International Labour Organization

STRENGTHEN2

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Employment impact assessment of the Merille-Marsabit road, Isiolo-Moyale transport corridor in Kenya

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Acronyms and abbreviations

ACLED	Armed Conflict Location and Event Data Project
DID	Difference in difference
DNB	Day Night Band
EmpIA	Employment impact assessment
EU	European Union
GDP	Gross domestic product
GIS	Geographic information systems
GoK	Government of Kenya
KES	Kenyan shilling
KNBS	Kenya Bureau of Statistics
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalised Difference Vegetation Index
NTL	Night-time lights
RS	Remote sensing
SSA	sub-Saharan Africa
VIIRS	Visible Infrared Imaging Radiometer Suite

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Executive Summary

The ILO STRENGTHEN2 project is conducting employment impact assessments of EU-funded investments in sub-Saharan Africa, to promote the creation of more and better jobs. This report presents an employment impact assessment (EmpIA) of part of the Isiolo-Moyale transport corridor project in Kenya, which includes the EU-funded section of the Merille-Marsabit road. The project was completed at the end of 2016 and aimed to increase economic activity and employment opportunity for Kenyans, increase trade and reduce transport costs.

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. The treated road, that was rehabilitated as part of the corridor project was compared to two untreated roads with similar characteristics. The increase in NTL brightness was compared pre and post treatment, whilst controlling for population, conflicts and other variables to analyse the economic impact of the road rehabilitation. The increase in NTL was translated into GDP using the national level elasticity and then further translated into employment, to estimate the percentage increase in employment caused by the improved road. This was estimated across four years following completion of the project and analysed at different distances from the road, to highlight where the impacts were greatest.

The results show that the improved sections of road increased night-time light luminosity between 11 and 22.8 per cent at the administrative level, between one and four years following completion of the project, respectively. It is estimated that this produced an increase in GDP between 4.6 per cent, one year after completion and 9.6 per cent, four years after completion and taking into account the elasticity between lights/GDP and GDP/employment, this equates to an increase of between 1.4 and 3 per cent in employment. Taking the estimate of two years after completion of the project, the results present a 5.4 per cent increase in GDP and 1.7 per cent increase in employment after project completion. Impacts continue to increase over time, across the four years of the study. It was observed that the largest effects fell within one kilometre of the improved road, where the impacts after a distance of two kilometres from the road are negligible. It is recommended that future road construction in Kenya is prioritized within this distance of target beneficiaries. These findings can feed into future planning and monitoring of road investments in Kenya and sub-Saharan Africa as a whole.

When presenting the results in terms of million Euro invested and km of road built, using the total of the Isiolo to Moyale transport corridor, it is estimated that per million invested, GDP is estimated to increase by 0.03 per cent, using the maximum of four years after completion of the project. For employment, this equates to an increase of 0.01 per cent per million Euro. In order to compare to other similar projects, when looking at the results per 100km of road constructed or rehabilitated, this is equivalent to an increase in employment of 0.6 per cent and an increase in GDP of 1.92 per cent.

The study highlights the applicability of using satellite data to measure the economic and employment impacts of infrastructure investments in sub-Saharan Africa. It is recommended that similar assessments are 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 de l'impact sur l'emploi d'investissements financés par l'Union Européenne 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 d'une partie du projet portant sur le corridor de transport Isiolo-Moyale au Kenya, qui comprend la section de route Merille-Marsabit financée par l'UE. Le projet a été achevé fin 2016 et visait à accroître l'activité économique et les opportunités d'emploi pour les Kényans, ainsi qu'à augmenter les échanges commerciaux et réduire les coûts de transport.

Les données et les méthodes de Systèmes d'Information Géographique (SIG) ont été utilisées pour évaluer les impacts du projet à long terme sur l'économie et l'emploi. L'imagerie satellite de luminosité nocturne constitue la base de données principale, offrant une mesure des émissions de lumières nocturnes et pouvant être appliquée comme un indicateur de l'activité économique. La route traitée, qui a été réhabilitée dans le cadre du projet de corridor, a été comparée à deux routes non traitées présentant des caractéristiques similaires. L'augmentation de la luminosité nocturne a été comparée avant et après traitement, tout en contrôlant des variables telles que la population, des conflits et autres variables pour analyser l'impact économique de la réhabilitation de la route. L'augmentation en luminosité nocturne a été convertie en PIB en utilisant l'élasticité au niveau national, puis convertie à nouveau en emploi, afin d'estimer le pourcentage d'augmentation de l'emploi causé par l'amélioration de la route. Cette augmentation a été estimée sur quatre ans suivant l'achèvement du projet et analysée à différentes distances de la route, afin de mettre en évidence les endroits où les impacts étaient les plus importants.

Les résultats montrent que les sections de route aménagées ont entraîné l'augmentation de la luminosité nocturne entre 11 et 22,8 pour cent au niveau cantonal, respectivement entre un et quatre ans après l'achèvement du projet. On estime que cela a produit une augmentation du PIB (Produit Intérieur Brut) entre 4,6 pour cent un an après l'achèvement du projet, et 9,6 pour cent quatre ans après l'achèvement du projet, tout en tenant compte de l'élasticité entre la luminosité/le PIB et le PIB/l'emploi ; cela équivaut à une augmentation entre 1,4 et 3 pour cent de l'emploi. En prenant l'estimation référente de deux ans après l'achèvement du projet, les résultats présentent une augmentation de 5,4 pour cent du PIB et de 1,7 pour cent de l'emploi après l'achèvement du projet. Les effets positifs continuent d'augmenter tout au long des quatre années d'étude. Il a été observé que les effets les plus importants se situaient à moins d'un kilomètre de l'aménagement de la route, tandis que les impacts au-delà de deux kilomètres de la route sont négligeables. Il est ainsi recommandé que les futures constructions de routes au Kenya soient réalisées dans cette distance limite afin de mieux cibler les bénéficiaires. Ces résultats pourront aider la planification et le suivi de futurs investissements routiers au Kenya et dans l'ensemble de l'Afrique subsaharienne.

Lorsque l'on présente les résultats en termes de millions d'euros investis et de kilomètres de route construits sur la totalité du corridor de transport entre Isiolo et Moyale, on estime que le PIB augmente de 0,03 pour cent par million d'euros investi, quatre ans après l'achèvement du projet. Pour l'emploi, cela équivaut à une augmentation de 0,01 pour cent par million d'euros. Afin de comparer avec d'autres projets similaires, cela équivaut à une augmentation de l'emploi de 0,6 pour cent et à une augmentation du PIB de 1,92 pour cent pour 100 km de route construite ou réhabilitée.

Cette étude met en évidence l'applicabilité de l'utilisation de données satellites pour mesurer les impacts sur l'économie et l'emploi des investissements en infrastructures en Afrique sub-saharienne. 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 de l'impact sur l'emploi.

1. Introduction

The STRENGTHEN2 project aims to leverage employment impact assessment (EmpIA) in sub-Saharan Africa to promote the creation of more and better jobs. STRENGTHEN2 is working to assess the employment impact of EU-funded infrastructure investments in Kenya, among other countries. The Merille-Marsabit road project, as part of the wider Isiolo to Moyale corridor, aimed to enhance trade, reduce transport costs between Kenya and Ethiopia and increase economic growth for the surrounding population. The corridor was constructed in four parts, with the final part completed at the end of 2016. It was financed by the European Union (EU), the African Development Bank (AfDB) and the Government of Kenya (GoK). This report presents the EmpIA for the project, using Geographic Information Systems (GIS) analysis and night-time lights (NTL) data to assess the long-term employment effects. It outlines the country context for Kenya, the project description, methodology, results and discussion and recommendations.

Assessing the employment impacts of infrastructure projects once they are complete is important to understand the long-term effects that interventions have produced, although these impacts are arguably the most difficult to measure. Operationalizing the use of GIS in EmpIA is relatively new, but there has been 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). This work 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

Kenya is a country in sub-Saharan Africa (SSA), within East Africa, with a population of 47.6 million as per the 2019 national census, and an annual growth rate averaging 2.2 per cent. As of 2020, the population is estimated to be about 54 million (World Bank 2020). The country is divided into 47 counties and has a population density of 74 per sq. km, where the average household size is 3.9 (KNBS 2022). The rural population represent 72 per cent of the total population (World Bank 2020).

Kenya's gross domestic product (GDP) is approximately US$110 billion, with annual GDP growth in 2022 at 4.7 per cent (World Bank 2022a). The major economic sectors in Kenya as of 2020, with high value-added and therefore the potential for delivering high economic growth rates, are agriculture (contributing 33 per cent to GDP), manufacturing (contributing 15 per cent to GDP), wholesale and retail (contributing 8.4 per cent to GDP), finance and insurance (contributing 6 per cent to GDP), transport and storage, real estate, construction, public administration and education (KIPPRA 2020). The agriculture sector contribution to employment is significant, employing between 56 and 54 per cent between 2017 and 2019, based on ILO estimates. On the other hand, the services and industry sectors employed approximately 39 and 6 per cent between 2017 and 2019 respectively (World Bank 2022a).

The private sector in Kenya is split into two parts: a formal, large business sector which is relatively healthy and productive and a larger, informal small business sector which is poorly understood and supported yet employs almost nine out of ten workers (KNBS 2022). The share of private-sector employment was 68.3 per cent in 2021 (KNBS 2022). Links between the formal and informal sectors are fragile – and initiatives that bridge the gap should be prioritized. The private sector contributes 80 per cent of Kenya's GDP (AfDB 2013), 70 per cent of total employment, and the bulk of export earnings (IFC 2019).

Unemployment in Kenya increased from 7 per cent in 2015 to 10.4 per cent in 2020, largely due to the economic slowdown caused by COVID-19. The majority of the unemployed (about 85 per cent) are under the age of 35 (AfDB 2021). About 30 per cent of the unemployed have attained primary-level education, 35 per cent secondary, 11 per cent mid-level and 9 per cent university education.

The state of infrastructure (under the construction sector) expanded by 6.6 per cent in 2021 compared to a growth of 10.1 per cent in 2020. The growth was mainly supported by continuous public investment in road infrastructure (KNBS 2022). Some major road construction activities that boosted the sector's performance include the Nairobi expressway and the rehabilitation of the Longonot-Malaba railway line. Overall national government expenditure on roads increased from 195.3 billion Kenya shillings (KES) in 2020/21 to 207.2 billion in 2021/22 (KNBS 2022). In 2021, there were 2,712.5 kilometres of “R2000 Programme” and “R10000 Programme” roads under improvement and upgrading, with an estimated construction cost of KES 355.5 billion (KNBS 2022). Road construction was funded primarily using public debt

3. Project description

The Merille-Marsabit road is located in the Marsabit county of Kenya. Marsabit is a predominantly rural county, and before 2011 no tar road linked it to the rest of Kenya. The road is 120.6 km long and underwent upgrading and asphalting as part of the intervention. The project was contractually completed by 26 May 2017, where roadworks began on 24 July 2013. The EU provided a grant of 85.2 million Euro for the project. The road was upgraded to include 10 bridges, 83 box culverts, 72 cross pipe culverts, 2.9 million m^3 of excavation and fill, 29,000 m^3 of concrete, 893 tonnes of structural steel, 315,000 m^3 of sub base, 295,000 m^3 of crushed stone base and 50,500 m^3 of asphalt. Over 1,000 workers were employed directly during the project road construction.

The road forms part of the strategic transport corridor, the Isiolo to Moyale corridor linking Mombasa Port and Addis Ababa. The corridor aimed to provide a vital transportation and trade link between Kenya and Ethiopia and was financed for a total of approximately 420 billion Ksh or 320 million Euro. It included four sections of road, which are displayed in figure 1, along with additional information on the year of completion and funding source in table 1. Each road was completed during a different time between the years 2015/16. The Merille-Marsabit road was the only road co-funded by the EU, with AfDB co-funding the remaining three lots. Due to the close timing of roads and similar characteristics, three lots of the road (Lots 2, 3 and 4) were included in the analysis; these fell within the timelines for the data availability. As Lot 1 was completed much earlier (in July 2011) and fell outside the time period of available data, this was included in the study but not as part of the treatment group, with its status of being previously treated was controlled for in the analysis.

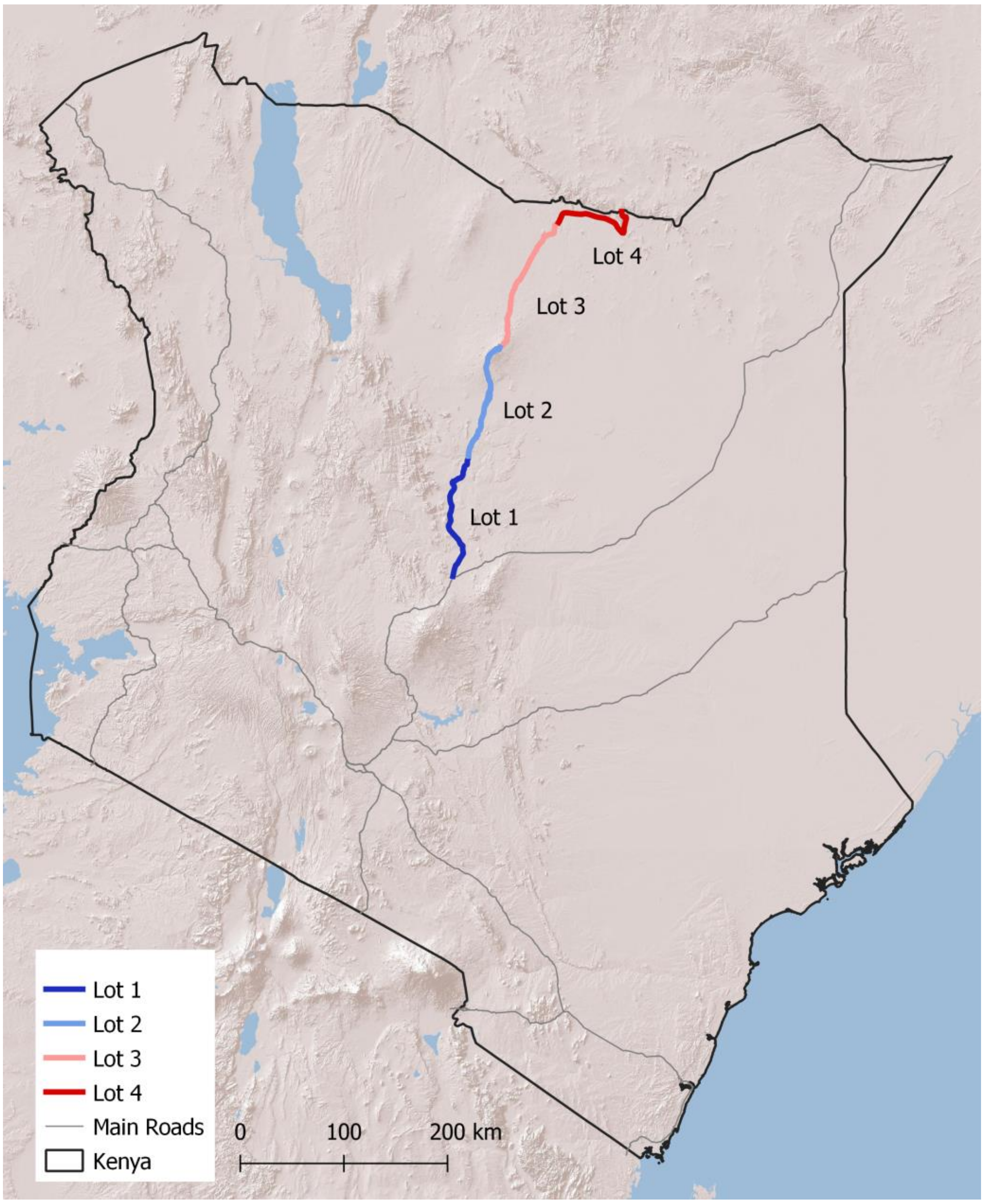
The roads further form part of the Trans East African corridor from Cairo to Cape Town. They are also a component of the Lapsset corridor, which is an ongoing corridor project aiming to link Kenya, Ethiopia and South Sudan.

▶ Table 1. Project information on the Isiolo to Moyale corridor, separated by road section

Road	Length (km)	Completion date	Financing
Lot 1 (Isiolo to Merille)	137	July 2011	AfDB and GoK
Lot 2 (Merille to Marsabit)	120.6	December 2016	EU and GoK
Lot 3 (Marsabit to Turbi)	121	March 2015	AfDB and GoK
Lot 4 (Turbi to Moyale)	121	September 2016	AfDB and GoK

Source: Ministry of Transport, Infrastructure, Housing and Urban Development (2017)

▶ **Figure 1. Isiolo to Moyale transport corridor project, shown by section of road (lot)**



Data source: Main roads (OSM 2022), Kenya country boundary (GADM 2012), road lots (own research)

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 implemented road project passes through three counties in northern Kenya: Isiolo, Marsabit and Samburu, which were used as the study area for the analysis. The three completed sections of road were selected as the treatment group and compared to primary or secondary roads in the counties; these were selected as the control groups. These other roads had received no treatment for the years of focus in the study (2012-20); however, part of them make up sections of the above-mentioned Lapsset corridor project, which is currently under construction. This analysis offered an interesting comparison to see the potential effects that initiative could have in Kenya once completed.

4.2. Night-time lights

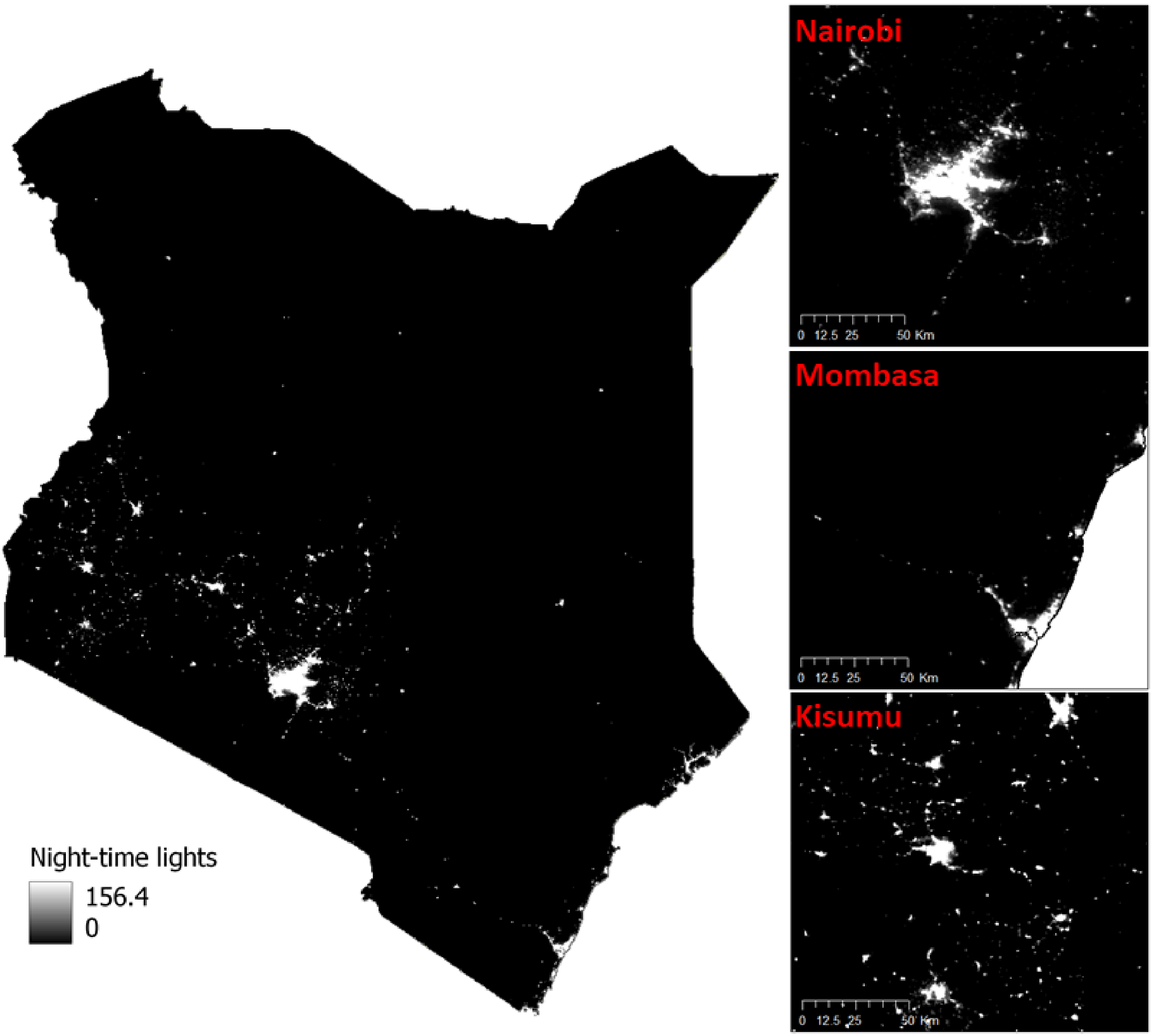
Monthly NTL data from NASA's Visible Infrared Imaging Radiometer Suite (VIIRS) Day Night Band (DNB) instrument were used as the dependent variable of interest. Due to the timing of the project, it was possible to use only NTL data from the VIIRS satellite. Many previous studies have also had to use data from the previous satellite Defense Meterological 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 2 presents a map of NTL data in Kenya for one year.

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 one to accurately detect short-term changes in rural areas that are often characterized by low light.

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 boards 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 Kenya is in the tropical zone, the intensity of the NTL can still vary due to the 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), we decompose the DNB radiance series into three components.

▶ **Figure 2. Night-time lights data across Kenya and its main cities, to illustrate the dataset**



Data source: Night-time lights (Elvidge et al. 2013)

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 other factors that could potentially influence the NTL brightness, a range of variables were included in the analysis. The Normalised Difference Vegetation Index (NDVI) provides a measure of vegetation greenness and can be used to identify changes in land use over time; this was obtained on an annual basis for the time period of focus (2012-20) from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) dataset. To control for population growth, annual gridded population estimates from Worldpop were also included, which provides a population count across the country at the approximate 100 m grid cell. Precipitation data from the Integrated Multi-satellite retrievals for GPM (IMERG) were obtained on a yearly basis at a resolution of approximately 10 km. Locations of conflicts between 2012-20 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.

5. Methods

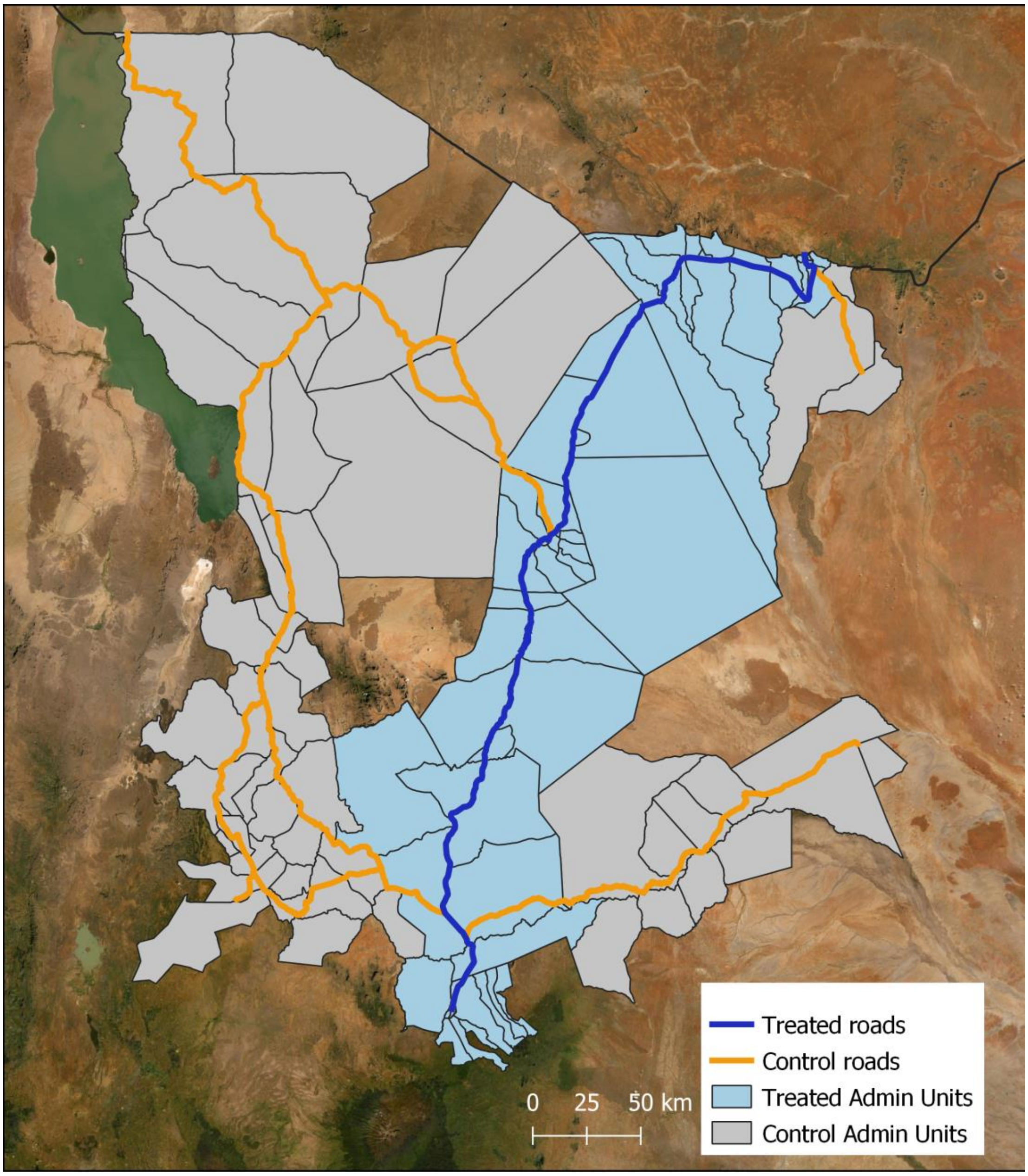
5.1. Econometrics

This analysis closely follows the methodology 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 results in a further increase in NTL.

The analysis aims to use NTL data to assess the economic and employment impacts of the road intervention. It assesses the impacts of the road at both the administrative Level 3, the smallest administrative level where data was available for Kenya, 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 2.5 km distance from the road are used in the benchmark regressions and there are a total of 90 such units in the study area that fall within this distance from both the treated and control roads. The treated and control roads are presented in figure 3, along with the administrative units within the study 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 was used in the analysis for the years 2012-20, providing a total of 108 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. Due to the large number of zero NTL values in the pixel-level data, a result of the rural characteristics of the study area, the inverse hyperbolic sine transformation (HIS) was applied to the brightness values, following Mitnik, Sanchez, and Yañez-Pagans (2018). This was then adopted as the dependent variable of interest.

▶ **Figure 3. Treated administrative units (areas benefiting from the road project, within 2.5 km) vs control administrative units used in the analysis**



Data source: Administrative units (GADM 2012), roads (OSM 2022)

A 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 and the covariates of population, conflicts, NDVI and precipitation. These different regressions were run for each year after completion, a span of four 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:

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

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, precipitation, NDVI 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

As mentioned earlier, much previous literature has focused on the translation from NTL to economic activity, in the form of GDP. National level quarterly GDP data and annual data at the county level was sourced from the Kenya Bureau of Statistics (KNBS) for the years of analysis. Employment data was also obtained from KNBS on the number of people employed, which was available annually, and quarterly only from 2019. Taking the monthly NTL images, these were converted to quarterly data by calculating the mean brightness value across three consecutive months. The national level elasticity between the NTL brightness and GDP was computed, following the method of Henderson, Storeygard, and Weil (2012). The translation to employment was tested by calculating the elasticity between GDP and employment and a direct elasticity between NTL and employment.

6. Results

6.1. Descriptive statistics

Tables 2 and 3 show the descriptive statistics for each of the variables included in the analysis, spanning the years 2012-14, prior to the completion of any of the sections of the road. The first table, showing the untreated areas, are administrative areas that were included in the control group and did not receive part of the road improvement. The treated areas 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, and they also had higher populations. Both categories had no large conflicts for the years included in the sample. The NDVI remained similar across both treated and untreated areas, though untreated units had a slightly higher level of precipitation.

▶ **Table 2. Untreated administrative area summary statistics**

	Mean	St.Dev
NTL luminosity	1.970	6.917
IHS of NTL luminosity	0.590	0.934
Precipitation	70.021	24.634
Conflicts	0	0
Population	8 389.218	6 651.566
NDVI	0.339	0.140

Where NDVI is the Normalized Difference Vegetation Index (NDVI)

Source: Own research

▶ **Table 3. Treated administrative area summary statistics**

	Mean	St.Dev
NTL luminosity	4.693	10.986
IHS of NTL luminosity	1.227	1.244
Precipitation	61.317	12.777
Conflicts	0	0
Population	9 109.434	6 458.820
NDVI	0.355	0.088

Where NDVI is the Normalized Difference Vegetation Index (NDVI)

Source: Own research

6.2. Main results

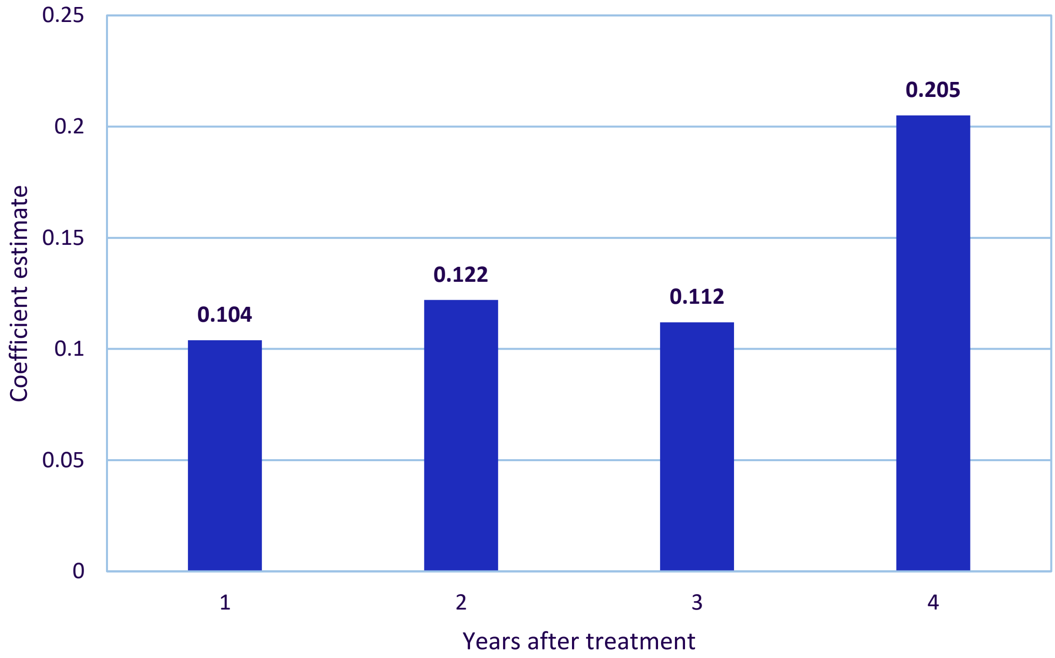
Tables A.1 to A.4 in the Annex present the main results from the DID estimation, looking at different years after completion of the final section of the road. Table 4 starts with one year after completion, all the way through to table 7 which presents four years after completion of the road project. The main results, using the preferred specification, are also presented in figure 4. 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 in the tables. Administrative and time-fixed effects were first introduced, followed by variables for population, conflicts, NDVI and precipitation. Lagged covariates were the final component to be included, where a lag of one year was tested. When looking at the coefficients of the covariates, as Mitnik, Sanchez, and Yañez-Pagans (2018) did not include a clear justification for the inclusion of precipitation and NDVI, both raised issues of reverse causality, so they were excluded from the preferred specification. Due to this and the outcomes of these regressions, it was decided to include only population and conflict, with no lag, as these were most relevant with regard to the potential impact on the NTL data. 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.[1] 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 highest without covariates or fixed effects (column 1 in each table). For one year after treatment, this coefficient is 0.617, compared to 0.33 for four years after treatment (Annex tables A.1 and A.4). The introduction of administrative area fixed effects decreases the coefficients of interest across all years and is reduced even further after the inclusion of month fixed effects (columns 2-3). Column 4 presents results after the inclusion of the control variables of population, NDVI and precipitation. The presence of conflicts is also included, 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. The treatment effect increased after adding these covariates and then decreased after also including covariates with a lag of one year. As highlighted above, the final preferred specification, including only the current variables of population and conflicts is presented in column 6 in the tables and the bar graph in figure 4. The coefficient for one year after treatment using this specification is 0.104, increasing up to 0.205 when looking at four years after treatment. When exponentiating the coefficient for interpretation of the results, using (exp(X) -1), this is equivalent to an 11.0–22.8 per cent increase in NTL for administrative areas that received the road improvement project.

Looking at the different years after treatment, the impact continues to increase over time, with the smallest effect being seen within one year after the completion of the project. An increase can be seen in two years after treatment, with a coefficient of 0.122 using our preferred specification, which equates to a 13 per cent increase in NTL. This then decreases slightly to an 11.9 per cent increase in the NTL for three years after treatment, before increasing again after four years following completion. It was decided to use two years after treatment following Mitnik, Sanchez, and Yañez-Pagans (2018), providing a relatively conservative estimate of the impact of road improvement on NTL, which was correspondingly the basis of our estimates of GDP and employment elasticities. The bar graph in figure 4 shows the coefficient estimates for the impact of the road project on NTL, using the preferred specification for different years after treatment (project completion).

[1] Regarding the coefficient estimates for covariates, these were not presented in Mitnik, Sanchez, and Yañez-Pagans (2018) so it is unclear how these findings compare to the previous literature.

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



Source: Own 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. The analysis was also conducted at the pixel- level 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.

Using the 2.5 km buffer around roads and two years after treatment, to facilitate comparison with the administrative area results above, table 4 presents the main result at the pixel-level. The treatment effect of 0.046, which is equivalent to a 4.7 per cent increase in lights following the completion of the road, is substantially lower than the effect observed at the administrative area, but remains positive and statistically significant. This smaller result at pixel level follows a similar pattern to Mitnik, Sanchez, and Yañez-Pagans (2018).

▶ Table 4. Impact on NTL luminosity following road improvement, at the pixel level, within 2.5 km of the road

	NTL luminosity
treatment	0.046***
	(0.0005)
pop	0.001***
	(0.00001)
conf	0.205***
	(0.001)
Observations	1 755 495
R^2	0.863
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: Own research

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. Table 5 outlines the results, where the largest impact can be seen closest to the road, at 0-1 km distance, with an impact of 3.1 per cent; this decreases but remains statistically significant at 1-2 km away from the road, with a 1.2 per cent increase in lights, when exponentiating the coefficient for interpretation as per the formula above. After 2 km, the sign changes and the effect becomes negative and statistically significant, although it is very small. This may suggest that after a 2 km distance, effects drop off or that there is even a slight decline in NTL in areas with a road improvement after this distance. This effect remains small and is only significant at the 10 per cent level for between 4-5 km distance away from the road.

It was chosen to look at distance from road using increments of 1 km, to aid the interpretation of results based on an equal set of distances that can be easily compared. These increments differ from Mitnik, Sanchez, and Yañez-Pagans (2018) who tested different final buffers of interest at the pixel level of 2-2.5 km, 2-3.5 km and 2-5 km. They also discovered that NTL declines as distance from the road increases, and the coefficient decreases in significance after 2 km. Between 0-1 and 1-2 km, the result is statistically significant; however, direct comparison across all distance is not possible due to the distances selected for the buffers.

▶ Table 5. Impact on NTL luminosity following road improvement, at the pixel level, changing the distance from the road

	NTL luminosity				
	0-1 km	1-2 km	2-3 km	3-4 km	4-5 km
treatment	0.031***	0.012***	-0.006***	-0.009***	-0.002*
	(0.001)	(0.001)	(0.0004)	(0.0004)	(0.001)
Observations	724 684	706 225	702 984	684 797	661 495
R^2	0.826	0.85	0.974	0.995	0.984
Note:			*p<0.1; **p<0.05; ***p<0.01		

Source: Own 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 instructive, 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 both national and county levels, 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 county-level data[2] and including county fixed effects. The elasticity is 0.424, which is greater than that estimated in Mitnik, Sanchez, and Yañez-Pagans (2018), but more in line with Henderson, Storeygard and Weil (2012), who estimated an elasticity of around 0.3 for a group of low- and middle-income countries. Assuming that this elasticity holds at the administrative level 3, this suggests an estimated increase in GDP of 5.4 per cent based on the results of our preferred specification assessing impact two years after completion of the road project. The range for one to four years after the project is between a 4.6 and 9.6 per cent increase in GDP.

[2] County-level data was used as GDP data was not available at the administrative level 3 that was used in the analysis.

▶ Table 6. Elasticity between annual GDP and NTL luminosity, at county level, including county fixed effects

	lnGDP
lnNTL	0.424***
	(0.022)
Observations	329
R^2	0.992
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: Own research

Using national level quarterly GDP data and NTL data, table 7 presents the NTL/GDP elasticity that was calculated. An elasticity of 0.25 was computed, lower than the elasticity calculated using the county-level data. This elasticity was calculated to facilitate comparison with Mitnik, Sanchez, and Yañez-Pagans (2018), who also used national data to investigate the NTL/GDP elasticity and is higher than their result for Haiti. Assuming that the elasticity of 0.25 holds at the administrative area level and using the preferred result of two years after treatment, this suggests an increase in GDP of 3.25 per cent in areas that received the road improvement, on the assumption that we can apply the national average to the area under consideration. Due to the greater number of observations available at the county level, we regard the elasticity at that level (0.424) as to be used as the main result.

▶ Table 7. Elasticity between annual GDP and NTL luminosity, at national level

	lnGDP
lnNTL	0.253**
	(0.066)
Observations	24
R^2	0.404
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: Own 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.

Using employment data from KNBS, on the number of persons employed per year, the relationship between GDP and employment is presented in table 8. The log difference was used to investigate the elasticity between GDP and employment. It should be noted that the data on employment is available only from 2008, which results in a limited number of observations for the regressions, spanning the time period 2008-21. The coefficient is 0.32, which is in line with previous work that studied the relationship at the provincial level in China (Charpe 2022). Taking the lights/GDP elasticity of 0.42 and this coefficient of 0.32 produces a combined coefficient of 0.13.

▶ Table 8. Relationship between annual employment and GDP

	D.lnEmp
D.lnGDP	0.317**
	(0.136)
Observations	13
R^2	0.330
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: Own research

Using the second approach of calculating the direct elasticity between NTL/employment, table 9 outlines the regression results. The coefficient estimate is 0.12; although similar to the combined coefficient above, it is not statistically significant. Due to the limited number of observations, we prefer the indirect approach of NTL /GDP and GDP/employment elasticities to estimate the employment impacts of the road investment. Taking the coefficient of 0.13 suggests that the road project in Kenya results in an estimated 1.7 per cent increase in employment two years after the completion of the project. Applying these same elasticities for one year after the project produces a 1.4 per cent increase and for four years after the completion, shows that the investment results in an estimated 3 per cent increase in employment.

▶ Table 9. Relationship between annual employment and NTL

	D.lnEmp
D.lnNTL	0.121
	(0.069)
Observations	9
R^2	0.302
Note:	*p<0.1; **p<0.05; ***p<0.01

Source: Own research

7. Conclusion and research recommendations

The Merille-Marsabit road project, as part of the Isiolo-Moyale transport corridor, has brought increased economic activity and employment to the surrounding areas in Kenya since the final stage of its completion at the end of 2016. This analysis provides an innovative approach to investigating the long-term impacts of investments in transport infrastructure, showcasing the potential for GIS and satellite data to measure economic changes over time. This work builds upon the previous limited literature that studies the impacts from roads using night-time lights data in other countries but is the first to be done in the context of Kenya and sub-Saharan Africa more broadly. To our knowledge, it is also the first study that uses night-time lights data to go on to look at the link to employment generated by transport infrastructure investments.

As shown from the results, the sections of the Isiolo-Moyale corridor project, including the Merille-Marsabit road, produced an increase in night-time light brightness between 11.0 and 22.8 per cent at the administrative level, for the different years after completion of the project. A positive impact could already be observed one year after completion of the road; however, impacts continued to increase over time, with the largest impacts being observed at four years following completion. Based on the elasticity between lights and GDP, the range for one to four years after the project is between a 4.6 and 9.6 per cent increase in GDP. Taking the preferred result of two years after completion it is estimated that the administrative areas around the road saw a 5.4 per cent increase in GDP compared to those that did not receive a road improvement. The pixel-level analysis highlights impacts are concentrated within 2 km of the road project, where beyond this the impact appears to be negligible. The largest impacts can be seen within 0-1 km of the new road, providing insight for future planning and targeting of similar investments. When translating this increase in GDP to employment, using the indirect method of measuring the relationship between GDP and employment, it is estimated that the project produced a 1.7 per cent increase in employment two years after the completion. This ranged from an increase of 1.4 per cent after one year to a 3 per cent increase, four years after completion.

When presenting the results in terms of million Euro invested and km of road built, using the total of the lots of the Isiolo to Moyale transport corridor, it is estimated that per million invested, GDP is estimated to increase by 0.03 per cent, using the maximum of four years after completion of the project. For employment, this equates to an increase of 0.01 per cent per million Euro. In order to compare to other similar projects, when looking at the results per 100 km of road constructed or rehabilitated, out of a total of 500 km, this is equivalent to an increase in GDP of 1.92 per cent and in employment of 0.6 per cent.

Although these estimates could be improved through access to more data on employment in Kenya, the valuable application of night-time lights as a proxy for economic activity is clear and further work should be done on studying the employment impact and associated spill-over effects. This work has also attempted to address the potential heterogeneity in placement of road projects, by studying the impacts across distance at the pixel level. However, it is encouraged that future work should explore this further by combining additional data that could address this. In order to conduct such analysis efficiently, it is recommended that GIS information should be collected at the beginning of infrastructure projects, which would involve mapping the location of projects. This is particularly valuable for projects involving multiple components, such as rural road projects consisting of smaller rural roads, as these data are sometimes difficult to obtain. Although this information is often collected, it is sometimes not readily available or accessible, so that having it published publicly for use in future analysis and assessments would be valuable.

In regard to future road construction, it should be ensured that newly constructed roads or targeted roads for rehabilitation are prioritised to fall within 2 km of the target populations that should benefit. These findings can feed into future planning of new road investments in Kenya and sub-Saharan Africa more broadly. The existing demographic, economic and employment situation of populations should be assessed, to prioritise areas and locate projects to serve specific groups such as women and youth.

Looking ahead, this analysis shows the applicability of satellite data, specifically night-time lights, as a proxy for economic development and how this can begin to be translated into employment. As there are only a few specific previous examples of this work being applied to transport investments, it is recommended that this analysis is replicated, in different settings, to further explore the potential of harnessing these data to measure the impacts of infrastructure projects. Streamlining the methods and highlighting the applicability of the data further will encourage the workflow to be operationalized within development banks and other institutions to measure the long-term impacts of their investments. GIS and remotely sensed data also offer the opportunity to measure the impacts of the project in other sectors such as agriculture or energy, and this should also be further explored.

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Annex

▶ **Table A.1. Administrative level treatment effect, one year after project completion**

	NTL luminosity					
	(1)	(2)	(3)	(4)	(5)	(6)
treatment	0.617***	0.409***	0.108***	0.143***	0.110***	0.104***
	(0.067)	(0.037)	(0.038)	(0.039)	(0.039)	(0.038)
Admin Level FE	NO	YES	YES	YES	YES	YES
Month FE	NO	NO	YES	YES	YES	YES
Covariates	NO	NO	NO	ALL	ALL	pop/conf
Lagged Covariates	NO	NO	NO	NO	n-1	NO
Observations	6,408	6,408	6,408	6,408	5,340	6,408
R^2	0.013	0.769	0.815	0.816	0.850	0.815
Note:				*p<0.1; **p<0.05; ***p<0.01		

Source: Own research

▶ **Table A.2. Administrative level treatment effect, two years after project completion**

	NTL luminosity					
	(1)	(2)	(3)	(4)	(5)	(6)
treatment	0.500***	0.400***	0.117***	0.134***	0.113***	0.122***
	(0.059)	(0.033)	(0.035)	(0.036)	(0.035)	(0.036)
Admin Level FE	NO	YES	YES	YES	YES	YES
Month FE	NO	NO	YES	YES	YES	YES
Covariates	NO	NO	NO	ALL	ALL	pop/conf
Lagged Covariates	NO	NO	NO	NO	n-1	NO
Observations	7,476	7,476	7,476	7,476	6,408	7,476
R^2	0.009	0.775	0.812	0.813	0.848	0.812
Note:				*p<0.1; **p<0.05; ***p<0.01		

Source: Own research

▶ Table A.3. Administrative level treatment effect, three years after project completion

	NTL luminosity					
	(1)	(2)	(3)	(4)	(5)	(6)
treatment	0.423***	0.273***	0.091***	0.113***	0.098***	0.112***
	(0.049)	(0.028)	(0.031)	(0.032)	(0.031)	(0.032)
Admin Level FE	NO	YES	YES	YES	YES	YES
Month FE	NO	NO	YES	YES	YES	YES
Covariates	NO	NO	NO	ALL	ALL	pop/conf
Lagged Covariates	NO	NO	NO	NO	n-1	NO
Observations	8,544	8,544	8,544	8,544	7,476	8,544
R^2	0.009	0.772	0.804	0.805	0.841	0.804
Note:				*p<0.1; **p<0.05; ***p<0.01		

Source: Own research

▶ Table A.4. Administrative level treatment effect, four years after project completion

	NTL luminosity					
	(1)	(2)	(3)	(4)	(5)	(6)
treatment	0.330***	0.297***	0.181***	0.252***	0.269***	0.205***
	(0.040)	(0.028)	(0.031)	(0.031)	(0.032)	(0.031)
Admin Level FE	NO	YES	YES	YES	YES	YES
Month FE	NO	NO	YES	YES	YES	YES
Covariates	NO	NO	NO	ALL	ALL	pop/conf
Lagged Covariates	NO	NO	NO	NO	n-1	NO
Observations	9,612	9,612	9,612	9,612	8,544	9,612
R^2	0.007	0.635	0.662	0.675	0.693	0.669
Note:				*p<0.1; **p<0.05; ***p<0.01		

Source: Own research

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