COST-BENEFIT ANALYSIS: VOLTA RIVER

TRANSPORTATION

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Academic Abstract

This paper analyzes the effect of investment into Ghana's Volta Lake transport system that would improve mobility of passengers and cargo in this region. This project requires large investments in infrastructure and recurring operational costs to sustain the system and offer benefits to the communities surrounding Volta Lake and to Ghana in general. The goal of the multi-modal corridor is to be competitive when compared to the alternative corridors in Ghana and neighbouring countries, which all transport passengers and cargo to Northern Ghana and landlocked countries to the North. The results show that the economic feasibility of the project is highly dependent on the percentage of cargo-carrying traffic that chooses to use the multi-modal corridor compared to competing corridors. For this reason, analysis of projects that change the attractiveness of competing corridors should be considered for further project analysis and implementation.

Key Words: Ferry, Cargo transport, Cost-Benefit Analysis, Volta Lake

Policy Abstract

The Problem

Ghana has had a period of significant economic growth. They have also experienced steady population growth between 2.4% and 2.7% over the past few decades. In the face of this growth, there is a need for the transport sector to grow to be able to maintain increased transport of goods and passenger travel. Improving the depreciating infrastructure and expanding the capability of road and water transport is vitally important for Ghana's continued economic growth. The state of transport infrastructure has a direct impact on the communities living in the Volta Lake area. Poor mobility, whether due to bad roads or lack of water access, makes it more difficult or costly to access nearby communities where there might be markets, access to health care, and regional development programs. Therefore, Ghana needs a solution to improve the poor state of its roads and water transport in order to support economic growth and rural mobility around Volta Lake.

Intervention: Volta Lake Transport System

Overview

This analysis will consider transportation improvements on the Volta Lake. The goal of the intervention is to develop the Volta Lake into a major transportation artery by building modern ferry ports and providing upgraded ferries and pontoons in collaboration with the private sector.

The primary benefits of this project are expected to be reduced transportation costs associated with shipping to the north of Ghana and beyond (ex. Burkina Faso). To properly identify the impact of the intervention on different stakeholders, we will consider the allocation of costs and benefits to different stakeholder groups.

In preparation of a Master Plan for Volta Lake, Roche (2014) identified 11 passenger ferry routes for prioritization. These locations were chosen using traffic forecasts of 2018 demand. They identified the need for 7 major ferry routes that had a projected demand of 500,000 passenger crossings annually, as well as 4 ferry routes with lower demand that would serve isolated communities (Roche 2014, 120). The project includes building new landing infrastructure and reception facilities, and the purchase of new ferries for these routes.

For carrying cargo North-South, Mpakadan is the most viable location for the Southern port and has existing infrastructure for ships. In addition, investment and construction has already begun in support of a new rail line connecting Tema Port to Mpakadan, near Akosombo. For the Northern Port, the considered location is Buipe as it provides connectivity through existing infrastructure (Roche 2014, 109). During certain parts of the year, Buipe is not available by ship due to low water levels. For this reason, there is also a port at Debre capable of handling the ships when the water level is too low to get to Buipe. However, the identified long-term solution is to invest in dredging from Debre to Buipe.

There are multiple options to achieve the goal of reducing transport costs for cargo and increasing access to transport in rural areas. In Ghana's Volta Lake area, there is a question as to whether improvement in road, rail, or transport by ferry will provide the most benefits. Although each of these projects has the possibility of reducing transport costs and providing better access to transport, each option has different costs and benefits that accrue to stakeholders. The scope of this analysis is only to measure the costs and benefits of investing into ferry transport on Volta Lake. Due to the fact that there are multiple options for transporting goods, the analysis will also assess how much cargo needs to be transported on the multi-modal corridor in order for the project to have an overall positive economic impact.

Implementation Considerations

There is a need for an integrated plan that addresses the issue of how a new project would impact the current use of the lake. Specific consideration should be directed towards the use of the lake as fishing grounds for isolated communities. This would require an environmental assessment and analysis of how the removal of tree stumps would affect Volta Lake's fisheries, including a direct assessment of how implementation of the ferry and cargo routes will impact the environment, the fisheries, and the livelihoods of the lake communities.

Another consideration is the relative importance of the multi-modal corridor for transporting cargo. Specifically, the use of the multi-modal corridor will depend on its attractiveness and competitiveness compared to alternative transport routes, both in Ghana and in neighbouring countries. If any improvements to roads that compete with the multimodal corridor are being considered or implemented, it will affect the figures presented in this report.

Costs and Benefits

Costs

The costs associated with this project include investment, operational costs, the costs of tree stump removal, increased carbon emissions on complement roads, handling costs at transitions, and increased handling time. These values assume 80% percent of cargo are diverted to multi-modal corridors but sensitivity analysis for this parameter is conducted later in the paper. These costs are analyzed over a twenty-year time period in Table 1 below.

Table 1: Costs of Volta River Transport System

Items	Cost (USD)	Cost (GHS)
Investment Cost	239,486,643	1,317,176,538
Operational Cost	424,913,968	2,359,653,493
Tree Stump Removal	94,000,000	522,005,500
Increased Carbon Emissions on Complement Roads	16,043	89,091
Handling Costs	184,834,751	1,026,433,581
Increased handling time	2,429,114	13,489,477
Total Cost	847, 209, 149	4,759,953,627

Note: All figures reported with 8% discount rate; assumes an exchange rate of 5.55 USD/GHS (Bloomberg)

Benefits

The benefits associated with this project include vehicle operational cost savings, road maintenance savings, reduced carbon emissions, and informal boat service operational cost savings. The benefits over a twenty-year time period are shown in Table 2 below.

Table 2: Benefits of Volta River Transport System

Items	Benefit (USD)	Benefit (GHS)
Vehicle Operation Cost Savings	616,761,860	3,425,032,799
Carbon Emissions Averted	13,171,407	73,144,116
Informal Boat Service Operational Cost Savings	288,911,805	1,604,399,481
Total Benefit	1,049,933,510	5,830,543,264

BCR Summary Tables and Graph

Table 3 and Table 4 provide summaries of the BCR for the proposed project with Table 3 presented in U.S. dollars and Table 4 presented in Ghanaian Cedi. The BCR is greater than 1.0 at all discount rates and the quality of evidence for each of the discount rates is rated as "Medium". Similarly, Figure 1 provides a visual representation of the costs and benefits by type.

Table 3: Summary of Benefits and Costs, USD

Discount Rate	Benefit (USD)	Cost (USD)	BCR (80%)	Quality of Evidence
5%	1,555,129,974	1,161,195,156	1.34	Medium
8%	1,049,933,510	851,680,520.18	1.23	Medium
14%	535,767,056	531,210,152	1.01	Medium

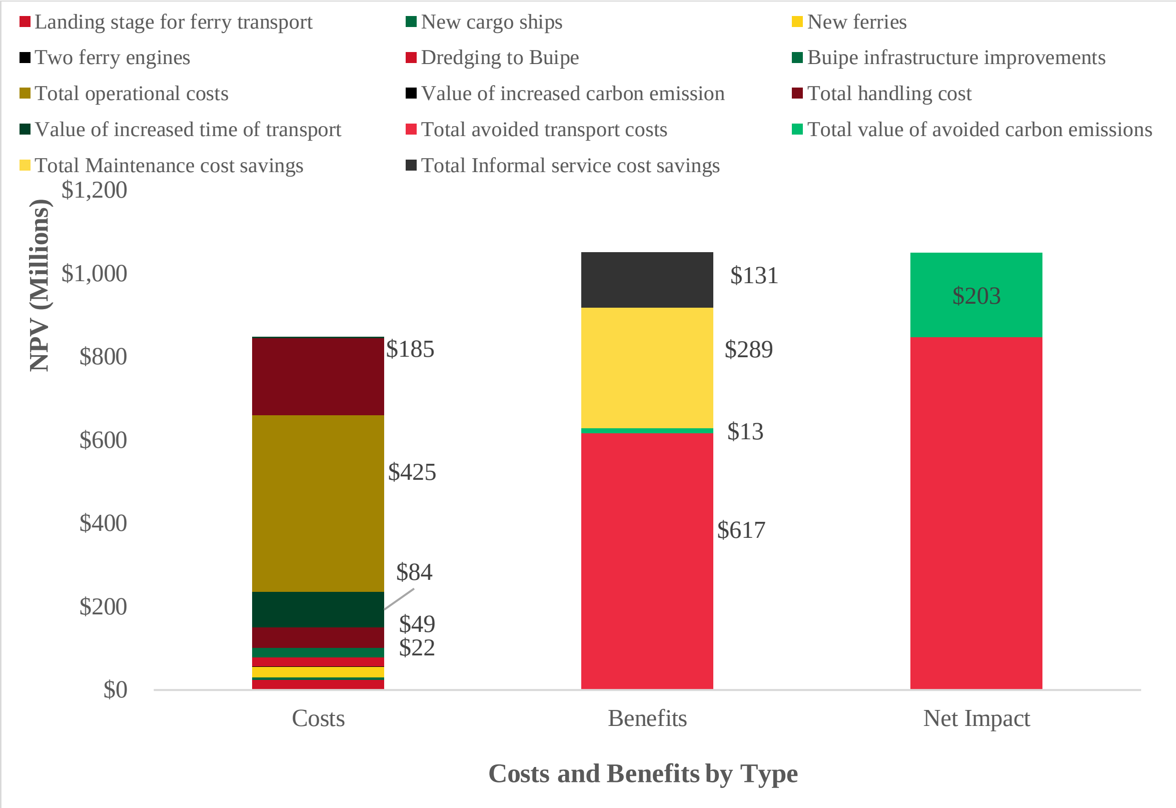
Notes: All figures assume 80% of traffic diverted to multimodal corridor, sensitivity analysis conducted below

Table 4: Summary of Benefits and Costs, GHS

Discount Rate	Benefit (GHS)	Cost (GHS)	BCR (80%)	Quality of Evidence
5%	8,553,214,856	6,386,573,362	1.34	Medium
8%	5,774,634,302	4,684,242,861	1.23	Medium
14%	2,946,718,807	2,921,655,839	1.01	Medium

Notes: All figures assume 80% of traffic diverted to multimodal corridor, sensitivity analysis conducted below

Figure 1: Summary of Benefits and Costs by Type, USD



Introduction

Ghana has been experiencing steady growth in GDP and population. This growth, however, is not supported with enough infrastructure to encourage more sustainable growth that will further improve the welfare of Ghana's people. One of the sectors of infrastructure that requires significant improvement is transport. The roads that lead from Tema Port to the more northern parts of Ghana and beyond are in poor condition. Despite this situation, most cargo is carried by transport trucks.

The implementation of the multi-modal corridor, including investment in improved ships and landing facilities for cargo to travel to the north of Volta Lake, provides one potential solution for addressing the region's transport issues. The improved transport system will improve access to ferry transport for communities living in the surrounding area, which is currently served by an informal service of boats and roads that are generally in poor condition.

This paper assesses the economic and financial feasibility of this transport system based on the current data available and discusses what other data and analysis would be required prior to project implementation.

Volta Lake Transport

Background

According to a Roche survey of boat building around Volta Lake and Volta Lake Transport Company (VLTC) records, approximately 2,727,000 people travelled on Volta Lake in 2012. Out of this population, 2,400,000 used informal boat services and sixty-nine percent of all travelers were crossing the lake on market days (Roche 2014).

Cargo being carried across the lake is almost split evenly between VLTC and informal services. Currently, VLTC carries cargo using two push tugs and five barges, while cargo carried by the informal service is normally goods being carried on with passengers. The most common cargo includes oil products, cement, and yams. Volta Lake Transport Company would be able to carry more goods if they were less susceptible to breakdowns as people prefer to use the more reliable informal service, especially if bringing cargo such as fresh produce or fish to market.

The VLTC currently runs 5 ferry vessels with an average capacity of 400 passengers each. The bad condition of the vessels has led to less frequent trips, longer travel time, and less people crossing the lake (Roche 2014). Moreover, the bad condition of the vessels and infrastructure limits the capacity to operate the ferry or carry cargo. The fact that the service is unreliable reduces demand for the ferry service and reduces the transport of goods. By investing in new vessels and operating on a more regular schedule, we can reduce the cost of crossing the lake and of transporting cargo to Northern Ghana and the landlocked countries to the North.

Ghana has had a period of significant economic growth. They have also experienced steady population growth between 2.4% and 2.7% per year since 1960. Over the next twenty years the population is expected to grow at an average of 2.5% annually. The Integrated Transport Plan forecasts that over the next 20 years, real household expenditure will grow at an average of 4.64% in Northern Ghana and around Volta Lake. In the face of this growth, there is a need for the transport sector to grow to be able to keep pace with the increased transport of goods and passenger travel. Improving the depreciating infrastructure and expanding the capability of road and water transport will be an important barrier to overcome in order for Ghana to be able continue to grow.

The state of transport infrastructure has a direct impact on the communities living in the Volta Lake area. Poor mobility, whether due to bad roads or lack of water access, makes it difficult to access markets, health care, and regional development programs. Therefore, Ghana needs a solution to the poor state of roads and water transport in order to support economic growth and rural mobility around Volta Lake.

Description of intervention

In preparation of a Master Plan for Volta Lake, Roche (2014) identified 11 passenger ferry routes for prioritization. The Master Plan developed 20-year forecasts for passenger demand based on projected demand for 2018 and data from the 2012 boat building survey. Locations for ferry transport were chosen based on crossings data from the survey and traffic forecasts. They identified the need for 7 major ferry routes that had a projected demand of 500,000 passenger crossings annually, and 4 ferry routes with lower demand that would serve isolated communities (Roche 2014, 120). The project includes building new landing infrastructure and reception facilities as well as the purchase of new ferries for these routes.

For carrying cargo North-South, Mpakadan is the most viable location for the Southern port and has existing infrastructure for ships. Investment and construction have already started for a new rail line connecting Tema Port to Mpakadan, near Akosombo. For the Northern Port, the considered location is Buipe as it offers some existing infrastructure (Roche 2014, 109). During certain parts of the year Buipe is not available by ship due to inadequate water levels. For this reason, there is also a port at Debre capable of handling ships when water levels are too. In the long run, the identified solution is to invest in dredging from Debre to Buipe.

There are multiple options to achieve the goal of reducing transport costs for cargo and increase access to transport in rural areas. In Ghana's Volta Lake area, there is a question as to whether improvement in road, rail, or transport by ferry will provide the most benefits. Although each of these projects has the possibility of reducing transport costs and providing better access to transport, they will each have different costs and benefits that accrue to different stakeholders. This analysis looks to identify the costs and benefits solely of investing into ferry transport on Volta Lake and how it will affect different stakeholders. Due to the fact that there are multiple options for transporting goods, the analysis will also assess how much cargo needs to be transported on the multi-modal corridor in order to have a positive overall economic impact.

Data

Much of the data in this analysis is based on the Roche 2014 report on the medium-term master plan for Volta Lake. Other than the Roche consultancy services there has been very little data collection or research conducted in the Volta Lake region. In order to ensure our choice of parameters was as accurate as possible, we reviewed other ferry projects for investment and capital costs.

Calculation of Costs

Investment Cost

Construction costs include the construction and improvement of infrastructure needed to operationalize the North South cargo service and 11 ferries at the desired capacity. This includes the required docking facilities, reception facilities, and improvement of necessary access roads. The Northern and Southern cargo ports, at Buipe and Mpakadan respectively, require increased infrastructure to allow for increased cargo handling capacity. Buipe is not always accessible by ship due to the varying water levels of the lake. Debre was not chosen as the main Northern port due to difficulties expanding the Debre port facilities and therefore is only used when Buipe is unavailable (Roche 2014, 110). There are two possible remedies to this, the first is to improve the facilities at Debre and the other option is to dredge the length of the Black Volta River from Debre to Buipe. According to the Ministry of Transport Ghana, the first option is estimated to have a cost of approximately 45 million USD while the dredging is estimated to cost 25 million USD. Based on feedback from the Ministry of Transport we have chosen to include the project with the dredging option. However, it should be noted that if improvement of Debre is chosen, it will increase investment costs. Nine out of the eleven routes require new ferries but there are two ferries that only need engine replacements.

Table 5 provides a summary of the key variables used to calculate the investment costs. These costs are incorporated into the model beginning in the 1st year of the project. In total, these costs represent $168.8 million (GHS 937 million) with U.S. dollars adjusted to 2020 levels.

Table 5: Investment Costs

Inputs		Unit	Value	Source of verification
$I^{landing}$	Landing stage investment for passenger ferries	USD/GHS	2.6 million / 14.4 million	Roche 2014, v
I^{ships}	Cost of cargo ships	USD/GHS	2.9 Million / 16.1 million	Samsung 2019
I^{Ferry}	Cost of passenger ferries	USD/GHS	3 million / 16.5 million	Samsung 2019
$I^{Ferries}_{engines}$	Engines replaced for Adawso and Dambai ferries	USD/GHS	2.4 million / 13.3 million	Madsen 2011, 5
$I^{Northern\ Port}_{Dredging}$	Dredging	USD/GHS	25 million / 138.8 million	Transport Ministry
$I^{Northern\ Port}_{Facilities}$	Northern port container handling facilities	USD/GHS	25 million / 138.8 million	Roche 2014, vi
$I^{Southern\ Port}_{Facilities}$	Improved Container handling abilities at Mpakadan	USD/GHS	60 million / 330 million	Roche 2014, vii
N^{Ships}	Number of cargo ships required	#	2	Roche 2014, 39
$N^{LandingS}$	Number of landing stages required	#	11	Roche 2014, 20
N^{Ferry}	Number of ferries required	#	9	Roche 2014, 120
Calculation				
Cost:	$C1_t^{Primary\ Implementer} = I^{landing} \times N^{LandingS} + I^{ships} \times N^{Ships} + I^{Ferry} \times N^{Ferry} + I^{Ferries}_{engines} + I^{Northern\ Port}_{Dredging} + I^{Southern\ Port}_{Facilities}$			

Operational Cost

Operational costs include the cost of fuel consumption and maintenance required for the operation of 2 cargo and 11 ferry boats. The analysis assumes that each ferry route will make a trip 5 times a day. In the first years of operation the expected cargo imported would require 324 round trips by ship per year and the number of trips per year will grow to 1254 round trips per year by 2044 (Roche 2014, 112). Maintenance costs for ferry and cargo boats assume 30 dollars per operational hour and an average of ten hours of operation per day (State of Washington Joint Transportation Committee 2006). The cost of fuel is based on the 10-year historical average.

Table 6 provides a summary of the key variables used to calculate operational costs. These costs are incorporated into the model beginning in the 4th year after the project has started. In total, these costs represent an NPV of $424.9 million (GHS 2.359 billion) using a discount rate of 8%.

Table 6: Operational Costs

Inputs		Unit	Value	Source of verification
C^{Fuel}	Cost of fuel per gallon	USD / GHS	3.52 / 19.54	tradingeconomics.com
L^{Fuel}_{ships}	Fuel consumption per km for cargo ships	Gallons	32	Grønsedt 2014, 31
K^{Ships}	Kilometres of a roundtrip	Km	400	Roche 2014, 36
$L^{Fuel}_{Ferries}$	Fuel consumption per km for ferries	Gallons	1.875	Parametrix 2006,4-1
$K^{Ferries}$	Kilometres per week for ferries	Km	3535	Roche 2014,118
T^{Weeks}	Weeks of operation per year	#	52	
$N^{Roundtrips}$	Number of north-south trips per year (2023)	#	324	Roche 2014, 112
$G^{Roundtrips}$	Increase in trips per year	%	7	Roche 2014, 112
$M^{Maintenance}$	Maintenance cost per year per route	USD / GHS	109,500 / 19,718	Parametrix 2006,4-1
S^{Ferry}	Staff needed for each ferry	#	4	Parametrix 2006,4-1
$N^{Ferries}$	Number of passenger ferries	#	11	Roche 2014, 20
W^{Staff}	Daily wage for staff	USD/Day / GHS/Day	2.16 / 11.9	ghanaweb.com
N^{Ships}	Number of cargo ships	#	2	Roche 2014, 39
S^{Ships}	Staff needed for each cargo ship	#	12	Roche 2014, 47
Calculation				
Cost:	$C2_t^{Primary\ Implementer} = [L^{Fuel}_{ships} K^{Ships} C^{Fuel}] N^{Roundtrips} (1 + G^{Roundtrips})^{t-t0} \times N^{Ships} + [H^{Ferries} N^{Ferries} L^{Fuel}_{Ferries}] \times T^{Weeks} + M^{Maintenance} [N^{Ferries} + N^{Ships}] + W^{Staff} [N^{Ships} S^{Ships} + N^{Ferries} S^{Ferry}]$			

Tree Stump Removal

The routes for the cargo ship and ferries need to be cleared in order to be navigable and safe. When the Volta River was created, many trees and rocks were left that now block the route the ships need to take. The cost of removing these trees was estimated by the Transport Ministry in Ghana. This represents the cost of physically removing the trees and rocks that block the lake routes. There are, however, more costs to society beyond the physical costs of removing the trees. Tree stumps act as a breeding, nursery, and feeding ground to fish in Volta Lake. Removing the trees could reduce fish breeding and the fish population, and, by extension, result in a negative impact on the incomes of local fishermen. In fact, there was concern from affected stakeholders that the removal could lead to the extinction of some fish species (Roche 2014, 130). Attempts to remove the tree stumps were previously met with resistance from communities surrounding the lake.

Table 7 provides a summary of the costs to physically remove the tree stumps from Volta Lake, including $94 million (GHS 522 million) with U.S. dollars adjusted to 2020 levels. There is a need to identify what the other effects of the tree removal on the lake might be and how the routes can be cleared while causing the least damage to the Lake and to the incomes of the fishermen. The data needed to analyze this effect was not available at the time of analysis, but it should be considered before project implementation.

Table 7: Tree Stump Removal

Inputs		Unit	Value	Source of verification
I^{Trees}	Cost of tree removal	USD/GHS	94 million / 522 million	Transport Ministry

Increased Carbon Emissions on the Complement Roads

The project is expected to decrease the cost of importing goods through Ghana for the landlocked countries to the North. These reduced costs would result in increased demand from the northern countries, which would lead to an increased shipment of goods coming through Ghana. These increased shipments would increase the amount of carbon emissions emitted from transporting cargo from Tema to Mpakadan, which currently is not part of the trucking route. It would also increase the carbon emissions emitted on the northern compliment road which is also expected to have an increase in traffic as a result of the project.

Carbon emissions are valued using the suggested parameters from the CCC, including the figures presented in Table 8. These costs are incorporated into the model beginning in the 4th year after the project has started. In total, these costs represent an NPV of $16,043 (GHS 89,093) using a discount rate of 8%.

Table 8: Carbon Emission Increase on Complement Roads

Inputs		Unit	Value	Source of verification
$D^{Reduction}$	Traffic diverted in first year	TEU	35,138	Roche 2014, 39
G^{With}	Annual growth of cargo with project	%	7.5%	Roche 2014, 39
$G^{Without}$	Annual growth without project	%	4.67%	Roche 2014, 15
T^{Weight}	Average weight of TEU	Tonnes	21	Roche 2014, 39
$E^{Averted}$	CO2 Emissions per tonne/kilometre	Grams	91.73	Mathers 2014, 11
$K^{Complement}_{South}$	Kilometres Mpakadan to Tema	Kilometres	71	Google Maps
$K^{Complement}_{North}$	Kilometres Buipe to Ouagadougou	Kilometres	474	Google Maps
$V^{Emissions}$	Value of one metric ton of carbon emission (2020)	USD/GHS	29.9 / 166	CCC
G^{Value}	Growth in value of carbon emissions	%	2%	CCC
Calculation				
Cost:	$B2^{Ghana}_{t} = [E^{Traffic} - (E^{BRT} + (1 - U^{BRT}) \times E^{Traffic})] \times V^{Emissions}(1 + G^{Value})^{t}$			

Handling Costs at Points of Transition

The transportation of cargo will now require that containers be transferred from rail to ship and then to the truck to be brought to its final destination. Handling costs at the two points of transition are assumed to be similar to the cost of handling at Tema Port. These costs of handling are based on the evaluation of Tema Port handling costs prepared by Annequin et al. (2010) for USAID and West Africa Trade Hub.

Table 9 provides a summary of the key variables used to calculate handling costs. These costs are incorporated into the model beginning in the 4th year after the project has started. In total, these costs represent an NPV of $184.8 million (GHS 1.026 billion) using a discount rate of 8%.

Table 9: Handling Costs

Inputs		Unit	Value	Source of verification
$C^{Handling}$	Port handling cost per tonne	USD / GHS	10.62 / 58.98	Annequin et al. 2010, 85
$T^{Increase}$	Traffic diverted in first year	TEU	35,138	Roche 2014, 39
$G^{Project}$	Annual growth of cargo with project	%	7.54%	Roche 2014, 39
$N^{Transitions}$	Number of Transitions	#	2	Author's assumption
Calculation				
Cost:	$C5_t^{Primary\ Implementer} = C^{Handling} \times T^{Increase}(1 + G^{Project})^{t-t0} \times N^{Transitions}$			

Increased Handling Time for Cargo

The amount of time it takes to get from Tema to the final destination will change due to the intervention. We calculate the value of this time change by first estimating what the difference in time will be for the speed of travel by road and on the multimodal corridor. We then multiply the time change by the average value of the cargo and multiply it by the hourly interest rate calculated for Ghana. Volume of cargo is estimated by the same method as in other costs. The travel time from Mpakadan to Buipe by ship was estimated by the average speed of around 37 km/hour over a distance of 400km. Handling time was estimated using average handling time for the Tema Port. The interest rate was based on the average interest rate in Ghana from 2002-2019 of 17.94% and then was divided to yield an hourly interest rate.

Table 10 provides a summary of the key variables used to calculate the increased handling costs for cargo. These costs are incorporated into the model beginning in the 4th year after the project has started. In total, these costs represent an NPV of $2.429 million (GHS 13.489 million) using a discount rate of 8%.

Table 10: Handling Time for Cargo

Inputs		Unit	Value	Source of verification
S^{Truck}	Average travel speed by road	Km/hour	40	Nathan Associates 2010, 48
$K^{Substitute}$	Kilometres of substitute road	Km	545	Annequing et al. 2016, 39
K^{Ferry}	Kilometres to cross Volta Lake	Km	400	Annequing et al. 2016, 38
$K^{Compliment}$	Kilometres of Compliment Road	Km	71	Roche 2014, 46
S^{Ship}	Average speed of the cargo ship	Hours	37	Rodrigue 2017
$T^{New}_{S.Port}$	Handling time for loading cargo	Hours	12	Toebes 2017
$T^{New}_{N.Port}$	Handling time for unloading cargo	Hours	12	Toebes 2017
$D^{Reduction}$	Traffic diverted in first year	TEU	35,138	Roche 2014, 39
G^{With}	Annual growth of cargo with project	%	7.5%	Roche 2014, 39
V^{Cargo}	Estimated average value of one TEU	USD/GHS	12,765 / 70,887	Annequin et al. 2010, 29
I^{Hourly}	Hourly interest rate	%	0.002%	tradingeconomics.com
Calculation				
Cost:	$C6_t^{Shipping\ Customer} = \left[\frac{K^{Substitute}}{S^{Truck}} - \left(\frac{K^{Ferry} + K^{Compliment}}{S^{Ship}} + T^{New}_{S.Port} + T^{New}_{N.Port}\right)\right] \times D^{Reduction}(1 + G^{With})^{t-t0} \times V^{Cargo} \times I^{Hourly}$			

Calculation of Benefits

Vehicle Operational Cost Savings

Reduction in vehicle operating costs represents the avoided costs of transporting cargo by transport trucks. It is measured in reduced twenty-foot equivalent units (TEU). The substitute road for this analysis is defined as the current route from Tema to Buipe. Growth in the amount of cargo travelling along this corridor is based on forecasts done by Roche (2014). Growth without the project is based on the expected annual growth of household income over the next 20 years. Creation of the multi-modal corridor through Ghana would reduce the vehicle operation cost of using this corridor compared to competing transport corridors. Due to the uncertainty surrounding whether there will be improvements in competing corridors and how this will affect traffic volumes, we perform sensitivity analysis to determine how much traffic is needed on the multimodal corridor for the project to break even. Not estimated in the vehicle operational cost savings is the benefit to other vehicles (e.g. vehicles other than transport trucks) who travel on the substitute road. This calculation is not performed due to lack of data.

Table 11 provides a summary of the key variables used to calculate the decreased vehicle operating costs for transport trucks. These benefits are incorporated into the model beginning in the 4th year after the project has started. In total, these benefits represent an NPV of $616.7 million (GHS 3.425 billion) using a discount rate of 8%.

Table 11: Vehicle Operation Costs

Inputs		Unit	Value	Source of verification
$K^{Substitute}$	Kilometres of substitute	km	545	Google Maps
$T^{Corridor}$	Traffic expected on corridor in first year	TEU	35,138	Roche 2014, 39
$G^{Project}$	Annual growth of cargo with project	%	7.54%	Roche 2014, 39
$G^{Without}$	Annual growth without project	%	4.67%	Roche 2014, 16
$C^{Transport}_{Current}$	Current cost per TEU/Km for transport	USD/GHS	$2.4 / 13.32	Nathan Inc 2010, 81
Calculation				
Benefit:	$B1_t^{Shipping\ customers} = T^{Corridor} \times C^{Transport}_{Current} \times K^{Substitute} \times [(1+G^{Without})^{t-t_0} + (1+G^{Project})^{t-t_0} - (1+G^{Without})^{t-t_0} \times 0.5]$			

Carbon Emissions Averted

The project will reduce the distance that freight needs to be carried by truck in order to reach Northern Ghana and the landlocked countries to the North. The transport of goods represents a significant source of emissions globally and in Africa. Carrying goods by truck is not as efficient as by rail or by cargo ship. Therefore, there is an opportunity to reduce carbon emissions by moving cargo transport to the multimodal corridor as opposed to a corridor that carries cargo by road only.

Table 12 provides a summary of the key variables used to calculate the benefits of averted carbon emissions. These benefits are incorporated into the model beginning in the 4th year after the project has started. In total, these benefits represent an NPV of $31.1 million (GHS 73.1 million) using a discount rate of 8%.

Table 12: Carbon Emissions Averted

Inputs		Dimensions	Unit	Source of verification
$D^{Reduction}$	Traffic diverted in first year	TEU	35,138	Roche 2014, 39
$G^{Without}$	Annual growth without project	%	4.67%	Roche 2014, 15
T^{Weight}	Average weight of TEU	Tonnes	21	Roche 2014, 39
$E^{Averted}$	CO2 Emissions per tonne/kilometer	Grams	91.73	Mathers 2014, 11
$K^{Substitute}$	Kilometres of substitute	km	545	Google Maps
$V^{Emissions}$	Value of one metric ton of carbon emission (2020)	USD/GHS	29.9 / 166	CCC
G^{Value}	Growth in value of carbon emissions	%	2%	CCC
Calculation				
Benefit:	$B2_t^{Ghana} = [D^{Reduction} \times (1 + G^{Without})^{t-t_0} \times E^{Averted} \times K^{Substitute}] \times C^{Emissions} \times G^{Value}$			

Road Maintenance Savings

High volumes of trucks carrying cargo increases the rate of deterioration of roads and leads to increased maintenance costs for the Government of Ghana. The analysis assumes that with the current level of trucking the roads require reconstruction every 10 years and that once most of the trucking is diverted to lake transport, the roads will need reconstruction every 30 years. (Roche 2014, 111). The annual maintenance cost is estimated by taking the cost of reconstructing 1 kilometre of the road which is priced at $1 million USD and dividing it by the frequency that the roads need reconstruction (Roche 2014, 111). This approach is taken because it is assumed that not all reconstruction will occur at the same time. The Transport Ministry expressed that these values may be greater than what Roche (2014) found, however, updated data is currently unavailable. This suggests that road maintenance savings may be greater than expressed in this analysis.

Table 13 provides a summary of the key variables used to calculate the benefits of reduced maintenance costs. These benefits are incorporated into the model beginning in the 4th year after the project has started. In total, these benefits represent an NPV of $288.9 million (GHS 1.604 billion) using a discount rate of 8%.

Table 13: Reduced Maintenance Costs

Inputs		Unit	Value	Source of verification
$C_{Current}^{Maintenance}$	Cost of maintenance per kilometer/year without project	USD	100,000	Roche 2014, 111
$K^{Substitute}$	Kilometres avoided	km	545	Google Maps
$C_{Project}^{Maintenance}$	Cost of maintenance per kilometer/year with project	USD	33,333	Roche 2014, 111
Calculation				
Benefit:	$B3_t^{Gov't} = K^{Substitute}\left[C_{Current}^{Maintenance} - C_{Project}^{Maintenance}\right]$			

Informal Service Operational Cost Savings

There will be 11 ferry routes, including the following: Adawso/Ekye Amanfrom, Akateng/Adikukope, Dzemeni/Galelia, Kpando-Torkor/Agordeke, Dambai/Dodoikope, Kete Krachi/Kojokrom, Yeji/Makango, Kpetchu/Adembra, Asuso/Begyemse, Bride Ano/Ntoaboma, and Kojokrom/Kete Krachi. Currently, demand for lake crossings at these locations is met by informal services carrying passengers across the lake and/or VLTC. With the implementation of the project, the cost of the informal service on these routes will be avoided. Due to the lack of market power and the competitive nature of the market we can assume that loss of revenues is negligible. Roche (2014) conducted a survey in order to get figures for how many people are crossing at these locations and how much it costs. They used this data to conduct passenger modelling to forecast the demand for crossing at these locations using population size and growth and adjusting to acknowledge alternative transport routes (Roche 2014, 17).

Table 14 provides a summary of the key variables used to calculate the benefits of informal service cost savings. These benefits are incorporated into the model beginning in the 4th year after the project has started. In total, these benefits represent an NPV of $131 million (GHS 727 million) using a discount rate of 8%.

Table 14: Informal Service Operation

Inputs		Unit	Value	Source of verification
$D^{Passengers}$	Demand for Lake Crossing	#	4,528,900	Roche 2014, 21
$C^{Passenger}$	Cost for crossing per passenger	USD	1.57	Roche 2014, 115
G_{Demand}^{With}	Growth rate of demand with project	%	8.2	Roche 2014, 21
$G_{Demand}^{Without}$	Growth rate of demand without project	%	2.76	Roche 2014, 21
Calculation				
Benefit:	$B4_t^{Passengers} = D^{Passengers} C^{Passenger} \left[(1 + G_{Demand}^{Without})^{t-t0} + \frac{(1+G_{Demand}^{With})^{t-t0} - (1+G_{Demand}^{Without})^{t-t0}}{2} \right]$			

Increased Road Safety

Traffic accidents are a major problem on Ghana's roads. The amount of accidents, and the injuries and death rates that these accidents cause, has become cause for concern among many institutions. Reducing the volume of transport trucks on the substitute roads would increase the safety for other users. Increasing road safety can have major benefits from reduced deaths, injuries, and damage to vehicles. At the time of analysis, however, we did not have data to estimate the traffic and accident rate on the substitute routes or how the project would affect accident rates.

Assessment of Quality of Evidence

The body of evidence used to analyze this intervention was medium. There were many areas where data availability was limited. Many other ferry and cargo transport analyses were referenced but data specific to the context in Ghana was mainly sourced from the Roche 2014 analysis.

Sensitivity Analysis

This project is being considered alongside improvements to the roads that run along the east and west of Volta Lake. These three corridors act as substitutes to each other. Therefore, investment in one or multiple corridors affects the others. Due to the uncertainty surrounding the future of transport in Ghana, there is little evidence with which to estimate how much the investment in the multimodal corridor will change how many people choose to use each of these corridors. As a result, we perform an analysis to determine how much traffic is required on Volta Lake in order for the benefits and costs to break even. With the assumption of 80%

of cargo traffic being diverted to the multimodal corridor, the benefit-cost ratio of the project is 1.01 at a 14% discount rate. Therefore, under this scenario the benefits are slightly greater than the costs. Per guidance provided by the Copenhagen Consensus Center, we also look at the benefit-cost ratio with a discount rate of 8% and 5%. Although this does give a much larger benefit-cost ratio, the literature review suggests 14% as being the appropriate discount rate for similar projects.

Projects investing in infrastructure of this size are open to uncertainty throughout the life of the project that could change the impact on society. In this analysis we consider how changes to certain costs and benefits will change the benefit-cost ratio. Due to the nature of the project, the areas of uncertainty we are interested in analysing are changes to the level of usage of the corridor and changes to the capital investment needed.

Decisions as to which corridor to use will be made by shipping customers and shipping companies based on variables like cost, time, and different levels of risk on different corridors. There is uncertainty surrounding how much of the cargo traffic travelling through Ghana will use the multi-modal corridor, especially with future investments in competing corridors. With a discount rate of 14%, we need at least 75% of the expected cargo traffic to use the multi-modal corridor in order to result in a net benefit for society. The project's benefits occur over a 20-year time horizon making this project sensitive to the discount rate. It is important to note that this project requires most cargo travelling through Tema Port to use the multi-modal corridor in order for benefit to outweigh the costs at a 14% discount rate. With an 8% discount rate the project would have positive benefits as long as 37% of expected cargo traffic was using the multi-modal corridor.

When looking at the changes to capital investments, we assessed the percentage change in investment costs that could occur during the investment period that would still produce a net benefit or a benefit-cost ratio greater than 1. This analysis shows that the project will have benefits greater than costs at a 14% discount rate, as long as costs overruns do not exceed 30 percent of investment costs.

Overall, this project is sensitive to the volume of cargo that travels on the multi-modal corridor. It is also sensitive to the discount rate. If implementation of the project is being considered, projected cargo should be analyzed with updated data and it should be considered how investment in competing routes could change passenger and cargo use in the multi-modal corridor.

Table 14: BCR Sensitivity: Varying percentage of cargo traffic using multi-modal corridor, USD

Discount Rate	Benefit (USD)	Cost (USD)	BCR (80%)	BCR (70%)	BCR (37%)
5%	1,555,129,974	1,161,195,156	1.34	1.29	1.10
8%	1,049,933,510	851,680,520.18	1.23	1.18	1.00
14%	535,767,056	531,210,152	1.01	0.96	0.80

Table 15: BCR Sensitivity: Varying percentage of cargo traffic using multi-modal corridor, GHS

Discount Rate	Benefit (GHS)	Cost (GHS)	BCR (80%)	BCR (70%)	BCR (37%)
5%	8,553,214,856	6,386,573,362	1.34	1.29	1.10
8%	5,774,634,302	4,684,242,861	1.24	1.18	1.00
14%	2,946,718,807	2,921,655,839	1.02	0.96	0.80

Policy Discussion

This project will most likely involve costs incurred by the Government of Ghana, a potential investor, and the Volta Lake Transport Company. Revenues from Volta lake transportation were calculated using fares from Roche (2014), while tariffs for cargo transport were from Volta Lake Transport Company found in Toebes (2017). The revenues from the project at these fares are not enough to cover the cost of the investment or the operational costs. For the project to be sustainable there is a need for the government to subsidize both the investment and operation cost of the project or to find another investor who can support the project. While there may be options in terms of raising more revenue to finance this project, this could reduce the economic benefit to many stakeholders. Our analysis shows that if the multimodal corridor attracts 70% of the cargo traffic expected to go through Ghana, the investment and approximately 75% of the operational costs will need to be subsidized. This is an area that can be further explored beyond our analysis if updated data becomes available. However, prices for these transport routes must be compared to alternatives for carrying cargo to the north. Ferry prices must compete with prices charged by the informal sector and cargo prices cannot exceed the cost of using road transportation in any of the nearby transport corridors.

There is a need for an integrated plan that addresses the issue of the use of the lake as a fishing grounds for many isolated communities. This would require an environmental assessment and analysis of how the removal of tree stumps would affect the fisheries of the Volta Lake and how the implementation of the ferry and cargo routes themselves will affect the environment, the fisheries, and the livelihoods of the communities on the lake.

Conclusion

Investing in passenger and cargo transport on Ghana's Volta Lake could have positive impacts, such as reduced vehicle operational costs, reduced carbon emissions, and decreased maintenance of substitute roads. At the same time, these estimated benefits come with costs that need to be carefully considered. For example, the cost of investment and ongoing operational costs are likely to be substantial and require some level of government subsidization. Additionally, removing the trees that remain in the lake potentially has negative impacts on the environment and the communities surrounding the lake. More information is needed to accurately measure these impacts. The economic impact this project will have is also heavily dependent on expected demand for ferry passenger and cargo transport. If this investment is to move forward, more updated data needs to be collected to give the most accurate estimate for this project.

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