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RESEARCH ARTICLE

LONG RANGE LANDSLIDE EARLY WARNING DEVICE.

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Abstract

The project Long Range Early Warning Device for Landslide was designed to measures the current movement and moisture content of the soil, that includes the device's position and orientation that sends the data to base station every 2 minutes. The device is connected to a pole while its base is buried securely to the ground.

The device used wireless telemetry system using high powered RF Transceivers connected with Yagi antenna. It supports directional long-range communication; base station and remote station is positioned with the distance of 2.74 km line of sight. The data will be sent to the cloud and can be accessed in public viewing through www.thingspeak.com (free version; it is an IOT analytics platform service)

The device has LED indicator light that is serves as devices transmit - receive status. Red light indicates standby mode while green indicator light activates when data was received. There are three categories that the landslide micro monitor displays; normal environmental, alert level 1 as low hazard, and its status show high hazard landslide occurrence when it reaches alert level 2. At the base station; Alarms will be based on the type of hazards the data gives. The methodology used in the study was scaling method to provide the efficient and effective output.

The installation of the device within the areas susceptible to landslide provide satisfactory as a result of the analysis in the following: a) Soil moisture and movement detection testing regarding the percentage of the moisture content and the tilting of the device. b) The warning station provides level of alarms when a transmitter was triggered on its hazard level.

Introduction:-

In the recent news, there were 65 reportedly dead and some are still missing due to the landslide during the typhoon Ompong and another 15 in another landslide tragedy in Naga City Cebu. It couldn't be counted as fault from the government since we already have Republic Acts. RA 10121, known as the Philippine Disaster Risk Reduction and Management (DRRM) Act of 2010, an act mandated to strengthen disaster management in the Philippines, a country prone to natural hazards.

This scenario should have been prevented if there were early warning device that will detect the possible occurrence of landslide in the areas forecasted that has a high risk of landslide.

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Due to the deteriorating status of the vegetation in our country, landslide had become one of the most prevalent disasters that took several lives.

The law promotes the development of capacities in disaster management at the individual, organizational, and institutional levels. It recognizes local risk patterns and trends and decentralization of resources and responsibilities and thus encourages the participation of NGOs, private sectors, community-based organizations, and community members in disaster management. It inhibits the full participation of the Local Government Units (LGUs) and communities in governance. The approach tends to be "response-oriented" or "reactive." This is evidenced by the widespread emphasis on post-disaster relief and short-term preparedness, such as forecasting and evacuation, rather than on mitigation and post- disaster support for economic recovery.
In support to this law, the students of LSPU develop equipment, "Long Range Early warning Device for Landslide, a device that can measures the current movement and moisture content of the soil, data that can help predict possible landslide. With this device LGU's can warn their residents, commuters and passer's by for the possible landslide. It can help save lives, time and delays of transportation.

The application of advanced technologies for landslide identification was determined through data acquisition from the municipality of Cavinti, Laguna. The 12.24% (2,649.09 has) of the total land area of the municipality found in the barangays of Anglas, Banco, Tibatib, West Talaongan, East Talaongan, Poblacion, Labayo, Udia, Bukal, Sumucab, Cansuso, Paowin and Lumot is classied under "high susceptibility to landslide". Only 8.53% (1,846.91 has) of the total land area is classified as "low susceptibility to landslide".

Methodology:-
The methodology used in the study was scaling method to provide the efficient and effective output.

Scaling is the trend to manufacture ever smaller mechanical, optical and electronic products and devices. Examples include miniaturization of mobile phones, computers and vehicle engine downsizing. In electronics, Moore's law predicted that the number of transistors on an integrated circuit for minimum component cost doubles every 18 months. This enables processors to be built in smaller sizes.

Results And Discussion:-
The Long-Range Early Warning Device for Landslide transmits data through wireless telemetry signal and Global System for mobile communication. As the researchers conducted surveys and evaluated the locations susceptibility to landslide, Barangay Anglas and Silangan Talaongan are the site that has been prone to mud slide. The researchers conclude the high elevation of the Anglas and locate the wireless transmission for it is directional and proven line of site to its nearby town Pagsanjan, Laguna. Line of sight is a type of propagation that can transmit and receive data only where transmit and receive stations are in view of each other without any sort of an obstacle or obstruction between them.

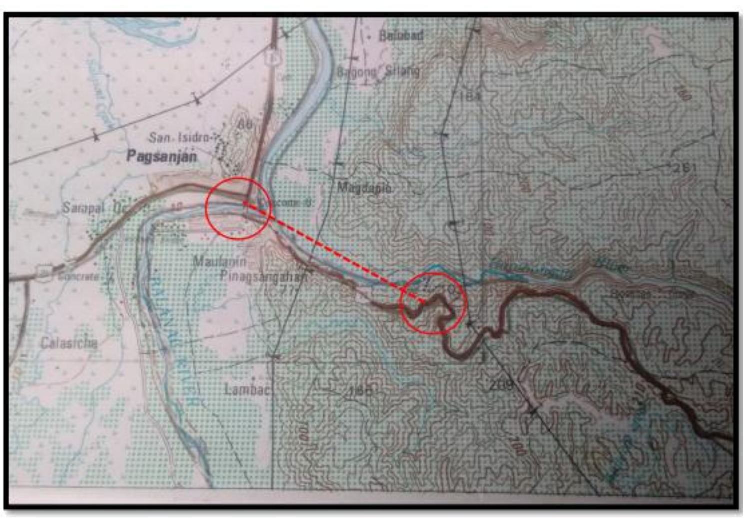


Figure 1:-Topographic Map of Pob. Uno, Pagsanjan, Laguna to Brgy. Anglas, Cavinti, Laguna

Computing antenna height of Line of sight direction communication using Freznel's formula:
Point – point Transmission

Where: F = first Freznel
FF = Freznel Factor
eoh = total obstruction height

				Pagsanjan	Anglas	elevation	eb	
				0	2.74	1	0	
				1	2	1	0.1	
				2	1	1	0.1	
				2.74	0	103	0	
	First Obstruction							
				F1 = $17.31\sqrt{\frac{d_1 d_2}{Df(2)}}$				
				F1 = 4.92 $17.31\sqrt{2.74(9)}$				

		F = F1 x FF	
		F = 4.92 x0.6	
		F = 2.95	
	eoh = elevation + eb + tga		
	eoh = 1 + 0.1 + 0		
		eoh = 1.1	

$$\frac{d}{D}(h_2 - h_1) + h_1 - eoh$$

$$2.95 = \frac{1}{2.73}(0.36h_2 - 0.36h_1) + h_1 - 1.1$$

$$\mathbf{4.05 = (0.36h_2 - 0.36h_1)} \text{ – first equation}$$

Equate equation 1 and 2

$$h_1 = 4.05$$
$$h_2 = 4.05$$
$$a_1 = h_1 - e_1$$
$$a_2 = h_2 - e_2$$

Second Obstruction

$$17.31\sqrt{\frac{d_1 d_2}{Df_{(2)}}}$$

$$F_1 = \sqrt{\frac{1(2)}{2.74(9)}}$$

$$\mathbf{F_1} = 4.92$$

$$F = F_1 \text{ x FF}$$
$$F = 4.92 \text{ x } 0.6$$
$$\mathbf{F = 2.95}$$
$$eoh = elevation + eb + tga$$
$$eoh = 1 + 0.1 + 0$$
$$eoh = 1.1$$
$$F = \frac{d}{D}(h_2 - h_1) + h_1 - eoh$$
$$2.95 = \frac{2}{2.74}(0.73h_2 - 0.73h_1) + h_1 - 1.1$$

$4.05 = (0.73h_2 + 0.27h_1)$ - second equation

a_1 = 3.05 meter (Poblacion Uno, Pagsanjan, Laguna)

a_2 = 3.05 meters (Brgy, Anglas, Cavinti, Laguna)

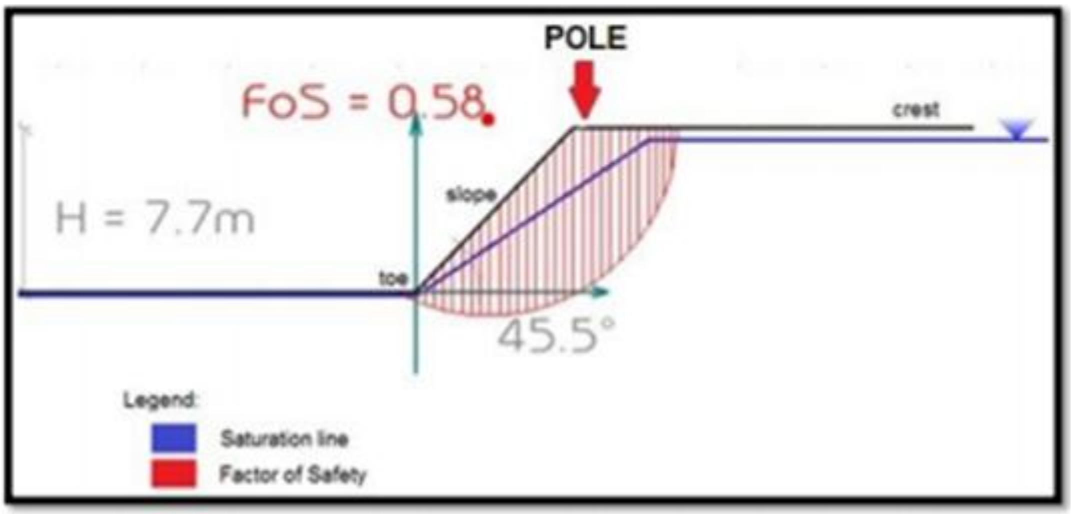


Figure 2:-Location of the pole along the slope in Brgy. Anglas, Cavinti, Laguna

Longitude

$$\frac{9.35 \text{ KM}}{5'} = \frac{7.6 \text{ KM}}{Y}$$
$$Y = \frac{7.6(5)}{9.35}$$
$$= 4.06'$$

Longitude = 14 °20' – 4.06'

= 14° 15.94'

Longitude = 14° 15' 56.4" N

Latitude

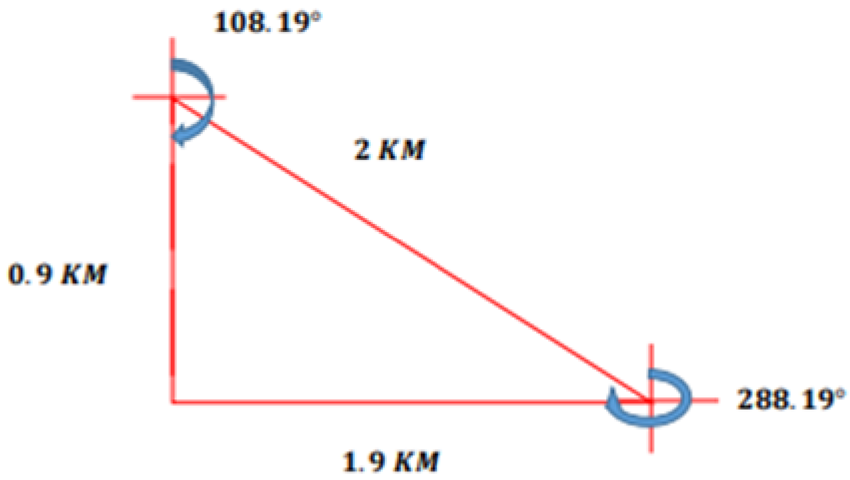
$$\frac{9KM}{5'} = \frac{5.9 \text{ KM}}{X}$$
$$X = \frac{5.9(5)}{9}$$
$$= 3.28'$$

Latitude = 121° 25' + 3.28'

= 121° 28.28'

Latitude = 121° 28'16.8" E

Azimuth



$$A = \cos^{-1}\frac{1.9\text{ KM}}{2\text{ KM}}$$
$$A = 18.19°$$
$$A_{az} = 90° + 18.19°$$
$$\mathbf{A_{az} = 108.1948°}$$
$$B_{az} = 270 + 18.19°$$
$$\mathbf{B_{az} = 288.19°}$$

Note:**A** is Poblacion Uno, Pagsanjan, Laguna and **B** is Brgy. Anglas, Cavinti, Laguna.

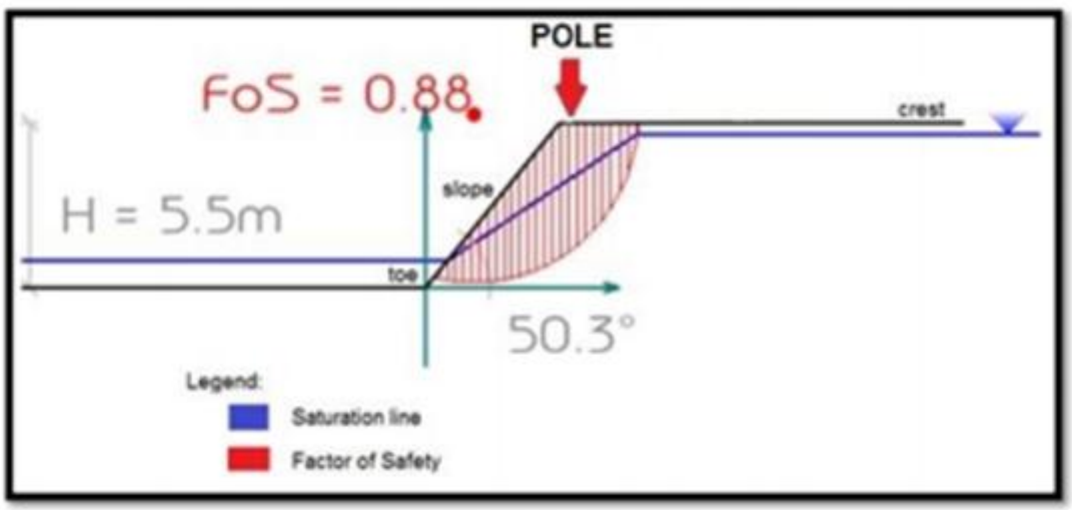


Figure 3:-Location of the pole along the slope in Brgy. East Talaongan, Cavinti, Laguna Longitude

$$\frac{9.35\text{ KM}}{5'} = \frac{6.08\text{ KM}}{Y}$$
$$Y = \frac{6.08(5)}{9.35}$$
$$= 3.25'$$
$$\text{Longitude} = 14°20' – 3.25'$$
$$= 14° 16.75'$$
$$\textbf{Longitude = 14° 16' 45" N}$$

Latitude

$$\frac{9\text{ KM}}{5'} = \frac{4.95\text{ KM}}{X}$$
$$X = \frac{4.9(5)}{9}$$

= 3.28’
Latitude = 121° 30’ + 2.75’
= 121° 37.75
Latitude = 121° 37’45

Table 1:-Soil Moisture Content Data Results

Soil Moisture Sesor			
Trial 1			
Anglas		Silangan Talaongan	
Moisture Content (%)	Interpretation	Moisture Content (%)	Interpretation
47.21% - 48.19%	Dry soil	50.12% - 51.22%	Dry soil
67.74% - 68.33%	Moist soil	55.03% - 55.52%	Moist soil
77.03% - 77.42%	Wet soil	64.71% - 65.10%	Wet soil
Trial 2			
49.66% - 49.76%	Dry soil	51.61% - 52.10%	Dry soil
66.08% - 66.57%	Moist soil	57.28% - 60.12%	Moist soil
77.61% - 78.10%	Wet soil	65.29% - 67.64%	Wet soil
Trial 3			
46.73% - 47.21%	Dry soil	52.49% - 53%	Dry soil
66.18% - 66.59%	Moist soil	60.99% - 62.66%	Moist soil
74.68% - 75.17%	Wet soil	66.76% - 69.4%	Wet soil

Table 1 shows the data results of soil moisture content sensor. The 3 trials on the dates of April 9, 2018 to April 22, 2018. On April 9, 2018 we had moderate rainfall. The researchers conducted a site test wherein they tested the limit of moisture sensor on saturated soil. Since it’s one of the main factors to identify the possibility of landslide occurrence, the trials were made to provide evidences that the sensor is reliable to detect accurate moisture content level of the soil. Also, Soil test simulations with samples of dry, moist and wet were used to examine the accuracy of the device soil moisture sensor.

Table 2:-Raindrop Sensor Data Results

Condition	**Landslide Micro Monitor Reading**	**Remarks**
Rainy	Yes	Accurate
Not Rainy	No	Accurate

Table 2 shows the data results of raindrops sensor. This is done to provide evidence that the Device raindrop sensor is reliable to sense the actual rain condition which is another factor to identify if there is a possibility that a landslide may occur. The output displays “NO” if there is no rain and it displays “YES” if raining occurs within the area. The output from expected to actual were accurate. The researchers observed that there are similarities between the study of Charge, A & Angal Y.S, June 2016. Their study named “Landslide Measurement System” has the same principle with the authors study but uses different tilting sensor. This is the reason for the similarity with conclusion. Their research states that considering the initial tilt angle of sensor nodes to be 105 90 degrees along X-Y axis, as angular change goes to 80 degrees people be alarmed to vacant from their areas for safety reason. When the angular change in 60 degrees can be definite of land sliding, all necessary preventive measures can be taken.

Table 3:-Trial of Accelerometer+ Gyroscope + Magnetometer Sensor

TRIAL 1		
ACCELEROMETER + GYROSCOPE +MAGNETOMETER		
Actual output		
Accelerometer (X,Y,Z)	Gyroscope (X,Y,Z)	Remarks
00173,-0024,02113	00007,00001,00012	Simulated soil movement environment
00188,-0005,02125	00006,00005,00012	
00173,-0014,02124	00005,-0003,00011	
00177,-0024,02106	00007,00002,00014	
00191,-0023,02117	00008,-0004,00010	
-0889,00497,01814	-0179,-0573,-0127	
-0773,00521,01928	-0028,-00072,-0018	
-0577,01204,01765	00828,00451,-0018	
-0574,-1607,01251	-0021,-0020,00023	
-1272,00495,01626	00265,00162,00059	
-0275,-1611,0133	00020,-0020,-0047	
00193,-1481,01739	-0675,01927,00762	
-1056,-0022,01895	-0525,00848,01823	
-0356,-1217,01700	00005,-0004,-0010	
-0525,00848,01823	-0057,-0034,00006	
-0227,-1165,01774	-0174,00155,00005	

Table 3 shows the testing results of Accelerometer + Gyroscope + Magnetometer. The researchers initiate the simulation by the manually tilting the device in random positions. The experiment begun on April 15, 2018, the device is tilted, slanted, and sloped depends while testing the device which is transmitting every 2 minutes interval. The trial was conducted to test the capability of the sensor to detect landslide occurrence by depending on its device's tilting and orientation.

Table 4:-Angle Testing of Accelerometer + Gyroscope + Magnetometer Sensor

ACCELEROMETER + GYROSCOPE +MAGNETOMETER			
Tilting and orientation	Actual output		Remarks
	Accelerometer (X,Y,Z)	Gyroscope (X,Y,Z)	
Left 60˚	-0686,00005,02063	-00223,-0005, -0004	Simulated soil movement environment
Left 45˚	-1158,00062,01834	-0028,-0004,-0002	
Left 30˚	-1480,00393,01481	-0027,0004,0547	
Right 60˚	01171,0037,01810	-0023,-0009,-0005	
Right 45˚	01541,-0009,01471	-0012,-002,0004	
Right 30˚	01838,-0372,00973	-0021,-0009,-0004	
Front 60˚	01264,00055,01755	-0025,00000,-0082	
Front 45˚	01518,00107,01491	-0021,0008,-0002	
Front 30˚	01826,-0010,-01056	-0025,-002,-0005	
Back 60˚	-0757,-0043,02030	-0025,0003,-0002	
Back 45˚	-1207,00235,01754	-0016,-0016,-0002	
Back 30˚	-1566,00339,01376	-0024,-0010,-0006	
Vertical 90˚	-0056,-2077,00340	-0024,-0010,-0006	
Vertical 90˚	-0068,-2071,00336	-0024,-0004,-0004	
Vertical 90˚	-0055,-2080,00325	-0023,-0008,-0001	

Table 4 shows the testing results of Accelerometer, Gyroscope and magnetometer. The researchers imitate the environment of the soil movement by manually tilting the device. The simulation happens on April 9 to 16, 2018, the device is tilted, slanted, and sloped depends on the direction and angle indicated by the researchers. The Accelerometer, Gyroscope and magnetometer is the major factor to determine if the landslides occur within the area, the information provided above stated how consistent the sensor produce exact data. Furthermore, the orientation of the device is demonstrated by conducting the same test procedure.

Table 5:-General Data Results of JUAN MAAGAP: Long Range Landslide Early Warning Device

GENERAL DAT RESULTS				
Alert level	Landslide Micro monitor Display Status	Alarm will be triggered for	Interpretation	Remarks
0	Accelerometer, gyroscope and magnetometer (X, Y, Z); - -	No alarm	Normal	
	Rain : no			
	Soil Moisture content:			
	Anglas : 49% - 57%			

	Silangan Talaongan : 50% - 53%			
1	Accelerometer, gyroscope and magnetometer (X, Y, Z); (Minimal changes) Rain : yes Soil Moisture content: Anglas : 58% - 65% Silangan Talaongan : 54% - 63%	10 minutes alarm	Low hazard	One (1) hour alloted time to announce the possibility of landslide. Afer one (1) hour period, the possibility of landslide is very high
2	Accelerometer, gyroscope and magnetometer (X, Y, Z); N/A or no movement at all Rain : yes Soil Moisture content: Anglas : 65% - 74% Silangan Talaongan : 64% - 70%	15 minutes alarm	High hazard	Landslide already occurred

Table 5 shows that the general data result of the trials made to test the accuracy of wireless sensors to make sure that the Long-Range Early Warning Device for Landslide was functioning well. Numerous trials were conducted to come up with this standard, the previous test is the groundwork to determine the level of landslide status. When the device senses that the area is in normal condition, it considers as no alert level. The displays status of Accelerometer, Gyroscope and magnetometer is in fixed position with no rain at all. The soil moisture content ranges from 49% - 57% in Anglas while 50% - 53% in Silangan Talaongan, it means the soil condition is dry. The time and date are correctly shown in the display as well as the coordinates of the position of the device. The alarm on normal condition indicated no alarm at all. When the device senses that the area is in Low hazard condition; it considers as first alert level. The displays status of Accelerometer, Gyroscope and magnetometer has minimal changes in parameters with little to more rain. The soil moisture content ranges from 58% - 65% in Anglas while 54% - 63% in Silangan Talaongan, it means the soil condition is moist. The device displays “yes” when the rain sensor detects rainy atmosphere. The time and date are correctly shown in the display as well as the reading of GPS sensor in coordinates of the device’s position. When the device reaches the low hazard, it means the warning station alarms for about 30 seconds to give early warning and notify commuters and neighborhood that a landslide may occur in any moment.

Under the low hazard and sets off the alarm, there is a one hour allotted time to announce the possibility of landslide. This is to give ample time for evacuation to a safer place and to give an advisory to motorists and commuters that a landslide is about to occur. After the one-hour period, the possibility of landslide is very high. Lastly, when the device senses that the area is in High hazard condition; it considers as alert level 3. The displays status of Accelerometer, Gyroscope and magnetometer has random changes in its parameters; no measurement at all. The soil moisture content ranges from 65% - 74% in Anglas while 64% - 70% in Silangan Talaongan, it means the soil condition is very wet and subjected in any moment to soil erosion and landslide. The device displays “yes” when the rain sensor detects rainy atmosphere. The time and date are correctly shown in the display as well as the last reading of GPS sensor in coordinates form. When it reaches the High hazard, the device possesses a possibility to be shut down; therefore, the data transmission is ended. Locate the last GPS transmitted position to locate the device’s position. The warning station alarm for about 15 minutes to give warning to commuters and neighborhood that a landslide is already occur and harms are present on their way. The researchers conducted the trials to test the accuracy of the wireless sensors. Based on the results of wireless sensor testing, all sensors of Long Range Early Warning Device for Landslide gave accurate results in detecting landslide probability.

Conclusions:-

1. The development of Long Range Early Warning Device for Landslide was feasible, due to its qualification of providing accurate early warning landslide information sensed by the remote stations installed in different elevated areas in Cavinti, Laguna.
2. The installation of the device within the areas susceptible to landslide provide satisfactory as a result of the analysis in the following: a) Soil moisture and movement detection testing regarding the percentage of the

moisture content and the tilting of the device. b) The warning station provides level of alarms when a transmitter was triggered on its hazard level.

Recommendations

1. Development of mobile application for easy access of the public
2. Application of the Long-range early warning device for Utility model before implementing it to the community.
3. In the occurrence that the project needs development, maintenance or repair the proponents are the one accountable for these.
4. The Barangay / municipality officials are responsible in the monitoring of the system.
5. Some of the potential partners are Barangay and Municipalities, PDRRMC/ MDRRMO/ CDRRMO.
6. Add an extra anti-theft features to advance the device security.
7. Incorporate desktop as server.

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