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BLACK BOX APPLICATION IN PUBLIC TRANSPORTATION AS AN INTELLIGENT TRANSPORT SYSTEM AND THE RESULTS OF DRIVER PERFORMANCE: THE CASE OF ISTANBUL ELECTRICITY, TRAMWAY AND TUNNEL ADMINISTRATION (IETT) BLACK BOX PROJECT

AKILLI ULAŞIM SİSTEMİ OLARAK TOPLU ULAŞIMDA KARAKUTU UYGULAMASI VE ŞOFÖR PERFORMANS SONUÇLARI: İSTANBUL ELEKTRİK TRAMVAY VE TÜNEL İŞLETMELERİ (İETT) KARAKUTU PROJESİ ÖRNEĞİ

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ÖZ

Son yıllarda, bilgi ve iletişim teknolojilerinin gelişmesi ve uygulamaların kent yönetim sistemine entegrasyonuyla yeni bir şehir modeli olarak Akıllı şehirler gündeme gelmiştir. Akıllı şehirlerin bileşenlerinden biri olan Akıllı Ulaşım Sistemleri, başlangıçta kent içi ulaşımını daha güvenli ve sürdürülebilir kılmak; trafik yönetim birimleri ile sürücü, yolcu ve yayaların, yol ve trafik şartları hakkında sürekli olarak bilgi edinebileceği yaklaşımı ile ortaya çıkmıştır. İstanbul Elektrik Tramvay ve Tünel İşletmeleri (İETT), İstanbul'da toplu ulaşım hizmeti sunmaktadır. 1995 yılında elektronik bilet AKBİL ile başlayan akıllı ulaşım sisteminin kent içi ulaşımında kullanılması süreci günümüzde birçok proje ile devam etmektedir. Sürdürülebilir toplu taşımanın geliştirilmesi, ekonomik, konforlu ve güvenli sürüş ve yakıt tasarrufunun sağlanması, kaza sayısının, emisyonun azalması akıllı ulaşım sistemlerinin hedeflerinden bir kaçıdır. Bu amaçla, İETT tarafından "Karakutu Projesi" geliştirilmiştir. Bu çalışmada, projenin kapsam ve hedefleri ayrıntılı bir şekilde ortaya konulacaktır. Projenin şoförlerin güvenli, ekonomik ve konforlu sürüş karakterlerine etkisi, şoförlerin çevresel farkındalıklarına katkısı, kaza sayısı, yakıt tasarrufu ve emisyondaki değişim oranları incelenecektir.

Anahtar Kelimeler: *Akıllı Ulaşım Sistemleri, Toplu Ulaşım, Personel Yönetimi, İETT, Karakutu Projesi*

Jel Kodları: *L62, L91, O18, O38.*

ABSTRACT

In recent years, smart cities emerged as a new city model by the advancement and development of information and communication technologies and the integration of new applications into metropolitan management. Intelligent Transport System which is one of the components of Smart Cities emerged as to make citywide transportation more secure and sustainable and to provide road and traffic conditions continuously to drivers, passengers, and pedestrians along with traffic management units. Istanbul Electricity, Tramway and Tunnel Administration (IETT) provides public transit service in Istanbul. This process that started with AKBIL in 1995 still continues with the use of much intelligent transport system in citywide transportation. Several goals of smart transport systems are providing sustainable public transport system development, securing economic, comfortable and secure driving experience, ensuring gas savings and reducing the number of accidents and the level of emission. With this goal in mind, IETT developed the Black Box Project. In this study, the scope and objects of the study will be outlined in detail but this study examines the effects of bus drivers to secure, *economic and comfortable driving. It also investigates the contribution to the environmental consciousness of bus drivers, number of accidents, gas savings, and changes in emission rates.*

Keywords: *Intelligent Transportation Systems, Public Transportation, Personnel Management, IETT, Black Box Project*

Jel Codes: *L62, L91, O18, O38.*

1. INTRODUCTION

The characteristics that Smart Cities require for both local governments and central governments find a place as objectives in various exploratory local programs and initiatives. According to United Cities Local Governments (UCLG, 2012), smart cities as a new city model are more livable, functional, competitive, technology-centered, modern and information managing cities.

For smart cities to reach pre-defined goals, there are certain components to consider. In fact, smart cities are evaluated through six different components: 1. Smart Economy 2. Smart Transportation 3. Smart Environment 4. Smart People 5. Smart Living 6. Smart Governance (http://smartcitiescouncil.com/tags/smart-city-components). Smart Transportation which is one of the components of smart cities is used at the same time in Smart Connections and Smart Mobility concepts and expresses city-wide mobility applications as a whole such as Integrated Solutions, Mixed Access Model, Environment-Friendly and Engineless Transportation options. In addition, Smart Transportation encompasses Citywide Transportation Systems, National and International Accessibility, Information and Communication Infrastructure and Sustainable Transportation Systems (http://www.smart-cities.eu).

Istanbul is a metropolitan city bigger than many world metropolises with its 14.804.116 as of 2016. The total number of daily passengers using traditional land-based transportation including buses, metro buses, taxis, vans, and private van services is 10,095,405. The total number of transport is approximately being 21 million.

IETT provides public transit service with 5881 buses, 12.601 bus stops and 748 different routes in Istanbul. IETT is known as the architect of many innovative implementations in city-wide transportation. The company which started to serve Istanbul public in 1869 under the name of Dar-saadah Tram Company has been managing the tunnel since 1875, known to be the second subway of the world. This process that started with AKBIL in 1995 still continues with the use of much intelligent transport system in citywide transportation.

Several goals of smart transportation systems are providing sustainable public transportation system development, securing economic, comfortable and secure driving experience, ensuring gas savings and reducing the number of accidents and the level of emission. With this goal in mind, IETT developed the Black Box Project.

IETT expresses that Black Boxes aim to increase road safety and driving security, to decrease the number of accidents, to minimize servicing charges, to enhance passenger comfort, and to save on gas (http://iett.gov.tr).

This study examines the impact of bus drivers to safe, economic and comfortable driving. It also investigates the effects of bus driver environmental consciousness, the number of accidents, gas savings, and changes in emission rates.

The results obtained from this study will help to contribute to the improvement for the city of Istanbul's transportation and shed light on the point where we are in public transit. It is also expected to be set an example to other metropolitan cities as well as improvement of the public transit systems.

2. PURPOSE, SCOPE AND METHODOLOGY

Smart cities, which began to be defined by the development of information and communication technologies since the 1980s, have taken place in the conceptual framework as a focus point in the solution of urban problems and using the information technologies in urban applications (Celikyay, 2017:151). Information and communication technologies (ITC) such as internet, web technologies, mobile technologies, internet of objects (IoT) in public organizations carry out and present the production of public goods / urban services by removing the time and space limitation in order to create value in urban services (Bensghir and Demirci, 2017: 385-386).

Intelligent transportation systems are one of the most important components of Smart cities. Especially in metropolitan cities, which have the important urban problems, it is important to solve transportation problems with intelligent transport systems.

The purpose of this study is to make the theoretical framework of intelligent cities and intelligent transportation systems and then to analyze the results of the Karakutu project which is developed by İETT for Istanbul city and to find out whether it can be a solution for urban transportation in the context of intelligent transport systems.

In this study, intelligent transportation systems were widely studied after the first emergence of smart cities and their various descriptions. The city of Istanbul, which is the subject of field study, has been dealt with in the concept of transportation dynamics. Also IETT which serves urban transportation services to Istanbul city is presented with its dynamics and characteristics.

Furthermore, the need, purpose and technical features of the Black Box Project, which constitutes the subject of this study, are included in the article. After the application phase, the results from the Black Box Project were carried out in detail, and then the impact of the project on urban transportation in the context of intelligent transport systems was analyzed.

3. SMART CITIES[1]

The cities started to be called with different names as the information and communication technologies develop and the mobile information applications spread in metropolitan management. The terms used to define cities that started to be called “virtual city,” “digital city,” “information city,” “sustainable city,” “cyber city,” “learning city” at beginning of the 1980s are developed and now called “Smart Cities” (Monaty, S. P. et al., 2016: 60; Cocchia, 2014:13-19). In Smart Cities, Information and Communication Technologies (IT and ICT) integration supports energy efficiency and sustainability (Siddhart and Nadimpalli, 2015:1).

The definitions that are grounded as the user-friendly information and communication technologies in municipality services for the metropolitan areas are developed in relation to the growth and the future of the cities (Stadt Wien, www.wien.gv.at). Smart cities are cities that are productive, participatory, citizen-centered and transparent and solve problems with the contribution of the public, decreases the bureaucracy, decides and prioritize the problems with objective criteria, specifies current and potential issues in time and in place (http://www.akillikentler.org/hakkimizda/3/9-akilli-kentler-nedir.html).

[1] The theoretical information in this section is mostly taken from the paper entitled “The Role of Intelligent Transportation Systems in Public Transportation: The Case Of Istanbul Electric Tram And Tunnel (IETT) Administration Akyolbil Project" presented on the Public Administration and Policies of Digital Age Forum in Isparta on November 01-03, 2017.

Smart cities are places that use digital and telecommunication technologies for the benefit of the public to offer traditional networks and service in a more flexible, efficient and sustainable manner. Smart cities offer greener, safer, faster and friendlier service. To strengthen the city's collective intelligence, smart cities is the city which connects the business infrastructure, physical infrastructure, information technology infrastructure and social infrastructure. In other words, the smart cities are innovative cities that use the efficiency of urban operations and services in a sustainable way by using information and communication technologies to improve the quality of life. In smart cities, social and environmental needs of present and future generations are met (Monaty, S. P. et al., 2016).

Smart cities are future-centered, forward-looking and productive in natural resource efficiency and at the same time should provide a high quality of life, secure economic competitiveness power for metropolitan population and quality of the life, support the social and technological innovations and connect current physical infrastructures of a metropolitan with each other smartly (Stadt Wien, www.wien.gv.at).

In general, smart cities attempt to provide a sustainable life for future generations. A smart city provides an ideal and perfect metropolitan mobility, access to services, opportunities for health, education and work and access to affordable homes. Smart cities aim to decrease the complexities and the negativities that are expected to accompany future metro-poles (Siddhart and Nadimpalli, 2015:1).

According to United Cities Local Governments (UCLG, 2012), smart cities as a new city model are more livable, functional, competitive, technology-centered, modern and information managing cities. Smart cities are future-centered, forward-looking and productive in natural resource efficiency and at the same time should provide a high quality of life, secure economic competitive power for urban population and the quality of the life, support the social and technological innovations and connect current physical infrastructures of a metropolitan with each other smartly (Stadt Wien, www.wien.gv.at).

For smart cities to reach pre-defined goals, there are certain components to be considered. In fact, smart cities are evaluated through six different criteria (Manville et al., 2014: 29-30):

1. Smart Economy
2. Smart Transportation
3. Smart Environment
4. Smart People
5. Smart Living
6. Smart Governance

In addition to these components, Intelligent Infrastructure for Smart Cities, Smart Energy, Smart Healthcare, Smart Technology also are listed among these components. These components are fully engaged in the smart and efficient cities (Monaty, S. P. et al., 2016).

3.1. Intelligent Transportation Systems

The metropolitan city of Istanbul is developing projects for each area of the 6 smart city components. Intelligent Transportation Systems (ITS) is one of these components under development through the implementation of different transit projects. ITS is a collection of various technologies that include information processing, communications, control, and electronics. The purpose of ITS is to increase the efficiency and convenience of passengers by making them more efficient and environmentally sound. ITS technologies have been organized into three separate categories in terms of the potential uses of ITS in public transportation: Fleet Operation and Management, followed with Fare Collection, and conclude with Customer Information, or known as Traveler Information Systems (Hough et al., 2002: 2).

The concept of Intelligent Transport System (ITS) emerged to make city-wide transportation more secure and sustainable and to provide road and traffic conditions continuously to drivers, passengers and pedestrians along with traffic management units. It also emerged as an approach to develop technological infrastructure based on a strategic plan to implement traffic control and optimization mechanisms more effectively and productively.

Smart Transportation which is one of the components of smart cities is used at the same time with Smart Connections and Smart Mobility concepts and expresses city-wide mobility applications as a whole such as Integrated Solutions, Mixed Access Model, Environment Friendly and Engineless Transportation options. In addition, Smart Transportation encompasses Citywide Transportation Systems, National and International Accessibility, Information and Communication Infrastructure and Sustainable Transportation Systems (http://www.smart-cities.eu). As there are components of the smart city, there are also defined components for intelligent transportation systems such as smart products, smart tools and smart infrastructure (Stefansson and Lumsden, 2008).

Intelligent transportation systems are also known as "intelligent vehicle highway systems" and use advanced technologies in areas such as computer technology, information technology, electronic communications and control systems and emerging technology such as artificial intelligence. It encompasses integrated and instantaneous systems from car to car and from road to car. Many intelligent transportation systems aim to reduce the intensity of traffic and to manage traffic during the journey. Systems are designed to help you avoid accidents and redirect the traffic by communicating with the navigation systems and the driver through touch screen display panels (Nagappan and Chellappan, 2009:14).

The four main goals of intelligent transportation systems are to increase the development and the production, to boost safety, to make environmental policies more responsive and to better the quality of life (huawei.com, 2016). In addition to these, Intelligent Transportation System objectives can be listed as in the following: minimizing the environmental impact of transport, maximizing the benefits of both car users and passengers and the business, exchanging multi-faceted and versatile data between human, vehicle and infrastructure, securing the safety of the traffic, using the roads in line with their traffic capacity, increasing mobility, reducing damage to the environment and providing energy efficiency (Ilıcalı et al., 2016:4). In short, the proposed fundamental goal in Intelligent Transport Systems is to better use of public resources, to increase the quality of the services given to public and to decrease the cost of the service (Zanella et al., 2014:22).

Intelligent Transportation Systems that are categorized in two main groups of “Applications for the solution of the problem of Traffic" and "applications for users" (Yokota 2004:7), in practice, are developed in 9 different areas such as Passenger Information, Traffic Management, Road Management, Advanced Driving Support, Electronic Payment Passes, Vehicle Management, Public Transportation Management and Casualty and Damage Liabilities (Yokota, 2004:3-4).

Intelligent transportation system can be defined and listed around the goals used to develop applications for traffic management to relieve traffic in the dense residential areas, to minimize fuel consumption and delays, to suggest alternative transportation axis and management of these new transit axes, to develop systems for rapid response to emerging situations and to improve environmental emissions targets. In short, the proposed fundamental goal in Intelligent Transport Systems is to better use of public resources, to increase the quality of the services given to public and to decrease the cost of the service (Zanella et al., 2014:22).

Quality of the public transport services depends on several factors of the service; some are quantitative (e.g., average travel time and its reliability, transit waiting time, monetary costs) while others are qualitative, whose effects on user behavior are more difficult to assess (e.g., riding comfort, information, personal security). Assessment of service quality requires methods for defining standard quality indicators and related measurement techniques (Cascetta, E. and Carteni, 2014: 84). One of these methods to increase the service quality is the analysis of the data taken from the black box applications.

In order to fulfill to increase the quality of the services and to decrease the cost of the services, IETT developed Black Box Project to contribute to the city of Istanbul transit using intelligent transportation systems, to improve the road and driving safety, to lower the number of accidents and vehicle maintenance costs, and to increase the comfort of passengers and to achieve fuel savings.

4. IETT

4.1. The History of IETT

IETT is known as the architect of many innovative implementations in citywide transportation. The company which started to serve Istanbul public in 1869 under the name of Darsaadah Tram Company with the construction of Tunnel Facilities. In 1871, the first horse pulled trams started to operate and in 1914, electric trams started to carry passengers. The Electric, Tramway and Tunnel Administration attained its current institutional status under the name of IETT Administration General Directorate with Law no. 3645 in 1939.

With a law passed in 1982, all electricity services are transferred to Turkish Electricity Authority (TEK) with rights and obligations. Later in 1993, air gas distribution activities were terminated. Today, IETT provides only urban public transport services, buses, trams, and tunnels, as well as the management, execution, and supervision of Private Public Buses (IETT Annual Report, 2015).

The company which started to serve Istanbul public in 1869 under the name of Darsaadah Tram Company has been managing the tunnel since 1875 which is known to be the second subway of the world. The tunnel started to be constructed in July 30, 1871 and completed as a 573-meter-long tunnel in December 1874. It started the operation in January 17, 1875. The tunnel that has 64.800 trips annually covers 37.066 kilometers with its two wagons between Karakoy and Tunnel station and it transports 11.000 passengers daily (IETT Annual Report, 2016:19).

Trams started to operate between Tophane and Ortakoy stations in Istanbul in September 3, 1869 while New York, Paris and London trams started to serve in 1842, 1854 and 1869 respectively. Later on, other routes such as Tepebasi - Taksim - Pangalti - Sisli, Beyazit - Sehzadebasi, Fatih - Edirnekapı - Galatasaray - Tunnel and Eminonu - Bahcekapi were opened. Still, the historic tram with its 2 wagons on 1.64-kilometer route operates 14.600 trips annually and covers 23.944 kilometer on average daily carrying 1.500 as a tourist attraction (IETT Annual Report, 2016:21).

To support the Tramway Operation started in 1871, the permission to operate 4 buses was given to Darsaadah Tramway Corporation. The first bus started to operate in 1926. 4 buses started to operate between Bayazit and Karakoy route in 1930 to serve as a public transit service.

In April 3, 1943, 15 buses were purchased and 5 buses were purchased in 1944. A fleet of 29 buses were formed to serve Istanbul public. The fleet of 15 buses continued to serve Istanbul until 1955.

The procurement of buses continued until 1960 and at that time there were 525 buses. In 1969, the number of buses reached to 300; by 1980, 495 buses were provided to serve public transit of Istanbul public. 136, 63, 206, and 159 busses were added to the fleet in 1997, 1998, 1999 and 2000 bringing to the number of busses in the fleet up to 564. In 2005 and 2006, 450 buses were purchased. In 2007, 50 double deck and 94 solo buses were purchased.

As of 2016, IETT which provide public transportation service with 5881 buses, 12.601 bus stops and 748 different routes set the goals such as to exchange data in a multi model among human, vehicle, infrastructure and center, to provide a secure traffic, to use roads in line with their capacity, to increase mobility, to provide energy efficiency, to minimize impact on environment, to have an effective fleet management and security, and to communicate the use of the capacity in buses to the command center (IETT Annual Report, 2016:23).

4.2. Transit Dynamics of The City of Istanbul

The metropolitan city of Istanbul is the capital of Roman, Byzantium and Ottoman Empires for 16 centuries with its history going back to 300.000 years. Istanbul is both a metropolitan and cosmopolitan city that needs to be handled from many different perspectives such as geography, history, memory, sociology, cultural heritage, strategic location and economy. Istanbul has a complex and various transit problem because of its every increasing annual population, carrying Europe, Euro-Asia and Middle East geographies' transit axis, located on the cross-section of main thoroughfares where the major arteries meet the sea and the door of Silk Road extending to Europe (Celikyay, 2012: 148-153) and becoming a gate for international transport. As a result, Istanbul faces major city-wide transit problems in urban public public transit.

Istanbul is a metropolitan city with its 14,804,116 population which is greater than many European countries and it has an annual increase of 1% in 2016. In addition to its population, the number of tourists visiting Istanbul in 2016 was 9,203,987. The tourist mobility for a day is 25.000 on average. The total number of daily passengers using traditional land-based transportation including buses, metro buses, taxis, vans, and private van services is 10,095,405 and the total number of transport is approximately being 21 million.

In Istanbul, the land-based transit share was %77.79, sea-based transit was just %4.75 and rail transit was %17.46. Total number of trips was measured to be 1.831.029.603 in Istanbul. The problems caused by transit have a important role in daily lives of Istanbul residents. For the transit management, there are intelligent transit systems being developed and a strategic infrastructure for managing and controlling traffic is built. Using Intelligent Transport System implementations, IETT aims to increase the capacity of current roads, to decrease the number traffic accidents, to save time spent in traffic, and to decrease the material loss to contribute to the national economy (http://iett.gov.tr and http://tkm.ibb.gov.tr).

It is a need and a requirement for Istanbul to develop new project with such features using intelligent transit systems. In this context, IETT stepped another foot forward and developed a Black Box Project and started to implement to collect data on many different facets of driving experience and driver behavior.

5. BLACK BOX PROJECT[2]

5.1. The Goal of the Project

The Black Box Project, also known with the name of Sustainable Public Transit By Designing and Developing a Black Box To Provide Driving Safety and Fuel Saving is simply the implementation of Black Box Technology utilized in airplanes to public transit vehicles. The project relies on the technology that allows remote connection to data on the vehicles and register the condition of the driver and the vehicle at the time of an accident using the existing electronic communication network that exists in public transit vehicles.

The fundamental goal of the project is developed innovative implementations in metropolitan service and implement these

[2] The data and graphics are taken from IETT General Directorate Transit Technologies Division after a meeting on August 25, 2017.

innovative tools to increase the quality of life in Istanbul. The priorities of the project are to increase road and driving safety, to decrease the number of accidents and minimize the cost of maintenance, to increase the comfort level of the passenger and to ensure fuel savings. At the same time, it is possible to access the data in public transit vehicles at the time of an accident and to register the condition of the driver and the vehicle again at the time of an accident remotely using the electronic communication network with the help of this Black Box Project.

IETT which provide city-wide transit service in a metropolitan city where an average of 3 million mobility occur daily aims to realize a project that is a first in Turkey and a developing implementation in the world. The use Black Box technology already utilized in different sectors is expected to increase the quality of public transit. This technology aims to prevent accidents and to investigate the cause of accidents; in addition, developing a productive method of use and educating the bus drivers according to this method to ensure greater fuel savings in public transit using technical infrastructure of rubber-wheeled public transit vehicles and collecting data from the communication network of the vehicle.

This project provides a system in which 80 different instant data from many areas such as from the temperature inside the vehicle to fuel savings ratio, from average breaking to engine temperature, and from break down information to idle time can be collected and the system does not just form a data source and it provides a way of managing the data from a single location. Using this project, IETT can conduct investigations on causes of the accidents after they occur as well as how to avoid of accidents. This will allow IETT develop an efficient public transit vehicle driving method and IETT can train its bus drivers according to this system.

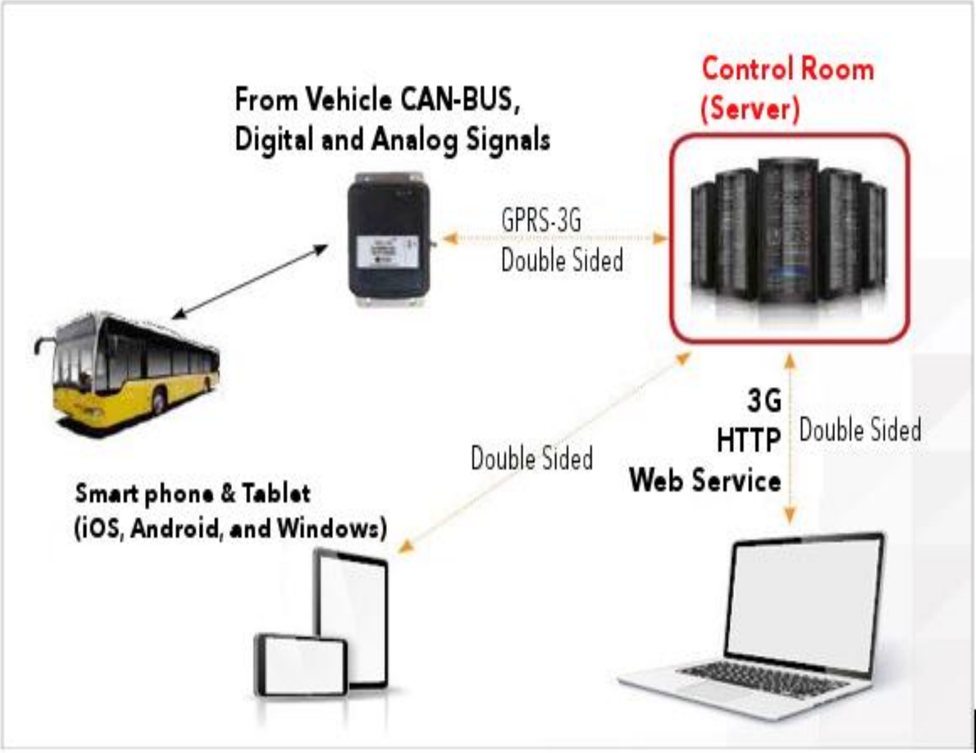
5.2. The Technical Features of Black Box Device

Black Box is defined commonly as a small machine that records information about an aircraft during its flight, used to discover the cause of an accident (http://dictionary.cambridge.org/dictionary/english/black-Box). Black Box is also known as a device registering and saving the conversation of pilots during their flight along with the messages coming from air traffic control towers to cockpits (http://www.tdk.gov.tr). In recent times, Black Boxes are used in vehicles to measure and monitor the performance of bus drivers. In this regard, its definition is “a piece of equipment placed in a car that records information about how well someone is driving” (http://dictionary.cambridge.org/dictionary/english/black-Box).

Black Box mentioned in this study is a custom design of the data technology used in airplanes for the public transit vehicles such as buses. After Black Boxes are integrated into buses, they are expected to store data drawn out of steering wheel, transmission, drivetrain and climate control units. Black Box will be able to provide relevant data at the time of accidents and breakdown.

Using this system, urgent interventions, location of the vehicle in accidents, monitoring drivers, maintenance planning, managing breakdowns, chronic breakdowns can be identified. In addition, all drive movement data such as vehicle engine speed, vehicle speed, the position of the accelerator pedal, brake pedal position, instant fuel consumption and maneuverability, stop info, line planning will be captured by Black Boxes, sent to the central servers for processing; information both vehicle and driver will be analyzed and reported to resolve potential problems.

Figure 1: Black Box Device Data Communication Model



The indicator data such as the fuel level, AdBlue[3] level, total covered distance in kilometers, external air temperature and the status of air conditioning inside the vehicle; oil temperature, oil pressure, fuel temperature, break pressure, battery, engine temperature, transmission, thickness of brake pads and the status of breakdowns are all registered to Black Boxes.

Black Boxes can store 6-month long data with an 8 GB SD Card. Every 3 minutes all data can be sent to servers. All data sent to servers are analyzed and reported before backed up and stored for future reuse.

For this project, Black Boxes are integrated to buses used in public transit. In order to send the data collected in Black Boxes over a desired frequency, the internal GPRS system and GPS system are used to pair the data read with location in an intranet network. The features of built-in GPS receiver are as follows: 48 Channel GPS Architecture, the Acquisition: -147dBm, Navigation: -160dBm, Tracking: -163dBm.

In the hardware, there are two analog entry and exit ports. The device is designed and manufactured in a way to protect the data and the device hardware at the time of the accident. The data selected by IETT are communicated to the servers instantaneously in specific time frames by using GPRS.

The accumulated data of the vehicle at the end of the day is communicated to the servers when the vehicle enters into bus garages using Wi-Fi points. The internal memory of the device computer received data in a frequency specified by IETT. The data communication model is shown below.

The internal storage unit in the device should be 8 GB capacity and is a Micro SD

[3] AdBlue is a liquid solution used by some diesel engines with selective catalytic reduction to lower nitrogen oxide (NOx) emissions (http://www.turkf1.com).

card. Black Box registers the daily data into the data registration system and the data flow into internal and external storage systems. The data received from buses are stored in IETT servers.

5.3. The Process of the Project

In Black Box project, we first decided to roll out a pilot implementation. For this pilot implementation, we identified the types of data that can be collected from different types of vehicles. Working on the communication and storage of data, the operational principles of Black Box device are developed.

The work needed to integrate Black Box Device into buses is also planned and executed. In the first phase of the project, 520 Black Boxes are mounted onto 520 buses. Black Box Device registers vehicle specific 48 different types of data related to vehicles such as gas pedal, brake pedal, fuel level, transmission lever, bus speed, break pad thickness, all vehicle malfunction data, oil pressure, fuel pressure, engine temperature and related to the use of the vehicle such as position, temperature, route, line, and environmental effects.

There are different algorithms designed and developed to receive, analyze and store data to generate reports, to issue warnings and to provide a readable analysis to decision makers. Instant warnings and reports dating back to past dates can be prepared by using the collected data. Instant data can be managed from a single point of interaction and it is possible to intervene when needed. 31 different reports can be generated through the analysis of data collected in this project. In Table 1, there is a list of reports prepared by using the data received from Black Boxes.

Table 1: Report Generation Form

Report List
Vehicle Incident Report (Priority): This is a report of the warnings mentioned in Attachment C when paired in terms coordinates, time and driver data for the desired two dates and times.
Speed Report: This is a report of the distance covered data read of CANBUS and is paired up with coordinates, time and driver information for the desired two dates and times. In this report, GPS speed is not utilized.
Vehicle Detailed Report
Stop Summary Report: In cases when the vehicle stops and is forced to stop, this data is paired up with position, time and driver info and reported in two different date and time periods.
Daily and Monthly Summary Report (Priority)
Speed Violation Summary Report: This is a report of the warnings mentioned in Attachment C when paired in terms coordinates, time and driver data for the desired two dates and times. Speed data will be received from CANBUS and GPS speed data will not be used.
Distance Covered Summary Report in Kilometers: This is a report of the distance covered data read of CANBUS and is paired up with coordinates, time and driver information for the desired two dates and times.
Start Switch on Summary Report
Speed Violation Report Based on Work Hours
Work Hours Summary Report
Idling Summary Report: In cases when the vehicle stops and is forced to stop, this data is paired up with position, time and driver info and reported for two different date and time periods.

Report List
Trip Summary Report
District Summary Report
Route Summary Report
Driver Incident Report (Priority): This is a report of the warnings mentioned in Attachment C when paired in terms coordinates, time and driver Data for the desired two dates and times. This report is designed to be reported driver specific and driver violations and warning can be reported in periods.
Who Used What Vehicle Report: This is a report that shows which vehicles, when, and for how long drivers used. It can be reported between two different dates and times.
Who Used the Vehicle Report: In the scope of the project, this is a report that indicates which bus driver used this vehicle when and for how long. It can be reported between two different dates and times.
Vehicle Specific Summary Report (Priority)
Driver Specific Summary Report (Priority)
Vehicle Specific Summary Report (Priority)
Driver Speed Report
CANBUS Detail Report: This is a report of the data selected and given in the Attachment A paired up with position, time and drive information for two date and times in a graphic.
CANBUS Performance Summary Report: This is a report of total distance covered, total consumed fuel, total engine run time, total idle fuel consumption, total idle run time, total AdBlue consumption, average RPM, average gas pedal position, average vehicle speed, maximum RPM, maximum speed information generated for two desired dates.
CANBUS Fuel Level Detailed Report: This is a report of the fuel level data paired up with position, time and drive information for two date and times in graphically and numerically.
AdBlue Level Detailed Report: This is a report of the AdBlue data paired up with position, time and drive information for two date and times in graphically and numerically.
Vehicle and Drive Specific Malfunction Report (Priority)
Vehicle and Drive Specific Malfunction Report (Priority)
Driver Specific Education Success Ratio Report (Priority)
Off Operation Idling Summary Report (Priority)
Driver Category Report (Priority)

All warning signals such as Beginning of Exceeding Speed Limit Warning, Engine Temperature Violation Warning, Beginning of Idling Warning, Unauthorized Vehicle Start Warning, Engine RPM Violation Warning, Low Fuel Level Warning, Fuel Level Change Warning, Passenger Section Temperature Warning, Low Battery Voltage Warning, Periodic Maintenance Warning, Engine Oil Level Warning, Break Pad Thickness Warning can be communicated to fleet management, garage representatives and drivers simultaneously. Both driver and central fleet management receive instant warnings. Warnings are listed in Table 2.

Table 2: Warning List

Warning List
Sudden Speed Warning
Sudden Slowdown Warning
Beginning of Speed Exceeding Warning
End of Speed Exceeding Warning
Beginning Idling Warning
End of Idling Warning
Disconnection Warning
The Device Started Function Warning
Low Battery Warning
Key Switch on Warning
Key Switch Off Warning
Unauthorized Operation Warning
CANBUS Speed Violation Warning
Engine RPM Violation Warning
Engine Temperature Violation Warning
Low Fuel Level Violation Warning
Fuel Level Change Violation Warning
Card Read Warning
Passenger Section Temperature Warning
Engine Oil Level Warning
Engine Oil Pressure Warning
Engine Fuel Pressure Warning
Engine System Periodic Maintenance Warning
Break System Periodic Maintenance Warning
ECAS System Periodic Maintenance Warning
Transmission System Periodic Maintenance Warning
Periodic General Vehicle Maintenance Warning
Break Pad Thickness Related Warning
Break Circuit 1 and 2 Pressure Related Warning

Warning List
Sudden Fuel Level Change Warning
ABS System Malfunction Warning
Engine System Malfunction Warning
Break System Malfunction Warning
Suspension System Malfunction Warning
Transmission System Malfunction Warning
Low Battery Voltage Warning
Hand Break Pulled Warning and Audio Warning When the Transmission Arm was Drive Mode
Not-oust Warning

Idle time that first occurs in garages and driver performance evaluation reports are generated. In this system, vehicle specific data related to vehicles such as gas pedal, brake pedal, fuel level, transmission lever, bus speed, break pad thickness, all vehicle malfunction data, oil pressure, fuel pressure, engine temperature and related to the use of the vehicle such as position, temperature, route, line, and environmental effects are reported and analyzed to improve the use of assets and passenger experience.

At the end of driver performance evaluation, the drivers are categorized and training are organized to inform them about driving characteristics. The drivers are evaluated in 5 different levels according to their performance reports.

A. High Performing Drivers
B. Drivers Close to High Performing
C. Drivers with Average Performance
D. Drivers with Below Average Performance
E. Drivers with Low Performance

Driving maps of drivers based on their driving behavior captured through data registered in Black Box are generated and 680 IETT drivers are trained through general information given and individual mistakes made using the reports generated.

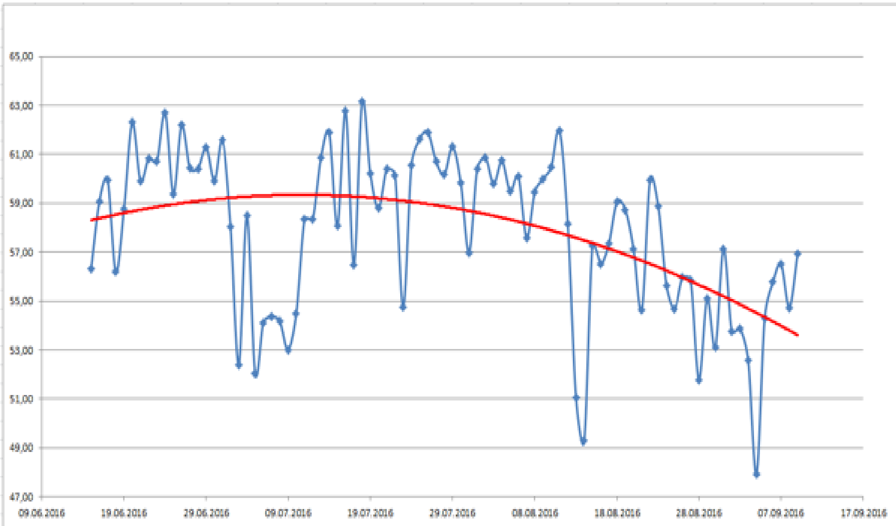
One of the data acquired with this project is occupancy rate of buses. In this system in which the weight of the buses can be measured, the occupancy rate of the buses can be determined and additional buses were added to the routes where there is high rate of occupancy. Passenger occupancy rates are integrated into MOBIETT, a smart phone application of IETT. In this way, the passengers are able to track the occupancy density of the bus that they are waiting for through their smart phones.

5.4. Results Achieved So Far

In this project, the driver behavior is observed carefully and effectively and their trainings are conducted. Safe, economic and comfortable driving traits are improved along with their environmental impact understanding. Due to improvement in the use of buses, maintenance costs are lowered. In parallel to trainings, there are improvement observed in passenger comfort level and trip standards and safety also was enhanced.

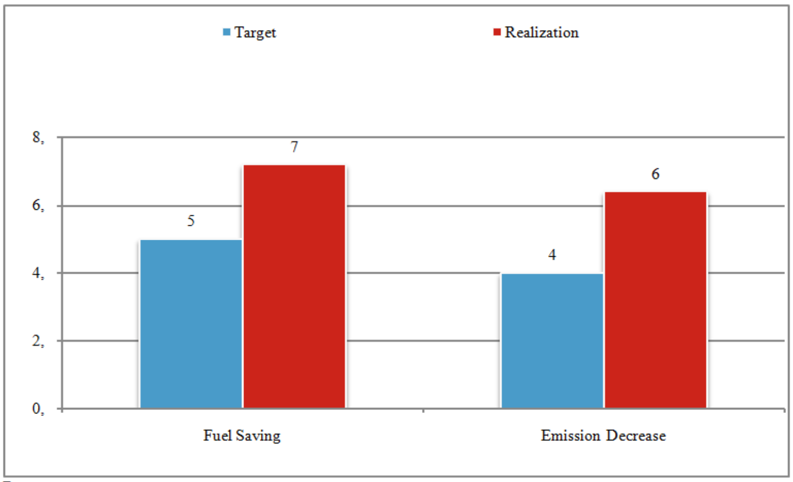
Identifying vehicle and driver behaviors malfunction management, fuel cost savings, identifying route characteristics, lowering emission rates are concrete results of Black Box Project. After the pilot implementation, improvements such as fuel savings, decrease in the number of accidents and lower emission rates are being observed.

Figure 2: Fuel Consumption for LT/100KM



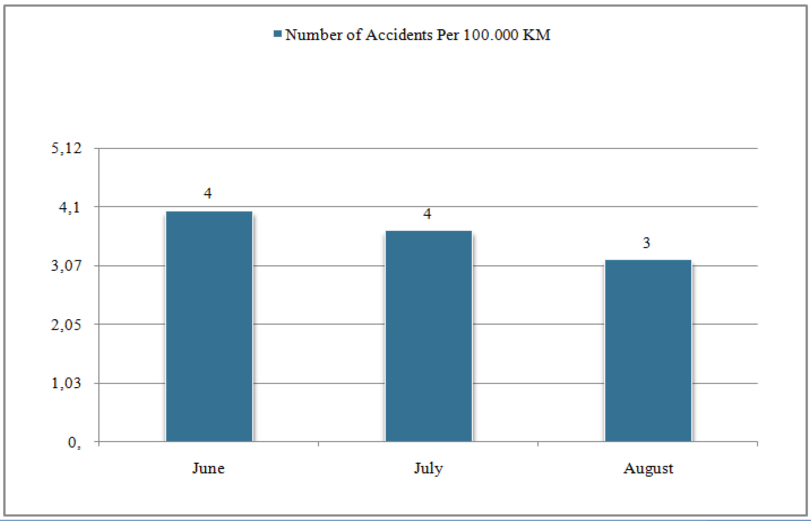
In the first phase of the project faulty behavior of 700 bus drivers were identified and 680 drivers went through the training. After the training, 7.2% fuel consumption, 21.27% decrease in the number of accidents, 6.4% decrease in emission rates has been observed. Sample fuel consumption graph is as follows:

Figure 3: Fuel Savings and Decrease in Emission Release



At the beginning of the project, the target for fuel savings were 5% but the realization was 7.2%. Emission release curtailment target was 4% and the realized figure was 6.4%. As a result, the project targets were realized above expectations. The related data is shown in Figure 3. At the end of the project, the training given to the driver allowed to decrease the number of accidents at a remarkable rate of 21.27%. The number of accident for a 3-month long period is as in the following:

Figure 4: June - July - August (2016) Months Accident Decrease Rates



The contributions of this pilot project are the development of bus manufacturers, the decrease of service loss due to malfunction management, the savings on fuel costs, the increase in the passenger comfort due to the evaluation and the training of the drivers, the safe travels and the increase in the standards. In addition to all of these, there are also social wins in a city where there are approximately 3 million urban commutes daily.

6. CONCLUSION

The outputs of IETT's Black Box Project can be examined in four fundamental results: Public transportation service companies, vehicle manufacturers, public transportation drivers and passengers who use public transportation.

Project outputs, with public transportation service companies, vehicle defects and improve previously identified and planned maintenance programs. In this way, the activities of the unit costs for maintenance and repair of vehicles will be reduced; at the same time, a reduction in fuel use will contribute to the country's economy with it.

In the visible improvement in fuel savings in the project is well known,. Probable malfunctions with the data from the vehicle and maintenance programs have been developed.

The second output is the vehicle manufacturers. Data that is received from the tools in the project provides the ability to track vehicle and monitor drivers for businesses that offer public transit service. Vehicle error data analyzed will contribute to the formation of new ideas and tools for the development of future vehicles. Therefore, the standards for vehicles in use will increase.

The third output is public transportation drivers. Public transportation companies, raising their awareness of the driver driving behavior with aggregated data will be capable of categorizing drivers numerically on issues such environmental consciousness. In this way, many individual errors that are not visible to management companies will be identified and resolved safely and economically through training offered to bus drivers. As a result, the sustainability of the public transport will be increased.

As part of the project, improvements in vehicle and driver behavior in public transport would increase passenger comfort and reliability of the journey. These gains will help passenger to be more satisfied with public transportation. At the same time, the data obtained can be used in mobile applications and information screens, and concrete outcomes of the project will cause social gains.

When all the contributions above are considered, the project will be an exemplary project to start in Istanbul first; and then to be disseminated to all of the Turkey and other international metropolitan cities in the world to achieve similar objectives. This Black Box project will contribute to the intelligent transportation systems, and bring many wins to transport companies, vehicle manufacturers, drivers and passengers.

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