Algorithm-Embedded Information Technology Applications in Knowledge Cities and the Case of Istanbul

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Industrial and Systems Engineering.

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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 that existing city resources are used in an optimal manner by minimizing cost and maximizing utility. Such resources include physical resources such as transportation networks, schools, clinics, electricity, water and natural gas lines, sewers, and waste sites and human resources such as physicians, teachers, and other qualified personnel. 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 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.

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

Bilgi Şehirlerinde Algoritma Gömülü Bilgi Teknolojileri Uygulamaları ve İstanbul'un Durumu

Muhammed Ali ÖNDER

Öz

Dünyadaki şehir kaynakları, sürekli artan nüfustan dolayı en üst kapasitelerine ulaşmaya başladıkça; gelişen bir bilgi şehri için büyük bir zorluk, sakinleri için yüksek kalite yaşam şartlarını sürdürebilmektir. Bu yüzden, şehrin mevcut kaynaklarını, maliyeti en aza indirerek ve sağlanılan faydayı maksimuma çıkararak ideal bir düzeyde kullanmak, mecburi ve kaçınılmazdır. Bu kaynaklar; ulaşım ağları, elektrik, su ve doğal gaz hatları, kanalizasyon, atık alanları, okul ve hastaneler gibi fiziksel kaynakları ve doktor, öğretmen ve diğer kalifiye personel gibi insani kaynakları içermektedir. Bu maksada yönelik olarak, algoritma gömülü bilgi teknolojileri araçlarının, şehir karar vericileri için son derece faydalı olduğu kanıtlanmıştır, ve algoritma gömülü sistemleri içeren teknolojiler, daha önce hiç olmadığı kadar sık kullanılmaktadır. Hususi olarak, dünyadaki yeni gelişen bilgi şehirlerinden birisi olarak İstanbul, şehir kaynaklarını daha iyi kullanmak adına bu uygulamaları çeşitli düzeylerde uygulamaktadır. Bu çalışmanın amacı iki türlüdür: bir şehirdeki kaynak ve hizmetlerin yönetimi ile ilgili algoritma gömülü bilgi teknolojileri uygulama alanlarını sistematik bir yol ile sınıflandırmak, ve her bir uygulama alanının güncel bir gözden geçirmesini yapmak ve İstanbul'daki algoritma gömülü bilgi teknolojileri kullanımı seviyesini incelemektir. Bu çalışma, devlet görevlileri için ve diğer yeni gelişen bilgi şehirlerinin görevlileri için de, mevcut algoritma gömülü bilgi teknolojileri araçlarının kendi şehirlerinde kullanımı ile ilgili sonuç ve tavsiyeler sunmaktadır.

Anahtar Sözcükler: Algoritma gömülü bilgi teknolojileri uygulaması, Bilgi teknolojileri, Karar destek sistemi, Akıllı sistem, Bilgi şehri, İstanbul

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Abbreviations

ACLS	**A**dvanced **C**ardiac **L**ife **S**upport
ACO	**A**nt **C**olony **O**ptimization
AEIT	**A**lgorithm **E**mbedded **I**nformation **T**echnology
AHP	**A**nalytic **H**ierarchy **P**rocess
CBT	**C**omputer **B**ased **T**raining
CDSS	**C**linical **D**ecision **S**upport **S**ystems
CADIA	**C**omputer **A**ssisted **D**ensitometric **I**mage **A**nalysis
EDSS	**E**arthquake **D**ecision **S**upport **S**ystem
EHR	**E**lectronic **H**ealth **R**ecord
EU	**E**uropean **U**nion
FATMS	**F**ully **A**daptive **T**raffic **M**anagement **S**ystem
GDP	**G**ross **D**omestic **P**roduct
GPRS	**G**eneral **P**acket **R**adio **S**ervice
GPS	**G**lobal **P**ositioning **S**ystem
INCOIS	**I**ndian **N**ational **C**enter for **O**cean **I**nformation **S**ervices
IT	**I**nformation **T**echnology
LCD	**L**iquid **C**rystal **D**isplay
MEA	**M**illenium **E**cosystem **A**ssessment
QSM	**Q**uality **S**creening and **M**anagement
RFID	**R**adio **F**requency **Id**entification
RODIA	**R**elative **O**ptical **D**ensity **I**mage **A**nalysis
R&D	**R**esearch & **D**evelopment
SCADA	**S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition
USA	**U**nited **S**tates of **A**merica

Chapter 1

INTRODUCTION

It is estimated by 2050, about 70% of the world's population will be living in cities (Lederbogen *et al.* [1]) . Thus, efficient city resource management has become a top priority in world's knowledge cities. As stated in Yigitcanlar *et al.* [2] and Ergazakis *et al.* [3], these resources include physical as well as human resources in the broad context of knowledge-based urban development policies. Clearly, a functional physical infrastructure system is a prerequisite for efficiency and effectiveness of human resources, both of which are vital for economic and spatial development of knowledge cities (Yigitcanlar and Lönnqvist [4]). Nevertheless, actual models, tools, and cases in the emerging field of knowledge-based development are still scarce (Yigitcanlar [5]).

Besides, especially in cities with inadequate 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 and services. 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 and services as one of their priorities (Yigitcanlar [6]).

Today's emerging knowledge cities should not only deal with the improvement of human resources such as knowledge base, human expertise, industrial infrastructure, quality of life, urban diversity, social equity (Winden *et al.* [7]), but also physical resources such as transportation, energy and water distribution, waste and sewage collection, clinics, educational institutions and so on. An emerging knowledge city can survive if it is able to improve its resources, services, and knowledge utilization, otherwise a knowledge city will face significant threat.

Knowledge workers are the main backbone of a knowledge city (Yigitcanlar *et al.* [8]). 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 [9]). Knowledge workers should not spend their time due to inefficiencies of the city's resources. Therefore traffic congestions, inefficiencies in patient care and education, scheduling problems, 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 resources create significant inefficiencies for knowledge workers, not only knowledge workers may decide to migrate to another city with better infrastructure and services, but also companies which are using those knowledge workers as well (Bulu [10]).

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 resources 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 resources such as transportation networks (e.g., roads, railways, and metro lines), electricity, water and natural gas lines, clinics, schools, teachers, physicians, and specialist expertise, 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 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 [11], Istanbul is the most competitive city of Turkey. Istrate *et al.* [12] 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 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.

The city resources, of which AEIT applications are able to improve the utilization, are divided into two sub categories in our perspective: physical resources and human resources. Physical resources are generally categorized as infrastructure of the services, which can be increased if additional funding and physical places exist. However, human resources can be defined as human expertise and knowledge, which cannot be easily increased and improved with more funding. AEIT applications can improve the utilization gained from physical infrastructure as well as from human resources such as human knowledge, teacher expertise, and physicians' knowledge. This utilization of resources includes both maximizing the use of physical and human resources; and validating decisions and minimizing errors of human resources.

Validating decisions of human expertise is very crucial for the life standards of citizens. An inefficient decision or a wrong choice of a city official may result in traffic congestion and electricity shortages, or may lead to diseases or human illnesses. According to World Health Organization, for example, industries with a perceived higher risk such as the aviation and nuclear industries have a much better safety record than health care. There is a 1 in a million chance of a traveler being harmed while in an aircraft. In comparison, there is a 1 in 300 chance of a patient being harmed during health care, which is directly related to effective and efficient use of human knowledge and expertise. (World Health Organization [13])

Our analysis of AEIT applications is specifically categorized under the following seven titles:

(i) Transportation

(ii) Energy

(iii) City infrastructural safety

(iv) Water management

(v) Waste management

(vi) Healthcare

(vii) Education

This study 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 thesis is organized as follows: Chapter 2 presents reviews of AEIT applications in the literature as well as in the industry. Chapter 3 presents Istanbul as a case study for AEIT applications. Chapter 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 Chapter 4.

Chapter 2

AEIT Applications in the Literature and the Industry

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 seven 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. Schutter and Moor [14] from Netherlands developed a traffic light control algorithm for a single intersection. Wiering *et al.* [15] designed an intelligent traffic light control system and demonstrated its performance. Regarding traffic control systems other than traffic light control, Wen

[16] 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 *et al.* [17] predicted bus arrival times with an artificial neural network algorithm and Bin *et al.* [18] did a similar study using support vector machines. Liu *et al.* [19] 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 [20] 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 [21] 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 [22]). 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 [23]).

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 [24]). 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 [25]). 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 [26]). 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 *et al.* [27] surveyed and listed smart grid concepts and studies worldwide. Zheng [28] presented a smart grid application in India and Feisst *et al.* [29] described and analyzed a similar concept in the USA. As an application in the most crowded country of the world, Li [30] 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 [31] presented load and demand side management study in China. Miguélez *et al.* [32] 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 [33] did an early study to diagnose power quality problems. Dash *et al.* [34] 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 [35]). 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 [36]). 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 [37]). 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 [38]). 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 minutes 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 [39] designed a knowledge-based AEIT application with a similar purpose for earthquake-resistant design. Being the most potentially dangerous energy system, Nelson [40] 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 and Wang [41] 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 [42] 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 and Kumar [43]). 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 (MEA, Millennium Ecosystem Assessment [44]). 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 [45]). 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 [46]), 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 [47]).

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 [48]). 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 *et al.* [49] 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 *et al.* [50] 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 [51]). 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 [52]). 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 [53]).

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 *et al.* [54]). 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 et al. [55] 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.* [56]. 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 [57]). 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.

2.6 Healthcare

AEIT applications have been used in medicine commonly with the name CDSS (Clinical Decision Support Systems). With the increased interest in preventing medical errors leading to adverse health outcomes and even death, computer-based systems are being developed to improve patient safety and treatment effectiveness. An AEIT application can help a physician in identifying healthcare problems of a patient and assist in medical decision making.

The methodology employed in a CDSS can be expert-based or it can be pre-defined algorithms including artificial neural networks or Bayesian networks. The first implications of AEIT applications emerged with EHR (Electronic Health Record) systems. EHR is defined as a collection of electronic health information about individual patients and populations. EHR is not considered an AEIT application, but with the addition of a decision support system, a patient management system can be integrated into EHR software as did Zedmed Clinical. The system checks the medication provided to a patient and other data as input, processes the algorithm, and outputs the result as a notification to the physician if a treatment has any adverse outcome on the patient.

Apart from integrated AEIT applications, numerous other studies have been carried out for medical diagnosis. One early algorithm-based application in healthcare was done in the 1990s by United Healthcare Corporation. UHC developed its first AEIT application, Quality Screening and Management (QSM), to analyze the healthcare records of its members (Leatherman, Peterson, Heinen, and Quam [58]). For a certain condition, QSM compares the care prescribed by a physician to the treatment recommended by pre-defined practice principles and national standards, and outputs certain information about treatment and patient as a report. Analysis results were then used to produce quality management actions, to identify improvement strategies, and to examine the impact of these systems. In spite of the lack of direct support at the moment the care is performed, it enables the healthcare providers to improve the performance of treatment.

Similarly, Relative Optical Density Image Analysis (RODIA) is a software solution used in medical imaging and diagnostics in Poland (Kornacki and Glinkowski [59]). It allows performing a quantitative analysis of medical images such as X-ray and ultrasonography and enables early detection of problems. Input for RODIA is in the form of a graphic file and does not require pre-processing. Another example of image analysis, Computer Assisted Densitometric Image Analysis (CADIA), requires standardization of input. It provides image transformation in order to obtain medical results not visible before.

Other than algorithm-based software development for medical problems, some studies and analysis running algorithms were carried out to diagnose certain diseases. Burroni *et al.* [60] performed computer assisted diagnosis of melanoma by analyzing digitized images of skin lesions and Joo *et al.* [61] studied computer-aided diagnosis of breast cancer with differentiation between benign and malignant breast nodules based on multiple ultrasonography features.

For the specific case of HIV and AIDS, there are several studies to diagnose, which differ in the way they are developed and take different forms of expertise. Sloot *et al.* [62] used grid technology to develop an HIV diagnosis system. Masizana-Katongo *et al.* [63] developed an AEIT application developed by Microsoft for HIV and AIDS information. In the application, some information about HIV and AIDS is derived through inference as opposed to simple data retrieval.

In addition to the diagnosis of diseases, applications on quality of components and procedures are very crucial in terms of managerial decisions. Problems with hospitals and clinics and the methods physicians are using should be analyzed for the sake of quality of health services. Geraci *et al.* [64] designed an application-based model to identify hospitals with potential quality problems by comparing hospital profiles based on risk-adjusted death. These kinds of algorithm-embedded methods should be implemented to see whether the services provided are in high quality level.

Here we also look at the commercial AEIT applications in medicine. Because healthcare is the most basic service for a person and there are many institutions providing healthcare services in a city, this service area is quite popular from a commercial companies' perspective. Thus they are developing alternative information technology applications for the use of physicians. These IT applications may not be algorithm-embedded due to a lack of healthcare expertise and the companies are participating in partnership with medical institutions to provide intelligent solutions for medical issues.

One of these companies developing an AEIT application for healthcare is IndiGO standing for "individualized guidelines and outcomes" (10 Innovative Clinical Decision Support Programs [65]) . IndiGo takes patient data as input from patients' history, risk factors, and treatments, applies mathematical algorithms on them, and exports the results into a model simulating proposed healthcare processes and human physiology. Other than patient specific analysis, IndiGO interfaces analyze databases to identify risky patients and therefore suggest appropriate treatments according to historical data and rule-based user-defined algorithms. After the determination of the patient to be treated, the system can form patient specific care programs for improved healthcare management.

An example of a more specific solution than IndiGO, IBM researchers in Haifa, Israel developed a solution for diagnosis of a certain disease, AIDS in this case. The application EuResist, which IBM participated in, includes mathematical models providing a smarter selection to suggest the best drug combinations for any given HIV variant (IBM and EU Partners Create a Better Way to Fight AIDS Virus [66]). Because HIV has the ability to develop resistance to some antiretroviral drugs, physicians need to continuously monitor and prescribe new treatments to remain effective, which the EuResist application does instead of a doctor. The application is based on genotype information, runs an algorithm-based analytic model, and outputs the right combination of drugs that work for the longest period of time, which is near 76% accurate and better than human expertise and all other commonly used HIV resistance prediction tools.

As mentioned in the academic literature survey above, AEIT applications in healthcare are not limited to human diseases and there are companies providing solutions on component and hospital performance management issues, one example of which is one MicroStrategy provides. MicroStrategy Intelligence Platform provides performance improvements to hospital officials using a benchmarking algorithm (Business Intelligence Solutions for Healthcare Providers [67]) . After giving hospital-specific data as an input to the model, the system provides performance measures against comparative benchmarks to help improve processes and performance in the organizations.

2.7 Education

Computers have been used in the education area for many decades for which computer-based training (CBT) systems are employed. In these systems, there is no intelligent algorithm running, that is, learner's ability and reactions are not taken into account. Although this kind of systems enabled effective learning process, they do not provide same attention a student can receive from a human expert. Therefore, research within the field of artificial intelligence in education area has been gaining importance to assist with educational diagnosis and assessment. There are many applications and studies to provide students a more effective learning process, providing a simulated real life experience or learning through playing a game.

An example for intelligent tutoring system is the Advanced Cardiac Life Support (ACLS) described in Eliot and Woolf [68]. In this application, the learner takes a role to provide emergency life support for patients having heart attacks. The application provides a realistic learning environment with a simulation, monitors the student's actions, evaluates performance, and acts accordingly according to the algorithm inside. The aim is to test knowledge, to allow learner to experience real problems, which is not likely in a traditional class.

Hwang *et al.* [69] proposes an approach developing the knowledge of the system by examining teachers' problem-solving behaviors. Therefore, the AEIT application performs as a teacher to help the learners in enhancing their web-based problem-solving skills. Other than improving learning efficiency, algorithm-based applications can be used in managerial actions. Generating timetables is a common issue for all institutions of higher education and usually done by taking previous year's schedule and modifying it by hand. Sbeity *et al.* [70] described a genetic algorithm to construct annual exam timetable by satisfying most of the teachers' preferences, which is performed according to their scores obtained with analytic hierarchy process (AHP) technique.

In reference to commercial AEIT applications in the area of education, as an emerging city AEIT application, IBM implemented its smart education solution in Hamilton County Education Department, USA (Deeper Student Insights Leave a Deep Impact [71]) . Department officials asked IBM researchers to develop a solution and a model with a rule-based algorithm analyzing the performance of students who have a tendency to drop out of school. The reference point and the decision criteria in this application is the average level of students in nearly 78 schools. Day-to-day data of the students are loaded in the model and an analytic algorithm with user-defined sections processes the data with curriculum, class, and teacher data. As an output of this algorithm-embedded application, the system gives decision support suggestions for at-risk students regarding curriculum and teaching changes as well as suggestions about future performance problems. The model also gives suggestions for class level and school level, as well as student level.

These intelligent tutoring systems may sometimes include solutions for scheduling problems but because this problem is very common in institutions and may be very complex, we suggest examining scheduling problem as a separate AEIT area. Because this issue is widespread across institution, especially of higher education, many commercial companies are developing solutions regarding many possible real-life parameters.

Mimosa, one of the commercial applications in this popular area, developed a parametric scheduling application in Finland (Schedule Software for School and University Timetables [72]). The intelligent system needs student, teacher, classroom, and lecture data as input and runs a multi-dimensional analysis algorithm on the data. Then it outputs more than one solution to help decision-making. However the system supports decision criteria such as teachers' preferences so it will be able to give the best solution to help decide the most appropriate schedule.

Chapter 3

The Case of Istanbul

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,

(iii) it has been facing serious efficiency and effectiveness problems in terms of infrastructure and resource-related 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 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 (Kocabaş [73]).

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.* [12]). 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 and Dokmeci [74]). 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 *et al.* [75]).

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 $ 500M 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 [76]).

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 51 universities 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 [77]).

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, Ministry of Healthcare, Ministry of National Education, 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 [78]).

As discussed in detail in Chapter 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 city resources. As a result of our literature review, industry applications' analysis, and interviews with domain experts, we categorize AEIT applications under seven groups:

(i) transportation,

(ii) energy,

(iii) city infrastructural safety,

(iv) water management,

(v) waste management,

(vi) healthcare,

(vii) education.

Table 1 shows the summary of academic studies and commercial projects. We use the same structure to scrutinize AEIT use in Istanbul.

Table 3.1: 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.* [15], De Schutter [14]	Oslo Street Lighting System Slashes Energy Use [35] 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.* [19], Chien *et al.* [17]	Smart City project in Serbia [25] by Ericsson
Energy	Production and Distribution	Electricity production and consumption schemes are optimized with analysis of past, meteorological, and constitutional data.	Feisst *et al.* [29], Zheng [28]	Stockholm Implementing Smart Grid [38] by Ericsson
	Government-related Regulations	Organizing and scheduling consumption and productions offers and determining optimal decisions.	Mingjun [31], Miguélez *et al.* [32]	Cisco Energy Optimization Service [37]
	Quality Applications	Diagnosing power quality problems like over loading.	Dash *et al.* [34], Key [33]	IBM Smarter Cities Challenge-Glasgow [36]
Infrastructural City Safety	Early Identification of Disasters	Determination of disasters like hurricane and earthquake is performed.	Berrais [39], Nelson [40]	Emergency & Disaster Management [45] 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 & Wang [41], Tufekci [42]	Smart City Resilience [46] 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.* [49], Bougadis *et al.* [50]	IBM develops smart technologies to help combat global water issues [51]

Table 3.1: (continued)

Area	**Subsystem**	**Description**	**Academic Studies**	**Commercial Application**
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.* [55], Haastrup *et al.* [56]	Smart Waste Collection [57] by Urbiotica
Healthcare	Clinical Decision Support System	By using treatment and patient history data, system assists physicians in identifying healthcare problems.	Kornacki & Glinkowski [59]	Commercialization of the Archimedes Model (2014) by IndiGO
	Applications for Special Diseases	Diseases such as prostate, HIV, and AIDS are diagnosed with data analysis, sound analysis, or image process.	Masizana [63]	IBM and EU Partners Create a Better Way to Fight AIDS Virus [66]
	Constitution-related Problem Diagnosis	Problems with hospitals, clinics, and treatment methods are examined and quality of health services is evaluated.	Gordon *et al.* [64]	Benchmarking for Hospitals to Assess Relative Performance [67] by MicroStrategy
Education	Intelligent Tutoring Systems	Teaching application that monitors student's action, evaluates performance, and acts accordingly with case-based reasoning.	Hwang [69]	Deeper student insights leave a deep impact [71] by IBM
	Scheduling	Annual exam and course scheduling according to school and instructor data.	Sbeity *et al.* [70]	Mimosa Scheduling Software [72]

We first prepared a questionnaire with 17 questions, which is presented in Appendix 1. Our questionnaire specifically included questions aimed at understanding AEIT applications in transportation, energy, city infrastructural safety, water distribution, waste management, healthcare, and education 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 21 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 and governmental agencies. The responses of the domain experts were analyzed, compiled, and summarized for each one of the seven 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.

Table 3.2: 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
	Interviewee #4	Ozyegin University	Asst.Professor
	Interviewee #5	Marmara University	Professor
Group2: Public Sector Experts	Interviewee #6	The Municipal Data Processing Corporation of Istanbul (BELBIM)	Project Development Manager
	Interviewee #7	Istanbul Municipality Traffic Department	Senior Software Engineer
	Interviewee #8	Istanbul Gas Distribution Company	Innovation Systems Manager
	Interviewee #9	Istanbul Gas Distribution Company	Project Evaluation Engineer
	Interviewee #10	Istanbul Traffic Management Company	R&D Manager
	Interviewee #11	Istanbul Traffic Management Company	Project Manager
	Interviewee #12	Istanbul Waste Management Company	R&D Manager
	Interviewee #13	Ministry of Health	Project Manager
	Interviewee #14	Ministry of Health	Assistant Specialist
	Interviewee #15	Ministry of Education	Web Solutions Specialist
	Interviewee #16	Provincial Directorate for Education	Project Coordinator
	Interviewee #17	Public Hospital	Physician
	Interviewee #18	Istanbul Transportation Company	Ex-General Manager
Group3: Private Sector Experts	Interviewee #19	IBM	Manager of University Relations
	Interviewee #20	IT Company (Verisun)	General Manager
	Interviewee #21	IBM	Software Manager

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,

(iv) Ministry of Interior,

(v) Ministry of Health,

(vi) Ministry of National Education.

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.

Table 3.3: Algorithm-embedded information technology applications in Istanbul for management of physical and human resources.

Function	Company	AEIT Application	Web Address
Natural Gas Distribution and Management	IGDAS (Istanbul Gas Company)	Earthquake natural gas shutoff system	www.igdas.com.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.iski.gov.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
Public Healthcare Services Management	Ministry of Healthcare	Baby Vaccine Alert System	www.saglik.gov.tr

TABLE 3.3: (continued)

Function	**Company**	**AEIT Application**	**Web Address**
Local Public Healthcare Services Management	Istanbul Local Health Authority	Chronic Disease Follow-up System & Hospital Information Management System	www.istanbulsaglik .gov.tr
Local Public Educational Services Management	Istanbul Provincial Directorate for National Education	E-School Weekly Course Distribution System	istanbul.meb.gov.tr

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

3.1 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.

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.

3.2 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.

3.3 Earthquake Emergency Natural Gas Shut-off 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.

3.4 Hospital Information Management System

Acibadem Hospital in Istanbul has a 4-layer information management system called HIMS. Comprehensive clinical information about patients is collected into HIMS on a regular basis, including data about treatment, drugs, and various lab tests (Koç, Şengül, Özkaya, and Gökçe [79]). With respect to AEIT applications, HIMS includes the following sub-systems: drug-drug interaction system, drug dosage adjustment system, allergy warning system, and critical diagnosis system.

Drug-drug interaction system is used to assess appropriateness of a drug prescribed to a patient after treatment considering the various side effects of the drugs. This system is pre-loaded with all the drug information of patients. When a physician enters a drug for a patient, a pop-up window shows drug warnings, which may be red (indicating high-level interaction), green (medium level interaction), or blue (low level interaction).

HIMS also includes a drug-food interaction alert algorithm. After adding a new drug for the patient, system opens a warning window showing drug-food interaction information to the physician. The drug-drug and drug-food interaction systems are also used in the Hospital's pharmacy for detection of drug interactions after treatment in the Hospital.

As a part of the critical diagnosis system, the Hospital makes use of a heart surgery system that supports physicians' decisions determining open-heart surgery risk of patients. Inputs to this system are patient information upon admission to the hospital, medical history and clinical status of the patient, and previous cardiac progress. The system then computes a risk factor for open-heart surgery using machine learning techniques.

3.5 Baby Vaccine Alert System

Ministry of Health is an active user of business intelligence systems with the Health Net System monitoring the health status of city residents. This intelligent application keeps track of demographic information about patients, vaccine information, and dates when patients are vaccinated (Turkeli [80]). The system is effectively and efficiently in use especially for infants. The system generates suggestions and warnings for physicians according to the following date data for each vaccine type:

- Date when the vaccine is first applicable,
- Date when the vaccine is last applicable,
- Date when the vaccine was applied, if applicable.

When a vaccine application date is not between the limits or if the vaccine is becomes overdue, the system gives a warning to the patient's physician.

3.6 Chronic Disease Follow-up System

Hospitals in Istanbul provide a mobile health service to their patients measuring their blood pressure and diabetes with a mobile measurement tool on a daily basis. The tool, which is able to measure diabetes both when the patient is hungry and satiated, sends patient measurement data to the system with Bluetooth technology and mobile communication services (Mobile Chronic Disease Follow-up Program [81]). The algorithm inside the application comes into play at this stage, which continuously analyzes data from patients. When any abnormality is observed with respect to current and historical medical data, qualified medical personnel get in touch with the patient and provide medical consultancy over the telephone.

3.7 E-School Course Timetabling System

Ministry of Education has a web-based IT system to gather, analyze, and report data from all public schools (E-School Weekly Course Distribution Application [82]). A subsystem of this online application enables school officials to find a feasible timetable for their schools. Inputs to this application are information about the courses, teachers, and interactions between them. The output of the system is a feasible timetabling solution, which can be then uploaded to the school's IT system. The system can account for teacher availability information as a constraint for more appropriate solutions. Once all the data and constraints are entered, the system employs certain algorithms and reports a feasible timetable for the school. In particular, the system needs the following specific data to function:

- Course start and finish hours,
- Course teachers and sections,
- Teacher information (total number of courses and total duration for each teacher),
- Course information (total number of classes and total duration of courses),
- Student information (total number of courses for each class-section and total number of courses).

3.8 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 interview results, there are currently no AEIT applications under deployment in the areas of water distribution or waste collection pertaining to management of infrastructure resources.

Chapter 4

Summary and Conclusions

Emerging knowledge cities are not only competing with each other but also with developed knowledge cities as well. Providing efficient and effective working services 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 seven areas. Our observation was traffic light management, public transportation, and human disease diagnosis 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. Another 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. Healthcare is perhaps the most critical area for AEIT applications because these applications' effectiveness is directly related to life of human beings. In this category, special diagnosis applications are common in a satisfactory level but almost all decisions of a physician should be supported by an AEIT application and there should be an integrated system for healthcare decision support as a human body is an integrated system. The last area we study is education; scheduling solutions are quite popular in this area but intelligent tutoring systems capturing teachers' expertise are not widespread enough in applications. If a city is using AEIT applications in all of these seven 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 and human disease diagnosis and follow-up 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. Also healthcare related solutions are getting popularity in the last decade because the public services in healthcare were below the critical level and are becoming better and better, still remaining below the good level. 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 three-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,

(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,

(iii) human disease diagnosis and follow-up applications are being used in a satisfactory level but they should be enhanced and the areas implemented should be increased.

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 resources in order to make them more effective and efficient. These areas are smart grid applications, waste collection routing and timing decisions, water quality and water demand evaluation, and intelligent tutoring systems for students and trainers. 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, water supply, and educational and teacher efficiency problems 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 resources and services. There are decision makers in Istanbul Municipality, Ministry of Healthcare, Ministry of National Education, Ministry of Transport, Maritime Affairs and Communications, Ministry of Energy and Natural Resources, Ministry of Interior, and private companies responsible for management of resources and services. Unfortunately there are few efficient coordination mechanisms between these decision-making authorities. This management structure causes considerable mismanagement of the resources 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 A

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 resources to work more efficiently.

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

We have two goals in this study:

(1) to determine which algorithm embedded information technologies from different cities of the world are being used in Istanbul,

(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 the questions 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 systems related to physical resources (e.g., transportation, energy production and distribution, safety, water and waste management, schools, clinics, etc.) and human resources (e.g., physicians, teachers, 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. What AEIT applications are there in Istanbul in the area of healthcare? Please explain.
9. What AEIT applications are there in Istanbul in the area of education? Please explain.
10. Are there any other AEIT applications in physical resources operation of Istanbul? Please explain.
11. Are there any other AEIT applications in human resources operation of Istanbul? Please explain.
12. Do you think that AEIT use in Istanbul makes resource opportunities more efficient? If your answer is yes, please explain briefly in which area (e.g., transportation, energy production and distribution, safety, water and waste management, healthcare, education, etc.) there is an efficiency increase, and how it occurs?

13. If you think that AEIT applications are not sufficiently used in Istanbul, please explain the reasons (e.g., lack of qualified men power, executive vision, materials, etc.).

14. Is there any AEIT application in Istanbul that may be a model for other cities around world? If there is, please elaborate these examples.

15. 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.

16. In your opinion, does it make a serious impact on the operations in Istanbul (in daily life) if AEIT applications are implemented on the resources of Istanbul in all areas in which AEIT applications are available? Please explain.

17. Please explain any other issues that you want to point out.

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