APPLICATION AND ANALYSIS OF PROJECT MANAGEMENT TECHNIQUES IN DEVELOPMENT OF A HAPTIC FEEDBACK NAVIGATION SYSTEM

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Application and Analysis of Project Management Techniques in Development of a Haptic Feedback Navigation System

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GPS navigation systems and applications have transformed the way drivers get to their destination. With the guidance of a computer-generated voice, users can receive turn-by-turn directions without the dangerous distraction of a map – but what about deaf drivers who cannot hear this voice? Despite the millions of deaf and hard-of-hearing drivers in the United States, this group has limited solutions for safe, convenient, and simple navigation. A team of six undergraduate students came together to provide a solution to this problem in the form of a wristband that uses haptic feedback to guide users to their destination.

To develop this solution, several project management techniques were applied, with varying degrees of success. The goal was to apply these techniques to this student project as if it was a professional product development project, with appropriate timelines and cost estimates. After an initial project management plan including a work breakdown structure (WBS), responsibility matrix, feasibility study, and earned value plan was developed, the project began. Data regarding project progress was collected on the 30th and 60th day of progress and used to calculate project performance metrics.

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I would like to thank Dr. Charles Culp for his guidance and support throughout the course of this project, and for teaching me how to be a better project manager. I would also like to thank Dr. Timothy Morgan for his guidance in all things related to human resources, and Dr. Vahid Faghihi for his guidance in developing the engineering project management plan. Thanks also to the other members of the BuzzMap team, Elisha Gerhard, Jordan Roiko, Compton Stocki, and Jamie Duong, for their hard work on the BuzzMap project team – none of this would have been possible without them. Thanks also to the staff of the Engineering Innovation Center and the Inventeer program for allowing my team to use their facilities and for funding the development of our prototype.

CHAPTER I

INTRODUCTION

According to the national Survey of Income and Program Participation, 2-4 out of 1,000 people in the US are functionally deaf. That means that about one million people in the US alone that are functionally deaf. In addition, almost 10 million citizens are hard of hearing (Mitchell). Every state allows deaf and near-deaf individuals to drive; however, navigation solutions are hard to find for these hearing-impaired drivers. GPS devices and applications for drivers primarily use voice commands to provide directions, and visual methods of communicating the information such as subtitles or highlighted routes on a map cannot be used since they inherently result in distracted driving.

Proposed solutions to this problem include a steering wheel with vibration motors built in which would trigger the appropriate vibrator on the left or right side to indicate direction. However, this is an expensive solution that would be offered as an optional feature on new cars and could not by those who cannot afford a new car. While several articles were written about this solution in 2012, there is little indication of progress on the technology and no major car manufacturer offers the vibrating steeling wheel as a possible feature.

Another solution is simply using a hearing aid. However, this solution cannot be used by those with complete hearing loss, and according to the National Institute on Deafness and Other Communication Disorders, “Among adults aged 70 and older with hearing loss who could benefit from hearing aids, fewer than one in three (30 percent) has ever used them. Even fewer adults aged 20 to 69 (approximately 16 percent) who could benefit from wearing hearing aids have ever used them.”

To provide a solution to this problem, a team of six students came together to create a wristband containing vibration motors. This wristband would communicate via Bluetooth with a turn-by-turn navigation app on the user’s smart phone, then relay the instructions to the user by using vibrations. This study describes the application of project management principles to this technical project and an analysis of the effectiveness of those techniques.

CHAPTER II

METHODS

Since the end goal of this effort was to be as true to professional processes as possible, this project used same phased product development process used in industry. The initial phases – conception and development – were the focus of this year's efforts. The later phases, such as manufacturing, testing, and market introduction, will follow in future months depending on the success and popularity of the design. The three completed phases are described below.

Conception Phase

The focus of the conception phase is to study the need for the product and whether it is worth investing in. Two important project management tasks in this phase are the performance of a feasibility study and the creation of a technical proposal. The feasibility study includes a survey of currently existing solutions as well as the rationale for a new system. The feasibility study was performed by researching existing solutions, including the cost, function, and user reviews for each product.

The technical proposal is a document containing technical, cost, and qualifications information which is written by the project manager and must be approved by the customer before the project begins. The client can be an individual, another company, or another part of the project manager's own company. In this case, the client was the Inventeer program at Texas A&M, which is a program to help engineering students develop their designs, create startups, and gain experience in the product development process A proposal for the project, nicknamed BuzzMap, was submitted to the Inventeer program and accepted at the start of the fall 2016 semester.

Development Phase

After a project proposal has been approved, the project will enter the development phase. For this project, the management of the development phase included a project plan and a project schedule.

The project plan included a project charter, which is a document written immediately after the acceptance of the project proposal to guide the start of the work, including the project goals, scope, stakeholders, constraints, assumptions, and risks. In addition to the project charter, the project plan also includes a Work Breakdown Structure (WBS), responsibility matrix, and risk analysis.

The project schedule draws on elements of the project plan to create a day-to-day picture of the work that needs to be done. It includes the tasks in the work breakdown structure, with variances and earned value associated with each task. As the project progresses, performance is assessed by how closely it follows this project schedule.

Analysis

One of the most important parts of this effort is to determine the effectiveness of the techniques applied. In industry, a project is considered well-managed if the cost and schedule remain close to predicted values throughout the project. A comparison of the planned value (PV), earned value (EV), and actual cost (AC) of a project yields values that allow a quantitative analysis of project performance, which is provided at the end of the results section.

CHAPTER III

RESULTS

This research was performed in three major sections – engineering project management plan, business plan, and human resources plan. All three are inter-related, but the engineering project management plan provides the foundation of the project itself, and therefore it is where the development of the BuzzMap project begins. Since the goal of the project is to be as close as possible to a real startup, the project management plan includes calculations that assume the original four team members were being paid the average starting salary for someone in their major recently graduated from Texas A&M.

Conception Phase

The BuzzMap project had its unofficial beginning in May 2016 when the idea of creating a navigation system that used vibration rather than a synthetic voice to indicate directions was born. A project team was assembled and the following summer was spent performing market research and generating design concepts with the goal of submitting a proposal for the idea to the Inventeer program.

Initial Market and Feasibility Study

The first step of the project was to confirm an existing need for the product and that our solution was technically feasible, as well as analyze existing alternatives. Our research began by reading articles about deaf drivers. Several articles by the National Association of the Deaf as well as content posted in deaf community forums and blogs describing the lack of GPS systems that can accommodate the hard of hearing confirmed the presence of an existing need in the market. Alternatives to the arm band design included a pad with integrated vibration motors that

Table 1. Existing Navigation Solutions for the Hard of Hearing.

Alternative	Cost	Pro	Con
Hearing Aid	$800-$4000*	User may already own one.	Cannot be used by the completely deaf, and fewer than 30 percent who could benefit from hearing aids use them. (National Institutes of Health, 1)
Apple Watch	$269+	User may already own one.	Non-intuitive vibration system and prohibitive cost.
Shoe Insert by Lechal	$180	Lower cost, intuitive	Limited availability

could be placed over the driver seat; however, a similar design was already patented by Hyundai (although it is not currently on the market). A system that used LEDs rather than vibration motors was considered, but discarded since it could potentially lead to distracted driving. Table 1 at the top of this page describes the alternatives that are currently available.

Proposal

Once it was established that the project was viable, we prepared a proposal to the Inventeer project. A portion from each section of the BuzzMap project proposal is summarized below.

Technical Section

Our team will create a wristband with nine coin vibrator motors placed in a circle the size of a watch face. The vibrational motors as well as a Bluetooth-enabled microcontroller will be mounted to a flexible substrate and the entire band will be wrapped in fabric with a Velcro fastener to ensure a secure fit around the user's wrist. The microcontroller will be paired with the user's phone, which will use information provided by a turn-by-turn navigation app to determine when to activate the appropriate vibration motor sequence. The final product at the end of the year will be a wristband that communicates with a turn-by-turn navigation app on a smartphone

Table 2. Materials and Costs for Early Prototype.

Material (Quantity)	**Cost**
Vibrational motors (9)	$0.38 per motor
Bluetooth-enabled microcontroller (1)	$20
Flexible substrate material	Provided by EIC
Wires/solder	Provided by EIC
Fabric for cover	$2

to provide navigational assistance through haptic feedback, as well as a ‘video game’ for demonstration purposes that will allow users to try the system without getting into a car.

Cost and Payment

The costs for initial prototypes is low considering the size and scope of our project. Details regarding the early costs are show in Table 2. Note that these costs do not include any labor costs since the neither the Inventeer program nor any other entity will actually pay the team for their work on this project.

Development Phase

The development phase began in September 2016 with the Inventeer kickoff. Activities in this phase included assembling a project plan, making a schedule, and tracking progress. The project plan began as a project charter, which listed the project goals, scope, stakeholders, milestones, costs, constraints, assumptions, and risks. This information was combined with a responsibility matrix, quality plan, documentation plan, and work breakdown structure to create an overall project plan. The charter was written early in the semester and began with a paragraph of background information outlining the need for the device, then described several characteristics of the project. The overall project plan was used to determine time and cost estimates.

Scope, Stakeholders, Constraints, and Risks

The BuzzMap team will create a system that uses haptic feedback to assist drivers with navigation as well as a videogame that can be used to demonstrate the system. This "system" is limited to the haptic feedback device and any support required for its function (such as an app), and does not include any modifications to a vehicle or a smartphone beyond required software downloads. The stakeholders include four main groups: the client, which for BuzzMap is the Inventeer program; the sponsor, which is our advisor Dr. Charles Culp and the Inventeer Program Leadership. The constraints associated with the project are the cost (<$300), size (must be wearable), battery life (at least 1 hour of function without charging), time (1 academic year), human resources (only students). Our assumptions include that drivers own smartphones and at times drive alone with no passengers. The major risks include schedule slip, limitations due to skin desensitivity, and poor vibration motor calibration

Responsibility Matrix

A responsibility matrix usually consists of an integrated work breakdown structure (WBS), which is a hierarchical list of tasks, and organizational breakdown structure (OBS), which is a hierarchical list of project team members. However, due to the small size of the team, each team member is on the horizontal axis of the table rather than a full OBS, which would include departments, then work groups, then work group members. The full responsibility matrix for the BuzzMap project is found in Table 3.

Risk Analysis

An overall risk plan was assembled that contained information on each risk. The full risk plan includes the probability, impact, and owner of each risk. The risks were broken into three categories: risks related to labor and materials, risks related to the academic programs which support our project, and technical issues that our project may encounter. As in a professional risk plan, each risk is given a reference number, title, and description. Each risk is then assigned to a risk owner who is in charge of tracking that risk. Depending on the probability and impact of the risk (here ranked from 1-5 with 1 being the lowest), the risk is then assigned to a risk category of high, medium, or low. A mitigation plan is then attached to each. The full risk plan is listed in Table 4.

Table 3. Responsibility Matrix. OBS is on the horizontal axis and WBS is on the vertical axis.

P - Primary Responsibility **A** - Approval Authority **S** - Supporting Responsibility **I** - Information Only					
	Katherine Schneider	**Jordan Roiko**	**Elisha Gerhard**	**Jamie Duong**	**Dr. Charles Culp**
Software Development					
Planning code	S	P	S		
Writing code	S	P	S		
Microcontroller integration		P	S		
Hardware Development					
Design	A	S	P	I	I
Parts Selection		S	P		
Parts Ordering	P				
Construction		S	P	I	
Documentation					
Monthly status reports	P				A
Presentation Prep	P			S	
Thesis	P			S	A
Research					
Age/touch relationships	P	I	I	S	
Skin sensitivity over time	P	I	I	S	

Table 3. Continued.

Market research	P			S	I
Graphic Development					
Video game storyboarding	A			P	
Virtual Model				P	
Game development	I			P	
System Integration					
Hardware/Software Integration	I	P	S		
Hardware/Game Integration	I	S	S	P	
Testing					
Game testing	S	S	S	P	I
Road testing	S	P	S	S	I

Table 4. Overall Risk Plan.

Risk ID	Risk Title	Risk Description	Risk Owner(s)	Probability	Impact	Risk Category	Mitigation Plan
Labor and Materials							
1.1	Shortage of electronics specialists	Current electronics specialists leave the team	Katie	1	5	Low	Currently we have two electronics specialists. If one withdraws, the other can continue working on the design
1.2	Shortage of software specialists	Current software specialist leaves the team	Katie	2	5	Medium	Find another software specialists
1.3	Shortage of graphics specialists	Current graphics specialist leaves the team	Katie	4	2	Low	Find new graphics specialist or remove the graphics from the scope of the project
1.4	Shortage of business specialists	Current business specialist leaves team	Katie	2	1	Low	Other team members perform business functions if needed
1.5	Shipping delay	One or more hardware components takes an unexpectedly long time to ship	Elisha	3	1	Low	Order parts with a significant lead time before hardware demonstration deadlines
1.6	Part failure	One or more hardware component fails, delaying the project	Elisha	2	2	Low	Have extra of each part
Academic Programs (Includes Schedule and Cost Risks)							
2.1	Inventeer Withdrawal	Inventeer withdraws its support of the project, including the funding for materials	Katie	2	1	Low	Accept this risk because the costs of materials is low
2.2	Engineering Innovation Center Withdrawal	The EIC withdraws its support of the project, including providing build space and tools	Katie, Elisha	1	2	Low	Move to the ESET electronics labs if this occurs.
2.3	Undergraduate Research Scholars (URS) Withdrawal	URS withdraws its support of the project	Katie	3	1	Low	Accept this risk because URS only provides the URS distinction
2.3.1	Missed URS Mandatory Event	One or more team members does not attend a mandatory URS event	Katie	2	2	Low	Send reminder 2-3 days before the event and the day of the event
2.3.2	Missed URS Mandatory Submission	Team lead does not submit a mandatory URS installment before the due date	Katie	3	3	Medium	Set reminders for 1 week and 1 day before the due date
2.4	Dr. Culp Withdrawal	Dr. Culp decides to no longer support the project	Katie	2	5	Medium	Keep Dr. Culp's work-load to a minimum and work around his schedule

Table 4. Continued.

Risk ID	Risk Title	Risk Description	Risk Owner(s)	Probability	Impact	Risk Category	Mitigation Plan
2.5	Missed Engineering Project Showcase	The project is not complete by the EPS	Katie	2	5	Medium	Work over Christmas and spring break if we fall behind schedule
3.1	Cordova Errors	Our software strategy involves using Cordova to build the mobile app. However, none of us have ever used it before.	Compton	3	5	Medium	Test programs often, and have Cordova experts in contact in case errors or roadblocks occur
3.1.1	Bluetooth plug-in error	The Cordova plug-in for Bluetooth may be unable to communicate to the Arduino microcontroller	Compton	1	4	Low	Accept this risk because the plug-in is designed to work with Arduino
3.1.2	Google Maps plug-in error	The Cordova plug-in for Google Maps may be unable to provide the necessary data	Compton	3	5	Medium	Find another plug-in, such as MapQuest
3.2	Microcontroller errors	The microcontroller may be unable to read the data quickly enough, or not at all	Elisha, Jordan	4	3	Medium	Be prepared to change to another microcontroller
3.2.1	Unexpected Power Draw	The system may draw more power than calculated, reducing the battery life below the required 6 hours between charges	Elisha	4	2	Low	Have a back-up design that allows for additional batteries
3.2.2	Inability to read Cordova program	The microcontroller may be incompatible with the program developed in Cordova	Compton	2	5	Medium	Be prepared to change to another microcontroller
3.3	Integration Errors	Errors may occur when interfacing the mobile app, Cordova program, video game, and hardware systems	All	5	4	High	Test interface points as early and as often as possible

Table 5. Team Member Salary Data.

	Average Annual Salary	**Pay Per Day**
Katherine Schneider	$61,979.00	$246.93
Elisha Gerhard	$66,857.00	$266.36
Jordan Roiko	$66,857.00	$266.36
Jamie Duong	$34,500.00	$137.45
Compton Stocki	$68,044.00	$271.09

Project Schedule

With the project broken into manageable work packages and project methodology in place, it was time to create the project schedule. The schedule, the duration, and cost of each task is listed below. In industry, earned value is used to track project performance. By assigning each team member a “salary,” we gained a method of measuring the extrinsic value of the time spent on the project. Although none of the team members are being paid for their time on the project, the costs provided below were calculated assuming that they were being paid at the average salary for a recent graduate from Texas A&M in their major. The pay per day was calculated assuming 261 working days in a year. The salaries listed in Table 5 were used to calculate all of the labor costs in the following section. The full project schedule includes a task; its preceding tasks (the tasks which must be completed before the listed task can be started); the proposed start date, duration, and end date; and the total earned value associated with the task.

Table 6. Project Schedule.

Task	Predecessor	Start Date	Duration (days)	Team Members	End Date	Earned Value	Per Day Cost
Submit Proposal	NA	9/1/16	1	Katie	9/2/16	$246.93	$246.93
Perform Research	Submit Proposal	9/2/16	25	Katie	10/7/16	$6,173.21	$246.93
Draft Thesis	Perform Research	10/7/16	21	Katie	10/28/16	$5,185.49	$246.93
Culp Review Draft	Draft Thesis	10/31/16	7	Dr. Culp	11/8/16	$4,113.27	$587.61
2nd Thesis Draft	Culp Review Draft	11/8/16	7	Katie	11/17/16	$1,728.50	$246.93
Final Thesis Draft	2nd Thesis Draft	11/17/16	7	Katie	11/25/16	$1,728.50	$246.93
Submit Thesis	Final Thesis Draft	11/25/16	1	Katie	11/26/16	$246.93	$246.93
Brainstorm HW Ideas	Submit Proposal	9/2/16	7	Jordan, Elisha	9/13/16	$3,729.08	$532.73
Diagram HW Plan	Brainstorm HW Ideas	9/13/16	7	Jordan	9/22/16	$1,864.54	$266.36
Brainstorm SW Ideas	Submit Proposal	9/2/16	7	Compton	9/13/16	$1,897.64	$271.09
Write pseudocodes	Brainstorm SW Ideas	9/13/16	7	Compton	9/22/16	$1,897.64	$271.09
Select final SW plan	Write pseudocode	9/22/16	7	Compton	11/3/16	$1,897.64	$271.09
PM approval	Diagram HW Plan Select Final SW Plan	11/3/16	7	Katie	11/14/16	$1,728.50	$246.93
Select parts	PM Approval	11/14/16	2	Elisha	11/16/16	$532.73	$266.36
Write code	PM Approval	11/14/16	14	Compton	11/30/16	$3,795.28	$271.09
3D Print substrate	PM Approval	11/14/16	7	Katie	11/23/16	$1,728.50	$246.93
Order Parts	Select Parts	11/16/16	2	Katie	11/18/16	$493.86	$246.93
Upload to MC	Write code	11/30/16	2	Elisha	12/2/16	$532.73	$266.36
Debug Program	Upload to MC	12/2/16	4	Jordan, Elisha	12/6/16	$2,130.90	$532.73
Solder Parts	Order Parts	11/18/16	3	Jordan	11/22/16	$799.09	$266.36
Make Cover	Order Parts	11/18/16	7	Katie	11/26/16	$1,728.50	$246.93
Mount Components	Solder Parts	11/22/16	1	Elisha	11/23/16	$266.36	$266.36
Integrate HW	Mount Componets Make Cover 3D Print Substrate	11/26/16	3	Elisha	11/30/16	$799.09	$266.36
Storyboarding/Planning	Submit Proposal	9/2/16	25	Jamie	10/7/16	$3,436.25	$137.45
Virtual Modeling	Storyboarding/ Planning	10/7/16	7	Jamie	10/18/16	$962.15	$137.45

Table 6. Continued.

Task	**Predecessor**	**Start Date**	**Duration (days)**	**Team Members**	**End Date**	**Earned Value**	**Per Day Cost**
Final Game Development	Virtual Modeling	10/18/16	14	Jamie	11/4/16	$1,924.30	$137.45
PM Approval	Integrate HW Debug Program Final Game Development	12/6/16	2	Katie	12/8/16	$493.86	$246.93
HW/SW Integration	PM Approval	1/16/17	7	Elisha, Compton	1/25/17	$3,762.18	$537.45
HW/Game Integration	PM Approval	1/16/17	7	Jordan, Jamie	1/25/17	$2,826.69	$403.81
Test Drive	HW/SW Integration	1/25/17	14	Jordan	2/13/17	$3,729.08	$266.36
Refine Prototype	Test Drive	2/13/17	7	Elisha	2/21/17	$1,864.54	$266.36
Complete Documentation	Test Drive HW/Game Integration	2/13/17	14	Katie, Elisha	3/2/17	$7,252.28	$518.02
Prepare Oral Presentation	Refine Prototype	2/21/17	7	Katie	2/29/17	$1,728.50	$246.93
Create Project Poster	Complete Documentation	3/2/17	7	Jamie	3/13/17	$962.15	$137.45
Project Completion	Submit Thesis Create Project Poster Prepare Oral Presentation	3/13/17					
		Planned End date:	**3/13/17**		**Total Cost:**	**$74,186.86**	

Tasks with Variances

It is unlikely that the project will stick to the schedule above. For more realistic schedule information, it is important to take the variance, or likely deviation from the predicted value, into account. Each task in the WBS is listed in Table 6 along with its predecessors, best case duration (A), most likely duration (M), worst case duration (B). This can then be used in the following equation to compute the expected duration.

Expected Duration = (A + 4M + B) / 6

This information was then used to compute the total project duration with 95% certainty.

Table 6. Project Schedule Variance.

Task	Predecessor	A	M	B	Expected Duration	Variance
Submit Proposal	NA	1	1	1	1	0
Perform Research	Submit Proposal	14	30	60	32.3	58.8
Draft Thesis	Perform Research	7	21	30	20.2	14.7
Culp Review Draft	Draft Thesis	2	7	10	6.7	1.8
2nd Thesis Draft	Culp Review Draft	3	7	10	6.8	1.4
Final Thesis Draft	2nd Thesis Draft	3	7	10	6.8	1.36
Submit Thesis	Final Thesis Draft	1	1	1	1	0
Brainstorm HW Ideas	Submit Proposal	3	7	14	7.5	3.4
Diagram HW Plan	Brainstorm HW Ideas	1	7	9	6.3	1.8
Brainstorm SW Ideas	Submit Proposal	3	7	14	7.5	3.4
Write Pseudocode	Brainstorm SW Ideas	1	7	9	6.3	1.8
Select Final SW Plan	Write Pseudocode	1	7	12	6.8	3.4
PM Approval	Diagram HW Plan Select Final SW Plan	1	7	14	7.2	4.7
Select Parts	PM Approval	1	2	5	2.3	0.4
Write Code	PM Approval	7	14	21	14	5.4
3D Print Substrate	PM Approval	3	7	10	6.8	1.4
Order Parts	Select Parts	1	2	3	2	0.1
Upload to MC	Write Code	1	2	3	2	0.1
Debug Program	Upload to MC	1	4	7	4	1
Solder Parts	Order Parts	1	3	7	3.3	1
Make Cover	Order Parts	1	7	14	7.2	4.7
Mount Components	Solder	1	1	1	1	0
Integrate HW	Mount Components Make Cover 3D Print Substrate	1	3	7	3.3	1
Storyboarding/ Planning	Submit Proposal	14	30	44	29.7	25
Virtual Modeling	Storyboarding/ Planning	4	7	10	7	1
Final Game Development	Virtual Modeling	7	14	21	14	5.4
PM Approval	Integrate HW	1	2	3	2	0.1

Table 6. Project Schedule Variance.

Task	Predecessor	A	M	B	Expected Duration	Variance
HW/SW Integration	PM Approval	3	7	10	6.8	1.4
HW/Game Integration	PM Approval	3	7	10	6.8	1.4
Test Drive	HW/SW Integration	7	14	21	14	5.4
Refine Prototype	Test Drive	1	7	14	7.2	4.7
Complete Documentation	Test Drive HW/Game Integration	7	14	21	14	5.4
Prepare Oral Presentation	Refine Prototype	2	7	10	6.7	1.8
Create Project Poster	Complete Documentation	2	7	10	6.7	1.8
Project Completion	Submit Thesis Create Project Poster Prepare Oral Presentation				85.2	45.6
	95% Chance of Completion by:			**103**	**days**	

This 95% completion date is 103 working days from the start of the project (September 1). Our deadline for completion is the date of the Engineering Project on April 2 at which the BuzzMap team will demonstrate our prototype. There are 120 working days from the project start until the deadline, assuming no work on the weekends or over the Christmas break.

Comparison of Planned Value and Actual Value

Now that we had a plan, the team ready to begin work. The blue line on Figure 1 represents the planned progress of our project by showing the planned value (PV) for the first 85 days of our project. The earned value (EV) is represented by the red dots in Figure 1 and represents the amount of work finished by a certain date. If the red dot is below the blue line, the project is behind schedule; if it is above the blue line, the project is ahead of schedule. The actual cost of work performed (AC) is represented by the orange dots in Figure 1 and describes the amount of resources it actually took to reach a certain amount of earned value.

The schedule delays in the second month were due to unforeseen delays in debugging the software and integrating the hardware that pushed both of those tasks into month three.

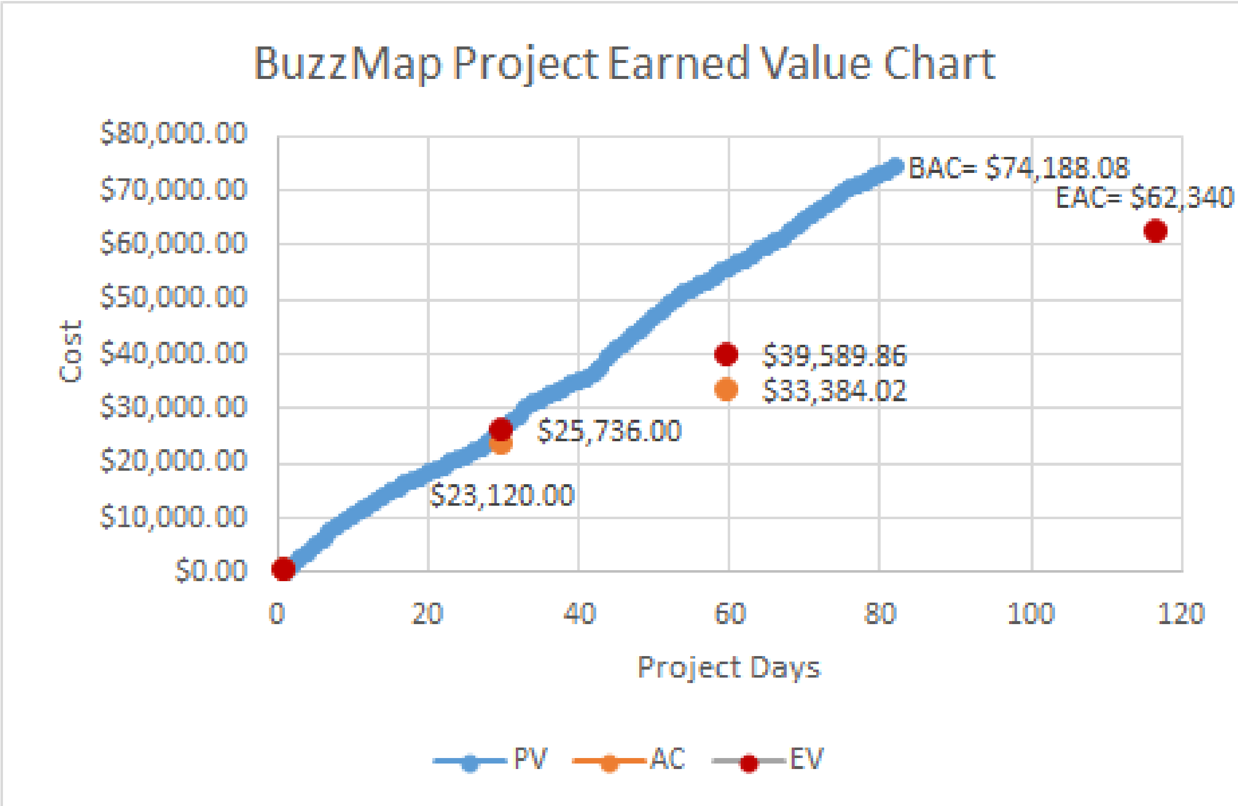

Figure 1. Projected vs Actual Project Performance.

However, the data in Figure 1 was calculated based on working days, not calendar days. Therefore, it does not include a 30-day lag due to Christmas break, during which we can work to catch up to the schedule if necessary. This adds an extra 37 working days, before the deadline (not counting weekends), which means we should still be able to achieve our goals before the deadline. Several common performance metrics for engineering projects are calculated in Table 7 for the 30th and 60th day of the project. The method for calculating each metric is also given.

Table 7. Project Progress Metrics.

Metric	Formula	Day 30	Day 60
PV	NA	$26,428	$55,877
EV	NA	$25,736	$39,589
AC	NA	$23,120	$33,384
Cost Variance	(EV-AC)	$2,616	$6,205
Schedule Variance	(EV-PV)	($692)	($16,288)
Resource Flow Variance	(PV-AC)	$3,308	$22,490
Schedule Performance Index	(EV/PV)	0.97	0.71
Cost Performance Index	(EV/AC)	1.11	1.19
Critical Ratio	(CPI/SPI)	1.08	0.84
Percent Budget Spent	(AC/BAC)	31.2%	45.0%
Percent Completed	(EV/BAC)	34.7%	53.3%
Work Remaining	(BAC-EV)	$48,450	$34,600
Budget Remaining	(BAC-AC)	$51,070	$40,800
Estimate at Completion	([BAC-EV]/SPI)	$66,840	$62,340

This concludes the project management efforts on the project for this academic year. Moving forward with the project, we will work on finishing the development phase and catching up to the project schedule before the execution phase begins in the spring. At that point, we will focus on manufacturing and presenting our final product, as well as planning the structure of the company we will form to sell this product. Current documentation procedures such as weekly schedule updates and monthly progress reports will continue throughout the project duration. Additional activities in the execution phase will include system integration, lab testing, field testing, and entry-to-market plan execution.

CHAPTER IV

CONCLUSION

The BuzzMap project has come a long way from its initial conception in May. Thorough research and front-end loading led to the project being accepted into the Inventeer program and remaining on schedule for the entire first month, although delays occurred in the second month as we started putting the first prototype together.

Conclusions from Project Metrics

According to Dr. Vahid Faghihi, professor for engineering project management in the Civil Engineering Department at Texas A&M, most projects in industry with a schedule performance index (SPI) or cost performance index (CPI) below 0.9 is considered in "grave danger." However, for a lower cost, lower risk project such as this, a value of 0.9 would be considered acceptable and even indicative of a successful project. By that standard, the BuzzMap project was successful at the end of Day 30, with healthy SPI and CPI values at 0.97 and 1.11 respectively. If the project continued on a similar trajectory, the total project cost would have been $68,840, which would have been 9.9% under the predicted cost. Unfortunately, the outlook wasn't so bright at the end of the second month. Due to unforeseen problems in software development, the project fell behind schedule and the SPI dropped to 0.71. Since the other team members could not work on their portions of the project without the software, they spent less hours on the project and thus the CPI actually increased to 1.19. These values of SPI and CPI mean that the project was behind schedule, but under budget.

So was the project in trouble? The answer lies in the Critical Ratio (CR) which is the product of the SPI and CPI. If the CR falls below 0.9, the project may be in trouble. For Day 30, the CR was a very healthy 1.08. For Day 60, it had fallen to 0.84. At this point is possible, although unlikely, for the project to return to a healthy schedule.

Conclusions from Project Delays

The major source of delays in the project schedule came from unforeseen tasks coming up after the project plan had been created. This is not necessarily due to an error in method; more likely it is due to the team's inexperience with projects of this type and the tasks required to complete them. Rather than creating a WBS myself, it would have been better to consult experts to determine all of the necessary phases and tasks involved. Still, all team members agree that the heavy front-loading of the project and using these project management techniques and documents did increase the overall efficiency of the project compared to past student engineering projects.

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