Smart Bus Shelters
Enhancing Public Information Systems in Bus Shelters by Integrating Smart IoT solutions

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Abstract

Various initiatives are carried out towards developing Smart cities that aim to make cities more sustainable. The Internet of Things (IoT) is a key aspect, where sensors are integrated in various ‘things’, creating devices that are aware of, and respond to their environment. Bus shelters are among the facilities that are highly used by people in the city while commuting. Despite this high usage, they have remained the same technologically over the years. However, with new IoT technologies, bus shelters have the potential to be improved, providing a better experience to commuters, as well as creating value for businesses and public transport providers.

This paper proposes a novel method that integrates IoT in bus shelters, enhancing the way information is displayed to the public through display screens. The information in focus involves digital signage advertising, public announcements or other information concerning the happenings nearby. The location and the time that the information is displayed are key factors considered, to effectively communicate the relevant information to the target audience. Furthermore, through the use of sensors, data analytics can be generated that describe the commuter traffic flow, thus providing useful information for public transport providers.

Various use case scenarios are considered whereby smart bus shelters can be useful and a small scale prototype is developed to illustrate a proof of concept for the proposed solution. From the prototype, we demonstrate dynamic advertising through social media and show the potential of machine learning in predicting commuter flow from sensor data. We evaluate our work using questionnaires for the business and commuters, in order to find out the value created through implementing such a system. Additionally, we conduct functional testing of the prototype to evaluate its functionality. Other benefits are considered, such as reducing energy consumption by appliances such as lights, screens and smart heating systems for bus shelters.

With our work, we hope to inspire further research into more suitable and innovative ways, in which bus shelters can be technologically enhanced. Furthermore, we believe that enhancements in bus shelters to provide a better experience for commuters while waiting for the bus, is a factor that could encourage more use of public transportation, providing value to public transport providers and local municipalities.

Keywords: Smart bus shelters, Internet of things (IoT), advertisements, Location-based, Time-based, display
Popular science summary

In various parts of the globe, there are a number of initiatives to create smart livable cities and communities. Several cities are planning and investing to become more efficient, while providing a better environment for citizens and becoming more attractive to businesses. The concept of smart cities has its foundation on smart infrastructure such as smart buildings, smart mobility, smart environment and so on. In most of these applications, the core characteristic that underlies them is that they are connected and that they generated data which can be intelligently used to facilitate optimal performance and use of resources.

With the increasing use of the Internet of Things (IoT), more facilities in cities are being connected and integrated to provide a sustainable environment to the people. However, while being one of the most used facilities in cities, bus shelters had remained virtually unchanged over the years. Recently it is being realized that bus shelters can be much more than just sitting areas used while waiting for the bus. New technologies are being used to transform ordinary bus shelters into smart bus shelters, creating new business models and becoming one of the key elements in smart cities.

This paper aims to investigate some of the ways that bus shelters can be improved with the use of IoT, to provide useful information to the public, while creating value for the stakeholders. A small scale prototype focusing on smart advertising in bus shelters is modeled and evaluated. The proposed solution is believed to provide insight on one way that create value for businesses which often use bus shelters to advertise their products or services.
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Joel.
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List of Acronyms

IoT: Internet of Things
ECOS: Emergent Configurations of Connected Systems
IoTaP: Internet of Things and People
QR: Quick Response
LTE: Long-Term Evolution
WSN: Wireless Sensor Networks
RFID: Radio Frequency Identification
NFC: Near Field Communication
ITS: Intelligent Transport System
GPRS: General Packet Radio System
GSM: Global System for Mobile
BPS: Binary Proximity Sensors
PIR: Proximity Infra Red
ML: Machine Learning
CS: Case Scenario
SBSS: Smart Bus Shelter System
FTC: Functional Test Case
1. Introduction

The Internet of Things (IoT) paradigm is becoming more prevalent as the need for connected devices across different environments grows. The ubiquity of connected devices can be observed in virtually every environment; from transportation and logistics domain, healthcare domain, smart environments, personal and social domain [1]. The Internet of Things definition is usually derived differently among various research in academia and practice, creating fuzziness around this term. However, from a user-centric perspective, it can be described as interconnection of sensing and actuating devices capable of information sharing across platforms through a unified framework [2]. Enabling technologies with characteristics such as the reduction in size (complexity), energy consumption and costs, provide more potential application possibilities for IoT integration into our everyday life. Current trends emphasizes particular interests in the application of IoT to urban context by governments. Smart city initiatives aim to address and improve economic prospects, environmental aspects and the quality of life for the public [3].

The potential social and economic benefits for various stakeholders have made cities to become the focus for a great deal of innovation and experimentation with IoT technology [4]. In the smart city domain, IoT is widely adopted to provide solutions that make use of public resources to increase the quality of services offered to people while reducing operational costs [3].

Although there is no clear definition of a “smart city” [4], the objective towards smart city initiatives is usually aimed to deploy a seamless integration of communication infrastructure, sensing and actuating technologies. Applications that allow access to different public services are used, thus unleashing potential synergies and increasing transparency to the citizens. Cities in North America and Europe are leading efforts in implementing smart technologies to address urban issues such as energy usage in street lamps, traffic congestions, smart traffic lights at intersections, smart buildings, smart bus shelters, etc. [5].

In urban environments, bus shelters are usually found at strategic locations that provide convenience to commuters, becoming attractive to advertisers since they are highly visible to passing by vehicles as well as pedestrians [6]. Various efforts are being
put forward to digitize and improve public spaces such as bus shelters with the aim of providing quality service to the public, while increasing revenue for stakeholders. Visionaries identify potential benefits towards outdoor media companies as well as transportation agencies through data collected from hotspot bus shelters [8].

Figure 1: Ericsson’s concept of the connected bus shelter

Source: http://www.ericsson.com/news/150611-connected-bus-stop_244069646_c

Figure 1 is an illustration of the connected bus shelter, which was unveiled by Ericsson in the UITP World Congress 2015. The idea is to have a bus shelter that incorporates 3G and Wi-Fi connectivity and to provide transport providers with an additional source of revenue [15], in terms of digital advertisements by outdoor media companies. It is capable of providing commuters with real-time information about bus movements, interactive maps with tourist information, local news, as well as USB charging port for mobile devices.
1.1. Project Idea

Our research is associated with Emergent Configurations of Connected Systems (ECOS), which is a part of the research projects in the Internet of Things and People (IoTaP) research center at Malmö University. The research encompasses the Smart city domain, where we investigate how IoT can be applied in smart bus shelters to add value to stakeholders such as businesses, institutions, transport providers as well as the commuters.

The focus of the project is about utilizing digital display of information in public spaces such as bus shelters. The information or content that we focus on in the research concerns digital advertisements or announcements from businesses, institutions and other points of interest around the city. We try to investigate a smart approach towards connecting businesses with the target audience in a particular bus shelter. This focus is expected to contribute to new smart advertising opportunities that create value for stakeholders. The integration of IoT in the smart bus shelter involves the use of sensors that collect contextual data from the commuters as well as the environment. Such data can be useful in the system’s decisions making, when it comes to what content is displayed on the screens. This “smart behavior” results in a context aware system that optimizes the relevance of information displayed, at a given time, location and for specific commuters in a bus shelter. Another aspect that utilizes the sensors concerns automation of the bus shelter. This reduces unnecessary energy consumption by different appliances such as lights, display screens or heating in the bus shelter. Motion sensors can, for instance, influence the dimming of lights whenever the bus shelter is not in use for a set period of time.

Various use case scenarios are considered where commuters can be engaged in a smart bus shelter. This enables to investigate the value adding aspects of IoT both in the user’s (commuter’s) perspective and in the business perspective.

The content that is displayed can be: (1). Location – based, implying that it concerns businesses and institutions within the surrounding location of the bus shelter, and, (2) time – based, given that the information is relevant at a particular time, for instance, an advertisement for a lunch offer taking place in a nearby restaurant is displayed a few hours before lunch hour.
It should be noted that while there exist various approaches towards building smart bus shelter, our proposed solution is not meant to be an articulate way of designing a new type of smart bus shelter. Rather, it is an additional feature that should be considered when implementing a smart bus shelter.

1.2. Motivation

The application of IoT in cities and urban areas is gaining momentum where a number of institutions and governments are pushing the adoption of smart solutions to manage public affairs [3]. The Smart bus shelter will be a way to connect various businesses and institutions to public transport commuters. Through considering alternative design approaches, bus shelters can relate to the wider urban environment and everyday practices, which includes complex relationships between multiple stakeholders and public transport services, functions, design, and management [7]. The use of IoT enables advertisers determine how effectively information is conveyed by identifying the potential number people that view the message in a public space such as the bus shelter.

Furthermore, an increased number of mediated messages delivered through billboards, posters, direct mail, e-mail spam, etc., tend to be intrusive to the viewer [5]. New interactive advertising methods are being adopted in public spaces to capture audiences and engage them, tending to make cities “livelier”, and becoming more effective for attracting customers [5]. Smart bus shelters can be interactive in the sense that the screens activate with motion detection, giving a certain experience to the commuter which is more likely to capture their attention while waiting for a bus [5].

Frequently replacing advertisements can be time and resource consuming. This, often at times, leads to the information displayed on posters lasting longer and becoming outdated or irrelevant to the audience. A smart way to update the information based on time and location can be cost effective, whereby new content is displayed without the need to replace the posters periodically. It is believed that this can be beneficial to the outdoor media companies, that rely heavily on advertisements in public spaces such as bus shelters.

Adoption of smart devices in bus shelters can be useful in various use cases, adding value to several stakeholders from different perspectives, i.e. the commuters (the user’s
perspective), nearby businesses or institutions (business perspective), the transport provider and other potential stakeholders. Some of the use case scenarios are summarized in Table 1 below, showing the description and the value added to different types of stakeholders.

<table>
<thead>
<tr>
<th>Use Case scenario</th>
<th>Description</th>
<th>Value Added</th>
<th>Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advertisements</td>
<td>Advertisement of offers and sales in nearby shops, restaurants, malls etc.</td>
<td>Connects businesses to potential customers</td>
<td>-Businesses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Commuters</td>
</tr>
<tr>
<td>Public Information</td>
<td>Public Events; Concerts, Gallery openings etc.</td>
<td>Creates awareness of the happenings around the area for tourists and commuters</td>
<td>-Commuters</td>
</tr>
<tr>
<td></td>
<td>Public information regarding nearby sites and facilities e.g. parks, museums etc.</td>
<td></td>
<td>-Public institutions, -Tourists.</td>
</tr>
<tr>
<td>Traffic Monitoring</td>
<td>Sensor data indicate Frequency of commuters in particular bus shelters at given times.</td>
<td>Increase quality of service for public transport providers. Reducing waiting times in bus shelters.</td>
<td>-Transport providers -Commuters</td>
</tr>
<tr>
<td>Connect to Smart Services</td>
<td>E.g. Smart garbage collection systems, Smart parking systems etc.</td>
<td>Efficient and convenient means of information for other smart services in the city</td>
<td>-Smart service providers.</td>
</tr>
<tr>
<td>Time Based advertising</td>
<td>Real time updates on events and happenings; e.g. A movie showing at a nearby cinema,</td>
<td>Relevant information is available to commuters</td>
<td>-Commuters -Businesses</td>
</tr>
</tbody>
</table>

1.3. Value of Smart bus shelters

Perhaps one of the common value adding aspect of the smart bus shelter is in the sense that it is an enabler of effective communication of the city to the public. Information is usually of value if communicated and utilized appropriately. The information displayed in a bus shelter for instance, can create awareness of the happenings around the city which creates interest for the commuter. An example of a case scenario is described in Table 1, in which an offer or a public event happening might trigger the interest and hence the commuter decides to buy into a certain offer for instance.

The value added can be looked at from two perspectives:

i. User perspective: The user refers to the public transport commuter or a pedestrian that interacts with the smart bus shelter. Relevant information about the city can be of value to the user in terms of saving costs. From the
user perspective, another key aspect that comes into play is the user experience in a bus shelter while waiting for the bus,

ii. Stakeholder perspective: The stakeholders are the public transport provider, businesses and institutions that rely on smart bus shelters to convey information to the commuters. Public transport providers consider services that convey traffic information such as a real time update of the bus position or the estimated time of arrival. Businesses and institutions on the other hand invest in public announcements of events, or advertisement of local sales or offers.

The focus of our research is on the business side and how local businesses, institutions or outdoor media companies can communicate information and connect to specific commuters.

1.4. Goals

The main objective of our research is to investigate ways in which IoT can be integrated in smart bus shelters to create value for public transport providers, private businesses as well as the users (commuters). It becomes clear that a wide range of aspects would need to be covered in order to realize all the possibilities that create value for different stakeholders as mentioned. Therefore, it requires to narrow down our research to focus on value adding aspects specifically for local businesses and institutions within the city.

To achieve the goal a literature review is conducted that covers related work. This gives insight on the current state-of-the-art as well and to help identify the gap when it come to the relation between the bus shelter and local businesses. In this light, a smart system is proposed, that govern the content displayed at different times, as well as the interaction with the commuter. To realize this, various case scenarios are considered, where commuters use a bus shelter and the factors that might come into play. A small scale low-fi prototype is then developed, that includes the software system to manage the display of advertisements, and the hardware components.

The concept of smart bus shelter should have functionality that includes:
1. Smart system which can pull the reliable information from local businesses, for instance through their social media and display them on the screen in the bus shelter.

2. Time and location –based display of relevant information the particular bus shelter.

1.5. Research Questions

In order to achieve the goal of our research, the following focus points had to be investigated to give insight on the system’s impact towards value addition to businesses, commuters and transport providers.

A hypothesis was made that bus shelters can be improved by using the Internet of things technology to become more useful to stakeholders. This gave rise to the given research questions that were investigated:

**RQ.** What are the value adding aspects when integrating IoT in bus shelters, that make them more useful to stakeholders such as public transport providers and private businesses?

**SRQ1.** How can IoT be used to enhance the way information is displayed in bus shelters, based on time and location.

**SRQ2.** How can a proof of concept for the proposed system be realized, in order to demonstrate an automated smart bus shelter.

A literature review was conducted where we expect to gain insight on the implementations of bus smart bus shelters, and the value added to stakeholders involve in bus shelters. A smart system was proposed to determine how information is displayed in a bus shelter. The believe is that such a system could add value to private businesses who utilize outdoor advertisements, especially in bus shelters to reach out to their customers. Finally a small scale prototype was built that simulated the way the system would behave when applied in an advertisement case scenario.
1.6. Expected Result

The research was expected to lead to a contribution to knowledge about smart bus shelter implementation in smart cities through the use of IoT. This included the technologies used, how useful data can be derived from the system and how this could benefit the local businesses or institutions in the city.

The smart system was expected to consider the context of the commuters that using the bus shelter in terms of the time and location of a bus shelter. This helps to govern what is displayed at different instances. From the business side, the value added is that the smart bus shelters optimize conveying of advertisements or information towards target audiences. The information displayed is expected to be of relevance to the commuters.

Furthermore, a small scale prototype should demonstrate the feasibility of such a system and in order to effectively give a visualization of how the system should work during our investigation.

2. Background and Literature Review

A background study is conducted with the aim to give insight on the current state-of-the-art regarding IoT in smart cities from related work. A summary of related work on smart cities is first presented in this section to give a background in the context of value addition towards public transportation. This is followed by a subsection regarding public spaces to summarize related work in the context of advertising. The concept of interactive advertisements is discussed and why it is an important aspect in public spaces such as bus shelters. It is followed by a take on the architectural technologies used when implementing IoT with efforts to improve bus shelters as well as public transportation. An approach to estimate crowd density in public spaces by use of sensors is presented. Additionally, the concept of machine learning is introduced and how it could be used in our work. The challenges faced in IoT in regard to smart cities are presented and the measures taken to address these challenges. Finally, we summarize the overall literature review and show its relevance to our research.
2.1. Smart Cities

Despite the frequent use of the term “Smart City”, there is still not a clear definition of the concept among practitioners and academia [9]. A limited number of studies investigate and systematically consider questions regarding the smart city phenomenon. However effort has been put forward to investigate defining characteristics and key aspects of interests in Smart Cities. Hafedh et al in [9] identifies eight crucial factors considered in smart city initiatives from various disciplines; management and organization, technology, governance, policy context, people and communities, economy, built infrastructure, and natural environment [9]. These factors form the basis of a proposed integrative framework that can be used to examine how local governments are envisioning smart city initiatives [9].

A smart city can be described as one that integrates physical infrastructure with digital infrastructure, in order to improve the quality of life and economic prospects while reducing environmental impact [10]. Various areas stand to benefit from IoT in smart cities such as public health and safety, resource management, businesses and institutions and transportation.

J. Manyika et al [11] identifies transportation as the largest domain for application of IoT – based systems to manage traffic flow and reduce congestion in cities. The use of IoT to track data from public transit systems add to great economic potential.

“Up to 70 percent of commuting time today is “buffer time”—the extra time between when the rider arrives at a stop or station and when the bus or train actually leaves. Reducing the buffer in cities across the world could provide time savings equivalent to more than $60 billion per year.”[11]

The integration of IoT in bus shelters enables transport providers to analyze data that can reflect the movement of commuters in the city at different times. The information is useful to optimize bus allocation thus reduce buffer times.

M Kopielski et al [22] investigate the use cases of SMARTIE, a smart city initiative, which include smart public transport specifically regarding smart bus shelters. Users (commuters) of the public bus transport interact with the system using their smart phones, through associated augmented reality markers (AR markers), available on
specified bus stops. A dedicated mobile application indicate information on the time of arrival to that bus shelter and suggest alternative routes to the commuter. **Figure 2** shows an illustration of the solution.

![Figure 2: Illustration of a possible response to traveller request: (a) bus stop with AR marker; (b) bus arrival time information on traveller’s smartphone following the AR marker scanning; (c) detailed information on available routes as requested by traveller [22]](image)

### 2.2. Interactive advertising in public spaces

The convenient location of bus shelters has made them attractive spots for advertisements where they are likely to be seen by multiple viewers. Commuters as well as passer-by pedestrians are often at times, captured by various eye – catching posters placed in bus shelters. Passive advertising refers to the traditional medium of advertisement where isolated objects are displayed in framed points of focus, for example posters, billboards etc., for potential audiences to see [5]. In contrast, interactive advertising emphasizes involvement of the audience, taking into account the viewer’s entire sensory experience [5]. H. Huang [5], observed that interactive installments in public spaces tend to capture the attention of more passing-by audience. The display screens are affected by the presence of a person for instance, they can activate when someone passing by is detected.
Figure 3 is an example of an interactive advertisement created by Adobe for the launch of Creative Suite 3. The installation is fitted with infrared sensors that lock onto pedestrians as they walk past by [5], where the person closest to the wall is able to control a CS3 rich media advertisement via a projected button at the bottom of the wall. The slider moves along as the person continues to walk which displays a colorful animation in the same direction.

Kai et al [14] define an interactive place to be a space that has meaning: Public spaces are merely constructed areas or spaces, while interactive places involve the engagement and activities that capture people’s interests [14]. Interactive screens encourage participation from people and tend to create a more interesting environment. One way to achieve public interactive installations is through touch screens, motion sensors or interaction with mobile devices, for instance through scanning a Quick response (QR) code [14].

A trial for a smart shelter was done in Auckland, New Zealand [32], whereby a survey was performed to assess user acceptance and experience associated to the new bus shelter. Among notable findings was that a surprising number of users actually
interacted with the screen and tried out different content types without any instructions or training (Figure 4).

![Figure 4: Usage of the connected bus shelter interactive display (% of users) [32]](image)

In relation to our work, the research investigates the importance of having interactive installations in different public spaces. Additionally, the aspect of connectivity consequently leads to linking the business to the advertisement in the bus shelters. The commuter can interact with the advertisement displayed through integrating QR codes that can be scanned. Once scanned, it can reveal more information concerning the subject and display it on a commuter’s mobile device.

2.3. **IoT Architectural Technologies**

Several efforts have been put forward to digitize bus shelters with the aim of providing better service to commuters. Ericsson unveiled the connected bus shelter in 2015 that incorporates a 3G, Long-Term Evolution (LTE) and Wi-Fi small cell technology for communication [15]. Small cells are low-powered access nodes that can operate in a licensed spectrum or unlicensed carrier–grade Wi-Fi. They typically have a range of 10 meters to several hundred meters. Due to the low power consumption [16], they are a promising candidate for backhauling Wireless Sensor Networks (WSNs).

WSNs are spatially distributed autonomous sensors that monitor certain environmental conditions such as temperature, motion, humidity, etc. The sensed data is forwarded to a gateway through communication protocols [17] and incorporates interfaces that enable interoperability with other heterogeneous devices. WSNs contain sensor interfaces, processing units, transceiver units and power supply [2], which enable
connection of a large number of smart sensors. The sensor data are shared among sensor nodes and sent to a centralized system for analytics. J. Gubbi et al [2] identify the major components of WSNs which include: WSN hardware, WSN communication stack, WSN middleware and secure data aggregation.

Radio Frequency Identification (RFID) technology was a major breakthrough that enabled automatic digital identification of various things that were otherwise digitally unidentifiable. They are composed of three main components [16]: RFID tag, reader and application system. RFID tags are attached to the objects and consist mainly of a coiled antenna and a microchip for storing data. The reader activates the tag and acts as the communication interface between the application and the tag.

**Figure 5** shows a pedestrian operating a touch screen that shows the map of the city in an interactive bus shelter. The design for this particular bus shelter was proposed by SmartCitiesLab [21]. It includes WiFi connection for pedestrians, QR and NFC (Near Field Communication) technology as well as a USB outlet to charge a mobile phone. An added screen is used to offer dynamic digital advertising. The digital display gives information on bus arrivals as well as information about surrounding areas of interest [21].

![Interactive bus shelter, Barcelona.](http://smartcity.bcn.cat/en/smartquesina.html)

Initiatives for connecting bus shelters by various companies such as Ericsson, Cisco and JCdecaux are relevant to consider when conducting our research since it provides
insight on the technologies used and benefits that motivate such initiatives. The connected bus shelter also acts as an information hub to show the map, including points of interests nearby. In our research, we contribute towards connecting businesses or institutions in terms of the content displayed on the advertisement screen.

2.4. **IoT in public transportation**

Boja et al [12], proposes an IoT system for an Intelligent Transport System (ITS) that includes a GPS system to track the location of the bus, NFC (Near Field Communication) device in the bus, and sensors to monitor the ambient environment in the bus i.e. temperature, humidity and air quality. The idea was to have an ITS that gets context data on the bus and conveys it to the transport provider, as well as the public commuters using a web server [12]. Useful data is presented to the commuters, for instance the number of seats currently available in the bus, say if a commuter plans to board a certain bus down the route. The ITS also makes the driver aware of commuter information, i.e. source – destination.

The system architecture of the ITS consists of 3 subsystems: Location subsystem, Commuter subsystem and the ambient subsystem. The location subsystem consists of a Global System for Mobile (GSM) module with General Packet Radio Service (GPRS) modem for communication with other devices [12]. The commuter subsystem consists of an NFC reader which enables payment by the commuter. The ambient subsystem consists of temperature sensors, humidity sensors and air quality sensors. It is responsible for monitoring the ambient environment in the bus.

The ITS system proposed in the research relates the smart bus shelter in terms of the goals intended to be achieved. The ITS aims to improve the quality of service provided to the commuter by presenting useful information about the oncoming bus. It was deployed in India and seemed useful for the public transportation system. Similarly, the information system in a smart bus shelter provides information concerning surrounding businesses or other points of interest around the city. This improves the commuter’s experience in a bus shelter while they wait for the next bus.
2.5. Estimating crowd density in public spaces

The density of pedestrian crowds in public places has often been determined by use of cameras that have the capability to identify distinct objects in the field of view. However, it raises an issue of privacy in various areas. In the case of the bus shelters, using cameras to determine the density of an occupied bus shelter may be expensive to implement for every bus shelter, resulting to less viability.

A number of researchers have investigated the possibilities of using sensors instead, to map the density of an occupied space. Binary Proximity Sensors (BPS) provide a low cost and privacy preserving solution to track mobile objects in a smart environment [20]. A BPS is a low cost sensor that outputs a “1” when motion is detected within a given range, and “0” otherwise. A more common BPS used in prototyping is the Passive Infrared Sensor (PIR). The challenge is that it does not distinguish between individual or multiple objects, neither does it provide information about the position of a specific target. The approach used in [20] considers \( n \) sensors deployed in a two dimensional array in a given area of interest. The counting of targets is achieved by synchronization of the readings from the sensors and mapping on a grid through a dynamic color technique. Several sensors with an output of “1” implies a higher density of detecting targets and vice versa. Each sensor reading corresponds to a different color in the grid. Thus presenting potential regions where the targets are located.

The research suggests that sensors can be used to estimate the density of a crowd in an occupied space, without compromising the user’s privacy as it would with cameras. It is relevant to our research since we try to strategically estimate the crowd density in a bus shelter. We suggest using dynamic infrared distance sensors which are an improvement to standard PIR’s. A distance sensor has a varying output that is proportional to the proximity of the detected object. A standard infrared distance sensor is the Sharp GP2Y0A21YK, which can detect close range objects from a distance of 10cm – 100cm. Using a similar setting as mentioned in [20], the values obtained from the sensors are dynamic, indicating how close or far a person is to the sensor.
2.6. Machine Learning

Machine learning is a method where the system analyses data and uses algorithms to iteratively learn from the data, increasing its performance from experience [26].

The use of Machine learning (ML) has been spreading rapidly with the increase of data collected and availability of devices that can collect contextual data from various sources. Machine learning systems continuously improve the performance of the executing program by learning from past examples [25]. The basic idea of machine learning is to take data from a sufficiently vast data set and identify patterns that exists within the data. The patterns are used to predict and determine the future behavior of the machine without having to program it more. There are many types of ML that exists, however the more common methods are:

i. Classification: It includes a Classifier, which is a system that inputs a set of discrete/ continuous values called features, and outputs a single discrete value called a class. P. Domingos [25], describes ML as consisting of a combination of three key components: Representation, Evaluation and Optimization.

ii. Linear regression: [26] A ML technique used to predict continuous values. It is a well known training method for ML that requires a sufficiently long enough human labeled dataset to predict values based on the patterns of the dataset. Since the field of predictive modeling is primarily concerned with minimizing the error of a model or making the most accurate predictions possible, linear regression, a known statistical method becomes highly significant to machine learning [27].

ML is common in IoT systems, where sensor data analytics can be used to learn and predict the changes in the environment of a smart device [28]. Currently, online tools such as Microsoft’s Azure and Google’s Tensor flow, are frameworks that have inbuilt ML algorithms. Therefore, as a user or developer, one can make use of such tools to apply ML techniques to any given data set.

Machine learning can be introduced in the smart bus shelter system whereby sensor data is recorded over time to predict future usage of certain bus shelters. This functionality is useful for both the transport provider and the advertisers to optimize the number of people that an advertisement reaches.
2.7. Challenges faced

IoT is associated with features that enable large-scale heterogeneous network elements and massive data exchange among them. On the other hand, strong and dynamic autonomy is required for each local tightly-coupled region. Therefore, it poses a challenge when it comes to resolving the apparent contradiction between large scale heterogeneity and the dynamics of IoT system, and the requirement of highly efficient data exchange [13]. Hua-Dong [13] points out another challenge characterized by uncertainty in the sensor data which needs certain representation after network processing procedures. This leads to another key research problem: how to reorganize and represent sensor data, and provide effective integration of uncertain information [13]. They propose mechanisms and methods of information presentation which take into account, the attributes of different sensed data, during the interaction process among network elements.

Shanzhi et al [14] have identified challenges faced from the perspective of smart cities. Key challenges listed include: Architectural challenges that are open and follow standards that don’t restrict end-to-end communication, Low cost hardware with sufficient functionality, privacy and security challenge, and interoperability. The business model is also a challenge to be considered in IoT [14]. There are many possibilities and uncertainties in its application case scenarios, thus it is important to consider solutions that create value for the stakeholder.

2.8. Summary

The goal of our research is to contribute towards improvement of bus shelters. The overall literature review relates to our research in the sense that the smart bus shelter is associated with smart city initiatives, which aim at improving the quality of services offered to the public. Motivations towards the installation of interactive displays in public spaces become relevant for our research where digital display screens form a key element in smart bus shelters. From the literature review conducted, it is found that there are several initiatives that aim to create connected bus shelters. Most initiatives emphasize on enabling the commuter to access digital maps showing public transport information. The gap identified is that there is little or no emphasis on connecting the
smart bus shelter with businesses or institutions in close proximity. We intend to contribute to this gap by creating a system that enables businesses or institutions to connect to commuters through smart bus shelters. Furthermore, we believe that integrating sensors presents the opportunity to analyze sensor data concerning the usage of bus shelters, and predict the movement of commuters using machine learning methods.
3. Research Methodology

Design and creation method was chosen where a small scale smart bus shelter prototype was developed and evaluated to investigate the feasibility and value of such a system towards commuters and businesses or institutions. Referring to the research questions, the intention was to provide a design for the proposed system thus getting insight on SRQ1. The design is used to develop prototype hence addressing SRQ2. The smart bus shelter display system includes rules that govern what content is displayed at particular instances of time and location. It also integrates with sensors that obtain information about the commuters such as the density of how a bus shelter is occupied.

In this chapter, an elaboration about the process of design and creation with regard to the activities conducted in our research is presented. In the sections that follow, an overview the Design Science Research (DSR) process model, adapted from the design process model by Takeda, et al. (1990) [18], is presented. Figure 6 illustrates an overview of process steps in a DSR model and the knowledge contribution. Second, a breakdown of the process steps in the DSR process model is discussed in the subsections that follow. The steps acted as a guideline to our research process. As derived from the DSR, the research process was conducted in five phases; requirement analysis, design phase, development phase, evaluation phase and conclusion phase. Each subsection presents a description of the respective phase in the research and the expected outcome of that phase. Finally, a summary of our design and creation process is illustrated in figure 7, where we present the phases and the activities carried out.

Through careful and articulate conducting of the research steps, we expected to answer our research questions SRQ1 and SRQ2 and contribute to knowledge on value adding aspects of IoT when integrated in smart bus shelters.

3.1. Design and creation

Design deals with the creation of a new artifact that doesn’t exist [18]. The strategy of design and creation in computing involves analyzing, designing and developing a computer – based product, supported by scientific explanation, critical evaluation and justification for the artifact [19].
In the light of our research questions, it was possible to acknowledge three main aspects of research:

1. The concept and design aspect, relevant to software engineering whereby the system was designed that can collect data and display relevant content.
2. The technical aspect where the objective was to build an artefact and test its feasibility and functionality.
3. The value addition aspects that involved investigating potential value to be gained from implementation of bus shelters.

![Figure 6: Design Science Research Model (DSR cycle) (extracted from [18])](image)

We leveraged this understanding to make an instructed decision and chose the Design and creation method. The Design Science Research (DSR) Process model was useful as a guideline to our research. Figure 6 illustrates the process steps taken in a DSR model [18].

Activities carried out in our research were mapped with the DSR process steps [18] in order to follow a systematic approach that creates a contribution to knowledge. Initial steps involved identifying the functional and non-functional requirements for the system. Requirement analysis was derived from being aware of the problem that we try to address using the system. Through conducting a literature review, it was found that
there was a need for improvement of various entities and public services in smart cities where IoT is the key player. From the requirement outlined, a tentative design for the system was developed in the suggestion phase. The design was used as a guideline to develop the functional components for the prototype in the development phase. An evaluation was done through testing whether the prototype fulfilled the functional requirements, and questionnaires were made to evaluate the potential value towards stakeholders. Various changes were expected to occur during development, therefore it was done iteratively. Finally, the contribution achieved through the design and creation process is discussed in the conclusion phase.

A summary of the steps taken throughout our research process is outlined below:

1. **Requirement analysis**: outline functional and non-functional requirements
2. **Design phase**: A tentative design illustrating functional components
3. **Development phase**: prototyping and coding the system
4. **Evaluation phase**: Functional testing of the prototype
5. **Conclusion phase**: Summary of the contribution and the design and creation process.

### 3.1.1. Awareness of the problem (Requirement Phase)

The recognition and articulation of the problem were derived from identifying a gap when it comes to the design of smart city initiatives. From the findings in the literature, a need for improvement of public spaces such as bus shelters was identified, in terms of the quality of service to commuters and relevance of advertisements for businesses in proximity to a particular bus shelter. Therefore a system was proposed, that monitors and displays content based on the time and location of the bus shelter. It includes mechanisms that can connect the displayed advertisements to nearby businesses, for instance through social media. Sensors are incorporated to automate the display as well as the heating system of a bus shelter. Sensor data is collected and analyzed to give useful information on the use of the bus shelter in terms of the density of commuters. To achieve such a system, the requirements identified were specified and acted as the foundation for the system design. The output of this phase was a proposal [18] that includes the specified functional and non-functional requirements.
General requirements include the overall features of the system that allow location and time-based functionality.

A particular case scenario was described; for instance, to display of a lunch offer at a certain restaurant during a given set time, where a user can scan the QR code to redeem the offer, then the requirements were identified for the system to achieve such functionality. In this case it would: monitor the time, be aware that advertisement is a lunch offer and generate a QR code. The table below illustrates description and system requirements of particular use case scenario examples.

<table>
<thead>
<tr>
<th>Case scenario</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
</table>
| Time – based advertisement    | A lunch offer that the user redeems with a QR code.                         | 1. Timer: Display particular type of advertisements at particular times.  
2. QR code.                  |
| Crowd density estimation      | Estimates whether the bus shelter is densely occupied                      | 1. Proximity sensors.                             
2. Visualization of how densely occupied the bus shelter is.  
3. Microcontroller to control the sensors. |

3.1.2. Suggestion (Design Phase)

The suggestion phase is essentially where the system was designed [18], based on the functional requirements. The design was illustrated using block diagrams that show the overall representation of the system. The preliminary design illustrates functional components of the system which act as a guide in the development phase.

The general approach to system design involved formulation and consolidation of different system components. The result should was an elaborate design that shows the logical functions and relation of each of the components.
3.1.3. Development Phase

The design was implemented whereby the coding for the necessary software was done as well as integration with the hardware i.e. prototyping board and the sensors. The intention was to perform pair programming where one student codes while the other follows through to ensure there is consistency. Connection of sensors and the arduino board was done mostly in the lab in order to test the functionality of the system.

Coding was done for the functional requirements in order to simulate the given case scenario. In the use case scenario focused on, various twitter user accounts were used to simulate various businesses where we simulate advertisements and announcements. A twitter API was used to display a twitter feed to a small arduino TFT screen. It simulates a lunch offer, for instance, in a restaurant from which it is twitted and displayed on the advertisement screen in a smart bus shelter.

3.1.4. Evaluation Phase

Functionality testing was done to evaluate the prototype. The prototype would demonstrate how content is displayed at designated times, for example, a lunch offer displayed a few hours before lunch. The prototype would also have the capability to display content from the social media for instance twitter. We connected it to a Twitter account whereby a lunch offer is simulated through a tweet with the hash tag “#Lunchoffer”. Finally, the prototype would also demonstrate automation of the bus shelter using sensors and actuators.

In order to evaluate how such a system would be valuable to stakeholders, questionnaires were formulated. The aim was to investigate out how commuters interact with advertisements in bus shelters and what impact would the new features have on them. A questionnaire was also formulated for the businesses to investigate the value that can be gained from the implementation of the proposed system.

3.1.5. Conclusion Phase

The results of the development process are consolidated [19] in the conclusion phase. It involves a reflection of all the processes undergone throughout the Design and creation
process. The limitations of our research as well as identified areas of future work are described.

### 3.2. Alternative research methods

An alternative appropriate research method that could be used is a quantitative research. A survey could be conducted on the usage of bus shelters by commuters and various businesses that make use of bus shelters for advertisement. Empirical results would provide insight on commuter experience in bus shelters, giving solid requirements for possible aspects that could be improved to enhance the user experience in the bus shelter. This would further be investigated by implementing a real world solution and deploying it in one bus shelter to evaluate to provide more accurate results. However, design and creation was chosen since it demonstrates the proposed solution as a small scale prototype that can be a reference point to a real world implementation. Furthermore, the time and scope of the thesis is not sufficient to conduct the study in such a scale. It is suggested as part of the future work that would investigate further, the real world deployment and the effects of the smart bus shelter.
4. Research Results

In this chapter, the results of the literature review are discussed. This includes the findings on various use case scenarios for smart bus shelters and the value adding aspects towards the stakeholders involved. Further, an analysis of a particular use case scenario is done to find out how a commuter would interact with the proposed system. The system requirements and functional components are established and used for the system design.

In the research on related work, the findings include a number of aspects that are relevant to our research. Motivations toward implementing smart bus shelters include improving how people use bus shelters to access information about the buses, and their surroundings. The common stakeholders involved include:

I. Public transport provider (bus company): Bus companies view smart bus shelters as an opportunity to provide better service to commuters in terms of information concerning arrival times for buses and their location on the map [21].

II. Businesses and institutions: Several businesses and institutions use bus shelters to advertise or communicate to the public. Most businesses attempt to advertise to their target market by strategically placing advertisement in the best (busiest) bus shelters, to widen the scope to more viewers.

III. Outdoor media companies: Bus shelters have an interesting business model in that they are primarily built and managed by private outdoor media companies, who enter into long-term leasing agreements with cities or transportation agencies. An appropriate profile of the demographics and interests of bus shelter commuters can be useful to better monetize its digital signage advertising [8].

IV. Commuter: Refers to the person using the bus shelter. Smart bus shelters aim to provide commuters with a better experience while waiting for the bus.

The smart bus shelter incorporates key functionalities and characteristics such as: Connectivity, interaction, digital maps, digital information display etc.. In typical cases, connectivity is achieved using a 3G modem router that connects to the local mobile service provider. This allows the system to connect to the public transport web server as well as the cloud, whereby further information about the city is retrieved. Smart bus shelters deployed in Paris, include functionality that displays information and the
happenings across the city, aimed to be a tour guide for tourists and other interested individuals [23].

The aspect of interaction is facilitated by touch screens where commuters select various points of interest on the map. Huang [5] points out how interactive advertising in public spaces tends to attract more engagement, which results to value addition towards the advertiser. Various attempts are being implemented such as the smart poster for digital advertising. It incorporates a QR code or an NFC tag that the potential customer can scan or tap, effectively providing more information about the advertisement on their mobile phone.

The need for crowd detection and monitoring sensors in public spaces is increasing in various cities. This is necessary when it comes to allocation of public facilities at different points of the city. While some cameras have this capability, they are expensive, hence not feasible for installation in every bus shelter. Furthermore, they raise concerns for privacy in various cases. Solutions are proposed, that make use of sensors installed strategically to detect motion in various spots within a particular space [20].

A number of use case scenarios were identified from the literature review, which indicate the use of smart bus shelters. We identified potential value adding aspects to the stakeholders mentioned above for each use case scenario. The results are consolidated in table 3, which indicate five different scenarios identified from the literature review.
Table 3: Use case scenarios for Smart bus shelters

<table>
<thead>
<tr>
<th>Use Case scenario (CS)</th>
<th>Description</th>
<th>Value Added</th>
<th>Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS1: Smart Advertising</td>
<td>Location &amp; time – based advertising</td>
<td>Effective advertising; Connects businesses to more potential target customers, thus increasing revenue.</td>
<td>Businesses, Outdoor media companies, Commuters</td>
</tr>
<tr>
<td>CS2: Public Information</td>
<td>Public information regarding nearby institutions and facilities.</td>
<td>Effective communication from institutions to the public</td>
<td>Institutions, Commuters</td>
</tr>
<tr>
<td>CS3: Bus location information</td>
<td>Real time location information for buses on route. A map indicates the position of the bus by use of GPS</td>
<td>Efficient information and update provided to commuters hence better service to commuter</td>
<td>Public transport provider, Commuter</td>
</tr>
<tr>
<td>CS4: Commuter flow analytics</td>
<td>Sensor data indicate frequency of commuters in particular bus shelters at given times.</td>
<td>Better planning and allocation of buses for certain routes</td>
<td>Public transport provider, Commuter</td>
</tr>
<tr>
<td>CS5: Smart Heating</td>
<td>Sensors detect presence of people in a bus shelter and turns on the heating system during cold seasons.</td>
<td>Better user experience for commuters during cold seasons</td>
<td>Public transport provider, Commuter</td>
</tr>
</tbody>
</table>

The next section presents an analysis of case scenario CS1 involving smart advertising.

4.1. Case Scenario Analysis

In this section, the case scenario CS1 from table 3 on smart advertising is discussed further, to determine the system design. Firstly, a visualization of the case scenario is presented, that looks at the flow of events when a commuter waits for a bus in a bus shelter, as well as the dynamics that may arise in terms of multiple commuters. This is useful in identifying the system functional components required to display relevant information and interaction. An overview of the system architecture is presented to show each component and their relationship with each other.
4.1.1. Case scenario CS1

Description

Suppose a user (commuter) intends to move from one bus shelter A to his/her destination in bus shelter B. The motion detector activates the screen which displays a map of the city. A message appears which prompts the user to select their preferred destination stop. From this interaction, the system highlights points of interest or businesses having. This shows businesses within the route to be taken by the commuter, and businesses in proximity to the user’s destination. The user may opt to select a one of the highlighted businesses which opens up details about the offer they have. If the user is interested with the offer, he/she can scan using QR code or NFC and get the details on their phone.

Suppose various businesses having a social media account such as twitter and they tweet about an offer that they are having. They can be displayed and updated on the screen such that users can see and read them. The tweets are based on the user context. For instance, if the user chooses a certain restaurant in the interactive screen, the tweets selected to be displayed contain messages with similar offers such as lunch offer, meal coupons, etc. Selected tweets are displayed based on a defined set of rules determined by, time of day, proximity to the bus shelter, user destination, etc. Most prioritized tweets are displayed at the bottom part of the screen such that the user may see and read them.

System Functional components

1. **Main System:** This refers to the main component having functions that control how the user interacts with the system, and the content displayed to the user. It includes rules that govern which tweets to be pulled displayed based on the context of time and location.

2. **Sensors:** Detect user presence in a bus shelter, activate screen, light and other actuators. The smart bus shelter is conceptualized to include features such as automated heating and lighting whereby motion sensors help to activate / deactivate, consequently saving energy consumption. Proximity sensors indicate high values whenever an object is in close proximity.
3. **Sensor interface:** It gets sensor data and passes them to the main system to determine the density of occupancy in the bus shelter.

4. **Cloud/social media interface:** The interface that allows retrieval of twitter feeds to be displayed on the screen.

5. **Display system:** The main display screen whereby advertisements are displayed. Most connected bus shelters are build having to at least two display screens; A smaller screen to display the map which is preferably touch screen, and a larger screen to display the advertisements. For our proposed system, the assumption is that the twitter information is displayed on the smaller screen.

6. **User Interface:** Allows users to purchase or redeem the coupon for instance (NFC, QR).

**System dynamics**

The case scenario CS1 described is dynamic in the sense that other factors come into play; - In case of a group of people in the bus shelter, or In most cases, more than one activity would be taking place in a city such as gallery openings, throw away offers in supermarkets, concerts, etc.

In order to realize the substantial results, the system should have predefined rules that govern the display of information, based on location of the bus shelter, time of day or week and input from sensors. A predefined set of rules helps to determine the content displayed, based on time, location and commuters in the bus shelter.

**System Rules**

Various system rules are devised in order to retrieve and display the most likely relevant content based on the time of day or the date. The following scenarios indicate examples of some of the system rules that would apply for certain kinds of information.

1. **Sales:**

   In the case scenario above, the first rule is to that ensure offers such as lunch offers should be displayed before lunch

   If (Time < 11:00) Display, (Lunch offer);
2. **Events:**

   In the case of different events, the system should determine the time/date when the event starts:

   Get Event $\text{StartTime/Date}$

   The first Event to be displayed should be the one which is sooner

   If ($\text{StartTimeA} < \text{StartTimeB}$) {
   
   Display $\text{EventA}$, Then Display $\text{EventB}$
   }

3. **Group of people:**

   In the case of multiple commuters in the bus shelter, content displayed depends on the context of the people in the bus shelter. The context can be derived from the certain characteristics such as:

i. **Time of day / week** ie. If it is during the evening hours and the shelter is occupied, it is more likely that the occupants of the bus shelter could be going home after work for instance. In this case, the content displayed should involve activities that take place after work such as, evening shows, after work events. Sales and offers in grocery stores may be relevant to commuters going home from work as well. In the smart bus shelter, offers displayed include locations along the routes to be taken by the bus after the bus shelter, as well as near the destination.

ii. **Location of bus shelter:** A bus shelter located near a school for instance, would most likely be occupied by students at particular times. For example, during evening hours after students leaving the classes, the content displayed during this time should be related to students, i.e. Student discounts, events, openings etc.
High proximity sensor readings indicating indicate a higher number of people around the bus shelter. Therefore, when the system reads high values, the content that is prioritized and displayed should be relevant to a larger group of people. In this case, the factors stated above are considered before pulling an advertisement for display.

**Figure 8** illustrates the flow of events in case scenario CS1. It shows how the system would behave depending on whether there is a single or multiple commuters around the bus shelter: The display screens activate when motion is detected by the motion sensor. The commuter has the option to enter their preferred destination through a touch screen. The system uses this selection to pull advertisements for businesses that are either close to the destination, or on-route to the destination. If the commuter prefers not to select the destination, then the system should display offers around the city. If a commuter is interested in an offer, he / she can scan the QR code associated with the offer and have it displayed on their mobile phone.
4.2. System Requirements

Based on part of the literature review, it was found that advertising in bus shelters can be enhanced to allow businesses to effectively reach target customers. To this, a Smart Bus Shelter System (SBSS) is proposed that displays relevant information based on the time of day, the location of the bus shelter and the potential type of commuters within a bus shelter at a particular time.

Thus the SBSS system is:

i. Time – based: could be morning hours, evening, Friday, weekends etc.

ii. Location – based: could be near a school, gym, shopping mall, town centers etc.

The information displayed may refer to advertisements of offers or sales, events openings, public announcements.

It should be noted that the SBSS is not a substitute to the current system used to display the map and other traffic information. Rather, it is an addition or enhancement to the current state-of-art whose aim is to have a more intelligent / smart system, that takes into account the factors mentioned above.

The system requirements are classified as functional and non-functional requirements, -which are explained in detail in the sections that follow.

4.2.1. Functional Requirements (FR)

The system functional requirements define the specific functions expected from the system in order to operate successfully according to the case scenario.

**FR1- Activation / Deactivation**

The system is automatically activated when motion is detected in the bus shelter through motion sensors. It should deactivate (or enter sleep mode) if the bus shelter is left unused for a period of time. This is done in order to conserve the energy whenever the bus shelter is idle, for instance during the night.

A Proximity Infra Red sensor (**PIR**) is used in the prototype due to its efficiency to detect motion.
FR2 – Determine density of occupants in the bus shelter

The density of occupants refers to the approximate number of people occupying a bus shelter. The reason as to why the exact number is not specified is due to the lack of sensors that can determine this number. Current devices that are used to achieve such a result are cameras that detect heat signatures from distinct objects. However, they are expensive and unavailable for the small scale prototype. Therefore, small scale infrared proximity sensors are installed strategically at different points in the bus shelter model.

Proximity sensors determine whether bus shelter is densely occupied or not based on the readings in each sensor. For instance, if three proximity sensors ($S_1$, $S_2$ and $S_3$), are placed at different positions in the bus shelter, the density of occupation $D$ is given by an aggregation of the respective sensor readings.

$$D = S_1 + S_2 + S_3$$

The Sharp GP2Y0A21YK proximity sensors are used in the prototype due to the capability to determine proximity in short range distances (10cm – 80cm). Three proximity sensors are placed in separate positions in a model for the bus shelter. Each sensor gets readings ranging from a value of approximately 200 – 700.

From previous trials, it was observed that the aggregate readings from the sensors would be below 600 when no object is detected, and above 1600 when multiple objects are detected.

FR3 – Connect to social media

The connectivity aspect of the Smart bus shelter system is one of its underlying significance towards presenting relevant content. This means that the advertisements or information displayed should be presently significant, rather than having outdated advertisements. The prototype should connect to twitter and retrieve tweets having a specific hashtag for instance “#LunchOffer”, from specific twitter accounts. Twitter accounts were created that represent different local businesses where to simulate a lunch offer, afterwork offers, gallery opening, sales, etc.
FR4 - Time – based information display

Time – based display refers to the capability of the system to determine the right time to display certain information. The aim is to demonstrate a smart system that can display at the right time when the information it is more likely to be relevant to the target audience. Looking at the use case scenario CS1, the system includes rules that control the time that an advertisement is displayed based on its attributes. For instance, an advertisement for a lunch offer is likely to be irrelevant after lunch. Therefore, in this case, another type of advertisement is prioritized to be displayed for example, afterwork offer.

Each type of information (or advertisement) is assigned an attribute that determines the optimal time for it to be displayed. The attributes refer to the period of time that an offer is available or the type of offer it is. Table 4 below shows examples of offers and their likely times of display.

Table 4: Possible advertisements displayed in case scenario CS1

<table>
<thead>
<tr>
<th>Advertisement</th>
<th>Attributes</th>
<th>Time to display</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type of offer</td>
<td>Time/date offer is available</td>
</tr>
<tr>
<td>Lunch offer</td>
<td>Daily offer</td>
<td>12:00 – 14:00</td>
</tr>
<tr>
<td>Afterwork</td>
<td>Weekly offer</td>
<td>Fridays</td>
</tr>
<tr>
<td>Gallery opening</td>
<td>One time offer</td>
<td>Wed, 25 May, 15:00</td>
</tr>
<tr>
<td>Amusement park offer</td>
<td>Weekends</td>
<td>(Sat - Sun)</td>
</tr>
<tr>
<td>Shopping mall sale</td>
<td>Daily</td>
<td>(5th May – 30th May)</td>
</tr>
</tbody>
</table>
**FR5 - Location – based information display**

The system should include the capability to display information based on the location of a particular bus shelter. Looking at the case scenario, various factors influence the information displayed at a particular bus shelter. In a real world scenario, advertisements involving premises near to the commuter’s destination would likely be more relevant than those concerning current departure location, i.e. If a commuter at bus shelter A is waiting for a bus to go to a destination at bus shelter B, then the advertisement for an offer near bus shelter B is more likely to capture their attention. Thus the smart system should include the capability to suggest various options based on the possible destination of commuters.

**FR6 – Interaction**

Interactivity in the system refers to the commuter’s ability to interact with an advertisement. This is advantageous in the case that the commuter prefers to have more information about the offer on their phone. A QR code is used that point to the URL of a particular advertisement for instance. The commuter can use this URL to redeem an offer at the business premise or to get more information about the location of the offer.

A summary of the system’s functional requirements is presented in Table 5, giving a brief description of the expected result from each requirement.
Table 5: Summary of the functional requirements

<table>
<thead>
<tr>
<th>Requirement ID</th>
<th>Requirement name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR1</td>
<td>Activation / Deactivation</td>
<td>The system activates through motion detection and deactivates if left unused for a specified period of time.</td>
</tr>
<tr>
<td>FR2</td>
<td>Determine density of occupants</td>
<td>Indicate high values in case of multiple objects in the bus shelter.</td>
</tr>
<tr>
<td>FR3</td>
<td>Connect to social media</td>
<td>Connect to Twitter and retrieve tweets from selected handles with selected keywords for example #lunchoffer</td>
</tr>
<tr>
<td>FR4</td>
<td>Time – based information display</td>
<td>Display the latest updates of tweets with the from selected handles with specified keywords.</td>
</tr>
<tr>
<td>FR5</td>
<td>Location – based information display</td>
<td>Display tweet messages from twitter handles located in specific geological locations.</td>
</tr>
<tr>
<td>FR6</td>
<td>Interaction</td>
<td>Display a QR code that points to the advertiser’s URL</td>
</tr>
</tbody>
</table>

4.2.2. Non – Functional Requirements (NFR)

NFR’s elaborate the performance characteristics of the proposed system.

NFR1 - Reliability: A measure of how relevant the information displayed in the bus shelter is to the commuter depending upon his interests and the route he is taking. The information is meant to be targeted to a specific set of audience. Hence, a highly reliable system should capture a substantial number of the targeted group.

NFR2 – Accuracy: A measure of how accurate information is displayed based on the time and location attributes. A lunch offer should not be displayed three hours after lunch for instance.

NFR3 - Availability: When motion is detected in the bus shelter, the screen activates and displays the information. The information displayed should be available through efficient connectivity for the bus shelter.
4.2.3. **Prototype requirements**

A small scale prototype was developed to demonstrate the behavior of the proposed system in the case scenario discussed previously. The aim was to fulfill the requirements and show how such a system would be helpful to surrounding business premises.

The arduino platform was used because of the availability of the hardware components and previous knowledge when working on prototype development using the platform. The hardware and software requirements for the prototype are described in table 6.

![Table 6: Hardware and software requirements for the prototype](image)

<table>
<thead>
<tr>
<th>Hardware Requirements.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Model</strong></td>
<td><strong>Quantity</strong></td>
</tr>
<tr>
<td>Proximity sensors</td>
<td>Sharp GP2Y0A21YK</td>
<td>3</td>
</tr>
<tr>
<td>Motion sensors</td>
<td>PIR sensor</td>
<td>1</td>
</tr>
<tr>
<td>Prototyping board</td>
<td>Arduino Uno</td>
<td>2</td>
</tr>
<tr>
<td>Connection shield</td>
<td>Ethernet Shield</td>
<td>1</td>
</tr>
<tr>
<td>Arduino screen</td>
<td>2.8 inch Arduino tft screen</td>
<td>1</td>
</tr>
<tr>
<td>Breadboard</td>
<td>Standard</td>
<td>1</td>
</tr>
<tr>
<td>Connection cables</td>
<td>Standard</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Software Requirements.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Software</strong></td>
<td><strong>Version</strong></td>
<td></td>
</tr>
<tr>
<td>Arduino IDE</td>
<td>1.0.6</td>
<td></td>
</tr>
<tr>
<td>Processing IDE</td>
<td>3.0.2</td>
<td></td>
</tr>
<tr>
<td>Eclipse (Java)</td>
<td>Mars</td>
<td></td>
</tr>
</tbody>
</table>

4.3. **System Architecture**

The system retrieves tweets from twitter using a twitter API, filters the tweets according to the specified keywords and selects which tweets should be displayed depending on the time of day. The two main software components for the prototype are developed using *Processing IDE* and the *Arduino IDE*. The arduino IDE gets sensor
values from the arduino and controls the activation and deactivation of the TFT screen. The processing IDE connects to twitter through the twitter API and retrieves tweets having a specific hashtag. It contains a function that specifies the geographical location from which the tweets should be retrieved.

Figure 9 illustrates an overview of the system architecture, including various functional components. The twitter API is used to retrieve specific tweets. The location function filters tweets from a specific geological location while the time function governs the appropriate time to display certain tweets.

Figure 10 shows the sequence for retrieval and display of tweets from the cloud (tweeter) to the display screen. It is expected that the tweets are first stored in a buffer before being displayed which is indicated as the advertisement repository. The main system pulls information based on the set rules mentioned in the previous section. A QR code can be scanned to retrieve more information about the offer from the advertiser.
4.4. Prototype

A cardboard box was used for bus shelter model where three proximity sensors (Sharp GP2Y0A21YK) were strategically placed at different points in the model to detect different positions of an object. A PIR motion sensor detected motion whenever objects were placed in the bus shelter model. Figure 11 illustrates photographs of the bus shelter model.

Two arduino prototyping boards were used where one was used to control the display on the TFT screen, while the other was used for connection through the Ethernet shield. The sensors were connected to the arduino through the analogue ports.
4.4.1. Processing

The software part was programmed using the processing and the arduino software. Processing is a simple programming environment that makes it easier to develop visually oriented applications, providing users with instant feedback through interaction [24]. It is based on Java whereby the code is termed as a “sketch”. Processing enables the low level arduino language to interact with other high level languages, operating systems, formats and communication protocols. A Twitter library was included in processing that allowed the prototype to connect to Twitter and process the requested tweets. The library used was Twitter4j, which is an open source Java library that connects to the Twitter API and retrieves tweet responses in the form of JSON (JavaScript Object Notation) format.

Four twitter accounts were opened with the following handles: @restaurant1_0, @restaurant2_0, @supermarket1_0, @gallery1_0.
The twitter handles represented four different Test businesses that advertised different offers at different times. The system was designed to retrieve tweets from the twitter accounts. The figure 12 shows the twitter messages retrieved having the hash tag “#lunchoffer”. It was observed that the system is able to retrieve tweets from the twitter accounts created (@restaurant1_0 and @restaurant2_0), however, it could retrieve tweets having a similar hash tag from other users.

**Location–based functionality**

A location filter was able to retrieve tweets from a given geographical location. The function to enable filtering of tweets by location was added to the processing code as given:

```java
query.geoCode(new GeoLocation(55.6050,13.0038),5.0,"mi")
```
The constructor “GeoLocation” shown above takes parameters that describe the location in terms of **longitude** (55.6050); **Latitude** (13.0038), and having a radius of 5 miles.

On applying the location filter with the coordinates above, the tweets retrieved were from Malmö. The limitation observed was that triangulation from specific parts of Malmö city was a challenge. However, in a real world situation, it is recommended to filter tweets from specific user accounts, rather than the GeoLocation function.

### 4.4.2. Arduino

The arduino software is based on C programming and enables one to easily write code and upload it on the arduino board. A TFT library had to be added to the code to enable functionality of the display screen. Since it is a small 2.4 inch low resolution screen, the twitter messages could not be successfully displayed. Since the TFT was a small representation of actual display screens used in real world scenarios, it was not necessary to show actual twitter feeds because this would be implemented differently for a real world scenario.

### 4.4.3. Sensor Readings

As stated in the functional requirement **FR2**, sensor values from sensors S1, S2 and S3 are added to the aggregate sensor readings. The total sensor reading \( D \) was used to represent the density of how much a bus shelter is occupied.

![Figure 13: Sensor values observed in an empty bus shelter model](image)
Figure 13 shows the readings observed from sensors S1, S2 and S3 in an empty bus shelter model. Sensors S1 and S2 are shown while S3 is off the frame.

It was observed in the bus shelter model, the total sensor readings would range from a value of approximately 600 (when the bus shelter is empty) to approximately 2000, (when fully occupied).

Thus the sensor values were classified into 3 categories, to give a clear visualization of how densely is a bus shelter occupied. Table 7 illustrates the grouping used for the sensor readings.

<table>
<thead>
<tr>
<th>Total sensor value (D)</th>
<th>Density of occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>000 - 1000</td>
<td>Low</td>
</tr>
<tr>
<td>1000 - 1500</td>
<td>Medium</td>
</tr>
<tr>
<td>1500 – 2000 and beyond</td>
<td>High</td>
</tr>
</tbody>
</table>

4.5. Machine Learning

The system’s ability to learn was achieved through the use of sensor data recorded at different times during the day. Looking at a particular day, for instance Monday, the sensor values were recorded at time intervals throughout the day. It was expected that high sensor values would be observed at rush hours and vice versa. When similar patterns are observed in the weekdays, the system could learn from these patterns and predict traffic flow of commuters in the coming week.

The assumption made during the investigation is that no holiday, or events that disrupt the normal flow of commuter traffic occur, since different results would be observed during the time of the day. For example, on a holiday whereby few people go to work, lower sensor values could be observed in the morning hours.

We chose a machine learning tool called Microsoft Azure Machine Learning Studio [30] to simulate the sensor values that would be recorded during the day from 06:00 hrs to 22:00 hrs. The values were recorded every 15 minutes and consolidated with the days of the week. Table 8 shows the values and the respective time that they were recorded
for Monday. The table also contains sensor values for the rest of the week, i.e. Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday. However, values for Friday, Saturday and Sunday were slightly tweaked to represent the changes in the commuter traffic pattern. This dataset was exported to Azure in order to predict the values that would occur in the following week.

Table 8: day of the week and consecutive sensor values at different times of day
(Extracted from Excel file).

<table>
<thead>
<tr>
<th>DAY</th>
<th>TIME</th>
<th>SENSOR VALUE</th>
<th>DAY</th>
<th>TIME</th>
<th>SENSOR VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONDAY</td>
<td>6:00</td>
<td>582</td>
<td>Thursday</td>
<td>6:00</td>
<td>552</td>
</tr>
<tr>
<td>MONDAY</td>
<td>6:15</td>
<td>603</td>
<td>Thursday</td>
<td>6:15</td>
<td>653</td>
</tr>
<tr>
<td>MONDAY</td>
<td>6:30</td>
<td>620</td>
<td>Thursday</td>
<td>6:30</td>
<td>720</td>
</tr>
<tr>
<td>MONDAY</td>
<td>6:45</td>
<td>750</td>
<td>Thursday</td>
<td>6:45</td>
<td>850</td>
</tr>
<tr>
<td>MONDAY</td>
<td>7:00</td>
<td>754</td>
<td>Thursday</td>
<td>7:00</td>
<td>774</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thursday</td>
<td>7:15</td>
<td>776</td>
</tr>
<tr>
<td>Tuesday</td>
<td>6:00</td>
<td>599</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>6:15</td>
<td>600</td>
<td>Friday</td>
<td>6:00</td>
<td>552</td>
</tr>
<tr>
<td>Tuesday</td>
<td>6:30</td>
<td>620</td>
<td>Friday</td>
<td>6:15</td>
<td>600</td>
</tr>
<tr>
<td>Tuesday</td>
<td>6:45</td>
<td>750</td>
<td>Friday</td>
<td>6:30</td>
<td>711</td>
</tr>
<tr>
<td>Tuesday</td>
<td>7:00</td>
<td>724</td>
<td>Friday</td>
<td>6:45</td>
<td>750</td>
</tr>
<tr>
<td>Tuesday</td>
<td>7:15</td>
<td>776</td>
<td>Friday</td>
<td>7:00</td>
<td>763</td>
</tr>
<tr>
<td>Tuesday</td>
<td>7:30</td>
<td>810</td>
<td>Friday</td>
<td>7:15</td>
<td>798</td>
</tr>
<tr>
<td>Tuesday</td>
<td>7:45</td>
<td>929</td>
<td>Friday</td>
<td>7:30</td>
<td>801</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td>6:00</td>
<td>572</td>
<td>Saturday</td>
<td>6:00</td>
<td>500</td>
</tr>
<tr>
<td>Wednesday</td>
<td>6:15</td>
<td>623</td>
<td>Saturday</td>
<td>6:15</td>
<td>599</td>
</tr>
<tr>
<td>Wednesday</td>
<td>6:30</td>
<td>640</td>
<td>Saturday</td>
<td>6:30</td>
<td>602</td>
</tr>
<tr>
<td>Wednesday</td>
<td>6:45</td>
<td>760</td>
<td>Saturday</td>
<td>6:45</td>
<td>601</td>
</tr>
<tr>
<td>Wednesday</td>
<td>7:00</td>
<td>744</td>
<td>Saturday</td>
<td>7:00</td>
<td>589</td>
</tr>
<tr>
<td>Wednesday</td>
<td>7:15</td>
<td>796</td>
<td>Saturday</td>
<td>7:15</td>
<td>656</td>
</tr>
<tr>
<td>Wednesday</td>
<td>7:30</td>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The data set was imported into Azure as a CSV file (Comma Separated Value). Figure 14 illustrates the workflow of the ML process in Azure:

i. SBS Sensor values full week: This module represents the reader for the data set that was imported.
ii. **Select Columns in Dataset:** This model is used to select the columns in the dataset that are necessary to make the right prediction[29]. In our case, the columns selected that would be useful to predict the sensor values include: DAY, TIME, and SENSOR VALUE

iii. **Split Data:** The dataset is split where part of the data is used to create a model for predicting unknown values while the other part is used to evaluate the prediction model. In our case, 70% of the data was used to create a prediction model while the remaining 30% was used for evaluating its accurateness.

iv. **Linear Regression:** This is the algorithm used to predict the sensor data. The linear regression algorithm was chosen since it is commonly used to predict continuous values [26] such as the sensor values.

v. **Train Model:** The Train model is used to connect the algorithm and the data. The column that is to be predicted is specified in the train module. In our case, we chose the SENSOR VALUE column.

vi. **Score Model:** It shows the predicted results obtained through applying the algorithm.

vii. **Evaluation model:** The evaluation model is used to evaluate the results to show how well the prediction model did.

---

![Figure 14: Workflow diagram of the ML prediction model in Azure](image)

---

**Figure 14:** Workflow diagram of the ML prediction model in Azure
Having simulated the sensor values that would be read each day for a period of three weeks, we were able to obtain a prediction for the following week. The results obtained from are shown in the figure 15.

![Bus shelter occupancy prediction](image)

**Figure 15 : Prediction results for sensor value from the dataset**

The highlighted column (SENSOR VALUE) holds the predictions for different days of the week. According to the results it was observed that on Friday at 17:45 for instance, the predicted value is *High* at 2198, while on Monday at 11:30, it is *Low* i.e. 600. This shows that the system was able to predict the traffic flow, based on the given sensor data. It is therefore possible able to predict the expected number of people present at different times of the day. **Figure 16** shows how accurate the predictions made, were from the evaluation model.

It should be noted that the assumption made is that only normal days of the week showing normal traffic flow were considered. This excluded the fact that a special day,
for instance, a holiday would affect the normal flow of commuter traffic. However, in a real world situation, the sensor values would be based on the actual flow of commuter traffic. Thus, it is expected that the system would learn from real values that reflect the accurate flow of commuter traffic over time.

![Bus shelter occupancy prediction](image)

**Figure 16 : Evaluation metrics from predicted results**

The prediction of the number of people at particular bus shelters at a particular time is useful for the various stakeholders such as public transport providers and outdoor advertising companies. It would allow public transport companies to use the data while planning bus routes, as well as provide data that show hot spots for public advertisements.
5. Evaluation

An evaluation was done through questionnaires to investigate the value adding aspects towards commuters and local businesses through. Functional testing of the small scale prototype was done, whereby different functional test cases (FTC) are done to determine the functionality of the prototype. This section presents the questionnaires that were used for the commuters and businesses as well as the results. Finally, the description and results of the FTC’s are presented.

5.1. Questionnaires

To evaluate the value adding aspect of smart bus shelters, questionnaires were distributed to various commuters at different bus shelters, as well as various businesses that use bus shelters in their advertisement campaigns. Two distinct types questionnaires were distributed; - One type directed to the commuters while the other to the businesses.

The participants were chosen through both random sampling and opportunity sampling technique [19][31], where we asked random commuters who were available to fill out the questionnaire. It included views from different kinds of people, i.e. students, elderly, working commuters e.t.c, therefore the results are believed to represent the target population[31]. The businesses selected were handpicked using a purposive sampling technique [19], in order to consider businesses that make use of bus shelters to advertise their products and offers. Thus, it is noted that the results of the businesses questionnaire may not be fully representative of all kinds of businesses in general.

5.1.1. Commuters

The aim of the questionnaire was mainly to investigate out how many commuters pay attention to current advertisements in bus shelters and the impact it could have, if bus shelters were equipped with modern digital advertisement screens. We also investigated the commuter’s response to the possibility of having digital coupons in their mobile phones through QR scanning.
Table 9: questionnaire directed to commuters

<table>
<thead>
<tr>
<th>Commuters</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not at all</td>
</tr>
<tr>
<td>1. How often do you normally see information or advertisements that are</td>
<td>1</td>
</tr>
<tr>
<td>relevant to you in bus stops?</td>
<td></td>
</tr>
<tr>
<td>2. How much do the advertisements influence you to purchase the items</td>
<td>1</td>
</tr>
<tr>
<td>advertised?</td>
<td></td>
</tr>
<tr>
<td>3. How much would a digital advertisement at a bus stop capture your</td>
<td>1</td>
</tr>
<tr>
<td>attention compared to the current poster advertisements?</td>
<td></td>
</tr>
<tr>
<td>4. Consider a digital advertisement where you can scan and get a coupon</td>
<td>1</td>
</tr>
<tr>
<td>for an offer on your mobile phone, right there in the bus stop. How much</td>
<td></td>
</tr>
<tr>
<td>do you think you would use this feature/service?</td>
<td></td>
</tr>
<tr>
<td>5. How valuable would it be for you to see information or advertisements</td>
<td>1</td>
</tr>
<tr>
<td>that are relevant to you, such as offers etc.</td>
<td></td>
</tr>
</tbody>
</table>

Results

A sample size of 33 commuters contributed to the questionnaire. Table 10 shows the results of the responses from commuters towards each question.

Table 10: Results of the questionnaire directed to commuters

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commuter 1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 5</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Commuter 6</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 7</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Commuter 8</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 9</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 10</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 11</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Commuter 12</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 13</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Commuter 14</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 15</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 16</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 17</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 18</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Commuter 19</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 20</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 21</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 22</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 23</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 24</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 25</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Commuter 26</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 27</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 28</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 29</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commuter 30</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 31</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 32</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Commuter 33</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
The **Table 11** below shows the number of people/times that each option in the scale was selected, for each question.

**Table 11: Results showing the number of times selected for each option in the scale**

<table>
<thead>
<tr>
<th>Questions</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1 (Not at all)</td>
</tr>
<tr>
<td>Q1</td>
<td>7</td>
</tr>
<tr>
<td>Q2</td>
<td>5</td>
</tr>
<tr>
<td>Q3</td>
<td>0</td>
</tr>
<tr>
<td>Q4</td>
<td>0</td>
</tr>
<tr>
<td>Q5</td>
<td>0</td>
</tr>
</tbody>
</table>

Looking at **table 11**, it shows that, for instance, the scale of 1 was selected 7 times for question 1, while scale 2 was selected 20 times for question 1 and so on. The table is interpreted graphically and shown in **figure 17** below.

![Graphical representation of the selected option for each question](image)

**Figure 17**: Graphical representation of the selected option for each question

It was observed that a large number of commuters find value in having relevant information delivered to them in bus shelters. Discussions with a number of commuters
in bus shelters revealed that most people pay attention to advertisements showing offers or sales, especially those that are offered nearby, or in a location convenient to them.

Furthermore, more people would feel comfortable using the QR code scanner to retrieve coupons for such offers. It was perceived to be an innovative alternative to the current paper coupons that are cumbersome to carry where people tend to forget them when they need to redeem the coupons.

An observation was made of an event that utilized location based advertising posters, found near Pildamsparken in Malmö, Sweden, where an event taking place in the park was to occur. This showed that the factor of the nearby location seems to be important when trying to reach out to the target audience interested.

5.1.2. Businesses

The questionnaire directed to businesses seeks to investigate how businesses make use of advertising in bus shelters, and whether they see the value of our proposed solution. Table 12 shows the questions that were directed to businesses.

Table 12: Questionnaire directed to businesses

<table>
<thead>
<tr>
<th>Businesses</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not at all</td>
</tr>
<tr>
<td>1. How often do you advertise your products or offers in bus shelters?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2. Do think that advertisements on bus shelters normally influence your</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>sales of the product or service?</td>
<td></td>
</tr>
<tr>
<td>3. How much do you think the advertisements placed in bus shelters really</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>communicate to your target audience?</td>
<td></td>
</tr>
<tr>
<td>4. How much would you consider advertising your offers or products</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>digitally in a bus shelter?</td>
<td></td>
</tr>
<tr>
<td>5. Consider a smart bus shelter, having the features described above.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>How much value would it bring to your business when compared to the</td>
<td></td>
</tr>
<tr>
<td>current alternative methods that you use to advertise?</td>
<td></td>
</tr>
</tbody>
</table>

Results

The results in Table 13 shows the response from 10 different businesses who participated in the questionnaire. The frequency of each answer chosen is represented with the bar graphs as shown.
Similar to the commuter’s results, the number of time chosen for each option was tabulated in Table 14 and illustrated by the chart in figure 18.

Table 13: Results of the questionnaire directed to businesses

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>El Giganten</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Media Markt</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>H&amp;M</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Burger King</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Coop</td>
<td>2</td>
<td>3</td>
<td>N/A</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Teknisk Magasinet</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Max</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>ICA</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Thai Wok</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Mc Donalds</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 14: Results showing the number of businesses that selected each option

<table>
<thead>
<tr>
<th>Questions</th>
<th>Scale</th>
<th>A1(Not at all)</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5(Very much)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td></td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Q2</td>
<td></td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Q3</td>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Q4</td>
<td></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Q5</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure 18: Graphical representation of results by businesses
Results indicate that 60% of the businesses would highly consider advertising in smart bus shelters and 80% found it very useful to optimize the reach of their target audience. One of the representatives of a particular business showed a lot of interest towards having such systems in bus shelters since it would be of value to the business if they were able to tell how many target audiences are influenced by their advertisement campaign.

From Question 5 of the questionnaire, various business owners and representatives shared similar views on being able to identify the amount of influence that their advertisements may have in bus shelters.

### 5.2. Functional Testing

Functional testing was done to observe whether the prototype fulfills the functional requirements. The Function Test Cases (FTC) for each of the requirements are presented in this section. Each FTC was conducted and the remarks for the observations were recorded.

<table>
<thead>
<tr>
<th>FTC1</th>
<th>Name of Functional Requirement: Activation/Deactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Description: When a motion is detected in the bus shelter.</td>
</tr>
<tr>
<td></td>
<td>Sequence of action: The screen activates</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected results</th>
<th>Test evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the PIR detects motion</td>
<td>The screen activates</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>When the bus shelter is empty for some time</td>
<td>The screen deactivates or shuts down</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

The PIR sensor was able to respond adequately on detecting motion. The prototype model used was small thus the PIR was sensitive to slight motion triggers.
FTC2

Name of Functional Requirement: Determine density of occupants in the bus shelter

Description: In case the bus shelter is occupied by a single or multiple commuters

Sequence of action: Change of sensor readings with movement of commuters inside the bus shelter

\[ D = S_1 + S_2 + S_3 \]

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected results</th>
<th>Test evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the bus stop is fully occupied</td>
<td>High sensor readings (&gt; 1200)</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>When the bus stop is less occupied</td>
<td>Low sensor readings (&lt; 600)</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

Sensor readings from the three sensors were observed to range from values of approximately 600, when no object is placed in the bus shelter model, to values of approximately 2000, when the model is filled with objects.

FTC3

Name of Functional Requirement: Connect to social media

Description: Connect to twitter and retrieve tweets based on set criteria

Sequence of action: Display tweets having the set hashtag in a list, starting from the latest tweet.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected results</th>
<th>Test evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display tweets with the hashtag “#lunchoffer”</td>
<td>Only tweets containing #lunchoffer are displayed</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

The prototype was able to filter specific keywords from twitter posts as expected. The keywords “#lunchoffer” and “afterwork” were used to simulate different types of offers happening at different times.
FTC4

Name of the corresponding Function: Time – based information display

Description: To demonstrate a smart system that can display at the right time

Sequence of actions: Control the time an advertisement is displayed based on its attributes

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected results</th>
<th>Test evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning hours (08:00 – 14:00)</td>
<td>The lunch offers are displayed</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>Afternoon &amp; Evening hours (14:00 – 19:00)</td>
<td>Afterwork offers are displayed</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

Time filter was used and attributed to the lunch offer and the afterwork offers. Observed results were satisfactory whereby, the offers were only pulled during their designated times i.e. The system could display tweets with the “#lunchoffer” before 14:00 and those with “#afterwork” after 14:00.

FTC5

Name of the corresponding Function: Location – based information display

Description: The capability to display based on the location of the source of information.

Sequence of actions: Each information is assigned a location attribute based on the distance from the bus shelter is displayed on the screen.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected results</th>
<th>Test evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus shelter near a particular location.</td>
<td>Display offers in the nearby restaurants</td>
<td>Partially satisfactory</td>
</tr>
</tbody>
</table>

The location filter used in the code could retrieve tweets from specific geographical locations, however, it could not triangulate to specific point of the city. This was a limitation in the geographical locator for the twitter API used. It was not possible to triangulate to the specific point in which the tweets originated.
**FTC6**

Name of the corresponding Function: Interaction

Description: Display QR code that points to more information of the advertiser

Sequence of actions: The QR code is displayed on the screen which is scanned to point to the advertiser’s web page.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected results</th>
<th>Test evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan QR code</td>
<td>Give the URL for the test businesses</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

The QR code generated pointed to the URL address specified as expected. The application of a QR code in a real world scenario can be embedded into the advertisement content whereby it points to a digital coupon that potential customers can redeem. The QR code was displayed in the TFT screen of the arduino together with the advertisement referred to.
6. Conclusions and Future work

In this chapter, conclusions made for the research are discussed. A number of limitations are discussed, which involves various aspects that are not included in the scope of the research. Finally, potential applications of IoT in regard to smart bus shelters are presented which opens possible areas of future research.

6.1. Conclusions

In the research, various useful ways in which IoT can be applicable in bus shelters are established, including particular value adding aspects to stakeholders. The stakeholders identified are, i.e. public transport provider, outdoor media advertisement companies, businesses and commuters. In most cases, the advertisement companies are the major stakeholders in the sense that they build and maintain bus shelters.

Looking at our initial hypothesis; (“Bus shelters can be improved by using the Internet of things technology to become more useful to stakeholders”), a number of use cases were found (Table 3). Integration of IoT to connect bus shelters facilitates the possibilities of data collection through sensors, that is useful to various stakeholders such as local businesses, advertising companies and public transport providers. Currently, the main source of revenue generated in bus shelters comes from advertisements. Thus, to investigate the value adding aspects of smart bus shelters, we focused on the use case on smart advertising. The concept of dynamic and interactive advertising in bus shelters is being adopted widely since it has a positive influence on the target market. With the prototype we sought to demonstrate one way in which dynamic advertising can be achieved through connecting to social media, as well as location and time-based advertising. Since this is the first research done on such a system, we saw the need to develop a small scale prototype in order to further gain insight on how the concept would be built. Additionally, it was important as a visualization of the concept while evaluating the value added to the commuters and the businesses. We believe this brings about the possibility to display other types of valuable information such as real time location of buses as well as local public announcements by the city council.
The IoT technology, facilitates connectivity and control of various aspects by the involved stakeholder i.e. for instance, outdoor media companies controls how various content is displayed in different bus shelters across the city from a central hub. The value that comes from such implementations involve efficient updating of advertisements to ensure that the information reaches the right target audience. It was established that sensor data may also be useful to monitor the movement of commuter traffic across the city as well, ensuring suitable planning and allocation of buses in different routes. Vast amounts of sensor data collected over time introduce the possibility machine learning for the smart bus shelter, whereby the system learns the movement of people at different times of day resulting to better response and performance. This application would be useful in optimizing the bus routes, as well as the information displayed at certain time of the day, week or month.

Through critical analysis of the case scenario and system requirements, an elaborate design for a system that could help achieve such efficient time and location-based advertising was developed, addressing the research question SRQ1. The implementation and testing of the prototype showed how a feasible proof of concept can be achieved, that gets a message from local businesses to commuters, using social media. Thus addressing the research question SRQ2.

Furthermore, through evaluating the questionnaires, it was found that the implementation of smart bus shelters can bring about the positive response towards advertisements by commuters, creating value for businesses. Additional values towards businesses involve the ability to determine the effectiveness of their advertisements in bus shelters. Innovative methods are used, such as the interaction of the commuter with the advertisement on the screen whereby they can scan QR code to obtain coupons. Based on the possible ways in which bus shelters can be improved, it was found that through IoT, bus shelters can be more useful to stakeholders thus holding our initial hypothesis true.

6.2. Ethical concerns

Since our research generally focuses on the advertisement sector, ethical concerns arise, such as the commuter’s privacy when it comes to their daily movement habits. It is a challenge when dealing with a commuter’s willingness to disclose their intended
destination when interacting with the system, especially in a bus shelter occupied by other strangers. A mobile application can be developed that connects to the bus shelter system where the commuter can choose to privately access the offers displayed.

6.3. Limitations

**Scalability in real world deployment:** Our implementation is based on a small scale prototype where the results reflect those that could be achieved in a limited controlled environment. While the system functionality would be similar to a real world situation, challenges arise from additional factors that come into play in a real world deployment. The factors include;

**Connectivity:** In the prototype we use the Ethernet shield for connectivity, however, in a real bus shelter, the system would have to be connected in other ways such as 3G or wifi. This introduces other players in the system such as the mobile service providers to facilitate the connection infrastructure.

**Location triangulation:** It was observed that the method used for location triangulation was not accurate enough to specific points in the city. It could only go as far as selecting twitter feeds from various parts of the world given the longitude and latitude parameters. However, alternative methods can be applied for location based advertisements. Since the outdoor media companies are the key stakeholders involved in advertising in bus shelters, the smart system can be configured based on the commuter demographics. This means that the type of commuters using a bus shelter at a particular time can be studied, in order to determine what type of information or advertisements they might be interested in.

**Limited functionality:** In the small scale prototype used, the hardware has limited capability which hinders additional functionality to be explored. We use a small screen for the prototype having limited capabilities, while the real world situation, the screen would be bigger, enabling display of more content, details and interaction such as touch screens.

Furthermore, additional features of the smart bus shelter for instance smart heating system could not be included. This system was found to be unnecessary for the prototype since it would introduce large, expensive and energy consuming hardware
which in any case, is not the main goal of the research. However, a simple LED light was used to simulate the actuator that is influenced by motion detection.

**Sensors:** Infrared sensors have a limitation that causes inaccuracies in determining the exact number of people in a bus shelter. This is due to the fact that infrared does not penetrate an object, thus if a person blocks the sensor, it cannot detect whether someone else is behind them or not. The sensor readings, therefore, are limited in that they will not reflect an accurate number of people in a bus shelter. One way to overcome this limitation is to use a larger number of sensors arranged in an array. This would increase the resolution of the density mapping of commuters, giving more accurate readings.

**Case scenarios:** While several case scenarios were identified where IoT could be useful in section 4, we only critically analyzed first scenario on smart advertising. The limited amount of time did not allow us to explore more case scenarios and implement them. However, it presents opportunities for future research.

### 6.4. Future work

Deployment of the smart bus shelter in a real world scenario should be done and tested to evaluate the user interaction as well as the effective advertising from local businesses. Further research should be employed to investigate the applications of machine learning in the smart bus shelters. This implies to the system’s capability to learn different patterns from an array of factors, and help identify or predict the number, type and interests of people in a given bus shelter a given time. Further development presents an opportunity for data analytics that can be used to optimize to bus allocation in different routes.

Based on the remarks of one of the business representatives that participated in the questionnaire, (section 5.1.2), it was observed that businesses are interested in following up on the number of audiences influenced by their advertisements. To this, we propose future work that could lead to more solutions that enable businesses to determine how much influence their advertisements have on commuters in bus shelters.

Other useful areas for IoT and bus shelters involves environmental benefits whereby sensors can be used to monitor the air quality at different point of a city for instance.
Such systems could be of value, especially when installed in public spaces that are used regularly such as bus shelters. The data patterns related to the movement of people and the air quality open up a different perspective towards environmental effects.
References


[26] [X. Li, Y. Chen and K. Zeng, "Integration of Machine Learning and Human Learning for training optimization in Robust Linear Regression" , State University of New York & George Mason University, 2016.


