ENGINEERING PROJECT MANAGEMENT

EMGT 5220 – Fall 2022

Smart Adaptive Traffic Control System

Project Proposal Final

Team 1

Authors:

Gabriele Ansaldo
Ole Martin Kjorholt
Prachi Patel
Jayanth Reddy Rachamallu
Kshitija Sonavane
Jignasuben Rohitbhai Vekariya

Team's Point of Contact:

Gabriele Ansaldo
ansaldo.g@northeastern.edu

December 9th, 2022

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Letter of Transmittal

December 9th, 2022

Professor Bajracharya, Sharad
Northeastern Graduate School of Engineering
130 Snell Engineering
360 Huntington Avenue
Boston, MA 02115

Dear Professor Bajracharya,

The attached project proposal proposes the implementation of the Smart Adaptive Traffic Control System (SATCS) in Boston. As a result of this system, traffic congestion and environmental impact are expected to be reduced, while mobility and safety will be enhanced.

The purpose of this report is to investigate how sensor technologies and Artificial Intelligence (AI) optimization tools can be used to reduce traffic congestion in Boston. A technical overview is provided in order to clarify the feasibility of the SATCS. Moreover, the report contains a schedule and resource allocation for the implementation plan and execution plan. As part of the proposal, a risk analysis and budget justification have been included in order to ensure a successful management strategy.

It is our hope that you will find this proposal to be both effective and persuasive. Throughout the course, your instructions and constructive comments were invaluable in helping us to develop this project and to shape us as potential future project managers.

Sincerely,

Team Members of Team 1

Executive Summary

In order to optimize and improve the flow of traffic in Boston, the NUS team has developed the Smart Adaptive Traffic Control Project. This project proposes the use of novel sensor technologies and Artificial Intelligence (AI) optimization tools in order to solve the problem of traffic congestion in the City. To control traffic lights efficiently, it is proposed to implement a Smart Adaptive Traffic Control System (SATCS). Using this type of system, traffic data can be collected around traffic lights, such as the type, number, and waiting time of vehicles. The purpose of this project is to develop the next generation of integrated traffic signal systems that include a rapid simulation of future traffic conditions. As a result of this system, crashes, pollution, and delays for road users are expected to be reduced.

As part of this project, the SATCS system will be deployed on 70% of the 840 traffic lights within the city of Boston. As part of the SATCS project, advanced traffic control strategies will be utilized to maximize the efficient utilization of existing roadway capacity through dynamic traffic routing in order to achieve the main objectives of reducing traffic congestion, reducing environmental impact, enhancing mobility, and improving safety.

A number of hardware components have been implemented in order to accomplish this goal, including the Smart Micro Sensors for traffic management, which can detect up to 256 vehicles, and enable the system to detect vehicle locations for 300 meters and over a 100-degree field of view, as well as detecting up to ten lanes regardless of the weather conditions. Artificial intelligence and machine learning are also extensively used to develop a smart system that allows the control of traffic lights based on real-time traffic data. In order to automate the control of traffic lights, it is necessary to gather sufficient data points in order to calibrate and train the artificial intelligence software. A central computer and server running AI software for traffic control management receives real-time data directly from the sensor site. The communication process is carried out using 5G waves, which enable a faster and more efficient transfer of information while keeping the budget and the time as key factors in consideration.

There are four main phases in the implementation plan, which is defined by a work breakdown structure (WBS). During the initiation phase, it is necessary to define the project's problems, objectives, goals, the identification of stakeholders, and the assignment of leadership roles. During the project planning phase, customer needs and product requirements are identified, followed by the project execution phase which involves all aspects of the development, design, deployment, installation, and maintenance of the system, including testing, training, deployment, installation, and maintenance. The majority of the work is expected to be completed during this phase, followed by the project closure phase where all management and control activities are completed, and the final report is prepared.

Project Manager, Financial Managers, Resource Managers, and Product Managers are responsible for their respective departments and accountable for completing major tasks on time and within the allocated budget. In order to ensure flexibility and viability of the project, the proposed budget for the duration of the project, which includes labor, materials, and equipment, as well as a contingency of 7%, is expected to be approximately $ 9,824,975.40.

It is evident that the Smart Adaptive Traffic Control System Project has enormous potential for both the city and its residents. By implementing this system, drivers' fuel consumption, state fuel consumption, delivery times, shipping costs, mechanical failures of cars caused by stop-and-go traffic, and employee turnover could be reduced.

1 Introduction

1.1 Problem

The city of Boston has long been plagued by traffic problems. Throughout the years, various projects such as the Big Dig have been carried out to ease road congestion and improve traffic flow (Serna, 2019). Although traffic levels remain high in the city and surrounding region, it is evident that roadway construction is limited. Nevertheless, new roads are costly, stimulate induced demand, and negatively affect the environment. Even with recent and substantial investments, Boston ranked consistently within the top ten congested cities in the United States (Friedman, 2020). Congestion has major impacts on economic growth and productivity, and it leads to increased fuel consumption, emission, and reduced road safety for both drivers and pedestrians. Due to high traffic levels, a recent phenomenon that began to emerge is the one of cut-through driving, which is a tactic used to avoid heavy traffic and long delays, whereas drivers take secondary routes. Once again, this phenomenon aggravates the already existing congestion and it contributes to other traffic jam on the cut-through streets, along with accompanying problems such as collisions, pollution from exhaust, or road rage. According to projections, the population of Boston will grow by approximately 15 - 17% by 2030, reaching 710,000 to 724,000 people (City of Boston, 2017). This indicates that high demands will be placed on the road system, and an early solution is necessary.

1.2 Solution

When it comes to traffic control, the use of traffic lights is one of the major components. Several studies have demonstrated that traffic lights can be used efficiently to reduce congestion and all its associated issues. There is no doubt that traffic is a major issue affecting the city of Boston. Therefore, for the purpose of alleviating traffic congestion, this project proposes the implementation of novel sensor technologies and Artificial Intelligence (AI) optimization tools. Specifically, it is proposed to implement a Smart Adaptive Traffic Control System (SATCS) to efficiently control traffic lights. This type of system would allow the collection of traffic data around traffic lights, such as the type, number, and waiting time of vehicles. Through the use of this data, Machine Learning (ML) techniques can be used to optimize the control of traffic lights to reduce traffic congestion throughout the city. Upon completion of the project, the team will have installed SATCS devices throughout Boston. In particular, it is intended to create the next generation of integrated traffic signal systems that include rapid simulation of future traffic conditions. This system is also expected to reduce crashes and pollution as well as balance road-user delays. To realize such a project successfully, an will work in concert with the project manager. Most of the engineers working on this project are from the city of Boston, which means that they are familiar with the city and the issues associated with traffic. As the Project Manager hired by the City of Boston has previously managed similar projects, he or she will be able to guide the project smoothly and will be aware of any issues that might arise. This project has great potential for both the city and its residents. As a result of implementing this system, drivers' fuel consumption, state fuel consumption, delivery times, shipping costs, mechanical failures of cars caused by stop-and-go traffic, and employee turnover could all be reduced.

2 Purpose & Objectives

2.1 Purpose

The purpose of this project is to improve the road infrastructure of the city of Boston by reducing traffic congestion with the use of a SATCS, which ultimately will maximize the use of existing roadway capacities while allowing for smoother traffic, reduction in fuel consumption and noise and air pollution, and increased road safety for both drivers and pedestrians. In particular, this project aims to develop and install a SATCS on 70% of the traffic lights in the Boston area within twelve months. With the aid of AI and ML, this system will continuously monitor traffic and control traffic lights in real time to optimize traffic flow. With the integration of this technology, Boston will be able to meet the increased demand to the road system that is expected to occur as a result of a substantial population increase over the next few years.

2.2 Objectives

The objective of this project is to deploy the SATCS system on 70% of the 840 traffic lights within the city of Boston (III, 2020). Through the use of advanced traffic control strategies, the SATCS project will enable dynamic traffic routing to maximize the utilization of existing roadway capacity. As part of the SATCS project, a suite of modeling tools and methods will be required to implement AI routing techniques. A dynamic and proactive evaluation of AI strategies using real-time and historical data will be possible through the application of these techniques, tools, and methods by the city of Boston. Following is a list of objectives that are based on the purpose and goal of this project:

Goals	Objectives
Reduce Traffic Congestion	- Reduce waiting at intersections and traffic lights
	- Higher traffic management ability
Reduce Environmental Impact	- Reduce noise pollution
	- Reduce air pollution and vehicle emissions
Improve Mobility	- Reduce travel time for drivers
	- Reduce fuel consumption and costs
	- Reduce travel stress
Increase Safety	- Faster detection of accidents
	- Pedestrians and drivers' safety monitored

Table 1: Goals and Respective Objectives of SATCS

3 Technical Overview

This technical overview summarizes the technical approach in the SATCS, which aims to improve the efficiency of traffic flow within the city of Boston. This technical overview provides an overview of three major components of the project.

Hardware (Electrical)

The hardware design consists of SmartMicro sensors for traffic management. Designed to manage intersections and highways, these sensors provide ultra-high-definition capabilities (4D/UHD). They are capable of detecting up to 256 vehicles at a time and outperform commonly used traffic sensors in aspects such as separating objects by speed, range, azimuth angle, and measuring elevation angles. In contrast to traditional sensors, the SmartMicro sensor uses a forward firing beam, enabling it to detect vehicle positions for 300 meters and over a 100-degree field of view. Furthermore, it is capable of detecting up to 10 lanes in all weather conditions as well as lane-specific detection. Due to the fact that many roads in Boston are not straight, the sensors can support any and every shape of road by sophisticatedly bending the virtual lanes.

Software

The Traffic User-Interface Wizard facilitates the planning and field installation of sensors in a step-by-step process that includes not only configuration of single sensors, but also highway and intersection installations. Along with the physical installation of the device, configuration also provides information regarding site planning and sensor selection in order to meet the project's specific needs. A basic one-window user interface provides features such as guided alignment and local awareness through which it is possible to receive feedback directly. AI and ML is extensively used to develop a smart system which allows to control traffic lights according to real-time traffic data. The AI software is indeed at the heart of this project as it will be able to control the complex traffic running through the city of Boston. For achieving high performance, it will be necessary to collect enough data points for the AI software to calibrate. Once calibrated and trained, the AI will be used to automate the control of traffic lights depending on the state of the roads. Additionally, continuous data-collection and calibration of the system will be performed while the systems run.

Interference & Communication

Smartmicro sensors are equipped with interference mitigation to prevent a reduction in sensitivity and detection range, resulting in inaccurate traffic detection. AI and ML are also used to implement an algorithm that suppresses interference, thus preventing false detections. Real time data is directly transmitted from the location of the sensor to central computers and servers that run the main AI software for traffic control management. Communication is performed through 5G waves, this is proven to be an effective way of sending data fast and reliably. As cars start to become more smart and technologically advanced, the system implemented has the ability to transmit the collected data from the sensors directly to vehicles in the surroundings. This enables information transfer such as lane specific data, inclusive of pedestrians, heavy trucks etc; between vehicles to improve traffic conditions.

An overview of how the main components of the system interact can be found in the following diagram. In order to collect the information, SmartMicro devices are placed on existing traffic lights. In order to efficiently regulate the flow of traffic, this information is transmitted to a server room and into the control room, where a computer model based on advanced artificial intelligence determines when to change traffic lights from red to yellow to green.

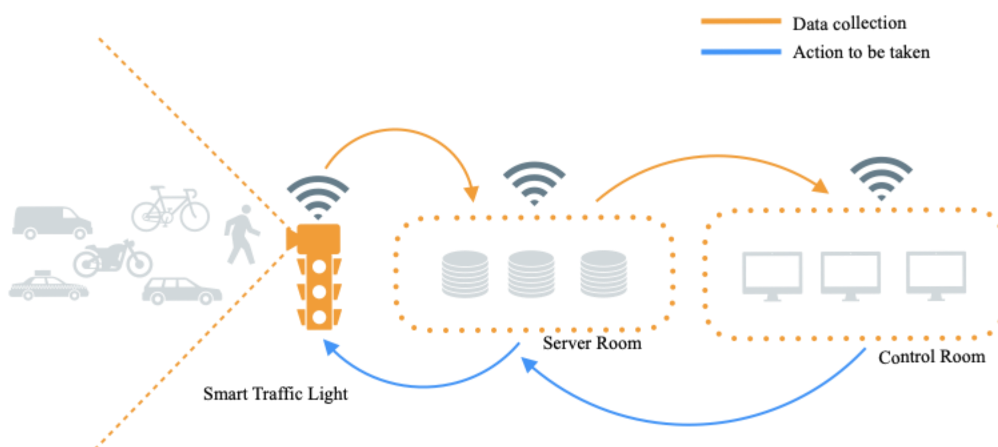

Figure 1: Technical Overview Diagram

4 Implementation Plan

4.1 WBS

To develop and implement the SATCS successfully, the Work Breakdown Structure (WBS) is used to define the entire set of activities and tasks that need to be completed. Activities are hierarchically organized in the WBS in accordance with the 8/80 rule, which stipulates that the majority of tasks will take more than eight hours, but not more than eighty.

The WBS includes four major phases: Project Initiation, Project Planning, Project Execution, and Project Closing.

1. ***Project Initiation***: This phase involves the definition of the project's problem, objectives, and ultimate goals, as well as the identification of stakeholders. Furthermore, leadership roles assignments are evaluated and assigned in accordance with the experience of the members of the project team.

2. ***Project Planning***: A large portion of this phase is devoted to identifying both customer needs as well as product requirements. In addition, this phase includes vendor selection, component procurement, risk management planning, and identification and allocation of project funds.

3. ***Project Execution***: The purpose of this phase is to complete all activities associated with the development of a solution, including the design of hardware and AI software. As part of this phase, testing, training, deployment, installation, and maintenance of the system are also conducted.

4. ***Project Closing***: In this phase, all activities associated with management and control are performed in order to monitor the performance of the solution and resolve any technical issues that have previously arisen. Upon completion of the project, a final report is generated.

A detailed version of the WBS can be found in Appendix A.

4.2 Schedule

To ensure the successful completion of this project, a schedule was developed as a tool for monitoring and controlling project activities identified in the WBS. As part of the project schedule, tasks, resources, and due dates are organized in an optimal sequence so that the project can be completed on time.

The schedule was developed using the open-source software *GanttProject*. Through this tool, the project manager is able to update task durations throughout the project, add new tasks, modify existing tasks, and portray accurate progress through the use of a Gantt chart. Appendix B contains the project’s Gantt chart.

4.3 Responsibility Chart

The responsibility chart identifies the role of each stakeholder in relation to each task in the work breakdown structure. The RACI matrix utilizes the work breakdown structure format to map out every task, milestone or key decision involved in completing the project and assigns which people are *Responsible* for each action item, which personnel are *Accountable*, and, where appropriate, who needs to be *Consulted* or *Informed*. The matrix can be found in Appendix C.
It is necessary to identify the responsibilities of different parties in order to easily visualize who is associated with specific parts of the project. Overall, the RACI matrix ensures that no single person is in charge of too many responsibilities and establishes everyone's role for each task outlined in the plan.

4.4 Resource Allocation

In order to allocate resources effectively, tasks must be assigned to the appropriate team members. A comprehensive allocation of resources has been developed based on the tasks identified in the WBS. A description of the labor and materials required at each stage of the project can be found in Appendix D. However, a high-level resource allocation chart is provided below. Allocating resources ensures that workloads are not underutilized or overutilized. Depending on the current availability of resources and the timeline for completing the project, people may be reassigned if necessary. Overspending on resources or running out of them halfway through a project can be prevented by proper allocation.

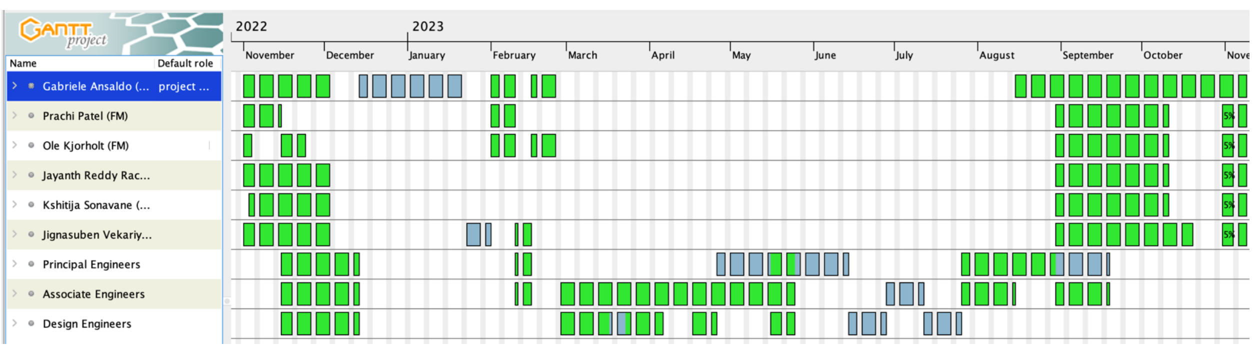

Figure 2: High-Level Resource Allocation Chart

4.5 Stakeholders

The following section gives an overview of all internal and external people and parties that are considered to have a stake in the project. In order to identify the main stakeholders of this project a Mendelow's matrix was built. This helps analyze individual stakeholders by measuring their interest and power. This information can then be used to determine their potential level of impact on the project. The Matrix can be viewed in Figure 1 below. A thorough analysis of the stakeholders involved in this project can be found in Appendix E.

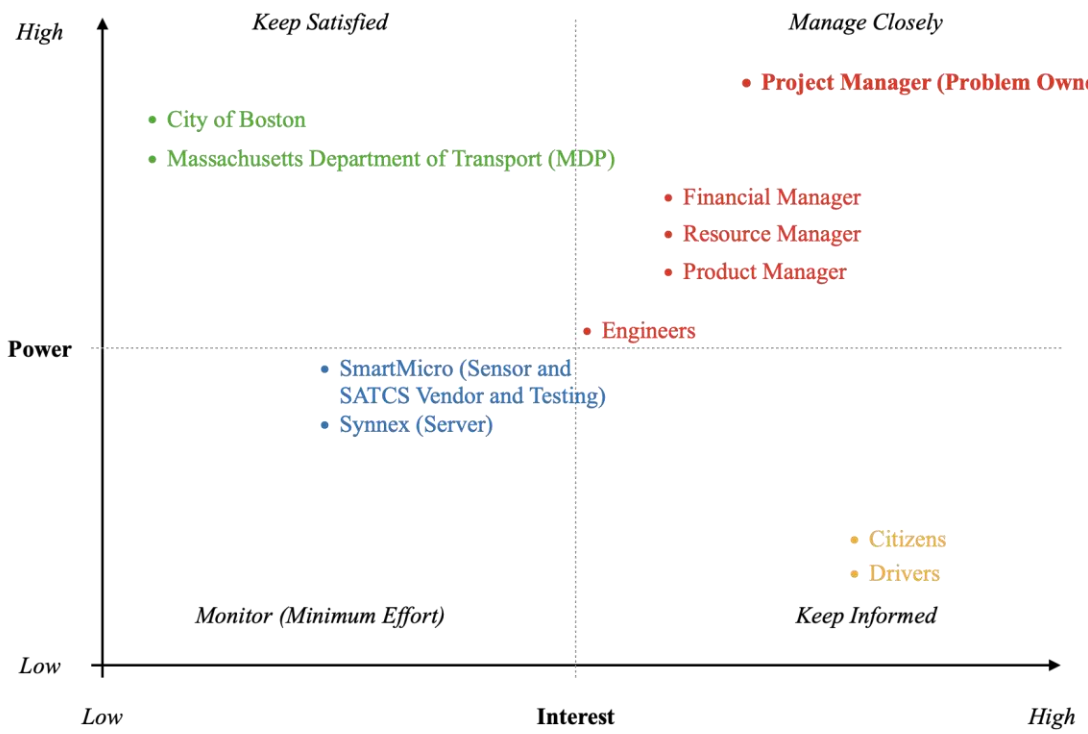

Figure 3: Mendelow's Power Interest Matrix

Project Team:

- **Project Manager** - Gabriele Ansaldo:
- **Financial Manager** - Prachi Patel & Ole Kjørholt:
- **Resource Manager** - Jayanth Reddy Rachamallu & Kshitija Sonavane:
- **Product Manager** - Jignasuben Vekariya:

The Project Manager, Financial Manager, Resource Manager and Product Manager are all fully engaged with the project and their interest will therefore be high. They are also authorized to make changes thus impacting the project, meaning that their power is categorized as high.

Principal Engineers

- **Electrical Engineers**
- **Software Engineers**
- **Civil Engineers**

The principal engineers will consist of highly skilled workers with many years of experience in their field. They will mostly help with specific technical tasks throughout the project, meaning that they will only have a medium interest in the project as a whole. In addition, they are important, but not irreplaceable, to the project which results in them being placed close to the middle of the Power Interest Matrix.

Vendors & Manufacturers:

- **SmartMicro**
- **SYNNEX**

These companies will be providing resources and expertise but will not be interested in the project after they have delivered their part of the deal. Their participation in the project is however crucial, meaning that they have a reasonable amount of power. There are a number of smart traffic light vendors that have been investigated, including SmartMicro, Sensys Networks, Blyncsy, Telensa, Miovision Technologies, and MetroTech Net. The research, however, revealed that SmartMicro is thepioneer in the development of state-of-the-art traffic control technologies. Furthermore, the costs between the investigated sensors were found to be similar. As a result, SmartMicro was selected as the preferred option.

Authority:

- **City of Boston**
- **MDP**

The City of Boston and the MDP will have high power on the project as the project relies on their approval and it will be important to keep them satisfied. However, they are less interested in project specific details.

The Public:

- **Boston Citizens**
- **Drivers**

Citizens and drivers will be highly interested in the new development in the city as it will directly affect them. This means that even though they have a small impact/power over the project, they should be kept informed about work progress.

5 Execution Plan

5.1 Project Monitoring

Project monitoring is intended to ensure that the Smart Adaptive Traffic Control System will be completed on time and within budget. Therefore, identifying risks and implementing solutions in a timely manner is essential to ensuring high-quality implementation and functioning of the SATCS and satisfaction among customers and stakeholders.

Monitoring the project will be based on the following key factors and indicators:

- ***Costs****:* An essential element of project management is cost control, which ensures that expenses are controlled and potential financial risks are mitigated. A detailed analysis of all project costs will be conducted, including project funding, budgeting, material expenditures, and salaries. The reporting system will appropriately track estimated costs, bills, receipts, and payable amounts to employees, vendors, and manufacturers.

- ***Schedules****:* In order to ensure that the project is progressing as planned, schedule control is an important aspect of project management. As the project progresses and changes occur, the schedule will be updated. According to the Work Breakdown Structure and the baseline schedule in Appendix B, the project is expected to be completed within the specified timeframe. In order to understand whether the project is ahead or behind schedule, actual progress will be compared with planned progress. Monitoring the schedules will ensure that the project proceeds according to plan and that deadlines are met. Several indicators will be monitored by the team on a weekly basis, including:
  - Dates of the start and end of each activity will be compared to the previously defined expected durations
  - Dates of signing and closing of vendor and manufacturing contracts
  - Dates of receipt of SATCS components
  - Dates of completion of hardware development and AI software development
  - Dates of implementation and completion of product testing

- ***Personnel*****:** Based on the RACI Matrix a variety of personnel will be required. Therefore, the following aspects will be constantly monitored:
  - Acquisition of personnel,
  - Contract agreements,
  - Role or responsibilities,
  - Amount of personnel required,
  - Training of personnel.
  - Time required to complete each role's responsibilities and the availability of personnel. sa

  To monitor key factors and indicators throughout the life of the project, a report system will be designed based on the Work Breakdown Structure and RACI Matrix.

- ***Quality*****:** A number of internal procedures and standards will be established to ensure proper coordination between project teams. Additionally, these standards are essential for controlling and ensuring the quality of SATCS implementations. In order to ensure that quality standards are met, quality assurance measures will be defined for the main deliverables of the project. Implementation of the following documents and standards will take place:
  - Standard for manufacturing design,
  - Standard for installation,
  - Standard for software coding,
  - Standard testing procedure.

  It is intended that the knowledge gained from the implementation of the project will be documented for use in future projects. In addition, quarterly and monthly quality audits will be conducted.

- ***Changes*****:** During the lifecycle of the project, it is expected that changes will need to be made. An implementation of a procedure will ensure proper tracking and management of project changes. As a result of changes to the project, the scope, budget, and schedule might be affected. Monitoring and tracking will be carried out as follows:
  - Maintain a record of change requests,
  - Prepare an assessment of the impact of change,
  - Coordinate the approval of changes,
  - Monitor the implementation of changes.

5.2 Project Control

In order to ensure the success of the project, feedback control will be used throughout. The various factors being monitored will be discussed in biweekly meetings where each management sector will provide a report. Below is a summary of which management sector is responsible for which key factor.

Control Responsibility	
Key Factor	***Sector Responsible***
Cost	Financial Management
Schedule	Project Management
Personnel	Resource Management
Quality & Changes	Product Management

Table 2: Project Control Responsibility

5.3 Project Auditing

The project is regularly audited to ensure that it remains on schedule, within budget, and within scope, keeping clients informed and satisfied. A project audit is typically conducted to review the progress of the project by evaluating the performance of the team and the individual on the basis of their contribution and positive development. Typically, audits are undertaken following the achievement of a milestone in order to complete the three steps that comprise an audit - research preparation, in-depth research, and report development. As mentioned earlier, each phase of this project is audited upon completion. As part of this project, the following audits will be conducted:

Technical Overview

As part of the design process, all technological choices will be examined collaboratively. The following will be included in the technical audits:

- Different requirements should be listed
- Designing the integration of SATCS
- The design of the AI software
- Assembling of products
- System testing

Project Status Overview

There is a possibility that the initial project cost and timeline may not match the actual costs incurred, and as a result, the status of the project may change. A status update will include the adjustments to the budget and schedule necessary to reflect the suggested scope changes in order to support the project team.

A variety of system designs have been finalized; integrated designs have been completed; test plans have been successfully completed; in-house testing has been completed; post-deployment of SATCS has been completed; post-pilot consumer deployment has been completed; training has been completed; the project is complete.

Final Audit

It is necessary to perform a final audit in order to confirm that the following factors have been considered:

- The schedule has been adhered to closely, and milestones have been met.
- The technical overview and prerequisites have been completed.
- The level of customer satisfaction was achieved.
- A high level of quality has been achieved in the deliverables.
- Working as a team among the members of the group.
- Contributions and professionalism of coworkers.
- A successful deployment of the system and the accuracy of the final product.

5.4 Project Closure

As part of the design, production, and distribution of the SATCS, the team will make every effort to maintain the scope, budget, and timeline. As the project nears completion, one of the most important questions to ask is whether the planning for its duration was accurate. In other words, was the product developed in accordance with the scope requirements and, in addition to being on schedule, was it also profitable? If not, what could have been done to alter the outcome in order to make this initiative more beneficial to the company's goals?

It is crucial for a corporation to be aware of project success and failure in order to move forward with future projects. In the event that the initiative is a success, it can be used as a model for future proposals, and in the event that it fails, the corporation will know how to focus its efforts in the future.

6 Risk Assessment Management Plan

It is crucial to recognize and plan for the potential challenges associated with various aspects of this venture. There are several risks identified in this section, and a matrix was created to illustrate the probability of each risk in relation to its level of impact on a scale ranging from low to high. As a starting point for formulating backup plans for each scenario, an identifier was assigned to each stage of this scale.

6.1 Identification and Analysis of Risks

Internal risks:

- Lack of experience
- Lack of funding
- Going over budget

Design Risks:

- Malfunctioning hardware
- Malfunctioning software
- Data security
- Not meeting quality requirements
- Product is difficult to install in mass
- Product maintenance is challenging

Manufacturing Risks:

- Lack of diversification in suppliers
- Increasing costs due to inflation
- Uncooperative client

Probability/Impact	Low	Medium	High
High	- Uncooperative client		- Going over budget - Data security
Medium	- Not meeting quality requirements - Lack of diversification in suppliers	- Lack of funding - Malfunctioning software	- Malfunctioning hardware
Low	- Product is difficult to install in mass	- Product maintenance is challenging	- Lack of experience - Increasing costs due to inflation

Reject
Control
Avoid
Monitor
Accept

Figure 4: Risk Matrix

6.2 Risk Management Plan

An extensive list of potential risks was compiled, and then the Borda method was used to rate the severity of each risk. A management team will be established to address each of the concerns. If the risk is low in probability and impact, it can be accepted since there are better uses for the few resources available. Every risk with a medium impact and/or medium probability will be closely monitored in order to ensure that the probability of occurrence does not increase. Risks in the level above will be minimized as much as possible. It is the responsibility of the management team to keep these factors continuously in mind at the control level, and to provide regular updates on how they are being managed and what the contingencies will be. Risks that fall into the "reject" category will be mitigated by the risk team at any cost in order to prevent any damage to the project being caused by these risks.

6.3 Continuous Risk Assessment

A process of identifying and managing risks will be an ongoing endeavor that must be undertaken multiple times in order to anticipate future problems and keep the project under control. A team that is organized and actively participates in the work being performed is more likely to stay on schedule and under budget.

7 Financial Plan with Budget

7.1 High Level Details

With the help of this project, 70% of Boston's 840 traffic lights will be equipped with the SATCS system. A key component of the SATCS project is the use of advanced traffic control strategies to optimize the utilization of existing roadway capacity through dynamic traffic routing. The achievement of this goal requires the involvement of financial resources. To ensure the successful management of the project, a budget must be developed and tracked. The following is a high-level overview of the budget for the project. Please refer to Appendix F for a detailed description and justification of the budget.

Budget Summary	
Resources	***Total Cost***
Labor	$ 2,996,120.00
Materials & Equipment	$ 6,129,600.00
Miscellaneous	$ 56,500.00
7% Contingency	$ 647,755.40
Total	**$ 9,824,975.40**

Table 3: Budget Summary

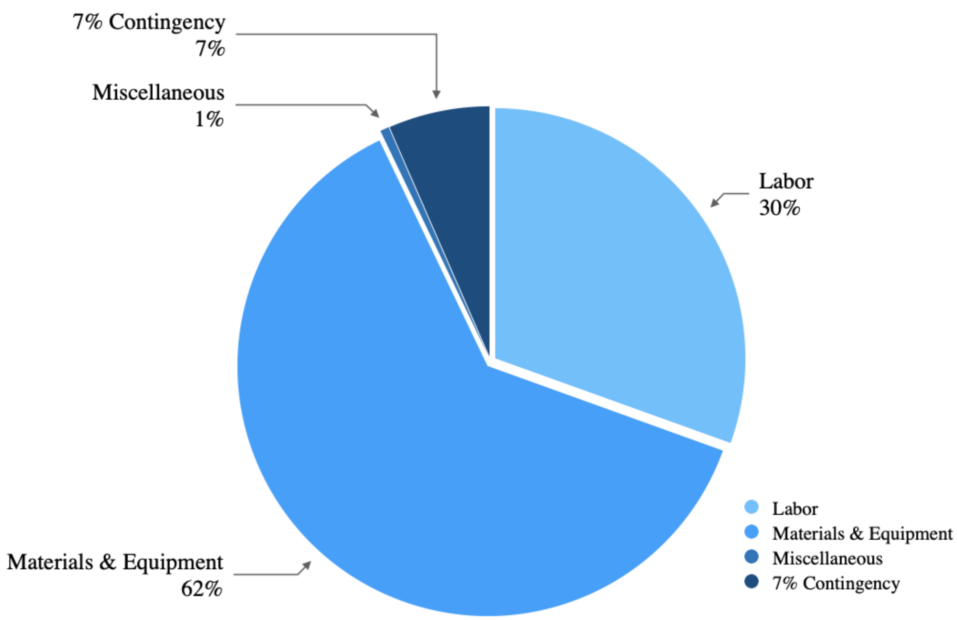

Figure 5: Budget Summary Pie-Chart

7.2 Budget Justification

The salaries of the managers participating in the project are based upon merit pay, market rate for each fiscal year, and are crossed checked with internet data (U.S. Bureau of Labor Statistics, 2022) . Salaries for non-managerial positions are established in conjunction with their employers and skill of the employee. The general and administrative expense budget focuses on operating expenses such as administrative salaries, depreciation, and office expenses. These non-selling expenses can be planned and predicted. The general and administrative expense budget includes both fixed and variable costs.

An estimated total of 2,136,425$ is required for the materials and supply to conduct the 13-month long project of installing smart traffic control system, which include 4D/UHD+ sensors, AI software, smart adapters, SATC systems among others. The material and supply costs have a direct impact on facilitating the project and are essential to the project's functionality. Based on data collected from the internet, the table below provides a detailed budget justification.

Budget Justification

Resources	***Type***	**Company**	***Role***	***Effort (hrs)***	***Rate/hr***
Gabriele Ansaldo	Labor	NUS	Project Manager	1416	90
Prachi Patel	Labor	NUS	Financial Manager	544	90
Ole Kjorholt	Labor	NUS	Financial Manager	600	90
Jayanth Reddy Rachamallu	Labor	NUS	Resource Manager	656	90
Kshitija Sonavane	Labor	NUS	Resource Manager	600	90
Jignasuben Vekariya	Labor	NUS	Product Manager	744	90
Principal Engineers	Labor	NUS	Hardware Develop.	1464	130
Associate Engineers	Labor	NUS	Engineer	4072	45
Design Engineer	Labor	NUS	Engineer	1680	65
General & Administrative	Labor	N/A	General	1352	45
Pilot Consumers	Labor	SmartMicro	Testing	648	65
Test Equipment	Material	SmartMicro	Design/Reliability	-	-
Design Materials	Material	SmartMicro	Design	-	-
Server Room Equipment	Material	Synnex	Design	-	-

Table 4: Budget Justification

8 Project Impact & Future Scope

SATCS implementation could have the following impacts, according to Carnegie Mellon research (Smith, 2013):

- Reducing average travel times by 25%,
- Shorten signal wait times by 40%,
- Lower emissions by 20%

In this study, real data was used in a simulated environment to examine the benefits of smart traffic management.

The implemented system also has the potential to be continuously improved once installed. Some of the most crucial improvements for such system could be:

- Adapt machine learning models to changes in congestion
- Add an alternative method of managing lights to increase pedestrian safety
- The location and design of traffic lights could be updated
- Use collected traffic data to share with third party apps such as Google Maps, Waze, and Maps
- As sensor technology improves, update the sensors with latest improvements
- As smart cars begin to grow, add the ability to connect with them

9 Team Credentials

Gabriele Ansaldo

Gabriele is a graduate student at Northeastern University studying Engineering Management. Previously, he earned a Master's degree in Mechanical Engineering from TU Delft and a Bachelor's degree in Industrial Engineering & Management from the University of Groningen. He spent a year as a Research Student at Northeastern University at the MAGICS Lab focusing on reinforcement learning and robotics. His previous experience includes co-founding a start-up focused on developing IoT devices to help people monitor the effects of their actions on the environment. Through his startup experience, he was able to translate engineering skills into business and industry language. Particularly, he developed qualities such as discipline, time management, leadership, and commitment.

Ole Kjørholt

Ole is a graduate student pursing Engineering Management at Northeastern University. Prior to this, he graduated from the University of Central Arkansas with a Bachelor of Science in Engineering Physics. He has experience in robotics and has completed internships related to software development and automation. Besides his technical expertise, he also served as captain of both the Division 1 soccer teams at his universities, which has provided him with invaluable experience in leading and working as a member of a team.

Prachi Patel

Prachi is a graduate student at Northeastern University pursuing a master's degree in Data Analytics Engineering. Previously, she worked as a software engineer at an aerospace firm after interning there for six months where her major project involved optimizing video surveillance systems for commercial aircraft. Among her other endeavors are internships with an educational services firm and technical training at HAL, both of which she completed during her studies at MS Ramaiah Institute of Technology for her Bachelor of Science in Electronics and Instrumentation Engineering. Besides acquiring core technical skills, her experience as an intern and as a full-time employee has taught her valuable lessons about time management, team spirit, perseverance, and diligence.

Jayanth Reddy Rachamallu

Jayanth is a graduate student at Northeastern University pursuing his master's in Data Analytics Engineering. Prior to this, he earned a Bachelor of Technology from the Sreenidhi Institute of Science and Technology. With a background in Computer Science and Engineering, he has been an intern for six months developing a mobile application. In the final semester of his undergraduate studies, he worked on a major project related to IOT. In addition to enhancing his technical skills, these experiences have taught him about time management, team spirit, and commitment.

Kshitija Sonavane

Kshitija is a graduate student at Northeastern University pursuing her master's in Industrial Engineering. She holds a Bachelor of Technology degree in mechanical engineering from Vellore Institute of Technology. During her undergraduate studies, she worked as a project manager for SEDS INDIA, a student chapter organization established by MIT USA. The process of transforming an idea into reality has always been of great interest to her. In addition, she was a member of her university's robotics team and participated in competitions such as the European Rover Challenge (2nd position in Asia) and the University Rover Challenge, USA (19th place worldwide). Her commitment to giving back to society led her to participate in various outreach programs that taught science and astronomy to schoolchildren. Through these enriching experiences, she has been able to build a strong foundation for good technical and leadership skills.

Jignasuben Rohitbhai Vekariya
Jignasu is a graduate student at Northeastern University seeking a master's degree in data analytics engineering. She graduated from Veer Narmad South Gujarat University with a Bachelor of Science in Science, with a major in Computer Science, prior to this. Throughout her undergraduate education, she developed software, took part in workshops, and ran competitions to broaden her technological skills. Additionally, she enjoys volunteering, which boosts her confidence. She organized a seven-day social work camp for college students in addition to extracurricular activities like competitions and workshops, and she volunteered for three days at a camp to advertise her college. She presently contributes to Origin, a student group for data analytics engineers, and she goes to workshops focused on research to advance her career. Through her voyage, she gained skills in leadership, teamwork, discipline, and strength.

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Appendices

A Work Breakdown Structure: Smart Adaptive Traffic Control System

ID	Task	Duration (Days)
1	**1.0 Project Initiation**	**3**
2	**1.1 Project Kickoff Meeting**	3
3	1.1.1 Define Problem, Objectives and Goals, Scope, and Stakeholders	2
4	1.1.2 Assign Leadership Roles	1
5	**2.0 Project Planning**	**81**
6	**2.1 Define Requirements**	56
7	2.1.1 Customer Requirements	7
8	2.1.2 Product Requirements	49
9	2.1.2.1 Electrical Requirements	21
10	2.1.2.2 Mechanical Requirements	14
11	2.1.2.3 Software Requirements	21
12	2.1.2.4 Product's Purpose, Features, Functionality, and Behavior	14
13	2.1.2.5 Civil and Permit Requirements	28
14	**2.2 Component Procurement**	18
15	2.2.1 Find Vendors for Vital Components such as Traffic Sensors and Communication Modules (Junction Boxes and Cables)	7
16	2.2.2 Select Cost-Effective Vendors	7
17	2.2.3 Arrange Lead Times for Parts Shipment, Assembly, and Installation	4
18	**2.3 Risk Management**	14
19	2.3.1 Identify and Classify Possible Risks such as: Cost, Schedule, Performance, Operational, Strategic, Legal, and External Hazards Risks	7
20	2.3.2 Develop a Risk Management Plan	7
21	**2.4 Identification and Allocation of Project Funds**	7
22	**3.0 Project Execution**	**132**
23	**3.1 Develop SATCS**	42
24	3.1.1 Design Electrical System for Traffic Sensors	18
25	3.1.2 Design Communication System	14
26	3.1.3 Design AI Software	21
27	3.1.4 Build SATCS System	7
28	**3.2 Install and Test SATCS**	21
29	3.2.1 Physically Install SATCS Sensors and Communication Modules onto Traffic Lights	14
30	3.2.2 Install Communication System for Controlling Traffic Lights and Collect Data from SATCS	14
31	3.2.3 Test SATCS System in Integration with Traffic Controllers	7
32	**3.3 Train AI Software**	14
33	3.3.1 Collect Real-Time Data for Training SATCS Software for Efficient Traffic Control	14
34	**3.4 Deploy SACTS**	30
35	3.4.1 Implement Pilot Test and Validate Results	10
36	3.4.2 Perform Re-Training and Re-Calibration of SATCS if needed	10
37	3.4.3 Conduct a Second Pilot Test	10
38	**3.5 Training of Personnel**	14
39	3.5.1 Develop Training Materials for Traffic Control Personnel	14
40	**3.6 Develop Maintenance Plan**	11
41	**4.0 Project Closing**	**51**
42	**4.1 Management and Control**	30
43	4.1.1 Monitor Performance	14
44	4.1.2 Resolve Technical Problems	14
45	4.1.3 Hold Project Status Meetings	30
46	4.1.4 Monitor Stakeholder's Acceptance of Implemented SATCS	14
47	**4.2 Audit Procurement**	14
48	4.2.1 Close Out Vendor and Manufacture Contracts	7
49	4.2.2 Review Civil Permits	14
50	**4.3 Final Report**	7

B Project Schedule: Gannt Chart

C RACI Matrix

ID	Task	Project Management	Financial Management	Financial Management	Resource Management	Resource Management	Product Management	Principal Engineers
		Gabriele Ansaldo	*Prachi Patel*	*Ole Kjørholt*	*Jayanth Reddy Rachamallu*	*Kshitija Sonavane*	*Jignasuben Vekariya*	
1	1.0 Project Initiation							
2	1.1 Project Kickoff Meeting							
3	1.1.1 Define Problem, Objectives and Goals, Scope, and Stakeholders	R	C	C	C	C	C	
4	1.1.2 Assign Leadership Roles	R	C	C	C	C	C	
5	2.0 Project Planning							
6	2.1 Define Requirements							
7	2.1.1 Customer Requirements	C	C	C	A	R	R	
8	2.1.2 Product Requirements							
9	2.1.2.1 Electrical Requirements	I	C	C			R	R
10	2.1.2.2 Mechanical Requirements	I	C	C				R
11	2.1.2.3 Software Requirements	I					R	R
12	2.1.2.4 Product's Purpose, Features, Functionality, and Behavior	I			C	C	R, A	
13	2.1.2.5 Civil and Permit Requirements	A	I	I	R	R		
14	2.2 Component Procurement							
15	2.2.1 Find Vendors for Vital Components such as Traffic Sensors and Communication Modules (Junction Boxes and Cables)		I	I	R	A		
16	2.2.2 Select Cost-Effective Vendors	I	R	A	C	C		
17	2.2.3 Arrange Lead Times for Parts Shipment, Assembly, and Installation	R, A	C	C			C	I
18	2.3 Risk Management							
19	2.3.1 Identify and Classify Possible Risks such as: Cost, Schedule, Performance, Operational, Strategic, Legal, and External	R	C	C	C	C	C	
20	2.3.2 Develop a Risk Management Plan	R	C	C	C	C	C	
21	2.4 Identification and Allocation of Project Funds							
22	3.0 Project Execution							
23	3.1 Develop SATCS							
24	3.1.1 Design Electrical System for Traffic Sensors	A					A, R	
25	3.1.2 Design Communication System	A					A, R	
26	3.1.3 Design AI Software	A					A, R	
27	3.1.4 Build SATCS System	I	A	C	R	R		C
28	3.2 Install and Test SATCS							
29	3.2.1 Physically Install SATCS Sensors and Communication Modules onto Traffic Lights	I			C	C	C	R, A
30	3.2.2 Install Communication System for Controlling Traffic Lights and Collect Data from SATCS	I			C	C	C	R, A
31	3.2.3 Test SATCS System in Integration with Traffic Controllers	I					R, A	
32	3.3 Train AI Software							
33	3.3.1 Collect Real-Time Data for Training SATCS Software for Efficient Traffic Control	I					R	R
34	3.4 Deploy SACTS							
35	3.4.1 Implement Pilot Test and Validate Results	I	I	I	A	R	I	
36	3.4.2 Perform Re-Training and Re-Calibration of SATCS if needed	I					R, A	
37	3.4.3 Conduct a Second Pilot Test	A			R	R		
38	3.5 Training of Personnel							
39	3.5.1 Develop Training Materials for Traffic Control Personnel	C			R	A		
40	3.6 Develop Maintenance Plan	A	I	I	C	C	R	
41	4.0 Project Closing							
42	4.1 Management and Control							
43	4.1.1 Monitor Performance	I	I	I			R, A	
44	4.1.2 Resolve Technical Problems	C	I	I			R, A	R
45	4.1.3 Hold Project Status Meetings	R, A	C	C	C	C	C	
46	4.1.4 Monitor Stakeholder's Acceptance of Implemented SATCS	I	I	I	R	A		
47	4.2 Audit Procurement							
48	4.2.1 Close Out Vendor and Manufacture Contracts	A	R, A	R, A				
49	4.2.2 Review Civil Permits	A			R	R		
50	4.3 Final Report	A	R	R	R	R	R	

D Resource Allocation

ID	Task	Resources													
		Labor												Materials & Equipment	
		Total No. of People	*Gabriele Ansaldo(PM)*	*Prachi Patel(FM)*	*Ole Kjorholt (FM)*	*Jayanth Reddy Rachamallu (RM)*	*Kshitija Sonavane (RM)*	*Jignasuben Vekariya (Product M)*	*Principal Engineers*	*Associate Engineers*	*Design Engineer*	*General and Administrative*	*Pilot Consumers*	*Quantity*	*Description*
1	**1.0 Project Initiation**														
2	**1.1 Project Kickoff Meeting**													3	Office Supplies
3	1.1.1 Define Problem, Objectives and Goals, Scope, and Stakeholders	6	1	1	1	1	1	1							
4	1.1.2 Assign Leadership Roles	6	1	1	1	1	1	1							
5	**2.0 Project Planning**														
6	**2.1 Define Requirements**														
7	2.1.1 Customer Requirements	3	1			1	1							3	Computer Systems
8	2.1.2 Product Requirements													8	Computer Systems
9	2.1.2.1 Electrical Requirements	7							1	5	1				
10	2.1.2.2 Mechanical Requirements	7							2	4	1				
11	2.1.2.3 Software Requirements	6							1	3	2				
12	2.1.2.4 Product's Purpose, Features, Functionality, and Behavior	3	1			1	1								
13	2.1.2.5 Civil and Permit Requirements	3										3			
14	**2.2 Component Procurement**														
15	2.2.1 Find Vendors for Vital Components such as Traffic Sensors and Communication Modules (Junction Boxes and Cables)	4						1				3			
16	2.2.2 Select Cost-Effective Vendors	3	1	1	1										
17	2.2.3 Arrange Lead Times for Parts Shipment, Assembly, and Installation	5						1	1	3					
18	**2.3 Risk Management**														
19	2.3.1 Identify and Classify Possible Risks such as: Cost, Schedule, Performance, Operational, Strategic, Legal, and External Hazards Risks	3	1	1		1									
20	2.3.2 Develop a Risk Management Plan	2	1		1										
21	**2.4 Identification and Allocation of Project Funds**	2	1		1										
22	**3.0 Project Execution**														
23	**3.1 Develop SATCS**														
24	3.1.1 Design Electrical System for Traffic Sensors	3								1	2			840	Electronic sensors
25	3.1.2 Design Communication System	3								1	2			840	Hardware Components
26	3.1.3 Design AI Software	4								2	2			2	Software Tools
27	3.1.4 Build SATCS System	3								2	1			3	SATCS components
28	**3.2 Install and Test SATCS**														
29	3.2.1 Physically Install SATCS Sensors and Communication Modules onto Traffic Lights	7							2	5				45	Hardware tools
30	3.2.2 Install Communication System for Controlling Traffic Lights and Collect Data from SATCS	4							1	3					
31	3.2.3 Test SATCS System in Integration with Traffic Controllers	4								1			3		
32	**3.3 Train AI Software**														
33	3.3.1 Collect Real-Time Data for Training SATCS Software for Efficient Traffic Control	3							1			2			
34	**3.4 Deploy SACTS**														
35	3.4.1 Implement Pilot Test and Validate Results	3											3		
36	3.4.2 Perform Re-Training and Re-Calibration of SATCS if needed	2								1			1		
37	3.4.3 Conduct a Second Pilot Test	2											2		
38	**3.5 Training of Personnel**														
39	3.5.1 Develop Training Materials for Traffic Control Personnel	3							1	2				60	Physical copies
40	**3.6 Develop Maintenance Plan**	2										2			
41	**4.0 Project Closing**														
42	**4.1 Management and Control**														
43	4.1.1 Monitor Performance	3	1						1	1				1	Electronic components
44	4.1.2 Resolve Technical Problems	2							1	1					
45	4.1.3 Hold Project Status Meetings	6	1	1	1	1	1	1						3	Office Supplies
46	4.1.4 Monitor Stakeholder's Acceptance of Implemented SATCS	5	1	1	1	1	1								
47	**4.2 Audit Procurement**														
48	4.2.1 Close Out Vendor and Manufacture Contracts	2	1					1							
49	4.2.2 Review Civil Permits	2	1									1			
50	**4.3 Final Report**	6	1	1	1	1	1	1							

E Detailed Stakeholder Analysis

		Stakeholder Type				Stakeholder Impact										
Group	**Key Representative**	**Accountable**	**Responbile**	**Consulted**	**Informed**	**Outcome Accountable**	**Outcome Impacted**	**End User**	**Internal/External**	**Priority (High/ Med/ Low)**	**Direct/Indirect Involvement**	**Relationship with Project**	**Goals / Success Criteria**	**Impact on Project**	**What does the project need from this group?**	**Method of Communication**
Project Manager	Gabriele	Yes	Yes	No	Yes	Yes	Yes	Yes	Internal	High	Direct	Project Owner	Issue visibility, requirement satisfaction	Overall Control	Direction. Approval	Weekly Meetings with Team. Ad-hoc face to face meetings
Financial Manager	Prachi, Ole	No	Yes	Yes	Yes	No	Yes	Yes	Internal	Med	Direct	Manager	Issue visibility, requirement satisfaction	Day-to-day management	Direction. Information. Contacts.	Ad-hoc face to face meetings
Resource Manager	Jayanth, Kshitija	No	Yes	Yes	Yes	No	Yes	Yes	Internal	Med	Direct	Manager	Issue visibility, requirement satisfaction	Day-to-day management	Direction. Information. Contacts.	Ad-hoc face to face meetings
Product Manager	Jignasu	No	Yes	Yes	Yes	No	Yes	Yes	Internal	Med	Direct	Manager	Issue visibility, requirement satisfaction	Day-to-day management	Direction. Information. Contacts.	Ad-hoc face to face meetings
Software Engineer		No	Yes	Yes	Yes	No	Yes	Yes	Internal	Med	Direct	Engineer/ Worker	Issue visibility, requirement satisfaction	Day-to-day management	Information, Support	Ad-hoc face to face meetings
Electrical Engineer		No	Yes	Yes	Yes	No	Yes	Yes	Internal	Med	Direct	Engineer/ Worker	Issue visibility, requirement satisfaction	Day-to-day management	Information, Support	Ad-hoc face to face meetings
Civil Engineer		No	Yes	Yes	Yes	No	Yes	Yes	Internal	Med	Direct	Engineer/ Worker	Issue visibility, requirement satisfaction	Day-to-day management	Information, Support	Ad-hoc face to face meetings
City of Boston	Government	No	No	No	No	No	Yes	Yes	External	Med	Indirect	Approver	User satisfaction	None	Approval, Support	Meeting before and after project completion
Massachussetts Department of Transport	Government	No	No	No	No	No	Yes	Yes	External	Med	Indirect	Approver	User satisfaction	None	Approval, Support	Meeting before and after project completion
Citizen	Citizen	No	No	No	Yes	No	Yes	Yes	External	Low	Indirect	User	User satisfaction	None	Information, Support	Keep informed through media
Drivers	Drivers	No	No	No	Yes	No	Yes	Yes	External	Low	Indirect	User	User satisfaction	None	Information, Support	Keep informed through media
SmartMicro	Sales Representative	No	No	Yes	No	No	No	No	Internal	Low	Indirect	Supplier	Delivery on time	Delivery of Product	Support	Weekly phone call
Synnex(Server)	Sales Representative	No	No	Yes	No	No	No	No	Internal	Low	Indirect	Supplier	Delivery on time	Delivery of Product	Support	Weekly phone call

F Detailed Budget

Based on data collected on the internet, an estimation of material prices and salaries was made. The table below gives an overview of the main resources needed for the project alongside a reference used to properly estimate a price.

Resources	*Internet Reference*
Managers	https://www.talent.com/salary?job=senior+pricing+manager https://www.bls.gov/bls/blswage.htm
Principal Engineer	https://www.builtinboston.com/salaries/dev-engineer/principal-software-engineer/boston https://www.bls.gov/bls/blswage.htm
Associate Engineer	https://www.glassdoor.com/Salaries/boston-associate-engineer-salary-SRCH_IL.0,6_IC1154532_KO7,25.htm https://www.bls.gov/bls/blswage.htm
Design Engineer	https://www.salary.com/research/salary/alternate/design-engineer-project-lead-salary/boston-ma https://www.bls.gov/bls/blswage.htm
General & Administrative	https://www.ziprecruiter.com/g/Highest-Paying-Administrative-Assistant-Jobs https://www.bls.gov/bls/blswage.htm
Test Engineers	https://www.ziprecruiter.com/Salaries/Principal-Test-Engineer-Salary--in-Massachusetts https://www.bls.gov/bls/blswage.htm
Computer Systems	https://electronics.costhelper.com/computers-notebook.html
Tools Electronic Sensors	https://www.smartmicro.com/where-to-buy
Hardware Components	https://www.startech.com/en-us/product-sitemap
Software	https://itrexgroup.com/blog/how-much-does-artificial-intelligence-cost/
SATCS Components	https://www.itskrs.its.dot.gov/its/benecost.nsf/ID/5a53f0d1919aa5ee8525798300819b6e
Hardware Tools	https://www.acehardware.com/departments/tools/hand-tools/hand-multitools
Electronic Components	https://www.okaychip.com/product/category/integrated-circuits-ics-430.html

**Resource Allocation used for planning purposes only as a general guideline of labor distribution

Table 5: Internet Data for Budget Justification

In the next page the detailed budget is shown. This is based on the WBS, RACI matrix, resource allocation, and the justifications presented before.

ID	Task	No. of People	Working Hours	Average Hourly Rate	Estimated Cost	Quantity	Description	Unit Price	Estimated Cost	Miscellaneous	Task Total Cost
	Project Name: **Project Start Date:**									**Total Budget**	**$9,182,220.00**
ID	**Task**										
		Resources									***Task Total Cost***
		Labor				***Materials & Equipment***				***Miscellaneous***	
		No. of People	***Working Hours***	***Average Hourly Rate***	***Estimated Cost***	***Quantity***	***Description***	***Unit Price***	***Estimated Cost***		
1	**1.0 Project Initiation**		24								
2	**1.1 Project Kickoff Meeting**		24			3	Office Supplies	$80.00	$240.00		$240.00
3	1.1.1 Define Problem, Objectives and Goals, Scope, and Stakeholders	6	16	$90.00	$8,640.00						$8,640.00
4	1.1.2 Assign Leadership Roles	6	8	$90.00	$4,320.00						$4,320.00
										Phase Total Cost	$13,200.00
5	**2.0 Project Planning**		648								
6	**2.1 Define Requirements**		448								
7	2.1.1 Customer Requirements	4	56	$90.00	$20,160.00	3	Computer Systems	$1500.00	$4,500.00		$24,660.00
8	2.1.2 Product Requirements		392			8	Computer Systems	$1750.00	$14,000.00	$500.00	$14,500.00
9	2.1.2.1 Electrical Requirements	7	168	$60.00	$70,560.00						$70,560.00
10	2.1.2.2 Mechanical Requirements	7	112	$72.14	$56,560.00						$56,560.00
11	2.1.2.3 Software Requirements	6	168	$65.83	$66,360.00						$66,360.00
12	2.1.2.4 Product's Purpose, Features, Functionality, and Behavior	4	112	$90.00	$40,320.00						$40,320.00
13	2.1.2.5 Civil and Permit Requirements	4	224	$56.25	$50,400.00						$50,400.00
14	**2.2 Component Procurement**		144							$1,000.00	$1,000.00
15	2.2.1 Find Vendors for Vital Components such as Traffic Sensors and Communication Modules (Junction Boxes and Cables)	4	56	$56.25	$12,600.00						$12,600.00
16	2.2.2 Select Cost-Effective Vendors	3	56	$90.00	$15,120.00						$15,120.00
17	2.2.3 Arrange Lead Times for Parts Shipment, Assembly, and Installation	5	32	$71.00	$11,360.00						$11,360.00
18	**2.3 Risk Management**		112								
19	2.3.1 Identify and Classify Possible Risks such as: Cost, Schedule, Performance, Operational, Strategic, Legal, and External Hazards Risks	3	56	$90.00	$15,120.00						$15,120.00
20	2.3.2 Develop a Risk Management Plan	2	56	$90.00	$10,080.00						$10,080.00
21	**2.4 Identification and Allocation of Project Funds**	2	56	$90.00	$10,080.00						$10,080.00
										Phase Total Cost	$398,720.00
22	**3.0 Project Execution**		1056								
23	**3.1 Develop SATCS**		336								
24	3.1.1 Design Electrical System for Traffic Sensors	3	144	$58.33	$25,200.00	840	Electronic sensors	$2000.00	$1,680,000.00	$30,000.00	$1,735,200.00
25	3.1.2 Design Communication System	3	112	$58.33	$19,600.00	840	Hardware Components	$5000.00	$4,200,000.00	$10,000.00	$4,229,600.00
26	3.1.3 Design AI Software	4	168	$55.00	$36,960.00	2	Software Tools	$40000.00	$80,000.00	$6,000.00	$122,960.00
27	3.1.4 Build SATCS System	3	56	$51.67	$8,680.00	2	SATCS components	$70000.00	$140,000.00	$9,000.00	$157,680.00
28	**3.2 Install and Test SATCS**		168								
29	3.2.1 Physically Install SATCS Sensors and Communication Modules onto Traffic Lights	7	112	$69.29	$54,320.00	45	Hardware tools	$200.00	$9,000.00		$63,320.00
30	3.2.2 Install Communication System for Controlling Traffic Lights and Collect Data from SATCS	4	112	$66.25	$29,680.00						$29,680.00
31	3.2.3 Test SATCS System in Integration with Traffic Controllers	4	56	$60.00	$13,440.00						$13,440.00
32	**3.3 Train AI Software**		112								
33	3.3.1 Collect Real-Time Data for Training SATCS Software for Efficient Traffic Control	3	112	$73.33	$24,640.00						$24,640.00
34	**3.4 Deploy SACTS**		240								
35	3.4.1 Implement Pilot Test and Validate Results	4	80	$65.00	$20,800.00						$20,800.00
36	3.4.2 Perform Re-Training and Re-Calibration of SATCS if needed	2	80	$55.00	$8,800.00						$8,800.00
37	3.4.3 Conduct a Second Pilot Test	3	80	$65.00	$15,600.00						$15,600.00
38	**3.5 Training of Personnel**		112								
39	3.5.1 Develop Training Materials for Traffic Control Personnel	3	112	$73.33	$24,640.00	60	Physical copies	$2.00	$120.00		$24,760.00
40	**3.6 Develop Maintenance Plan**	4	88	$77.50	$27,280.00						$27,280.00
										Phase Total Cost	$6,473,760.00
41	**4.0 Project Closing**		408								
42	**4.1 Management and Control**		240								
43	4.1.1 Monitor Performance	3	112	$88.33	$29,680.00	1	Electronic components	$1500.00	$1,500.00		$31,180.00
44	4.1.2 Resolve Technical Problems	2	112	$87.50	$19,600.00						$19,600.00
45	4.1.3 Hold Project Status Meetings	6	240	$90.00	$129,600.00	3	Office Supplies	$80.00	$240.00		$129,840.00
46	4.1.4 Monitor Stakeholder's Acceptance of Implemented SATCS	6	112	$90.00	$60,480.00						$60,480.00
47	**4.2 Audit Procurement**		112								
48	4.2.1 Close Out Vendor and Manufacture Contracts	2	56	$90.00	$10,080.00						$10,080.00
49	4.2.2 Review Civil Permits	2	112	$67.50	$15,120.00						$15,120.00
50	**4.3 Final Report**	6	56	$90.00	$30,240.00						$30,240.00
										Phase Total Cost	$296,540.00
		Labour Total Cost			$2,996,120.0(	**Materials & Equipment Total Cost**			$6,129,600.00	$56,500.00	**$9,182,220.00**
										7% Contingency	**$642,755.40**
										Total Cost	**$9,824,975.40**