Expert Systems with Applications 41 (2014) 5625–5635

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Algorithm-embedded IT applications for an emerging knowledge city: Istanbul, Turkey

Melih Bulu [a,*], Muhammed Ali Önder [b], Vural Aksakalli [b]

[a] Department of Management, Istanbul Sehir University, Kuşbakışı Caddesi No: 27 Altunizade Üsküdar, 34662 Istanbul, Turkey
[b] Department of Industrial Engineering, Istanbul Sehir University, Kuşbakışı Caddesi No: 27 Altunizade Üsküdar, 34662 Istanbul, Turkey

ARTICLE INFO

Keywords:
Algorithm-embedded information technology application
Information technology
Decision support system
Expert system
Knowledge city
Istanbul

ABSTRACT

As city resources around the world begin to stretch beyond capacity due to ever-increasing population, a major challenge for an emerging knowledge city is to maintain high-quality living conditions for its residents. It is therefore imperative existing city infrastructural resources are used in an optimal manner by minimizing cost and maximizing utility. Such infrastructural resources include transportation networks, electricity, water and natural gas lines, sewers, and waste sites. To that end, algorithm-embedded information technology tools have proven to be tremendously useful for city decision makers, and technologies using algorithm-embedded systems are being used more frequently than ever before. In particular, as one of the emerging knowledge cities in the world, Istanbul has been deploying such applications at various levels for better use of the city's resources. The purpose of this study is two-fold: classify algorithm-embedded information technology application areas related to management of infrastructural resources in a city in a systematic way, and; provide an up-to-date review of each application area and investigate the level of algorithm-embedded information technology use in Istanbul. The study has implications for the city officials as well as officials of other emerging world knowledge cities regarding the use of existing algorithm-embedded information technology tools in their cities.

1. Introduction

It is estimated by 2050, about 70% of the world's population will be living in cities (Lederborgen et al., 2011). Thus, efficient city resource management has become a top priority in world's knowledge cities. As stated in Yigitcanlar, O'Connor, and Westerman (2008a) and Ergazakis, Metaxiotis, and Psarras (2004), these resources include hard as well as soft infrastructures in the broad context of knowledge-based urban development policies. Clearly, a functional hard infrastructure system is a prerequisite for an efficient and effective soft infrastructure, both of which are vital for economic and spatial development of knowledge cities (Yigitcanlar & Lonnqvist, 2013). Nevertheless, actual models, tools, and cases in the emerging field of knowledge-based development are still scarce (Yigitcanlar, 2010). Besides, especially in cities with inadequate infrastructural resources, the limits of city resources will soon be reached and living conditions will deteriorate considerably. Thus, providing high-quality living conditions will become an even more challenging task for the world's developing knowledge cities in the near future. Developed knowledge cities already have well-working infrastructure. Therefore, it is easy to provide high-quality living conditions in these cities for citizens. On the other hand, this is not the case in emerging knowledge cities. Emerging knowledge cities should be dealing with the improvement of city infrastructure as one of their priorities (Yigitcanlar, 2009).

Today's emerging knowledge cities should not only deal with the improvement of soft infrastructures such as knowledge base, industrial infrastructure, quality of life, urban diversity, social equity (Van Winden, Van den Berg, & Pol, 2007), but also hard infrastructures such as transportation, energy and water distribution, waste and sewage collection, and so on. An emerging knowledge city can survive if it is able to improve its infrastructure, otherwise a knowledge city will face significant threat.

Knowledge workers are the main backbone of a knowledge city (Yigitcanlar, Velibeyoglu, & Martinez-Fernandez, 2008b). They work in consultancy, law, engineering, and design companies; they are the decision makers in the management level of organizations. Members of the academia can also be categorized as knowledge workers. Without them, a city could not survive as a knowledge city. Therefore, providing a livable environment to knowledge workers is of vital importance (Edvinsson, 2006). Knowledge workers should

* Corresponding author. Tel.: +90 505 838 3838.
E-mail addresses: melihbulu@sehir.edu.tr (M. Bulu), muhammedonder@std.sehir.edu.tr (M.A. Önder), aksakalli@sehir.edu.tr (V. Aksakalli).

http://dx.doi.org/10.1016/j.eswa.2014.02.013
0957-4174/

not spend their time due to inefficiencies of the city's infrastructure. Therefore traffic congestions, electricity breakdowns, water shortages, sewage and waste collection problems can affect a knowledge workers' productivity negatively in their business life. These kinds of inefficiencies will create extra cost not only for knowledge workers but also for the companies using these skilled human resources. If the city's infrastructure creates significant inefficiencies for knowledge workers, not only knowledge workers may decide to migrate to another city with better infrastructure, but also companies which are using those knowledge workers as well (Bulu, 2013).

The task of maintaining acceptable living standards in knowledge cities can be achieved by two means: (*i*) build new infrastructure and provide new services or (*ii*) improve the utilization rate of existing infrastructure and city facilities. Due to lack of physical space and qualified personnel as well as inadequate funding, building new infrastructure and providing new services is not always a feasible option. Therefore, it is of utmost importance to maximize the use of existing city infrastructural resources such as transportation networks (e.g., roads, railways, and metro lines), electricity, water and natural gas lines, sewage systems, and waste sites. This maximization, however, is not a straightforward task. There are numerous performance metrics and stakeholders for any given city service or facility. Nonetheless, recent advances in computing power, sensor technology, new methodologies for storing and processing large amounts of data, and the wide-spread use of the Internet has opened a vast window of opportunity for optimization of virtually all resources used in a city. Putting these information technology tools to use for better use of a city's resources is a particularly exciting new area for researchers as well as practitioners.

Of particular interest is Istanbul, which is an attractive metropolitan city home to more than 14 million people living in a very dense region. The population of the city quadrupled in the last three decades with inadequate planning and minimal infrastructural investments, all of which have resulted in an extraordinary burden on the city's infrastructural resources. Even though the city is faced with various problems due to immigration, Istanbul is trying to upgrade itself by using available opportunities. According to Bulu (2011), Istanbul is the most competitive city of Turkey. Istrate, Berube, and Nadeau (2012) study shows Istanbul is the seventh in the world with respect to growth rate index composed of income and employment variables. Istanbul is therefore one of those metropolitans where algorithm-embedded information technology (AEIT) (or IT tools in general) hold a tremendous potential for better use of the city's resources, facilities, and services.

The purpose of this study is to present a brief yet up-to-date review of AEIT tools aiming to improve use of existing city infrastructural resources, classify them in a systematic manner for further studies, and analyze Istanbul in these areas. Our goal is to illustrate that AEIT tools are a viable approach for easing the pressure of ever-increasing city populations on already stretched city infrastructure, facilities, and services, and determine the advantages and disadvantages of Istanbul in the use of such AEIT applications.

Our focus in this work is on "algorithm-embedded" IT applications, which specifically encompass any IT solution containing at least one algorithmic component. Such algorithms typically include the following: artificial intelligence, image processing, pattern recognition, prediction and forecasting, mathematical optimization, case-based reasoning, and expert or decision support systems. Our definition of AEIT applications particularly excludes systems that merely collect, summarize, and/or present existing data. Our purpose with this limitation to algorithm-embedded applications is to stay within the confines of the knowledge city paradigm. Another aspect of our study is it is limited to the systems used for increasing efficiency and effectiveness of infrastructural resources of a city. Specifically, in order to keep our analysis at a reasonable complexity, we excluded the following city resources from consideration: telecommunication systems, health and education facilities such as public hospitals and schools, airports, and safety issues not directly related to preservation of infrastructural resources. The reason for this exclusion is our point of view this work is primarily from a city municipality perspective, and those resources, at least in the case of Istanbul, are managed by private companies (telecommunication systems, airports) or other government agencies (public hospitals and schools). Thus we confined our research under five titles. These are (*i*) transportation, (*ii*) energy, (*iii*) city infrastructural safety, (*iv*) water management, and (*v*) waste management.

Our work is novel on two fronts. First, to our knowledge, it is the first of its kind to unify existing knowledge city applications by taking the rather unique approach of combining them under the umbrella of algorithm-embedded information technology applications. Second, we are not aware of any previous studies providing a comprehensive review and summary of existing AEIT applications in the City of Istanbul.

The rest of this manuscript is organized as follows: Section 2 presents reviews of AEIT applications in the literature as well as in the industry. Section 3 presents Istanbul as a case study for AEIT applications. Section 4 concludes our study, including our recommendations for Istanbul in light of the applications around the world as well as our suggestions for other metropolitans that might potentially benefit from the current AEIT applications in Istanbul. Several directions for future research are also discussed in Section 4.

2. Literature review

With the advance of technology, millions of digital devices are producing data about virtually all aspects of city life. All this information can be turned into knowledge, either by a trained professional or by an algorithm-embedded information technology application. With the aim of acquiring this knowledge and making efficient decisions to increase quality of life for citizens, researchers have proposed various approaches and methodologies in the literature and private sector companies such as IBM, Ericsson, CISCO, and NEC have been working with city governments in developing AEIT applications. This section reviews such AEIT studies in the literature and applications in the industry for each one of the five broad application areas identified above.

2.1. Transportation

Increasing population and travel needs of residents in cities are making the traffic conditions worse. The potential solution for this problem is to manage the traffic intelligently. The most popular area in traffic management is traffic light control, on which many studies were carried out and many applications were developed. De Schutter (1999) from Netherlands developed a traffic light control algorithm for a single intersection. Wiering, Veenen, Vreeken, and Koopman (2004) designed an intelligent traffic light control system and demonstrated its performance. Regarding traffic control systems other than traffic light control, Wen (2010) presented an intelligent traffic management system with Radio Frequency Identification (RFID) technology that can be used in other areas such as tracing criminals and traffic speed prediction.

Regarding public transportation, there are many studies and algorithms to optimize travel times and routes. With the aim of time efficiency, Chien, Ding, and Wei (2002) predicted bus arrival times with an artificial neural network algorithm and Bin, Zhongzhen, and Baozhen (2006) did a similar study using support vector machines. Liu, Pai, Chang, and Hsieh (2001) developed a path-planning algorithm to improve route efficiency. Planning and managing driver schedules clearly plays an important role in metropolitan cities. Wren and Wren (1995) designed a genetic algorithm for public transport driver scheduling.

Many metropolitan cities are implementing a traffic control application developed by their own R&D resources. Sen and Raman (2012) presented the specific areas in which intelligent systems are used in Indian cities. In the Californian city of Placentia, an advanced intelligent traffic control system is in use controls traffic lights and informs the public on the current traffic conditions. An AEIT application is being used in Tucson, Arizona, gathering real-time information on red, yellow, and green lights and on pedestrian densities for traffic light optimization.

Here we also look at the commercial AEIT applications in the transportation area. In cities where population is ever increasing and mobility is high, citizen satisfaction in the area of transportation is critical. In order to maintain high standards and use energy more efficiently, metropolitan governments need AEIT applications and collaborate with experts to overcome congestion issues. The City of Boston has invested in infrastructure for transportation instruments and these sources are providing data with great potential value. An IBM team in collaboration with Boston University developed a system to achieve Boston's climate and traffic improvement goals by analyzing transportation data. The city wanted an AEIT solution to reduce traffic-related carbon emissions, which accounts for about 25 percent of the city's total carbon emissions. Another goal of the system was to provide reliable transportation information for residents' travel decisions (IBM Smarter Cities Challenge - Boston., 2013). In addition to Boston, the IBM team developed solutions for transportation challenges in other cities around the world, one of which is Cheongju from Korea. The proposed problem was not related to traffic congestion but to encourage less use of private cars and more use of public transportation (IBM Smarter Cities Challenge - Cheongju., 2013).

Another city where IBM developed a solution for its transportation problem was Jakarta in Indonesia, one of the largest cities in the world with a population of about 10 million. Like other metropolises in the world, Jakarta is struggling to meet transportation needs of its residents. IBM reviewed current state of city's transportation alternatives and met with transportation leaders to identify potential changes in the system. In addition to recommendations about transportation system, IBM team members collaborated with IT experts of the city to develop an AEIT application that would provide real-time visibility into traffic elements. The application was not only for public travelers and drivers but also for public transport operators to dynamically optimize existing transportation resources (IBM Smarter Cities Challenge - Jakarta., 2013). The most important component of the application is travelers are empowered with real-time transport information and dynamic route suggestions with respect to current conditions.

Another private company, Ericsson, developed the "EkoBus" system in collaboration with city officials and deployed in the cities of Belgrade and Pancevo in Serbia (Smart City project in Serbia., 2013). The system makes use of public transportation vehicles to acquire environmental parameters and additional information for travelers such as bus locations and estimated arrival times to bus stations. These data taken through GPRS devices are stored in an external database, from which web application prediction models are developed. For monitoring environmental and end-user parameters, the system is available via web and a mobile application. It is also possible to request real-time information about arrival time of the bus to a specific bus station, which is beneficial for residents' travel decisions.

Both population increase and decrease in fuel reserves make government officials search for alternative transportation methods for their citizens. This search generally ends up with the need for railways and the use of water transport, which should be planned in a way that the boats will not crash among themselves and with other vehicles on the water. HSH Nordbank has a case study in Mumbai, India in order to ease the urban traffic congestion by making water transport effective, efficient, and safe (Water Transport Solutions., 2013). The company, in collaboration with a government agency, established a system to administer water transport of the city. Other than scheduling the vehicles, the system uses real time motion data and route information of vehicles to avoid congestion and crashes. When the data process has a significant output, the system sends directions to the vehicles via radio frequencies to optimize the total efficiency of the system.

2.2. Energy

Energy is one of the vital resources of a city. Increasing energy prices necessitates cities to use energy more efficiently and effectively. In the literature, most of the applications concern electricity. AEIT applications in electricity are predominantly in balancing the production and the distribution of electricity energy. The most popular application in this regard is the smart grid, which is an electrical grid for improving efficiency of production and distribution of electricity using information about behaviors of suppliers and consumers. Many studies and implementations have been carried out for this purpose. Hashmi, Hanninen, and Maki (2011) surveyed and listed smart grid concepts and studies worldwide. Zheng (2007) presented a smart grid application in India and Feisst, Schlesinger, and Frye (2008) described and analyzed a similar concept in the USA. As an application in the most crowded country of the world, Li (2009) described the transition of the Chinese smart grid.

In deregulated electricity markets, there exists a regulatory agency that tries to achieve market equilibrium between demand for electricity and supply by private and public sector companies by selectively accepting offers from these companies. For the sake of effectiveness and fewer errors, intelligent applications are required in this area as well. Generally each country is trying to develop its own application mainly for safety issues. Mingjun (2005) presented load and demand side management study in China. Miguélez et al. (2004) stated a practical approach for this issue in Spanish electricity market.

In order to analyze power quality, many studies with various methods have been undertaken. Analyzing and improving power quality can avoid serious problems and this is useful for both companies and governments. Neural networks, fuzzy logic, or newly defined algorithms are being used to develop this kind of applications. Key (1979) did an early study to diagnose power quality problems. Dash, Mishra, Salama, and Liew (2000) developed an artificial intelligence algorithm to deal with power quality issues.

With the newer resources of energy and higher population, production, distribution, and consumption of energy have become an important issue for metropolitan governments. To optimize the benefit from finite resources, government officials from cities are asking companies to develop an application or to design a solution. One solution implemented in the city of Glasgow in this category is from the company IBM who designed an approach for efficient energy use. This proposal will lead to reducing fuel expenditure through greater energy efficiency, thus releasing money back into the local economy and in turn creating employment and inward investment.

The City of Oslo asked the company Echelon to optimize its outdoor lighting system for reducing energy use. As a European city, an outdoor lighting system can account for 38% of city's total energy use, so optimizing the benefit injects money back into the local economy (Oslo Street Lighting System Slashes Energy Use., 2013). As a part of the solution by Echelon collaborating with Philips, streetlights were revised so they communicate over existing power line using Echelon's power line technology. The AEIT solution remotely monitors and controls the lights, dimming them based on traffic, weather, and available light. The system also analyzes the performance data of streetlights and identifies failures. The implemented solution achieved a good performance level with 62% reduction in energy consumption.

In Glasgow, despite considerable improvements in the quality and energy efficiency of housing stock in recent years, growth in the city's population has led to fuel poverty, which is currently at about 35% and increasing. For understanding the issue and acquiring data, IBM staff visited organizations, energy utilities, and homes of people in fuel poverty. They engaged in a data analysis phase with the Glasgow City Council to improve understanding of which people are in fuel poverty, where they are, and why (IBM Smarter Cities Challenge - Glasgow., 2013).

As an output of this work, the IBM team developed an application related to energy literacy for the use of citizens. The application is not integrated with electricity network but works online with manual inputs by end-users. This solution helps residents choose the best energy tariffs according to their energy use schedule, understand their energy bills, control their heating more efficiently, and take appropriate energy conservation measures. The general recommendations within the application are standardized but an algorithm using residents' energy usage data makes decisions about which energy tariff should be chosen. The proposed solution with an application will in turn help drive economic and environmental sustainability, which is the ultimate goal for using AEIT.

Not specifically implemented on a city but as a commercial application, CISCO developed an energy management tool called CISCO EnergyWise to realize significant cost savings and to increase energy efficiency (Cisco Energy Optimization Service., 2013). The solution works very well for within the IT infrastructure of a system and thus can be implemented on top of the information technology infrastructure of a city. After integrating the application with the current system, the service assesses power consumption profiles to identify non- and under-used assets, identifies inefficient systems according to these profiles, performs cost and benefit analysis for changes, and more importantly gives recommendations for energy efficiency and management. As expected from an AEIT application, this assessment provides analysis and decisions to help officers maintain availability while reducing energy consumption and costs. With this energy optimization service for design, installation, or operating practices that compromise efficiency, the government will be able to achieve the best efficient energy use.

Apart from the energy management tools, there is another popular area where many commercial applications are developed: the Smart Grid. Smart grids are very beneficial in cities with high population and they are becoming more efficient and effective with research and development projects. Many private sector companies are developing applications and solutions for smart grids and implementing in various cities. As an example, Ericsson implemented their smart grid concept in Stockholm that is moving toward a more sustainable city via effective energy end-usage (Stockholm Implementing Smart Grid., 2013). Moreover, their smart grid application can be connected from mobile devices and computers.

Smart grid devices and systems that smart grids are connected to output many kinds of data in Stockholm, one of which is use data. It is typically captured by time integrating demand measurements and may be acquired on certain time periods ranging from seconds to 30 days but residential metering may acquire data on 15 min periods. Another type of data is related to the power quality and taken from voltage and current waveforms. These waveforms data sampling are at very high rates for some devices performing power quality monitoring.

The perfect smart grid should work in real-time and proposed smart grid application by Ericsson analyzes and process consumer feedback in near-real time. It acquires real-time electricity price information, analyzes consumer data, and presents those data with appropriate decision suggestions on a private dashboard. The application provides visualization of smart grid data, large data storage, consumer demand response, and grid communication with the necessary facilities.

2.3. Infrastructural city safety

Floods, earthquakes, fires, and hurricanes are common disasters threatening a city's infrastructure. Studies on this subject can be categorized into two categories: early identification and applications in emergency conditions. An example for early identification of a disaster is Earthquake Decision Support System (EDSS) designed to support officials for making effective decisions, consisting of decision aiding models with a user communication. The intelligent system can assess the impact of an earthquake, estimate the cost of improvements, and estimate expected savings from these improvements. Berrais (2005) designed a knowledge-based AEIT application with a similar purpose for earthquake-resistant design. Being the most potentially dangerous energy system, Nelson (1982) developed an AEIT application to diagnose nuclear reactor accidents from a large knowledge base. This system monitors the facility, captures deviations, determines the significance, and makes suggestions for remedial action.

As an example for algorithm embedded application to manage emergencies, Wang and Wang (2003) analyzed decisions in emergency conditions and built an emergency decision support system that processes crisis information and knowledge with case-based reasoning. As an example for a more specific condition, Tufekci (1995) presented an effective decision support system for hurricane emergency management. The application uses optimization models, estimations for evacuation time, and real-time information about road conditions.

We now provide a discussion on commercial AEIT applications regarding infrastructural city safety. Clearly, natural disasters such as earthquakes and tsunamis are not preventable, and the best safety measure a city can take is to prepare and mitigate damage. In the case of tsunamis, AEIT applications take the form of early detection systems. For instance, a warning center using AEIT was established at Indian National Center for Ocean Information Services (INCOIS) receives real time data from national and international stations (Nayak & Kumar, 2008). The system has pre-defined scenarios and when an earthquake occurs, its characteristics are analyzed and an appropriate scenario is selected from the database for generating a recommendation. The algorithm embedded in the system uses real-time seismic, tide gauge, and bottom pressure measurements for generating the best possible recommendation.

Research on the impact of human actions on the natural world indicate humans have changed nature more rapidly over the past 50 years than in any comparable period (Millennium Ecosystem Assessment, 2005). Human mistakes as well as natural disasters have resulted in serious incidents like the Chernobyl disaster in 1986 and the Japanese tsunami disaster in 2011. Therefore infrastructural city safety is a critical and fundamental issue in metropolises. All metropolises are vulnerable to disasters such as earthquakes, volcano eruptions, hurricanes, or tsunamis, which make emergency and disaster management an important component of city safety and security.

Regarding early detection of disasters, NEC has devised a solution using sensors to gather data about disaster signs such as cameras, water level and rain metering, and seismometers (Emergency & Disaster Management, 2013). All data are fed into the system that decides whether an evacuation is needed. The solution works in three phases, which are observation, data analysis and decision-making, and announcement. In the first stage, data from the environment are acquired through earth observation satellite, land/river/rainfall observation system, and ocean bottom observation system and this information is gathered in the disaster management communication network. Then using the historical data and current data, data analysis algorithms are processed and decisions are made according to the analysis result. If there is a critical issue concerning public safety, the third phase is enabled and appropriate information is announced via the municipality disaster management radio system and public common system.

The federal government in Japan launched this emergency warning system in February 2007 (Smart City Resilience., 2013), providing its municipalities a plan to respond to disasters and this disaster management solution by NEC functioned at the time of Great Eastern Japan Earthquake, which led to a devastating tsunami. The impact of the tsunami was destructive, causing serious damage to cities and human life. However, the smart system prevented the tsunami from having even greater effects. In Tokyo, subways were evacuated, gas was disconnected, and nuclear reactor operations were stopped with the help of the decision made by the real-time working AEIT application. No trains derailed, no bridges collapsed, and fewer people died, helping the country recover from the disaster (Tokyo Metropolitan Disaster Prevention Center., 2013).

2.4. Water management

Increasing city populations cannot maintain their living standards without water, but we take water for granted without engaging in where it comes from (Our Region's Water, 2013). In urban areas, there are water suppliers owned by the government who manage many facilities bringing water from sources to your home. Helping these facilities plan and direct their water supplies efficiently is one of the main goals of municipalities. The water supply network in todays' cities is very complex, so AEIT applications should be considered in order to effectively handle water supply issues. These issues vary from forecasting water demand especially in peak load periods to providing water quality services.

Cheng, Yang, and Chan (2003) presented a decision support system to assist environmental management agencies to improve water quality in China. The analysis that municipal water quality does not depend only on environmental conditions but also on economic activities as well as social systems has led to a need for expert systems. Cheng's algorithm takes into account both environmental conditions and information related to economic activities and outputs decision suggestions for environmental management. This algorithm is implemented as an AEIT application by an environmental protection agency in the Yellow River Basin of China for providing an improved water quality service to the public.

Water demand forecasting is a critical component in water management. Bougadis, Adamowski, and Diduch (2005) presented an application for water demand forecasting for the city of Ottawa in Canada. As other cities have the same issue, existing water supply infrastructure does not satisfy the increasing population, this study was conducted for determining peak water demand management. The system uses regression, time series, and artificial neural network tools to predict peak water demand, which is required for the operation of urban water management systems. The effect of climatic variables such as rainfall and air temperature is fed into this AEIT application in addition to historical water demand data.

Regarding commercial AEIT applications, when compared to other areas, water management is not a popular area and projects and developments have been initiated only in recent years. IBM's strategic water management solutions include components for governments and water utilities. IBM developed and deployed a system in Ireland with the Marine Institute of Ireland. The solution uses sensor systems to monitor wave conditions, marine life parameters, and pollution levels and provides real time information for the Ireland economy as well as critical water condition predictions. "Regardless of industry or geography, smarter water management is an issue faced by every business and government on the planet," says Vice President for Big Green Innovations at IBM (IBM develops smart technologies to help combat global water issues, 2009). In this way, the system developed by IBM provides sufficient insight into near-term factors affecting the water supply and useful in helping the government to manage its water supply system.

As a well-known private company dealing with water management issues, Siemens has done hundreds of case studies not only for industry but also for municipalities. All of their solutions are integrated with information technology applications and some of them, more interesting for our study, include algorithms and optimization techniques. The water management system of the Inegol Industrial Site in Inegol, Turkey had difficulty meeting peak load demand conditions and the city was seeking capacity expansion, during which they collaborated with Siemens team to optimize the quality of water they supply (Turkish Industrial Wastewater., 2013). Siemens developed a water management solution for the expansion phase to maximize use and minimize power consumption, including a software application called BioFlowsheet + for biological process optimization, which analyzes the existing system, its parameters, and environmental conditions and gives decision parameters for maintaining water quality after the optimization stage. In this case, Siemens provided 35% less energy consumption in biological processes to its customer, which corresponds to a savings of €700,000/year (BioFlowsheet + Solution, 2013).

2.5. Waste management

When collection and disposal of solid waste in cities are unscientific and chaotic, it has severe environmental impacts on water pollution and global warming (Gupta, Mohan, Prasad, Gupta, & Kansal, 1998). As city populations continue to increase, these problems are becoming more and more complex, so the question of how to collect and manage waste effectively and efficiently is a top concern of city decision makers. Clearly, there needs to be a mechanism taking into account possible scenarios and providing optimum suggestions on how to manage solid waste. Waste management issue does not end with collection, the facility should also plan its container positions, schedule when and how waste is collected, and decide on how to keep and dispose of it. Karadimas, Kouzas, Anagnostopoulos, Loumos, and Kayafas (2005) presented an ant colony optimization (ACO) system specifically for urban waste collection vehicle routing in municipalities. The designed AEIT application uses waste positions, road network map, traffic conditions, and population information as well as working schedules and vehicle capacities as input, processing with a statistical analysis model and outputting optimal solution for urban solid waste collection problem.

After collecting solid waste, the problems turns to, as mentioned above, how the municipality will treat it. Waste management should be in such a way that the methane gas accumulation within the waste, which can contribute to global warming and can led to a huge explosion, is removed. The disposal and recycling phase is affected by the disposal positions of solid waste and this problem is handled through the decision support system presented in Haastrup et al. (1998). The system considers alternatives with respect to environmental consequences and provides choices regarding at which positions the waste should be kept according to the historical data and existing conditions.

In reference to commercial AEIT applications, as an emerging knowledge city AEIT application, a private company implemented its smart waste collection solution in Barcelona (Smart Waste Collection., 2013). The system is designed for collection routes optimization and efficient waste collection. The algorithm, which is working integrated with other systems in the city, captures real time data from trashcans about their fill condition. Container fill level is automatically detected in this way and the information related to this situation is sent to city service platform. According to container positions, their fill level, vehicle positions and vehicle conditions, and with the help of GPS technology, the algorithm plans and optimizes waste collection. The resulting optimized routes are sent to the vehicle computer.

3. Empirical analysis

3.1. Case study

Istanbul is a natural case study for an AEIT investigation in the context of an emerging knowledge city due to three reasons: (*i*) it is one of the most crowded and densest cities on the planet, (*ii*) it is one of the important emerging knowledge cities in the world due its strategic location and economic growth, and (*iii*) it has been facing serious efficiency and effectiveness problems in terms of infrastructure issues in the past several decades. Our goal in this section is to present Istanbul as a case study for AEIT applications specifically geared towards better management of the city's infrastructural resources. Having reviewed existing academic studies and commercial applications on this topic, we would like to put Istanbul in perspective and assess how it compares to other world cities in reference to AEIT applications.

Since its re-establishment by the Roman Emperor Constantine in the 4th century as the "New Rome", Istanbul has played a central role in history, serving as the capital of the Roman, Byzantine, and Ottoman Empires. The historic and cultural heritage of the city has put its signature on visitors and inhabitants, but the conservation of this heritage was unfortunately disregarded (Kocabas, 2006). Today, from a colorful art scene to many historical places and natural beauty, this metropolis offers a colorful city life to its visitors and residents from different religions and ethnic backgrounds as the most popular and the most crowded city of Turkey.

In the 1950s, two decades into the establishment of the modern republic, Turkey started to experience a political reform as industrial production gained a significant momentum (Istrate et al., 2012). Since then, Istanbul has been the foremost industrial center of the country because of its rich capital and technology bases. People from rural parts of Turkey started to migrate to Istanbul with the hope of better jobs and better living standards. Since 1950, the city population has reached 15 million from 1 million and is still on the increase. This rapid increase in population growth created crucial infrastructural problems as well as deficiencies in services and resources (Gunay & Dokmeci, 2012). Construction increased and green areas have come to the brink of extinction and urbanization and construction with no controls have resulted in inefficiencies in infrastructure use (Baz, Geymen, & Er, 2009).

The increase in the number of vehicles travelling on the roads, for example, has lead to a tremendous increase in traffic congestion because there are no compensating roads being built due to lack of physical space. Whatever the reasons of the traffic are, people are facing problems caused by traffic conditions. These problems have direct impact on the environment, economy, and the psychology of people exposed to the heavy traffic.

Spending too much time in traffic impacts people's attitudes and these changes in attitudes may turn into changes in behavior. Also since traffic jams mean more vehicles and more people waiting inside those vehicles, and this will lead to an increase in the emission of pollutants. Additionally these emissions come from the fuel the car uses. The more the people stay in traffic, the more fuel use due to inefficient idling of the car. These inefficiencies have certain costs and crucial impact on the economy. Waiting for one hour in traffic in Istanbul, for example, costs the population $500 M annually.

Turkey started the implementation of new economic policies in the 1980s. Particularly among these policies was the privatization of many State owned companies. Later on in the 2000s Turkey's liberalization continued, resulting in an annual 5% GDP growth rate. Istanbul has been the leading city of this growth. Istanbul's GDP was $59 billion in 2000 whereas it reached $132 billion in 2010 (Outlook to Istanbul 2011, 2013).

In total 59% of companies having foreign partners are located in Istanbul. Istanbulians' median age is 30. This young population is an important asset for the city. There are 51universities with 400,000 students. These universities are educating especially the young population of the city. The city captures almost 50% of Turkey's total intellectual property application numbers. This outcome can be seen as the result of knowledge worker accumulation of in the city. Global companies locate their regional headquarters in Istanbul. They are directing not only Turkey operations but also Middle East, Caucasus, North Africa and Central Asia operations from Istanbul as well. Progressing towards EU membership, by its regional location, Istanbul has the potential to become an important center for gathering the financial resources of the region and redirecting them to the above-mentioned regions. Istanbul is an attraction point for tourists. More than 10 million people visited the city in 2013. Istanbul has 50 5-star hotels and 44 new hotels are being built. The city has 92 shopping malls, 647 movie theaters, 147 theater halls, and 77 museums (Fact Sheet Istanbul 2013, 2013).

Governmental agencies in Istanbul recently started to effectively use information technology systems for controlling and monitoring Istanbul's problems related to energy, infrastructure, transportation, and resources. Some of the agencies responsible for providing better living standards to citizens are the Ministry of Transport, Maritime Affairs and Communications, Istanbul Municipality, Ministry of Energy and Natural Resources, and Ministry of Interior. The more these agencies engage in AEIT applications, the better and the easier the life for Istanbul residents will be.

However, rather than optimization of existing resources and services, Istanbul gave weight to providing additional services and building new infrastructure. For instance, the new metro bus project and expansion of the subway system have already dramatically enhanced the city's public transport infrastructure (Alpkokin and Ergun, 2012).

As discussed in detail in Section 2, we conducted a comprehensive review of the latest academic literature and commercial projects regarding the use of algorithm-embedded information technology applications for management of infrastructural resources of cities. As a result of our literature review, industry applications' analysis, and interviews with domain experts, we categorize AEIT applications under five groups: (*i*) transportation, (*ii*) energy, (*iii*) city infrastructural safety, (*iv*) water management, and (*v*) waste management. Table 1 shows the summary of academic studies and commercial projects. We use the same structure to scrutinize AEIT use in Istanbul.

We first prepared a questionnaire with 14 questions, which is presented in Appendix 1. Our questionnaire specifically included questions aimed at understanding AEIT applications in

Table 1
Summary of global AEIT applications for each area or subsystem combination.

Area	Subsystem	Description	Academic studies	Commercial application
Transportation	Traffic Light Control	Optimization of traffic lights at road intersections	Wiering et al. (2004) and De Schutter (1999)	Oslo Street Lighting System Slashes Energy Use (2013) by Echelon
	Route and time planning	Decisions related to travel path and travel time are made according to real-time traffic and path data	Liu et al. (2001) and Chien et al. (2002)	Smart City project in Serbia (2013) by Ericsson
Energy	Production and distribution	Electricity production and consumption schemes are optimized with analysis of past, meteorological, and constitutional data	Feisst et al. (2008) and Zheng (2007)	Stockholm Implementing Smart Grid (2013) by Ericsson
	Governmental regulations	Organizing and scheduling consumption and productions offers and determining optimal decisions	Mingjun (2005) and Miguélez et al. (2004)	Cisco Energy Optimization Service (2013)
	Quality applications	Diagnosing power quality problems like over loading	Dash et al. (2000) and Key (1979)	IBM Smarter Cities Challenge–Glasgow (2013)
Infrastructural city safety	Early identification of disasters	Determination of disasters like hurricane and earthquake is performed	Berrais (2005) and Nelson (1982)	Emergency & Disaster Management, (2013) by NEC
	Applications for emergency conditions	Supporting decisions are made about what should be done which ways should be used in a certain emergency condition	Wang and Wang (2003) and Tufekci (1995)	Smart City Resilience, (2013) by NEC
Water management	Water management	Issues related to water such as water quality and water demand are evaluated and results are provided to support decisions	Cheng et al. (2003) and Bougadis et al. (2005)	IBM develops smart technologies to help combat global water issues (2009)
Waste management	Waste management	Waste collection routing and timing decisions are supported with the analysis of working schedule, vehicle data, traffic data, trash-can positions, etc	Karadimas et al. (2005) and Haastrup et al. (1998)	Smart Waste Collection (2013) by Urbiotica

transportation, energy, city infrastructural safety, water distribution, and waste management areas. In addition, we asked for a comparison of Istanbul with leading cities in AEIT applications. In these questions we wanted to learn what more can be done for Istanbul and which unique AEIT application experiences can serve as a success story for other world cities. Last, we asked recommendations for Istanbul on AEIT applications. Next we requested 13 domain experts to respond to this questionnaire. The experts were selected within three groups: academicians, private sector experts, and public officials in R&D departments within the Istanbul Municipality. The responses of the domain experts were analyzed, compiled, and summarized for each one of the five AEIT application areas. In addition, we analyzed the websites of relevant organizations in order to find complementary data. These experts along with their affiliations and positions are listed in Table 2.

According to the Turkish local governing system, infrastructure services in Istanbul are provided by different government agencies. These are: (*i*) Istanbul Municipality, (*ii*) Ministry of Transport, Maritime Affairs, and Communications, (*iii*) Ministry of Energy and Natural Resources, and (*iv*) Ministry of Interior. Ministry of Transport, Maritime Affairs, and Communications are responsible for maintenance of city highways and the two Istanbul straight (Bosporus) bridges. Istanbul Municipality provides infrastructure services via its sub-companies. Based on the responses of the domain experts, we tabulated Istanbul Municipality sub-companies and other companies along with their functions and the AEIT applications they are using in Table 3.

Analysis of the expert responses revealed that there are currently three AEIT applications in Istanbul involving management of the city's infrastructural resources: two in the transportation area, and one in the infrastructural safety area—there is also some mention to the other relevant areas. These AEIT applications are described below.

3.2. Public bus travel time prediction system

Istanbul's public bus system is the largest in Europe with more than 5,000 buses transporting millions of passengers on a daily basis. Despite each bus line having a fixed time schedule, it is virtually impossible for bus drivers to adhere to these schedules due to unpredictable traffic congestion as well as weather conditions. On the other hand, significant deviations from planned arrival times at bus stops cause tremendous frustration and dissatisfaction for passengers.

Table 2
Interviewee list.

Categories	Interviewees	Affiliations	Positions
Group 1: Academics	Interviewee #1	Istanbul Koc University	Professor
	Interviewee #2	Istanbul Sehir University	Asst. Professor
	Interviewee #3	Istanbul Sehir University	Asst. Professor
Group 2: Public Sector Experts	Interviewee #4	The Municipal Data Processing Corporation of Istanbul (BELBIM)	Project Development Manager
	Interviewee #5	Istanbul Municipality Traffic Department	Senior Software Engineer
	Interviewee #6	Istanbul Gas Distribution Company (IGDAS)	Innovation Systems Manager
	Interviewee #7	Istanbul Gas Distribution Company (IGDAS)	Project Evaluation Engineer
	Interviewee #8	Istanbul Traffic Management Company (ISBAK)	R&D Manager
	Interviewee #9	Istanbul Traffic Management Company (ISBAK)	Project Manager
	Interviewee #10	Istanbul Waste Management Company (ISTAC)	R&D Manager
	Interviewee #11	Istanbul Transportation Company	Ex-General Manager
Group 3: Private Sector Experts	Interviewee #12	Information and Communication Technology Company (IBM)	Manager of University Relations
	Interviewee #13	Information and Communication Technology Company (Verisun)	General Manager

Table 3
Algorithm-embedded information technology applications in Istanbul for management of infrastructural resources.

Function	Company/unit name	AEIT applications	Web address
Natural Gas Distribution and Management	IGDAS (Istanbul Gas Company)	Earthquake natural gas shutoff system	www.iski.gov.tr
Public Bus System Management	IETT (Istanbul Public Transport Company)	Public bus travel time prediction system	www.iett.gov.tr
Roads and Traffic Lights Management	ISBAK (Istanbul Traffic Management Company)	Fully adaptive traffic management system	www.isbak.gov.tr
Metro Lines Management	Istanbul Ulasim (Istanbul Subway Management Company)	No AEIT Applications	www.istanbul-ulasim.com.tr
Water Distribution and Management	ISKI (Istanbul Water Management Company)	No AEIT Applications	www.igdas.com.tr
City Waste Collection and Management	ISTAC (Istanbul Waste Management Company)	No AEIT Applications	www.istac.com.tr
City Fire Department	Istanbul Fire Brigade	No AEIT Applications	www.ibb.gov.tr/sites/itfaiye/workarea/Pages/AnaSayfa.aspx
Electricity Distribution and Management – Anatolian Side	AYEDAS (Istanbul Power Distribution Company)	No AEIT Applications	www.ayedas.com.tr
Electricity Distribution and Management – European Side	BEDAS (Istanbul Power Distribution Company)	No AEIT Applications	www.bedas.gov.tr
Disaster Management and Coordination	AKOM (Istanbul Disaster Prevention Company)	No AEIT Applications	www.ibb.gov.tr/sites/akom/ Documents/index.html

Therefore, a municipality sub-company, BELBIM (The Municipal Data Processing Corporation of Istanbul), implemented a bus travel time prediction system generating short-term predictions of arrival of a bus at down-stream stops based on historical data and current traffic data. The system is based upon combining historical and current travel time data minimizing deviations between predicted and observed travel times using statistical techniques. Specifically, the system optimally blends historical data with current data using a Kalman filter for road segments, which are defined as road portions between two consecutive bus stops. The historical data component for a segment is calculated as the weighted average of the past four weeks' travel time for the given day of week within a one-hour window. This weighting is achieved via exponential smoothing of data points after removal of statistical outliers. The current segment travel time data, on the other hand, is computed as the average of travel time of all the buses having traveled on the same road segment within the past half hour, again after removal of statistical outliers. These historical and current data points are then blended using a Kalman filter, which essentially outputs a linear combination of the two values proportional to their standard deviations.

Major bus stops in Istanbul are now equipped with LCD screens displaying predicted arrival times of buses in real-time, thereby providing valuable information to passengers. In particular, there are generally several alternative bus routes with different route durations and comfort levels between given two locations in Istanbul. In addition, these bus routes usually operate at different time intervals in different days of the week (weekday, Saturday, and Sunday). Thus, informing passengers waiting at bus stops about predicted arrival time of buses is of utmost importance for journey planning purposes.

3.3. Fully adaptive traffic management system

Adaptive traffic control systems have been in use for many years in different countries in conjunction with their local traffic conditions. In Istanbul, there are approximately 1,600 signalized intersections that are connected to a center and can be controlled remotely. For the purpose of controlling these intersections in an efficient and effective way, ISBAK, a subsidiary company of the municipality, developed an AEIT application named Fully Adaptive Traffic Management System (FATMS). It is an adaptive traffic light control system where light durations are determined dynamically in real time, by optimizing signalized intersections' green/yellow/red times based on parameters such as traffic volume and queue in order to minimize the average delays and average number of stops.

FATMS model mainly consists of four major components. The first one is called the "FATMS Designer", which allows an operator to define and configure any type of junction using a graphical user interface in a user-friendly manner. The main role for this component is to collect junction related configuration parameters and to store them to the main system as well as allowing operator making some off-line calculations with given parameters regarding the signalized junctions.

The second component of the system is the "FATMS Engine", which continuously runs on a dedicated server and implements all the jobs for managing and controlling the junctions. It is the core component of the entire FATMS system and can work in an isolated (for a single intersection) or coordinated (for a group of intersections) manner and manages all the junctions defined in the first component using measured volume, occupancy, headway, speed, and queue lengths data from the field collected by vehicle sensors.

The third component is the "FATMS Communication Engine", which manages all data traffic between junctions on the field and the FATMS system core. Finally, the fourth component is the web based "FATMS Monitor", which allows operators and system managers to monitor the system easily. It also generates some alerts if there is any critical situation such as communication failure and sensor failures, and if it is necessary, system managers can make some decisions and apply them to the field.

The algorithm embedded in this traffic flow model takes real-time data from the field as well as historical data as input for the application and processes these data with an optimization method based on fuzzy logic and neural networks. As an output, FATMS automatically creates ideal signal times for the whole system as well as providing rapid reaction to anomalies that may occur in traffic conditions without any intervention of the operators. It can also adapt itself to the cases occurring in the field in a short time period.

By implementing output decisions, FATMS decreases total delay times, number of stops, vehicle fuel consumption, and carbon emission values. Benchmarking studies show FATMS may decrease vehicular delay by up to 30% and may save $400 fuel cost per hour at signalized intersections. In this way, total travel times on the traffic road network and traffic jams are correspondingly reduced eventually resulting in increased driving comfort.

3.4. Earthquake emergency natural gas shutoff system

IGDAS (Istanbul Gas Distribution Industry and Trade Incorporated Company), a subsidiary company belonging to the municipality for natural gas distribution all around the city, has the ability to shutoff the natural gas distribution of any region in its network. In case of any safety related problem on the lines or on the field diagnosed by an application or human expertise, shutoff decisions can easily be implemented for a specified region or the entire city. In order to make this decision automated and faultless, IGDAS cooperated with TUBITAK (The Scientific and Technological Research Council of Turkey) in developing an AEIT application outputting the shutoff decisions in the event of an earthquake.

This emergency management AEIT application collects real-time earthquake data, processes them with an embedded algorithm, and decides whether to shutoff the gas distribution of a district. The communication between SCADA (Supervisory Control and Data Acquisition) System in IGDAS and the instruments on the fields is performed via GPRS modems providing real-time field data delivery. This communication network has alternatives such as satellite access and controls the natural gas lines of the city. When there is a data delivery interruption on the current network, the system automatically switches its data communication methods.

Nearly 120 earthquake sensors all around the city and many sensors measuring movements in seabed and temperature change in seawater have been placed to provide data to the server for automatically closing the gas supplying regulators. When a movement occurs, earthquake sensors measure accelerations in three dimensions and send the data to the server generating a closing signal. All movements do not generate gas-closing signal and an algorithm runs between the sensor data and shutoff decisions. The AEIT application gets movement data as well as corresponding movements in seabed and temperature change in seawater as input parameters and generates a decision according to the following conditions:

- Whether the movement data exceed threshold value.
- What proportion of threshold value is exceeded.
- Whether the number of sensors exceeding threshold value is significant.
- Whether there is any movement in seabed (through data taken from sensors in seabed).
- Whether there is any change in seawater temperature.

With the conditions stated above, the system runs a rule-based algorithm with the objective of minimizing false positives with the reason being that and shutting off the gas distributing regulators unnecessarily would result in a significant profit loss for IGDAS.

3.5. Other application areas

Two different private companies in Istanbul manage the electricity distribution. AYEDAS is responsible for electricity distribution on the Anatolian side and BEDAS is responsible for the European side. According to data coming from these two private companies, there are currently no AEIT applications used in Istanbul electricity distribution network. In addition, based on the interview results, there are currently no AEIT applications under deployment in the areas of water distribution or waste collection pertaining to management of infrastructural resources.

4. Discussion and conclusion

Emerging knowledge cities are not only competing with each other but also with developed knowledge cities as well. Providing efficient and effective working infrastructure is imperative for these cities. Use of AEIT applications may provide an opportunity to emerging knowledge cities in order to catch up with the developed ones. Thus, we advocate the need for efficient algorithm-embedded information technology applications for knowledge city transformation. In this study, we reviewed the literature for analyzing the use of AEIT systems for management of an emerging knowledge city's resources. Because of a lack of physical space as well as opportunities for additional resources and services, AEIT applications are vital for optimizing benefit gained from a city's resources. In addition to effective and efficient use of facilities and services, AEIT applications have significant contribution to reducing human errors. The way forward for these systems is not only replacing humans with expert systems, but also verifying and validating human decisions. This way, the quality of life in cities can be increased with the optimal use of resources and with less human error. This improvement is vital for an emerging city in order to attract knowledge workers who are the main inputs of a knowledge city.

After a thorough review of existing literature and commercial applications, we categorized AEIT applications into five areas. Our observation was traffic light management and public transportation are the most popular areas for AEIT applications. In the energy area, most of the literature is about the distribution optimization of electricity. Therefore smart grid AEIT applications are very popular. Disaster management is an important area for cities and two particular areas under this title are AEIT applications for preventing disasters and those for managing disasters. Clean water is a vital source for the residents of a city. AEIT applications are in use for managing water distribution in the cities. The last area we considered was waste management. Clearly, cities that manage waste efficiently will save money. Furthermore, they will have the opportunity of saving through recycling the waste. Additionally, energy production from waste can be a side benefit. If a city is using AEIT applications in all of these five categories, it can be considered to be investing in being more efficient and effective. Obviously, the mere fact a city is using AEIT applications does not guarantee an efficient and effective city operation. Nonetheless, if there are no AEIT applications deployed in a metropolitan city, it can be argued there is probably significant room for improvement regarding better use of the city's resources.

Our analysis reveals AEIT applications are used mainly in management of traffic in Istanbul. This is perhaps not surprising as traffic is one of the biggest problems in today's Istanbul. Therefore, decision makers are very confident to allocate budget for traffic related projects. Similarly, due to the 1999 earthquake, there is a priority on earthquake related projects. In particular, Istanbul has developed a sophisticated AEIT application regarding emergency natural gas shutoff during an earthquake. Istanbul's infrastructure areas of water distribution and waste management systems do not have any AEIT applications. Therefore, experts and decision makers should look at these areas for potential benefits of AEIT applications.

Our learning from Istanbul is two-fold: (*i*) the public bus travel time prediction system is a useful AEIT application that can be used in other emerging knowledge cities, especially for those where predicting bus travel times is difficult due to traffic congestion—such as Istanbul—and; (*ii*) a sensor-based system for emergency shutoff of natural gas during an earthquake is likely to provide significant benefits in emergency situations in earthquake-prone cities—such as Istanbul.

Our recommendation for Istanbul is, when comparing the world AEIT applications with the ones in Istanbul, Istanbul can use more AEIT applications in the management of various infrastructural resources in order to make them more effective and efficient. These areas are smart grid applications, waste collection routing and timing decisions, and water quality and water demand evaluation. Currently Istanbul is using its resources inefficiently due lack of AEIT applications in these areas. Moreover problems regarding to electricity distribution, waste collection, water quality and water supply can be managed better if Istanbul make an attempt on using AEIT applications in these areas. Decision makers of Istanbul in these potential AEIT applicable areas should be trained. Thus decision makers will have the basic knowledge regarding to benefits and applicability of AEIT applications in their responsible areas. Besides it is recommended to Municipality of Istanbul for providing more resource for the application of AEIT projects in infrastructure related projects. These new investments will upgrade the infrastructure of the city.

Another recommendation area for Istanbul is regarding to coordination problems due to management structure of Istanbul's infrastructure. There are decision makers in Istanbul Municipality, Ministry of Transport, Maritime Affairs and Communications, Ministry of Energy and Natural Resources, Ministry of Interior, and private companies responsible for management of infrastructure resources. Unfortunately there are few efficient coordination mechanisms between these decision-making authorities. This management structure causes considerable mismanagement of the infrastructure of Istanbul as well as existing AEIT applications.

Clearly, AEIT systems are a vital part of a knowledge city functions. As cities become smarter, a critical task is to measure, compare, and rank AEIT application use in cities. Our study lays a foundation for achieving this goal by unifying existing applications under the AEIT umbrella as well as categorizing them into application areas and subsystems. Future studies can build upon our approach and offer methodologies to achieve this task. For instance, a weighting system can be designed so a city can be graded with respect to AEIT use level. Thus cities would become more easily comparable regarding the use of intelligent systems.

Another future direction is the integration of various AEIT systems. For example, if an energy management system is coordinated in accordance with the traffic system, this might potentially increase the efficiency and effectiveness of both systems. Therefore, our AEIT analysis approach can be further enhanced by accounting for integration and coordination of various AEIT systems in a knowledge city.

Appendix 1.

AEIT Interview Questionnaire.

Algorithm-Embedded Information Technology (AEIT) applications are gradually becoming widespread in different areas of our daily life. AEIT applications can be defined as intelligent systems in which at least one algorithm is in place. For instance, if there is a software system working to minimize the waiting times of vehicles during red light at a road intersection, we can include this system into AEIT scope because in this system, there is an algorithm to minimize waiting times of vehicles at traffic. Thanks to AEIT systems, it is becoming possible to enable city infrastructures to work more efficiently.

We are conducting an academic study to understand the applications of AEIT in different areas of infrastructural resource management in Istanbul. By saying "infrastructure", we mean services required to be provided by the city such as transportation, energy production and distribution, safety, emergency management, water management and waste management.

We have two goal in this study: (1) to determine which algorithm embedded information technologies from different cities of the world are being used in Istanbul, and (2) to examine the potential contribution of the experiences of Istanbul in AEIT area to the other cities around the world.

In our study, we aim to reveal the developed and developing aspects of Istanbul in the area of AEIT. Thank you for your contribution to our study by answering appropriate questions listed below.

Name-Last Name:

Organization:

Position:

QUESTIONS:

1. How do you evaluate the position of Istanbul, on the area of Algorithm Embedded Information Technology (AEIT) applications in infrastructure systems (e.g., transportation, energy production and distribution, safety, water and waste management, etc.) with respect to other leading metropolitans?
2. In land, sea, air, and rail transportation, what AEIT applications are there in Istanbul for programming, control, time and route planning? Please explain.
3. What AEIT applications are there in Istanbul in the area of production, distribution and quality of energy? Please explain.
4. What AEIT applications are there in Istanbul in the area of safety? Please explain.
5. What AEIT applications are there in Istanbul in the area of emergency management? Please explain.
6. What AEIT applications are there in Istanbul in the area of water management? Please explain.
7. What AEIT applications are there in Istanbul in the area of waste management? Please explain.
8. Are there any other AEIT applications in infrastructure operation of Istanbul? Please explain.
9. Do you think that AEIT use in Istanbul makes infrastructure opportunities more efficient? If your answer is yes, please explain briefly in which infrastructure (e.g., transportation, energy production and distribution, safety, water and waste management, etc.) there is an efficiency increase, and how it occurs?
10. If you think that AEIT applications are not sufficiently used in the infrastructure of Istanbul, please explain the reasons (e.g., lack of qualified men power, executive vision, materials, etc.).
11. Is there any AEIT application in Istanbul that may be a model for other cities around world? If there is, please elaborate these examples.
12. In your opinion, what are the views of local executives in regards to AEIT applications? Do you think they take initiative to enable comprehension and application of these applications? Please explain.
13. In your opinion, does it make a serious impact on the operations in Istanbul (in daily life) if AEIT applications are implemented on the infrastructure of Istanbul in all areas in which AEIT applications are available? Please explain.
14. Please explain any other issues that you want to point out.

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