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FINAL REPORT - LEPTODETECTO

GROUP 7

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TEAM MEMBERS	ROLES
 TABINA KAMAL	***Project Manager*** ▫ Arranging and monitoring project ▫ Controlling project planning and execution processes ▫ In charge of tracking project progression
 WAN ADRIANA  AMIRUN FAHIM	***Engineers*** ▫ Creating and testing functionality of product prototype ▫ Creating product specifications ▫ Developing system software

<table>
<tr><td>
CHEN MINGYUE</td><td>Designer
▫ 3D Modelling
▫ Developing the outer appearance of product
▫ Producing final design of product prototype</td></tr>
<tr><td>
IMRAN</td><td rowspan="2">Finance Officers
▫ Cost estimation
▫ Keeping track of expenditures
▫ Equipment cost survey and research</td></tr>
<tr><td>
HAZIQ</td></tr>
<tr><td>
AIMAN IQBAL</td><td>Marketing Officer
▫ Conducting market research
▫ Developing marketing strategies
▫ Establish a position in the market</td></tr>
</table>

2.0 Background

There are 17 goals of the United Nations Sustainable Development that serve as a global call to action that unifies 193 nations. This organisation aims to tackle two of the goals; SDG 3 which aims to ensure healthy lifestyles and promote well-being for all ages and SDG 6 which aims for the availability and sustainable management of water and sanitation for all.

This aim of this project is to propose a solution to reduce the cases Leptospirosis which affects numerous people during flooding especially in developing countries. Most cases of Leptospirosis infections were found in tropical or sub-tropical zones due to the hot and humid environment. such as Southeast Asian nations. Leptospirosis is a zoonotic disease that causes by pathogenic Leptospira bacteria commonly found in rodents that act as carriers. Rodent species are the primary host of the Leptospira bacteria, which can infect humans through contact with urine contaminated water or soil.

The symptoms of Leptospirosis usually occur in 5 to 14 days following contact with the bacteria. However, they also could appear between 2- and 30-days following interaction. There are two phases of Leptospirosis infection; the Leptospiremic (acute) phase and the immune (delayed) phase. Early signs and symptoms in the Leptospiraemic phase are fever, headache, muscle aches, red eyes, vomiting, diarrhoea, and abdominal pain. However, there will be cases that the infected person shows no symptoms. For the immune phase, the infected person will develop severe symptoms such as jaundice and renal or liver failure. This phase indicates that the Leptospira has spread from the blood to the organs. However, most Leptospirosis cases are misdiagnosed due to symptoms similar to dengue and malaria. This misdiagnosis can increase the number of deaths among infected people.

1.03 million persons are affected with Leptospirosis yearly worldwide, and 58,900 persons are killed due to the Leptospirosis infection [6]. Floods have been the predominant cause of Leptospirosis infections because humans wade through contaminated water or soil during the flood. 10 - 100 cases of Leptospirosis per 100,000 population reported in tropical countries, with a fatality rate of about 6.85% [2]. In February 2017, leptospirosis cases were reported in Tanah Merah, Kelantan, which led to the death of a patient due to the Leptospirosis infection that affected his respiratory system [1]. Leptospirosis infections are expected to have a higher incidence due to rapid urbanization, global warming, and extreme climatic change, which can cause the occurrence of flood events frequently [7].

Commonly, the detection of Leptospira bacteria is done through conventional lab analysis method through water samples or blood samples from those who are infected. This method requires many procedures and is time-consuming. For example, in detecting Leptospirosis cases, PCR amplification of bacterial DNA is used by taking the blood from the Leptospirosis patient during the first week of developing the symptoms [11]. In addition, this method is also used to detect Leptospira by detecting the antibodies from the Leptospirosis patient after the first week of developing the symptoms [11]. It shows that this conventional method will increase human exposure to the presence of Leptospira in the environment and increase the number of infections as it requires many procedures and is a lot of time-consuming in declared Leptospirosis cases.

Thus, high-risk regions can be identified by detecting the environmental conditions suitable for the Leptospira bacteria, which will allow awareness and early warning to those affected by flooding and exposed to contaminated water. The measurement of environmental conditions will reduce the number of Leptospirosis cases reported as it gives quick and real-time detection of the possibility of Leptospira in the environment. Detection is crucial for keeping people updated about the status of their surroundings by transforming environmental conditioning data into information and delivering actionable insights to the community on time.

3.0 Project Definition

3.1 User requirements

In accomplishing the organisation mission, the LeptoDetecto system was proposed as a solution that can give early detection of the presence of Leptospira through the measurement of environmental factors; pH level of water, the salinity of water, the soil moisture, the temperature, and the humidity level [3], [4], [5], [9], [10], [11]. These are the main factors contributing to the survival and growth of the Leptospira bacteria in the environment, whose presence means that people are at risk of contracting Leptospirosis. The LeptoDetecto system provides in-situ monitoring and real-time detection using devices, which is more efficient for early warning in flood-affected areas. This solution allows quick detection and takes less than an hour to detect and identify areas with a high possibility of Leptospira in the environment. Thus, the information obtained can reduce and prevent potential Leptospirosis outbreaks that usually occur after flooding.

The research found that these bacteria can thrive within a pH level of 7.0 to 7.4 [9]. It shows Leptospira can survive and grow in neutral to slightly alkaline water and is sensitive to acid. The experiment of Leptospira in acid found that these bacteria gradually decreased after 10-hour exposure to pH 6 [11]. Besides, the optimum growth temperature for these bacteria is from 28 to 30 °C which is a high-range temperature for Leptospira survival [9]. These bacteria also can live up to 43 days in wet soil with a percentage of soil moisture is 20% [10], [12]. The experiment on soil moisture found that 67% of the experiment samples were positive Leptospira in soil with moisture content 20%, whereas only 23% of Leptospira in soil with moisture content 20% [12]. Next, these bacteria cannot survive and will die faster in the salinity of the water than 3%, which is equal to the salinity of seawater. However, there is a study that showed these bacteria survived only for 3 to 4 days in the water with a salinity 3% [12]. Besides, these bacteria only can survive in a high-humidity level environment in which the humidity level is > 65% [5]. These environmental factors show that the most suitable environment for these bacteria to survive and grow is a hot and humid environment, such as in tropical areas.

The optimum values of these environmental factors are suitable for the growth and survival of the Leptospira bacteria in the environment, which means the bacteria will remain infectious for weeks and months. Studies also showed that L. interrogans have survived and retained virulence in water for up to 344 days [12]. Hence, the measurement of environmental factors is crucial for early warning of the existence of Leptospira in the environment.

3.2 Working Principle

Figure 1: 3D modelled flooding scenario in residential area

Figure 1 above shows a modelled scenario of a flooded residential area that may pose of a risk of having the Leptospira bacteria in the environment. The in-situ LeptoDetecto devices are to be placed strategically in such areas to obtain the real-time information on the environmental conditions as shown in Figure 2. The environmental conditions are monitored using the following sensors; humidity sensor, pH sensor, humidity sensor, soil moisture sensor, temperature sensor and TDS sensor.

Figure 2: 3D model of in-situ LeptoDetecto monitoring devices in flooding scenario

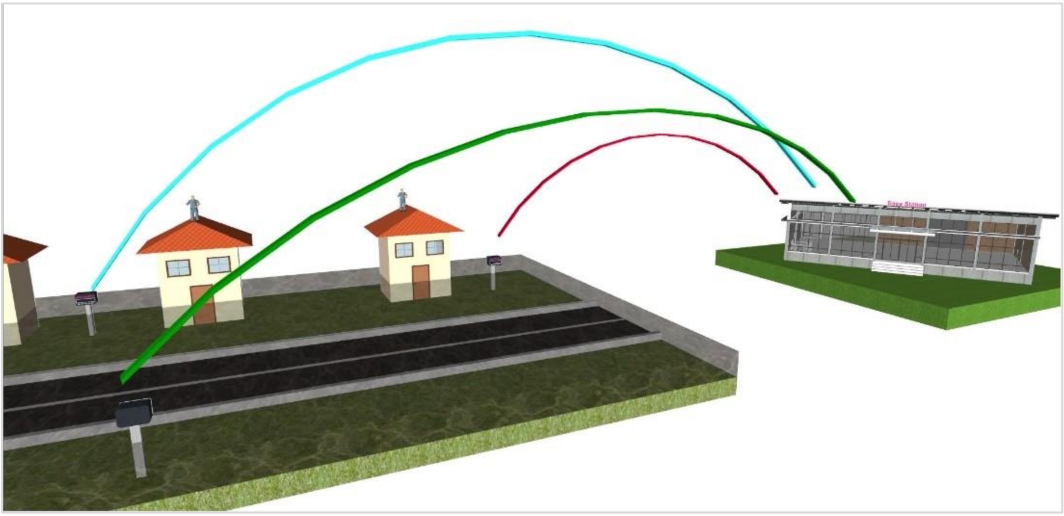


Figure 3: 3D model of in-situ LeptoDetecto devices transmitting data via LoRa from flooded area to a base station in unaffected area

The LeptoDetecto monitoring devices, continually upload the information obtained from the sensors to the base station at a location unaffected by flooding via LoRa as shown in Figure 3 above. The base station uploads information to the Cloud via 4G or 5G connection where the information is analysed as shown in Figure 4 below. This information is then sent to the relevant parties; authorities such as government agencies and NGOs who responsible for flood management as well as the affected civilians via dashboard. This will ultimately reducing the potential cases of Leptospirosis in shortest possible time.

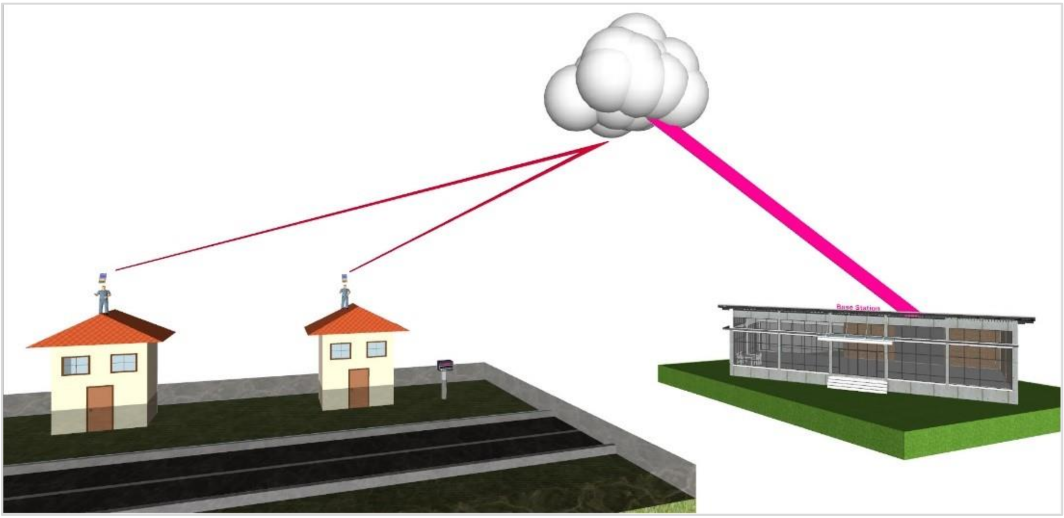


Figure 4: 3D model of base station sending data to cloud via 4G or 5G then being transmitted to the dashboard to civilians and authorities.

3.3 Project Scope

The scope of a project is the definition of the end result or mission of a project – a product or service for a customer. The scope clearly defines the deliverables for the end user and allow the organisation to focus on project plans.

The main goal of the LeptoDetecto system is to be able to fulfil SDG3 and SDG 6 by producing a functional prototype that is able to detect and provide real-time information on the favourable conditions of the Leptospira bacteria; as the end deliverable within the following seven weeks from the time of this report.

There has been one major limitation and exclusion due to the limited duration and testing environment of the project; the developed prototype of the LeptoDetecto will be different to the 'real-world' system in terms of technicality. This is due the complexity and impracticality of using LoRa and 4G/5G in a short distance but, would be fitting to the 'real-world' system instead due to the long distance and lack of electricity as mentioned prior. Wi-Fi will be used in the deliverable prototype however, the working principle and functionality of the LeptoDetecto system prototype remains unchanged and is able to detect and provide real-time information on the favourable conditions of the Leptospira bacteria which would help in identifying high-risk areas during flooding.

For this project, the developed prototype will use Wi-Fi to connect the in-situ monitoring devices to the Blynk application authority dashboard provide real-time information on the favourable conditions of the Leptospira bacteria as well as a notification system for the civilians to warn them of the risky areas.

4.0 Project Strategy

There are three main strategies of the LeptoDetecto system in detecting suitable conditions for the Leptospira bacteria. These strategies allow the accomplishment of the organisation goals and steer the direction of the project. The project strategies define what exactly is accomplished by the LeptoDetecto system. There are three main strategies concerning the network, hardware, and software of the system.

The first strategy is the type of network used for the LeptoDetecto system. LoRa (Long Range Radio) is used to transmit the data obtained at the in-situ devices to the base station. Usually, Wi-Fi would be used in an IoT setting; however, this method is used to overcome the issue of the lack of electricity in areas affected by floods. LoRa is suitable for usage over long-range distances and has a low power consumption. For the development of the prototype in this project, Wi-Fi was utilised as the substitute of LoRa due to limited time and technical competencies.

The next strategy is the hardware approach taken in the LeptoDetecto system. Several sensors will be used to detect favourable conditions for the Leptospira bacteria via in-situ monitoring devices placed in strategic locations. By monitoring the environmental conditions, the authorities involved in flood management will be able to identify the high-risk areas, in other words, areas with a high probability of Leptospira bacteria in the environment. This information will allow efficient allocation of resources and proper action taken by the authorities in flood-affected areas, thus reducing the potential cases of people contracting Leptospirosis. The humidity sensor is used to check the humidity levels. Research has shown that a humidity of 65% is enough for the Leptospira bacteria to live. Next, the soil moisture sensor detects the moisture content of the soil, and a moisture content of 20% and above is suitable for the bacteria to thrive. A pH sensor is used to determine the acidity or alkalinity of the flood waters; a pH range of 7.0 to 7.4 poses a risk of containing the Leptospira bacteria. A temperature sensor is used to measure the temperature of the environment. TDS (Total Dissolved Solids) sensor is used to test the salinity of the water. A salinity of 3% and above would significantly reduce the chances of the Leptospira bacteria surviving in the floodwater. This is one of the major components in determining the probability of Leptospira bacteria in flood water.

Finally, the software approach used in the LeptoDetecto system allows the information to reach the necessary parties; the authorities and the affected civilians. A dashboard will be developed for the parties involved in flood management, such as government agencies and NGOs responsible for allocating resources and aid to flood-affected areas. They will receive information on the location and conditions of the high-risk areas, allowing them to utilize resources efficiently. For the affected civilians, a mobile application will be developed which would inform them if they were in a high-risk area or not as well as the precautions to take to avoid contracting Leptospirosis. In this manner, both the affected people and the authorities can take the necessary steps to reduce the deaths caused potentially. For the development of the prototype in this project, the Blynk IoT Platform was used to create the authority dashboard. It shows all the readings taken form the in-situ device and uses the zone indicators to give a status of the risk level and also sending notifications to civilians to alert them of the risk level.

5.0 Work Breakdown Structure (WBS)

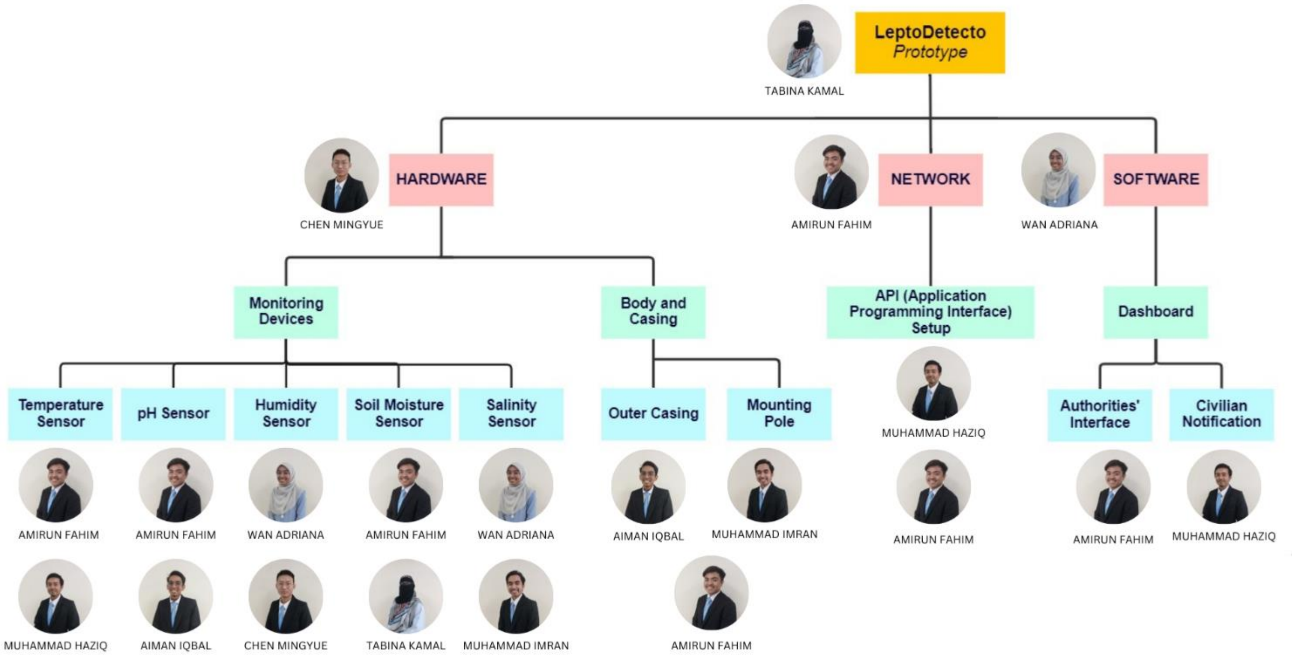


Figure 5: WBS of LeptoDetecto system prototype development

A Work Breakdown Structure (WBS) is a hierarchical breakdown of the overall scope of a project into more manageable parts. It serves as a foundation for thorough project planning and scheduling and is used to organise and define the overall scope of the project in a visual representation. It is a tool for organising, planning, and managing the development of a project. All the project deliverables and the tasks necessary to fulfil them are included in the WBS. By stating explicitly, the team members responsible for each task, possible hazards can be reduced and allows efficient communication among team members. It may also be used to track development, make necessary modifications, as well as to estimate the time and resources required to finish a project.

The WBS used for the development of the LeptoDetecto system prototype is shown in Figure 5 above. There are three major deliverables; hardware, network, and software. These major deliverables were controlled and supervised by the technical team of the group. These primary deliverables were then divided into more manageable and individually assignable work packages. Since most of the tasks in the work packages require coding, a pair-programming strategy was adopted to quickly and effectively complete the tasks. Additionally, as the prototype was developed in a different environment from the 'actual environment' and under time restrictions, the Work Breakdown Structure (WBS) for the prototype development is different from the WBS for the final system mentioned later in this report.

The hardware deliverable, has been separated into two sub-deliverables: the prototype body and the monitoring devices. The work packages in the monitoring devices section were distributed in pairs for each sensor module. The five sensors used in the prototype were; temperature sensor, pH sensor, humidity sensor, soil moisture sensor, and TDS sensor. These sensors are all used to monitor the environmental conditions for the growth of Leptospira bacteria. The body and casing prototype was completed through the cooperation and collaboration of all the team members. Each team member brought tools and materials to build the body. The activities relating to the construction of the body are shown in the Appendix below. The network deliverable consisted of the setup of the application programming Interface (API). For the network part, one pair was assigned to link the other work packages to the programming algorithm.

Finally, the dashboard and civilian notification setup under the software deliverable was carried out by the same members who completed the network deliverable due to the proximity of the tasks. The authority dashboard and the civilian notification system were created using the Blynk application. In the final stages of the project, the group engaged in a collaborative effort to optimize the design of the dashboard. All members were encouraged to share their ideas and insights, to ensure the efficiency and effectiveness of the algorithm. Through this process, all potential flaws were identified and addressed, resulting in a fully functional and high-performing dashboard.

6.0 Project Network

A project network is a connection of activities that show the logical relationships, activity interdependencies, and time of each task for the project. A project network diagram is arranged sequentially in a flow chart and represents activities and deliverables derived from the Work Breakdown Structure (WBS). The purposes of developing a project network are to provide the basis for scheduling labour and equipment, enhancement communication among project participants, and estimation of the project duration. A project network also helps to identify activities that can be considered critical tasks which is crucial in planning and thus the completion of the project within the allocated duration.

For the LeptoDetecto project, the project network was started by listing the ID of activities, activity descriptions, and the preceding activities for each activity, as shown in Table 1 below. Then, the list was illustrated in Precedence Diagramming Method (PDM) which uses nodes or boxes to depict the activities, as shown in Figure 6. This method is known as Activity-on-Node (AON), which uses nodes to represent the activities and arrows to illustrate the relationship among the activities. Based on Figure 6, two activities can be categorized as burst activities which are Product Design and Hardware Programming, since both activities have more than one activity immediately following them. The Hardware Programming and System Integration and Testing are categorised as merge activities since both activities have two and more preceding activities that flow into them.

Activity (ID number)	Description	Preceding Activity
11	Define Prototype Requirements	None
12	Product Design	11
13	Buying Components	12
14	Task Distribution	12
15	Hardware Programming	13, 14
15A	pH module	13, 14
15B	Temperature module	13, 14
15C	Humidity module	13, 14
15D	Salinity module	13, 14
15E	Soil moisture module	13, 14
15F	LCD module	13, 14
15G	Combine modules	13, 14
15H	ESP module	13, 14
16	Authority Dashboard	15
17	Civilian Notification System	15
18	Build and Test Hardware	15
19	System Integration and Testing	16, 17, 18

Table 1: Network information of LeptoDetecto system

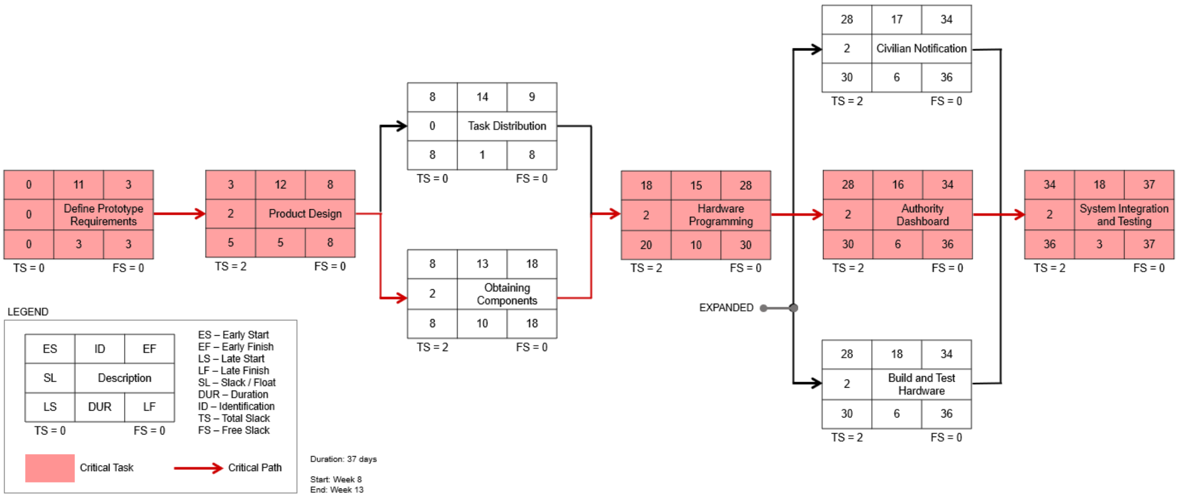


Figure 6: Project Network for LeptoDetecto system

In AON, the duration for each activity was assigned based on the allocation time for this project. The activity times along each path in the network were added using the forward pass computation (ES + DUR = EF). For example, the early start time for activity 11 is zero and the early finish (EF) is 3 days, (EF = ES + DUR, 0 + 3 = 3). The EF of activity 11 is the ES for activity 12 since activity 11 is a predecessor activity for activity 12. Thus, the EF for activity 12 is 8 days (EF = 3 + 5 = 8). All the activities used the following same process for determining their EF and ES. For the Late Start (LS) and Late Finish (LF), the backward pass computation was used by subtracting the activity times along each path starting with the project end activity, LF - DUR = LS. As an example, the LF for activity 13 is 18 days; thus, the LS for activity 13 is 8 days, (LF – DUR = LS, LS = 18 – 10 = 8). However, there are a few tasks that were completed before the allocated duration like in activity 12. The assigned duration in activity 12 is 5 days, but it was completed in about 3 days without affecting the project end date since the delay in the critical path started from activity 12 onwards.

A critical path is the longest path through the activity network that allows for the completion of all project-related activities. In this project, the critical path shown in Figure 6 above was defined as such as it consisted of the most critical tasks and had the longest duration. The outcome of the critical tasks would directly impact the completion date of the project. If a delay were to occur in the duration of critical tasks it would result in an overall delay in the project schedule. From Figure 6, the Total Slack (TS) shows the amount of time that has been delayed for each activity. These TS will affect the project duration since the delays occurred in critical tasks. However, the team members managed to finish the prototype of the LeptoDetecto within the duration given by focusing more on the critical tasks and employing project activity crashing whereby multiple tasks were completed in a short duration of time.

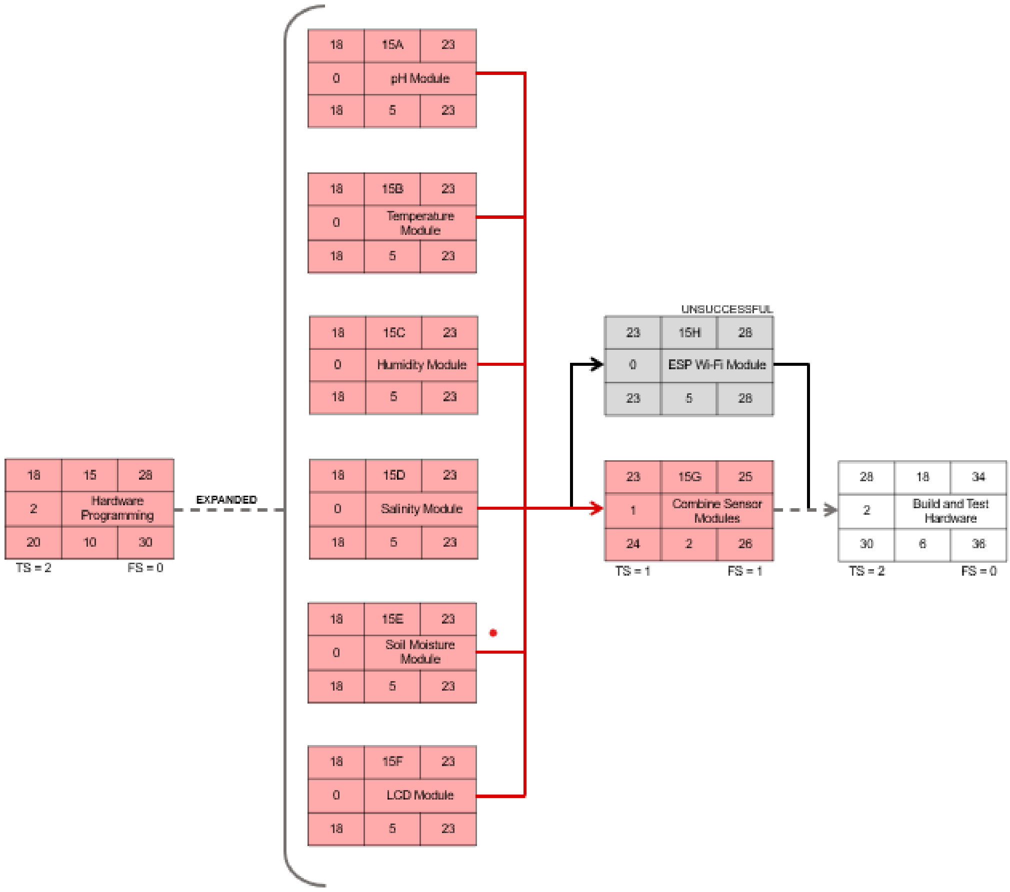


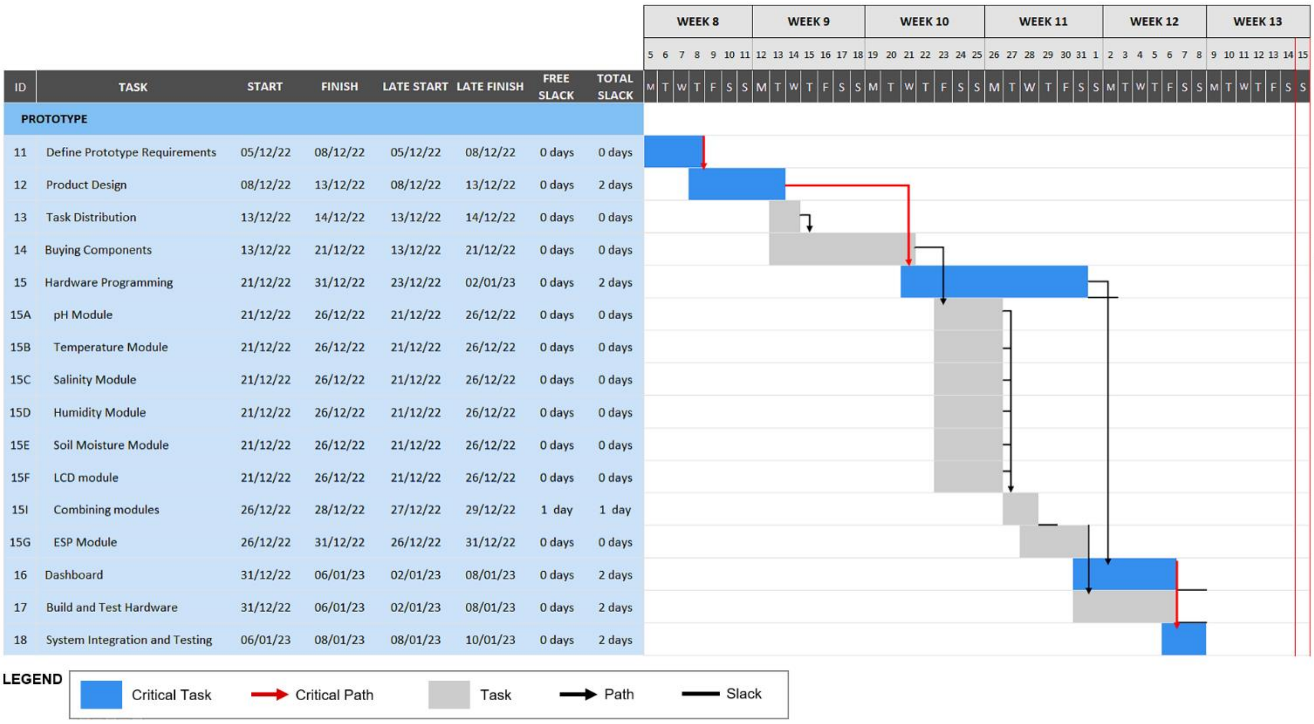
Figure 7: The expanded project network of Hardware Programming activity

Figure 7 shows the expanded project network for the hardware programming node. All of the modules used in hardware programming are critical tasks that needed to be completed to accomplish the objectives of the project. It is observed in Figure 7 that the Free Slack (FS) in activity 15G exceeded the EF date but did not affect the ES of activity 18. Since activity 18 is the merge activity, thus it allowed for activity 15G to have FS. Furthermore, in this expanded project network, the ESP8266 is the only module that was unsuccessful due to technical difficulties. However, this problem was overcome by using a recorded dataset and by using the API setup.

7.0 Gantt Chart

The Gantt chart, proposed by Henry L. Gantt, is a horizontal bar chart that provides a graphical representation of a project timeline. This graph assists the procedure of planning the overall project, administering the resources involved with it, and maintaining coordination among all team members, as carried out by the project managerial authority.

The design Gantt chart for the LeptoDetecto project began by numbering the task ID that was provided to assist team members to identify and refer to which task is under discussion or in the scope of focus. The task list was created to help the project team keep track of all sub-tasks in a project to ensure that nothing is neglected or delayed. The tasks displayed include start and finish dates, which are one of the most important components of the Gantt chart since they indicated when each task was scheduled to take place. The late start and late finish times were also included to provide flexibility in balancing resources between other tasks that could potentially affect the critical path, and consequently the project end date. The free slack column shows how much time a task could be delayed without delaying any subsequent tasks. If the task had no successors, free slack would be the amount of time a task can be delayed without affecting the completion date of the entire project.



ID	TASK	START	FINISH	LATE START	LATE FINISH	FREE SLACK	TOTAL SLACK
PROTOTYPE							
11	Define Prototype Requirements	05/12/22	08/12/22	05/12/22	08/12/22	0 days	0 days
12	Product Design	08/12/22	13/12/22	08/12/22	13/12/22	0 days	2 days
13	Task Distribution	13/12/22	14/12/22	13/12/22	14/12/22	0 days	0 days
14	Buying Components	13/12/22	21/12/22	13/12/22	21/12/22	0 days	0 days
15	Hardware Programming	21/12/22	31/12/22	23/12/22	02/01/23	0 days	2 days
15A	pH Module	21/12/22	26/12/22	21/12/22	26/12/22	0 days	0 days
15B	Temperature Module	21/12/22	26/12/22	21/12/22	26/12/22	0 days	0 days
15C	Salinity Module	21/12/22	26/12/22	21/12/22	26/12/22	0 days	0 days
15D	Humidity Module	21/12/22	26/12/22	21/12/22	26/12/22	0 days	0 days
15E	Soil Moisture Module	21/12/22	26/12/22	21/12/22	26/12/22	0 days	0 days
15F	LCD module	21/12/22	26/12/22	21/12/22	26/12/22	0 days	0 days
15I	Combining modules	26/12/22	28/12/22	27/12/22	29/12/22	1 day	1 day
15G	ESP Module	26/12/22	31/12/22	26/12/22	31/12/22	0 days	0 days
16	Dashboard	31/12/22	06/01/23	02/01/23	08/01/23	0 days	2 days
17	Build and Test Hardware	31/12/22	06/01/23	02/01/23	08/01/23	0 days	2 days
18	System Integration and Testing	06/01/23	08/01/23	08/01/23	10/01/23	0 days	2 days

Figure 8: Project Gantt Chart

The tasks were executed from Week 8 through Week 13 as seen in Figure 8 above. The Gantt chart illustrates two paths: the critical path the and normal path as indicated by the arrows. The slack in the diagram is indicated by a thick black line, which reflects the number of delayed days for specific tasks in the project.

8.0 Project Control Process and Organisation

A project is a temporary endeavour that is undertaken to create a unique product, service or result which in this case the project is the development of a working prototype of the LeptoDetecto system with a team of seven members. A crucial aspect of project management is control. Control is defined as the process of comparing the actual performance against the plan to identify deviations, evaluate possible alternative courses of actions, and taking appropriate corrective action [13]. The general project control steps are as the following in order; setting a baseline plan, measuring progress and performance, comparing plan against actual events and taking appropriate action.

The baseline plan developed for the project was based on the WBS shown in Figure 5 above which provided the basic elements of performance measurement. Work packages were assigned to the different members of the team. From the WBS, a tracking Gantt chart shown in Figure A and Figure B in the Appendix was developed to schedule the various activities and work packages in the project according to the allocated timeline.

Progress and performance were measured in terms of quality and by qualitative factors. A Kanban board shown in Figure 10 below was also created on the Miro platform to show the tasks that have yet to be started, tasks that are in progress as well as the completed tasks. This allowed team members to update their progress in a visual manner. This was used in addition to the tracking Gantt chart to keep track of the smaller details of each task. The Kanban system is an inventory control system used in just-in-time (JIT) manufacturing. It was developed by Taiichi Ohno, an industrial engineer at Toyota, and takes its name from the coloured cards that track production and order new shipments of parts or materials as they run out. The Kanban system simply means to use visual cues to prompt the action needed to keep a process flowing [12].

The Kanban system was found to be most effective as all team members could see the progression of the other members and allowed convenient tracking by the manager. Due to the preoccupations of the team members, there were numerous adjustments made to the timeline of the project. The dates in the Kanban board were then updated to the tracking Gantt chart and eventually the overall actual timeline of the project was obtained as shown in Figure 8 above. It is clear by comparison of the projected and actual Gantt charts that the latter tasks were done later than expected within a shorter duration. Due to the circumstances, the necessary steps were taken to ensure project completion. The team members were directed to meet physically on four days to complete tasks together as a means of crashing project activities. This was done to provide all team members with continuous time frame of around 8 hours daily totalling to around 32 hours for task completion. This also enabled instant communication which aided in resolving challenges quickly. Figure D to Figure F show the team members together during this duration of crashing activities.

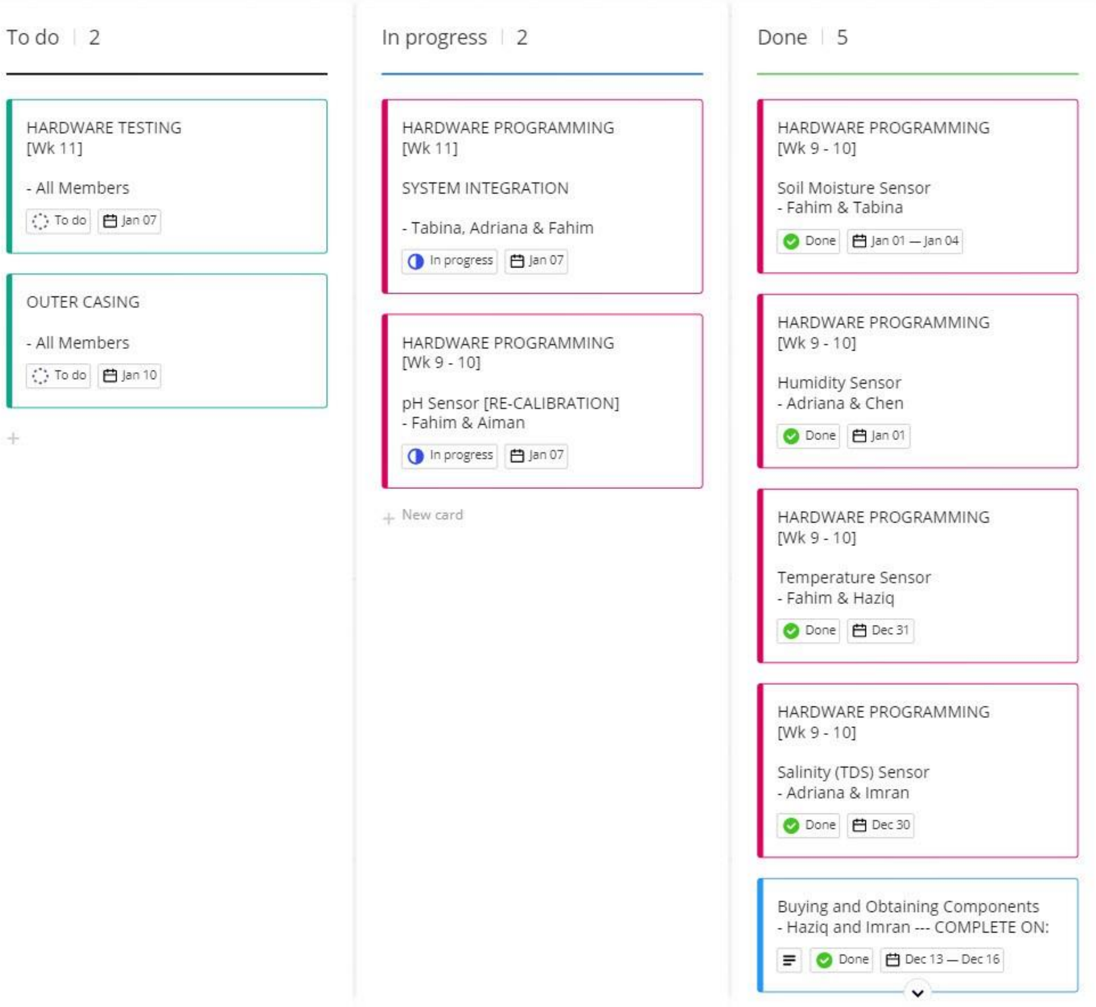
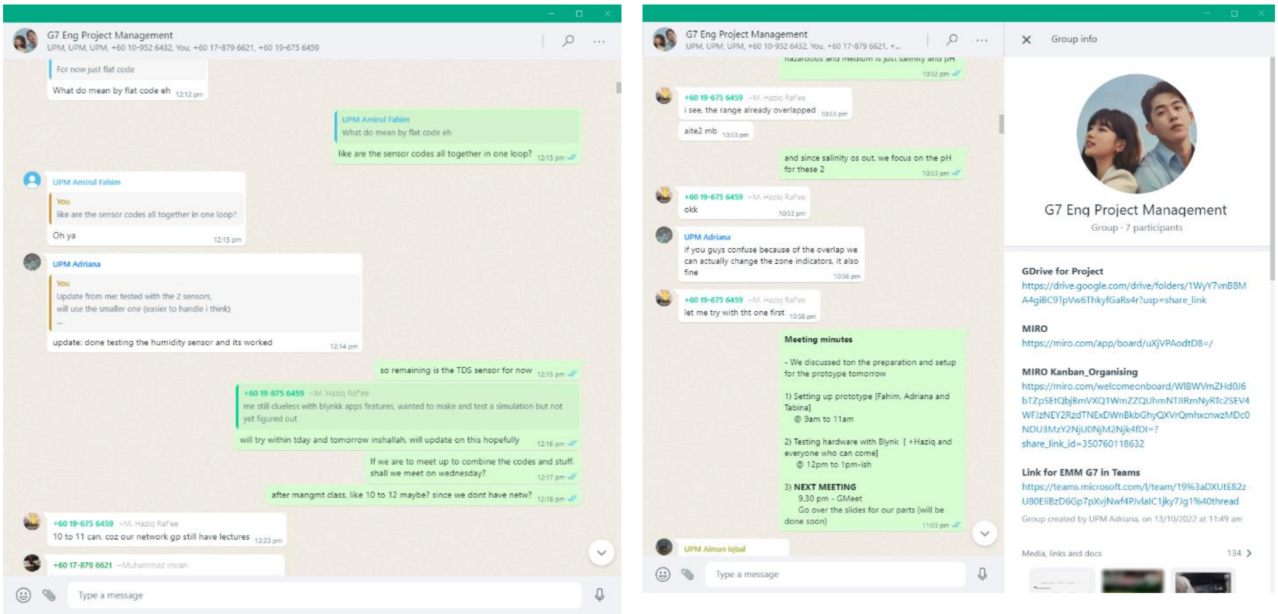


Figure 10: Progress tracking Kanban board on Miro

Using the above methods, the project tasks were completed successfully and within the allocated time and resources were utilised efficiently. Other than the project control process, the other crucial factor leading to the success of the project was organisation of project materials. The multi-faceted project required a method of keeping all aspects organised to ensure all team members were on track. Various tools and channels were utilised for the various aspects. The methods used were chosen based on the effectiveness and convenience of the team members. The instant messaging application, WhatsApp was utilised as the primary means of communication among the team members as well as the Google Meet video conferencing platform for group meetings. Most of the meetings were held online for the convenience of all members. Figure 11 below shows screengrabs from the team WhatsApp group. Microsoft Teams was utilised primarily for all team documents whereby all team members could work collaboratively on documents. A screengrab of the Microsoft Teams files is shown in Figure 12 below. Lastly, as mentioned prior, a Kanban board on the Miro application was used as the central progress-tracking method throughout the project.



(a) *(b)*

Figure 11: Screengrabs of team WhatsApp group

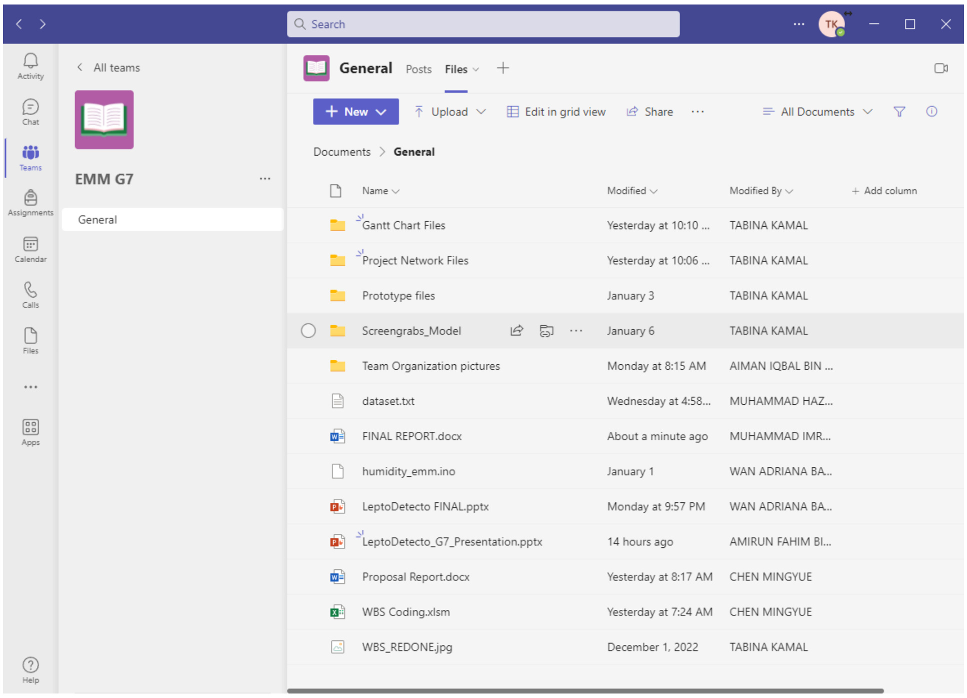


Figure 12: Screengrabs of files in Microsoft Teams group

9.0 Risk Management

A risk is defined as an uncertain event or condition that if it occurs, has a positive or negative effect on the objectives of a project. They have a cause and in the event of an occurrence, have consequences. Risks are almost inevitable in projects and no amount of planning can overcome them in other words, it is impossible to control the probability of chance events. Potential risks however can be identified beforehand to recognise and manage these unforeseen circumstances. Figure 13 below shows the general risk management process that was used as a framework to carry out effective risk management in this project. First, risk identification was carried out whereby potential risks were identified, then classified and presented into a risk breakdown structure in Figure 14 below. Next, the risks were assessed using a scenario analysis of impact and likelihood and presented in a risk severity matrix in Figure 15 below. The appropriate responses or contingency plans were made in response to the identified risks and are shown in Figure 16 below. Lastly, the strategies implemented in response to the encountered risks in the development of the prototype were documented in Figure 17 below.

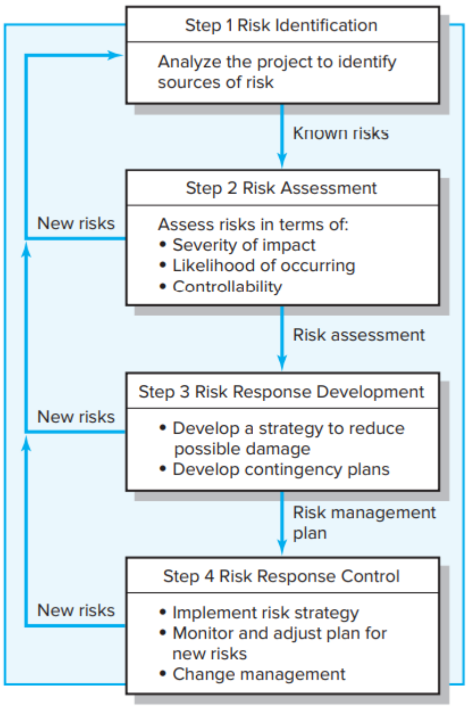


Figure 13: Risk management process

The first stage of the risk management process was risk identification. All the group members met for a brainstorming session shown in Figure C in the Appendix whereby all potential risks that could affect the project were identified. The benefit of risk identification using the brainstorming method is that various angles and perspectives of risks were able to be covered. After the brainstorming session, the list of potential risks was 'filtered' and classified into different categories shown in the RBS in Figure 14 below.

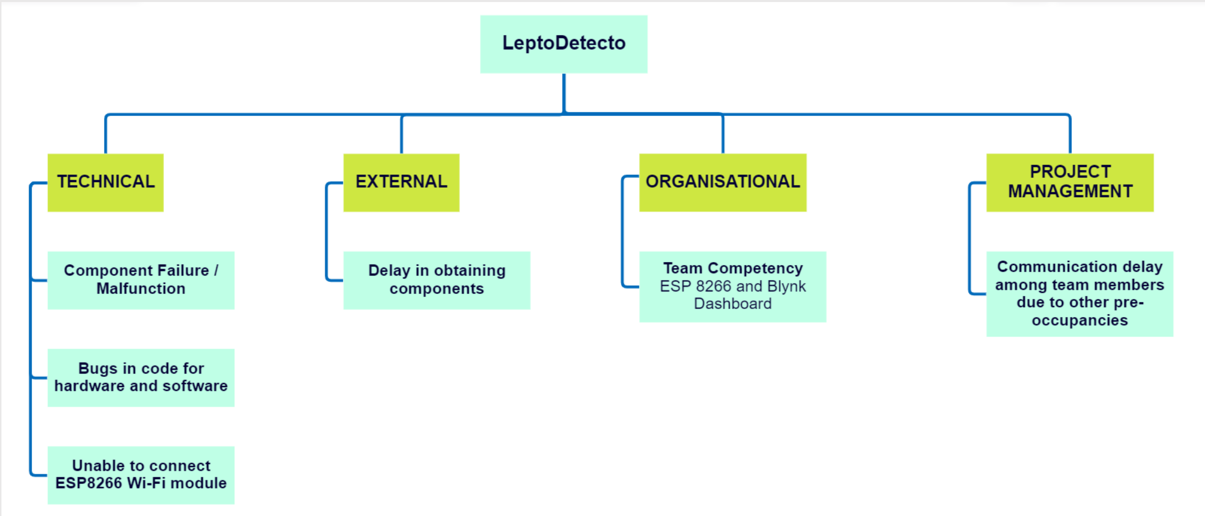


Figure 14: RBS (Risk Breakdown Structure) for LeptoDetecto prototype development

The second stage of the risk management process is risk assessment whereby the identified risks from Figure 14 above were analysed by the scenario in terms of impact and likelihood of occurrence. These two factors were scored on a scale from 1 to 5. The scores were decided by discussion among the team members and the average whole number was taken. Upon determining the severity of the risks, they were presented visually in the form of a risk severity matrix shown in Figure 15 below. The greatest risk in terms of both likelihood and impact was 'Unable to connect to ESP8266 module' seen in the 'Extreme Risk' zone in Figure 15. This risk was taken as it was a 'high-risk, high reward' situation whereby if the ESP8266 module was able to connect to the system, it would ensure perfect execution of the project and if not, there would be an alternative method which would compromise the performance quality of the developed prototype. The other risks in the 'Minor Risk' and 'Moderate Risks' were seen to be manageable and there were no major consequences identified in response to them.

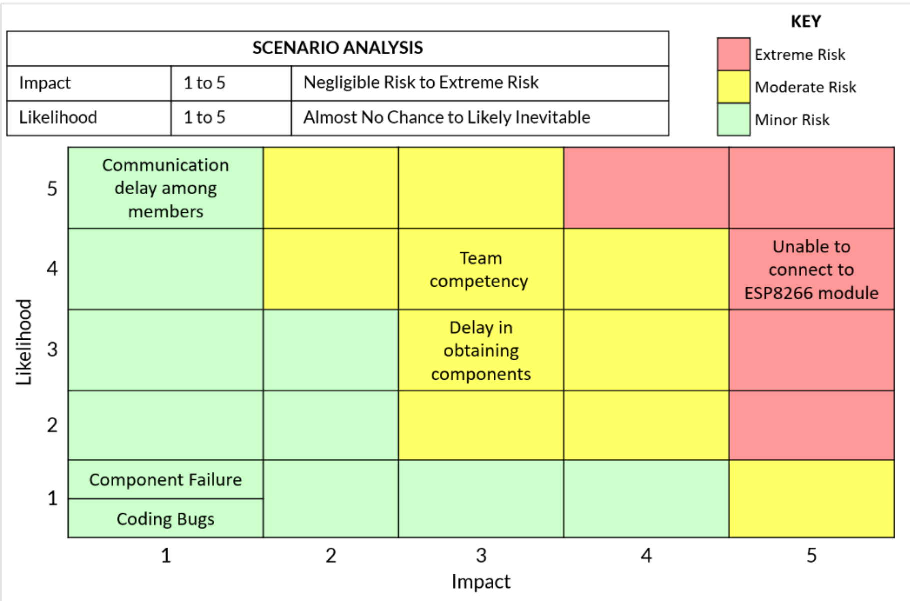


Figure 15: Risk severity matrix after risk assessment using scenario analysis for LeptoDetecto prototype development

The third stage of the risk management process is the development of appropriate risk responses and contingency plans that would be put into action in the event of the occurrence of the risk. Figure 16 below shows a risk response matrix of the identified risks and their respective responses, triggers, and contingency plans. The engineers of the team Wan Adriana and Amirun Fahim were made to be responsible for the technical risks and the other non-technical risks were handled by the project manager, Tabina Kamal. ‘Team Competency’ was an inevitable risk in which all members were responsible for themselves in obtaining knowledge for the connection of the ESP8266 module to the Blynk dashboard application.

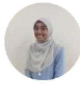
RISK EVENT	RESPONSE	CONTINGENCY PLAN	TRIGGER	RESPONSIBLE
Component Failure / Malfunction	**Mitigate** Obtain components from reliable source	Recheck connections / Buy new components	No data from sensor / Circuit burn	 WAN ADRIANA  AMIRUN FAHIM
Bugs in hardware and software	**Mitigate** Debug and rerun all codes	Pair programming to reduce chances of error	Error in compilation	 WAN ADRIANA  AMIRUN FAHIM
Unable to connect ESP8266 module with dashboard	**Accept** Compromise function after all attempts	Record a dataset using the hardware to run the simulated Blynk dashboard	Repeated failure to connect to ESP module	 WAN ADRIANA  AMIRUN FAHIM
Delay in obtaining components	**Accept** Wait for components	Proceed with hardware coding until component arrival	-	 TABINA KAMAL
Team Competency	**Mitigate** All members try to link ESP module to Blynk dashboard	-	Unable to proceed with module for >10 days	ALL
Communication Delay	**Mitigate** Regular updates with members	Contact the particular member	No update from member	 TABINA KAMAL

Figure 16: Risk response matrix for LeptoDetecto prototype development

The last stage of the risk management process is risk response control whereby the encountered risks in the project were documented. From Figure 13 above it is seen that from each stage of the risk management process, any newly identified risks would be put through the four stages for the appropriate action to be taken. Figure 17 below shows the risks that were encountered throughout the duration of the project and their respective responses. There were three risks in a total of which the prior two risks were identified in the prior stages and their contingency plans were executed. The third and new risk ‘Obsolete component’ was encountered in the end stages of the project. The TDS sensor used in the prototype was obsolete as it did not fulfill the minimum range for salinity measurements. The risk had to be accepted because there were no available TDS sensors in the market for the given range. For the prototype development, the TDS sensor was simply used to demonstrate the feature rather than the functionality. Although this was a risk that should have been considered in the beginning, the outcome would have been the same regardless of when this risk was identified.

ENCOUNTERED RISK	RESPONSE
Unable to link Blynk dashboard with ESP8266 Wi-Fi Module	Follow contingency plan: Record a dataset using the hardware portion to run the simulated Blynk dashboard
Team Competency In ESP8266 module and Blynk platform	
Obsolete component Range not suitable to measure salinity TDS sensor range: 0 to 1000 ppm Minimum required: 0 to 40000 ppm	Accept risk and compromise functionality of prototype. TDS sensor that can measure the salinity range is severely beyond budget

Figure 17: Risk response control documentation for LeptoDetecto prototype development

10.0 Project Cost

10.1 Estimated Cost

The cost estimation of this project is for the prototype stage of the LeptoDetecto system which comprise the following: sensors, microcontroller board, wireless fidelity module, and IoT platform as listed in Table 2 below. The cost estimation for each component was based on their current market price from store catalogues and online commerce sites such as *Shopee Components*, *Cytron.io* and *my.element14.com*.

No	Equipment List	Quantity	Estimated Cost (RM)
1	pH Sensor	1	80.00
2	Humidity Sensor	1	20.00
3	TDS Sensor	1	70.00
4	Temperature Sensor	1	5.00
5	Arduino Uno Board	1	45.00
6	Soil Moisture Sensor	1	16.00
7	ESP8266 Wi-Fi Module	1	16.00
8	Jumper Wires (2 types per packet)	2	8.00
9	Blynk IOT (Free Application)		0.00
10	Arduino IDE (Free Tool)		0.00
	Total		***260.00***

Table 2: Equipment cost list for LeptoDetecto prototype

The cost estimation statement in Table 2 above is only for the prototype of the functional portion of the LeptoDetecto system. The actual cost of prototyping design with structural body will include the casing cost. The spending will be done on a need-to basis. The full documentation of the LeptoDetecto prototype cost on the segment below is provided after the completion of our project. The free tools such as Blynk IoT application and Arduino Integrated Development Environment (IDE) will be used for the hardware and programming parts, respectively.

From Table 2, the total estimated cost is RM260. A contingency of around 15% was added for the event of any component failures and fluctuations of market price of the components in market, thus making the upper bound of the cost RM300. The price of the pH sensor and TDS sensor are significantly higher than the other components and cover 60% of the total estimated cost. The prototype equipment cost high due to the components being specifically for prototyping purposes however, the actual cost can be reduced by using devices suitable for the field. The projected in-situ device is to be on a single board which means that the potential cost would be reduced if mass-production were to take place.

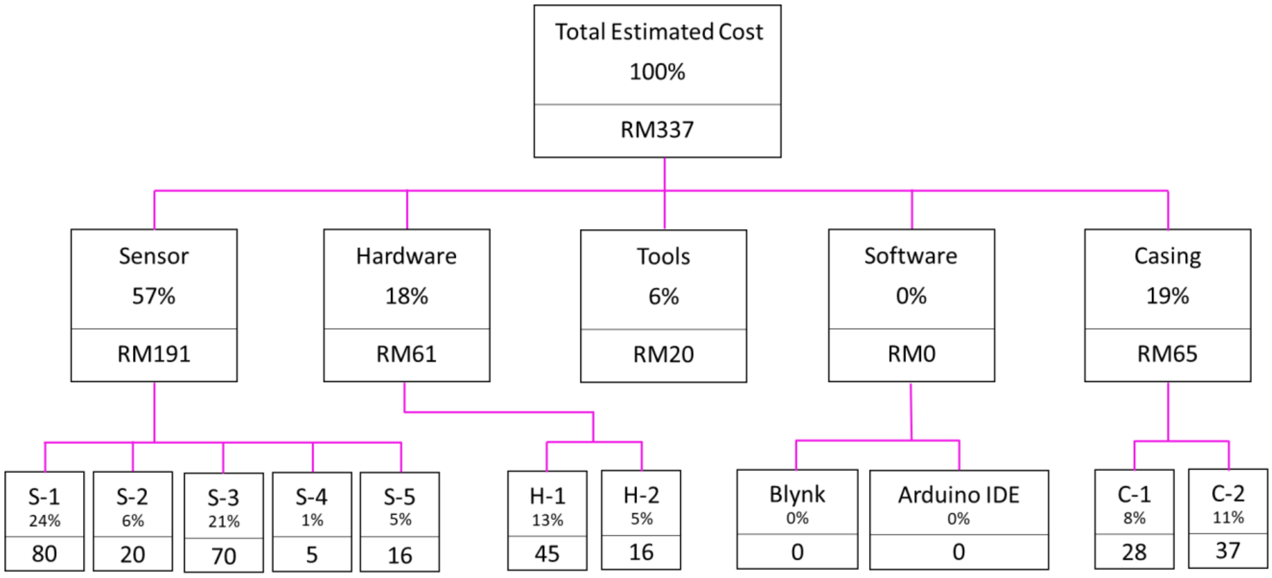


Figure 18: Bottom-Up Cost Estimation Approach

The cost estimation method that was used for the prototype of our project is the bottom-up cost estimation approach. This method allows the dependency of choosing the best equipment for the prototype to be designed. Moreover, the decision making for which items to use is more strategic and volatile since it is not restricted to limitations. The budget for this project was never mentioned because our objective to make the working design is the focus of the project. In Figure 18, the five item divisions are sensor, hardware, tools, software, and casing is included to estimate the cost of the prototype. The total estimated cost in Figure 18 is different with Table 2 since the casing and tools are included inside the estimation. Therefore, the cost is a lot higher than the earlier estimation.

10.2 Actual Cost

The actual cost for the prototype stage of LeptoDetecto system for the purpose of our project is significantly lower than the estimated cost even though the amount of equipment in the actual prototype is increased.

No.	Equipment list	Quantity	Cost (RM)
1	pH Sensor	1	0.00
2	Humidity Sensor	1	0.00
3	TDS Sensor	1	44.00
4	Temperature Sensor	1	10.00
5	Arduino Uno Board	1	0.00
6	Soil Moisture Sensor	1	5.00
7	ESP8266 Wi-Fi Module	1	16.00
8	Jumper Wires	-	0.00
9	Blynk IOT (Free Application)	-	0.00
10	Arduino IDE (Free Tool)	-	0.00
11	LCD	1	18.00
12	Nuts & Bolts		2.20
13	Screwdriver	1	8.80
14	Reducer 6-to-4 inch	1	30.00
15	Twist Tie	1	4.90
16	6-inch PVC Pipe	1	30.00
17	4-inch PVC Pipe	1	20.00
18	Multi-purpose steel band	1	8.80
19	Container	1	0.00

	TOTAL	**RM 197.70**

Table 3: Equipment cost list for LeptoDetecto prototype

From Table 3, the equipment added are the tools and materials for the casing design of the LeptoDetecto system and the LCD for displaying purposes. The actual cost is decreased from the estimated cost by 41.3%. The reason for the decrement of cost is due to the availability of certain equipment in the laboratory that was allowed to be borrowed such as the pH sensor which is high costed, Arduino Uno Board, Humidity sensor, and jumper wires. In addition, some of the equipment costs are cheaper than expected such as the Soil Moisture sensor and the TDS sensor. The equipment listed are all the items needed to build the prototype of LeptoDetecto System.

The prototype was tested, and it has been observed that certain functions can be improved. However, the cost of improvement will be higher than the original cost. Some functionality that reduces the performance of our prototype which related to the cost is the measurement range of the applied TDS sensor. The measurement range is smaller than the real one which disable the accuracy of the measurement. The improvement that can be made is to use a higher quality of TDS sensor which would cost around RM600 per sensor. The cost is way out of our budget that it is not inside our scope of consideration. One alternative for this is to add more TDS sensor to increase the measurement range but it will still cost a few amounts for the project.

Even so, the real time implementation of the product would cost higher than the prototype stage as it may need more concrete build to withstand environmental decay factors. In future works, we will be redesigning the casing of the product for better quality and less maintenance to capture the attention of the targeted authorities and agencies to apply the product. In consideration, the sensors must also have better quality to improve the accuracy of reading the actual measurement.

In the future, we plan to expose our product more to help achieve potential investors that can provide financial support for us to obtain continuous supply. Other than that, we would want to find a supplier that can mass produce the equipment that we need with a lower cost than the market price.

11.0 Project Closure

The final stage of any project is project closure and is the critical last phase in the project management lifecycle. During project closure, the team reviews the deliverables, then compares and tests their quality to the intended project outcome [14]. There are three main stages to project closure; wrap-up closure activities, performance evaluation, and project audit these can also be called the technical, learning, and people phases respectively [14]. All of which is documented. For this project, only the first stage was carried out, due to the scope of the project. Figure 19 below shows the stages of project closure and reviewing of deliverables.

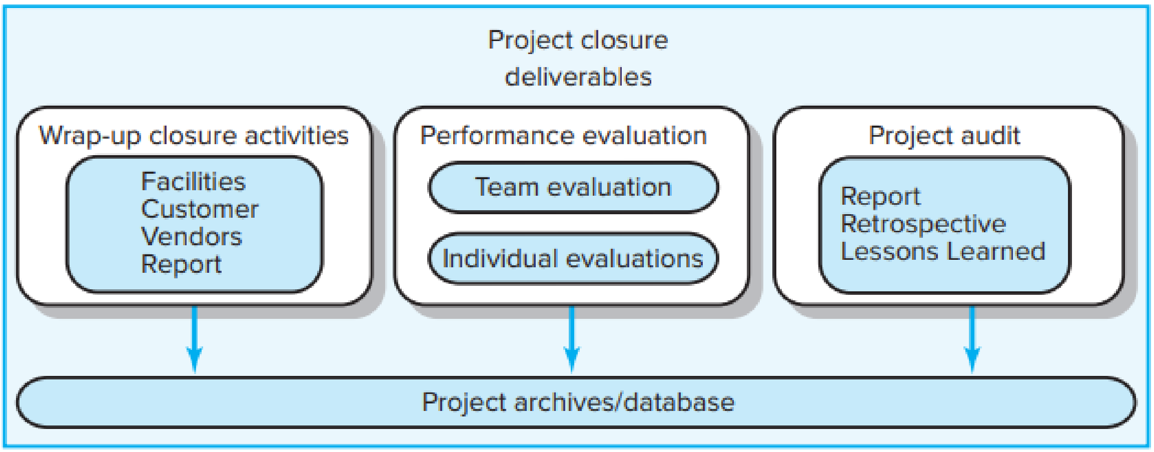
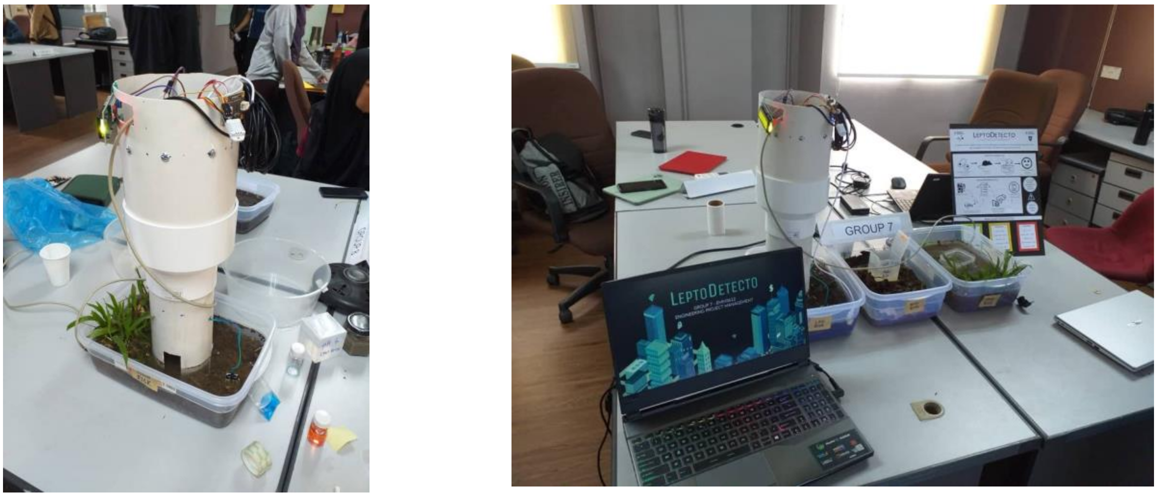


Figure 19: Project closure and review deliverables

The scope of this project was to develop an 'initial' prototype of the LeptoDetecto system using Wi-Fi linked to a dashboard for the authorities and a notification system for civilians. All the objectives of the project were accomplished. The final 'initial' prototype is shown below in Figure EE. The end of the demonstration marked the end of this stage of the project. All accounts were settled immediately after the demonstration as most of the items used were personal and the borrowed items were returned. This report covers the documentation of the incurred costs and is also indicative of team performance.



(a) Final hardware portion *(b) Prototype demonstration setup*

Figure 20: Final prototype of LeptoDetecto system

The WBS shown in Figure 21 below shows the ‘completed’ LeptoDetecto system which is to be developed after this initial stage. It is seen that there are new features and work packages for the fully functional system. There is a built-in power source under the hardware section, the setup of LoRa and the cloud under the network section, and the development of the authority and civilian interfaces under the software section. The cloud is to include machine learning for the analysis of obtained data and the prediction of the areas that could potentially be at risk of Leptospirosis infection.

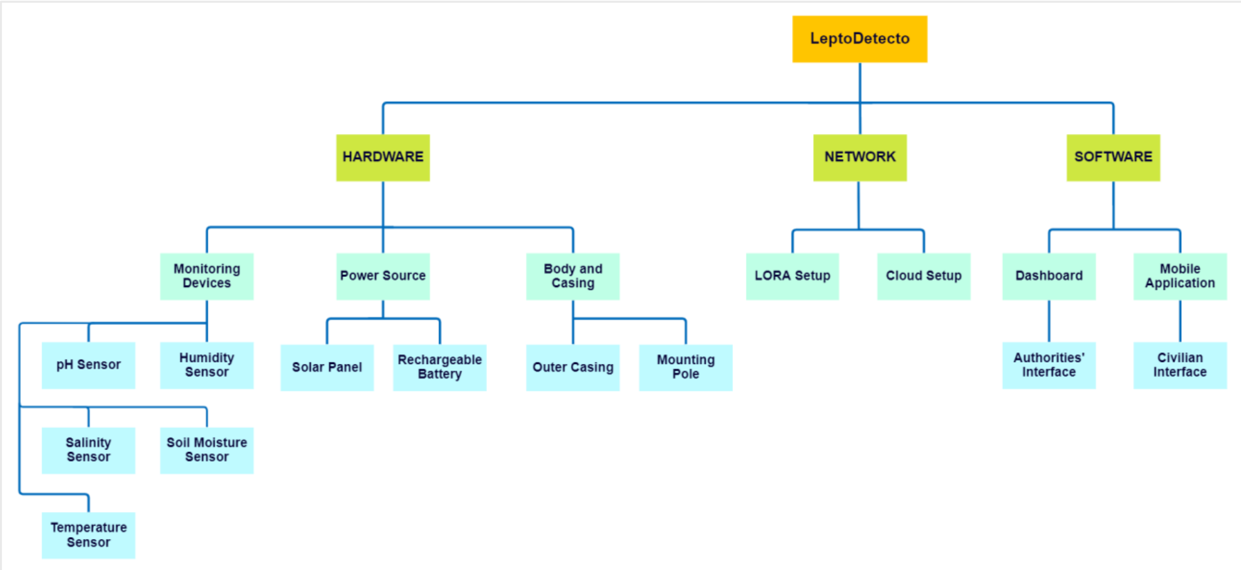


Figure 21: WBS for full LeptoDetecto system

This is a ‘development project’ and involves handing over the final design for production to the client. The Gantt chart in Figure 22 below shows a timeline of the projected timeline of the project past the prototyping stage. Each heading in the chart can be treated as a ‘sub-project’ under a main ‘mega-project’. The indicated region shows the duration of this project which involves the prototype design.

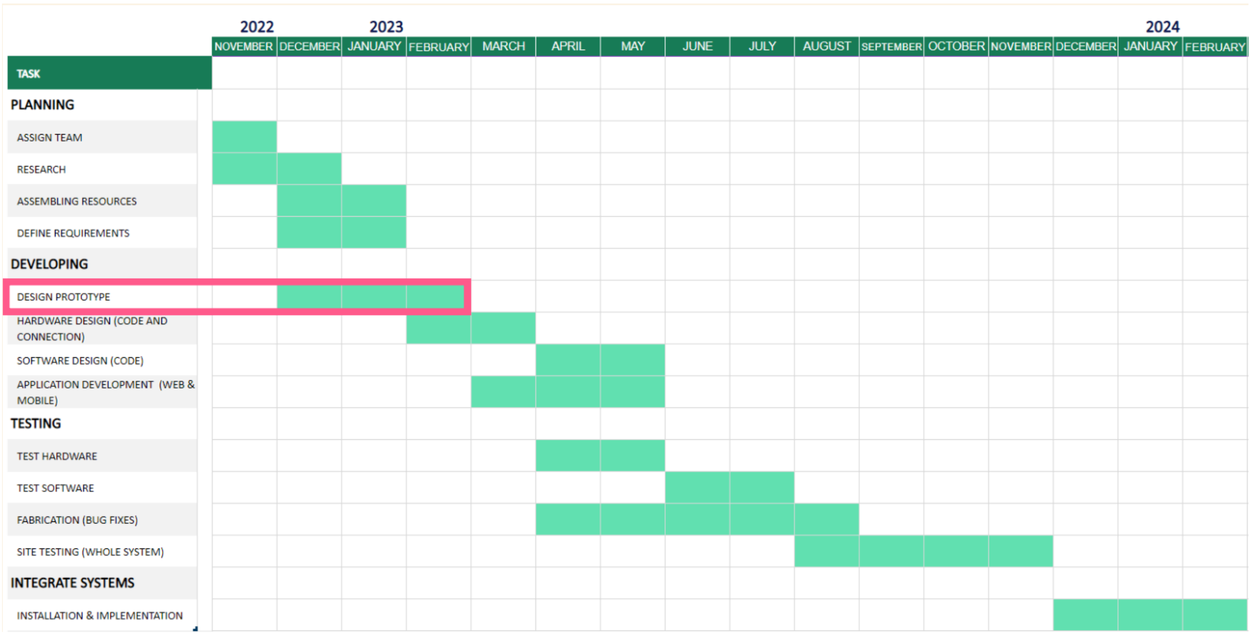


Figure 22: Long-term Gantt chart of the projected timeline

Upon completion of all the above stages, the team hopes to carry out testing to fix any existing bugs or faults in the system. Then the system will be handed over to the client. Upon handover, the team aims to carry out regular maintenance for a fixed duration to ensure the proper functioning of the system. The duration is dependent on the client and can only be determined after the completion of the stages in Figure 22 above however, the expected duration is around one to two years. Finally, the team also aims to provide consultancy services to all future clients to ensure product satisfaction and efficient usage.

12.0 References

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[13] Txtbk chp 13 480-535

[14] https://www.smartsheet.com/content/project-closure#:~:text=Closure%20with%20Smartsheet-,What%20Is%20Project%20Closure%3F,deliverables%20with%20the%20project's%20client.

13.0 Appendix

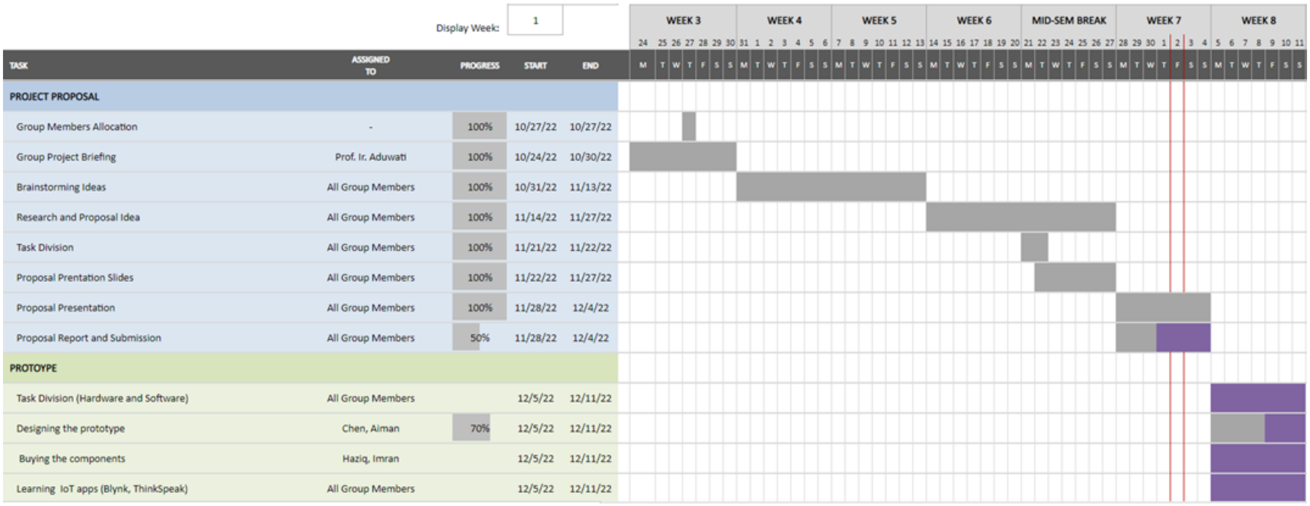

Figure A: Gantt chart of LeptoDetecto system prototype development from Week 3 to Week 8

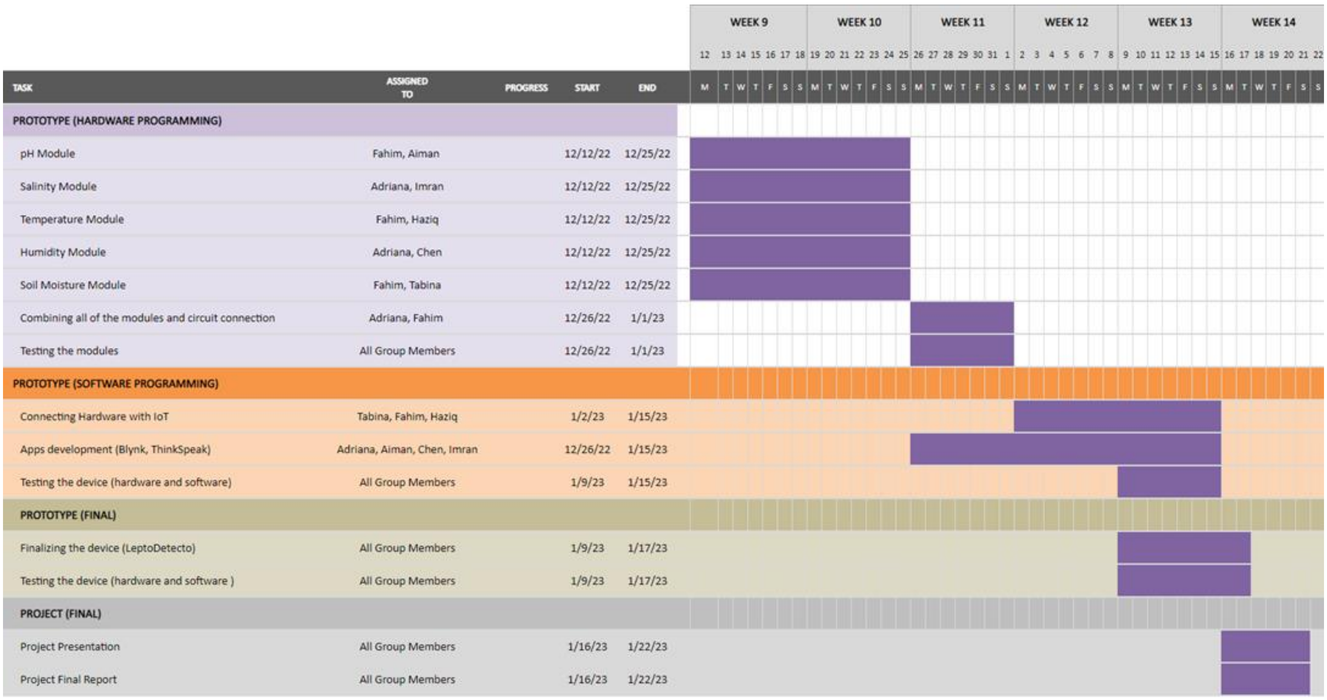

Figure B: Gantt chart of LeptoDetecto system prototype development from Week 9 to Week 14

Figure C: Brainstorming session for risk identification

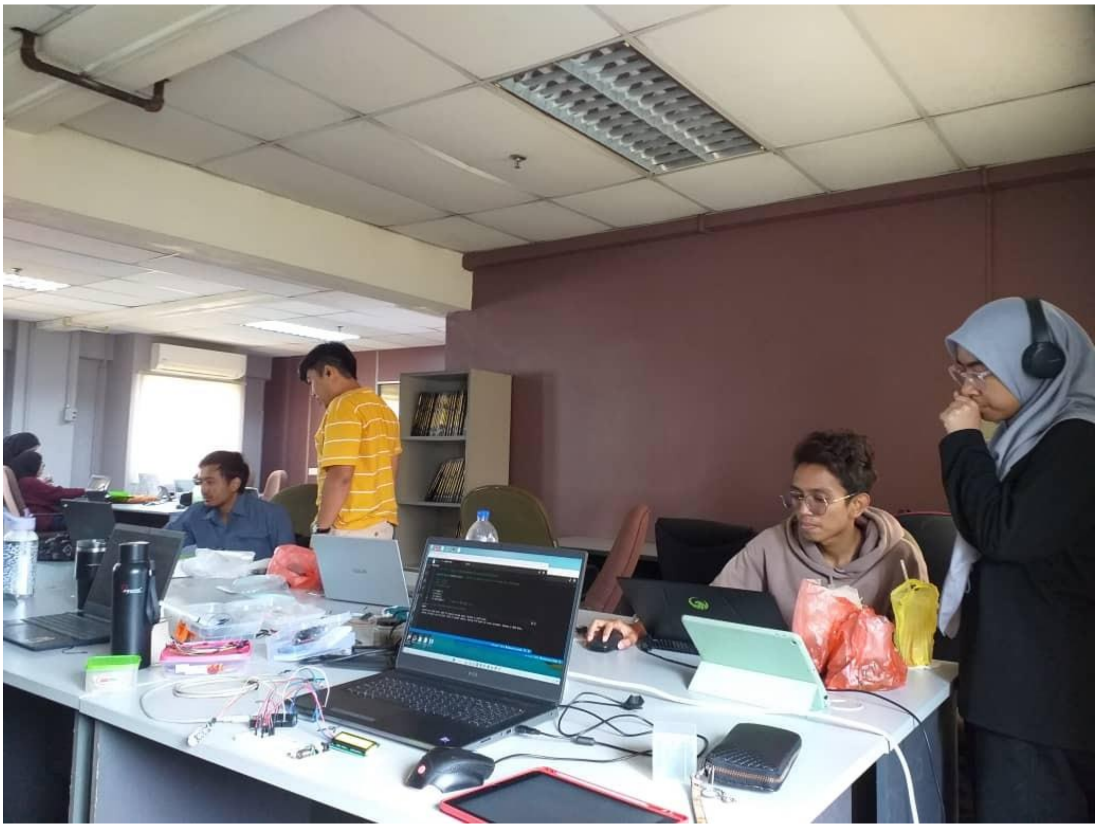

Figure D: Team members discussing

Figure E: Team members making outer casing and body

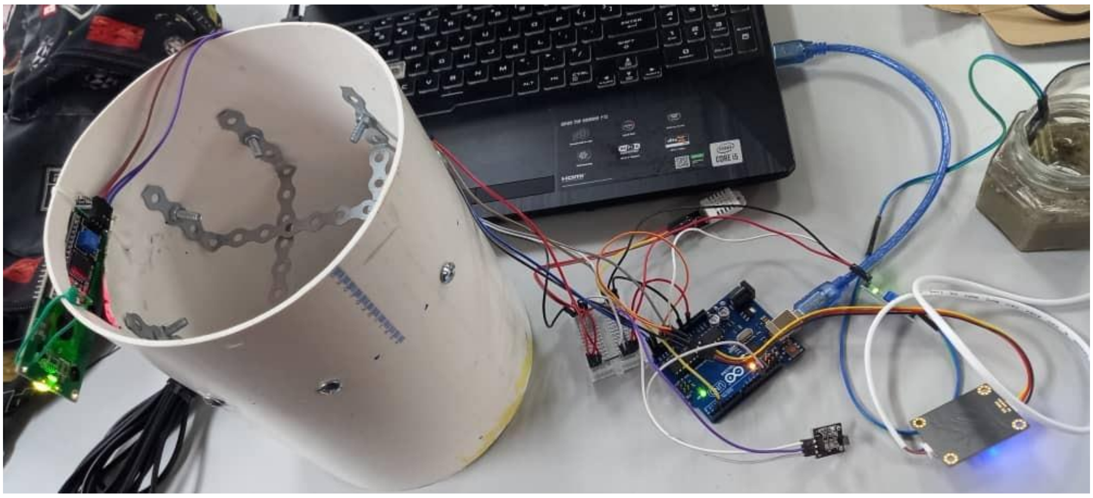

Figure F: Assembly of the outer casing and circuitry

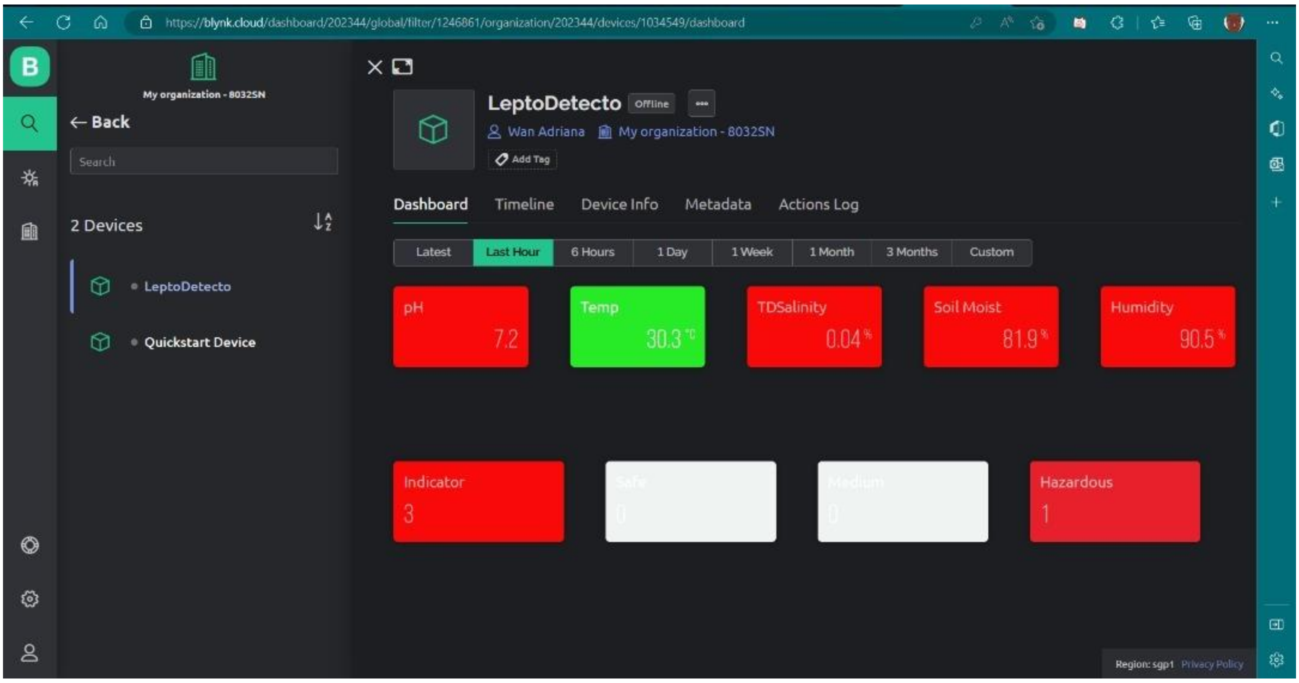

Figure G(a): Blynk Dashboard for Authorities showing high risk

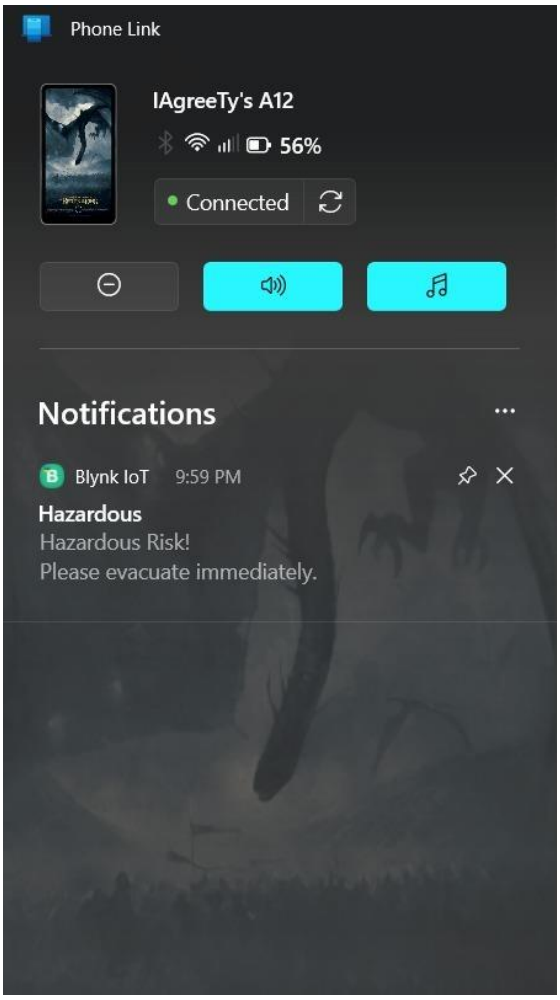

Figure G(b): Notification for civilians showing high risk

Figure H: Post prototype demonstration