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International Case Studies of Smart Cities

Tel Aviv, Israel

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Institutions for Development Sector

Fiscal and Municipal Management Division

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TEL AVIV

ISRAEL

IDB-KRIHS Joint Research

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THE REPUBLIC OF KOREA

KRIHS
Korea Research Institute for Human Settlements

GDPC
Global Development Partnership Center

Abstract

This case study is one of ten international case studies developed by the Inter-American Development Bank (IDB), in association with the Korean Research Institute for Human Settlements (KRIHS), for the cities of Anyang, Medellin, Namyangju, Orlando, Pangyo, Rio de Janeiro, Santander, Singapore, Songdo, and Tel Aviv. At the IDB, the Competitiveness and Innovation Division (CTI), the Fiscal and Municipal Management Division (FMM), and the Emerging and Sustainable Cities Initiative (ESCI) coordinated the study. This project was part of technical cooperation ME-T1254, financed by the Knowledge Partnership Korean Fund for Technology and Innovation of the Republic of Korea. At KRIHS, the National Infrastructure Research Division coordinated the project and the Global Development Partnership Center (GDPC) provided the funding.

In recent years, Tel Aviv has developed a unique bottom-up approach toward its Smart City project, focusing its efforts on direct resident-oriented services rather than expensive, large-scale infrastructure. This case study explains Tel Aviv's strategy, demonstrating how a high level of smart urban services was achieved using decentralized, low-cost methods. The report provides details on the approach, such as its reliance on the local startup ecosystem, its creation of services using open municipal databanks and public–private partnerships, and its emphasis on lightweight services that interact directly with residents. The case study analyzes the strengths and weaknesses of Tel Aviv's approach, discussing the technologies, processes, and strategies that can be used to implement a cost-effective smart city initiative.

JEL Codes: L86, L88, H72

Keywords: Smart cities, information systems, startup companies, municipal government, Tel Aviv

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Executive Summary

This report describes how the city of Tel Aviv, Israel, designs, develops, and maintains a set of smart services, taking several important steps toward fulfilling the promise of the Smart City initiative. Tel Aviv's unique smart city approach of focusing on its residents rather than on physical infrastructure was acknowledged when it received the World Smart City Award at the 2014 Smart City Expo World Congress held in Barcelona. This case study describes how one city achieved a high level of smart urban services and created impact using a decentralized and low-cost methodology, building on a modular approach and an open architecture. This approach is innovative and cost effective compared to those employed in several other smart city processes, making it possible to infer a more general model from this case study.

Tel Aviv's core smart city project is Digi-Tel, a platform that provides personalized access to services and information via email, text messages, a tailored website, and a tailored mobile application. The information provided is uniquely relevant to the citizens, taking into account their location, interests, needs, and other personal attributes. Digi-Tel creates a connection between the city and its residents by alerting them about neighborhood road works, showing them the nearest bike-sharing station, or offering discounts to cultural events. It also promotes active participation, as residents can report on anything from activities and events to city obstacles or hazards. In addition to Digi-Tel, the city has several smart service projects in areas such as smart traffic management, safety and security, emergency management, and parking. Many of these services are provided through partnerships with local startup technology companies.

The Tel Aviv smart city model has several significant strengths. These include:

- A focus on residents.
- Relatively low cost.
- The ability to receive ongoing feedback.
- Collaboration with startups and with the private sector.

These strengths spur more business opportunities for creative industries in the city, increase residents' satisfaction, and create shared ownership of the Smart City initiative. All of these strengths combine to create an image of the city and the local government as innovators, attracting desirable creative industries and young professionals to interact with the city.

At the same time, since the smart city is being built piece by piece, its many projects do not always coincide. The city currently supports several control centers for different functions, which creates redundancy in human resources and deficiencies in data integration.

Overall, in a world that is realizing the power of bottom-up processes in smart cities, Tel Aviv is setting an example of how to harness this approach for systemic benefit, putting forth an array of practical solutions and conceptual frameworks. This model, despite its weaknesses, may serve as a beacon for sustainable smart city agendas around the globe.

Seaside View of Tel Aviv (photo: Sergei25).

TEL AVIV, Israel

1. Introduction

1.1 Overview of the City

Tel Aviv is Israel's second most populous city and its main business, technological, and cultural center. In November 2014, the city won first prize in the Smart City competition held at the Smart City Expo in Barcelona (EU, 2014), shifting global focus to its unique approach that leverages technology to improve the quality of life in the city. This report outlines Tel Aviv's Smart City and derivative projects that affect the city and its residents.

Tel Aviv has been Israel's main urban center since its founding in 1909. From its very foundation by Jewish immigrants looking to create "the New York of the Middle East" to its current status as a global city, Tel Aviv has always had the beat of a metropolis. While the city itself has some 414,000 inhabitants, it is the focal point of the Tel Aviv metropolitan area, the country's most populated region, home to 3.6 million people (46 percent of Israel's population) in an area of 60 square kilometers (Statistical, 2013). Therefore, some municipal policies are executed at the regional level by central government offices (such as public transportation), and some are executed at the municipal level (such as parking). The city itself is located on the Mediterranean coastline, in Israel's geographic center, providing it with four typical seasons and a warm Mediterranean climate.

As Israel's leading business center, Tel Aviv is home to the Tel Aviv Stock Exchange, major bank headquarters, and many leading media, law, and financial firms—the main industries in the city's economic structure. In the past few years, however, Tel Aviv became known throughout the world as the center of Israel's vibrant high-tech and startup ecosystem, boasting one of the world's top ecosystems (Milian, 2012). The self-proclaimed "Startup City" has more than 700 startup companies and more than 1,000 entrepreneurs, and the numbers continue to grow each year.

This ecosystem is supported by many factors. First, as a leading business center, Tel Aviv is one of Israel's most affluent areas, supporting an average per capita gross domestic product (GDP) of US$42,000 compared to Israel's US$36,000 average (Global Metro Monitor, 2015). Second, Tel Aviv, like most of Israel, provides access to broadband connectivity and high-speed mobile data connections throughout the city, and has close to 100 percent mobile penetration. More than 80 percent of the population are active Internet users. Finally, the municipality has gone to great lengths to support the thriving startup economy. The city has recognized this sector's potential and has made high-tech companies, startups, and creative industries its top priority for business development. These efforts include lower city taxes, running several co-working spaces for startups for which startup companies need to apply, and special work visas for international entrepreneurs (Smart City Tel Aviv, 2014).

Tel Aviv is facing several challenges, including improving the urban infrastructure, environment, and services (e.g., transportation, pollution control, social inequality, public safety, energy efficiency), creating an appealing urban environment, and maintaining the city as a business and cultural center. At the same time, the municipality is aiming to improve communication with residents and businesses in the city, improving trust and engagement with residents. Alongside these challenges, which are common to many cities, Tel Aviv faces an unstable political and security situation in the region. Over the years, the city has experienced suicide bombings and other terrorist attacks carried out in its buses, streets, and cafes. Furthermore, during Operation Protective Edge in the summer of 2014, the city suffered daily rocket attacks from Gaza, causing residents to regularly run to shelters to protect themselves. The tools provided by the smart city were used, and are currently used, to directly confront these challenges.

1.2. Smart City Overview

Tel Aviv's Smart City project takes a unique path with regard to both goals and process. Tel Aviv, a prosperous municipality, did not set out to become "smart" only for the purpose of improving resource allocation, like many other cities (Batty et al., 2012). Its main motivation, as can be seen by the city's own definition of smart city and consistent with the challenges the city faces, was to improve resident engagement and strengthen trust between residents and the municipal government. Tel Aviv's municipality defines this process as "citymaking," that is, transforming a space and a place, where a space is a physical entity, while a real place draws people, has a clear narrative, and is embedded with meaning.

The main project in this space is Digi-Tel, which began in 2011. It aims to create multiple communication channels with the residents. In a booklet issued about smart cities, the municipality describes its project as follows:

> Tel Aviv, the Nonstop City, considers engagement a key value in implementing Smart City principles. It actively involves residents in the urban experience and urban development, while emphasizing engagement in decision-making processes and wisdom of the crowd as a means for smart municipal management in the new age.
>
> The city persistently acts to create a climate that facilitates the formation of collaborations between residents, business establishments, third sector organizations and the Municipality, while making use of cutting-edge technologies that enable learning and creativity (Smart City Tel Aviv, 2014: 6).

The main driver for becoming a smart city in Tel Aviv was to create a more open, transparent, and trusting relationship between the municipality and its citizens (Shapiro, 2006). This vision promotes more collaborative urban decision making with residents and local businesses. It also relates to Tel Aviv's branding as a technological innovation hub; the municipality was looking to be as innovative as its citizens, hoping to continue to lure desired startups and creative industries through such branding. This motivation has led Tel Aviv to focus mostly on citizen-oriented solutions (Cohen, 2015).

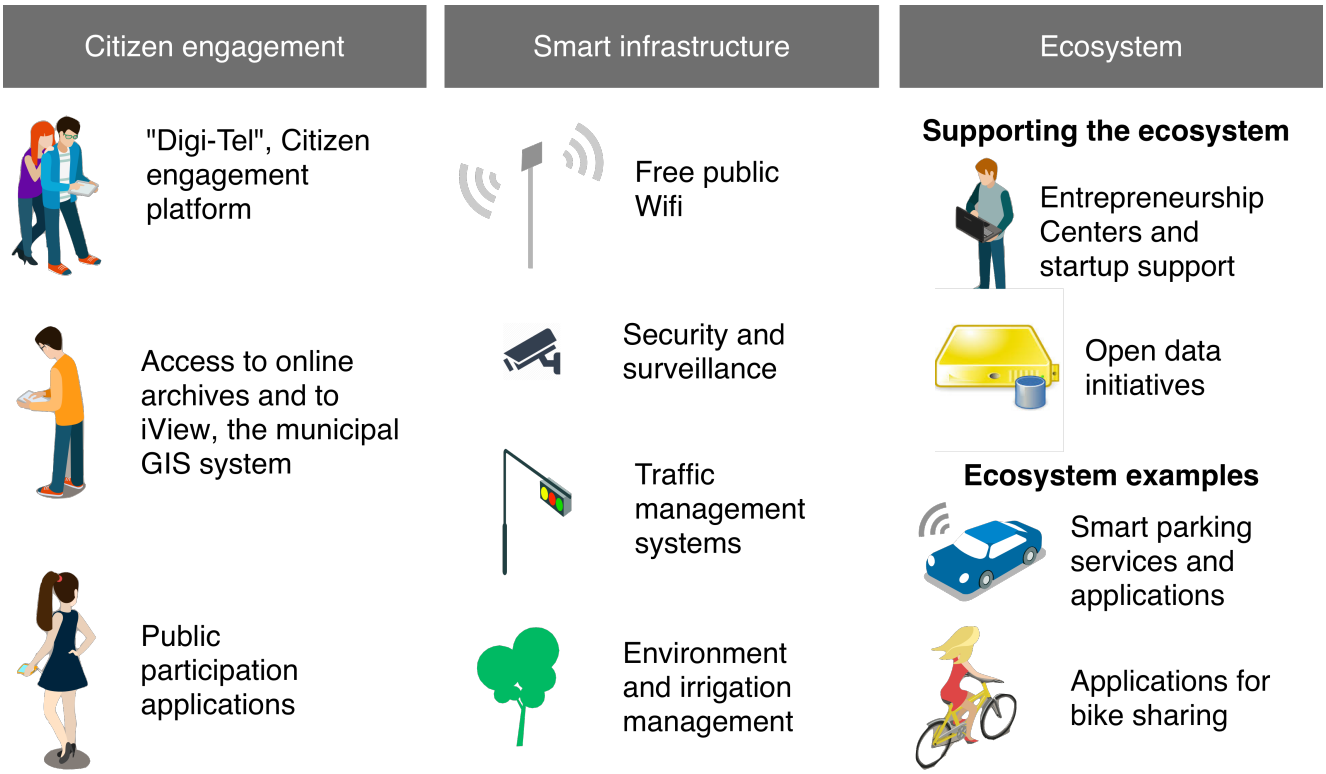
The process in which the smart city is being built is also unique to Tel Aviv. Unlike many other cities, Tel Aviv does not have one "smart city" initiative, envisioned and carried out in a top-down manner. Instead, Tel Aviv has embarked on a strategy that combines building specific smart services and leveraging the city's high-tech ecosystem to facilitate the construction of others. To describe and frame these services within a municipal process, it uses definitions by Hollands (2008) and Angelidou (2015). They define the smart city as a process of embedding technology into the fabric of the city. Therefore, the smart city is described as an ongoing project, rather than a finalized reality.

All of Tel Aviv's smart services are based on a connected set of information sources and systems. Tel Aviv has developed advanced solutions for urban administration and, more importantly, civic engagement, that can inspire continuous improvement through public–private partnerships.

A strategic plan for civic engagement, formulated at the municipal level, defined how to adapt municipal tools and infrastructure to current technological trends and needs. These include mobility, social media, big data, and others. A three-tier model was proposed:

- **Applications**: Applications and systems that aim to address a specific task/need. The latter include providing access and managing information about a particular community center, and messaging at schools and other locations.
- **Logical infrastructure**: Software infrastructure designed to be a platform for a wide variety of applications. The latter include the Digi-Tel project, an online residents' club designed to increase engagement, the city's Mobile App, the iView GIS system, open data repositories, and others.
- **Physical infrastructure**: Infrastructure that connects residents to the Internet, including the 1 Mbps free Wi-Fi in 80 locations throughout the city (Ziv and Ramati, 2013) and support for broadband connectivity infrastructure development.

Figure 1: Categorization of Smart City Activities in Tel Aviv



The result is that Tel Aviv has managed to become a smart city in many aspects in a surprisingly affordable way. Rather than investing heavily in expensive deployment of large-scale hardware infrastructure, integrating existing information systems, developing new systems to interact with residents, and opening municipal databases that can be used by third-party startups, the strategy supports the three main objectives outlined in the City Vision: implement citizen-oriented government, create a city for all residents, and maintain an appealing urban environment.

The basic forces that shape the Smart City project in Tel Aviv come from the bottom up, driven by the city's Chief Information Officer (CIO), Liora Schechter, who is in charge of the municipality's digital policies, tools, and vision and the municipal Chief Knowledge Officer (CKO), Zohar Sharon, who is in charge of data collection, management, and dissemination. The projects are strongly supported by Mayor Huldai and his administration as a strategic effort to meet the city's goals. Other forces involved are startups that build applications based on the city's information and drive the development and opening of information sources. Following the success of smart services with regard to improving trusting relationships between residents and the municipality, the city invests increasing efforts in smart services. Moreover, the municipality is starting to aggregate its many projects under a wider umbrella of Smart City initiatives and is writing a comprehensive policy for collaboration with startups and third-party applications.[1]

[1] The guidelines were not published publicly as of November 2015.

2. Service Spectrum

2.1 Overview

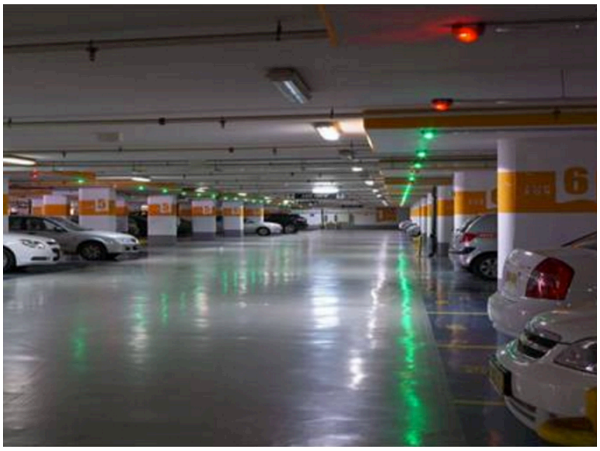
Tel Aviv's smart city services can be divided into three main groups of activities. The first is citizen engagement, which includes the array of tools and services under the umbrella of the Digi-Tel initiative. This project is the main focus of the Tel Aviv Smart City effort to date, with strong interest from leading city officials. The second is deployment of smart infrastructure in several areas, including security, public wireless communications (Wi-Fi), crisis management, and transportation. The third is the group of services that comprise an ecosystem of startups, private companies, and civil society. The initiatives in each sector of municipal services are discussed below.

2.2 Transportation and Urban Mobility

Transportation is traditionally one of the most technology-driven sectors of every city, and Tel Aviv is no different. As far back as the 1990s, the city had already deployed portable terminals for parking attendants, advanced traffic light control systems, and many other tools. Currently, Tel Aviv is focusing on specific issues: managing day-to-day traffic, reducing private vehicle use, and tackling the scarcity of parking places. The city is supporting several smart solutions to these challenges:

Traffic control: The city operates an integrated traffic control center, from which it oversees traffic flow and solves immediate issues. The center uses an automated system, Avivim, developed in collaboration with Technion–Israel Institute of Technology, to oversee the city's traffic flow. The system uses data collected from vehicle volume sensors, traffic cameras, and third-party systems such as Waze, to automatically or manually set traffic policies for traffic lights or to intervene with traffic in other ways.

Image 1. Example of Parking Sensors Deployed in Tel Aviv



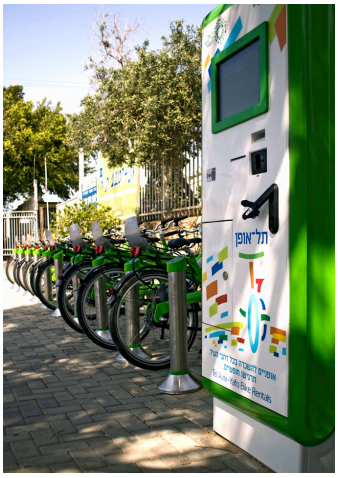
Source: **Tel Aviv Municipality.**

Parking: The city provides several services designed to better utilize parking infrastructure and increase revenue from parking. First, it allows drivers to pay for municipal parking on the sidewalk and in public parking facilities through collaboration with two companies: Pango and Cello-Park (Annex B), which enable drivers to pay for parking throughout the city using mobile applications. Parking wardens use the same system to see if the parking is valid and has been paid for. Camera-based enforcement is also used in specific locations around the city, including at busy intersections, handicapped spots, and others, to automatically ticket parking violators.

Finally, all municipally owned parking lots share data about the number and location of available spots. The data are displayed on smart signs in the city and are publicly available via iView GIS and through mobile applications.

Bike-sharing systems: The city has deployed a bike-sharing system, called Tel-O-Fun, around the city (Photo 3). The system includes a mobile and a web application that allow users to see the location of the nearest station and whether it has available bikes. A similar car-sharing system is planned to begin operations within a year.

Image 2: Tel-o-Fun Station



Source: **Tel Aviv Municipality.**

Public transportation: The municipality and other entities provide several information systems that support public transportation commuters. The Ministry of Transportation has deployed information screens at over 100 transit stops around the city. These stations, powered by solar energy, show when the next buses will arrive at the station according to real-time GPS data. Moovit, a local startup, provides trip-planning capabilities and local transit timetables. Alternatively, an application by local startup ZenCity, which won the municipal application competition in 2014, enables people to compare transportation options in the city, such as transit, bus, car, and bike, by sharing data about their time, cost, pollution, and effects on health.

2.3 Safety and Citizen Security

Tel Aviv's security apparatus is focused on three objectives: keeping the peace in public spaces, supporting law enforcement activities, and responding to attacks. To achieve the first two objectives, the municipality and the police department employ an extensive camera surveillance system. The municipality installed around 600 cameras (the number will be increased to roughly 1,000 in the next two years). The municipality uses automatic image analysis to recognize events, such as vandalism, and to direct municipal security or police forces to handle the event. In recent cases of terror attacks (see Kubovich et al., 2015), the cameras were manually aimed to support field forces.

The police department installed 150 cameras, which are controlled by its Integrated Operation and Control Centers (IOCC). However, in the case of security-related events, such as events reported through the 100 phone number (the equivalent of the American 911), the police have the ability to stream video from more than 3,000 existing cameras, including municipal cameras and security cameras installed in private venues (Hatoni, 2010). The city also employs a citywide alarm system, installed in schools and other public places, which enables municipal employees to request immediate intervention from the safety command and control center. The center coordinates the activities of the municipal security forces, and, if necessary, requests help from the police.

2.4 Emergency Response

Emergency response is one of the most important services that Tel Aviv is attempting to improve via smart services. Specifically, due to the tense security and political situation in

Israel, emergencies tend to include armed conflict, such as that between Gaza and Israel in the summer of 2014. The main tool for handling such events is the IOCC, from which representatives of many different entities manage the city in emergency situations. Preparation for emergencies includes mapping different data sets on the municipal GIS system, iView, such as people in need of assistance, local control centers, and so on. This area has also benefited from collaboration with the private sector: a group of developers has created an application that sends mobile alerts in the event of missile attacks (Red Color, Annex B). The integration of the emergency centers is described in the following sections.

Residents can notify the authorities about events through two channels. They can dial 100 to report events that require police intervention, and they can dial 106 (the local equivalent of New York City's 311) to report hazards that require municipal intervention. Incidents designated as 106 can be reported via the designated number, the municipal website, or the mobile app. Incidents are managed via an integrated customer relationship management (CRM) system provided by Microsoft, to which each relevant municipal department is dispatched to provide the necessary response. Municipal authorities can engage external agencies, such as the police, ambulances, and the army if the situation should escalate.

2.5 Environment

The most important smart environmental project is the city's public irrigation operations center, targeted at conserving public irrigation water. To accomplish this, the city deployed an irrigation system that is remotely controlled in real time and oversees garden sprinklers. To date, 72 percent of the city's gardening sites have been connected to the system. This method of irrigation makes it possible to automatically open and shut all sprinklers, monitor the amount of water allocated to each section of the garden, and receive detailed reports that track water consumption in municipal gardens. In the future, the local water and sewage company plans to install smart meters in residents' homes.

Tel Aviv has several pollution-monitoring stations deployed by the Ministry of Environmental Protection. These data are accessible to the public via collaboration with another local startup, Breezometer, which was initiated in one of Tel Aviv's first application competitions. Breezometer informs residents about the current level of pollution at the street level. The city, together with other smaller cities in the metropolitan area, has several projects that deal with solid and liquid waste, but the projects do not have existing Smart City project activities.

2.6 Energy Efficiency

Tel Aviv endeavors to create a more efficient and sustainable energy usage policy in the public and private sectors. At the municipal level, the city is currently piloting a LED program for public illumination in one of its main streets. Furthermore, about 340 switch boxes have been connected to a single control center that manages all of the street lighting in the city, taking into account the varying hours of daylight. Lighting in public spaces is reduced starting at 10:30 PM. The city plans to deploy adjustable LED systems in the future.

More broadly, the city resolved that all new buildings receiving permits should adhere to a set of green building ordinances (Guidelines, 2012). The municipality has been promoting green design of new educational institutions in

the city, encouraging greater energy efficiency in buildings, integrating green construction principles in existing neighborhoods, and circulating planning information dealing with green construction.

2.7 Citizen Interaction and Communication Mechanisms

Tel Aviv's Smart City initiative is targeted first and foremost at increasing citizen engagement and interaction, one of the city's strategic goals. Therefore, this sector has received special attention in terms of budget and municipal focus, and it is the cornerstone of all smart projects. Tel Aviv's conception of citizen engagement revolves around meeting the residents where they are. In a tech-savvy city such as Tel Aviv, this means providing services and information digitally. Another strong agenda item is to match each resident with the services and information he or she needs as easily as possible. The city achieves this through several projects.

Image 3: Illustration of the Digi-Tel Card Provided to Residents

Source: **Tel Aviv Municipality.**

Digi-Tel: Digi-Tel, Tel Aviv's flagship Smart City project, is an umbrella for several components at the infrastructure level. Digi-Tel's goal is to be a platform that allows increased citizen engagement, on top of which other applications can be deployed. The heart of Digi-Tel is a residents club through which residents can access personalized, curated information and services relevant to them. Digi-Tel provides access to online services through the mobile application, through mailings, and sometimes in physical venues through a card, as shown in Figure 2. Registration is carried out in one of about 40 (Digitel, 2013) permanent and temporary registration booths (see Photo 4). Upon registration, residents can share personal information, such as interests and marital status, and can choose their selected method of communication—email, SMS, or telephone. Once they are registered, residents receive personal notifications on items of interest to them, such as roadwork being performed close to their homes or events that might interest them, through the method selected. They also receive access to a private area in the municipal website where they can receive personalized information on many different topics, pay bills, enroll their children in school, and so on. To date, more than 110,000 residents, or about 30 percent of Tel-Aviv's population, have signed up for the personal service.

Image 4: Registration Booth for Digi-Tel Registration

Source: Tel Aviv Municipality.

Mobile application: Tel Aviv deployed a mobile application, supporting services such as reporting potholes, extinguished street lights, or sewage problems, calling city hall, and finding attractions near the user (Digi-Tel, 2013). In the future, Digi-Tel services will be accessible through the mobile application.

Municipal Website: The municipal website stores all relevant information and supports many services, including online payments, incident reporting, registering a complaint, receiving educational services, accessing data, and so on.

Social Media: The city has a very active social media department, operating more than 50 Facebook pages and groups as well as profiles on all other major social networks (Twitter, Instagram, etc.). The social media platforms enable the city to share relevant information with the public as well as other causes, such as:

- "Residents Make a City," a small-scale, local participatory budget initiative carried out through Facebook. Each year, the municipality chooses two neighborhoods to be renovated in the coming year. The residents of that neighborhood are then invited to join a Facebook page opened especially for the projects and present their ideas or needs for renovation. The renovation budget (around US$1M) is distributed according to their proposals.
- Resident feedback collected through Facebook via messages or posted on the municipal wall is integrated into the CRM and responded to like any other complaint.

Consultation platform: Tel Aviv uses a digital platform created by the local startup, Insights, to hold large-scale public engagements around specific topics, such as what community purpose a municipal building should serve or what the focus of next year's strategic plan should be. The platform allows a large number of individuals to contribute to the debate digitally. The company's technology collects and compiles the comments to help officials understand the public's concerns.

While some of these services are directed only at residents of Tel Aviv (such as the personalized Digi-Tel platform and the consultation platform), many others, such as Wi-Fi access and the open data portal, are accessible to all and even have English interfaces for tourists and visitors.

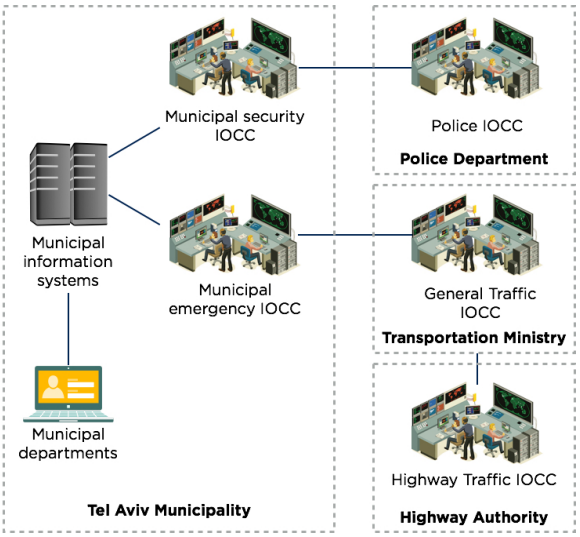
3. System Configuration

3.1 Overview

Tel Aviv's smart city configuration is decentralized, based on several databases, command and control centers, and multiple applications. Following the bottom-up process of building smart services, its configuration and integration are tied to particular uses. Figure 3 depicts the high-level configuration, illustrating

its crucial properties. As the diagram shows, Tel Aviv does not have a single IOCC or a single database that holds all the data related to smart services. Instead, several control centers address different facets of smart city operations, and several individual systems serve specific applications. There are also several generic information systems that provide infrastructure for a multitude of services, such as the municipal GIS system on which many applications operate, the CRM, which has various uses, and others.

Figure 2: Visual Representation of the Different IOCC



3.2. System Integration

The smart city architecture contains several physical IOCCs. As shown in Figure , two of them are controlled directly by the municipality and the police, and the Ministry of Transportation operates several others. Automatic algorithms configured by various departments in the municipality, especially the IT department, carry out many of the operations. For example, in Digi-Tel, municipal departments decide independently about notifying specific groups of residents.

3.3 System Architecture

3.3.1 System Layout

The smart city systems in Tel Aviv comprise several loosely coupled systems. Several systems are either independent or rely on moderate data flows and control flows between them. Figure 4 provides an overview of the main systems (some systems, such the smart irrigation system, are omitted).

A framework devised by Piro et al. (2014) illustrates how these systems work. The components are divided into data sources (such as parking sensors), data communication layer (such as a SCADA network), automated analysis layer (such as video analysis software), control and decision making (such as the various IOCCs), and various data outputs and deployment options (such as the mobile application).

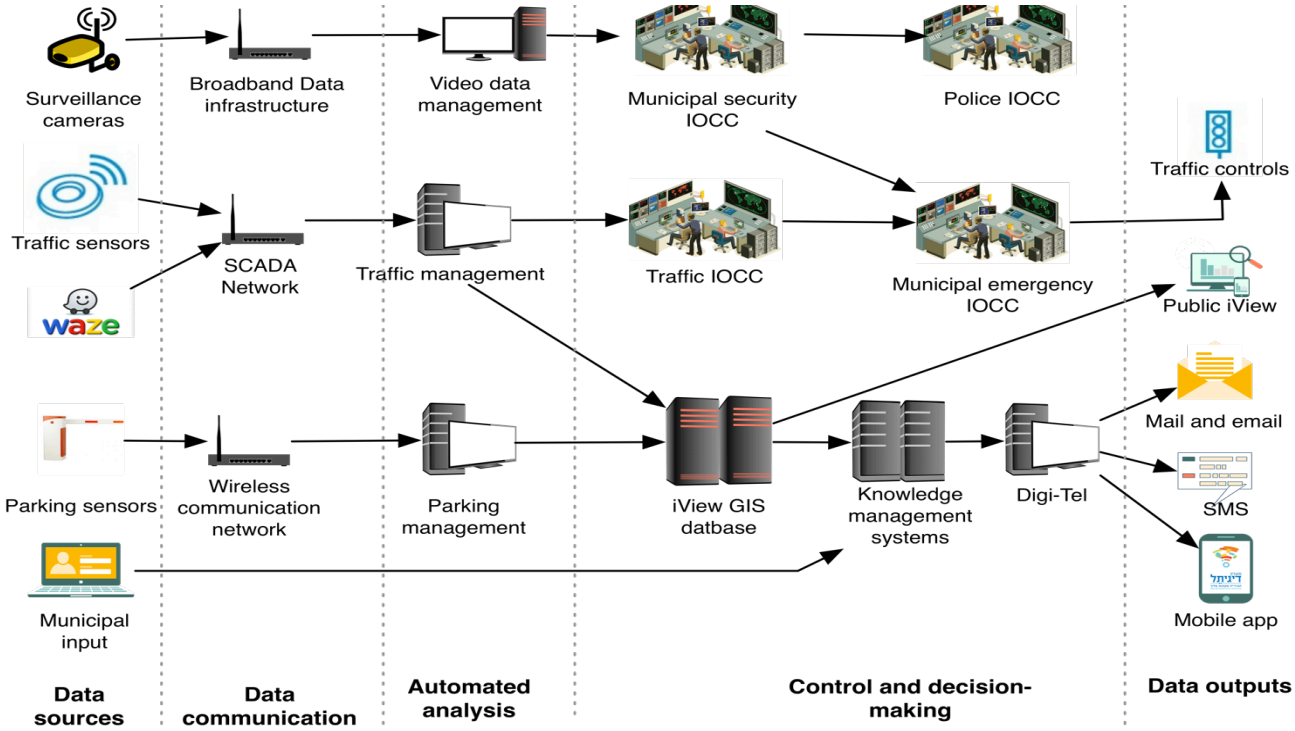
The following subsections describe the layers and the systems.

3.3.2 Information Flow

Tel Aviv smart services use multiple sources of information in several information flows. Data are collected through several means:

- Sensors, such as traffic sensors for traffic conditions, dedicated vehicle location sensors, irrigation sensors, and others
- Cameras, including security and traffic cameras
- Third-party applications, such as Waze (see Annex B), providing information about traffic conditions
- Municipal information systems from various departments, including safety, security, education, and welfare

Figure 3: High-level Configuration of the Tel Aviv Smart City Architecture

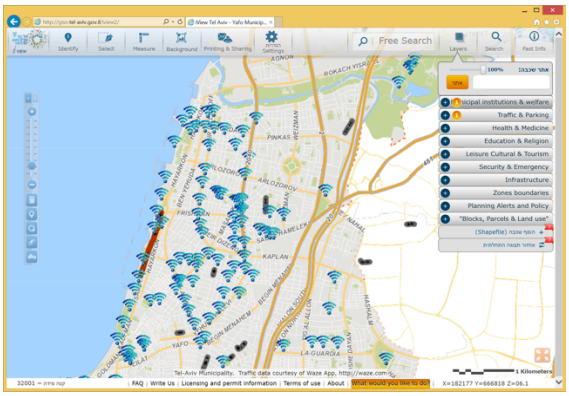


The data and camera feeds are transferred to centralized servers using a citywide fiber optic system build by Motorola, which also hosts the free Wi-Fi service. Video feeds can be distributed through a system called Vigilant to different IOCCs in the different offices in the municipality. The visual flow is described in Figure 4.

Beyond certain analytical functions in specific systems, detailed in the following subsections, the architecture includes several generic processing and analytical processes:

- **iView**: An advanced GIS platform with both an outbound and an inbound component. The outbound component is used to share many layers of data with the public and can be accessed by developers to create apps on top of it. The inbound component stores more
  sensitive data and serves as a base for many integrated control systems, as well as a tool for research by city officials. The platform was built internally by the municipality's Yair department, which is in charge of GIS services and is based on an ESRI ArcGIS server and a Microsoft Silverlight client.
- **Knowledge management infrastructure**: As part of the Digi-Tel project, data can be integrated and combined with other information sources and then channeled to different entities from multiple information systems, according to a set of knowledge rules.

Image 5: Screenshot of the iView Open GIS System, Displaying the Locations of Wi-Fi Hotspots and Traffic Conditions by Waze



Source: **Tel Aviv Municipality.**

Similarly, the architecture contains several generic data delivery services:

- **Open Data portal**, a one-stop web applications through which citizens and developers can access all data posted by the municipality.
- **The Digi-Tel framework** provides an infrastructure for notifying and interaction with residents through the municipal mobile applications, emails, text messages, and other means.
- **Third-party applications** such as Moovit and Waze (see Annex B), incorporate municipal data in their services, providing services through mobile applications.
- **The strategic planning departments** of both the municipality and the police department use business intelligence and data mining tools to analyze various aspects of the activities in the city. For example, the Avivim traffic management program provides an analytical tool for investigating traffic conditions at different intersections.

3.4 Integrated Operations and Control Centers

Tel Aviv has several IOCCs, operated by the municipality or other government agencies.

Municipal General Emergency IOCC. This center operates only in emergency situations, such as wars, floods, exceptional transportation events (e.g., marathon runs that require closing central roads), and so forth. The center is located in the basement of the municipal building and is staffed only when there is an event. The center can receive all available video and data feeds. The center was initiated in 2011 but underwent several renovations over the years. It receives feeds from all municipal systems, including video feed from the municipal security center, traffic feeds from the Ministry of Transportation traffic management center, and other municipal databases.

Municipal Security IOCC: The security command and control center (Image 6) is used under usual circumstances and provides access to all security cameras, communications, and underlying information systems. An operations center manned 24/7 by one or two attendants at a time monitors the cameras and other data sources. The small number of attendants is due to the usage of visual recognition software that automatically identifies events that can be handled by forces on the ground. The camera feed is fed to the city's safety IOCC, using a system developed by Vigilant. From the center, the feed can be transferred to another emergency IOCC, a secondary IOCC in another municipal building, or a mobile IOCC (carried by a van). During usual circumstances, however, the data are monitored automatically by a system called AgentBI, which alerts the sole human operator in the IOCC when predefined situations have occurred. The security department

configures these situations in an ongoing effort. In the case of events and emergencies, the center can hold up to five stations. The center was built in 2014.

Image 6: A picture of the Municipal Security Integrated Operations and Control Center

Source: Tel Aviv Municipality.

Traffic control center: The Ministry of Transportation operates an integrated traffic control center, from which it oversees traffic flow and solves immediate issues. Begun in 2005, the center has been gradually upgraded to operate automatically rather than manually.

Police control center: The Tel Aviv Metropolitan Police Department has an IOCC that employs around 15 attendants under normal load. The center is directly connected to several hundred surveillance cameras and to a command and control ICT system with all mobile police forces. Under the system known as Watchful Eye, during an event requiring deployment of the police, the control can stream video from over 3,000 private, municipal, and traffic cameras all over the city.

Highway control center: The highway control center oversees traffic on the largest highway in the Tel Aviv area (Netivai Ayalon). The center shares video feeds and traffic data with the Ministry of Science traffic center.

3.5 Field Systems

The city has deployed a limited number of field systems, generally aiming to avoid installing physical infrastructure wherever possible and relying more on mobile applications for sensing and notification. However, specific types of sensors are deployed:

Security cameras (around 600) and traffic cameras (around 40). Because of legal restrictions, the cameras are not used for both objectives.

- Traffic sensors embedded at major intersections and roads (around 450).
- Variable message signs on local highways (around 20).
- Moisture sensors for irrigation in public gardens (several hundred).
- Pollution and climate sensors in 15 locations around the Tel Aviv metro area.

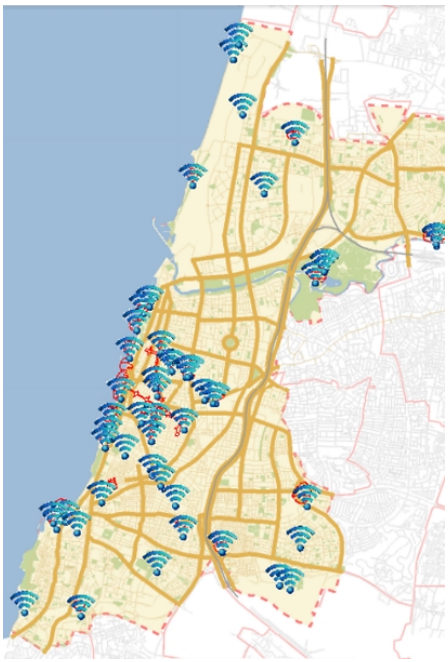
3.6 Communication Systems

The city recently deployed several communication systems. A citywide Wi-Fi infrastructure was installed in 2013, providing free Internet connectivity to residents and visitors. Photo 6 shows a sign for free Wi-Fi near the deployment of the hotspot, and Figure 6 depicts a map of the locations of the Wi-Fi hotspots, which cover mainly tourist points of interest (e.g., the seaside boardwalk) as well as dense urban areas. Currently, the Wi-Fi network covers all major pedestrian streets of the city center and parts of its outer neighborhoods.

Currently, the infrastructure includes around 50 hotspots, and the municipality is constantly adding more capacity. The infrastructure is also used to communicate video feeds from the

security cameras and to serve as a basic backbone to all of the municipality's systems. There is a logical separation between the two on the network level. The physical level uses the same infrastructure. The municipality also has a radio communication system for employees and security staff that includes voice and data communications.

Image 7: Map of Municipal Wi-Fi Hotspots in Tel Aviv



Source: **Tel Aviv Municipality.**

Image 8: Sign for Free Wi-Fi in Tel Aviv

Source: **Tel Aviv Municipality.**

3.7 Subsystems and Functions

3.7.1 Transportation and Urban Mobility

The city operates an integrated traffic control center, from which it oversees traffic flow and solves immediate issues. The Avivim control system oversees the traffic flow in the city and automatically controls traffic light scripts based on sensory data. Avivim is based on several data streams into the control center. It has three main sources:

- Traffic sensors: They feed directly into the system based on the roads or on traffic lights in main intersections, and report current traffic conditions. The data are transferred to the system through a SCADA[2] sensor network.
- Cameras: Traffic control cameras are deployed around the city. Their content is not automatically analyzed, but they allow the controllers to identify hazards and problems on the road. Recently a law was passed which allows the municipality to enforce transit lanes using these cameras, and the city is expected to widen its network to all transit lanes and deploy a relevant analysis system to enforce the usage automatically.
- Collaboration with Waze: The municipality recently initiated collaboration with the popular Google-owned local navigation startup. The company shares its data on current congestion around the city in

[2] SCADA (supervisory control and data acquisition) is a network that operates with coded signals over communication channels so as to provide control of remote equipment.

exchange for receiving updates from the municipality on roadwork.

Data from the sensors, cameras, and Waze are analyzed and stored in a database, which is used to control traffic lights and highway notifications. The "EYAL" component of the Avivim system makes online decisions by assigning each intersection a selected number of scripts and deciding about the proper script in real time according to the sensor data. The system also supports manual script changes by traffic controllers. Human controllers can watch and analyze the data using the INSYTE component of the system, which provides integrated analysis of video and traffic feeds.

The city has several smart services related to parking, one of the main challenges in Tel Aviv:

- Mobile parking payment: Through collaboration with local companies, Pango and Cello-park, parking throughout the city is paid for using mobile applications. Parking wardens use a smart terminal to see if the parking was paid for.
- Camera-based enforcement: In specific locations around the city (busy intersections, handicapped spots, etc.) camera systems automatically ticket people who are illegally parked.
- Parking lot data: all municipally owned parking lots share data about the number of available spots. The data are displayed on smart signs in the city and publicly available via iView GIS.
- An Israeli startup company is currently in a pilot program that uses video feeds from security cameras to locate empty parking spaces.

The city has deployed a bike-sharing system, Tel-O-Fun, around the city. Data from the sharing stations are aggregated and transmitted to a central database that keeps a record of the situation at the different stations—how many bikes are available and what their status is.

The system provides a mobile application (Tel-o-bike) that allows the cyclist to locate the nearest station and ascertain whether it has available bikes, using API calls to the municipal server. The application was developed by a private company for the city's first application competition in 2013 and is still widely used. A parallel car-sharing system is planned to begin operating in late 2016.

- Public vehicles: The city has acquired low-emission vehicles to be used for most of its services. The vehicles are being monitored using a designated data platform.
- Transit: Transit is not managed or controlled by the municipality; therefore, few solutions exist. Nevertheless, two important services exist in the city:
  - The Ministry of Transportation has deployed information screens in about 100 transit stops around the city. These stations, powered by solar energy, show when the next buses will be arriving at the station according to real-time GPS data.
  - Moovit, a local startup, provides trip-planning capabilities and local transit timetables. The application relies on a combination of open data, GPS data from buses, and data from users to provide the most accurate times available.
- Alternative, an application by local startup ZenCity which won the last municipal application competition, provides the ability to compare transportation options in the city—transit, bus, car, bike, and others—by sharing data on their time, cost, pollution, and effect on health. The data collected by the application can help the city manage and plan its transportation system. The application will be

launched as a pilot with the municipality in 2016.

3.7.2 Safety and Citizen Security

To augment safety and security activities, the city and other agencies developed several ICT systems. The city has deployed around 600 cameras around the city, and the number should be increased to roughly 1,000 cameras in 2017. The city employs two types of citywide alarm systems, both connected to the safety command and control center. The wired system is installed in schools and other public locations. Mobile patrol personnel use the wireless system.

3.7.3 Emergency Response

The main tools used for emergency response are municipal databases and a GIS system, iView, to map the resources in case of an emergency. These include:

1. Mapping shelters and makeshift shelters (such as underground parking lots) around the city.
2. Mapping people in need of assistance, such as elderly people living alone, to provide targeted help.
3. Mapping control centers and police forces.

The municipal systems are also connected to the Ministry of Defense alert systems. The emergency databases allow interaction with the public and the private sectors. For example, during the 2014 conflict with Gaza, a group of developers created a mobile application known as Red Color to guide residents towards the nearest shelter in case of missile attacks.

3.7.4 Environment

The city deployed an irrigation system that is remotely controlled in real time and oversees sprinklers in gardens. To date, 72 percent of the gardening sites in the city have been connected to the system. This method of irrigation makes it possible to automatically open and shut all sprinklers, monitor the amount of water allocated to each section of the garden, and receive detailed reports that track water consumption.

Tel Aviv also has several pollution-monitoring stations deployed by the Israeli Ministry of Environmental Protection. The data are accessible to the public via collaboration with another local startup, Breezometer, which was initiated in one of Tel Aviv's first application competitions. Breezometer enables people to monitor the current level of pollution at the street level.

3.7.5 Energy Efficiency

The city takes measures to create a more efficient and sustainable energy usage policy in the public and private sectors. First, at the municipal level, the city is currently piloting a LED program for public illumination in one of its main streets. Some 340 switch boxes have been connected to a single control center that manages all the street lighting in the city, taking into account the varying hours of daylight. Lighting in public spaces is reduced starting at 10:30 PM.

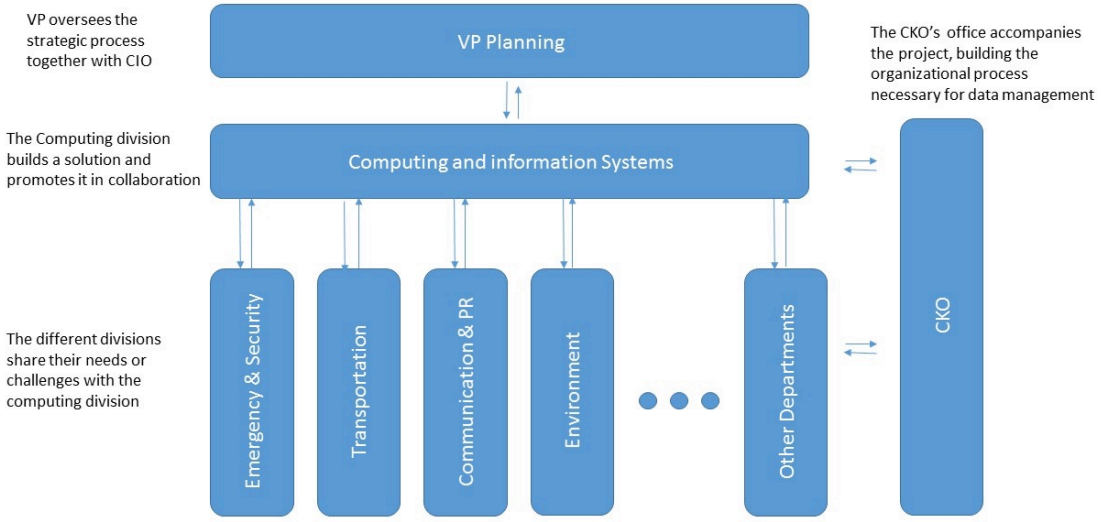
More broadly, the city resolved that all new buildings receiving permits should adhere to a set of green building ordinances (Green, 2012). The municipality has been promoting the green design of new educational institutions in the city, encouraging greater energy efficiency in buildings, integrating green construction principles in existing neighborhoods, and circulating planning information on green construction.

3.7.6 Citizen Interaction

Digi-Tel is Tel Aviv's flagship Smart City project. It is an umbrella for several different infrastructure components. Digi-Tel is a platform that allows citizens to be notified according to a set of rules initiated by the municipality, with an interface (in Hebrew) that allows residents to input their interests and preferences. To date, more than 110,000 residents have signed up for the service. The platform has several components:

- Resident database that includes information about the resident's gender, age, address, and interests (e.g., pets, children, sports, etc).
- Notification rules that enable targeting of specific information to specific residences, according to the information in the resident database and an evolving database of events and activities. For example, notifications such as "note that your street will be repaired on certain dates," "get access to the Tel Aviv Marathon," "story time for children aged 5 to 8 in the neighboring library," "don't forget to register your child at school next month," and "get discounted tickets to theatre shows this evening." Some rules are configured using automatic scripts and are executed according to the resident's preferences. City officials also configure some rules manually, overriding automatic rules.
- Notification channels that communicate with residents through email, SMS, telephone, and in the future the application.
  Personalized services that allow residents to access the private area in the municipal website where they can see personalized information on many different topics, pay bills, enroll their children in school, and so on.
- Tel Aviv deployed a mobile application, supporting services such as reporting incidents, calling city hall, and finding attractions near the user. While the application has several thousand downloads, it is far from reaching the mobile potential, and the city is planning to deploy a new application in the next few years.

Figure 4: Governance Model for Smart City Activities



4. Organizational Structure

Tel Aviv's smart city is not the product of a top-down process; rather, it has been created from the bottom up within the organization and is led by several entrepreneurs within and outside the municipality. The most prominent driving forces are the city's chief information officer (CIO) and chief knowledge officer (CKO), who are in charge of the overall municipal information systems and Digi-Tel, respectively.

The city's approach relies on promoting clear and specific projects rather than building large smart city infrastructure. Liora Schechter, the city's CIO, explains that a gradual approach is easier to implement politically and economically, provides more tangible benefits, and allows the municipality to learn and to adapt. Seeing the success of such attempts creates the trust and support necessary from residents, from the municipality, and from third parties to carry out increasingly larger and more integrated processes.

4.1 Governance Model

Tel Aviv's smart city model is based on project-oriented service development and internal and external entrepreneurship. The city promotes specific projects to tackle specific challenges, with the initiatives coming from both the municipality itself and third parties. The focal point of all these endeavors is the Computing and Information Systems Division (CIS), which serves a dual purpose—as both the driving force for creating new applications and infrastructure and the implementer of the solutions. As depicted in Figure 7, the CIS division interacts with many other divisions. The logic behind this process is to build the smart city step by step, earning the trust of all parties involved, and showing quick wins. This approach allows the city to optimize its services according to the feedback it receives from the various divisions, residents, and other stakeholders.

The process usually begins with a specific department working with the CIS division to identify its main challenges and how a data system can help solve it. This makes the initiative very much influenced by the inclination

of specific departments toward technological solutions. While this could be considered a weakness, since less tech-oriented departments do not enjoy the benefits of the smart city, it is also an advantage, as it makes department heads and other officials owners of smart city projects and drives them to champion initiatives throughout the organization. The joint proposal is then referred to the city's vice-president of planning, and if authorized, is carried out by the CIS division. The CKO's office participates in many of these projects, building the datasets necessary for success and implementing the workflows to support them.

4.2 Human Resources

The municipal staff that handle smart city development and operations are scattered throughout several departments and government agencies. While it was not possible to count the exact number of employees in each department, the following subsections include a rough estimate:

- **Computing and Information Systems Division**: the division is mostly devoted to creating and maintaining the different projects. Headed by the city's CIO, a leading figure in the process, it has a team of approximately 30 developers working to create in-house solutions and adapt procured ones, as well as other employees working on support, integration, and procurement.
- **Emergency and Security Division**: The department's IOCC is manned 24 hours a day by one or two people at a time. They are in charge of monitoring critical systems in the city, dispatching personnel when necessary, and remaining in touch with law enforcement.
- **Transportation, Mobility and Parking Division**: the Avivim center control room is manned by three people at a time, 24 hours a day.
- **Knowledge Department**: The CKO's office, which manages Digi-Tel, has around 20 people. The department uses employees from many other municipal departments (e.g., education, culture, welfare, and sports) to enter content into the municipal knowledge systems.
- **Communication and Public Relations**: The Public Relations department has a social media team in charge of operating and maintaining social media profiles, as well as taking part in working with startups. It has a two-persons team working regular work hours.

4.3 Information Control, Ownership, and Data Sharing

Tel Aviv shares data with a small number of agencies, including various central government departments, especially the Ministries of Environmental Protection, Education, Housing and Transportation, the Israeli police department, the fire department, and other municipalities in the metropolitan area. Specifically, several systems share data in a more structured fashion. One such system is the city's surveillance system, which is completely accessible to law enforcement agencies, and the city's traffic control system (Avivim), which is also used by other municipalities in the metropolitan area. Similarly, the city receives different datasets from these agencies, including welfare data from the Ministry of Housing and crime data from the police. Mindful of the limits of its jurisdiction, Tel Aviv opts to be as collaborative as possible with these agencies.

The city also shares data with private companies and the general public. Through the city's open data portal, developers and citizens can access, technologically or otherwise, the data shared with the public, and through designated systems information flows into the city from a variety of sources. Building on its strong array of systems, Tel Aviv's open data portal hosts all of the data that it has made publicly accessible. The portal contains explanations on what the data means and how to use it technically. This information includes data on property ownership, bike-sharing systems, and more. Furthermore, the municipality shares the services it develops, in addition to the data. One such service is the iView system, used regularly by other agencies such as NTA, the public company building Tel Aviv's light rail project, as well as the general public.

Finally, the city receives large amounts of data from third-party companies and agencies. Examples of such data include traffic control data from Israel's Ministry of Transportation, welfare data from the Ministry of Social Affairs and Social Services, and the city's collaboration with Waze (See section 2.2). The data are used mainly for operational purposes, although the strategic planning division aims to employ them in ongoing business intelligence processes.

4.4 Protocols and Procedures

The municipality and other government agencies have an array of procedures for many different scenarios and context. The most important ones are highlighted below:

- **Emergency Response**: Due to the political situation in Israel, emergency response is a clear priority for Tel Aviv. Therefore, the city has developed a clear protocol for different types of emergencies. During emergencies, the city changes its entire organizational structure to deal with the matter at hand. The city's leading administration, together with liaisons from relevant agencies, such as the Israeli Defence Forces (IDF), the Israeli Police, and emergency services, the central government enters into the IOCC, where they can get a clear image of the situation around the city, make quick decisions, and dispatch the appropriate personnel. All of their working relationships and jurisdictions are well defined to provide the most fluid collaboration when the need arises.
- **Open Data request**: In 2015, the municipality developed a standard protocol for making data available to the public. The protocol is initiated by receiving a request to open a specific dataset. The city counsel first reviews the request to understand if privacy concerns or other restrictions may prevent the data from being shared. If the request is authorized, it is referred to the CIS division, where the amount of work necessary to open the data is determined. If the request is approved, the data are shared with the general public (regardless of who made the request) via the open data hub and/or the iView system. All requests are shared with the public.
- **Collaboration with startups**: As a result of the great demand for collaboration and potential collaboration with startups, in 2015 Tel Aviv defined a standard protocol for working with such companies. For more information on the protocol, see subsection 4.6 below.
- **Installation of surveillance cameras:** Because of privacy laws and regulations, the municipality and the police department follow a procedure for mitigating privacy risks when deciding on the installation of cameras (Israeli Law, 2010). Before deciding whether to install

surveillance cameras, the issuing body needs to review the privacy risks relevant to the particular cameras, taking into account the objective of the camera and the possible threat to privacy, specifically of minors. Following the review, the agency must hold a public hearing with regard to the installation. After the hearing, a special committee, which includes agency officials as well as the relevant legal departments, decides on the installation and configuration of the camera.

4.5 Cost System: Annual Budget, Capex, and Opex

To understand the cost system of the Tel Aviv Smart City initiative, the 2014 budget was analyzed and verified through personal interviews. According to the documents describing the development and governance processes, the CIS Division incurs all development costs and most maintenance costs and executes all projects. Tel Aviv has an open budget policy and posts all of its budgets online (although not always in machine-readable format). The Tel Aviv budget is divided into two parts: the annual, regular budget, which is funded from city taxes and holdings and serves as the opex (operating expenditures), and the irregular budget, which is funded from various levies and serves as the source for all of the city's capex.

The total budget of the CIS division's regular budget (i.e., opex) in 2014 was 103M NIS (approximately US$26.6M[3]), of which 52M were allocated to maintenance and upgrading of existing systems (including human resources). This includes 9M for the GIS system, 11M for organizational information systems (CRM, etc.) and 10M for collection and online payments system. Another 17M NIS is allocated for customer services, provided either to the divisions' internal customers within the organization, or by outside vendors to the division.

Table 1: Smart City Projects Budget Analysis

Budget Item	Capex (irregular budget) amount	Capex (%)	Opex (regular budget) amount	Opex (%)
Digi-Tel	7.3	12	20.2	19.6
Payment system	10	16	9.9	9.6
Traffic enforcement	3.5	5.8	6.1	5.9
Microsoft CRM + KM	10.7	17.8	5.2	5
Total CIS budget	60	6.82 (out of total)	103	2.37 (out of total)
Other budget items	820	93.18	4,247	97.63
Total	880	100	4, 350	100

Source: **Tel Aviv Municipality.**

Examining the 2014 irregular budget (capex), the CIS division had a budget of 60M NIS. 7.3M was allocated for the development of the Digi-

[3] The exchange rate in 2015 was approximately 3.8 NIS to 1 USD.

Tel Residents club, 10M to a new collection and payments system, 3.5M to build the traffic camera enforcement system, and another 10.7M to Microsoft to upgrade their systems, mostly for deploying a new resident-facing CRM system and a new knowledge management system.

Overall, the city employs a combined strategy of procurement and in-house development (capex) together with significant budgets for day-to-day maintenance and feature development (opex) mostly done in-house, for an overall cost of approximately 160M NIS per year.

4.6 Special Focus: Collaboration with Startups

As technology startups are a major part of life in Tel Aviv and a great resource available to the city, the municipality has recently created a formal procedure defining its collaboration with startups. Based on the notion that startups can provide application-based solutions to various urban challenges and on the city's desire to encourage this industry, the procedure defines the benefits that working with the municipality can provide to startups and the process to take advantage of them. The municipality has recognized several services that it can provide to startups:

- Data: Startups frequently need access to data collected by the municipality.
- Promotion: Startups might want the city's stamp of approval for promotional reasons or want to be exposed via the municipal communication channels, such as social media, residents' club, or billboards.
- Consulting: Many startups are looking to consult with municipal experts. For example, transportation startups may want to consult with the municipal transportation authority, or a pet-oriented company may wish to talk to the city veterinarian.

The municipality has created an online platform that allows startups to contact it, describing their specific needs. A special municipal committee convenes to review these requests and refer them to the relevant departments at city hall. Each collaboration is paired with the appropriate function in the municipal government that can provide it and with a Service-level Agreement (SLA), making the process transparent and accessible.[4]

5. Monitoring and Control

Evaluating the benefits of smart city projects and their contribution to the city is one of the main challenges this field faces today. Leading city consortiums and research institutes, such as the City KEYS project (Kontinakis, 2015), the ISO Smart Cities mission (ISO/IEC, 2014), and the City Protocol Initiative (City Protocol, 2015), have promoted certain initiatives to define key performance indicators (KPIs). However, there is no standard way for a city to measure the success of its smart projects, especially when the emphasis is on resident services rather than infrastructure. This has led to the use of nonstandard evaluation methods in different cities around the globe—some are specific to smart cities while others are more general. The city does measure several indicators for its smart city projects, including congestion rates, customer satisfaction, and others.

[4] The SLA and the agreement documents were not publicly available as of November 2015.

Tel Aviv is not currently implementing one of the standardized KPI systems, and, generally, it did not appear as if a single method was being used citywide. Rather, Tel Aviv uses a mix of two levels of evaluation throughout its smart city sectors. At the basic usage level, monitored mostly by the CIS division, the city uses specific quantitative measures relating to information services, such as the number of visits to its web services or application downloads. On the strategic level, smart solutions are seen as a tool for reaching the strategic goals of the various departments. The participating departments do not use specific methods to measure the effectiveness of the Smart City project; rather, they incorporate them into other measures of their overall effectiveness in achieving goals, such as reducing traffic or creating public spaces.

5.1. Benefits to Selected Smart City Sectors

5.1.1 Transportation and Urban Mobility

The main goal of the transportation and mobility department is reducing the number of private vehicle trips in the city, that is, reducing the use of automobiles. The city is trying to achieve it by implementing policies such as encouraging the use of public transportation and reducing the amount of time spent searching for parking spaces. All of these policies involve smart city projects. The traffic management system measures congestion rates at different times of day and traffic flows along central routes.

5.1.2 Safety and Citizen Security

Since the city does not have the responsibility for crime prevention in general,[5] its main focus is on maintaining safe, well-organized, and inviting public spaces and institutions. This means reducing vandalism, loitering, littering, and increasing the perception of public spaces as safe and welcoming. The surveillance system helps achieve these goals, aiding law enforcement and enhancing the sense of safety. The AgentBI system, which automatically identifies events from the security video feed, is evaluated mainly according to the signal-to-noise ratio.

5.1.3 Emergency Response

As emergency response is one of the city's top priorities, Tel Aviv's main objective in this area is to increase preparedness for emergency situations, including reducing service-level agreements (SLAs)[6] and increasing the scope of response. The main measurement is qualitative, mainly in the form of feedback provided on large-scale exercises.

5.1.4 Environment

The main benefit in the environmental sector is reducing water usage in the city. A scarce resource in Israel overall, water is the main resource that Tel Aviv seeks to conserve. The main indicator used is the amount of water used per meter of vegetation, that is, the amount of

[5] Crime prevention in Israel falls under the authority of the Israeli Police, a national organization under the jurisdiction of the national government.

[6] A service-level agreement (SLA) is part of a service contract where a service is formally defined. Particular aspects of the service—scope, quality, and responsibilities—are agreed to between the service provider and the service user.

water the city uses to irrigate each garden per size of the garden. Currently, resident water use is not measured.

5.1.5 Energy Efficiency

Considering that energy management does not fall under the city's jurisdiction, the local benefit of smart energy systems is focused on reducing public spending on energy for purposes such as street illumination.

5.1.6 Citizen Engagement

Tel Aviv's top-priority project targets a few strategic goals, first and foremost raising the municipality's approval rating by its citizens, creating a better public image, and increasing trust between citizens and their government. Therefore, the municipality is measuring several indicators:

1. Measures of usage and utilization: Number of registered Digi-Tel users, number of entrances to the service, number of transactions, number of application downloads, and number of application uses
2. Measures of resident satisfaction: Satisfaction with residency in Tel Aviv, satisfaction with various municipal services, and satisfaction with interactions with the municipality
3. Comparative measures of service utilization between offline and online services: Number of service calls to human operators versus transactions on the website

5.2. Quantitative and Qualitative Measures for Benefit Analysis

5.2.1 Transportation and Urban Mobility

With the benefit of reducing car use, the measures applied survey the various policies implemented, and include levels of congestion over time (using Waze data), number of users of public transportation systems, number of cars in central intersections (using traffic sensors), and number of relevant traffic violations, mainly abuse of public transit lanes by private vehicles (enforced by an automatic detection system).

5.2.2 Safety and Citizen Security

The main measure in this sector is the number of events recorded using the video surveillance system and reported to the municipal response center. Reducing these numbers is regarded a success. Another important measure is the public perception of personal safety in different parts of the city, measured by surveys conducted throughout the city as well as in specific danger-prone areas.

5.2.3 Emergency Response

The city endeavors to improve its emergency response. It measures this improvement in real events as well as periodic drills. These include SLAs in case of events, percentage of population reach, and damages to life or property. According to the head of the department, the new information infrastructure yields more effort-effective response. Another important measure is citizen preparedness, that is, the degree of citizens' awareness of what they should do in an emergency. This includes knowing the location of the nearest shelter and

what to do in different situations. The latter is measured through periodic citizen surveys.

5.2.4 Environment

The main metrics in this sector are quantitative. One such metric is the amount of water used by municipal departments, which is measured monthly. Another important metric is the quantity and type of pollutants in the air, measured by government-issued meters scattered around the city.

5.2.5 Energy Efficiency

Since the benefit here is reduced spending, the main measure is the amount spent on energy per year. Other metrics include the amount of energy consumed by various municipal properties and functions.

5.2.6 Citizen Engagement

On the operational level, the city employs different metrics to evaluate its progress. The most important metric is the number of citizens registering for the Digi-Tel residents' club, which currently tops 110,000. Other important metrics are number and frequency of visits to the personal area by residents using the Digi-Tel platform. The most important metric, touching on the strategic goals themselves, is the degree of interaction with information, mostly inferred from the percentage of messages that have been read and the feedback received. As for social media, the main metric the city uses is Facebook page statistics—posts, views, and levels of interaction (comments and likes). Page likes are not an important metric.

On the strategic level, the city tries to assess quantitatively and qualitatively the levels of approval and trust and general perceptions of residents about various urban issues. This is done annually through a city survey, in which a sample of several thousand residents is asked a number of questions about the city and the municipality.

5.2.7 Digital Services

Tel Aviv is working to digitize its services, project by project. Quantitative methods are employed to evaluate the benefit of each service. While most services are evaluated by measuring the number of visits to the website, specific services employ other methods. For example, online payment components are evaluated by the total amount of payments collected using them.

5.3. Integration and Synergy

Because of the city's project-oriented approach, integration and synergy have not been prioritized. The fact that various initiatives are carried out simultaneously makes integration a lower priority. Each sector is focused on creating its required solution and tackling its own technological challenge. This can be seen in the large number of control rooms operated by the city, and the different adoption rates of technologies among different departments within the municipality. While some sectors make use of technology, others are far behind.

Nevertheless, Tel Aviv is in the process of promoting a few promising efforts in this area, some of which are yielding results. The main example of synergistic effects can be seen in the second level of the city's Smart City project, which includes systems on which applications, such as the residents club and the iView system, can be built. Although these systems were developed for specific purposes, most departments in the municipality use them today for their own purposes. Whether it is the Education Department using iView to divide

school zones, or the Art and Culture Department promoting its events through the residents club, these systems are used citywide. Furthermore, they facilitate collaboration between agencies and departments. Work on the city's light rail systems began in September 2015. The work, coordinated by NTA, a public–private company, required the collaboration of many agencies within the municipality as well as the police, the Ministry of Transportation, and others. Using the city's IOCC and information infrastructure, the different agencies were able to integrate their activities and data sources. Although this is not yet the standard in day-to-day operations, this experience shows the potential of integration and the synergy that can be achieved.

Looking forward, Ms. Schechter reports that the CIS division is leading an effort to improve synergy among the different smart city sectors, based on the creation of a more synergistic policy.

5.4. Stakeholder Expectations

5.4.1 Government

The main expectations on the government side are increasing citizen satisfaction and making the city more competitive. One of the primary motivations for the Smart City project was to increase citizens' approval ratings of the municipality. The municipal government, recognizing that its residents tend to be very tech-savvy, aims to "meet them where they are" by providing more and more information digitally and through mobile technologies.

This also makes the city more competitive for creative businesses, especially startup companies. The high-tech population has a strong inclination toward online services, and the Smart City projects can help attract them to the city.

5.4.2 Citizens

The citizens' main expectation is access to improved services and information. This is the complementary side of the government's motivation—citizens looking to access information and services online. Another increasingly important motivation is transparency. Tel Aviv has a very active and vocal civil society that demands a high degree of transparency and accountability from local government.

5.4.3 Private Sector

The main motivation for the business sector in Tel Aviv is the wide array of business opportunities emanating from this project. As a hub of ICT companies, the city's new policies create opportunities to develop products and services with financial benefits.

5.4.4 Example of Benefit Analysis

The best example to consider is the Digi-Tel project. It aims to create increased engagement with residents in order to increase trust between the city and its residents and raise municipal approval ratings.

The benefit analysis has several parts. First, the city uses quantitative measures to understand if the project is working, specifically, how many people have joined the club and their level of interaction with the platform.

After the level of adoption is determined, the strategic goal is then measured. Using the annual City Survey, the strategic goal is surveyed to determine the impact of the project on the main goals.

5.5 Examples of Data Collected

The city collects several types of information:

- **Demographic information and preferences:** Through the Digi-Tel registration process, the system collects data on the resident's age, gender, and interests, including activities for children, the elderly, pet owners, the arts, sports, and similar aspects. The city also collects contact information, including email addresses, telephone numbers, and mailing addresses.
- **Surveys:** The system continuously surveys resident about their satisfaction with municipal services (including new digital services).

6. Lessons Learned

Tel Aviv is a unique case, which promotes an inter-organizational, bottom-up approach to smart cities. This approach can greatly improve services, efficiency, and quality of life in the city, at low cost. From the opinions collected during the interviews, the following lessons can be extracted:

Entrepreneurship as Policy—Building the Smart City from the Bottom Up

Tel Aviv's Smart City project was not the product of a strategic management decision, nor was it implemented all at once. Instead, leading entrepreneurs from the organization promoted specific projects to answer pressing needs using smart solutions. This project-oriented approach, in which small-scale, lean projects were carried out, made the process much easier for the city to manage, from the standpoint of both the budget and the city's image. Tel Aviv was becoming a smart city by solving pressing problems. It also gave local leaders a strong sense of ownership. By promoting projects from within the departments, managers became stakeholders with a strong incentive to make the projects succeed.

Recommendation: Start with implementing specific, lean projects in areas with pressing needs, measure success, and move on to the next project, earning the trust of the stakeholders in the process.

Investment in Data and Information Infrastructure

One of Tel Aviv's main priorities was to create a strong physical and logical information infrastructure. From fiber optic cables to centralized data management, infrastructure enables the municipality and external developers to develop applications.

Recommendation: Invest in planning and implementing a modular, robust data infrastructure as a way to enable smart city applications.

Using Startups is an Effective Way to Make Simple but Meaningful Changes

One of the greatest strengths of Tel Aviv's smart city is its ability to harness the potential of its thriving, innovative startup ecosystem to drive solutions to pressing needs. For example, the city is supporting at least three transportation apps. The benefits of this collaboration are threefold: it provides a great service to citizens, which is continuously improving due to market demand; it decreases public expenditure; and it supports and encourages new, innovative businesses in the city.

Recommendation: The relationship between the municipality and local industries should be nurtured to incentivize business activity and create sustainable solutions. Bureaucratic support and open data are important foundations; events such as competitions can be great catalysts.

Market Limitations and Enablers—Learn Where to Invest

When collaborating with local industries, it is crucial to understand the market. Perfect markets with high demand, such as transportation, are a good place to rely on market solutions, while private corporations cannot expect to meet other needs, such as welfare. Direct investment enables those areas where the market is active and answers social needs where it is not.

Recommendation: Development focus should be placed on inbound products, information infrastructure on which applications can be built, and sectors where there is low or no market activity.

Engagement Builds Trust and Support for the Smart City

The main focus of Tel Aviv's smart city is the wellbeing of its residents. Developing smart city services that improve the daily lives of residents is creating new channels of communication between the city and its residents, which constantly improves the city's public image. It is important to involve citizens in the process of improving the city, which makes the process more sustainable and collaborative.

Recommendation: Make citizen services a top priority when planning the smart city. Residents need to see and feel the impact of the projects on their lives for the smart city to reach its full potential.

Internal Knowledge Management Processes are Crucial to Success

Zohar Sharon, the city's CKO, spent several years promoting internal data and knowledge management before shifting his department's focus to sharing that data with the public through Digi-Tel. The internal process, he emphasizes, was crucial to the success of the external one. Only when the city became internally data-driven and all of the relevant information was stored and regularly updated was it able to offer significant services to share this information externally.

Recommendation: Existing staff should manage the process. Data managers should be appointed in each department to implement information workflows within the municipality.

7. Conclusions

The Tel Aviv Smart City case study provides a strong example of how to achieve a high degree of smart urban services and create impact using a decentralized, low-cost method that builds on a modular approach and an open architecture. This approach is innovative and unique compared to that of most other Smart City initiatives. This is largely due to the intra-organizational, bottom-up approach adopted in Tel Aviv.

While this model has great advantages, it also suffers from important weaknesses, chief among them a lack of integration. Since the smart city is being built piece by piece, the projects do not always coincide. Thus, the city supports several control rooms that perform different functions,

creating a redundancy of human resources and data integration deficiencies.

Its significant strengths include low-cost private sector participation—which spurs more business opportunities for creative industries in the city—its impact on resident approval, and shared ownership among a number of sectors. All of these strengths combine to create an image of the city and the local government as innovators, attracting desired creative industries and young professionals to interact with the city.

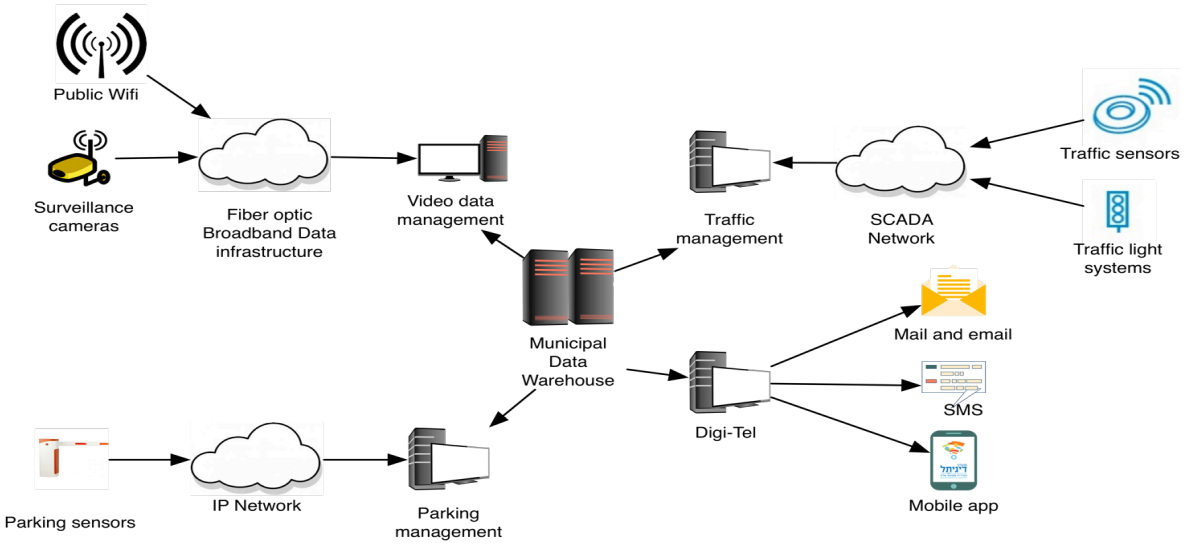
Another important lesson from this case study is the power of individuals. Tel Aviv's smart city status is a direct result of the individuals in key positions who have identified the potential of different projects and pushed them forward, taking ownership over the process.

An analysis of the case study also highlights two major weaknesses. First, the number of operations and control centers, including the municipal emergency center, the municipal security center, the police center, the transportation center, and the highway management center. These centers point to the need for more streamlined and efficient implementation. The reasons for the number of centers can be traced to the diffusion of responsibilities between central government agencies (e.g., police and transportation) and municipal agencies. Another reason could be the downside of the bottom-up approach, which has the potential to generate a large number of projects with various levels of integration. The downside of the bottom-up approach is also evident in the relative lack of performance measurement and clear quality performance indicators.

Overall, in a world that is unleashing the power of bottom-up processes in smart cities (Paskaleva, 2011; Townsend, 2013), Tel Aviv is setting an example of how to harness this approach for systemic benefit, putting forth an array of practical solutions and conceptual frameworks. This model, despite its weaknesses, may serve as a beacon for sustainable smart city agendas around the globe. Specifically, this model is especially relevant for cities that are supporting an active tech and ICT community.

ANNEX A – High-level Technical Specification

Figure A1: Technical Diagram of the Central Smart City Systems



1.1. Central System (Integrated Operation and Control Center)

All of the command and control systems rely on several information systems to carry out their core actions:

- Video management systems: In the municipal IOCCs, the Vigilant system is used to manage video feeds, record and store videos, and transfer video feeds between centers. In the traffic management IOCC, an internal system (INSYTE) integrates video feeds with traffic conditions. Technical information regarding the police department IOCC was not available.
- Information management systems for managing operations: Each IOCC uses proprietary systems to record events, record actions, and dispatch teams.
- Supporting systems: Both municipal and police departments rely heavily on GIS databases to coordinate responses, record consistent and temporal knowledge, and integrate video feeds with other types of data.
- The municipality has developed its own GIS system, iView, used both internally and externally. The system is based on an ESRI ArcGIS server and a Microsoft Silverlight client.

1.2. Field Systems

The field systems rely on several types of sensors and actuators that respond to information systems input. These include the following:

- Traffic sensors that rely on sensing vehicle weight
- Surveillance cameras
- Moisture sensors in public gardens
- Laser sensors for locating cars in municipal
- Other sensors, described in the main report

1.3. Communication Systems

As Figure 8 describes, the Smart City projects use a variety of communication networks:

- The traffic management system relies on a SCADA network, which serves mainly industrial controllers or large-scale hardware infrastructure. It includes local routers near every intersection, which are connected through a dedicated IP network to the IOCC.
- A dedicated fiber-optic broadband network, deployed by Motorola, connects Wi-Fi and municipal surveillance cameras. The cameras are connected to a virtual secured network (VPN), but share the same physical infrastructure as the Wi-Fi antennas. Each access point has around 20Mb bandwidth, and the maximal number of devices that can be connected to each hotspot is 25.
- Other sensor systems are connected through the general Internet network.

1.4. Subsystems and Functions

The urban mobility systems rely on several systems, including the following:

- Proprietary traffic management system (Avivim), which allows automated and manual management of hundreds of intersections in Tel Aviv.
- Bus information system, which includes a bus positioning component, central information management, public displays, and API to services such as Google Maps and Moovit.
- Parking sensors in municipal parking lots, which include plate recognition software in entrances and exits of the lot. In several large parking lot, the municipality installed systems that sense whether a particular parking place is occupied or not using laser capacity sensors.
- Parking payments and validation using mobile applications (Pango and Cell-o-Park).
- Public transportation information systems provided through Moovit.

1.4.2. Safety and Security

The municipality and the police department employ video feed management software. The municipality employs systems for behavioral recognition (AgentBI). Other systems are employed for alert management, event management, and internal communications.

1.4.3. Emergency and Response

The emergency and response system is based on the municipal data warehouse for storing resident information for a targeted response. The iView GIS database is used as a tool to document events and communicate them to all municipal and external teams.

1.4.6. Citizen Interaction

Citizen interaction systems rely on several systems, including the following:

- Data warehouse systems that integrate several internal databases
- Knowledge management systems based on Microsoft SharePoint
- Resident relationship management, handing calls and resident requests, based on Microsoft CRM

Smart City Applications in Tel Aviv Smart City

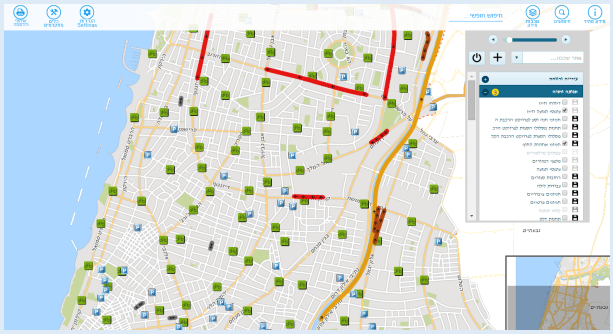
Applications by Tel-Aviv Municipality

Municipal Digi-Tel app

Tel Aviv deployed a mobile app, supporting services such as reporting incidents, calling city hall and finding different attractions near the user. While the application has several thousand downloads, it is far from reaching mobile potential, and the city is planning to deploy a new application in the next few years. The application was commissioned by the municipality and developed by a local vendor (Matrix technologies).

iView GIS

An advanced GIS platform with both an outbound and inbound component. The outbound shares many layers of data with the public and can be accessed by developers to create apps on top of it. The platform was built internally by the municipality's Yair department, which is in charge of GIS services, and is based on an ESRI ArcGIS server and a Microsoft Silverlight client.

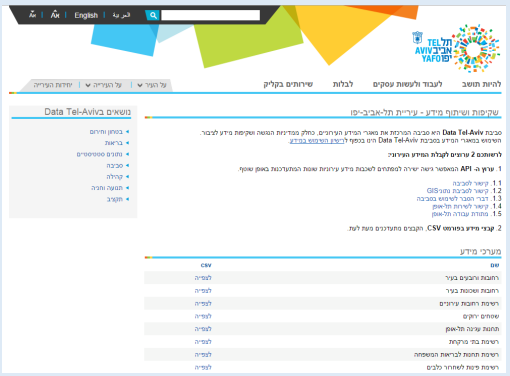


DigiTel Personal Zone

A private area in the municipal website where users can see personalized information on many different topics, pay their bills, enroll their children in school, and so on.

Open Data Portal

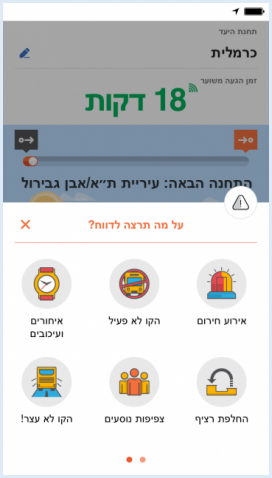
Tel Aviv operates an open data portal that hosts all of the data it has made publicly accessible. The portal contains explanations on what the data means and how to use it technically. This information includes property ownership, bike-sharing systems, and more.



Applications by External Developers

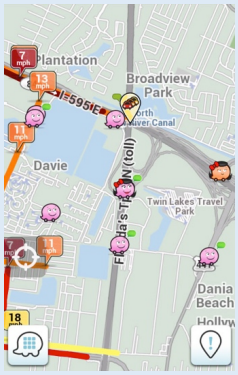
Moovit

A local startup provides trip-planning capabilities and local transit timetables. The app relies on a combination of open data, GPS data from buses and data from users to provide the most accurate times available. http://moovitapp.com/



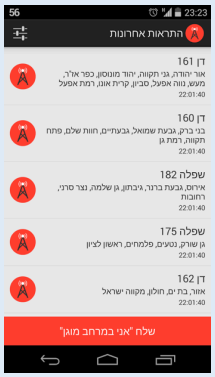
Waze

A Google-owned local navigation startup, which is very popular in Israel, provides driving navigation that takes into account traffic based on social capabilities. http://www.waze.com



Red Color

During the 2014 war with Gaza, a group of developers developed a mobile application named Red Color to guide residents toward the nearest shelter in case of missile attacks.



Pango/Cellopark

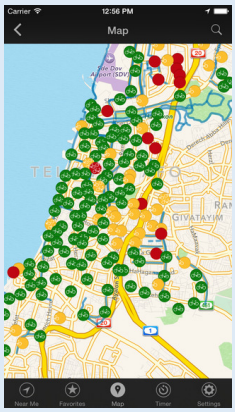
The parking throughout the city is paid for using mobile applications. Parking wardens use a smart terminal to see if the parking was paid for. http://www.pango.com

AlterNative

An app by local startup ZenCity, which won the 2014 municipal app competition, provides the ability to compare between transportation options in the city—transportation, bus, car, bike, and others—by sharing data about their time, cost, pollution, and effects on health. The data collected by the app can help the city manage and plan its transportation system. The app began a joint pilot with the municipality in January 2016.

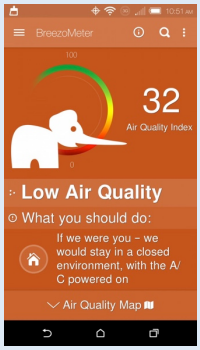
Tel-o-bike

An application that allows Tel Aviv's bike-sharing platform's users to see where the nearest station is and whether it has available bikes, using API calls to the system's server. The app was developed by a private company, Citylifeapps, for the city's first app competition in 2013 and is still widely used. https://itunes.apple.com/il/app/telobike-tel-aviv-bicycle/id436915919?mt=8



Breezometer

A company that was initiated in Tel Aviv's first app competition in 2013. Breezometer reports on the current level of pollution on a street level, accessing data from various sources and combining them in a simple, map-based UI. http://breezometer.com/



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Stakeholders Interviewed

1. Zohar Sharon, Manager, Knowledge Management and Digi-Tel project
2. Eitan Scwartz, Advisor to the Mayor
3. Mr. David Aharoni, Head of Operations and Security Division
4. Yifaat Mor, Manager, Residential Relations
5. Assaf Francis, Manager, Technology Innovation Program
6. Amit Kachvan, Manager, Startup Relations
7. Yael Weinstein, Director, International Economic Development
8. Michelle Sofge, Coordinator, Urban Affairs
9. Liora Scechter, Chief Information Officer
10. Asher Ben-Shushan, Manager, Transit and Parking Division
11. Adi Raptov, Manager, Sustainability Division
12. Doron Brankin, Head of Yair department (Geographical Information Systems).

ANNEX C – Links to Background Information

a. Sample of Data Collected

1. Digitel registration information: http://www.tel-aviv.gov.il/Tolive/digitel/Pages/joiningdigitel.aspx
2. Regulation for Green Building Construction (Hebrew): http://www.tel-aviv.gov.il/Tolive/Infrastructures/Pages/VideoItem.aspx?ID=10
3. Smart City Tel Aviv leaflet: http://www.tel-aviv.gov.il/eng/GlobalCity/Documents/SMART CITY TEL AVIV.pdf
4. Statistical Abstract of Israel 2005 - No. 56 Subject 2 - Table No. 25 (Hebrew): http://www1.cbs.gov.il/reader/shnaton/templ_shnaton_e.html?num_tab=st02_25&CYear=2013
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8. Tel Aviv Statistical Information Center: http://www.tel-aviv.gov.il/TheCity/Pages/StatisticalReview2014.aspx

Figure C1: Outtake from Tel Aviv's Promotional Materials on the Smart City Project

ANNEX D – Service Spectrum

Table D1: Service Spectrum

Service spectrum		Smart city functions and medium				
		Monitoring and data coll3ection	Control	Data processing and information production	Information communication with citizens	Information sharing with agencies*
Service domain	Service system	Signal controller, image detector, BIS, CCTV		Smart city center system…	VMS, VDS, BIS, Internet, mobile, call center, e-government, Open-API, broadcasting…	Information platform (control, ownership and sharing system)…
Transportation and urban mobility	Adaptive Traffic Signal Control System	4	4	4	3	4
	Advanced Traveler Information	3	2	1	4	3
	Bus Information System	4	0	0	4	3
	Incident Management System	4	3	2	4	3
	Automatic Enforcement System	3	1	1	0	2
	…					
Safety and citizen security	Crime Management System	4	1	3	0	3
	…					
Emergency and response	Disaster Management System	4	4	3	4	4
	…					
Environment	Water Management System	3	2	2	2	2
	Waste Management System	0	0	0	0	0
	Environmental Preservation System	3	0	0	4	2
	…					
Energy efficiency	Energy Management System	2	2	0	0	2
	…					
Citizen interaction and communication mechanisms	Public Communication System	2	3	4	4	4
	…					

* **Agencies**: Police officers and patrol cars, community groups, fire stations, military bases, related departments (roads, public transportation, river management, water management, environmental preservation, etc.).
Note: The numbers refer to the different levels of performance according to the following references: 4: Advanced; 3: Moderated; 2: Basic, 1: To be introduced in the future; and 0: Absent.


IDB