Northeastern University
College of Engineering

Project Proposal Final Draft
MBTA Green Line Optimization
EMGT 5220 Engineering Project Management
Summer 2 2017

Team Seven

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Team Members' Contribution Summary

Name	1st Draft	2nd Draft	Final Draft
Hanqing Luo	1. 0 Introduction 8.0 Team Credential Reviewed all sections	Work breakdown structure, responsibility chart, review	Project Monitoring, Project Control
Ben Peterson	2.0, 2.1, 2.2 Purpose, Objectives and Goals Reviewed all sections	Stakeholders, formatting and compiling, review	Risk management plan, formatting and review
Mikael Taveras	2.0, 2.1, 2.2 Purpose, Objectives and Goals Reviewed all sections	Technical overview, review	Executive Summary, feedback and review
Arif Jan	Table of Contents 8.0 Team Credential Reviewed all sections	Gantt chart, resource allocation, review	Project Auditing, Project Termination
Tanner Cobb	1. 0 Introduction 8.0 Team Credential Reviewed all sections	Financial plan and budget, review	Letter of Transmittal

Table 1 - Team Contribution

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Letter of Transmittal

August 17th, 2016
Massachusetts Bay Transportation Authority
Fiscal and Management Board
Director of Business Development
Mr. Joseph Aiello

Subject: Improving MBTA Green Line Tracking and Ridership Ticketing

Dear Mr. Joseph Aiello,

We submit herewith a project proposal to develop and implement a real-time Green Line train tracking software with an integrated QR-code rider ticketing mobile application. Our solution will serve to deliver a seamless and pleasant user experience that enables MBTA Green line riders to track their train in real time, while also preparing rider payment and authentication in the palm of their hand.

As we will be pursuing funds from third party sponsors, we are requesting a contribution from the MBTA to fund our budget of $416,300 in order to successfully complete this project. This includes our internal workforce development, software development, sales & business model, as well as hardware purchasing and installation, including full application operation for one year.

Our team is happy to serve the community we live in by enabling an easier and more robust solution for travel on the Green Line, helping Bostonians to support their city and the environment as a whole.

Respectfully,

Hanqing Luo
Arif Ashraf
Mikael Taveras
Ben Peterson
Tanner Cobb

TVII Technologies, Inc.
452 Boylston Street
Boston, MA

Executive Summary

TVII Technologies, Inc is an up and coming technology based business currently working towards the goal of improving the MBTA Green Line. The core team is working towards improving the reliability, efficiency, and compatibility of the Green Line. The team is taking the initiative in proposing a plan that will improve the Green Line experience via mobile app software, and GPS and scanner hardware developments. Because the Green Line carries the largest volume of commuters on a day-to-day basis, it is imperative that commuters can rely on the Green Line to be punctual and effective. Currently the Green Line has a much lower reliability rating than its counterparts, a measly 68% as compared to an average of above 90% for the other lines.

The team proposes a solution of implementing software improvements to the MBTA app and hardware installments in trains and train stations. The team will use Hubway's parent company's software team to develop a real-time feed of train locations via GPS. The software enhancements also include QR-codes for instant ticket purchasing and use. The hardware being implemented will be real-time GPS modules on every train to relay locations as well as QR-code scanners at the entrance of every train to read online tickets.

The overall breakdown structure of this project includes project planning, systems engineering, software development, hardware selection, system testing, support services, and finally installation. These tasks within the project branch out into many focus areas, some of which include GPS module design, software design, and user interface development.

The project being proposed by TVII Technologies, Inc. will span approximately 6 months before completion, including installment and launching. The proposed budget for this project is estimated to be $483,000. This budget will be used for acquiring and allocating the proper resources towards the internal workforce, external technology development, mobile app server hosting, GPS hardware selection and installment, and marketing and investment.

This project is valuable for elevating the public reputation of the Green Line as well as making any trips on the Green Line a more enjoyable and reliable experience. This project will improve the commuter volume flow in the greater Boston area as well as provide a venue for more users to use the Green Line at stations that may not have conventional ticket machines. This project is an action focused on making the Green Line more accessible.

1.0 Introduction

Every day, billions of people commute to play their part in the world economy. As cities grow more dense and the world population increases, the method of transportation and its rapidity can be measured in millions of dollars in productivity lost or gained per day. Boston has a long history of public transportation, being home to the oldest public underground rail system in the United States. Regardless of age, the Boston public transit accommodates more riders than ever with over 500,000 people using MBTA services daily. The Green line is the longest line in Boston with 23 miles of track and services the second highest daily commuter numbers via the most daily train trips, averaging 1177 one-way trips per day. In comparison, the next longest line in the MBTA system and the line with the highest daily commuter average is the Red line with 21 miles of track, but makes less than 50% of trips (438) as the Green line. These statistics easily identify that the Green Line has to service more stops on more track and conduct more trips than any other line. In order to to improve the MBTA Green line efficiency for each rider and for each one way train trip, we are seeking to improve the rider ticket validation and train tracking service. By making these small, but impactful improvements, we seek to maintain a reputation of reliable and timely service that will increase efficiency and allow for more ridership without additional improvements. We will accomplish this by focusing on a software approach to produce and implement a more efficiency mobile ticketing system and a more reliable commute tracking system.

By approaching this problem with a minimally invasive and cost conscious solution, we believe we can succeed where others have failed. Through a direct impact to the timely ticketing validation of passengers and accurate scheduling, we hope to increase the reputation of the Green line as a reliable travel method and increase the ridership that the Green line can facilitate through more efficient systems. If these two systems are successful, Boston will not only boast the oldest public transit system, but also the most highly regarded.

2.0 Purpose, Objectives, and Goals

2.1 Purpose

Millions of people in the United States rely on public transportation to get to and from work every day. In order to perform at their job and collectively work to advance the economy, public transport must be able to provide a reliable and efficient service to get workers to and from their place of work. In Boston, the MBTA includes five subway lines within the city. Of these lines, the Green Line transports the most amount of workers, an average of two-hundred and forty thousand rides per day, but receives reliability ratings that are 10% lower than the next best line. The purpose of the project is to assess the current state of the Green Line's infrastructure and functional flow and develop appropriate services and technological improvements to the Green Line in order to improve its efficiency, reliability, and overall functionality.

2.2 Objectives and Goals

The project goal is to make data-driven recommendations of interventions to increase the efficiency, compatibility, and reliability of the Green Line. The scope of this project includes an in-depth assessment of current the Green Line system to understand its inefficiencies and define their specific locations, and to produce a formal, data-driven recommendation for the appropriate intervention solution to increasing the efficiency, compatibility, and reliability of the Green Line experience.

Objectives

1. Understand the Green Line experience from a customer's perspective both qualitatively through interviews and public opinions, and quantitatively through time data for specific trips.
2. Learn from existing MBTA employees, city planners, and government officials to gain a holistic understanding of the current public transport system and highlight risks when implementing changes.
3. Synthesize our findings to produce with confidence a proposed set of solutions to improve the Green Line a foundation for implementation in a future phase.
4. Provide data supporting the current state of the Green Line that includes public input, expert evaluation, and qualitative and quantitative analysis.
5. Compile a report for the recommended updates and additions to the Green Line infrastructure which will include an associated risk analysis, estimated cost of implementation, and detailed plan for how to execute such improvements.

3.0 Technical Overview

In order to improve the efficiency, compatibility, and reliability of the Green Line, the proposed technical plan will be applied with the goal of developing both software and hardware improvements. These improvements to the MBTA Green Line will streamline the rider's experience

Efficiency is defined as improvement to reduce passengers' waiting time at the station platform. The design and implementation of a mobile app will display the estimated waiting time and dynamic location of the next available train thus improving train schedule visualization and reducing passenger annoyance at the green line platform. In addition to the mobile app there will be the installation of a dashboard display, which is already implemented in the orange, red, and blue lines, making it a mutual solution to improve the efficiency within reasonable cost.

Compatibility is defined as how to load and unload more passengers more quickly between rides. One goal is to add more cabins and redesign cabin seating to accommodate more passengers without reshaping the existing green line dimensions. With the mobile ticket system, passengers can scan their QR-Code as opposed to purchasing a ticket at a traditional machine. This will help MBTA reduce loading time, improve green line attendance rate, reduce physical ticket machine cost, reduce ticket machine maintenance, and reduce the number of paper tickets thus improving environmental impact.

Reliability is defined as the passengers' ability to estimate train arrival and trip duration accurately. Installation of the GPS module will increase the accuracy of this relayed time significantly (63% currently). Along with the GPS the app will build a trip estimator to estimate the waiting time, current traffic status, and the number of active Green Line trains. The app will also notify passengers whether there are hindered or jammed trains on route.

The first technical task of the project to be addressed is overall project management and systems engineering. This will give the team a timeframe for risk management, cost & scheduling, and technical planning. Once these tasks are completed and all data and feedback is properly documented, the team will begin working towards the software and hardware development for the project.

3.1 Software

The software team will start by researching and working with Hubway's parent company, The Boston Bikes program. The software utilized in the Hubway app is user friendly and will help both track real time GPS hardware and complete ticket transactions for the T. Hubway already utilizes an interface that allows riders to complete transactions, ride, or dock bikes in a manner that makes the overall experience efficient, reliable, and functional. They use a real-life timer to let users know when bikes are available. This same will be applied to GPS hardware that relays real time locations of Green Line trains to the app giving users the current traffic status and estimated waiting time until destination arrival. The software engineers will work within the parameters required to maximize the compatibility and interface of the app.

3.2 Hardware

The other task that will be done concurrently with software development is hardware acquirement and development. Electrical and mechanical teams will work to implement GPS hardware on every train that rides the Green Line. The overall size and design of the hardware should follow the team's parameters for functionality and implementation. Market research must be done in order to choose or develop the ideal GPS hardware.

4.0 Implementation Plan

4.1 Work Breakdown Structure

The Work Breakdown Structure shows the tasks that are necessary in order to collaborate with city of Boston and Hubway to design and implement new MBTA application for green-line and install GPS receiver on each train. The tasks are broken up into seven stages including project planning, system planning, software development, hardware development, system test, support services, and installation.

The table below shows the high-level tasks for each phase of the project. For a full schedule of the work breakdown, please refer to Appendix B.

Task Name	Start Date	End Date	Duration
Project Management	**09/01/17**	**09/14/17**	**10d**
System Engineering	**09/15/17**	**09/22/17**	**6d**
Software Development	**09/26/17**	**02/20/18**	**106d**
Hardware	**12/26/17**	**02/16/18**	**39d**
System Test	**02/19/18**	**04/27/18**	**50d**
Support Services	**04/30/18**	**05/31/18**	**24d**
Installation	**06/01/18**	**07/31/18**	**43d**

Table 2 - High Level WBS

4.2.1 Overview

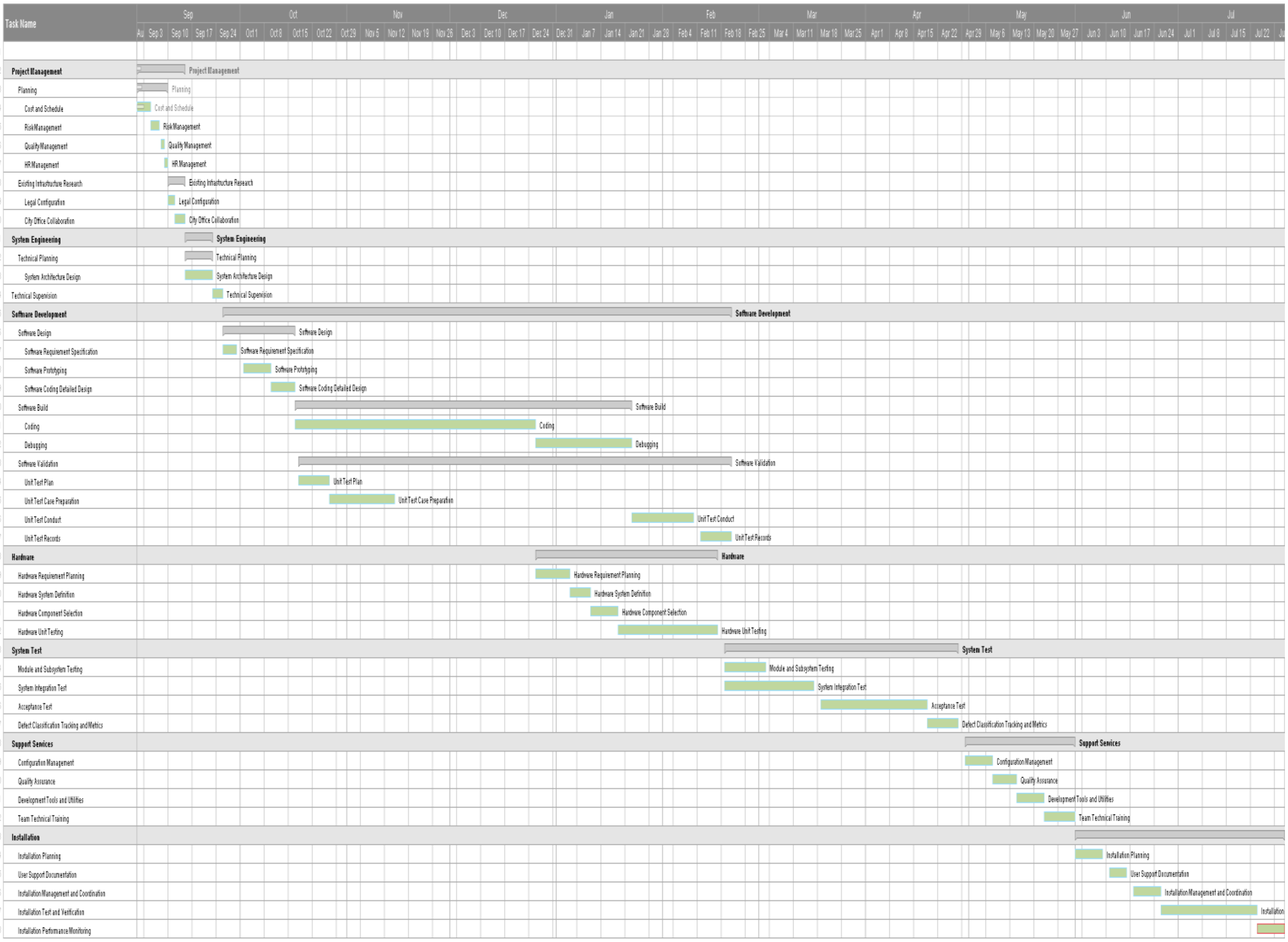


Figure 1 - Gantt Chart Overview

4.2.2 Project Management

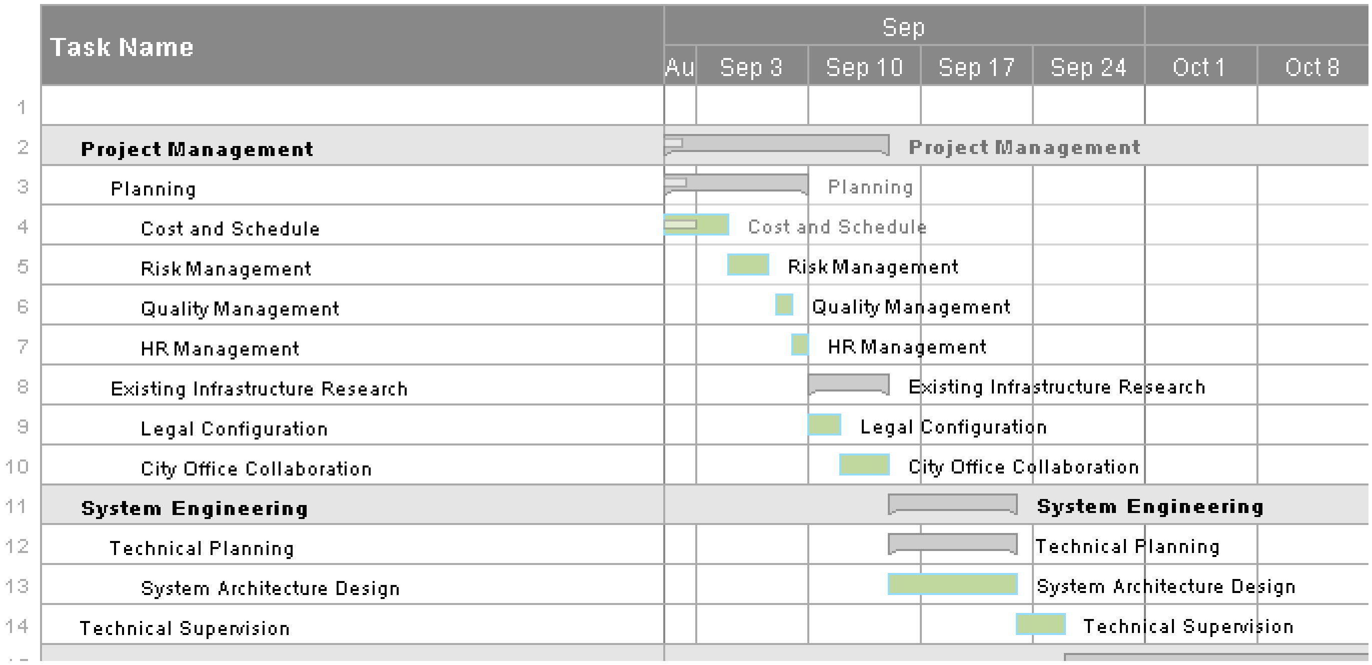


Figure 2 - Gantt Chart: Project Management

4.2.3 Software Development

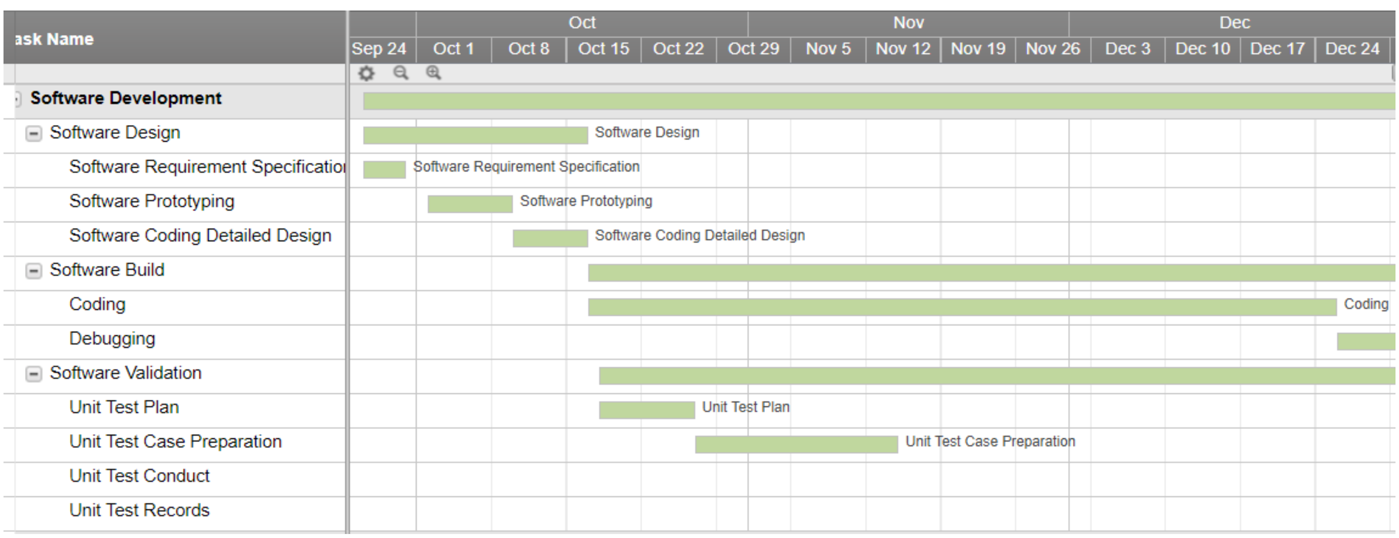


Figure 3 - Gantt Chart: Software Development

4.2.4 Hardware Development

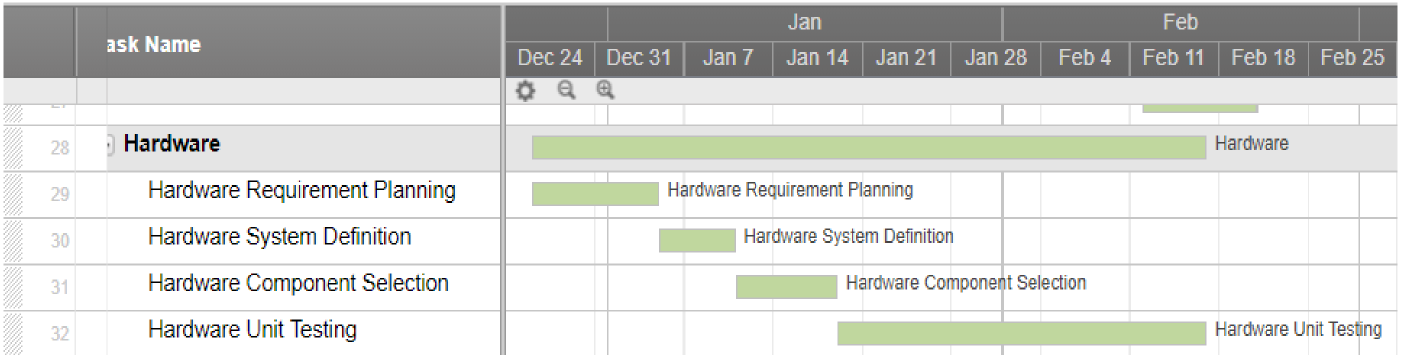


Figure 4 - Gantt Chart: Hardware Development

4.2.5 System Test

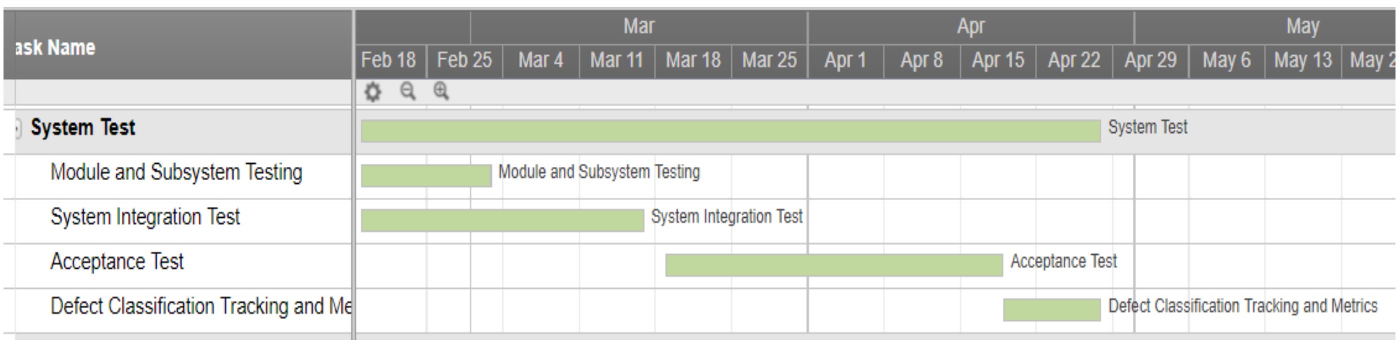


Figure 5 - Gantt Chart: System Test

4.2.6 Support Services

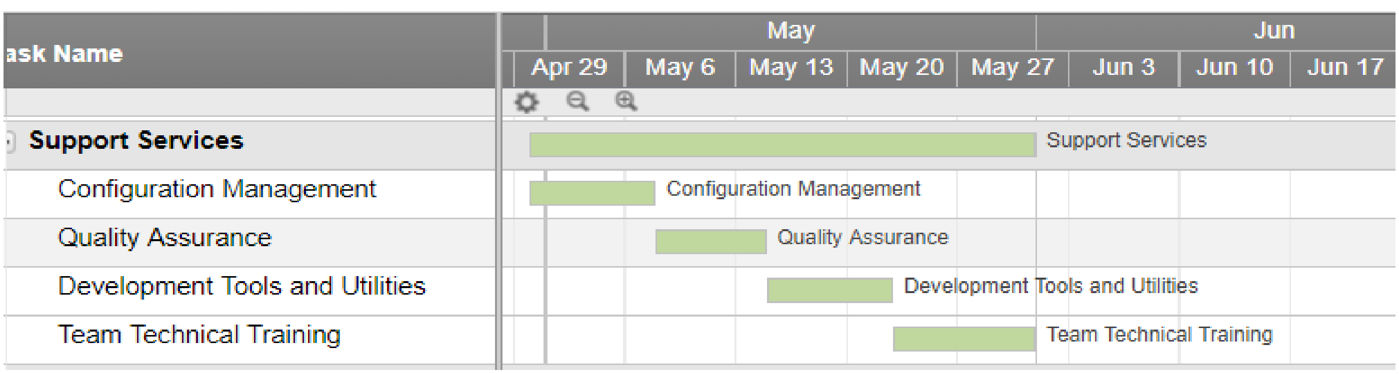


Figure 6 - Gantt Chart: Support Services

4.3 Responsibility Chart

		Project Management		Engineering			Maintenance	
	Task	Design Project Manager and HR Manager	Cost Manager and Risk Associates	System Engineers	Development Engineers (Hardware & Software)	Validation Engineer	Quality Assurance Engineer	Customer Support
Stage 1 - Planning	1.1 Project Planning	R						
	1.1.1 Cost and Schedule	S	R					
	1.1.2 Risk Management	S	R					
	1.1.3 Quality Management	S				R	R	
	1.1.4 HR Management	R						
	1.2 Existing Infrastructure Research	R	S			R		
	1.2.1 Legal Configuration	R	I					
	1.2.2 City Office Collaboration	R	I					
Stage 2 - System Development and test	2.1 Technical Planning			R				
	3.1 Software Design			C	R			
	3.2 Software Build			C	R			
	3.3 Software Validation			C		R		
	4.1 Hardware Requirement Planning			C	R			
	4.2 Hardware System Definition			C	R			
	4.3 Hardware Component Selection			C	R		I	I
	4.4 Hardware Unit Testing			S	R			
	5.1 Module and Subsystem Testing			R				
	5.2 System Integration Test			S		R		
	5.3 Acceptance Test			S		R		
	5.4 Defect Classification Tracking and Metrics			S		R		
Stage 3 - Public support and maintenance	6.1 Configuration Management				I		R	S
	6.2 Quality Assurance						R	S
	6.3 Development Tools and Utilities				I		R	R
	6.4 Team Technical Training						S	R
	7.1 Installation Planning				I		S	R
	7.2 User Support Documentation						S	R
	7.3 Installation Management and Coordination						S	R

Table 3 - RSCI Matrix

R = Responsibility; S = Support; C = Consult; I = Inform;

4.4 Resource Allocation

The Resource Allocation plan describes the overhead costs of the project. It includes managing tangible assets such as software, hardware, design to make the best use of human capital.

Resource	Role	Effort (Hours)	Rate/Hour	% Allocation
Hanquing Luo	Tech Developer	600	$70	100
Arif jan	Tech Developer	600	$70	100
Benjamin Peterson	Hardware Engineer	600	$70	100
Mikael Taveras	Hardware Engineer	600	$70	100
Tanner Cobb	Hardware Engineer	600	$70	100
Testing Resources	Validation Engineer	500	$60	100
Design Management	Design Project Manager	300	$60	100
HR	HR Manager	50	$50	100
Quality Management	Quality Assurance Engineer	30	$50	100

Table 4 - Resource Allocation

Software Engineer – Tier 1

Hardware Engineer – Tier 2

4.5 Stakeholders

The stakeholders for this project to improve the MBTA Green Line are those who will contribute to, have invested in, or will need to be informed of, the progress and state of the project. These members and groups include the city of Boston, the Massachusetts Bay Transportation Authority (MBTA), the private investors who have provided the finances to make this project possible and intend to see it through to completion. Additionally, the internal team here at TVII Technologies, Inc and any subcontractors that will be hired for additional engineering resources, who will be developing the software and technology for implementation will need to be constantly informed on project status and progress as active communication amongst the development team will be imperative to the project's success. Furthermore, senior management at TVII Technologies, Inc should be informed of project progress by the assigned Project Manager. This project, while ultimately for the City of Boston and the MBTA services, will reflect the goals and strategy of TVII Technologies, Inc and will become a portfolio piece showcasing the company's capabilities and success. Finally, the residents of Boston, who rely on MBTA services on a daily basis, will need to be notified of the project's progress both to encourage the excitement and public knowledge of the improvements to the Green Line, and to be aware of any impact to current services that would affect their commute during the development and implementation of the project's deliverables. Please find the stakeholder matrix below as a visual supplement to adequately identifying this project's stakeholders:

Figure 7 - Stakeholder Matrix

5.0 Execution Plan

5.1 Project Monitoring

Project monitoring is critical to the timely completion and progression of project phases. The monitoring process prevents deviation from project goals consequently ensuring the project within scope, cost, and time restraints set forth in the planning phase. Team seven, Inc will be responsible for the following in the design and construction phases of the project as a part of the project monitoring process:

1. Involves tracking, reviewing, and regulating project progress
2. Includes status reporting, progress measurement, and forecasting
3. Reports on scope, schedule, cost, resources, quality, and risks
4. Controls project and project document changes
5. Includes control of scope, schedule, costs, and risks
6. Formalizes acceptance of deliverables
7. Records quality control results
8. Implements risk treatment plans and actions
9. Administers suppliers

The key outputs we are achieving:

1. Progress and status reports
2. Plan updates
3. Risks registers
4. Change requests
5. Work products/deliverables

5.2 Project Control

Scope, cost and time will be controlled via a Go/No GO control system. The systematic progression of the project goals has a finish to start precedence requirement. The implementation of such phase gates ensures optimal quality of final project deliverables.

Our schedule is based on Go/No Go control system. At the end of each section of our three stages, the WBS, schedule, and responsibility chart are referenced to ensure that each responsible party's actual progress is in line with the forecasted project timeline.

5.3 Project Auditing

Project Auditing is an inspection designed to determine the status of work done on the project within the time, scope and cost given. The aim of Auditing is to ensure that project done is meeting the project management standards through reviewing, investigations and evaluations. This audit is carried out by an external member. After project completion, a project report will be presented to a Project Manager and then also an Audit report with suggestion and recommendations to make any changes will be submitted. The various check listed points considered are:

- Current status of the project.
- Future status
- Risk assessment and evaluation
- Methodologies and protocols
- Deadlines and degree of completion
- Budgets

Referencing to previous audits helps in project management as one is acquainted with successful methodologies, factors which determine failure and also success for a project. Auditing projects at the end help to highlight main aspects which resulted in the project being successful or unsuccessful and provides guideline for the future.

There will be 3 audits during the cycle of the project.

- Initial start of the project → After R&D stage
- Midway of the project → After development of the product
- Post project completion → After management signoff

5.4 Project Termination

As the updates or features of MBTA System is planned, designed, and manufactured, the project now enters termination process with a question as all the planning (scope, cost, time) was accurate as per standards. It doesn't only deal with developing project as per requirements, but did the project sell to the expectation while deployment?

There are few closeout activities during termination process that are vital to project completion. They include:

1. Operational Transition
2. Resource evaluation, Recognition and Release
3. Contractual Closeout
4. Knowledge Capture

There are also certain questions need to be asked when considering project termination. They include:

1. Is the output of the project still cost-effective?
2. Has the project been obviated by technical advances?
3. Are there better alternative uses for the funds, time and personnel devoted to the project?
4. Is it time to integrate the project as a part of regular operations?

This phase determines the project's survival in the market. If the project is successful, a proposal is made to make the features implemented, and if there is a failure, the company or team members need to put more focus and effort for a better future.

6.0 Risk Management Plan

6.1 Risk Management Planning

In the following section, we have defined and identified potential risks that could occur during the project's life cycle. This is a critical piece to the validity, credibility, and success of the proposed project. We will not blindly assume that no risks will materialize during the project, as that would be naïve and detrimental to the project's completion. Instead, we have performed several methods of risk identification, analysis, and response planning in the following sections to negate any surprises and limit risk impact.

6.2 Risk Identification

Below is a Fishbone diagram that has been created in the effort of identifying potential risks throughout the project's scope that would potentially endanger the team's ability to successfully reach project completion.

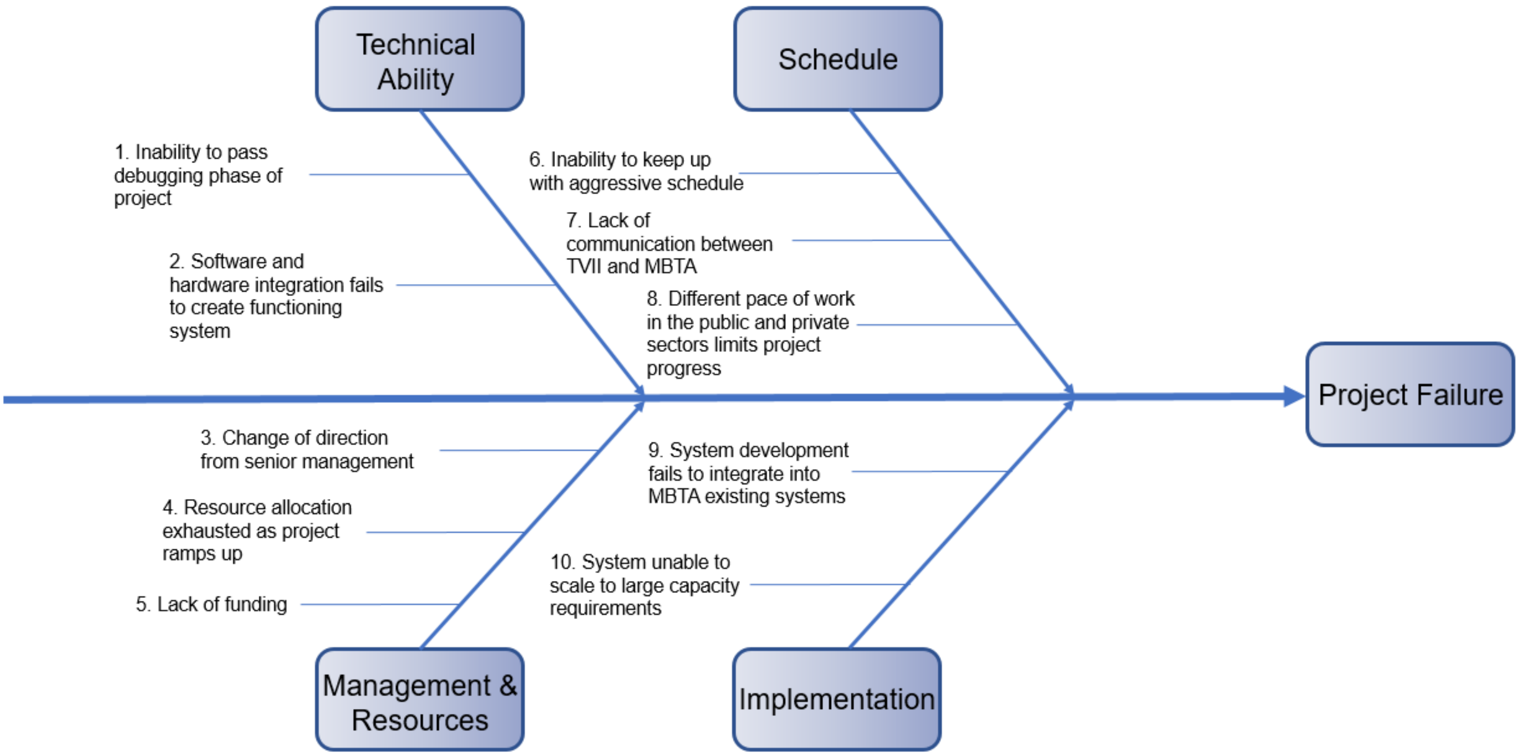


Figure 8 - Fishbone Risk Diagram

6.3 Qualitative Risk Analysis

The identified risks from the Fishbone diagram in the previous have been reformatted for the purpose of a qualitative risk assessment. While there are several tools to facilitate this form an assessment, we've chosen to produce a risk matrix and a way to visualize our analysis. Each risk that has been identified is organized in the risk matrix below. The matrix enables our team to plot each risk depending on its probability and impact to the project.

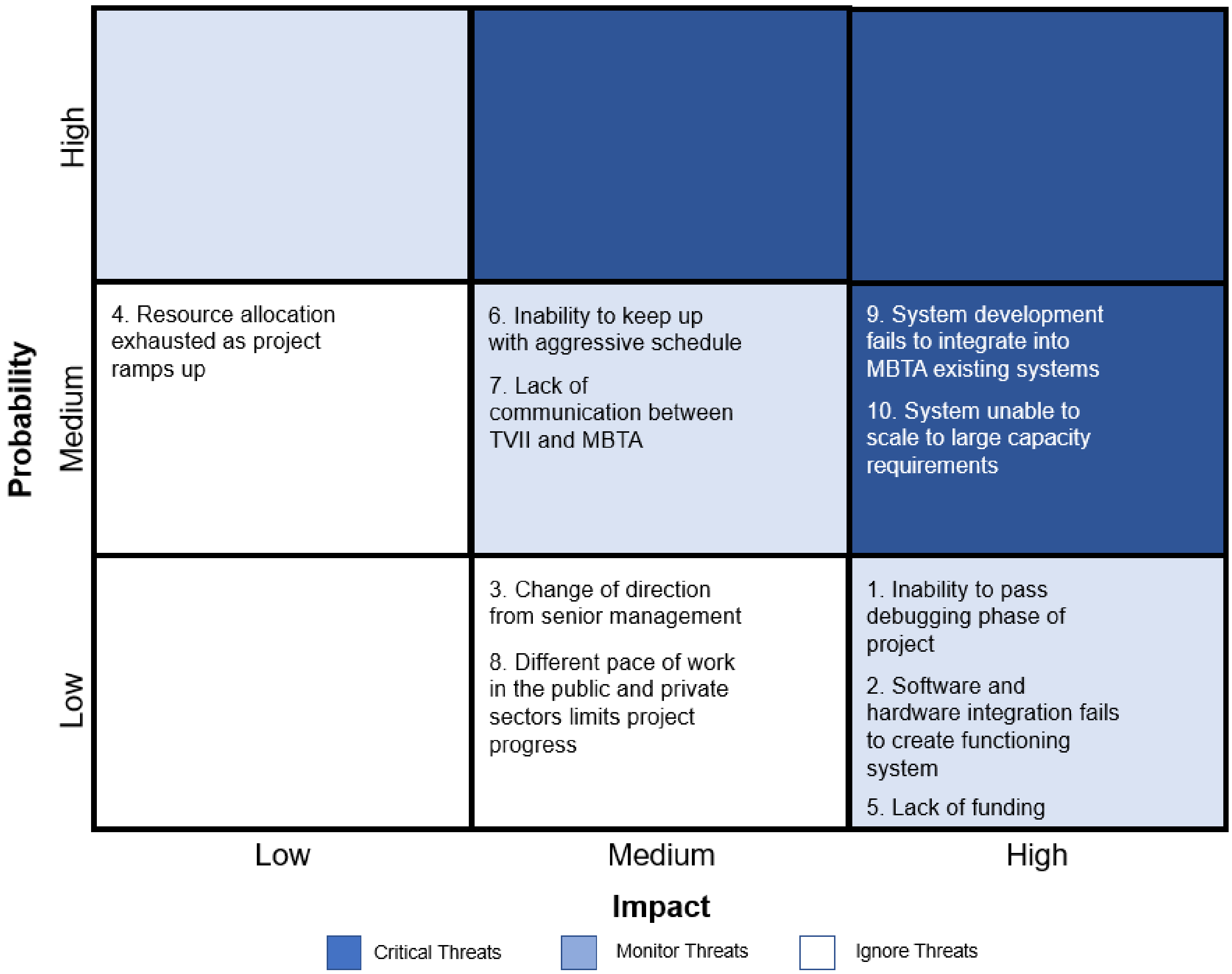


Figure 9 – Qualitative Risk Matrix

6.4 Quantitative Risk Analysis

We now arrange the identified risks from section 6.2 into a Failure Mode and Effect Analysis (FMEA) shown below. This method of quantitative risk analysis allows for the formation of a *Risk Priority Number (RPN)* for each identified risk. RPN's can be used as a helpful tool in assessing the significance of each risk based on its *severity, likelihood,* and *ability to be detected.* Each are graded on a scale from 1 to 10. Severity is given as a 1 if it will have no effect on the project, to a 10 if it will have a drastic impact. Likelihood is judged by 1 being extremely unlikely to happen, to 10 being almost certain to happen. Lastly, if a risk will be obvious to detect it will be given a 1, where as if it will be almost impossible to detect it is given a 10.

To determine the respective RPN for each risk, a simple calculation is performed to complete this method of quantitative risk analysis. It is shown below:

$$\boldsymbol{RPN} = \boldsymbol{severity}\ (\boldsymbol{S})\ \boldsymbol{x}\ \boldsymbol{likelihood}\ (\boldsymbol{L})\ \boldsymbol{x}\ \boldsymbol{ability\ to\ detect}\ (\boldsymbol{D})$$

Risk	Severity, S	Likelihood, L	Ability to Detect, D	Risk Priority Number (RPN)
1. Inability to pass debugging phase of project	9	1.5	1	13.5
2. Software and hardware integration fails to create functioning system	8.5	2	2	34
3. Change of direction from senior management	6	3	1.5	27
4. Resource allocation exhausted as project ramps up	3	5	4	60
5. Lack of funding	8	2	1	16
6. Inability to keep up with aggressive schedule	6.5	5	2.5	81.25
7. Lack of communication between TVII and MBTA	6	3.5	5	105
8. Different pace of work in the public and private sectors limits project progress	2	7	3	42
9. System development fails to integrate into MBTA existing systems	9	4	5	180
10. System unable to scale to large capacity requirements	9	3	5	135

Table 5 - Quantitative Failure Mode and Effect Analysis (FMEA)

From this process, we have a more complete understanding of the risks we've identified for this project. We will be looking most closely at risks that yielded Risk Priority Numbers over 100 (7, 9, and 10) as this is the cut off we have set as a team. Additionally, we will be carefully monitoring all risks with severity levels of 8 or above (1, 2, 5,9, and 10) as these would have detrimental effects to the project. Prior to the FMEA formation, our team settled on a cut off RPN of 200 to determine if any risk was too severe to warrant a modification in project scope. The analysis produced a highest RPN on 180 from risk

9. While this risk will warrant the greatest monitoring and control, we do not feel it is too risky to delay the project's progression.

6.5 Risk Response Planning

Finally, it is important to be prepared with plans for how to address each risk if they are to occur of the course of the project. While it is our ultimate goal to prevent any of these risks to happen, it not common to complete a project with no adversity or risk response along the way. For that reason, we have created a Risk Response Planning Chart to define how each identified risk will be addressed if it occurs. The categories *avoid*, *transfer*, *mitigate*, and *accept* are widely accepted in the field of Project Management as appropriate categories for addressing risk. Therefore, we have defined how each risk will be dealt with if it happens to occur in the following chart.

Risk	Avoid	Transfer	Mitigate	Accept
1. Inability to pass debugging phase of project			X	
2. Software and hardware integration fails to create functioning system			X	
3. Change of direction from senior management		X		
4. Resource allocation exhausted as project ramps up			X	
5. Lack of funding				X
6. Inability to keep up with aggressive schedule			X	
7. Lack of communication between TVII and MBTA	X			
8. Different pace of work in the public and private sectors limits project progress				X
9. System development fails to integrate into MBTA existing systems	X			
10. System unable to scale to large capacity requirements	X			

Table 6 - Risk Response Planning

It is essential to focus on and understand how each risk will be addressed if it happens to arise over the course of the project. Most importantly, risks that have been placed in the avoid category of response require active effort and monitorization in order ensure they will in fact be avoided. Unlike all other risks, which have plans for how to respond if they occur, risks to be avoided must be actively addressed throughout the project. For example, risk 7 can be avoided if the team can make an active effort to communicate with the MBTA staff, and risk 9 and 10 can be avoided through this communication and a thorough understanding of the scale and existing system of the MBTA prior to development.

7.0 Financial Plan with Budget

7.1 Overview

To successfully develop, deploy, and operate our proposed solution for one year, we will require a projected budget of $470,840. This project has two primary focuses of effort to enable success: workforce development efforts and hardware development. Our five-man team will be responsible for the project management, hardware selection, and software integration of the entire project. These efforts will be specifically focused on ensuring the selected solutions are integrated properly, the hardware solutions are fully compatible, installed, and tested with MBTA personnel, and the monitoring and control efforts made to ensure the on-time delivery of our product. Our personnel team will be supplemented by an external consulting company to fully develop the software solution for this product. We are currently considering the company Comentum, a full-service web enabled mobile application and server database development firm. To host the mobile application and server database necessary to sustain our application, we are proposing the selection of Amazon Web Services (AWS) who has the capacity, experience, and reliability necessary to ensure an extremely reliable and rapid data transfer to all users. The current GPS tracking hardware solution selected is the Live Trac G5 Pro Vehicle Tracker with a one year subscription. This item will be installed on all 205 train cars on the Green Line, detailed in the 2014 MBTA Bluebook 14th edition. This project will be managed by the five members of our team and implemented by July of 2018. Any additional costs to this project will be directly funded by a 5% project reserve of $23,542. If this project reserve is not utilized, this amount will be split amongst the five team members as a competitive bonus.

7.2 High Level Details

Internal Workforce Efforts				
Teams	**Team size**	**Hourly rate**	**Duration (days)**	**Sub-total Labor Cost**
1. Project Management Team	3	$40.00	10	$9,600.00
2. System Engineering Team	2	$55.00	6	$5,280.00
3. Software Development Team	5	$25.00	106	$106,000.00
4. Hardware Configuration Team	3	$25.00	39	$23,400.00
5. System Validation Team	2	$25.00	50	$20,000.00
6. Public Support Team	2	$20.00	24	$7,680.00
7. Installation Team	10	$15.00	43	$51,600.00
			Total Labor Cost:	$223,560.00
External Technology Development				
Technology Categories	**Quantity**	**Unit price**	**Duration/Quantity (mo)**	**Sub-total Technologies Cost**
1. Comentum Mobile/Web Development Fee	1	$158,000.00	1	$158,000.00
2. LiveTrac G5 Pro GPS tracker	246	$239.00	1	$58,794.00
3. Symcode 2D QR-Scanner	246	$83.00	1	$20,418.00
4. Amazon Web service Database platform subscription	1	$839.00	12	$10,068.00

			Total Technologies Cost:	$247,280.00
Project Contingency Reserve			5% Expected Cost	$23,542.00
			Entire Project Cost:	**$494,382.00**

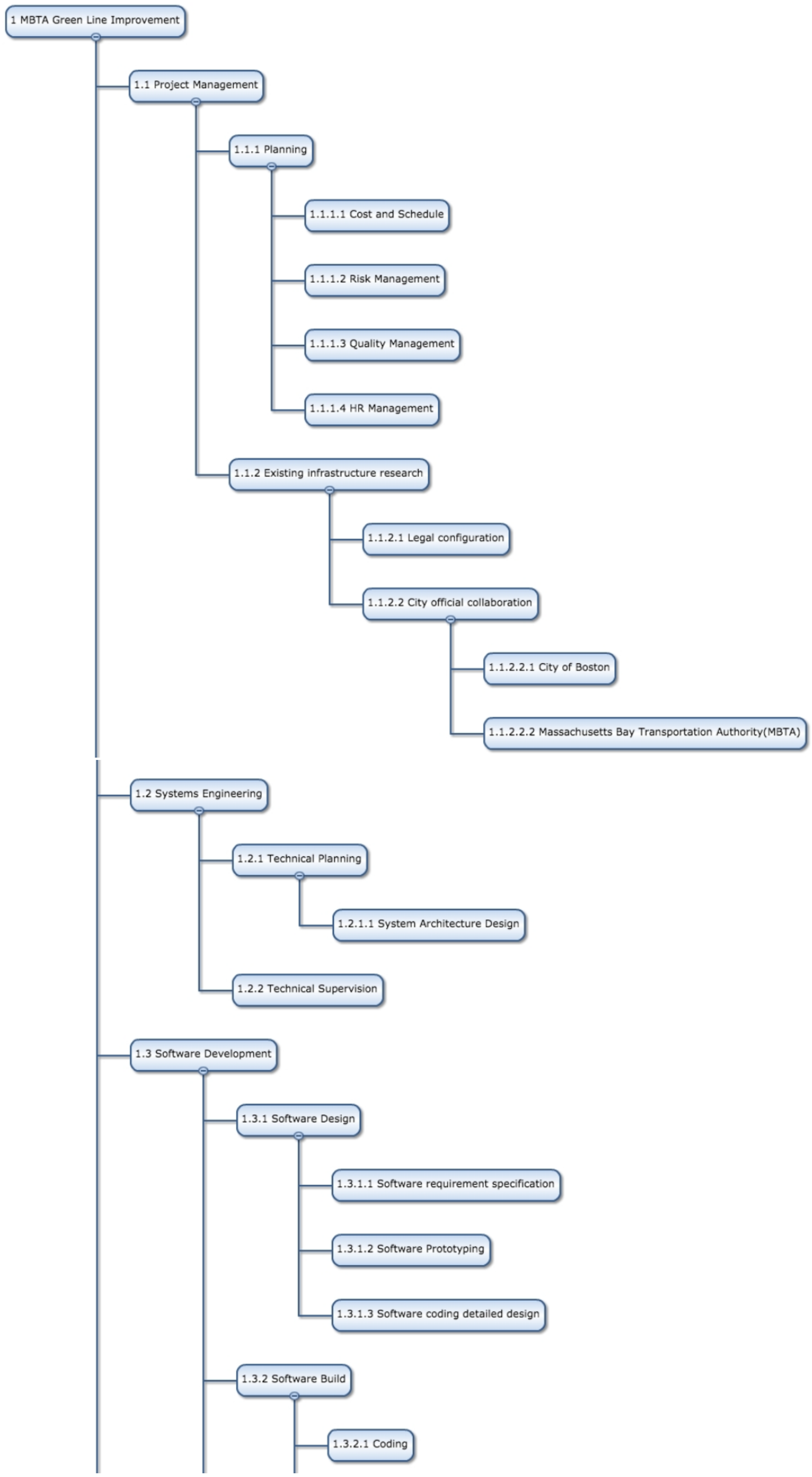
Table 7 - Itemized Budget Breakdown

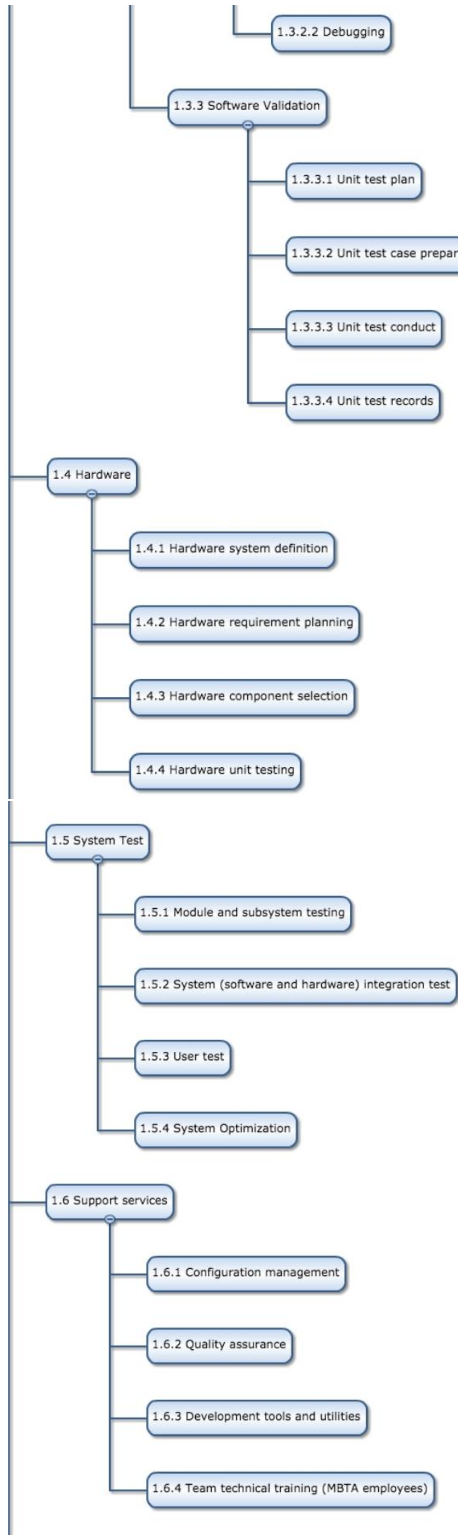
7.3 Budget Justification

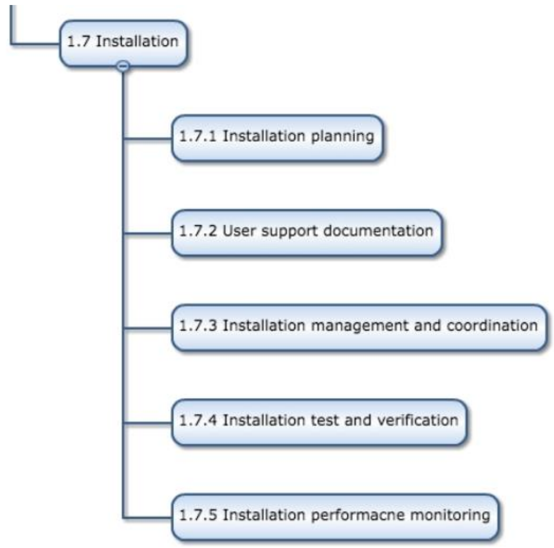
Calculating the projected budget required the considerations of two primary elements: the workforce development efforts and the hardware integration. For the hardware selected for this project, specifically the QR-scanner and GPS tracker, the quantity of 246 was selected as 120% of the 205 green line train cars currently operating based on the latest data published by the MBTA. The additional 20% is to account for initial defects and failures during the first year of operation. Comentum was selected as a digital mobile and web developer for their competitive pricing and full spectrum development, making them a one-stop shop for our entire software product. This avoided any integration issues between multiple developers and integration issues across different platforms. Amazon Web Services (AWS) was selected because of their reputation, capacity, experience, and reliability. Our projected budget is based on product and services research conducted by our team for appropriate solutions to our problem with quality service and technology. We are confident that our proposed solution will succeed in the market where others have failed and will gain significant user saturation within its first year of implementation. This projected budget will allow our company to fully implement our solution, market to investors and customers, and operate the entire solution for one-year. After this first year of operation, we believe we will have gained enough followership and daily usage to gain the support of the MBTA to expand to the remaining railed and rail-less MBTA services.

Appendix

Appendix A: Work Breakdown Structure – Tree View




1.3.2.2 Debugging
1.3.3 Software Validation
1.3.3.1 Unit test plan
1.3.3.2 Unit test case preparation
1.3.3.3 Unit test conduct
1.3.3.4 Unit test records
1.4 Hardware
1.4.1 Hardware system definition
1.4.2 Hardware requirement planning
1.4.3 Hardware component selection
1.4.4 Hardware unit testing
1.5 System Test
1.5.1 Module and subsystem testing
1.5.2 System (software and hardware) integration test
1.5.3 User test
1.5.4 System Optimization
1.6 Support services
1.6.1 Configuration management
1.6.2 Quality assurance
1.6.3 Development tools and utilities
1.6.4 Team technical training (MBTA employees)


1.7 Installation
1.7.1 Installation planning
1.7.2 User support documentation
1.7.3 Installation management and coordination
1.7.4 Installation test and verification
1.7.5 Installation performacne monitoring

Appendix B: Work Breakdown Structure – Chart View

	Task Name	Start Date	End Date	Assigned To	Duration
1	**Project Management**	**09/01/17**	**09/14/17**		**10d**
1.1	Planning	09/01/17	09/09/17		6d
1.1.1.	Cost and Schedule	09/01/17	09/04/17	Cost Manager	2d
1.1.2	Risk Management	09/05/17	09/07/17	Risk Associates	2.5d
1.1.3	Quality Management	09/08/17	09/08/17		1d
1.1.4	HR Management	09/09/17	09/09/17	HR Manager	1d
1.2	Existing Infrastructure Research	09/10/17	09/14/17		5d
1.2.1	Legal Configuration	09/10/17	09/11/17		2d
1.2.2	City Office Collaboration	09/12/17	09/14/17		3d
2	**System Engineering**	**09/15/17**	**09/22/17**		**6d**
2.1	Technical Planning	09/15/17	09/22/17		6d
2.1.1	System Architecture Design	09/15/17	09/22/17	Design Project Manager	6d
2.2	Technical Supervision	09/23/17	09/25/17		2d
3	**Software Development**	**09/26/17**	**02/20/18**		**106d**
3.1	Software Design	09/26/17	10/16/17		15d
3.1.1	Software Requirement Specification	09/26/17	09/29/17	Tier 1 (Software Engineer)	4d
3.1.2	Software Prototyping	10/02/17	10/09/17		6d
3.1.3	Software Coding Detailed Design	10/10/17	10/16/17		5d
3.2	Software Build	10/17/17	01/22/18		70d
3.2.1	Coding	10/17/17	12/25/17	Tier 1 (Software Engineer)	50d
3.2.2	Debugging	12/26/17	01/22/18		20d
3.3	Software Validation	10/18/17	02/20/18		90d
3.3.1	Unit Test Plan	10/18/17	10/26/17	Tier 1 (Software Engineer)	7d
3.3.2	Unit Test Case Preparation	10/27/17	11/14/17		13d
3.3.3	Unit Test Conduct	01/23/18	02/09/18		14d
3.3.4	Unit Test Records	02/12/18	02/20/18		7d
4	**Hardware**	**12/26/17**	**02/16/18**		**39d**
4.1	Hardware Requirement Planning	12/26/17	01/04/18	Tier 2 (Hardware Engineer)	8d
4.2	Hardware System Definition	01/05/18	01/10/18		4d
4.3	Hardware Component Selection	01/11/18	01/18/18		6d
4.4	Hardware Unit Testing	01/19/18	02/16/18		21d
5	**System Test**	**02/19/18**	**04/27/18**		**50d**
5.1	Module and Subsystem Testing	02/19/18	03/02/18	Validation Engineer	10d
5.2	System Integration Test	02/19/18	03/16/18		20d
5.3	Acceptance Test	03/19/18	04/18/18		23d
5.4	Defect Classification Tracking and Metrics	04/19/18	04/27/18		7d
6	**Support Services**	**04/30/18**	**05/31/18**		**24d**

6.1	Configuration Management	04/30/18	05/07/18	Quality Assurance Engineer	6d
6.2	Quality Assurance	05/08/18	05/14/18		5d
6.3	Development Tools and Utilities	05/15/18	05/22/18		6d
6.4	Team Technical Training	05/23/18	05/31/18		7d
7	**Installation**	**06/01/18**	**07/31/18**		**43d**
7.1	Installation Planning	06/01/18	06/08/18		6d
7.2	User Support Documentation	06/11/18	06/15/18		5d
7.3	Installation Management and Coordination	06/18/18	06/25/18		6d
7.4	Installation Test and Verification	06/26/18	07/23/18		20d
7.5	Installation Performance Monitoring	07/24/18	07/31/18		6d