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Case Study: Assessment of the Existing Condition of Road Side Drainage Structure, Wolaita Sodo Town, SNNPR, Ethiopia

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Abstract

The techniques used for assessment of the existing drainage condition were questionnaire by applying the purposive sampling, global positioning system and site over survey supported by photograph and video using digital camera. And also secondary information's like published research documents were used as supportive of the analysis. Accordingly, the collected information and data were analyzed. The results obtained from the questionnaires and observation shows that, the major causes of defects of these drainage structure were comes from blockage of longitudinal and cross drainage by solid waste disposal, absence of cross drainage structures and uses of limited data's and information's for design. The performances of these structures are poor. The occurrence of these situations was affecting the roads, movement of vehicles and live hood of community.

Keywords: *Assessment, Road side drainage structure, Cross drainage, Questionnaire, Purposive, Performance*

Introduction

Road is an important infrastructure in a nation or community of people. It greatly affects the economy of any nation. Roads are built to provide safe passage of vehicles and must be properly designed and constructed [1].

Therefore, water must not be allowed to develop sufficient volume or velocity so as to cause excessive wear along ditches, below culverts, or along exposed running surfaces, cuts, or fills. Provision for adequate drainage is of paramount importance in road design and cannot be overemphasized. Cut or fill failures, road surface erosion, and weakened subgrades followed by a mass failure are all products of inadequate or poorly designed drainage. As has been stated previously, many drainage problems can be avoided in the location and design of the road: Drainage design is most appropriately included in alignment and gradient planning [2].

Importance of Highway Drainage

The importance of drainage is one of the most important aspects for location and design of highway because of following reasons:

- ✓ To prevent subgrade failure: Soil subgrade excess moisture reducing the stability of pavement which leads to subgrade failure.
- ✓ To prevent reduction in strength of pavement material: The strength of pavement material like stabilized soil and WBM (water bound macadam) is reduced.
- ✓ To prevent frost action: In flexible pavement the formation of waves and corrugation take place due to poor drainage.
- ✓ To prevent shoulders and pavement edge: Excess, water on shoulders and pavement edge cause considerable damage.
- ✓ Prevent slope failure: Excess moisture causes increase in weight and thus increases in stress and simultaneously reduction in strength of soil mass which result into failure of earth slopes and embankment foundations.
- ✓ Prevent erosion of soil: Due to surface water, erosion of soil from top of road and slope of embankment [5].

Surface Drainage

Under the surface drainage, water is to be collected in longitudinal drains and then disposed of at the nearest stream, valley or water course [5].

Open Drainage

The function of the side drains (or ditches) is to collect water from the carriageway and surrounding areas and lead it to an exit point where it can be safely discharged. Side drains can be constructed in three forms: V-shaped, rectangular or as a trapezoid [6].

When steep grades are present, the possibility of ditch erosion becomes a serious consideration. Erosion can be limited by lining the channel with sod, stone, bituminous or concrete paving, or by providing small check dams at intervals that depend on velocity, type of soil, and depth of flows [3].

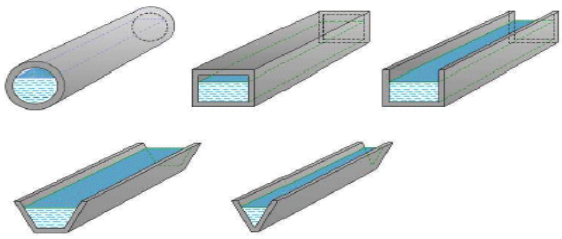

Figure 1: Types of open Channel [3].

Methodology

The main aim of this study is assessing the existing condition and the general over view of the drainage structure in the study area.

Qualitative research is also empirical, inductive and interpretative of a situation within a specific context. It involves examination of particular cases from which general principles, rules, and standing with participant knowledge and experiences [22].

For case studies, sampling applies to selecting cases and selecting data sources "that best help us understand the case". Thus, what is sampled occurs at two levels, the case and unspecified data sources within the case [21].

Sampling Technique

Purposive Sampling

Data gathering is crucial in research, as the data is meant to contribute to a better understanding of a theoretical framework [15]. It then becomes imperious that selecting the manner of obtaining data and from whom the data will be acquired be done with sound judgment, especially since no amount of analysis can make up for improperly collected data [18]. The purposive sampling technique, also called judgment sampling, is the deliberate choice of a participant due to the qualities the participant possesses. It is a nonrandom technique that does not need underlying theories or a set number of participants. Simply put, the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience [15]. It is typically used in qualitative research to identify and select the information-rich cases for the most proper utilization of available resources [17]. This involves identification and selection of individuals or groups of individuals that are proficient and well-informed with a phenomenon of interest [16].

The sampling methodology used is a key aspect for understanding the kind of information that can be obtained during this part of the assessment. The purposive sampling aims to focus on a small number of sites and collect enough information to get a good picture of the situation [14].

In this portion data collection and analysis were done. The primary sources of data collection were done by using the questionnaires and observations. The secondary data information's were used by collected from researches worked in this town on generation and composition of solid waste, and causes of motor cycle accidents.

The questionnaire has been filled by road infrastructure workers who work in Sodo town and elsewhere. The sites over survey/ observation/ were done and collected significant photos and coordinate data by using digital cameras and global positioning system (GPS) respectively. The secondary data's were also used as a support for analysis and discussions. The individuals in the questionnaire were selected based on their experience, well informed of the cases (phenomena), knowledge and willingness.

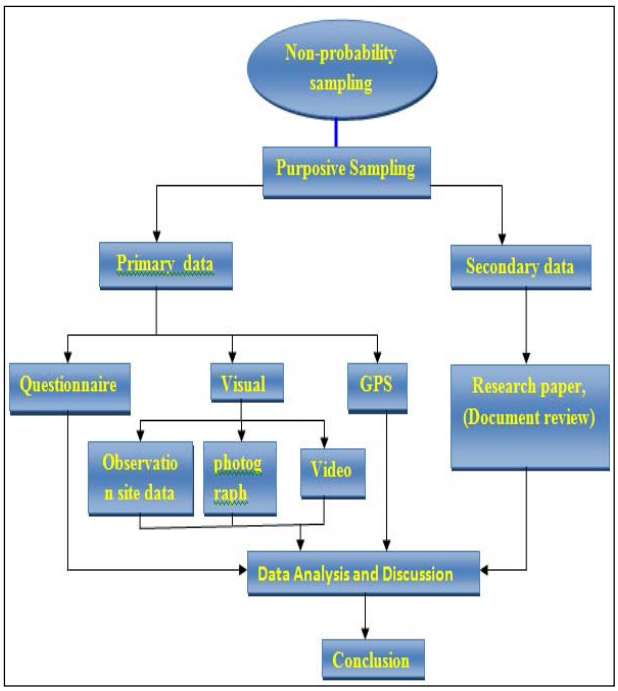

Chart-1: Methodology assessment flow chart.

The Study Area

Wolaita Sodo town, the administrative capital of the Wolaita zone, is located 390 Km South and 167 Km of South West of Addis Ababa and Hawassa, respectively. The town is located 6°49" N latitude and 37°45'' E longitude. Currently, the total area of the town is about 3,200 hectares and is divided in to three sub town ("Kifleketema"), eleven "kebeles" (administrative units) and ninety nine villages ("mender"). Based on the 2010 Census, the town has a total population of 110,660 (male 58,407 and female 52,252) with the projected annual growth rate of the 4.8% [11].

It is also a major transportation node, being the center of six national and regional transport routers. Trade is the most important lively hood of the resident of the city. Sodo has 16.28 Km concrete asphalt road, 9.9 km gravel road, 5.6 km Coble stone road and 92 km earth road. There are about 10 transport institutions that organize the transport arrangement in to different routes away from Sodo town & transit transport vehicles through six outlets [4].

The case study mainly focused on the road route from Commercial Bank of Ethiopia Sodo branch - Agricultural College – Geter Technology roundabout and 50m to the right and left of the route. These routes are highly crowded and busy by traffic. The coordinates are presented in Table-1.

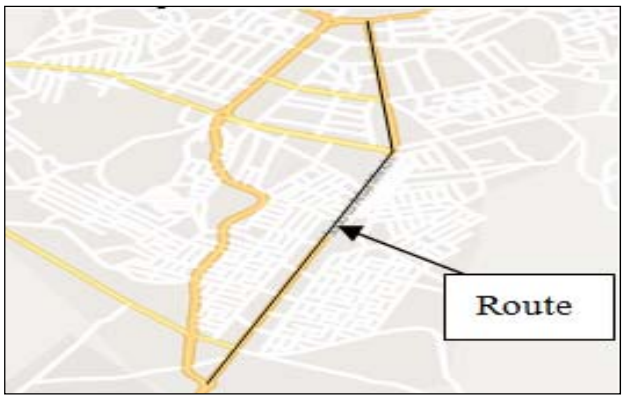

Figure 2: The main route under this project

Table-1: Coordinates of the points taken from the route.

S.no.	Easting	Northing	Elevation (m)	location
1	363398.21	758991.01	2078	Commercial Bank of Ethiopia, Sodo Branch
2	363531.8	758058.2	2045	Bilal Mosque
3	363417.72	758105.83	2021	On Maedot hotel- bus station route
4	363509	757906	2011	Bus Station
5	363231.85	757327.26	1984	Dashen Bank Tona Branch
6	363069.01	756876.41	1953	TAF Fuel
7	363152.4	756810.4	1942	Back of TAF Fuel
8	362830.19	756587.19	1949	Wadu (100m back of US College)
9	362814.29	756266.3	1933	Sodo ATVET College
10	362681.77	755996.13	1923	Geter Technology (Round about)

Data Collection, Analysis and Discussions

Data Collection and Analysis

The surface water collected from road side is flow in to road side open drainages. These drainage structures are called as open drain, and the causes of failures were due to different reasons.

Drainage in its most simplified form is a process of collecting, conducting, and disposing of drainage water [10].

According to [10] the followings are the check lists for designing proper drainage structure:

- ✓ Analyze topography: Check off-site drainage pattern (street, storm drains), on-site topography for surface runoff and percolation (pond, creek, retention basin), and means of disposal (natural drainage system (swales), Existing drainage system (drain pipe), Proposed drainage system)
- ✓ Analyze other site conditions: Land use and physical obstructions such as walks, drives, parking, patios, landscape edging, fencing, grassy area, landscaped area, tree roots, etc. Soil type determines the amount of water that can be absorbed by the soil. Vegetative cover will determine the amount of slope possible without erosion.
- ✓ Analyze areas for probable location of drainage structures.
- ✓ Identify what type and size drains are required. Design the system using a combination of surface and subsurface drain systems and underground pipes. Design pipe layout to convey water from the drains to the discharge point in the most direct and simple manner possible.

Sample Size Consideration

There are at least two consideration of sample size for qualitative research. These two questions are, sample size will reach saturation and how large this sample needed to represent the diversity. Though, for grounded theory/ethnography/action research, assess 20-30 people, which typically is enough to reach saturation. [20]. Saturation is reached when the information becomes to maximum and no new things arising.

Table-2: Response rate of participant in the questionnaire.

Respondents in questionnaire	Engineers (Professionals)		Average
Area of work	Lecturers (University) participated in related research	Road infrastructure	
	Yes	No		
Experience (year)	≥5	≥3	≥5	
Frequency of inspection of drainages	Twice per a month		Once per a month	
Number of questionnaire prepared	20	10	6	36
Participant responded	17	7	4	28
Response rate (%)	85	70	66.7	77.8

From Table 2 presented above, a response rate of 50% is adequate for data analysis and reporting, 60% is good and above 70% is very good [23]. The response rate of individuals in the questionnaire is 77.8%.

The necessary data and information's are very important for the design of road side drainage structures. The data presentation and analysis were done for information's collected from questionnaires.

Table-3: Percentage response of participant in respected points.

Place of work		Lecturers, participating in related research		Road infrastructure	Average
		Yes	No		
No. of participants		17	7	4	
Necessary Design consideration	Yes	58.8%	85.7%	50%	64%
	No	41.2%	14.3%	50%	36
Reason of defect of drainage	Poor maintenance	Out 64% who agreed in consideration of necessary data and information			66.7%
	Poor workmanship	-			33.3%
Expectation of runoff	Yes	76.4%	85.7%	25%	62.5%
	No	23.6%	13.3%	75%	37.5%

Reason for runoff	Solid waste	Out 62.5% who expect the occurrence of runoff in the study area, specifically Wadu	37.5%
	Construction activity		25%
	Absence of cross drainage		37.5%

- **Design Consideration:**

From the chart-3.1 presented below, the results obtained from questionnaire, 36% of the respondents are not agreed on considering the necessary information and data's during the design of the drainage. But 64% of them agreed on incorporating all necessary inputs needed for designing excellent drainage structures.

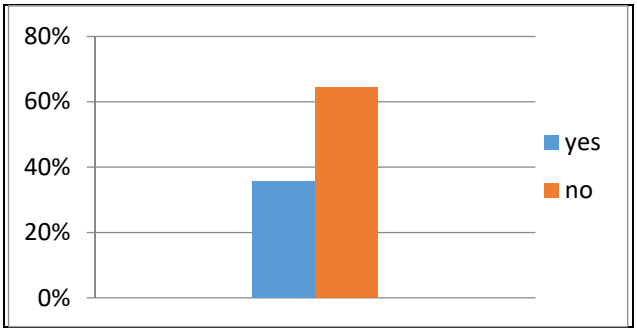

Chart-1: Percentage response of participants.

- **The Response of 64% Participant on Reason of Defect of this Structure:**

Out of 64% of participants agreed on incorporation of necessary data and information's , 42.67% of them concluded that the reason for defect of road side drainage structures were poor maintenance but 21.33% of them agreed on poor workmanship. No respondents are agreed on problems due to climate change [Chart 2].

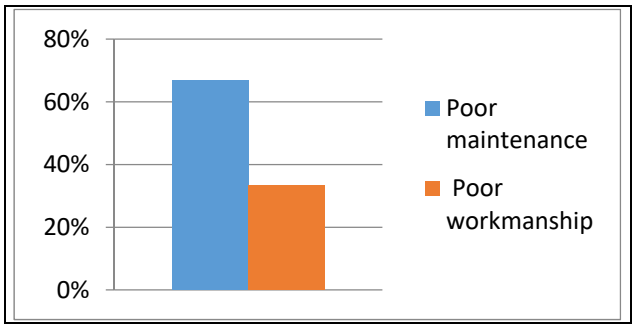

Chart-2: The reason of open drainage problems.

But all respondents on the questionnaire respond that, the application of detail designed parameters on road side drainage construction were not incorporated.

- **Expectation of runoff:**

Actually the runoff problem was happened by different reasons and affects the live hood of the community in the study area [Chart 3].

The respondents participated in this questionnaire responds that, the runoff problems happened in wadu area was expected by 62.5%. But 37.5% of the respondents were not expected.

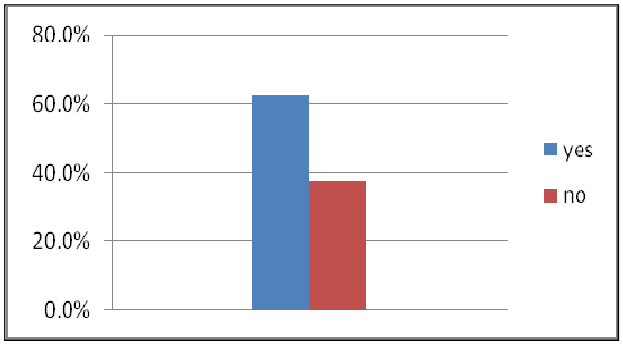

Chart-3: Percentage expectation of runoff problem.

- **The Reason for Occurrence of Runoff:**

Based on the response of participants' in the questionnaire, the reasons behind occurrence of runoff out of 62.5% were blockage of solid wastes (37.5%) and absence of cross drainage structures (37.5%). But 25% of them agreed on blockage of drainages by placement of construction material and activities [Chart 4].

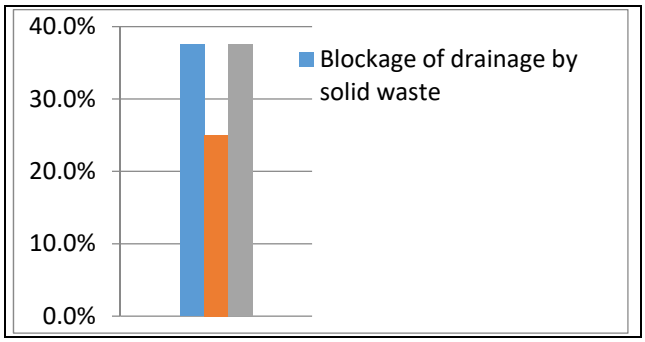

Chart-4: The reason of runoff in study area.

Performance Rating and remedial action

Table-4: Performance rating and recommendations or remedial action proposed by respondents.

Place of work		Lecturers, participated in related research topics		Road infrastructure	Average
		Yes	No		
Performance rating	poor	70.6%	42.3%	50%	55%
	good	29.4%	57.7%	50%	45%
	very good	-			-
	Excellent	-			-
Remidial action	maintenance	35.3%	14.3%	25%	25%
	Redisigning	64.7%	85.7%	75%	75%
	reconstruction	-	-	-	-

- **Drainage performance rating:**

The performance of road side drainage system was evaluated and 55% are categorized under poor and 45% of them categorized under good performance [Chart 5].

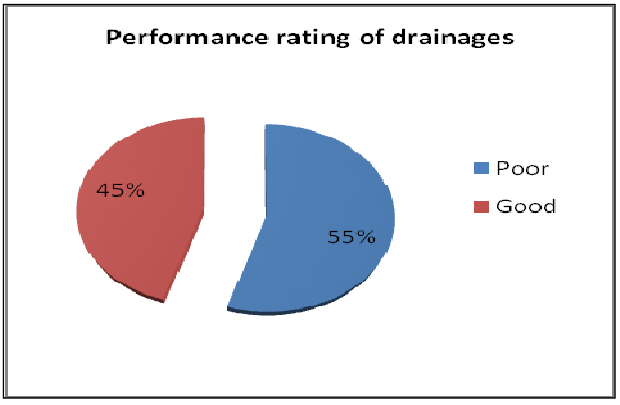

Chart-5: Rating of the drainage structure

- **Remedial action taken:**

For drainage structure having unsafe performance shown in [Chart 5], it needs Necessary measures. So 75% of respondents recommends redesigning and 25% of them maintenance [Chart 6].

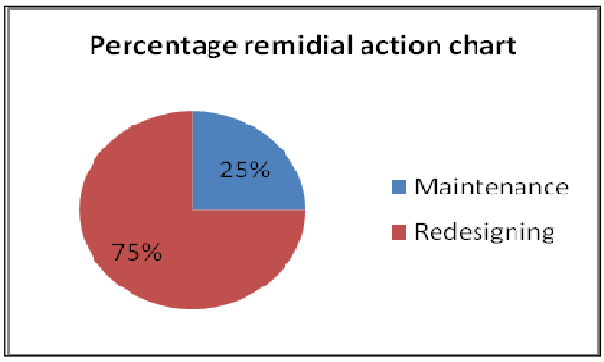

Chart-6: Remedial action of poor drainage structure.

The components of minor storm drainage systems can be categorized by function as those which collect storm water runoff from the roadway surface and right-of-way, convey it along and through the right-of-way, and discharge it to an adequate receiving body without causing adverse on- or off-site environmental impacts. In addition, major storm drainage systems provide a flood water relief function.

Storm water collection is a function of the minor storm drainage system which is accommodated through the use of roadside and median ditches, gutters, and drainage inlets [7].

Solid waste generated in Sodo town has high content of biodegradable waste (ash, food waste, yard waste, etc.) that can be composite (about 84% of Households waste (HHs)) and recyclables material (plastics, glass, metals, etc.) about 13.0%. These all account for about 97% of the total waste generated in the town and if all could be recycled and reused, the municipality would remain with almost 3.0% waste to be disposed [13].

The figures presented below were collected and analyzed through site over survey (observation) combining with secondary data findings related to solid waste.

Figure 3: longitudinal drainage blocked by solid waste, Construction materials (Cobble stones, masonry), sediments: (a) In front of TAF fuel distributor , (b) Back of TAF fuel, (c) Infront of Bilal Mosque gate.

Furthermore, the HHs average solid waste generation per-capita/day in Sodo town is 0.47 Kg and the town generates more than 18,856,464 Kg of solid waste (by weight) per year. This huge amount of solid waste generated in the town requires a good management to protect and bring about a healthy and sustainable environment. Therefore, the town municipality must develop an appropriate solid waste management plan and promptly implement it. Developing such management plan requires understanding the existing solid waste management practice in the town [13].

Figure 4: Cross drainage filled by sedimentation and solid wastes; (a) on the route bus station gate to Maedot (b) Back of US College.

The joint in between outlet of cross and inlet of longitudinal drainage structure is not properly designed and instolled [Fig.5].

The side drains need to have sufficient capacity to collect all rainwater from the road carriageway and dispose of it quickly and in a controlled manner to minimize damage [6].

Figure 5: Cross and longitudinal drainage structure (near to bus station)

According to [12] the dominant soil type found in Wolaita sodo town is silt. These soils are categorized under fine grained soil and have low permeability. Because of this, nearly all rain falls on the ground converted in to runoff.

Figure 6: Runoff flow over the road.

The images shown in Fig.6 (a) and (b) were located in front of Dashen bank Tona branch. Fig.6 (c) and (d) were located on the cobble stone road in front of Dashen bank Tona branch to prison, and infront of TAF fuel respectively.

The steep Slope of longitudinal drainage has high scouring impact on the bed and cross section of the ditch. Fig.7 'b, c, d' and 'a'are found in front of Dashen bank Tona branch and road under construction at the back of TAF fuel respectively.

Figure 7: Damaged road and drainage.

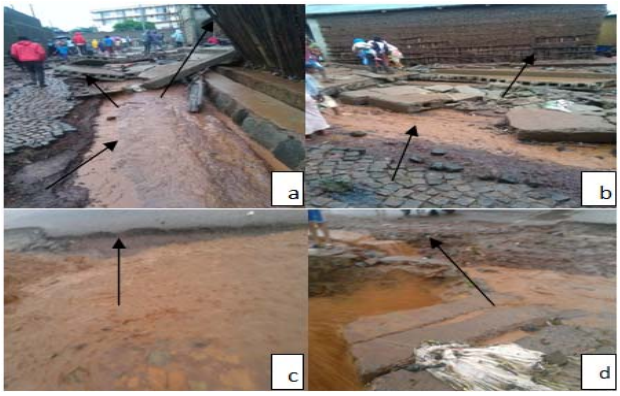

Figure 8: Damaged infrastructure and houses.

The road under construction[Fig.3, b], pavement edge [Fig. 8, c and d], cobble stone roads and houses [Fig. 8, a and b] were eroded by the runoff.

Discussions

The actual conditions of drainages were assessed based on response of respondents and site over survey. All necessary data and information (meteorological data, climatic conditions, land use/land cover, field survey data, data analysis and soil data etc) and appropriate design consideration were not considered. Even though, most of the respondents (64%) participated in the questionnaire were agreed on incorporating the collected inputs for designing excellent drainage structure. Even if, the results obtained from the questionnaire shows majority of participant agreed on the detail study of all necessary parameter for design, the site over survey and reviewed researches worked in the town shows there is a limitation in the study. Typical examples of longitudinal grade, point of concentration, high points, ridges and etc. These problems are clearly shown in Figures presented above.

According to [13], high amount of solid wastes are disposed in this town per a year. So that, the runoff problem happened due to blockage of drainage by solid wastes, construction activity and absence of cross drainage structures. Another very important factor collected from site over survey was, the cross section of the drainage could not constructed properly to accommodate the maximum probable discharge without damage on it[Fig. 3 and Fig. 6, c and d].

Furthermore, the roadside ditches cross drainage and culverts are filled by rocks and sediments [Fig. 4, a and b]. The gullies, debris and Solid wastes are also major materials which block the ditches in study area. The periodic removal of this material is required to maintain the hydraulic capacity of the ditches and protect the roadway and travelling public [8].

The exact dimensions of the side drains are dependent on the expected amount of rainwater and the distance to the next exit point where the water can be diverted away from the road [6]. The runoff occurred in April, 2018 in the project area was expected by 62.5% respondents answered by participants in the questionaire. These events were due to the result of poor surface drainages. The respondent answers showing that, the occurrence of runoff in this study area, were due to unexpected rainfall and low capacity of drainage structure due to sedimentation and solid waste. The 37.5% of respondents replied that the problem happened was due to unexpected runoff and in proper installation of drainage structures. The supervision of this road side drainage structure during and after construction was not sufficient and has weakness.

The design ditches should be able to function to overcome safety, maintenance, and water flow and erosion control [9]. The length and steepness of slopes influence the amount and rate of storm water runoff. As the extent and gradient of slope increase, the amount, rate, and velocity of runoff increase, thereby increasing the potential for erosion. On the other hand, soils that are flat, or with relatively no relief, do not drain well, but they seldom provide any threat in terms of erosion.

The greater the slope the more surface runoff and less soil absorption. Conversely, the lesser the slope the more soil absorption and less surface runoff are experienced [10]. In flat or slightly undulating terrain one would aim to achieve a longitudinal gradient between 2 and 5 percent (1:50 and 1:20) in the drains. With gradients less than 2 per cent, silting occurs easily while with gradients steeper than 5 percent the ditches will easily erode [6]. In fact, the gradients of most of the distances covered in this route are greater than 5 percent. Because of these, more surface runoff was happen. The route from TAF fuel to the gate of Sodo ATVET College has the slightly undulating terrain. That is why the drainages were filled by sediment and gullies [Fig. 3, a]. The runoff left rocks and gullies on the pavement and free movement of vehicles was affected [Fig. 6, d].

The mis joint of inlet of longitudinal and outlet of cross drainage [Fig. 8] structures were leads to pondage of water. The longitudinal distance versus elvation is presented in Fig. 9 below.

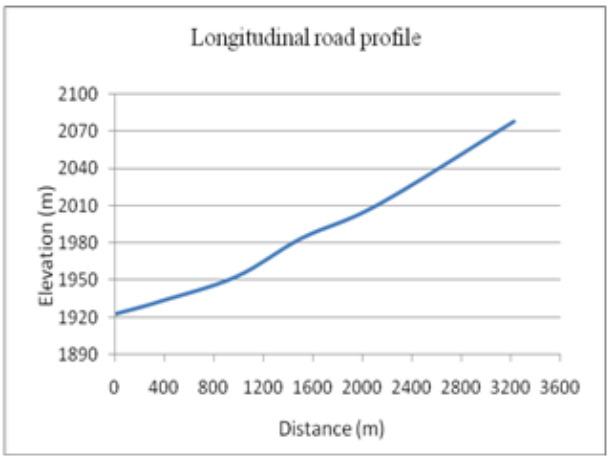

Figure 9: Longitudinal profile from Commercial bank of Ethiopia.

Sodo Branch to Geter Technology round about Finally the runoff problem affect the livelihood of the coommunities found around study area. It damages the houses and their properties. The placement of debris and gullies on the road due to run off, were affect the traffic flow.

According to [19], the final assessment result clearly indicates that more number of motor cycle accidents is due to road defects followed by the traffic violations. Though, the assessment shows that, one of the major causes of road defect comes from poor drainage.

Validity and reliability are an important aspect to effective research. It is concerned with the integrity of the conclusions that are generated from a piece of research. In qualitative data, validity can be addressed through the honesty, depth, richness and scope of the data achieved, the participants approached, the extent of triangulation and the disinterestedness or objectivity of the researcher [22].

The findings clearly shown in the questionnaire, own direct observations supported by video and photo; and the reviewed document (published) were integrated and have similar response. Keeping these in mind, captured videos and photographs are collected by direct observation used to eliminate subjective bias. The percentage response of participants is very good. So, this is the content validity measure of degree of representativeness of the sample.

Conclusions

The actual road side drainage structures in the study area have the limitation of assessing of all required data and information's. And yet, all the designed parameters were not implemented on the ground during construction. The drainage structures found on these routes were highly affected by the placement of solid wastes and Absence of cross drainage structures.

The challenge of constructing and maintaining of these drainage structures were leads to erosion of ditches and edges of the roads. Because of low permeability nature of silt soil and rolling topographic conditions, the degree of erosion by the runoff is high. Therefore, the runoff is leaving solid wastes, sediments, debris and eroded cobble stones within the drainage and on pavement roads. These were leads to challenge free movement of vehicles, losses of properties and affect livelihood of the community. The results obtained from the analysis shows that the performance of the existing drainage structures in the study area are not good.

So, the poor disposal of solid wastes should be managed and redesigning of road side drainage structure is needed.

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