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Full Length Research Paper

Road and urban storm water drainage network integration in Addis Ababa: Addis Ketema Sub-city

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Urbanization along with its impermeable structures is the major causes of flooding in urban areas. Urban storm water influences the service life of urban infrastructures. The rainfall intensity and characteristics of catchment area are the major factors for designing urban storm water drainage facilities. These facilities have a paramount advantage to safely dispose the generated floods to ultimate receiving system. This study has assessed the integration of road and urban storm water drainage infrastructure with the help of topographic map and also the condition, pavement type and hierarchy of every road and drain were assessed in Addis Ketema Sub-city. This study area, particularly, is bounded in between Addis Ababa Municipality (East), Addis 'Ketema' high school and General bus terminal (West), 'Yohannes' Church (North-East) and Bethel high school (North-west). The objectives of this study includes: to identify sites most prone to flooding problems, to assess the existing condition of road and urban storm water drainage infrastructure, to identify the extent of integration of urban storm water drainage infrastructure in road projects provision, to examine the impacts of Urban storm water drainage infrastructure integration on road performance and related environment issues and to make recommendations on road and Urban storm water drainage infrastructure integration and their provision and management. An exploratory and descriptive type of methods were used to describe and investigate the existing condition and coverage and level of integration between road and Urban storm water drainage infrastructure infrastructures respectively. Data collection methods were carried out using both primary and secondary data sources, but the secondary data source was only relevant to reinforce the primary data, which was accomplished with the help of topographic map and a check list. The collected data were analyzed and presented using Microsoft-excel, AutoCAD and ArcGIS and tables, graphs and percentages respectively. The findings of this study includes: the major causes of flooding which was found to be the blockage of urban storm water drainage lines along with inadequate/poor integration between road and urban storm water drainage infrastructures. This study strongly recommends improvement in the integration of road and urban storm water drainage infrastructure and integrated solid waste management to prevent over flowing of flood as a result of blockage of drains.

Key words: Drainage, irrigation, urban areas, flooding.

INTRODUCTION

Infrastructure is one of the indispensable elements in the process of urbanization and emergence and continuity of an urban growth. It is considered as motor/engine for economic development (World Bank, 2006). Infrastructure is important in eradicating poverty through various job creation opportunities and by so doing, it enables to speed up economic development and ultimately ensures improved quality of life.

According to World Development Report (2006), infrastructure development in Africa is abysmal, lagging behind the rest of the world in terms of quality, quantity, and access.

The situation is worse in poor countries like Ethiopia, where a myriad of problems have made the supply of physical infrastructure and services to continually lag behind the urban population growth rate.

The high urban population growth rate on the other hand produces features associated with urban expansion. For example, the increase in population generates greater infrastructure demand, including road and urban storm water drainage facilities. When road and urban storm water drainage facilities are not properly provided

nor integrated in a given urban area, the performance of road infrastructure can be limited. Problems like flooding and erosion when persistent can shorten the life span of road infrastructures and other urban utilities.

Other urban utilities like water supply lines, telephone and electric lines can also be affected since road infrastructure often influence the locational pattern.

With urbanization, impermeability increases because of the increase in impervious surfaces. This in turn changes the drainage pattern, increases overland flow resulting in flooding and related environmental problems. The impact of this is severe on spatial structures like road. This is because, flooding and its related environmental problems like sheet and gulley erosion, surface inundation tends to affect road services and its life span. Given the significance not only in socio-economic development, but also a path way for the location of other infrastructure, issues that affect its performance and longevity are critical areas of research.

Addis Ketema Sub-city is a major economic nexus of Addis Ababa City. It is also the oldest and most economically significant part of the city. The largest merchandize market in Africa, Merkato (AACA, 2006), is also located in this sub-city.

Unfortunately, street flooding, over topping and other environmental related problems are common in this area. This is particularly severe in areas where road infra-structure appears to be without adequate storm water drainage infrastructure.

Problem statement

Inadequate urban storm water drainage problems represent one of the most common sources of compliant from the citizens in many towns of Ethiopia (GTZ-IS, 2006), and this problem is getting worse and worse with the ongoing high rate of urbanization.

The pattern of urbanization and modernization in Ethiopia has meant increase densification along with urban infrastructure development. This has led to de-forestation, use of corrugated roofs and paved surfaces. The combined effect of this results in higher rain drop intensity and consequently accelerated and concentrated runoff.

Due to inadequate integration between road and urban storm water drainage infrastructure provision and poor management significant proportion of the area is exposed to flooding hazards/risks. This has resulted in negative impacts on urban storm water drainage provision and management.

The location of Addis Ababa being at the base of mountain “Entoto and Yeka” is also a challenge. These mountains are bare and predominantly covered by eucalyptus trees, which further exposes the ground for degradation and thus contributes to the generation of more flood to the city of Addis Ababa, because eucalyptus trees do not let shrubs and bushes and grasses to grow underneath due to its soil nutrient depletion nature and/or high competition for water and nutrients.

Erosion and flooding problems have become pronounced instead of hindering the phenomenon.

Therefore, this research analysis the extent of integration between road and urban storm water drainage net-work and associated problems.

Research objectives

General objective

To assess road and urban storm water drainage net-work integration and the challenge of their provision in Addis Ketema Sub-city.

Specific objectives

1. To identify sites/areas most prone to flooding hazard/problems.
2. To assess the existing condition of road and urban storm water drainage net-work infrastructure.
3. To identify the extent of integration of urban storm water drainage infrastructure in road projects provision.
4. To examine the impacts of urban storm water drainage integration on road performance and related environment issues like flooding.
5. To make recommendations on road and urban storm water drainage integration and their provision and management.

Significance of the research study

This study, generally, contributes the following major significances:

1) The sub-city will use it as reference while they are preparing their annual plans in relation to spatial and financial plans for roads and urban storm water drainage infrastructure.
2) It has a special relevance to use it as a reference for infrastructure inventory. So that the new added and upgraded infrastructure will easily be upgraded to a recent data report through appropriate software.
3) Policy makers and any organization working in the area of roads and urban storm water drainage infrastructure can use it as a further reference to fill the existing gap between road and urban storm water drainage demand and supply.
4) It will be an alternative means of solution in ensuring sustainable development in Addis Ababa by strengthening the environmental and socioeconomic

activities in regarding to road and urban storm water drainage infrastructures.

Scope of the study

This study is geographically limited to Addis Ketema Sub-city of Addis Ababa. Generally, it will address issues related to urban storm water drainage and its integration with road provision. The specific focus of it includes: extent of integration of urban storm water drainage infrastructures in road provision, existing condition of road and urban storm water drainage net-work, impacts of integration of urban storm water drainage on road performance and related environmental issues and flood prone areas.

The engineering design aspects of roads and urban storm water drainage net-work, in general, are not part of this study.

General description of the study area

The study area, Addis Ketema Sub-city (Figures 2 and 3), is located in the capital city of Ethiopia, Addis Ababa. It is located between 38°50′ latitude and 8°45′ longitude. It is situated at the centre and is accessible to all parts of the city, Addis Ababa.

LITERATURE REVIEW

About thirty two valuable materials, which were published by various authors, have been employed in this research work as a reinforcing input. These materials along with their authors include:

1. Development of road and its origin (World Bank, 2006).
2. The historical development of road (Addis Ababa City Roads Authority, 2008).
3. The development of modern roads (Rebekah, 2006).
4. The history and origin of road development in Ethiopia/Addis Ababa (Addis Ababa City Roads authority, 2008; National High Way Institute (2001).
5. The history and origin of urban storm water drainage development (Addis Ababa City Roads Authority, 2006).
6. The history and development of urban storm water drainage infrastructure in Ethiopia (Federal Urban Planning Institute, 2006).
7. Current approaches in managing urban drainage system (GTZ-IS, 2006).
8. Policy issues in managing urban storm water drainage (Federal Urban Planning Institute, 2008).
9. Urbanization and urban storm water run-off (Leopold, 1968; Hollis, 1975; Neller, 1988; Booth, 1990, 1991; Glazner, 2001; GTZ-IS, 2006).
10. The importance of urban storm water drainage infrastructures/facilities (Thomas and Andrew, 2002).
11. The importance of road and urban storm water drainage integration (Fabian and Barry, 2003).

RESEARCH METHODOLOGY

Both descriptive and exploratory types of researches were employed. The descriptive type was used to describe the existing condition and coverage of roads and urban storm water drainage facilities. Whereas, the exploratory type was particularly used to explore the existing condition and coverage of urban storm water drainage facilities which were not found in the base-map was collected from the sub-city.

Data types and sources

Quantitative as well as qualitative data types were employed. Of the total data about 95% of the research data was collected from primary sources. Where as the rest 5% was collected from secondary data sources-this was employed to reinforce the primary data source.

Data collection methods

The following data collection methods were used.
About 10% of the primary research data was collected through questionnaires and interview. The rest 90% was collected through field survey.

1. Questionnaires were prepared for kebele and sub-city professionals to identify: areas prone to flooding, major causes of flooding, techniques of urban storm water drainage contract and budget allocation to road and urban storm water drainage infrastructure.
2. Interview was employed to collect data related to flooding hazards and causes of flooding through household survey.
3. Field survey was the dominant method of data collection in this study using base map and check list. The sizes of urban storm drains and roads have been measured and checked for their length, width, height and/or radius. It was also employed to identify the existing hierarchy, condition and pavement of road and urban storm water drainage infrastructure.

Data analysis

The collected data was analyzed with the help of Microsoft excel, AutoCAD and ArcGIS softwares.

Data presentation

The analyzed data was presented in tables, graphs, charts and percentages. Besides, GIS and CAD figures and field survey photos were also incorporated.

DATA PRESENTATION AND ANALYSIS

Here, which is the core of the study, focuses on data presentation and analysis of primary and secondary data composed from the households (Figure 1), and Addis Ababa roads authority, sub-city and Kebele officials and

Figure 1. The actual study area (Source: Google earth and Field survey, 2009).

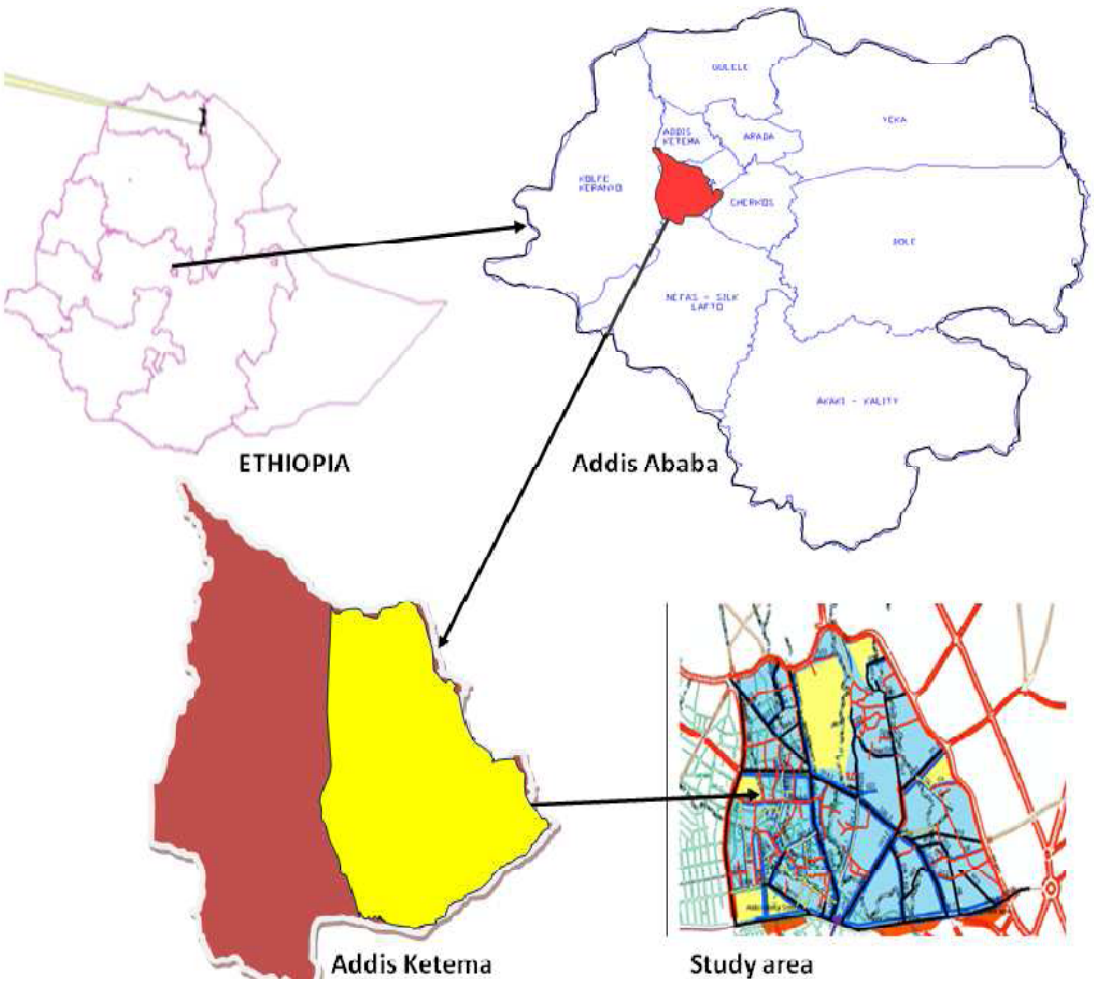

Figure 2. Location map of the study area (Source: GIS and AutoCAD analysis, 2009).

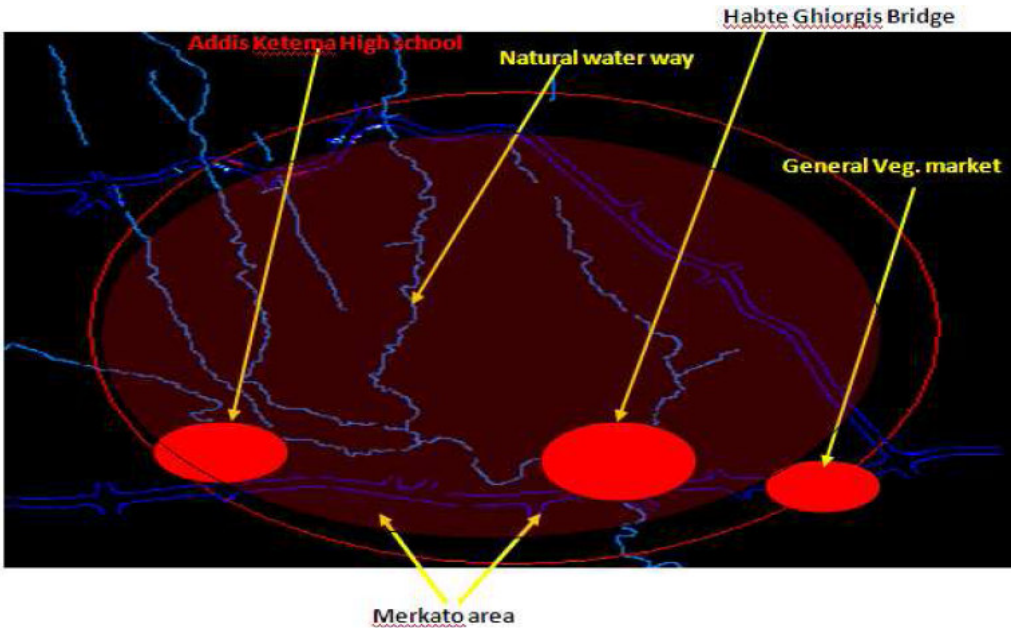

Figure 3. The major flood prone areas in the study area (Source: GIS analysis).

Table 1. Major flood prone areas in the study area.

Specific site/Kebele	Respondents in		Ranking of flood prone areas(high to low)	
	Number	percentage	Respondents' response	Field observation
Habte Ghiorgis area	12	35.29	1st	1st
Addis Ketema secondary school area	10	29.41	2nd	2nd
General vegetable market area	8	23.53	3rd	3rd
Neftegna locality(Kebele 31)	2	5.88	4th	4th
Addisu Michael area.	2	5.88	5th	-
Total	34	100	-	-

Source: Field survey April-May, 2009.

from researcher's direct observation The majority of this research work was drawn from researcher's field survey with the help of base map and checklists. The interviews and questionnaires were employed to reinforce the field survey data. In this research each and every road and urban storm water drainage infrastructures of the study area have fully been surveyed and observed.

Flood prone areas and causes of flooding in the study area

Major flood prone areas/sites in the study area

The major flood prone sites in the study area were identified through interviews from respondents, and questionnaires from kebele and sub-city officials along with field observations.

The purpose of identifying such flood prone areas was to investigate the root causes of the flooding problems and to give priority during the provision of urban storm water drainage facilities.

As depicted in Table 1 and Shown in Figure 4, a discussion with the community, the major flood prone area is Habte Ghiorgis (35.29%) followed by around Addis Ketema secondary school (29.4%) and General vegetable market (23.5%), which were evidenced from the respondents' response as well as field observation. The GIS Figure 3, shows the specific locations of these flood prone areas.

Causes of flooding

As it was observed during field survey the majority of the storm drains are blocked by solid wastes of various types and many residents illegally connect their sewerage system in to the existing drains. Besides, this idea is reinforced from respondents' response. Table 2 is an evidence to this truth.

Figure 4. Discussion with the respondents (Source: Field survey, 2009).

Table 2. The major causes of flooding.

No.	Major causes	Respondents	
		Number	Percentage
1	Blockage of drains by solid wastes	26	77
2	Sewer connection to drains	4	12
3	Inadequate drains	3	8
4	Absence of drains	1	3
	Total	34	100

Source: Residents and professionals interviews (April-May, 2009).

The implication of this analysis is that the Addis Ababa City Roads Authority, which is the sole urban storm water drainage and road provider in the sub-city, should give immediate attention for constructing closed/buried type urban storm water drainage lines in the provision of future road and urban storm water drainage infrastructure and a separate sewerage system. Besides, some corrective measures should be taken as per the actual design parameters/dimensions with a full consideration of the quantity of run-off generated in the respective catchment area.

Existing condition of road and urban storm water drainage net-work infrastructures

Existing condition and coverage of road infrastructure in the study area

The existing condition, coverage and hierarchy of roads in the study area were fully surveyed with the help of base map and check lists and the summary of the field survey is presented in Tables 3 and 4.

In this particular study, the least degraded road is stone surfaced and the highest one is asphalt. The implication of this is that: stone surfaced roads can give longer service life than asphalt and gravel roads. Thus, let alone comfort, stone surfaced roads are economical and asphalt with a high comfort has greater economic loss during construction as well as maintenance.

Existing condition and coverage of Urban storm water drainage net-work infrastructure in the study area

The flow of storm water run-off is one of the major problems in the study area as a result of urbanization and pavements of surfaces associated with blockage of urban storm water drainage net work management.

The summary of the condition and coverage of urban storm water drainage infrastructure is presented in Table 5.

From Table 5, the majority of drains is circular, which are closed/buried types. This implies that about half of the drains is open to the environment, which may cause

Table 3. Summary of road surface types and condition.

No.	Road type	Good(m)	Light (m)	Severe (m)	Total (m)
1	High way	2490	-	-	2490
1	Arterial	6345	-	-	6,345
2	Collector	3730	2923	3309	9,962
3	Local	4656	5678	2657	12,991
	Total	17,221	8,601	5,966	31,788 ~ 32km

Source: Field survey April-May, 2009.

Table 4. Detailed Length and condition of roads in the study area.

Road surface type	Total road		Counts	Road condition	Length (km)	Percent from total road
	Length (km)	Percent				
Asphalt	16.34	52	34	Good	13.62	42.6
				Light	0.533	1.70
				Severe	2.272	7.1
Stone surfaced	11.24	35	82	Good	3.32	10.40
				Light	6.20	19.4
				Severe	1.67	5.2
Gravel	4.2	13	19	Good	0.27	0.84
				Light	1.84	5.8
				Severe	2.02	6.3
Total	32	100	135		32	100

Source: Field survey (April-May, 2009).

Table 5. Summary of length and condition of urban drainage lines in the study area by type.

Drain shape	Construction material	Counts	USWD line length (km)	USWD condition	length (km)
Trapezoidal		13	3.82	Good	0.72
				Light	1.09
				Severe	1.58
			Percentage from total		17.4%
Circular/pipe	Masonry	58	10.50	Good	7.36
				Light	0.25
				Severe	2.98
			Percentage from total		47.7%
Rectangular		34	8.00	Good	2.51
				Light	4.27
				Severe	1.31
			Percentage from total		36.4%
Total		105	22.00		22.0

Source: Field survey (April, 2009).

many environmental problems including respiratory diseases. The other half is the open type it is because of this many of the drains are blocked by solid wastes.

All the circular/pipe drainage lines are buried/closed,

Table 6. Existing spatial integration between road and urban storm water drainage infrastructure.

The integration of	With			Total (km)	From the total drainage length (km) (%)
	Circular drainage line (km)	Rectangular drainage line (km) (%)	Trapezoidal drainage line (km)		
Asphalt road	10.59 (65.2%)	3.04 (18.7)	2.61 (16.1%)	16.24	74
Stone surface road	-	3.10 (86.4)	0.49	3.59	16
Gravel road	-	1.96 (87.1)	0.29	2.25	10
Total				22.08	100

whereas most of the rectangular and trapezoidal drains are open and are not environment friendly, which implies that these may encourage residents to connect and dump their sewerage systems and solid waste sources respectively resulting in unpleasant smells and are unaesthetic to the environment. As it was drawn from respondents during field survey, particularly open drainage lines are the major causes of respiratory diseases like Asthma, common cold and air pollution and other respiratory diseases.

The extent of integration of urban storm water drainage infrastructures in road projects provision

Provision of road and urban storm water drainage infrastructures are indispensable, particularly, in an urban center for safe and easy reachability from one area to another and to protect flood damage on infrastructure and utilities as a result of pavement. From the field survey and its analysis the integration of urban storm water drainage in road provision projects is summarized in Table 6.

From Table 6, for example the integration of asphalt road with circular, rectangular and trapezoidal drain types is 65.2, 18.7 and 16.1% respectively. From theses, the spatial integration between all roads and all urban storm water drainage infrastructures is found 42%. This implies that, it is only 42% of the roads have drains or for every kilometer of road there is only 420 m of drainage lines. The rest 58% of the road is without drainage facilities. Besides, the road density was analyzed and found 10%. The implication of these is that: the ever existing flooding problems will be continued, the gap between road andurban drainage integration gets widened, the environmental problems like soil erosion keeps continuing, the budget allocated for urban utilities will increase due to degradation of utilities and loss of effective land for other land use function increases.

The impacts of urban storm water drainage infrastructure integration on road performance and related environment issues

Deterioration of urban infrastructures and other urban utilities, bad smell and environmental pollution, urban land degradation, development of disease causing organisms were some of the findings resulted in inadequate integration between road and urban storm water drainage infrastructure.

Conclusions

1) Inadequate integration between road and urban storm water drainage lines followed by blockage of drains by solid wastes are the major causes of flooding in the study area.
2) Sewerage connection and solid waste dumping reduce the effective carrying capacity of drains.
3) To safely discharge the flood generated within the study area the urban storm water drainage facilities should be revised and designed.
4) Urban storm water drainage facilities should be contracted with roads for timely accomplishing and good work manship.
5) The budget allocated for the last and coming three years for road and urban storm water drainage provision has created a wider integration gap.

RECOMMENDATIONS

1) Proactive measures should be taken to reduce and manage flooding hazards (like clearing of drains before rain season begins).
2) Improvement on the integration of road and urban storm water drainage infrastructure.
3) Integrated solid waste management.
4) Urban storm water drainage infrastructure should be contracted with road infrastructure.
5) Encourage site infiltration through: Permeable pavements like porous concrete, coble stone, vegetated structures or grassing on road sides and vacant spaces/ gardens.
6) To ensure sustainable urban drainage management, there should be an integrated urban storm water drainage management.

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