INVESTIGATION OF FLOOD EFFECTS ON ROAD PERFORMANCE: A CASE OF ARUSHA, TANZANIA

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ABSTRACT

The effects of flooding on road performance have been a major concern in Tanzania, Arusha in particular. The paper aims at: identifying road elements susceptible to flooding, assess the financial cost of infrastructural damage, and suggest adaptation measures to improve transport services. The integration of empirical and spatial analysis enhances the identification of critical road components and hydraulic structures vulnerable to floods. The disruption of transport serviceability had wider economic impacts, estimated at 89% losses on 2011 regional GDP. Therefore the major effects were: maintenance cost, rerouting, congestions, delays and trip cancellation. These led to substantial impact on the economy, which may affect future flood adaptive capacity. This paper suggests for an interdisciplinary approach to support sectoral collaboration, between different stakeholders involving in transport to enhance sustainable resilience solutions on roads against the extreme flood events.
Key words: Flood effects, road performance, disruption link.

1. INTRODUCTION

1.1 Transport infrastructures and flood vulnerability

Flooding incidences in Arusha, Tanzania, resulting from high-intensity rainfall often affect transport infrastructure (URT, 2008). Usually flooding occurs during both the short (*Vuli*) and long rain (*Masika)* season, and it is sometimes associated with landslides (URT, 2014). This affects some sections of the road network exposed to multi-hydro hazards risks and unstable slopes. These unstable slopes tend to collapse during *Masika* and severely impair road service. In another view, soil erosion has also been a serious problem in the region (URT, 2008; Flores-Prieto et al., 2015). Apart from overstocking, overgrazing and other environmentally unfriendly activities. There is also evidence of black soil which covers large areas of Arusha and active volcanic activities that contribute to gully erosion (Flores-Prieto et al., 2015). Furthermore, the suspended sediments are usually deposited on the roads downstream the catchment, which in turn impairs transport services in the lowlands areas of Arumeru and Simanjiro during both wet and dry season (URT, 2008).

For the two decades before 2000, road maintenance received less attention in the road budget allocation in Tanzania. This oversight has led to an increase number of older infrastructure and the deterioration of road surfaces. There are a number of initiatives following the establishment of Tanzania Road Agency (TANROADS) and Road Fund Board (RFB) to reverse these trends and ensure the availability of funding for road maintenance, and upgrading the existing network to improve their resilience to floods. Despite these initiatives, inadequate and untimely maintenance has resulted in serious deterioration of road quality, which increases the level of susceptibility to flood damages and increase the adaptation cost. This places an additional burden on the already limited budget for road rehabilitation and/or reconstruction. The impacts, frequency, magnitude, and severity of these flood events are expected to increase with climate change (IPCC, 2012). This paper therefore aims to increase our understanding of the effects of flooding on road performance in Arusha region of Tanzania. In essence, the paper identifies road elements susceptible to flooding, assesses the economic cost of the infrastructural damages, and suggests adaptation measures to improve transport services.

1.2 Effects of floods on road performance

Empirical evidence shows that roads usually deteriorate more due to both rainfall and flooding incidences compared to temperature (Sultana et al., 2014). Usually, the deterioration of road performance may be due to excessive moisture content beyond the design threshold, which affects sub-grade surface and reduces their life cycle (Cervigni et al., 2017). The effects manifest through rutting, roughness, and potholes. Such conditions reduce road capacity, increase travel time and Vehicle Operation Cost (VOC and thereby lead to increment in transport cost. In the worst case scenario, flooding may even lead to link disruption. Furthermore, link or network disruptions after flooding may lead to trip cancellation, the use of alternatives routes or in a limited number of cases, and road users slowly making their way through the disruption section (Koetse & Rietveld, 2009). Jenelius and Mattson, (2012) indicate that unpredictable and irregular travel times are some of the important consequences of floods. This unreliability severely impacts on transportation of goods and the logistical chain efficiency which depends on reliable and short travel times. Meanwhile, the impacts of flood do vary depending on availability of alternative routes. The impact of floods is typically considered using a cost benefits analysis (Rolfe et al., 2011). However, in this paper, only costs associated with physical damages and link closure (small scale) was considered for analysis. Indirect costs have a substantial contribution to the total cost than direct cost (Rolfe et al, 2011; Wen et al., 2014). Their impacts, have both temporal and spatial scale, extend beyond the flooded area (Merz et al., 2010).

A review of literature indicates that travel time is the best quantification measure for road network performance (Jenelius & Mattsson, 2006; Krishnamoorthy, 2008; Rolfe et al., 2011). According to Rolfe et al., (2011), travel time considers delays and congestion time to reach destinations across different categories of both road users and traffics. It also measures social efficiency among other things. Meanwhile, a travel time metric was therefore, suggested for road performance. The use of this metric is also highlighted in Krishnamoorthy (2008); Serulle (2011); Rolfe et al., (2011); Pant 2012; Faturechi and Miller-Hooks (2015) among others. Unlike the total travel time, there are several road network performance metrics including throughput, economic loss and connectivity (Faturechi and Miller-Hooks, 2015), economic modelling approach (Rolfe et al., 2011), Vehicle Capacity (V/C) ratio (Timol, 2011) and Network Robustness Index (Scott et al., 2006) among others as alternative metrics for estimating increased travel cost due to network failure. Unlike Volume to Capacity (V/C) ratio, NRI allows evaluation performance of independent links, enhances both the understanding of the link and its spatial characteristics and informed transport planning decision. Pant (2012), summarizes this information in the form of an equation. The summation of the product of link flow and travel times over network. This implies that relative changes in total travel cost before and after breakdown, incidences or improvements, can be used as index of network performance.

Total Travel Time $=\sum_a Xa * ta(Xa)$

Where

X_a is the flow on link a

$t_a(X_a)$ is the travel time on link a.

2. METHODOLOGY

This paper will not only consider the cost of reconstruction, using the detour, delay, and congestion but also the wider economic effects. Here are steps systematically followed to carry out this analysis.

2.1 Description of the link under investigation

This study was conducted in Arusha, Tanzania. Arusha is the hub of international activities for the region and it is the headquarters of the East African Community. The area has diverse tourism activities which contribute to 20% of the regional GDP (URT, 1998). These activities attracted population growth, and stimulate the level of urbanization (Madulu, 2012). Arusha receives an average annual rainfall of between 600 mm to 1200 mm. The Arusha road network provides connections locally and internationally (see Figure 1, at the lower left corner). The analysis of effects of floods on-road performance considers the Makuyuni - Ngorongoro gate link only. The link is selected because of its importance to the economy. Despite these importance, there are poor alternative routes and sparse network, a situation which increases the risk of immediate effects. This link is a single route extending approximately to 76.54 km from Makuyuni junction. It traverses Mto wa Mbu, Karatu district to Ngorongoro Conservation Area gate. It is 2 hours' drive from Arusha to Ngorongoro gate. The alternative road traverses Babati town, connecting to an unpaved road via Karatu to Ngorongoro, which takes approximately 5 hours or more during the rainy season from Makuyuni Junction to Ngorongoro gate (Guides, 2015).

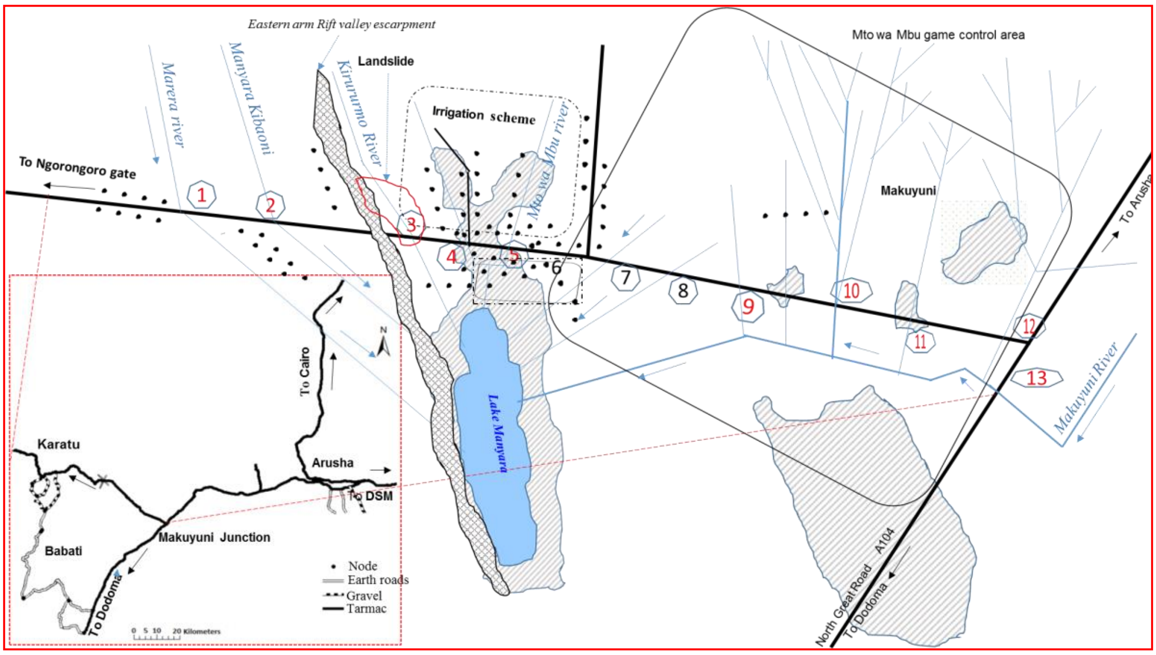

Figure 1 Sketch of selected stream crossings along Makuyuni - Ngorongoro gate link

2.2 Methods

This research adopted a mixed method approach in the understanding of the effects of flooding. Spatial, quantitative and qualitative data were integrated to answer the research objectives. The identification of flood prone areas considered are those affected by historical floods. Stream crossing locations along the Makuyuni- Ngorongoro gate link are identified and presented in a sketch map to enhance spatial analysis. The sketch maps were enhanced by vulnerability flood maps drawn by local participants and inferred by interviews with road agencies and selected informants in vulnerable road sections. Text analysis will be used in analysing the narrative stories and quotes from the respondents interviewed. In assessing economic cost of infrastructural damage, this study adopts a methodology from the Pant et al., 2010 and Rolfe et al, (2011) with modifications. Due to data limitation, the direct costs in this study is considered as the cost of emergency works for the whole region as reported by TANROADs. Estimation of indirect cost also forms part of the analysis. Due to data limitation indirect cost consider user impact and wider economic impacts, determined from narrative story during an informal interview with respondent from Ngorongoro Conservation Area. Furthermore, several assumptions were made to enhance estimation of impacts. Then, the results were combined to determine the total indirect cost, and hence total financial cost. This is regarded as minimum indirect cost as a result of 3 days road closure along Makuyuni - Ngorongoro gate. Total cost was also estimated to enhance the analysis of indirect costs.

3. RESULTS AND DISCUSSION

3.1 Identification of river crossings location

According to the damage report from TANROADs Regional Manager Office (RMO)-Arusha, there was flooding incident on 18th November 2011 as a result of high rainfall intensity. This affected box culverts on eight different locations; at 0.75 km, 5.25 km, 6.1 km, 7.5 km, 11.1 km, 12.6 km, 13.7 km and 13.8 km along Makuyuni - Ngorongoro gate link [Figure 1, numbered in red (left-right)). Sources of flood impacts were manifold, for example at location 1 & 2 evidence of siltation were observed. An Agricultural extension officer indicated that people damaged and broke the river banks to benefit from the flood water (re-route water for irrigation). In the process, the massive amount of eroded soil filled up the river channel and culverts, and thereby reduced the capacity of the hydraulic structures, it may be the source of overtopping, and hence, structural damages.

Figure 2 (a) - (f) Types of flood damages on road elements at Kirurumo Bridge
Source: Figure 2 (a) – (c) & (e) TANROADS (RMO) – Arusha; (d) & (e) Field survey, 2014

Landslide associated with flooding led to the bridge washout at *Kirurumo Perennial River due to the collapse of rift valley embankment* (Figure 2a, 2b & 2c), No, 3). This rift valley embankment has been weakened by persistent rainfall that saturated the soil over time. Informal discussion with an agricultural extension officer of Mto wa Mbu, at stream crossings location 4 – Simba bridge, indicated that *the bridge was flooded due to siltation as a result of the destruction of river banks upstream of the bridge*. Moreover, the site engineer indicated that *overtopping at* locations No. 9 to 12 is *caused by undersized culverts (Figure 3)*. Overtopping may be due to the large contribution of overland runoff generated from the degraded upstream catchment, and low level of the embankment (Figure 1, stream crossing No.11 & 12). This could be due to design restrictions and construction that should conform to wildlife Management Act specifications. Meanwhile, flooding damages on road pavement, side drains and bridges are evident in Figure 2a, 2b & 2c. These were direct impacts that led to reconstruction costs, clearing and cleaning which increased public expenditure. It also affected the flow of goods and services within and beyond the region, untimely reconstruction, could be lead to more effects on social welfare. It could affect timely product delivery, and loss of sales

Figure 3 Scouring downstream the culverts due to overtopping

3.2 Assessment of damages

3.2 1 Direct damages

Direct losses are the cost used for replacement of damaged facilities (Merz et al., 2010; Postance et al., 2017). In TANROADS reports this cost is regarded as cost of emergency works, it may not necessarily reflect the cost to reconsruction. Thus to enhance the analysis, summary of maintenance and emergency works for the period of 10 years (FY 2004/05 to 2012/13) are presented together for clear comparison (Figure 4).

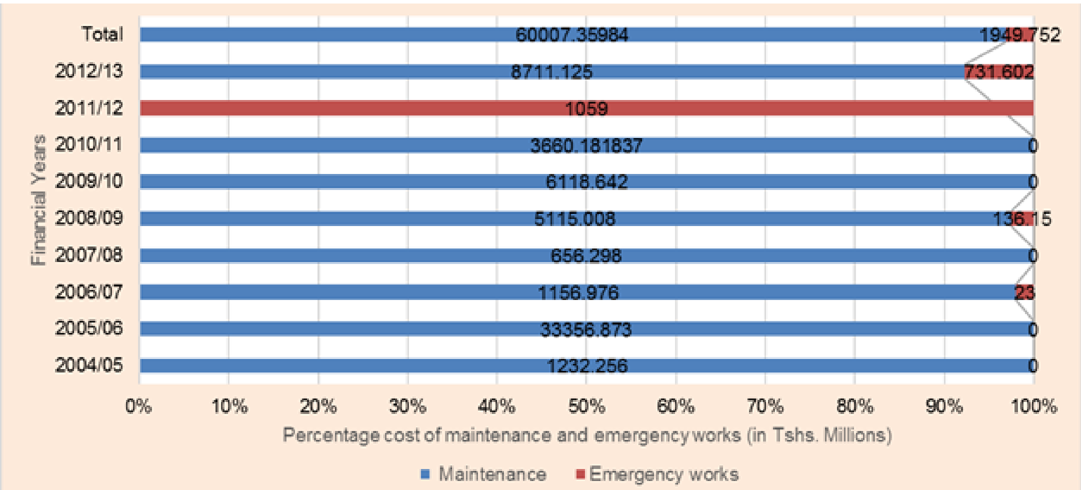

Figure 4 Cost of emergency works from FY 2004/05 to 2012/13

Source: TANROADS, 2014. Rate 2010: 1USD=1510.15 Tshs.

Results present nine and four years expenditure for maintenance and emergency works respectively (Figure 3). It appears that the damages do not only occur most frequently, but also their occurrence may not necessarily be caused by lack of maintenance. The total for emergence works is estimated at Tshs.1,949.745 million, equivalent to USD 1,291,094 (Figure 4). This is less than 5% of the total expenditure for the period of ten years. However this is considered to be the minimum estimation. So, the cost seems to be low, but could have an effect on the link robustness. The absence of the cost for the six years may mean that either no flooding occurred or that adequate and timely maintenance was done and, therefore, the risk level is low. Results also show the emergency works expense was approximately Tshs. 1059 million in the 2011/12, equivalent to USD 701255. This can be estimated at 54% of the total cost. It was also 100% of total expenditure in the same financial year, probably because 2011/12 was when the floods hit high, or it may be attributed by high spending on maintenance, which increases ability of infrastructure to resist the flood shock. Notably, the FY 2006/07 shows extremely low spending at 1% of the total direct cost. This could be an indication of low damages, or limited budget for emergency works (Figure 4). However, cost for emergency may have been diverted from developmental budget, and hence affecting other developmental trajectory, increase tax and prices. Direct damages are also associated with indirect losses which are presented in the subsequent sections.

3.2.2 Effects of bridge closure on the link performance - indirect losses

As previously indicated, a flooding incident occurred on 18th November 2011, led to a three days road closure. Traffic congestion and delays were among the immediate effects resulting from this link disruption (Figure 5a & 5b). Local communities are usually involved in restoring and improving the disrupted road section using local materials (Figure 5a). This was done to provide access for passengers to cross the river, to get services in the town while making their travel decisions. The response was essential to reduce immediate impacts on road users. It is evident that the restored accessibility is still poor compared to the situation before the flooding (see Figure 5b). Since the disrupted part is short, actual travel time and fuel consumption may not much consumed, compared to the previous situation. These costs, however, are typically the waiting time for the link to be restored, congestion time due to the traffic queue (Table 1).

Figure 5(a) Temporary accessibility improvement (b) One day after flood havoc

User impacts

In relation to damages of facilities, this paper considers the impact on users as a part of indirect cost. It therefore adopts total travel time metric with modification to estimate the impact of travel time losses. It also adopts historical standardised estimates used by local studies in Tanzania (TANROADS VOC, 2004). Results are summarised in Table 1.

Table 1 Estimate of users' travel cost in US$ in 2004 and 2011

Vehicle type category	Number of vehicles	Number of Passengers	Value of Time loss per hour ($) (W/hours-24h)	Value of Time loss per hour (NW/hours-48h	VOTT-2004 in US$	Value of Time loss per hour ($) (W/hours-24h	Value of Time loss per hour (W/hours-48h)	VOTT-2011 in US$	Percentages %
Cars	210	3.9	0.29	0.09	9238.32	0.46	0.14	14545.44	11.3
Pickups van	753	3.9	0.29	0.09	33125.976	0.46	0.14	52155.79	40.4
light lorries	11	3.9	0.29	0.09	483.912	0.46	0.14	761.904	0.6
Medium Lories van	90	3.9	0.29	0.09	3959.28	0.46	0.14	6233.76	4.8
Heavy lories	6	3.9	0.29	0.09	263.952	0.46	0.14	415.584	0.3
Very heavy lories	1	3.9	0.29	0.09	43.992	0.46	0.14	69.264	0.1
Small busses	67	14.4	0.29	0.09	10882.944	0.46	0.14	17134.85	13.3
Large buses	43	49.3	0.29	0.09	23912.472	0.46	0.14	37649.42	29.2
Labour Power	20		0.29		46.4	0.46		73.6	0
Total cost in US$					81957.248			129039.6	100

Source: Author's estimations based on TANROADs VOC, (2004) updated in 2011 & Traffic count (2011 & 2013)
Key: W/hours: Working hours NW/Hours: Non-working hours

Results indicate the contribution of each car category in the Value of Travel Time Loss (VOTT) (Table 1). It also indicates the amount estimated as VOTT at USD 129040. Such damage caused the region significant revenue loses in terms of business lost and delays. Out of this, pickup-vans present the highest percentage (40%). The high percentage could be attributed to the fact that tourism industry utilises more of these kinds of vehicles than other types of vehicles. Besides, tourism is the main activity in the area. Therefore, this may also mean that the tourism industry could have been more impacted when compared to others. The percentage of buses (large and small) tends to be higher than the pickup vans, and they carry large number of people which implies their impact could have also been high on the road surface. Other car categories and human labour time loses had very low percentages with a summation of less than 10%. Even so, they still experience significant time losses, lost business opportunities and lost significant productive time.

3.2.3 Wider economic impacts

In another occasion, a key informant from Ngorongoro Conservation Area interviewed telephonically, categorized the flood victims into two main groups. First, those who started their journey and second, those who were yet to start their journey. In the conversation the respondent reported:

> "…The first group was impacted differently (i) Tourists whose visas were about to expire were forced to amend their travel plan and use flights instead, from the nearby tourist airstrip (Ngorongoro). These inquired higher cost in terms of time and money. (ii) Tourists who used big traveling companies proceeded with their journey to Arusha and others to Ngorongoro and Serengeti immediately after crossing the river they were transferred to other cars. Meanwhile, those who hired vehicles from small companies had to cross the water and some had to either: (i) wait for accessibility to be improved so that their cars would take them to their destination (ii) or look for other alternatives transport available to transfer them to the airport. Meanwhile, the second group that was yet to start their journey from Ngorongoro to Arusha had to wait in the hotels for the accessibility to be improved and some had to use flights instead of road transport. These affected tourist businesses such that the numbers of tourist were reduced by 60% from 2500 to 1000 tourists per day".

This quote reveals different implications: (i) the people who changed their travel pattern went for alternative transport modes, paid more for the flight at the National park to connect the flights to their next destinations; though their number was difficult to obtain. (ii) The group that used the big tourist companies wasted considerable time during flooding, but have managed to recover their journey only after crossing the water. The major impact could have been the reduction of the percentage of tourist by 60% within one week. This reveals the wider economic effects, where a number of tourists cancelled their trips avoiding unforeseeable cost or effects of disruption. However, the business returned to normal after a week (Melita, 2015). The Melita's review indicates that the overall annual increase was observed for three consecutive years, 2012 to 2014, for a day trip, 1 day and 2 days' stay, while the through traffic to Serengeti had annual increase in 2013. This increase may be associated with other factors including quick flooding response, level of service, security, and availability of unique species of biodiversity rarely found in other places in the world.

Effects of link disruption on tourism business

The tourism business has many broad categories that contribute to the total income, including the entire transport sector, services like the hotel. Some of these costs need to be collected in aftermath of the floods. Owing to data availability, the analysis is limited to the tourism business at Ngorongoro Conservation Area Authority (NCAA). Based on the information obtained from informal discussions with NCAA, respondents revealed that the wider economic effects can be traced through business losses (Figure 6).

Assumptions used for business losses

Different assumptions were adopted to enable the calculation of business losses requirements. All the calculations are based on 2010 USD rates. According to the informant, 1000 tourists who visited NCAA came from Arusha. The assumptions include:

- Through traffic to Serengeti did not use the service facilities at Karatu.
- Normally the price for overnight stay accommodation ranges between USD 238 and USD 326. In the recession period, prices increase. Assuming pre-flood price is USD 238, while the post-flood price is USD282 (the average).
- Since the hotels are not locally owned, their impact will not affect local economy only. Thus, only the loss of revenue is qualified for macroeconomic analysis.
- Assuming that there were constant 1000 visitors, paid the same amount throughout the 4 days. The entry fee for accessing the crater remains USD 50 per head and USD 200 per vehicle with 3.9 passengers each. The estimates of induced business losses are summarised in Figure 5 above.

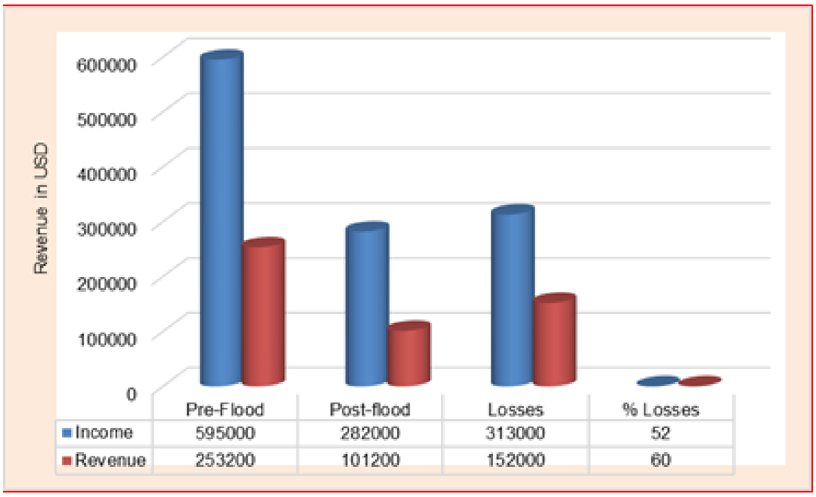

Figure 6 Flooding impact on business

Results indicate both pre and post flood situations and the losses accrued (Figure 6). The losses attributed to 52% decrease of income and 60% of revenue (Figure 6). This implies that there was more losses of revenue as a link disruption, than earning accrued in post flood. This could have an effect on the monthly earning from the NCAA. There was also 64% more percentage of earnings from service providers before the floods than after link disruption. This could have an impact on the operation and management costs. Evidently, results present decrease in both revenue and income in the two scenarios, which could have an impact on the authority income. Estimation of losses for a week after floods enhanced the determination of macroeconomic impact. The extent of the impact is summarised in Table 3.

Table 3 Wider economic effects

Loss category	Rate used for estimation	Total loses in US$	Percentages (%)
Loss of revenue (2500-1000 tourist)	1500*50 *4	300000	13
Loss of revenue 2500/3.9=641 vehicles; 1000/3.9=256. Thus, (641-256= 385)	385*200*4	308000	13
Loss of income for service providers for 1 night /person	282*1500*4	1692000	74
Total		**2300000**	**100**

Source: Author estimation based on 2010 US$ rates (1USD=1550.15Tshs; 2011GDP =683159, NBS).

Moreover, the results show that in the selected two categories, the losses amount to USD 2,300,000. Out of this, 26% account for revenue losses from entrance fees, for Ngorongoro crater, and, 74% for service providers. The loss of service providers seems to be higher than the loss on NCA revenue. However, the loss of service providers could not affect Arusha economy because the bookings for hotels and traveling are done in Dar es Salaam. The hotels are foreign owned, so the impact or contribution is not part of Arusha's economy, however, there may be effects on employment, and multiplier effects. This could have led to the temporary price increase and public spending, which could hamper the tax and increase borrowing. However, due to other peculiar characteristics of the tourist zone and other factors, tourist business recovered and maintained the annual growth rate.

3.3 Total Economic cost

The total economic cost can be determined since both direct and indirect costs are known. The summation of estimated costs was determined using direct cost, VOTT and loss of revenue from wider economic effects. Based on previous estimations in Figure 1, Tables 1, 2 and 3, the total cost as a result of 18th November 2011 link disruption was approximately USD 3,130,294. Results indicate 22% represents direct cost, 74% represents wider economic impact, and 4% represents value of time loss (Figure 7). It appears that indirect cost have higher percentage of loss (78%) than of direct lost. This coincides with other studies, like Rolfe et al., (2011), the estimated indirect cost in this higher than the summation of indirect costs. This may be as a result of the costs attributable to the eight different sections damaged by floods in the same link. This may increase tax and government indebtedness if the funding was transferred from the developmental budget.

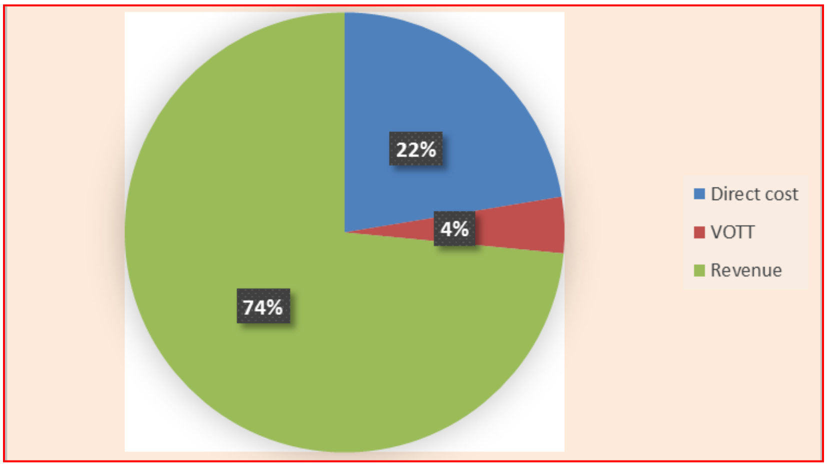

Figure 7 Total damages

4. CONCLUSION AND RECOMMENDATIONS

Based on both the descriptive analysis and findings reported in this paper, the following conclusions can be drawn: Firstly, flooding is a major threat to transport infrastructures in Arusha region where it has affected almost all road elements. Particularly it has affected undersized drainage structures due to overtopping in river crossing locations, and road surfaces exposed to erosion. Secondly, siltation tends to reduce hydraulic capacity and impairs transport serviceability in the lowland areas of Arumeru and Simanjiro. The impacts on the lowland areas are, however, expected to be low because of unpaved roads; repairs done by the community members tend to reduce macroeconomic impacts. Thirdly, the disruption of transport serviceability had wider economic impacts, estimated at 78% of total cost. Major effects were revenue losses, time losses and loss of sales. The total financial cost manifested through the cost of delays, revenue and income lost. This, however, cannot be generalized for the situation of Arusha region, because only one link was involved, which has unique characteristics. Thus, this result will inform other areas with the same characteristics.

Based on these findings, this paper recommends the following: First, an interdisciplinary approach to support sectoral collaboration between different stakeholders involving in transport which reduces future uncertainty. This requires knowledge sharing among different actors in assessing transport vulnerability of various links in the road network; enhance sustainable resilience solutions for the road network. Since hydraulic structures were frequently affected due to overtopping. Furthermore, this paper suggests for economic efficiency assessment to inform the decision of cost-effective options that will reduce the risk of flooding. Finally, the budget on emergency works and major rehabilitation should be increased not only to ensure timely and adequate maintenance but also enhance adaptation to extreme flooding events.

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