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STRENGTHEN2

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Employment impact assessment of Luangwa-Mwami road, part of the interregional Nacala Road Corridor Project, Zambia

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International Labour Organization (ILO)

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Acronyms and abbreviations

ACLED	Armed Conflict Location and Event Data Project
AfDB	African Development Bank
AFD	Agence Française de Développement
BRDF	Bidirectional Reflectance Distribution Function
DID	difference in difference
DMSP	Defense Meteorological Satellite Program
DNB	Day Night Band
EIB	European Investment Bank
EmpIA	employment impact assessment
EC	European Commission
EU	European Union
FE	fixed effects
GDP	gross domestic product
GIS	Geographic information systems
IV	instrumental variables
LFS	Labour Force Survey
MW	megawatt
NASA	National Aeronautics and Space Administration
NDP	National Development Plan
NRCP	Nacala Road Corridor Project
NTL	night-time lights
PAP	project affected person
RS	remote sensing
SADC	Southern African Development Community
SDA	Strategic Development Area
SSA	sub-Saharan Africa
VIIRS	Visible Infrared Imaging Radiometer Suite
ZamStat	Zambia Statistics Agency
ZMK	Zambian Kwacha

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Executive summary

The ILO STRENGTHEN2 project is conducting employment impact assessments of investment projects in sub-Saharan Africa (SSA), to promote the creation of more and better jobs. This report presents an employment impact assessment (EmpIA) of Phase 2 of the Nacala Road Corridor Project (NRCP) in Zambia, in collaboration with the African Development Bank (AfDB), which co-financed the construction of the corridor. The corridor is fed by the Great East Road, a project financed by the European Investment Bank (EIB).

Geographic information systems (GIS) data and methods were applied to assess the long-term economic and employment impacts of the project. Night-time lights (NTL) satellite imagery was the main dataset used, which provides a measure of light emissions at night and can be applied as a proxy for economic activity in the form of GDP. The treated road that was worked on as part of the corridor project was compared to untreated roads in the province that had similar characteristics but did not receive any intervention. The increase in NTL brightness was compared pre- and post-treatment, whilst controlling for population, conflicts and other variables to analyze the economic impact of the road's rehabilitation. The increase in NTL was translated into GDP based on the national level elasticity, and then further translated into employment using an indirect approach to estimate the percentage increase in employment caused by the improved road.

The results show that night-time light luminosity increased by 25 per cent in administrative units that were within 2.5 kilometres (km) of the road project, compared to those that were close to roads that did not receive improvement, two years after completion of the project. It is estimated that this produced an increase in local-level GDP of 12 per cent; taking into account the elasticity between lights/GDP and GDP/employment, this equates to an increase of 6.7 per cent in employment. When presenting the results in terms of euros invested, it is estimated that per million invested, local GDP is estimated to increase by 0.27 per cent. For employment, this equates to an increase of 0.15 per cent per million euros. Based on estimations of the number of people employed from Labour Force Survey (LFS) data, within the constituencies included in the treated study area, it is estimated that the 6.7 per cent increase in employment could equate to an estimated 13,657 people employed. When interpreting the results, it should be noted that this increase occurs within administrative units benefiting from the road intervention; however, it cannot be fully attributed to the road itself. Additional economy-wide factors could be responsible for an increase in employment over the years of the study. It has been identified that the increase in employment is higher than previous assessments of road infrastructure projects in sub-Saharan Africa; understanding the differences in project design and local characteristics that could have contributed to this would be valuable for the future planning of road investments in SSA.

The study builds upon previous assessments conducted by the STRENGTHEN2 project and adds to the literature on utilizing night-time lights data to measure the impacts of transport infrastructure. It highlights the applicability of using satellite data to measure the economic and employment impacts of infrastructure investments in SSA. It is recommended that similar assessments be produced in other countries and sectors to build upon this methodology and promote it for use in employment impact assessment.

Résumé exécutif

Le projet STRENGTHEN2 de l'OIT réalise des évaluations d'impact sur l'emploi de projets d'investissement en Afrique subsaharienne, afin de promouvoir la création d'emplois plus nombreux et de meilleure qualité. Ce rapport présente une évaluation de l'impact sur l'emploi de la seconde phase du projet de corridor routier de Nacala en Zambie, en collaboration avec la Banque africaine de développement, qui a cofinancé la construction du corridor. Le corridor est alimenté par la Grande Route de l'Est, un projet financé par la Banque européenne d'investissement.

Les données et les méthodes des systèmes d'information géographique ont été utilisées pour évaluer l'impact à long terme du projet sur l'économie et l'emploi. L'imagerie satellitaire de l'éclairage nocturne a été le principal ensemble de données utilisé. Elle fournit une mesure des émissions lumineuses nocturnes et peut être utilisée comme indicateur indirect de l'activité économique à travers le PIB. La route restaurée dans le cadre du projet de corridor a été comparée à des routes non restaurées de la province présentant des caractéristiques similaires mais n'ayant fait l'objet d'aucune intervention. L'augmentation de la luminosité nocturne a été comparée avant et après la rénovation, tout en contrôlant la population, les conflits et d'autres variables afin d'analyser l'impact économique de la réhabilitation de la route. L'augmentation de la luminosité nocturne a été traduite en PIB sur la base de l'élasticité au niveau national, puis en emploi à l'aide d'une approche indirecte pour estimer le pourcentage d'augmentation de l'emploi causé par l'amélioration de la route.

Les résultats montrent que la luminosité nocturne a augmenté de 25 % dans les unités administratives situées à moins de 2,5 kilomètres du projet routier, par rapport à celles situées à proximité de routes non rénovées, deux ans après l'achèvement du projet. On estime que cela a entraîné une augmentation du PIB local de 12 % ; compte tenu de l'élasticité entre éclairage/PIB et PIB/emploi, cela équivaut à une augmentation de 6,7 % de l'emploi. Si l'on présente les résultats en termes d'euros investis, on estime que le PIB local augmente de 0,27 % par million investi. Pour l'emploi, cela équivaut à une augmentation de 0,15 % par million d'euros. Sur la base des estimations du nombre de personnes employées provenant des données de l'enquête sur la population active, on estime que l'augmentation de 6,7 % de l'emploi dans les circonscriptions incluses dans la zone d'étude traitée pourrait correspondre à un nombre de personnes employées estimé à 13 657. Lors de l'interprétation des résultats, il convient de noter que cette augmentation se produit dans les unités administratives bénéficiant de l'intervention routière ; cependant, elle ne peut pas être entièrement attribuée à la route elle-même. D'autres facteurs économiques pourraient être à l'origine d'une augmentation de l'emploi au cours des années de l'étude. Il a été identifié que l'augmentation de l'emploi est supérieure aux évaluations précédentes des projets d'infrastructure routière en Afrique subsaharienne ; la compréhension des différences dans la conception du projet et l'évaluation de l'impact de la route sur l'emploi sont des facteurs importants.

L'étude s'appuie sur des évaluations précédentes menées par le projet STRENGTHEN2 et complète la littérature sur l'utilisation des données de l'éclairage nocturne pour mesurer l'impact des infrastructures de transport. Elle met en évidence l'applicabilité de l'utilisation des données satellitaires pour mesurer l'impact économique et l'impact sur l'emploi des investissements dans les infrastructures en Afrique subsaharienne. Il est recommandé que des évaluations similaires soient conduites dans d'autres pays et secteurs afin de s'appuyer sur cette méthodologie et de promouvoir son utilisation dans les évaluations d'impact sur l'emploi.

1. Introduction

The STRENGTHEN2 project aims to leverage employment impact assessment (EmpIA) in sub-Saharan Africa (SSA) to promote the creation of more and better jobs. STRENGTHEN2 is working to assess the employment impact of infrastructure investments in Zambia, among other countries. The Nacala Road Corridor Project (NRCP) is aimed at providing transport linkages to the port of Nacala for Malawi, Mozambique and Zambia, whilst improving accessibility for communities to markets and social services. The project was split into three phases, with two phases currently completed and one ongoing. Phase 2, which covered 360 kilometres (km) of road works from Luangwa to Mwami, is the focus of this assessment. It was completed in 2017 and financed by the African Development Bank (AfDB). It forms part of the Great East Road Rehabilitation project, which was co-financed between the European Commission (EC), AfDB, European Investment Bank (EIB) and Agence Française de Développement (AFD). This report presents the EmpIA for the project, harnessing Geographic Information Systems (GIS) analysis and night-time lights (NTL) data to assess the long-term economic and employment effects. It outlines the country context for Zambia, the project description, methodology, results, discussion and recommendations.

Assessing the employment impacts of infrastructure projects once they are complete is important to understanding the long-term effects that interventions have produced, although these impacts are arguably the most difficult to measure. Operationalizing the use of remote sensing (RS) and GIS in EmpIA is relatively new, but there has been much work done in utilizing geospatial data and satellite imagery for analysing the economic impacts of transport infrastructure. Much previous literature has shown the potential of NTL data as a proxy for economic activity, such as the work of Henderson, Storeygard, and Weil (2012) at the country level in the form of GDP. The high spatial and temporal resolution of the data makes it a valuable source, especially in areas where economic and employment data may be lacking from traditional sources. The use of NTL data for assessing the economic impacts of road projects has recently been applied in countries such as Haiti (Mitnik, Sanchez, and Yañez-Pagans 2018) and the West Bank (BenYishay et al. 2018). The STRENGTHEN2 project has worked on applying this methodology to assess the economic and employment impacts of roads in Kenya and Rwanda (Game and Kang 2023a, Game and Kang 2023b). The present assessment aims to build upon the past literature to demonstrate the applicability of NTL data for assessing the economic impacts of road investments. The analysis will be taken a step further by translating the change in economic activity to a change in employment, in order to assess the employment effects related to specific investments.

2. Country situation analysis

Zambia is a landlocked country bordered with Angola, Botswana, the Democratic Republic of Congo, Malawi, Mozambique, Namibia, the United Republic of Tanzania, and Zimbabwe. The country experiences a predominantly sub-tropical climate characterized by three distinct seasons: a hot and dry season, a wet rainy season, and a cool dry season. Zambia's land area spans approximately 752,612 square kilometres, with a population of 19.5 million people in 2022 and projected to grow to 27 million by 2035. In total, 83 per cent of the population are under the age of 35, of which 46 per cent are children (0-14 years) and 37 per cent youth (15-35 years (ZamStats 2010).

Zambia has been grappling with macroeconomic instabilities and fiscal constraints over the past years. Real GDP growth between 2015 and 2018 averaged 3.6 per cent. In 2019, growth was 1.4 per cent before sliding into a recession (-2.8 per cent) in 2020 and then posting recovery to 3.6 per cent in 2021. Further to this, inflation has risen sharply, to an annual average of 22.1 per cent in 2021 (MoFNP 2022a).

Fiscal deficits as a share of GDP increased from 5.7 per cent in 2016 to 14.5 per cent in 2020 and dropped to 9.0 per cent in 2021,[1] and this ratio is expected to rise to 9.8 per cent in 2022. Zambia has also been experiencing a heavy debt burden over the same period. The total debt as a share of GDP increased from 35 per cent in 2014 to 119 per cent in 2021. Domestic debt increased by 601 per cent to 193 billion Zambia Kwachas (ZMK) in 2021 from ZMK 27.51 billion in 2015. Furthermore, Zambia's domestic arrears stood at ZMK 45.5 billion at the end of September 2021 from ZMK 20.92 billion at the close of 2017. External debt increased further to US$13.04 billion at the end of 2021.

Zambia has experienced industrial growth over the period 2010 to 2018 but the contribution of the manufacturing sector to GDP is limited. Over the period 2017 to 2021, the wholesale and retail trade sector (20 per cent) accounted for the largest sectoral share of GDP, followed by construction (11 per cent), and mining and quarrying (10 per cent). Conspicuously, manufacturing and agriculture remained low at 8 per cent and 7 per cent respectively (ZamStats 2022).

The state of infrastructure in Zambia, based on the infrastructure pillar of the 2019 Global Competitiveness Index, remains problematic. In terms of energy, Zambia has 2,800 megawatts (MW) of installed electricity generation capacity, of which 85 per cent is hydro-based. National access to electricity averages 31 per cent, with 67 per cent of the urban and 4 per cent of the rural population having access to power. Notably, the country has made significant road investments in recent years. Budgetary expenditure on roads has outstripped expenditure in other sectors such as rural electrification, and water and sanitation. As a result, Zambia's score on the 2019 Global Competitiveness Index indicators on road connectivity (77.5) and quality of roads (40.6) was better than the Southern African Development Community (SADC) average of 71.5 and 39.2 (World Economic Forum 2019).

According to the 2020 LFS, Zambia's working-age population (15 years or older) was estimated at 9.9 million in 2020.[2] The size of the labour force was 3.5 million, representing 35 per cent. The youth labour force in 2020 accounted for 1.9 million, representing 54.4 per cent of the overall labour force. Moreover, a total of 1.3 million persons of the population outside the labour force made up the potential labour force (ZamStats and MLSS 2020).

Zambia's employed population was estimated at three million in 2020, which makes the employment-to-population ratio 30.2 per cent. Of the total employed population, about a third worked in firms and/or institutions in the formal sector, representing an absolute total of one million. Of interest is the informal sector, defined as referring to all economic activities by workers and economic units that are – in law or in practice – not or insufficiently covered by formal arrangements. In terms of employment in the informal economy by industry in 2020, agriculture, forestry and fishing had the highest percentage share at 33.1 per cent, followed by wholesale and retail trade; repair of motor vehicles and motorcycles accounted for at 23.8 per cent, while water supply, sewerage, waste management and remediation activities had the lowest share at less than 1.0 per cent (Zamstats and MLSS 2020). The employed population in the informal and household sectors were 45.4 and 20.7 per cent respectively. Notably, 26.2 per cent of employed persons in 2020 had social security cover at their jobs (that is, formally employed). The estimated number of informally employed persons was 73.7 per cent.

The unemployment rate was estimated at 13.8 per cent in 2020. Of this number, the male unemployment rate was 11.9 per cent and that of females was higher at 16.4 per cent. Youth unemployment was 19.9 per cent, where 17.6 per cent was for male youth and 22.7 per cent for female youth. Further, 33.5 per cent were

[1] Preliminary estimates.

[2] At the time of writing, the 2021 LFS had not been published.

in rural areas and 66.4 per cent in urban areas. The combined rate of unemployment and potential labour force was 37.3 per cent, where 44.1 per cent was for females and 31.8 per cent for males (ZamStats and MLSS 2020).

Overall, Zambia's development framework is guided by the Vision 2030 and National Development Plans. Currently, the draft[3] Eighth National Development Plan (8NDP) is expected to provide the strategic direction for the country with four Strategic Development Areas (SDAs): economic transformation and job creation; human and social development; environmental sustainability; and good governance environment (MoFNP 2022b). In terms of infrastructure development in the plan, the development challenges that Zambia faces, while incredibly diverse, all share an underlying need for modern, efficient and reliable infrastructure. In general, the 8NDP, like its predecessor the Seventh National Development Plan (7NDP), makes a strong case for infrastructure development as an enabler of growth. The plan emphasizes the need to maintain, modernize and integrate all transport modes – air, road, rail and water. In the energy subsector, emphasis is placed on instituting reforms to attract private investments, as well as on upgrading electricity transmission infrastructure to minimize transmission losses. The 8NDP also outlines several interventions for enhancing water security including water harvesting, and ground and surface water resources management. Lastly, in the communications subsector, the plan outlines strategies for enhancing digital capacity through investment in ICT infrastructure development and others (MoFNP 2022b). Overall, the priority sectors for investment, growth and job creation articulated in the 7NDP have been maintained in the 8NDP. However, the draft 8NDP differs in structure from the 7NDP, which included specific targets under various developmental outcomes. Nonetheless, the overall development framework remains the same.

[3] The Plan was in draft stage at the time of writing.

3. Project description

The Nacala Road Corridor Project (NCRP) contains a total of 1,033 km of road works in Malawi, Mozambique and Zambia and the construction of two one-stop border posts. The project is implemented across three phases (figure 1), with two phases completed and one still under implementation. The corridor aims to provide Malawi, Mozambique and Zambia with transport links to the port of Nacala in Mozambique, improving transport services through the reduction in transport and delay costs at border crossings. The project also aims to improve sustainability of investments by controlling axle loads and improving the accessibility of the communities in the zone of influence to markets and social services.

Table 1. Breakdown of the phases of the Nacala Road Corridor Project

Title	Total funding (UA million)	Fund breakdown (UA million)	Approval Date	Status
Multinational - Phase I (Loan to Mozambique)	180.03	102.72 (AfDB) 40.89 (JICA) 13.63 (Korean EXIM) 22.79 (Government of Mozambique)	24 Jun 2009	Implementation
Multinational - Phase I (Loan to Malawi)	15.91	14.32 (AfDB) 1.59 (Government of Malawi)	24 Jun 2009	Completion
Multinational - Phase II (Loan to the Republic of Zambia)	69.47	6.369 (AfDB) 0.102(Government of Zambia)	27 Sep 2010	Completion
Mozambique - Phase III	99.66	38.83 (AfDB) 49.34 (JICA) 11.49 (Government of Mozambique)	05 Dec 2012	Implementation
Multinational Phase IV (Malawi)	45.39	42.97 (AfDB) 2.42 (Government of Malawi)	04 Dec 2013	Implementation
Multinational Phase IV (Zambia)	5.5	5 (AfDB) 0.5 (Government of Zambia)	04 Dec 2013	Implementation
Supplementary funding - Phase IV	8.751	8,751 (AfDB)	Feb 2020	Implementation
Malawi - Phase V	45.289	26.6 (AfDB) 15.121 (EU) 3.568 (Government of Malawi)	19 June 2019	Implementation

Note: 1 UA = 1 SDR = US$1.33 (as of January 2024). (UA = AfDB Unit of Account, SDR = Special Drawing Rights)

The overall project is divided into three phases (table 1): Phase 1 consists in the realization of 361 km of road in Malawi and Mozambique, Phase 2 consists in the realization of 360 km of road in Zambia and Phase 3 consists in the realization of 175 km of road in Malawi and Mozambique with two single-border posts. The present assessment focuses on Phase 2 of the programme, which was completed in December 2017.

The NRCP Phase 2 comprised three road sections covering 360 km in total. The AfDB was responsible for 114.7 km of this length – Nyimba to Petauke (67.7 km) and Petuake to Sinda (47 km). In addition, further outputs were market sheds, community boreholes, capacity development, HIV/AIDS and TB awareness, tree planting and compensation for project affected persons (PAPs).

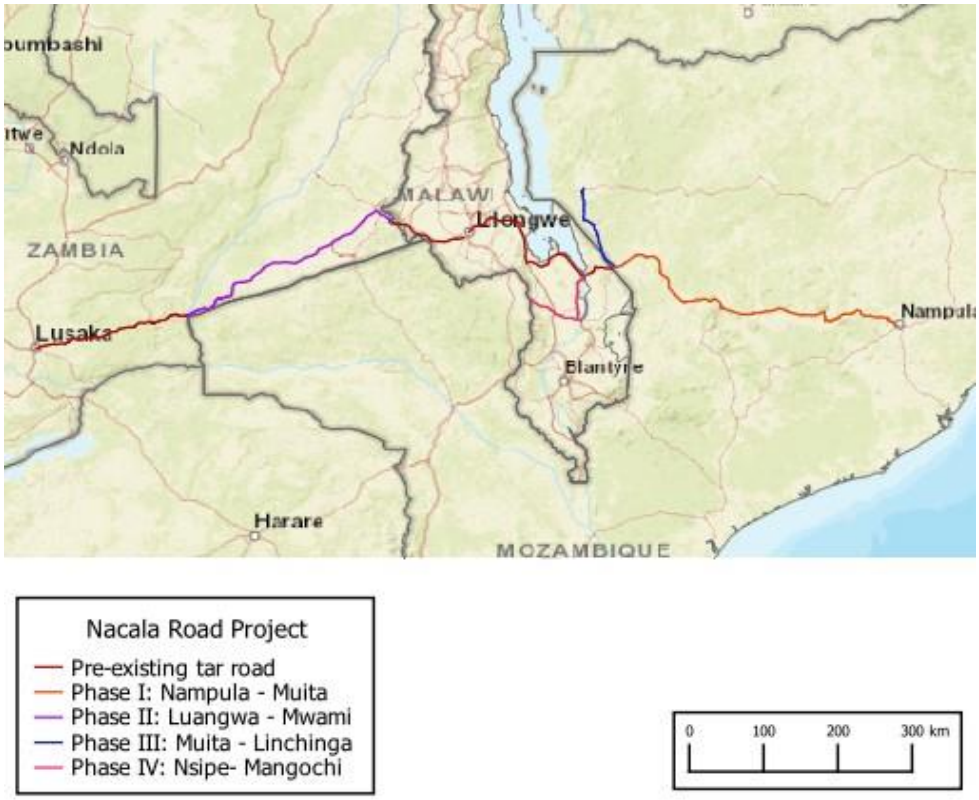
The project duration was almost six years. The development objective of improving the accessibility of the communities to social services and markets was realized; the travel speeds estimated at the appraisal have exceeded the 71.1km/h for medium trucks and 94.5 km/h for passenger vehicles targeted to be achieved at project completion. Travel times have also reduced with the increased speeds. This has also decreased the vehicle operating cost by 13.1 per cent for heavy vehicles and 14.9 per cent for light vehicles. The road safety awareness campaigns have also been effective in decreasing the number of accidents, from 929 in 2013 to 70 at completion (AfDB 2017).

The project led to an increase in income levels for both men and women through direct employment during construction and afterwards during maintenance. On average, the project engaged 360 unskilled workers of whom 30 (or 8.3 per cent) were women. This was well below the target of 20 per cent female employment. The employment generated an income of US$0.51 million per month, which was injected into the local economy. Of this, US$0.043 million per month accrued to women. Other economic activities such as provision of food for construction workers, hospitality services and roadside vending offered additional income-generating opportunities for the communities along the project route (AfDB 2017).

Due to the project, additional sources of income were realized for women through sales of food items to construction workers. The provision of nine borehole water points in selected communities served an estimated 1,800 households. Finally, the project included construction of three simple market structures, and women were the major beneficiaries of this activity since it improved the conditions under which women could sell their produce. On-the-job training of unskilled labour has improved the potential of the project workers to find employment with the same contractor or with other employers.

The NCRP feeds into the Great East Road Rehabilitation Programme, which involves the rehabilitation of 360 km of highway between Luangwa in Zambia and Mwami at the Malawi border. The overall objectives of the project are to reduce poverty and to promote economic growth and regional integration in Zambia. The project is currently under implementation and is co-financed between the EC, AfDB, EIB and AFD.

▶ Figure 1. Nacala road transport corridor project, four phases



Sources: Main roads: OSM 2022; Zambia country boundary: GADM 2012.

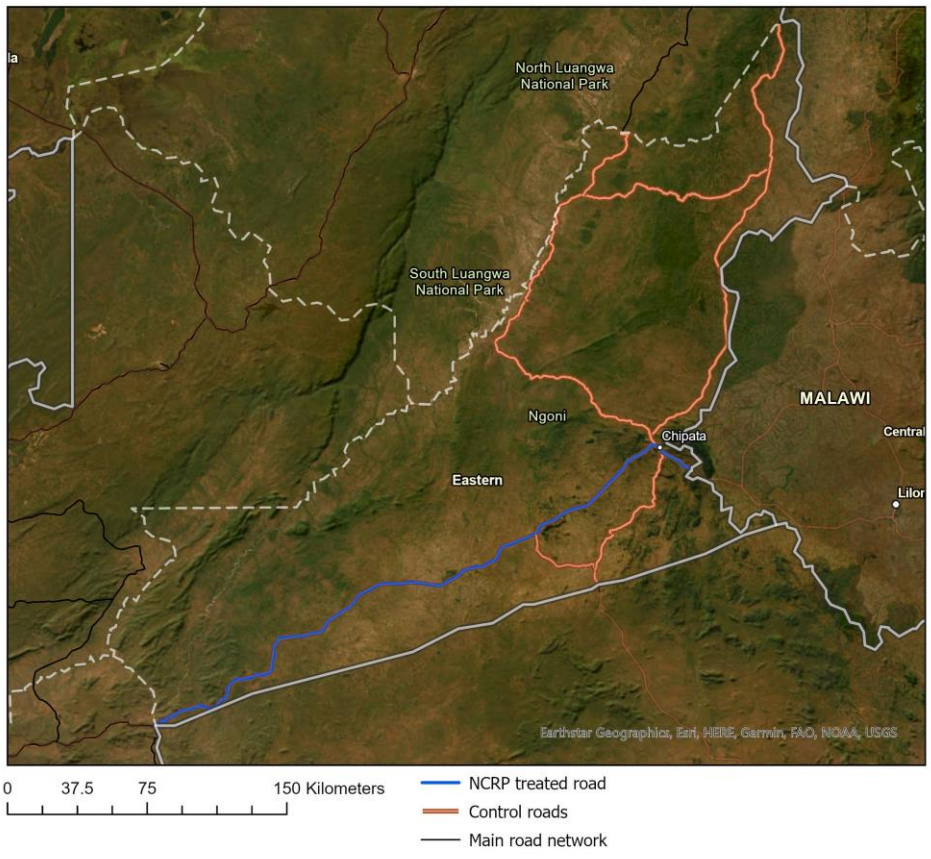
4. Data

GIS and remotely sensed satellite data were downloaded, processed and combined to conduct the assessment. The different data sources and processing required are outlined below.

4.1. Roads

The completed section of road under Phase 2 of the project was selected as the treatment group and compared to primary or secondary roads in the surrounding area, within the Eastern province of Zambia; these were selected as the control group (figure 2). These other roads had received no treatment for the years of focus in the study (2012-20). The geospatial coordinates of the road included in Phase 2 were provided by the AfDB.

▶ **Figure 2. Treated and control roads used in the study**



4.2. Night-time lights

Monthly night-time lights (NTL) data from NASA's Visible Infrared Imaging Radiometer Suite (VIIRS) Day Night Band (DNB) instrument were used as the dependent variable of interest. Due to the timing of the project, it was possible to use only NTL data from the VIIRS satellite. Many previous studies have also had to use data from the previous satellite Defense Meteorological Satellite Program (DMSP) (pre-2012), where further effort would have to go into calibration of luminosity values between satellites, which can cause some discrepancies in the outcome. NTL data were obtained from the beginning of 2012 to the end of 2020 at monthly intervals. NTL data values are presented as "radiance" or "brightness" values. Figure 3 presents a map of NTL data in Zambia.

Due to the background noise in high-frequency VIIRS data, NASA implemented the Black Marble Product Suite which calibrates luminosity emissions from non-human activities that can interfere with the NTL radiance. The product uses a novel "Turning Off the Moon" approach that combines cloud-free, atmospheric-, terrain-, vegetation-, snow-, lunar-, and stray light-corrected VIIRS DNB radiances, daytime DNB surface reflectance, Bidirectional Reflectance Distribution Function (BRDF) / Albedo, and Lunar irradiance values to minimize the influence of extraneous artifacts and biases (Román et al. 2018; Román and Stokes 2015). After adjusting for these systematic sources of uncertainty and measurement error, the VIIRS DNB's ultra-sensitivity and daily frequency enables short-term changes in rural areas that are often characterized by low light to be accurately detected.

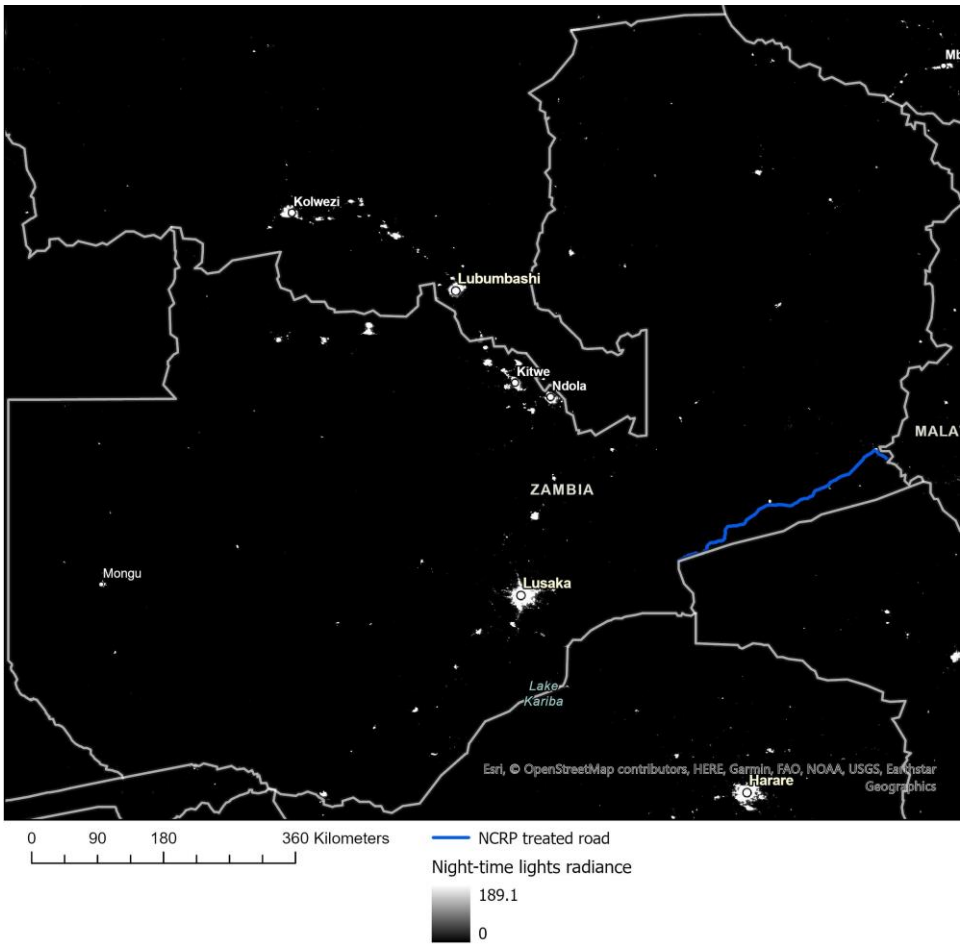
Although the monthly Black Marble Suite brings high-quality NTL data, it does not necessarily decrease the volatility of light emissions of pixels. Compared to the relatively stable annual DNB series, the monthly series captures the seasonal pattern of lights. The VIIRS instruments board two satellites, NOAA/NASA Suomi NPP and NOAA-20, on a polar orbit, to generate a full global image twice a day. The satellites pass all locations on earth at the same local times to keep the observation consistent and reduce the effects of sun and moonlight. Consequently, the observed light emission intensity will be low in the summertime due to the late sunset time and become higher in winter because of the early sunset. The variances of observations would not correctly indicate the real artificial light intensity that could be generated by the local infrastructures, which could make the DNB radiance series a poor proxy for socio-economic development. Even though Zambia is in the tropical zone, the intensity of the NTL can still vary due to seasonal farming, grazing, festivals and other interventions.

To calibrate the light radiance, the DNB series was first smoothed with a high-pass exponential smoothing method to remove outliers and fill missing values. Then, a Seasonal and Trend decomposition was used based on Loess (STL) to remove the seasonal component of the DNB series for each pixel. Following the work of Cleveland et al. (1990), the DNB radiance series is decomposed into three components:

$$Yi, j, t = Ti, j, t + Si, j, t + Ri, j, t$$

where Yi,j,t indicates the DNB radiance value for a pixel centred at longitude i degree and latitude j degree, Ti,j,t and Si,j,t represent the trend and seasonality component for the series, and Ri,j,t is the residual component. The de-seasonalized DNB series are then composed as the sum of trend and residual, Ti,j,t+Ri,j,t.

Figure 3. Night-time lights over Zambia



4.3. Additional GIS and remote sensing (RS) data

A range of GIS data were used in the analysis to include as control variables of interest. All data was resampled to a spatial resolution of approximately 450m x 450m to match the resolution of the NTL imagery. To control for population growth and account for an increase of lights due to expected increase in population each year, annual gridded population estimates from Worldpop were included, which provides a population count across the country at the approximate 100m grid cell. Locations of conflicts between 2012 and 2020 were obtained from the Armed Conflict Location and Event Data Project (ACLED) and filtered to include larger-scale conflicts such as explosions or riots, which could have influenced NTL brightness in target areas. The presence of other infrastructure investments in the study area during the time period of the analysis were researched; some projects that fell within the specific study area were present but were not yet completed during the time period of the analysis. This included rural electrification projects and other road interventions, which could influence the lights.

5. Methods

5.1. Econometrics

This analysis closely follows the methodology covered in previous assessments conducted by the STRENGTHEN2 project, in Rwanda and Kenya (Game and Kang 2023a, 2023b). This work built upon the research by Mitnik, Sanchez, and Yañez-Pagans (2018), with their assessment of road projects in Haiti. They examined the impacts of transport infrastructure investments on economic activity, discovering a 6-26 per cent increase in NTL following a road investment and a 0.5-2.1 per cent increase in GDP. They applied a difference in difference (DID) approach at both communal section and pixel level and discovered that the highest impacts were concentrated within two kilometres of the road. Other previous work has investigated the effects of transport investments on NTL, including BenYishay et al. (2018) who applied a quasi-experimental framework to look at the impact of projects in the West Bank at the pixel level. They discovered an increase in NTL due to these investments and that proximity to multiple roads resulted in a further increase in NTL.

The analysis aims to use NTL data to assess the economic and employment impacts of the NCRP Phase 2 intervention. It assesses the impacts of the road at both the administrative Level 3, the smallest administrative level where data were available for Zambia, and at pixel level (approximately 450m x 450m resolution). The analysis focuses on how impacts vary over time, or years after treatment, and as distance from the road improvement increases.

Administrative units within a 2.5 km distance from the road are used in the benchmark regressions and there were a total of 85 such units in the study area that fall within this distance from both the treated and control roads. If an administrative area fell within both the 2.5km distance from treated and control roads, it was assigned as a treated area. The pixel-level analysis was performed to investigate how impacts change across distance, where distances up to five kilometres from the roads were examined, with the end point of 5 km being selected based on the findings. The results of the impact on GDP and employment were derived from the administrative level analysis. Monthly NTL data were used in the analysis for the years 2015–20, providing a total of 72 monthly measures. For the administrative level analysis, NTL pixels that fell within each administrative unit were summed to get the total NTL brightness for each unit.

A consideration when assessing the impact of infrastructure projects is the endogeneity of road placement, where the prioritization and the location of roads are often based on economic and political factors, favouring areas that would already have more potential for economic activity and development. Research has been done on how to overcome these issues of endogeneity, Berg et al. (2015) provide an overview of how literature has dealt with endogeneity in the past, where methods include applying an instrumental variables (IV) strategy or DID approach, to introduce exogenous variation. It is also important to understand that the reasons for the road placement are exogenous in the first place. To account for this in the present study, a DID approach was applied and the end points of the corridor were omitted from the analysis, as they can be argued to be endogenous nodes.

The DID approach was applied to investigate the relationship between treatment (administrative areas that fell within 2.5 km of the road improvement) and NTL brightness. Starting from a reduced form specification, this was then built upon to include monthly, individual (administrative-level) fixed effects, the covariates of population and conflicts and lagged covariates. These different regressions were run for each year after completion, a span of three years, to understand when the largest effect could be identified. From this, a preferred specification was decided which was then used for the interpretation of final results and applied to the analysis at pixel level, looking at how NTL varies as a result of changing the distance from the road.

The equation below presents the general econometric specification that was applied:

$$Y_{i,t} = \alpha + \beta_1 Treated_{it} + \beta_2 X_{it} + \beta_3 Z_{it-j} + \lambda_i + n_t + \epsilon_{i,t}$$

where Y is the NTL brightness for the administrative unit or pixel, $Treated$ is the treatment variable that has a value of 1 for the month and year the area received a road improvement and 0 otherwise; λ_i are individual or administrative area fixed effects and n_t are monthly fixed effects; X_{it} are the unlagged control variables including population and conflicts; and Z_{it-j} presents lagged control variables, where a lag of one year was tested, as per Mitnik, Sanchez, and Yañez-Pagans (2018).

Different models were run, starting from the most reduced specification, to introducing fixed effects and finally including covariates which then led to deciding on a preferred specification. Each model addresses a different type of variation, where the simple specification including no fixed effects is looking at overall variation. Including administrative fixed effects addresses variation over time, and both administrative and time-fixed effects address variations over time within administrative units.

5.2. Translating NTL to GDP/employment

In order to examine the impact of lights on GDP, data were sourced from ZamStats on provincial level GDP and employment for the years 2017–21. There are two approaches to estimating employment using the NTL data. First, a direct approach examines the direct elasticity between lights and employment. The second is the indirect approach, which first calculates the elasticity between lights and GDP and then GDP and employment; the combined coefficient is taken from the two and applied to estimate the increase in employment. The NTL brightness was averaged across the provinces for each consecutive year, using the annual composites of the data.

6. Results

6.1. Descriptive statistics

Tables 2 and 3 present descriptive statistics for each of the variables included in the analysis, spanning the years 2015–17, prior to the completion of any of the sections of the road. Table 3 shows the untreated areas – administrative areas that were included in the control group and did not receive part of the road improvement. The treated areas (table 2) are those that fell within the 2.5 km buffer around the road project. Treated administrative areas had a higher NTL luminosity compared to those that were not treated. Both categories had no large conflicts for the years included in the sample.

▶ Table 2. Treated administrative area summary statistics

Statistic	Mean	St. Dev.
NTL luminosity	99.906	218.412
IHS of NTL luminosity	2.828	2.371
Conflicts	0.006	0.064
Population	18 248.240	15 092.080

Source: Authors' research.

▶ Table 3. Untreated administrative area summary statistics

Statistic	Mean	St. Dev.
NTL luminosity	18.083	65.674
IHS of NTL luminosity	1.084	1.773
Conflicts	0.001	0.013
Population	16 410.500	15 516.570

Source: Authors' research.

6.2. Main results

Table 4 highlights the results from the DID analysis at the administrative level, taking the benchmark of two years after completion of the project. Following the regressions of Mitnik, Sanchez, and Yañez-Pagans (2018) and starting from the most reduced specification, step by step, different elements were introduced into the models as outlined in each column. Administrative and time-fixed effects were first introduced, followed by variables for population and conflicts. The lagged covariates in column (5) were the final component to be included, where a lag of one year was tested. Lagged data were not included in the preferred specification because coefficient estimates from the lagged results did not conform to theoretical expectations, where there were changes of sign between current and lagged covariates. The specification in column (4) was taken as preferred and this was the model specification that was used for the pixel-level analysis.

All the regressions for the different years after treatment follow a similar pattern, with the treatment effect being negative without covariates or fixed effects (column 1). The introduction of administrative area fixed effects has a positive effect on the coefficients across all years (columns 3-4), where variation over time and within administrative units is now being observed. Column 4 presents results after the inclusion of the control variables of population and conflicts. The presence of conflicts is included by taking the form of a dummy variable with a value of 1 if a conflict occurred in the administrative area during the month and 0 otherwise. As highlighted above, the final preferred specification including only the current variables of population and conflicts, is presented in column 4 in the table. The coefficient using this specification is 0.231, when exponentiating the coefficient for interpretation of the results, using (exp(X) -1), this is equivalent to a 25 per cent increase in NTL for administrative areas that received the road improvement project. The change of sign between columns (1,2) to column (3) onwards could suggest a potential endogeneity issue; the fixed effects introduced after column 3 are a way to address this.

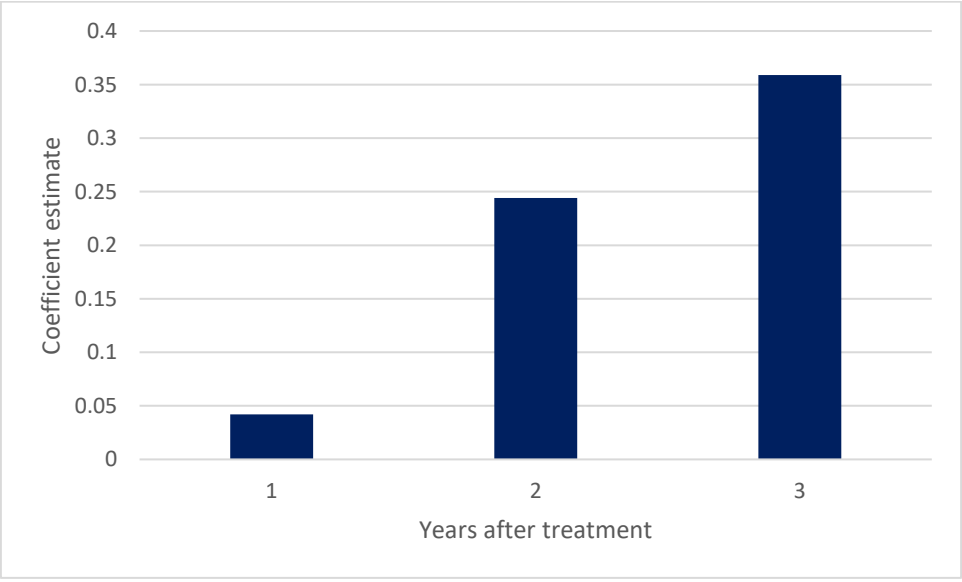
When looking at the tables for one to three years after completion of the project (see the Annex for one and two years, and figure 4), the impact continues to increase over time. The coefficient estimates for one year after completion are small and not statistically significant, implying that it took at least a year for the positive effects to be seen. Since there is a larger increase in NTL brightness three years after completion of the project, it was decided to use two years after treatment following the previous assessments and literature to provide an estimate of the impact of the road on NTL. This was then used as the basis for the estimates on GDP and employment.

▶ Table 4. DID analysis results, two years after completion of the project

Variables	1	2	3	4	5
treatment	-1.019***	-0.028	0.238***	0.231***	0.244***
	(0.061)	(0.028)	(0.042)	(0.042)	(0.046)
pop				0.021**	0.023
				(0.009)	(0.021)
conf				-0.168	0.029
				(0.197)	(0.099)
L12.pop					-0.001
					(0.018)
L12.conf					-0.277**
					(0.114)
Observations	5 640	5 640	5 640	5 640	4 512
R^2	0.034	0.883	0.888	0.888	0.882
Admin area FE	NO	YES	YES	YES	YES
Year FE	NO	NO	YES	YES	YES
Lagged covariates	NO	NO	NO	NO	t-12
Note:	Robust standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01				

Source: Authors' research.

▶ Figure 4. Coefficient estimates for the two years after completion of the road project



Source: Authors' research.

6.3. Pixel-level results

The above text outlines the results for the analysis at the administrative area, which were then used as the preferred specification to estimate the impact on GDP and then employment from the road project (column 4 in the regressions). The analysis was also conducted at the pixel level (table 5) to investigate how impacts on NTL vary based on distance from the road project. Understanding if the effects are concentrated around the road improvements is important from a planning and policy perspective, for the targeting of future investments.

To test for heterogeneity in results and explore how effects vary across distance from the road, the buffer outside the road was changed using increments of 1 km. Five regressions are run, looking at five 1 km buffers surrounding the road. It was chosen to look at distance from the road using increments of 1 km, to aid the interpretation of results based on an equal set of distances that can be easily compared. Table 5 outlines the results; all the effects are positive but very small, where the largest impact can be seen closest to the road, at 0–1 km distance, but this is not much different from the size of effects that can be observed throughout the other distances. There seems to be a small but positive effect across all distances, which may imply that the drop off occurs further than 5 km away from the road. This would vary from the results found in our previous assessments and in Mitnik, Sanchez, and Yañez-Pagans (2018), that discovered that the effects drop off and coefficients decrease in significance after 2 km.

▶ Table 5. DID analysis results, two years after completion of the project, at the pixel level

	NTL luminosity				
	0-1 km	1-2 km	2-3 km	3-4 km	4-5 km
treatment	0.008***	0.005***	0.007***	0.004***	0.006***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1 110 456	1 094 344	1 067 102	1 046 856	1,032,334
R^2	0.915	0.912	0.870	0.802	0.851
Pixel FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
Note:	Robust standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01				

Source: Authors' research.

6.4. NTL and GDP

So far this report has discussed the results in terms of an increase in NTL brightness, following the improved road project. However, to more fully understand the economic and employment impacts of road investments, it is imperative to express changes in NTL in terms of changes in GDP and then employment. As mentioned, previous literature has demonstrated the applicability of NTL as a proxy for economic activity in the form of GDP. Different levels of data were available for GDP at the provincial level, so both were tested to explore the relationship between GDP and NTL.

The main results are presented in table 6, which presents the elasticity between GDP and NTL, using annual provincial-level data for Zambia, including province-level fixed effects.

The elasticity is 0.489 and is statistically significant. This is greater than the elasticity for Kenya (Game and Kang 2023a) and greater than that estimated in Mitnik, Sanchez, and Yañez-Pagans (2018). It aligns more with the higher elasticities observed from using the VIIRS nighttime light data, such as in Beyer et al. (2022). Assuming that this elasticity holds at administrative level 3, this suggests an estimated increase in local GDP of 12 per cent based on the results of our preferred specification assessing impact two years after completion of the road project.

▶ Table 6. Elasticity between annual GDP and NTL luminosity, using provincial level data and fixed effects

	lnGDP
lnNTL	0.489***
	(0.138)
Observations	50
R^2	0.967
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: Authors' research.

6.5. Translating into employment

Now that the economic impact of the road improvement project has been studied in the form of GDP, work can be done on translating this into employment impact. There are two approaches to doing this. The first is to follow on from the previous NTL/GDP elasticity and then look at the relationship between GDP and employment. The second approach calculates the direct elasticity between NTL and employment. This section focuses on the first approach, examining the indirect relationship.

Using employment data from the ZamStats LFS on the number of persons employed per year, the relationship between GDP and employment is presented in table 7. The log difference was used to investigate the elasticity between GDP and employment. The coefficient is 0.55, which is again slightly higher than the coefficient observed in the Kenya assessment (Game and Kang 2023a), but in line with previous GDP/employment elasticity calculated for Zambia in the past (Harasty et al., 2015). Taking the lights/GDP elasticity of 0.48 and this coefficient of 0.55 produces a combined coefficient of 0.27. Taking this combined coefficient into account leads to an estimated 6.7 per cent increase in local-level employment for areas that benefited from the implementation of the project.

In order to establish an estimate for the actual number of jobs created, it was necessary to utilize LFS data during the years of the project. Access to the data was made available through collaboration with ZamStats. The survey is undertaken annually and representative at the national and provincial level. A representative sample of the population is collected and then the data are weighted to report for the country and provinces. Due to the NTL analysis being carried out at the ward and constituency level, there is a need to weight the data collected on employment to obtain the number of people employed at the constituency level. The individual annual weights were used for this, and it should be noted that these are meant to produce data representative at the national and provincial level, rather than constituency or ward level. This can provide an estimation of the number of jobs created based on employment at the constituency level, but the mismatch in level of representation should be considered when interpreting the results. Based on the constituencies within the study area, it was estimated that there were 203,829 people employed in the year the project was completed. From the estimation of a 6.7 per cent increase in employment in the treated study area, this would be equivalent to an estimated 13,657 people employed. It should also be noted that this level of employment cannot be fully attributed to the road programme, where additional factors could be responsible for the increase in the number of jobs.

▶ **Table 7. Relationship between annual employment and GDP at the provincial level**

	lnEmp
lnGDP	0.552*
	(0.308)
Observations	50
R^2	0.965
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: Authors' research.

7. Conclusion and research recommendations

The Nacala Road Corridor Project has increased economic activity in the form of GDP and employment at the local level, for areas that benefited from the rehabilitated road. This report highlights the long-term economic and employment impacts of the programme and feeds into the wider body of research on utilizing night-time lights data to measure the effects of investments in transport infrastructure. This assessment builds upon previous assessments by the STRENGTHEN2 project in Kenya and Rwanda, further exploring the use of GIS and satellite data to measure changes in GDP over time and extending this beyond the existing literature to highlight the employment effects of specific interventions. It also adds to the studies focused on countries in sub-Saharan Africa, which were previously less researched when examining the impacts of transport infrastructure on night-time lights.

The results highlight that the NRCP increased lights in areas that benefited from the road intervention compared to areas that did not, by an estimated 25 per cent at the administrative level. This was for two years after completion of the project, at the end of 2017, using the preferred specification including administrative level and time fixed effects and controlling for population and conflicts. When looking at the elasticity between lights and GDP across the country, using data from the provincial level, it is estimated that this led to a 12 per cent increase in GDP at the local level, across the administrative units within 2.5 km of the road. Taking the elasticity between employment and GDP and applying this to the outcome, it is estimated that this resulted in an estimated 6.7 per cent increase in employment at the local level. The results from the pixel level analysis indicate that there was a positive effect between 0 and 5 kilometres distance away from the roads, with the highest being within 1 km distance away. This indicates that positive impacts may drop off further from the road than the 5 km benchmark originally set.

Compared to the previous assessment of part of a transport corridor in Kenya (Game and Kang 2023a), the initial results for the NRCP are higher. When looking at the results in terms of millions of euros invested and km of road works, the results are approximately ten times larger. The total cost of Phase 2 of the project was approximately 43.3 million euros. Taking this into account, it is estimated that per million invested, local GDP increased by 0.27 per cent. For employment, this is equal to 0.15 per cent increase. When looking at the results per 100 km of road, out of a total of 360 km, this results in an estimated increase in local GDP of 3.3 per cent and employment of 1.8 per cent. Understanding why the impacts of this road project were larger compared to the corridor in Kenya would be interesting to feed into the future planning of road investment in sub-Saharan Africa. Reasons could lie in the characteristics of the different countries and locations of the roads, where the road in Kenya was serving a predominantly rural area which prior to the intervention did not have a paved highway. The NCRP is also part of a much larger programme that includes other projects, such as the Great East Road Rehabilitation Programme financed by the European Union, that feeds the Nacala corridor. This could potentially result in the generation of more economic activity in the study area in Zambia.

This work further highlights the application of night-time lights as a proxy for economic activity, but further work should be done on studying this relationship and the links to employment, to measure the impacts of infrastructure projects. Issues such as endogeneity of road placement should be further researched, where it was addressed through this work by applying a DID approach and could be acknowledged further through a better understanding of the prioritization of road placement for the particular projects being assessed. Having a general awareness of the issues surrounding endogeneity should be considered when examining the results of these large infrastructure programmes. This feeds into the issue of attribution of the increase in lights to the road project being assessed, although the presence of other infrastructure programmes during the study period (such as electrification projects or other roads) are researched and controlled for if present, there are still various other factors on the ground that could contribute to an increase in lights not due to economic activity generated by the road. There is however much opportunity for studying the long-term impacts of road investments using this methodology, which is not limited by data availability and is relatively less resource-intensive. It is recommended that this analysis is further replicated and improved upon to streamline the methodology further. Doing this will encourage the use of these data to be operationalized within development banks and other institutions to measure the long-term impacts of their investments. The outcomes of these assessments can feed into future planning and decision-making regarding interventions and provide insight for policy for national stakeholders and other interested parties.

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Annex

Table A1. DID results, one year after completion of the project

VARIABLES	(1) OLS	(2) FE	(3) FE	(4) FE	(5) FE
tp	-0.933***	0.026	0.033	0.028	0.042
	(0.082)	(0.030)	(0.044)	(0.045)	(0.048)
pop_k				0.010	0.017
				(0.010)	(0.022)
L12.pop_k					-0.023
					(0.019)
conf				-0.342	-0.187
				(0.279)	(0.124)
L12.conf					-0.133
					(0.100)
Constant	2.043***	1.918***	1.917***	1.736***	2.057***
	(0.037)	(0.011)	(0.011)	(0.168)	(0.282)
Observations	4,512	4,512	4,512	4,512	3,384
Adjusted R-squared	0.019	0.908	0.909	0.909	0.908
Admin area FE	NO	YES	YES	YES	YES
Year FE	NO	NO	YES	YES	YES
Lagged covariates	NO	NO	NO	NO	t-12

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A2. DID results, three years after completion of the project

VARIABLES	(1) OLS	(2) FE	(3) FE	(4) FE	(5) FE
tp	-1.040***	-0.041	0.352***	0.346***	0.359***
	(0.053)	(0.026)	(0.038)	(0.038)	(0.043)
pop_k				0.014**	-0.008
				(0.007)	(0.017)
L12.pop_k					0.023
					(0.017)
conf				-0.160	0.130
				(0.195)	(0.107)
L12.conf					-0.136
					(0.096)
Constant	2.083***	1.826***	1.726***	1.474***	1.458***
	(0.033)	(0.011)	(0.013)	(0.121)	(0.186)
Observations	6,674	6,674	6,674	6,674	5,546
Adjusted R-squared	0.042	0.873	0.880	0.880	0.874
Admin area FE	NO	YES	YES	YES	YES
Year FE	NO	NO	YES	YES	YES
Lagged covariates	NO	NO	NO	NO	t-12

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1