

ITS/CVO Cost						
Year	Costs per six months (USD)		Costs per trip (USD)		Costs per kilometer (USD)	
	1998	1999	1998	1999	1998	1999
ITS/CVO amortization cost	0	33.762	0	20	0,000	0,007
ITS/CVO fee	0	48.960	0	29	0,000	0,010
Total cost	0	82.722	0	49	0,000	0,017

5.6.5. Trip Costs

Trip costs are calculated by the data given by the financial department in the company and shown in Table 5.16. Driver costs are all costs related to drivers including insurances. General administration costs are composed of all costs related to office costs including office staff salaries. Highway cost is the passing fee paid to special roads and bridges both in Turkey and abroad. Train cost is paid for the train between Szeged and Wels in Austria. Maintenance and Repair Costs include all related fees paid both abroad and in Turkey. They also include oil costs. Insurance costs include only vehicles and the load not the driver. Commission is the cost paid to other companies for sub-contracted trips. In 1999, driver, general administration, and insurance costs have decreased because of the reduction in the number of vehicles. Fuel costs per kilometer have increased, the new system may have a negative effect on the drivers for urgent shipments. In relation to the increase in the number of accidents and annual total kilometers per vehicle, the maintenance and repair costs are also increased. In 1998, maintenance and repair cost per trip was 138-USD, but in 1999, this cost has reached to 164-USD per trip. In 1999, the trip costs have decreased significantly because of the efficient use of both vehicles and drivers.

Table 5.16. Trip costs

Trip Costs						
Year	Costs per six months (USD)		Costs per trip (USD)		Costs per kilometer (USD)	
	1998	1999	1998	1999	1998	1999
Driver Costs	879.104	775.698	544	463	0,193	0,159
Fuel cost	817.696	903.302	506	539	0,179	0,186
General Administration Cost	560.752	495.305	347	296	0,123	0,102
Highway Cost	357.289	398.516	221	238	0,078	0,082
Train Cost	235.936	196.346	146	117	0,052	0,040
Maintenance and Repair Cost	223.008	275.356	138	164	0,049	0,057
Insurance Cost	183.276	161.464	113	96	0,040	0,033
Tire Cost	103.263	108.396	64	65	0,023	0,022
Commission Cost	83.200	84.400	51	50	0,018	0,017
Trip Cost	3.443.524	3.398.783	2.131	2.028	0,756	0,698

5.6.6. Benefit / Cost (B/C) Ratio

One of the most widely used forms of economic analysis is the incremental benefit/cost ratio. Those cases with (B/C) ratios greater than 1.0 are economically viable, while those with ratios below 1.0 are not. For this study costs are the incremental costs are ITS/CVO costs, and the incremental benefits are the reductions in total costs. The necessary modified formula to calculate the (B/C) ratio is given in equation (5.9).

$$B/C = \frac{TR_{1999} - TR_{1998}}{TC_{1999} - TC_{1998}} \quad (5.9)$$

where, TR is the total revenue and TC is the total costs of 1998 and 1999. Table 5.17. is a summary of costs to be used in equation (5.9) for B/C ratio of the system.

Table 5.17. Total costs and benefits

Total Costs and Benefits		
Year	Costs and Revenues per six months (USD)	
	1998	1999
Vehicle Amortization Cost	865.041	761.871
Trip Cost	3.443.524	3.398.783
ITSC	0	82.722
TC	4.308.565	4.243.376
TR	5.229.376	5.500.632
B/C	-4,16	

The incremental benefits are 271,256 USD and the incremental costs are -65,189 USD. As a result, we get a negative (B/C) ratio of -4.16, which is a result of the reduction in total costs and the increase in total benefits. Highway and train costs may be excluded from B/C analysis since they are not affected by the new system, but the B/C ratio is still negative, which indicates that the installation of this new ITS / CVO system can be considered as economically beneficial for the company.

7. CONCLUSIONS AND RECOMMENDATIONS

In this study, problems of international transportation industry are discussed and a case study has been analyzed in order to investigate the effect of intelligent transportation systems on safety, efficiency and cost effectiveness of commercial vehicle operations.

As a result of the statistical and economical analysis, following conclusions have been drawn:

- The new system provided significant improvements in both import and export transit times. Higher improvements were observed in import transit times than export transit times.
- The new system provided the greatest benefit in idle times, because with the help of new system, it became easier to track the vehicles and recognize that they are empty.
- Loading / unloading times have decreased significantly after the installation of the new system, because the drivers are warned if they leave the vehicle during loading unloading operation.
- As a result of the reductions in export, import and complete trip times, the trip frequencies increased significantly by 18 per cent after the new system.
- AVLS provided a great reduction in empty kilometers. Empty kilometers have reduced by 15 per cent. Not only it reduces idle times, but also extra savings in trip fuel costs are achieved.
- Accident frequency have increased after utilization of ITS/CVO, because current focus of the company is primarily on the mechanical conditions of the truck and not on the condition of the driver. This situation also resulted in an increase in maintenance and repair costs. The solution seems to be monitoring the condition of drivers by an onboard computer system.
- Vehicle amortization costs are independent of the kilometers traveled. Thus, a vehicle should be used as much as possible. The vehicle amortization costs per kilometer have decreased in 1999, because of two reasons. First, less number of vehicles are used to do the same job. Second, these vehicles are used more efficiently than the previous year as can be seen from increases in trip frequencies.

- ITS/CVO provided benefits in efficiency of fleet operations of the company. In terms of economic analysis, the B/C ratio related to ITS/CVO is -4.16, which shows that, utilization of such a system in international transportation operations also provide cost effectiveness in fleet operations.

In summary, the case study indicate that ITS/CVO technologies improve the efficiency and cost effectiveness of the company, but had negative effects on safety of operations. Onboard computer systems may be proposed to decrease the accident frequencies by monitoring the condition of both the vehicle and the driver.

This study provided a basis for future ITS studies by transportation professionals or universities on solution of problems in commercial vehicle operations. Future investigations seem to be needed on safety of commercial vehicle operations. In these studies, indirect costs of accidents such as social costs or time costs should also be taken into account to see the benefits of ITS better in case of fatalities or traffic congestion.

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