FAMU & FSU COLLEGE OF ENGINEERING

Department of Mechanical Engineering

Construction Marking Robot

Product Plan and Product Specifications

EML4551C – Senior Design – Fall 2015

Team 19
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Abstract

This deliverable seeks to express Team 19's process so far in terms of defining the project at hand, which includes a needs assessment, further developed task lists and time estimates, as well as basic project specifications. So far the team has defined the problem as being that surveying construction sites can be problematic due to miscommunication between contractors which leads to inaccuracies in the markings for the overall layout. Additionally, the process in general is very time consuming. Based on this, the team has determined the goal to be to design and implement a "proof of concept" robot that will ultimately survey 100 square feet within a half inch margin of error for several layout plans. For the needs assessment, the team chose to focus primarily on communication with the sponsor from which the development of an in depth House of Quality was completed, as well as specific constraints for the robot and its output. With this information, project specifications were detailed based on using the Pioneer 2 as the robot base. These specifications include details about the Pioneer 2, plans for a marking mechanism, and information about the robotic total station the robot will have communication with. Finally, a Gantt Chart was created to have a preliminary schedule for the project.

1.Introduction

In this age where the inclusion of robotics in industrial settings has become increasingly prevalent, the construction industry stands as one of the last industries to take notice of the advantages robotic tools can offer. However, as the industry emerges from the recession, two observed trends have occurred: an increasing desire for higher efficiency and a hesitancy towards hiring new personnel to meet demand due to not knowing how long this boom in business will last. Due to this, Mark Winger of PSBI, believes that now is the time to introduce the application of robotics to the construction industry. Seeing that one of the most accident prone and time consuming areas of the construction process is that of the layout, Mark has tasked Team 19 with designing a “proof of concept” robot for the sake of marking of the preliminary layout of walls, electrical, HVAC, and water systems during the construction process.

2.Project Definition

a. Background research

The idea of a construction marking robot is a fairly recent idea in the construction industry. Currently there is research being done with the idea by companies such as Trimble and DPR, who are combining their specialties in GPS positioning products and construction to create an automated layout robot, or Laybot as they have termed it. This Laybot idea is similar to the group's construction marking robot in that it hopes to be able to mark multiple layouts on the ground, use downloaded 2D CAD files to input the layouts into the robot, and have communication with a robotic totaling station to ensure precise positioning[1].

Aside from the Laybot idea, there is also a patent for a construction marking robot by Joseph M. Prouty with Totalmark Technologies[2]. While designed to perform the same function as both Team 19's design and the Laybot, the robot by Totalmark Technologies "is controlled via an included tablet pc which is accessible via the internet from anywhere in the world, so long as the job site has Wi-Fi access."[3] It also is linked with a robotic totaling station to track position, and is able to function in complete darkness.

The differences between Team 19's design and the others is the plan of a different marking mechanism and different sensors on the robot. With the resources provided to the group, and the materials available, the final design for the construction robot is guaranteed to be different than the products currently being researched and produced by other companies.

Opposition to the project comes with the resistance to newer technology in the construction industry. There is a skeptical view of automated processes due to a lack of newer technology in the field, and a fear of robots taking job opportunities. The goal of this project is not to encourage the removal of jobs, but to increase efficiency in those jobs and provide a tool better equipped to help.

b. Needs Statement

Surveying construction sites can be problematic. Communication between contractors that have to lay markings down arise, which can cause inaccuracy in the layout and the final outcome.

Marking every floor by hand is time consuming. Productivity in construction is low and there needs to be a way to compensate for lack of hands. Team 19's sponsor, Mark Winger of PSBI, is asking for a "proof of concept" robot that will ultimately survey 100 square feet within a half inch margin of error for several layout plans. This project would help with efficient surveying and lessen the confusion and problems between contractors that have to work around one another.

"Since the recession, productivity in construction is too low"

c. Goal Statement & Objectives

i) Goal Statement

"Design a 'proof of concept' high precision marking robot that will lay out the preliminary floor plan of a construction site"

ii) Objectives

The Construction Marking Robot (CMR) must be able to avoid obstacles autonomously. It must also produce an error report upon the presence of an obstacle with information on what markings it missed and where the errors can be found. The CMR should be capable of marking a 100 square foot layout in approximately 10 minutes. It must also must work without a human input and solely use a special 2d cad file uploaded to its memory.

d. Constraints

- The robot must be able to obtain its precise position in the room
- The robot must be able self-navigate and avoid obstacles
- The robot must be able to mark on concrete the given floor lines
- All marking lines must be within a half inch accuracy from the floor plan
- The total cost must not exceed $8,000
- The weight of the robot must be such that a single person could carry it

e. Methodology

For the Construction Marking Robot, Team 19 will implement a strategy focused around the preliminary design of the system similar to the one mentioned in *Engineering Design* by George Dieter. The team will be using a product development process known as Quality Function

Deployment (QFD), which is a graphical, multistep process that creates relationships between key parameters throughout the entire design process. This tool will help focus the team's attention to satisfying the customer's needs. One of the beginning steps of this process is constructing a House of Quality (HOQ), which is a design tool in the form of a relationship matrix which compares the customer's needs to the engineering characteristics set by the design team. Once the system has been designed conceptually, the team will move into the embodiment phase of the design where more specific figures and values will be chosen. QFD is a very iterative and involved process which will make for a better final design.

f. Schedule

Team 19 will focus around the two Midterm Presentations and use them as milestones throughout the semester as self-evaluation points in the design process. These milestones can be seen in Figure 1 and are denoted by the blue diamonds. The arrows on the Gantt chart represent tasks that must be completed before other tasks, or predecessors. Knowing which tasks need to be completed before others provide the team with an idea of float, which is similar to lag, where it provides the team with a time padding in knowing which tasks can be started early and started or finished late.

g. Resource Allocation

Resource allocation is something Team 19 will need to focus on in the near future. With simultaneous project deadlines approaching, the team needs to know what needs to be done and who needs to do it. In Figure 3 and Figure 4 it can be seen who is responsible for what parts of the project and their respective due dates. As seen in these figures, there are still many project parts that need to be allocated soon to ensure deadlines are being met.

h. Design Specifications

i) Mobile Robot Platform

For this project, the team has been provided a Pioneer 2-DX mobile robotic platform (Figure 1) to work off of so the team's efforts can be focused on designing a marking mechanism and overall system functionality in terms of the program used to fulfill the team's goal. This platform is a versatile mobile robot with an embedded controller and is powered by a 12 Volt battery. For locomotion, the Pioneer 2-DX is equipped with a caster wheel and two 19-cm wheels which are driven by DC motors coupled with 500-tick encoders. For object detection, this robot has a set of sixteen ultrasonic sensors (eight in front and eight in the rear), a laser range finder for more accurate readings, and bumper switches for collision detection in a worst case scenario. For user interfacing, this platform has ports compatible for a keyboard and USB devices. With all of these components, the robot currently weighs in at about 45 lbs, which should be within the desired weight range, even with the addition of the marking mechanism[4].

Figure 1: Pioneer 2-DX

ii) Marking Mechanism

In addition to the Pioneer 2-DX platform, a mechanism for actually producing the markings is currently being designed so as to complete the system in terms of fulfilling the sponsor's needs. Since the design is to be for a "proof of concept" robot, taking into account the sponsor's input, the team has determined that the design for the marking mechanism should prioritize simplicity and functionality so as to guarantee said functionality. That being said, the team is currently attempting to design a mechanism with less than six degrees of freedom which can still perform all tasks necessary for the eventual "proof of concept" demonstration. This will ideally simplify the mechanical and electrical designs as well as the coding required to properly actuate it, allowing the team to focus on fine tuning it so it will consistently function to the desired degree of accuracy.

iii) Robotic Totaling Station

At the request and supply of the sponsor, the team will be using a robotic total station (RTS) in conjunction with the mobile robotic system for accurate localization. Additionally, the utilization of the RTS will require the team to design the mobile robotic system so as to include a series of prisms so the RTS can track the position and orientation of the robot.

3.Conclusion

This project is the start of advancements in technology in the construction industry. Designing a “proof of concept” construction marking robot that will survey 100 square feet can jump-start the construction project presented by Mark Winger of PSBI. The marking robot will mark all of the layouts will make the contractor's job simpler and more accurate than each subcontractor coming in and surveying one by one. Our end goal is eliminating confusion and increasing productivity in surveying while meeting our customer needs and project constraints.

4.References

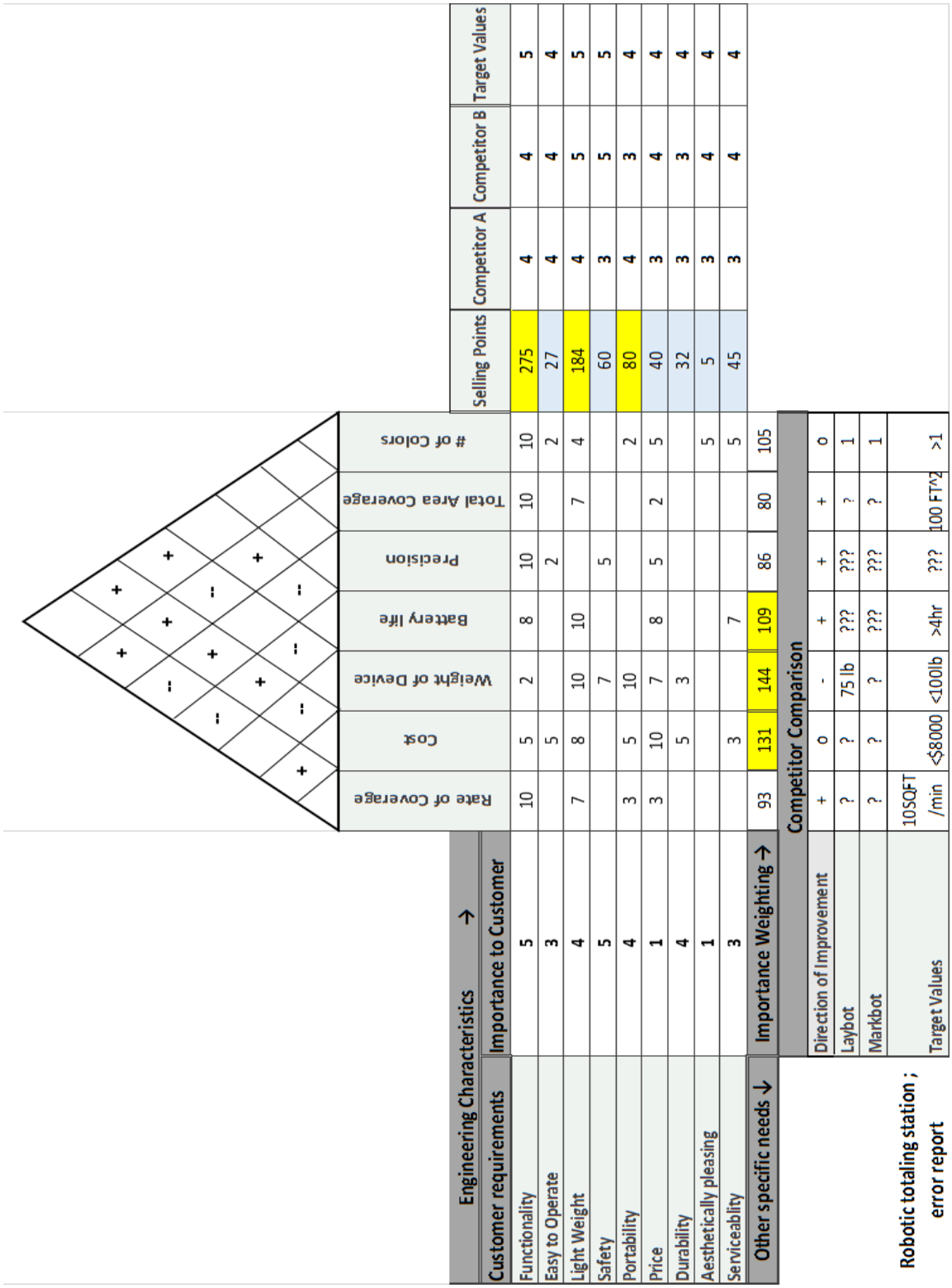
[1] "Project Lion - A DPR/Trimble Automated Layout Robot." *YouTube*. YouTube, 25 Apr. 2013. Web. 25 Sept. 2015.

[2] Prouty, Joseph M. Robotic Construction Site Marking Apparatus. Joseph M. Prouty, assignee. Patent US 20130310971 A1. 21 Nov. 2013. Print.

[3] "Construction Industry- Robotic Layout." *Totalmark Technologies*. N.p., n.d. Web. 25 Sept. 2015.

[4] "Specifications & Controls." *ActivMedia Robotics Pioneer 2/PeopleBot Operations Manual V10*. N.p.: n.p., July 2002. 10-18. Print.

5.Appendix



Engineering Characteristics →		Rate of Coverage	Cost	Weight of Device	Battery life	Precision	Total Area Coverage	# of Colors	Selling Points	Competitor A	Competitor B	Target Values
Customer requirements	Importance to Customer											
Functionality	5	10	5	2	8	10	10	10	275	4	4	5
Easy to Operate	3		5			2		2	27	4	4	4
Light Weight	4	7	8	10	10		7	4	184	4	5	5
Safety	5			7		5			60	3	5	5
Portability	4	3	5	10				2	80	4	3	4
Price	1	3	10	7	8	5	2	5	40	3	4	4
Durability	4		5	3					32	3	3	4
Aesthetically pleasing	1							5	5	3	4	4
Serviceablity	3		3		7			5	45	3	4	4
Other specific needs ↓	Importance Weighting →	93	131	144	109	86	80	105				
	Competitor Comparison											
	Direction of Improvement	+	o	-	+	+	+	o				
	Laybot	?	?	75 lb	???	???	?	1				
	Markbot	?	?	?	???	???	?	1				
Robotic totaling station ; error report	Target Values	10SQFT /min	<$8000	<100lb	>4hr	???	100 FT^2	>1				

Figure 2: House of Quality

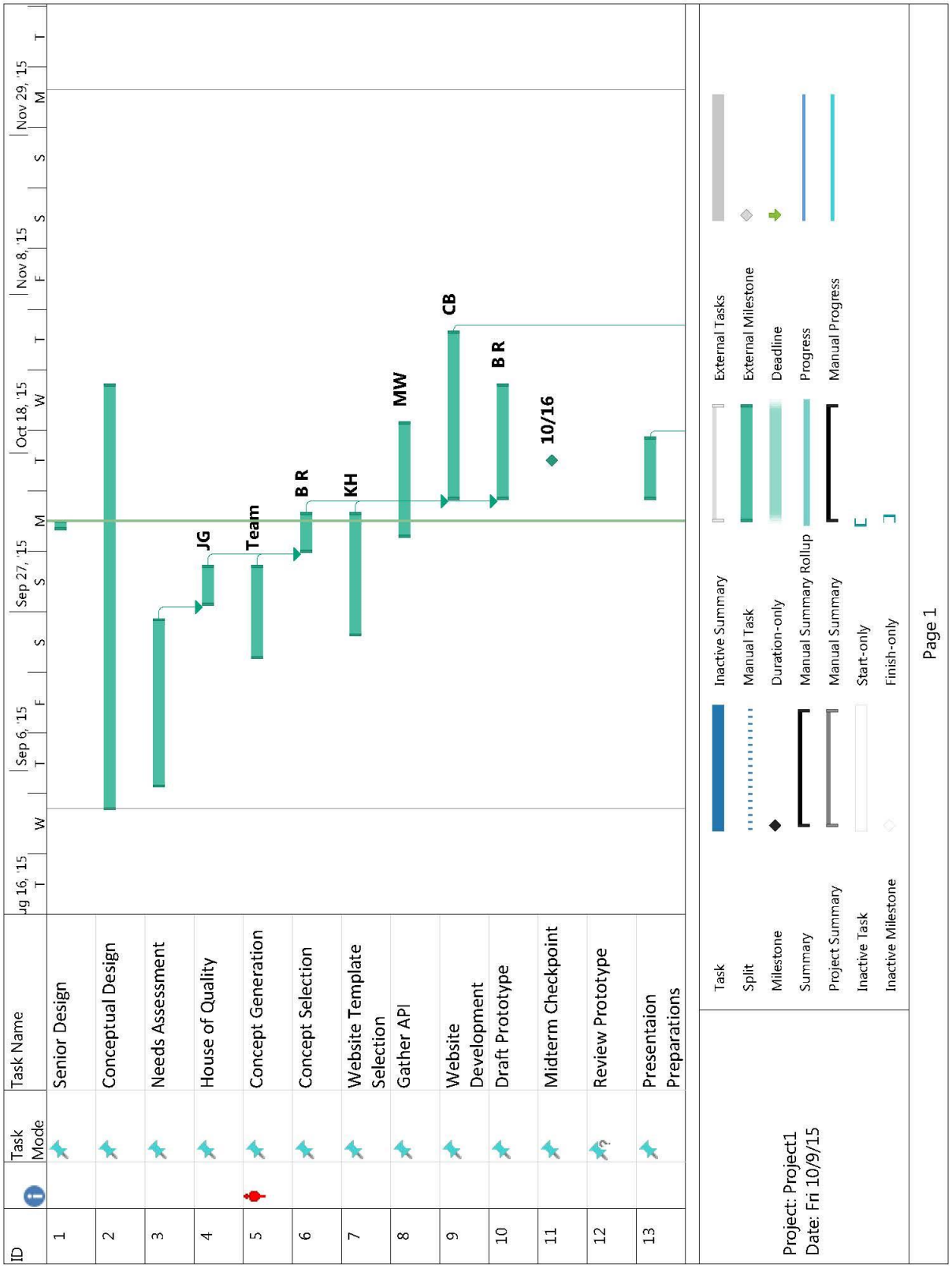


Figure 3: Gantt Chart (1)

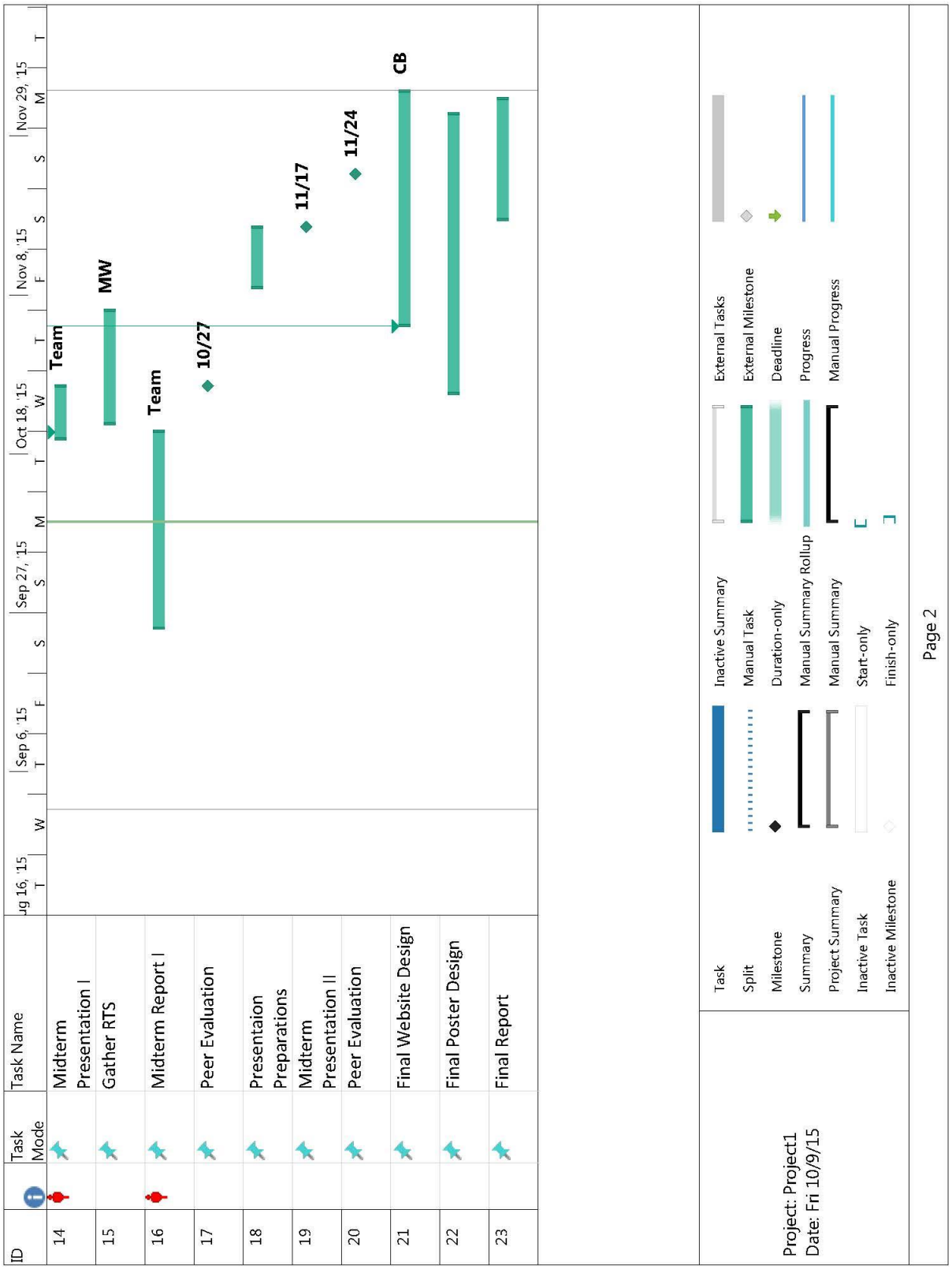


Figure 4: Gantt Chart (2)