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GIS Contribution to Africa-China Studies: the Case of the SICOMINES Agreement in the DRC

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Abstract

The Sino-Congolese SICOMINES agreement (2008) is a prime example of a "Resources-for-Infrastructure" (RFI) deal, but assessing its impact has been notoriously difficult due to the structural opacity surrounding Chinese-funded projects in Africa. This study uses the SICOMINES agreement as a case study to explore how Geographic Information Systems (GIS) and remote sensing can help address this challenge. Focusing on the Munkamba - Mbuji-Mayi road in the Kasaï Oriental province of the Democratic Republic of the Congo, a corridor included among the infrastructure commitments of the agreement, the research applies a longitudinal GIS methodology drawing on Landsat and Sentinel-2 satellite imagery and WorldPop demographic data. Road conditions and accessibility are analyzed across three time periods - 2013 (baseline), 2023 (pre-renegotiation), and 2025 (post-renegotiation) - and compared against a counterfactual scenario representing the road conditions that would have resulted if the rehabilitation specified in the agreement had been delivered. Through road classification and accessibility modelling, the study quantifies travel times and the population affected across these scenarios, linking the gap between commitment and delivery to spatial inequality in Kasaï Oriental. The findings show that the corridor has not been rehabilitated as committed, and that the population exposed to these conditions has grown substantially over the period. Methodologically, the study contributes to Africa-China research by demonstrating that GIS and remote sensing can provide independently verifiable evidence of infrastructure conditions in opaque RFI contexts, complementing, rather than replacing, other methods of verification.

Extended summary

L'accordo sino-congolese SICOMINES (2008) è un esempio emblematico di accordo "Risorse in cambio di infrastrutture" (RFI), ma valutarne l'impatto si è rivelato notoriamente difficile a causa dell'opacità strutturale che circonda i progetti finanziati dalla Cina in Africa. Questo studio utilizza l'accordo SICOMINES come caso di studio per esplorare come i Sistemi Informativi Geografici (GIS) e il telerilevamento possano contribuire a superare questa difficoltà. Concentrandosi sulla strada che collega il villaggio di Munkamba alla città di Mbuji-Mayi nella provincia del Kasaï Orientale della Repubblica Democratica del Congo, un corridoio incluso tra gli impegni infrastrutturali dell'accordo, la ricerca applica una metodologia GIS longitudinale basata su immagini satellitari Landsat e Sentinel-2 e dati demografici di WorldPop. Le condizioni stradali e l'accessibilità sono analizzate in tre periodi temporali: 2013 (periodo di riferimento), 2023 (prima della rinegoziazione) e 2025 (dopo la rinegoziazione), e confrontate con uno scenario controfattuale che rappresenta le condizioni stradali che si sarebbero verificate se la riabilitazione prevista dall'accordo fosse stata effettivamente realizzata. Attraverso la classificazione delle strade e la modellazione dell'accessibilità, lo studio quantifica i tempi di percorrenza e la popolazione interessata in questi scenari, collegando il divario tra impegno e realizzazione alla disuguaglianza spaziale nel Kasaï Orientale. I risultati mostrano che il corridoio non è stato riabilitato come promesso e che la popolazione esposta a queste condizioni è cresciuta considerevolmente nel periodo considerato. Dal punto di vista metodologico, lo studio contribuisce alla ricerca sulle relazioni Africa-Cina dimostrando che i GIS e il telerilevamento possono fornire prove verificabili in modo indipendente delle condizioni infrastrutturali in contesti RFI opachi, integrando, anziché sostituire, altri metodi di verifica.

Preface

This dissertation examines whether the infrastructure commitments made under the 2008 SICOMINES agreement have actually been fulfilled for the Munkamba - Mbuji-Mayi corridor in Kasaï Oriental, Democratic Republic of The Congo, and what the consequences of the resulting gap have been for the local population. The case lies at the intersection of several broader questions addressed in this work: how Chinese "Resources-for-Infrastructures" agreements in Africa fulfill, or fail to fulfill, their stated commitments; how to evaluate such agreements when official information is scarce or concealed; and what the failure to fulfill an infrastructure commitment concretely means for the people dependent on the road in question.

My interest in this topic developed gradually. During an Erasmus exchange in Belgium, a country still dealing with its colonial history in the Democratic Republic of The Congo, I became interested in how more recent forms of external engagement on the African continent, particularly Chinese investments, relate to and diverge from previous models. This interest was broadened by my experience with an association in my hometown, of which I have been a member for several years, which contributed to the construction of the incinerator at Munkamba hospital. Through this connection, I had the opportunity to visit Munkamba and Mbuji-Mayi. This experience is not included in the analysis presented in this thesis as a source, however it helped shape my belief in the importance of this topic. Speaking with people who regularly use this road gave me an understanding of the significance of infrastructure deficiencies beyond the data presented here: what it means to plan a trip to a market or hospital based on the condition of a road for which there are no official data. I also noted that many people, including those well-informed about the country's affairs, were unaware of the existence of the SICOMINES agreement or its renegotiation in 2024. This gap between decisions made under these agreements and the information available to affected communities is not something this thesis directly measures, but it is one of the reasons why it is important to have independent and transparent evidence of their impacts.

During the writing of this thesis, AI language tools were used for grammatical correction and light editorial support. All research questions, methodological choices, empirical analysis, data interpretation, and argumentative decisions are entirely the author's own. No AI tool was used to generate, process, or interpret data.

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LIST OF ABBREVIATIONS

CREC	China Railway Engineering Corporation
DRC	Democratic Republic of The Congo
GIS	Geographic Information System
ITIE	Initiative pour la Transparence des Industries Extractives
MoU	Memorandum of Understanding
N1	Route Nationale 1
OSM	Open Street Map
RFI	Resources for Infrastructures
SICOMINES	Sino-Congolaise des Mines
SOTERCAF	Soil and Terrain Database for Central Africa

CHAPTER 1: INTRODUCTION

1.1 Chinese infrastructure finance in Africa and the opacity problem

China has become one of Africa's most important development partners, and "Resources-for-Infrastructures" (RFI) agreements, through which African governments exchange access to natural resources for Chinese-financed infrastructure, have become a central model of this collaboration. However, evaluating these agreements is complicated by widespread opacity: they are typically negotiated bilaterally, implementation data are rarely published, and independent monitoring mechanisms are usually absent. Consequently, assessing whether promised infrastructure has actually been built remains difficult. This is not just a methodological gap: the gap between commitment and implementation has direct consequences for the communities that depend on these infrastructures, impacting mobility, market access, health services, and food security. Bridging this gap requires methods that go beyond official documents and statistics, using independently verifiable sources.

1.2 The SICOMINES agreement and the infrastructure gap

The 2008 SICOMINES agreement, signed between the Democratic Republic of the Congo, the China Railway Engineering Corporation (CREC), and the Sinohydro Corporation, is one of the largest and most studied Resources-for-Infrastructures (RFI) deals in Africa. In exchange for access to copper and cobalt deposits in Katanga, China pledged to finance a broad infrastructure program, which included the rehabilitation of major national roads. These included Route Nationale 1, and specifically the Kananga - Mbuji-Mayi - Kasongo - Kindu corridor (887 km) containing the Munkamba - Mbuji-Mayi section: a corridor supplying food and goods from the capital Kinshasa to Mbuji-Mayi, the DRC's third-largest city. The promised infrastructure has not been fully implemented and the 2024 renegotiation implicitly acknowledged this. However, no study had independently verified this gap through geospatial methods, assessed how road conditions along this corridor have changed over time, or quantified the impact of this infrastructure deficit on accessibility for the population living along its route.

1.3 Research objectives and research questions

This thesis pursues four objectives: to conduct a longitudinal GIS-based analysis of road conditions on the Munkamba - Mbuji-Mayi section of the N1; to model accessibility changes across scenarios using travel time analysis; to quantify the population affected by the infrastructure gap; and to assess the methodological contribution of GIS as a research tool in data-scarce contexts.

These objectives are pursued through three research questions:

RQ1: What infrastructure was promised under the 2008 SICOMINES agreement, and what does satellite evidence reveal about actual infrastructure delivery on the N1 Munkamba - Mbuji-Mayi corridor?

RQ2: How can GIS-based analysis measure and visualize infrastructure gaps in a data-scarce context and what are the methodological implications for Africa-China research?

RQ3: What was the accessibility cost of the infrastructure gap for the population along the corridor and what would delivery of the contractually specified standard have meant?

1.3.1 Significance of the study: a methodological contribution to Africa-China studies

This thesis contributes to the literature on RFI agreements in Africa by demonstrating that Geographic Information Systems (GIS) can serve as an alternative framework for verification in contexts of document opacity. It also contributes to the literature on spatial inequality and infrastructure-driven development by quantifying the costs of accessibility for the affected population. The methodology is intentionally open-source and replicable and could be applied to other RFI agreements across Africa, where similar conditions of opacity and data scarcity persist.

Existing approaches have addressed some aspects of this challenge separately. AidData's "skytruthing" approach demonstrated the feasibility of using satellite imagery to verify the existence of Chinese-funded infrastructure projects (Perkins, 2014), while machine learning approaches have been used to assess large-scale road conditions from satellite imagery (Workman et al., 2023). However, neither of these approaches has been applied to systematically verify the fulfillment of contractually specified infrastructure commitments, to model changes in accessibility over time, or to quantify impacts on populations through counterfactual analysis. This thesis represents an attempt to bring these elements together.

CHAPTER 2: STUDY AREA

2.1 Administrative and political context of the Democratic Republic of The Congo

The Democratic Republic of the Congo (DRC) is the second-largest country in Africa by area, after Algeria, with an area of approximately 2,345,410 km² (United Nations Data, n.d.), and the eleventh largest in the world. With French as its official language, it is also the most populous French-speaking country in the world, with a population of 109,276,265 in 2024 (World Bank Open Data, n.d.).

According to Article 2 of the Constitution "The Democratic Republic of Congo is composed of the city of Kinshasa and 25 provinces with legal personality. These provinces are: Bas-Uele, Equateur, Haut-Lomami, Haut-Katanga, Haut-Uele, Ituri, Kasaï, Kasaï Oriental, Kongo Central, Kwango, Kwilu, Lomami, Lualaba, Kasaï Central, Mai-Ndombe, Maniema, Mongala, Nord-Kivu, Nord-Ubangi, Sankuru, Sud-Kivu, Sud-Ubangi, Tanganyika, Tshopo, and Tshuapa. Kinshasa is the capital of the country and the seat of national institutions. It has provincial status" (Democratic Republic of the Congo, 2011). The reform was approved in February 2006 and came into force in 2015.

The study area is located in Kasaï Oriental, one of the provinces created by this reform, derived from the former province of the same name. It comprises six administrative subdivisions: the territories of Kabeya Kamwanga, Katanda, Lupatapata, Miabi, Tshilenge, and the city of Mbuji-Mayi, located in Tshilenge territory and the provincial capital (UNICEF, 2021). The road corridor analyzed in this study extends primarily within the territories of Mbuji-Mayi and Kabeya Kamwanga, making these two administrative subdivisions the primary spatial reference points for infrastructure assessment.

Kasaï Oriental has historically suffered from severe logistical isolation. Despite its large population, Mbuji-Mayi "remains remote, with poor connections to surrounding provinces or to Kinshasa and Lubumbashi" (Mindat, n.d.). Although there is a train station in the region, this is located kilometers away from the city, leaving road and air transport as the main means of connection, with its airport in the process of being expanded (Action Contre La Faim, 2023). The N1 constitutes "the only gateway to the sea and the provinces" of Kasaï (African Development Bank, 2005), making its rehabilitation a precondition for connecting the region to the national economy and improving living conditions for the population. This structural isolation has direct economic consequences. According to the World Bank Group (2016), approximately 50 percent of DRC's territory remains inaccessible by road or rail transport, and

only four provincial capitals are connected to Kinshasa by road, so it is often not possible to travel by land between the main population centers, nor to reach rural areas. The World Bank (2022) further notes that weak transport infrastructure and high transportation costs have led to geographic isolation and limited interconnectivity, exacerbating social and economic inequalities across and within provinces. For Kasaï Oriental, road infrastructure is the primary determinant of connectivity, and its reliance on a single road corridor, the N1, makes its condition a matter of critical importance for the province's population.

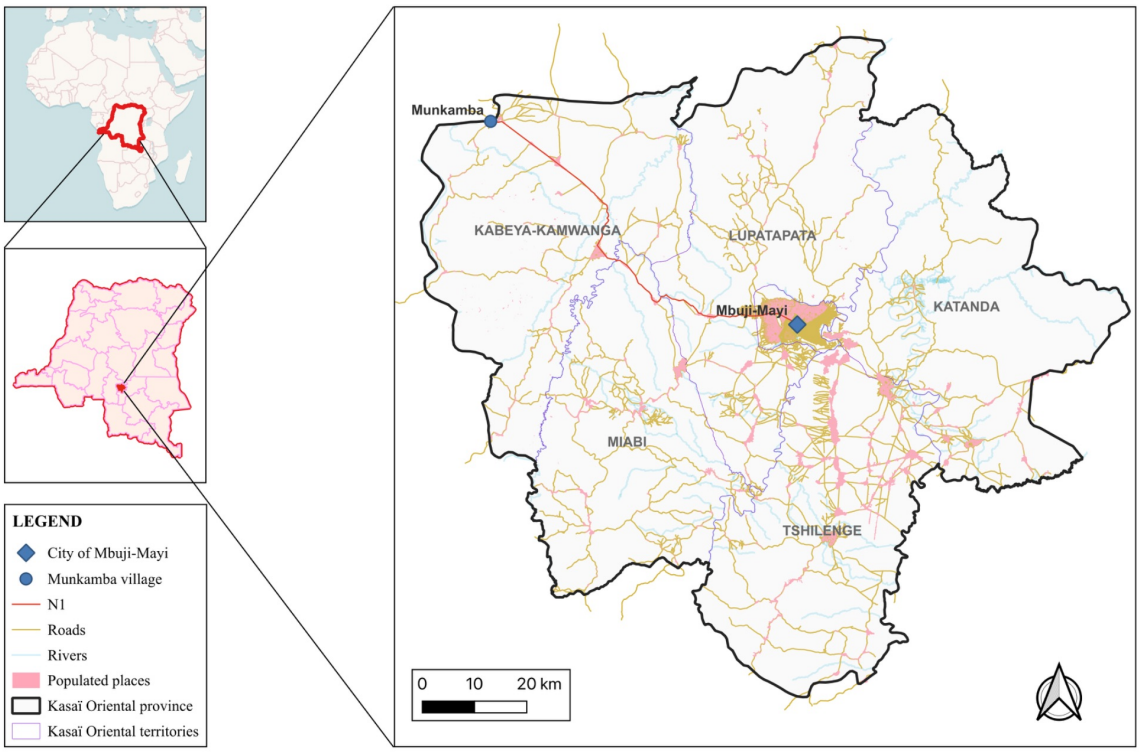


Figure 1: *Map of the study area (Author's construct)*

The political history of the Democratic Republic of the Congo, since independence in 1960, has been marked by prolonged instability. After independence from Belgium, the country experienced a series of political crises before falling under the authoritarian regime of Mobutu Sese Seko, who seized power in the 1965 coup and ruled until 1997 (Britannica, 2026). The First Congo War (1996-1997) ended Mobutu's regime and was followed almost immediately by the Second Congo War (1998-2003), which involved nine African nations and dozens of armed groups. Based on five mortality surveys, the International Rescue Committee estimated 3.9 million deaths between 1998 and 2004, most of which were attributable to disease, malnutrition and displacement as a result of the conflict, making it the deadliest crisis since World War II (International Rescue Committee, 2007). Although a peace agreement was signed

in 2002 and the first multiparty elections were held in 2006, armed conflict has persisted in the eastern provinces, and governance across much of the country remains weak (Council on Foreign Relations, 2026).

For Kasaï Oriental in particular, the post-conflict period has led to limited recovery. The province has historically suffered from political and economic marginalization by the central government (International Organization for Migration, 2021). In August 2016, tragic actions by the Kamwina Naspu militia spread from Kasaï Central to Kasaï Oriental, which was less severely affected than neighboring provinces but still caused deaths, displacement, and tensions that persisted even after the peak of violence. “Nonetheless, intercommunity tensions do exist in the province, particularly fuelled by land disputes, and have led to significant displacement in 2020. Social cohesion is fragile, particularly with competition over land, resources and basic services, which remain inadequate, particularly outside of Mbuji-Mayi” (International Organization for Migration, 2021). This broader context of regional instability is relevant to this thesis as it illustrates the fragile political and social environment in which the SICOMINES infrastructure program was intended to be implemented.

2.2 Demographic and economic context

The province of Kasaï Oriental covers 9,545 km² and has an estimated population of approximately 12,215,861 (Ministère des Infrastructures et Travaux Publics, 2022), with a population density of 574 inhabitants per km². Its capital, Mbuji-Mayi, is the third largest city in the Democratic Republic of the Congo (International Organization for Migration, 2021), with a population of 3,788,739 (Ministère des Infrastructures et Travaux Publics, 2022). This population represents an ethnocultural mix in which various tribes coexist. The Bantu constitute the majority of the population of Kasaï Oriental. They are sedentary, with a system of patrilineal succession and virilocal residence, and have been subject to migration since the end of the first millennium AD. This ethnic group (Bantu) comprises 13 main tribes: Luba, Tetela, Kanyoka, Babindi, Bakwa Mputu, Songe, Kanintshina, Kuba, Bambole, Bakete, Ohindo, Basha, and Bankutshu. The Luba ethnic group is the main tribe in the Kasaï Oriental province, and the languages spoken are Tshiluba and French. The cosmopolitan city of Mbuji-Mayi is primarily a Baluba stronghold, meaning that Tshiluba is the most spoken language, followed by Swahili and, in order of frequency, Songhai, Tetela, Kanyok, and Lingala (Ministère des Infrastructures et Travaux Publics, 2022).

Mbuji-Mayi's demographic evolution is unique: the city had only 30,000 inhabitants at independence in 1960, before rapidly expanding thanks to waves of internal migration driven

by the diamond industry, reaching approximately three million inhabitants today (Action Contre La Faim, 2023). This human growth has far outpaced the development of urban infrastructure and services, creating a city whose population size is in stark contrast to the level of available services.

The regional economy remains centered on diamond mining, with the province producing approximately one-tenth of the world's industrial diamonds by weight through mining operations historically operated by the Société Minière de Bakwanga (Britannica, 2026). However, this abundance of mineral resources has not led to real development, as the mining industry has gradually declined, trapping the province in a vicious cycle of structural poverty, which has worsened rather than diminished over time, giving way to agriculture as the province's main activity. However, the main crops, often used for subsistence farming, are staple foods (cassava, corn, peanuts, rice, etc.). Livestock farming is very underdeveloped. Some industrial crops are also grown, but on a small scale (coffee, cotton, oil palm, and rubber) that have no significant impact on the provincial economy or household income (Ministère des Infrastructures et Travaux Publics, 2022). While several provinces in the DRC saw a reduction in extreme poverty between 2005 and 2012, the provinces of Kasaï and Maniema saw poverty incidence increase between 8.6% and 23.3% over the same period (Yeboua, 2023). In 2019, the Global Data Lab estimated the poverty rate in Kasaï Orientale at 99%, the highest of any province in the country (Manyong et al., 2024). Today, mining is practiced almost exclusively on an artisanal basis, while the population struggles with a shortage of drinking water, insufficient agricultural production, and high food prices, exacerbated by the city's geographical isolation (Action Contre La Faim, 2023). The implications for food security are severe: a 2020 survey found that 75% of rural households in the province were food insecure in terms of dietary adequacy, and access to sufficient and nutritious food was a critical issue for the entire sample (Manyong et al., 2024). At the provincial level, the 2023 IPC analysis classified 27% of the population of Kasaï Oriental (approximately 1.1 million people) as in crisis or worse (IPC Phase 3 or higher), placing it among the most food-insecure provinces in the country (IPC, 2023). Furthermore, considering the specific territory crossed by the road connecting Munkamba to Mbuji-Mayi, "among the five territories that make up the province of Kasaï Oriental, Kabeya Kamwanga and Lupatapata have, on average, lower access to education (e.g., number of schools per village) and health services (e.g., rate of antenatal visits), as well as poorer infrastructure than the other territories" (Manyong et al., 2024).

This isolation represents the main economic constraint: Mbuji-Mayi relies on neighboring provinces for food supplies, but the poor condition of the connecting roads makes transportation

expensive and unreliable, pushing food prices beyond the reach of much of the population (Action Contre La Faim, 2023). Road connectivity is therefore not only a matter of economic development, but also of food security. This context gives concrete weight to the infrastructure commitments made under the SICOMINES agreement: for the communities of Kasaï Oriental, the improved road network has represented not only a better transport route, but also a potential turning point compared to decades of neglected development.

2.3 Physical geography, climate and soils

Kasaï Oriental is situated in the south-central part of the DRC, within the broader Kasaï region. The province has two main seasons: the rainy season, which lasts eight months (September, October, November, December, January, February, March, and April), and the dry season, which lasts two months (June and July), with the remaining two months (May and August) being transitional. During the eight-month rainy season, an average of 60 rainy days is recorded, with two peaks (November and March), with November being the wettest month. Average monthly precipitation is 185.5 mm, with the highest number of rainy days in December. The climate is characterized by southeast trade winds during the dry season and northeast trade winds during the rainy season. Ambient temperatures range between 20° and 30°, with an annual average of 25.2°C (Ministère des Infrastructures et Travaux Publics, 2022). Bangelesa et al. (2023) predict that extreme rainfall intensity indices in the Democratic Republic of the Congo will increase towards the end of the 21st century, with implications for infrastructure resilience across the country. Specifically, they estimate that, by the end of the century, the western region of the DRC will see an overall decrease in average daily rainfall, especially during the MAM season (March-April-May), but simultaneously, there will be an increase in the intensity of extreme rainfall and a reduction in the number of consecutive rainy days. This means that, despite fewer rainy days, rainfall events will be more severe when they do occur, increasing the risk of floods, landslides, and infrastructure damage (Bangelesa et al., 2023). The province's soils adhere to the broader pattern documented for the Congo Basin by the Soil and Terrain Database for Central Africa (SOTERCAF): the dominant types are Ferralsol, Acrisol, and Arenosol, deeply weathered tropical soils characterized by a weak macrostructure and a propensity for compaction under mechanical loading (NGONGO et al., 2013). These properties limit the bearing capacity of unpaved road surfaces, particularly under seasonal saturation conditions. The Kasaï sub-basin, within which the province is located, has been identified as the sub-basin with the highest specific sediment export rate in the entire Congo River system, at 8.92 t/km²/year, with surface erosion as the dominant degradation process (Mushi et al., 2019).

It should also be noted that the soil in the city of Mbuji-Mayi is in an alarming state of degradation, characterized by erosion, ruts, landslides, and other forms of subsidence. This situation is a direct consequence of uncontrolled land development, deforestation, and the absence, inadequacy, or insufficient presence of drainage systems. Erosion, ruts, and landslides dominate the landscape, as demonstrated by over 700 meters of documented erosion, according to a 2008 survey conducted by the Urban Environmental Coordination in collaboration with the Belgian Technical Cooperation (BTC). Previously, a study conducted between 1997 and 1998 with the support of USAID had already observed that erosion in the city of Mbuji-Mayi was progressing at a rate of 431 meters every eight rainy months, equivalent to approximately 41.5 meters per year. Both the central and provincial governments are working to halt the advance of some gullies or even channel them, using large-scale erosion control measures (Ministère des Infrastructures et Travaux Publics, 2022). Taken together, these physical conditions create an environment structurally predisposed to rapid infrastructure deterioration.

2.4 The Munkamba - Mbuji-Mayi road

National Route No. 1 (RN1) is the backbone and main transformative artery of the road transport system in the Democratic Republic of the Congo. It connects the ports of Banana and Matadi to the main cities in the western part of the country, particularly Lubumbashi in the south, up to the border with Zambia, for a length of approximately 3,130 km. It mainly serves the provinces of Kongo Central, Kinshasa, Kwango, Kwilu, Kasaï, Kasaï Central, Kasaï Oriental, Lomami, Haut Lomami, Lualaba, and Haut Katanga, home to a large portion of the Congolese population. Finally, from Mbuji-Mayi, it connects to RN2, which serves Kasongo, Bukavu (South Kivu), and Goma (North Kivu), located in the eastern part of the country, thus serving as a crossroads with Rwanda and Burundi (African Development Fund, 2019).

Given the importance of this road to the country's economic and social development, the access it provides to the interior, and its key role in intra-regional trade, the government has allocated the majority of funding from donors operating in the transport sector to its gradual restoration (African Development Fund, 2019). The Munkamba - Mbuji-Mayi section is part of the central segment of the N1 in the province of Kasai Oriental. This section connects the rural area of Lake Munkamba, in the territory of Kabeya Kamwanga, to the provincial capital, Mbuji-Mayi, crossing a predominantly agricultural corridor that serves as a supply route for food and goods entering the city from the west.

The strategic importance of this road is evident on multiple levels. At the national level, it is part of the only land link between Kinshasa and Mbuji-Mayi, a city of over three million inhabitants with no navigable waterways and a limited rail network. At the provincial level, it is the main artery through which agricultural products from the western territories of Kasaï Oriental reach the urban market of Mbuji-Mayi, so the road conditions along this corridor are a determining factor in food security and price levels in the city. The road's vulnerability to deterioration is well documented. The stretch connecting Mbuji-Mayi to the Lake Munkamba area has repeatedly been affected by muddy conditions, sandbanks, waterlogging, and erosion, making heavy vehicle transit extremely difficult (Agence Congolaise de Presse, 2021). Radio Okapi, a radio network operating in the DRC and created by the United Nations Mission in the Democratic Republic of Congo (MONUC), reported in 2015 that the 180 km stretch of road from Kananga to Mbuji-Mayi (which includes the Munkamba - Mbuji-Mayi section) took two to three days to travel (Radio Okapi, 2015). The stretch of road has repeatedly been at risk of being closed at the eastern entrance to the city of Mbuji-Mayi due to erosion grooves created by torrential rains, which has also led to serious accidents involving motorcycles used for public transport (Agence Congolaise de Presse, 2021). These conditions are not accidental, but structural: the combination of tropical rainfall, clay soils, and the lack of adequate drainage and infrastructure makes this corridor particularly vulnerable to rapid degradation without ongoing maintenance.

2.5 Data landscape in the study area

A characteristic of the study area, and a central motivation for the methodological approach adopted in this thesis, is the scarcity of reliable, detailed, and up-to-date geospatial data. East Kasai represents a context in which conventional data sources are incomplete or insufficiently detailed for subnational spatial analysis. This data scarcity, however, is not specific to the study area alone but reflects a broader national crisis in statistical infrastructure. Statistical infrastructure is dramatically lacking. The country has not undertaken a population and housing census since 1984, has not organized an agricultural census since 1974, and is yet to organize a business census. The lack of quality data on industrial and agricultural production makes estimates of macroeconomic aggregates unreliable. The absence of population data affects much of the statistical system and reduces the credibility of development planning and management (World Bank, 2018). The statistical infrastructure needed for the production of reliable and accurate statistics is dramatically lacking (World Bank Group, 2015), and this systemic weakness at the national level inevitably and directly impacts the availability of subnational data for provinces such as Kasaï Oriental.

There are no official data on road conditions in the Munkamba - Mbuji-Mayi corridor in any publicly accessible form for the 2008-2025 study period. No government agency has published systematic surveys of road surface quality, bridge conditions, or passability along the RN1 in this section, and such data were not identified in donor reports or academic literature for the study period either.

Crowdsourced geospatial data suffers similar limitations. OpenStreetMap (OSM) is an open-source collaborative mapping platform that relies on volunteer contributions to build a global geographic database and to assess the historical development of OSM data in the study area, the “ohsome dashboard” was used , a web-based tool developed by the Heidelberg Institute for Geoinformatics Technology (HeiGIT) that generates statistics on the historical evolution of OSM data for a given region. The analysis, conducted in April 2026, indicates a high level of road mapping saturation in the study area at the moment, but historical data reveal that most road data was added to OSM between 2016 and 2018, meaning that for the reference year, 2008, OSM coverage was almost entirely absent. Furthermore, a systematic inspection of OSM road attributes along the RN1 between Munkamba and Mbuji-Mayi reveals inconsistent attribute coverage across segments of the same road: some sections include a surface classification, but others are completely lacking in qualitative road attributes, and no segment includes information on road smoothness, road conditions, or historical surface changes. This fragmented and inconsistent attribute coverage, combined with OSM's inability to capture historical road conditions, makes it unsuitable as a primary data source for the longitudinal assessment of road conditions over the 2008-2025 study period.

Demographic data presents specific challenges as well. Population estimates for Kasai-Orientale at the subnational level are available through WorldPop, a research program based at the University of Southampton that produces high-resolution, open-access population estimates, but these are explicitly model-based estimates, not census-derived counts. For countries that have not conducted a census in a long time and where there are significant subnational variations in migration, fertility, and mortality, the official population data used as input and the projections based on them can be highly uncertain (WorldPop, n.d.). Furthermore, according to WorldPop, for countries where recent censuses have not been undertaken, or where census data were unavailable, published estimates from NSOs or UN agencies were used, and these carry substantial uncertainties (WorldPop, n.d.).

For the study, administrative boundary data were obtained from the Humanitarian Data Exchange (HDX). Satellite imagery from the USGS Landsat archive provides longitudinal

coverage of the study area for the entire study period. These open-source datasets constitute the primary data infrastructure for this research and are described in detail in Section 4.2 and limitations of this data environment are further discussed in Section 4.4.

CHAPTER 3: LITERATURE REVIEW

3.1 Chinese presences in Africa: critical perspectives, opacity and the case for alternative methodologies

The relationship between China and Africa dates back several decades before the current infrastructure boom. Its roots can be traced back to the Cold War, when China positioned itself as a fellow victim of Western imperialism and colonial exploitation, offering solidarity to newly independent African states on explicit anti-colonialist grounds. Unlike Western donors, China did not impose political conditions on its aid, a stance rooted in the principle of non-interference in the internal affairs of sovereign states. This approach made China a seemingly different partner, capable of offering support without the governance conditions associated with Western development funding. However, it would be misleading to conclude that China's commitment is therefore unconditional. RFIs agreements typically have implicit requirements, including the use of Chinese contractors, labor, and materials, with credit lines often tied to a minimum 50% sourcing from China (Alves, 2013), introducing a different form of conditionality rather than eliminating it altogether. As Pepa (2021) argues, China's rhetorical commitment to non-intervention frames its involvement as purely technical and neutral, but this depoliticization obscures the power relations that shape its presence on the ground. Scholars have challenged both the rhetoric of non-interference and the dominant narrative of mutual benefit (Mohan & Tan-Mullins, 2019), highlighting how China's growing economic interests in Africa have eroded the principle in practice, even if it remains central to China's official foreign policy discourse.

The institutional consolidation of relations between China and Africa took place with the establishment of the Forum on China-Africa Cooperation (FOCAC) in 2000, which created a multilateral framework for what had previously been managed through bilateral channels (Ceccagno & Pepa, 2025, 31). The FOCAC summits, held every three years, have since served as the main platform for announcing China’s commitments to African development. The FOCAC III summit held in Beijing in November 2006 marked a qualitative turning point, representing “the first heads of state summit” (Alden & Large, 2019, 3) and publicly “showcasing the nature, ambition, and mountain power of attraction China had in its relations with all but a handful of Taiwan-recognizing African states” (Alden & Large, 2019, 4). Furthermore, the launch of the Belt and Road Initiative (BRI) in 2013 provided a new overarching framework for Chinese infrastructure investments globally, with African countries not being formally integrated into the initiative until 2017 (Ceccagno & Pepa, 2025, 31).

The scope of China's engagement in Africa has grown exponentially over the past two decades, and this expansion has attracted considerable interest from the academic and political communities, to the point that Africa-China Studies has now established itself as a new field of research (Ceccagno & Pepa, 2025, 9).

3.1.1 Epistemological challenges

Yet the study of China-Africa relations faces persistent epistemological challenges. Lee (2017) first proposed the notion of "global China" as a necessary empirical and methodological reorientation, challenging China studies to move beyond methodological nationalism and engage with China's transformation into a global force intertwined with global capitalism. Building on this foundation, Franceschini and Loubere (2022) propose "Global China as a Method", an approach that refuses to treat China as an externalised "other" existing outside global capitalism. Instead, they argue for an understanding of China as intimately entangled with global processes and phenomena, subject to the same capitalist dynamics as all the other actors. They identify three dominant frames that hold this view of China as "othered": essentialism (treating China's political system as the sole explanation for everything it does), the so-called maieutic approach (the now-declining expectation that engagement with the West will liberalise China), and "whataboutism" (dismissing criticism of China as hypocrisy, which foster apathy and makes critical analysis pointless). Regardless of their political stance, all three frames share the same core assumption: they render China as an externalised, separate, and self-contained "other" (Franceschini & Loubere, 2022, 5). The call here is to move beyond an analysis of China that renders the country a flat caricature and take a step further highlighting the importance of perceiving China as a complex actor intimately entangled with global histories, processes, phenomena and trends (Franceschini & Loubere, 2022, 5).

Ceccagno and Pepa (2025) take this methodological call and extend its core critique - against the framing of China as an externalised "other" - to the study of Africa-China relations. Drawing together insights from recent scholarship, they articulate warnings against essentialism. First, there is no monolithic Chinese actor. Citing Pairault (2022), they suggest speaking of plural "Chinese presences" in Africa, because different institutional actors (the Ministry of Foreign Affairs, the Ministry of Finance, policy banks, State-Owned Enterprises) may have divergent, even contradictory, views and priorities. Second, reducing Africa to a mere passive recipient of Chinese power is equally misleading, first and foremost because the actors involved are, on the one hand, a single state - China - and, on the other, a group of 54 nation-states across the African continent. This risks oversimplification by crushing the diversity and complexity that

characterize the African continent from political, economic, social and cultural perspectives. At the same time, there is a risk of obscuring the agency exercised by the various African countries within their different national and local contexts (Ceccagno & Pepa, 2025, 10). Chinese actors are well aware of this plurality and implement diversified strategies in Africa not only in response to their own interests but also in accordance with the agency of African states themselves (Ceccagno & Pepa, 2025, 11). Many infrastructure projects involving China are conceived and requested by African governments, which see Chinese credit and construction companies as ideal partners for addressing their urgent infrastructure needs. This is not a simple matter of financial necessity: as Nugent (2018) documents in his concept of "re-enchantment" (Africa's re-enchantment with big infrastructure), African states have rediscovered a genuine enthusiasm for large-scale infrastructure as a development strategy after years of disillusionment. The African Development Bank confirms the scale of this demand, estimating that the continent requires $130-170 billion annually in infrastructure investment (Freeman, 2020). Chinese infrastructure finance thus responds to an existing African demand and it’s not created from scratch. Third, Ceccagno and Pepa (2025) show that China actively constructs itself as an "other" vis-à-vis the West through a process of “self-othering” (Sciorati, 2024), presenting itself as a genuinely anti-hegemonic force and a model that is irreconcilable with and opposed to the dominant one (Ceccagno & Pepa, 2025). Official Chinese rhetoric emphasises solidarity with the Global South, a shared colonial past, and China's own status as a developing country, positioning Chinese development cooperation as a genuine alternative to Western conditionalities. However, their book shows that China's counter-hegemonic strategies, far from challenging existing power asymmetries, seek merely to shift the balance of power in China's favour (Ceccagno & Pepa, 2025). As Carrozza and Benabdallah (2022) demonstrate, this South-South solidarity is inscribed in hierarchical narratives: the language of win-win cooperation and mutual benefit is instrumental to China's unilateral appropriation of the role of spokesperson for the Global South. Even more radically, Huang (2024) documents the emergence of racial hierarchies within Sino-African relations, showing how a Sinocentric global racial hierarchy (Chinese/China, white/West, black/Africa) operates even in the absence of direct Western involvement (Ceccagno & Pepa, 2025, 27).

3.1.2 Opacity and the limits of conventional data: GIS as a methodological response

China's approach to disclosing data on foreign development financing has long diverged from that of Western multilateral lenders, and while the establishment of the China International Development Cooperation Agency (CIDCA) in 2018 marked a significant institutional shift, transparency challenges persist in practice. The creation of CIDCA was partly intended to

distinguish Chinese foreign aid from more commercially oriented financial flows, addressing long-standing criticisms of opacity (Cheng, 2019). However, hopes that the reform would reduce fragmentation and bring greater transparency to Chinese aid delivery have not been fully realized (Rudyak, 2018): CIDCA does not publish data in international transparency registries such as IATI, and many analysts remain sceptical about its actual role and influence, noting that much project management and implementation remains unchanged and that the Ministry of Commerce (MOFCOM) retains considerable influence over foreign aid (Yuan et al., 2022). Chinese bilateral loan agreements continue to contain broad confidentiality clauses; in fact, Gelpern et al. (2021) confirm that neither Chinese lenders nor their borrowers typically make the text of their loan agreements public, and many contracts include a commitment by borrowers not to disclose the terms or, in some cases, even the existence of the contract itself. Two of China's major development finance institutions (the China Development Bank and the Export-Import Bank of China) do not publish detailed reports on their activities, and in 2020, China scored 1.2 out of 100 on the Aid Transparency Index, the lowest transparency score among all donors. Consequently, researchers have been unable to apply the same level of precision to Chinese finance as used in the analysis of other development finance institutions (Ray et al., 2021).

This opacity is not accidental, but it serves multiple functions: it protects Chinese and host government officials from domestic accountability; it allows for flexible renegotiation of terms; and it shields both parties from international scrutiny over labour standards, environmental impacts, and debt sustainability. Moreover, China's loan agreements are the subject of intense debate: some have suggested that Beijing deliberately pursues 'debt trap diplomacy', imposing harsh terms that allow it to seize strategic assets when borrowers default (Gelpern et al., 2021). Regardless of whether this characterisation is accurate, the opacity of Chinese contracts makes independent assessment of their terms extremely difficult.

For researchers seeking to evaluate the outcomes of China-financed infrastructure, this opacity thus represents a fundamental methodological obstacle.

3.2 Chinese presences in the Democratic Republic of the Congo

The Democratic Republic of the Congo occupies a unique position in China's engagement with Africa, thanks primarily to its extraordinary mineral wealth. The country possesses vast deposits of minerals such as cobalt, copper, diamonds, and gold, as well as significant hydroelectric potential. According to Shen & Fu (2024), the DRC holds over 46% and 12% of the world's

cobalt and copper reserves respectively and, in 2022, it accounted for approximately 70% and 10% of global cobalt and copper production. For China, whose industrial economy and electric vehicle sector depend crucially on these minerals, the DRC represents a strategically indispensable partner. It is estimated that in 2022, Chinese companies accounted for over three-quarters of the DRC's cobalt production, with nearly all of this production shipped back to China, where, as of that same year, China possessed approximately 76% of global cobalt refining capacity (Cobalt Institute, 2023). The strategic importance of these minerals has grown in recent years, making the DRC not only a trading partner but a geopolitical priority in the context of the global energy transition.

The diplomatic history between China and the Democratic Republic of the Congo dates back further than is often acknowledged in contemporary analyses of these relations. According to Shirambere (2020), diplomatic relations between the two countries date back to the time of Congolese independence on June 30, 1960, when the heads of government, Patrice Lumumba and Zhou Enlai, exchanged correspondence. Relations became complicated during the Mobutu era (1965-1997), mainly because Mobutu's regime maintained de facto diplomatic relations with Taiwan, which led China to support secessionist opposition movements, including Laurent-Désiré Kabila's Popular Revolutionary Party (PRP), founded in 1967. Nevertheless, from 1972 onward, diplomatic relations between the two countries saw gradual and sustained development across multiple different regimes. Relations gained new momentum after Laurent-Désiré Kabila took power in 1997 and signed trade agreements with Beijing (Shirambere, 2020). When Joseph Kabila succeeded his father, who was assassinated in 2001, having himself been trained in China, he immediately sought to maintain and deepen bilateral relations, recognizing the political and financial weight they carried, given the limited international support the DRC enjoyed at the time (Shirambere, 2020).

China-DRC relations have strengthened significantly in the post-conflict period following the end of the Second Congo War (1998-2003). The election of Joseph Kabila in 2006, after almost four years of transitional government, and the resulting political stabilization created the conditions for large-scale foreign investment. China moved quickly to establish itself as the Democratic Republic of the Congo's primary bilateral partner. A contributing factor was the failure of Western donors to honor their commitments to the newly elected Kabila government. Shirambere (2020) documents that Kabila had launched his 2006 presidential campaign expecting approximately $4 billion in reconstruction funding from traditional Western partners to finance his ambitious *cinq chantiers* program, which covered infrastructure, employment, housing, water and electricity, health and education. This support did not come: Western

donors, citing concerns regarding governance and the presence of former militant actors within the new institutions, held back the promised funding on conditionality grounds. Having observed the precedent of the China-Angola partnership, the Kabila administration turned to Beijing as an alternative (Shirambere, 2020). For China, the DRC represented a secure source of strategic natural resources, a market for manufactured goods, and an arena for infrastructure investment. For the DRC, China offered financing and technical expertise without the governance conditionalities associated with Western development funding.

This dynamic is reflected in the explicit preferences of the Congolese political leadership. In a 2024 interview with a French journalist, actual President Félix Tshisekedi stated that China and Russia are “much less arrogant” than Western countries, adding: “African realities are not well understood, and it's a real shame, because I've always said that Europe, for example, would be Africa's best partner” (Ceccagno & Pepa, 2025, 51). When asked to explain this distance, Tshisekedi replied: “It is hard to understand how European countries can lecture us on human rights when the same things are happening elsewhere” (Ceccagno & Pepa, 2025, 51). This statement encapsulates the political logic that has made China an attractive partner for the DRC and other African states: not necessarily a preference for China’s development outcomes, but a rejection of Western conditionalities and perceived hypocrisy. As Shirambere (2020) notes, the Chinese approach, rooted in the Five Principles of Peaceful Coexistence (mutual respect for each other’s territorial integrity and sovereignty; mutual non-aggression; mutual non-interference in each other’s internal affairs; equality and co-operation for mutual benefit; peaceful co-existence) and formally avoiding conditionalities based on governance or human rights, has offered what the Angolan government had previously described as free of “humiliating conditions.”

The centrepiece of relations between China and the DRC is the 2008 SICOMINES agreement (analysed in detail in section 3.5), whose terms of the agreement between China and the DRC have come under increasing scrutiny from Congolese civil society. In a report published on March 5, 2025, the coalition “Congo n’est pas à vendre” (CNPAV) warned about significant financial losses incurred under the 2008 RFI agreement, despite its renegotiation in 2024. The coalition documented a $132 million deficit for the DRC in that year alone, attributing it to the extensive tax exemptions granted to Chinese companies which, according to CNPAV, have continued to undermine the country’s financial gains from the agreement. The report also criticized the exclusion of the SICOMINES agreement from the Congolese Mining Code, which allows these tax privileges to operate outside the standard regulatory framework (Global South World, 2025).

3.3 Resources-for-infrastructure deals in Africa

3.3.1 China's Resources-For-Infrastructure (RFI) model in Africa

"Resources-for-Infrastructure" (RFI) agreements represent a unique form of development funding in which African governments use future revenues from natural resource extraction as a guarantee or direct payment for infrastructure financed by China and, unlike traditional development loans, these agreements bypass standard lending assessments and transparency requirements.

It should be noted that commodity-secured financing in Africa is by no means a Chinese invention. This mechanism was broadly used in the early to mid-1990s to deal with the African context of chronic capital shortages and low creditworthiness, and was first developed in London by private banking institutions (British, French, Dutch, and later South African) to mitigate the risk of lending to resource-rich African governments, or to fund the development of specific mining projects such as the Lumwana copper mine in Zambia and the Golden Pride gold mine in Tanzania (Alves, 2013). What distinguishes Chinese financing from the rest is the sheer size of the loans, their expanding geographical footprint, and the fact that they are designed solely as a state venture: the loan is extended by Chinese state banks, the services providers are Chinese construction SOEs, materials and equipment are sourced from state enterprises back in China, and Chinese national resource companies retain the off-taker rights, being the proceeds from each sale used to service the loan. In line with China's "going out" policy, infrastructure-for-resources loans are thus drafted in a way that minimises lending risks and favours the expansion of Chinese companies, particularly construction and resources SOEs, into African markets (Alves, 2013).

China's infrastructure-for-resources formula is largely the product of a timely convergence of interests between China and African countries at the dawn of the 21st century. Alves (2013) identifies several domestic pressures on the Chinese side: growing external reliance on strategic resources, the need to carve out a position for its enterprises in the global market and its swelling foreign exchange reserves (already the second largest stock in the world by the late 1990s) that, all together, led to the implementation of a groundbreaking policy that came to be known as the "go global" policy (Alves, 2013). From the African side, the model responded to a genuine and longstanding demand for infrastructure financing that existing multilateral and bilateral channels had failed to meet. Sub-Saharan Africa lags behind other developing regions in most standard indicators of infrastructure development, and its deficient infrastructure could cost up

to one percentage point per year of GDP per capita growth (Foster et al., 2009). Most African countries lacked the credit ratings necessary to access international capital markets nor the fiscal capacity to finance large-scale infrastructure on their own, making China's offer a financial and political alternative, as a rejection of the conditionality-based framework attached to Western development funding.

The operational structure of the model reflects these institutional arrangements. China Exim Bank and China Development Bank provide financing on the condition that infrastructure is built by Chinese state-owned enterprises, using Chinese equipment and labor (Alves, 2013). Agreements are typically rooted in two legal instruments: a framework cooperation agreement between governments and a lending agreement between China Exim Bank and the borrower. Interest rates are set below the benchmark of the People's Bank of China, with the difference subsidized by the central government. Fundamentally, financial flows "never actually leave China": funds are transferred directly from Exim Bank to Chinese contractors (largely State Owned Enterprises, SOEs) who win infrastructure tenders, severely limiting local economic multiplier effects (Xu, 2020).

The canonical example of the model is Angola. In 2002 and 2003, the Angolan government sent several diplomatic missions to Western countries with the aim of organizing a donor conference to raise the funds needed to begin the country's much-needed reconstruction after three decades of civil war, but all potential financing came with conditions requiring compliance with IMF rules (Corkin, 2011). Beijing offered a way out to this: a $2 billion unconditional line of credit backed by oil from China Exim Bank to finance infrastructure projects listed in Luanda's public works budget, namely roads, railways, sanitation, housing, and water and electricity supply lines. A second tranche of $2 billion followed in 2007 (Foster et al., 2009). The reimbursement was structured through oil sales from Sonangol, Angola's national oil company, to the Chinese trading company UNIPEC (SINOPEC's commercial arm) (Alves, 2013). Under the terms of the agreement, 70% of construction and civil engineering contracts were awarded to Beijing-approved Chinese firms, with funds paid directly by the China Exim Bank to the contractors (Corkin, 2011). Although the infrastructure projects themselves were not directly linked to the oil industry, the agreement served as a gateway for Sinopec's entry into the Angolan oil sector: it is this agreement that the literature identifies as the template for what has become known as the "Angolan model" (Corkin, 2011).

Nigeria, under President Olusegun Obasanjo, has also welcomed China's infrastructure-for-oil deals, which reportedly amount to around $12 billion (Alves, 2013). Chinese national oil

companies (like CNPC, CNOOC and Sinopec) secured their first stakes in Nigeria's oil industry in exchange for commitments to major infrastructure projects, including the rehabilitation of the Kaduna oil refinery ($2 billion, by CNPC) and financing from China Exim Bank for both the Lagos-Kano railway (1,350 km) and the Mambilla hydroelectric power plant ($2.5 billion), secured by Nigerian oil blockades (Mthembu-Salter, 2009).

Another interesting example is the one of the Lobito Corridor, that illustrates how the logic of the model began to attract competing actors. The corridor, linking the port of Lobito in Angola to the mineral-rich provinces of Haut-Katanga and Lualaba in the DRC and the Copperbelt of Zambia through a combination of rehabilitated and newly built railway infrastructure, was originally rehabilitated with a Chinese loan between 2006 and 2014 and is currently operated by the Lobito Atlantic Railway (LAR) consortium (Walschot, 2025). While not a new initiative, it has become a flagship of Western investment strategy following the announcement by European Commission President von der Leyen in September 2023 (Walschot, 2025), but the project starts way before. In January 2023, Angola, Zambia, and the DRC signed the Lobito Corridor Transit Transport Facilitation Agency agreement to promote cross-border trade along the route and this regional effort was then taken up by the G7 Partnership for Global Infrastructure and Investment (PGII) in May 2023 (Way, 2024). In September 2023, the United States and the European Union announced their co-leadership of the project, and in October of the same year, a seven-party memorandum of understanding was signed between the United States, the EU, Angola, the DRC, Zambia, the African Development Bank, and the Africa Finance Corporation (Walschot, 2025). Sarah Way (2024) describes the Lobito Corridor project as the United States' largest effort to counter China's presence in Africa and the EU has explicitly framed it as a means of ensuring access to critical minerals, particularly copper and cobalt.

3.3.2 Critiques and controversies

The RFI model has attracted ongoing criticism on several fronts. Transparency concerns are central: as discussed in Section 3.3.1, RFI agreements are typically negotiated outside of public scrutiny, with confidentiality clauses preventing host governments from disclosing the details of their obligations (Gelpern et al., 2021). Xu (2020) notes that this opacity represents a significant methodological obstacle for researchers, and that most RFI agreements cannot be independently evaluated precisely because their texts remain unpublished. This difficulty is compounded by broader structural constraints on access to research. Muchapondwa et al. (2014) document that field verification of Chinese development finance projects in Africa is costly,

subject to significant selection bias, and often hindered by officials' reluctance to share project details. In the specific context of the SICOMINES agreement, these difficulties are also structural and politically entrenched. The ITIE RDC evaluation report (2021) documents in detail the obstacles encountered during its official evaluation: numerous Congolese state institutions did not respond to requests for information, the BCPSC (Bureau de Coordination et de Suivi du Programme Sino-Congolais), that is the body responsible for overseeing the agreement's implementation, engaged in what the report describes as a systematic withholding of information amounting to a refusal to cooperate and and several institutions stated that they had been deliberately kept at a distance from the agreement's management. SICOMINES itself initially redirected all requests and limited field visits to a carefully controlled tour. The report also documents contradictory financial data across institutions, with figures not matching, making an independent financial evaluation impossible (ITIE RDC, 2021).

The fundamental question is whether the promised infrastructure is actually delivered. Evidence is mixed at best: Alves (2013) argues that outcomes are highly dependent on the negotiating capacity of African governments and the specific terms of individual agreements, while Mohan and Tan-Mullins (2019) document more systematically that benefits to local communities, particularly rural populations, remain limited, with agreements often negotiated at an elite level and completely bypassing local governance structures.

The presentation of these agreements as "win-win" has been particularly contested. As Carrozza and Benabdallah (2022) demonstrate, the language of mutual benefit and South-South solidarity is often instrumental, serving to legitimize agreements that reproduce rather than challenge existing asymmetries of power and resource exploitation. Xu (2020) adds a structural dimension: by conditioning reimbursement on mining revenues and redirecting financial flows through Chinese contractors, the RFI model is designed to minimize risks for China while expanding the reach of Chinese construction and resource exploitation firms in African markets.

3.4 The SICOMINES agreement

3.4.1 Negotiation and structure of the deal

In 2007, China and the DRC signed the SICOMINES agreement after Joseph Kabila's government failed to secure financial support from its Western partners. This agreement led to closer economic ties and remains one of the most significant Sino-African RFI agreements to date (Skaltsounis, 2025; Shirambere, 2020).

The formal process began with a Memorandum of Understanding (MoU) signed on September 17, 2007 between the DRC government, represented by its Minister of Infrastructure, Public Works and Reconstruction, and a group of Chinese state-owned enterprises represented by the CEO of China Railway Engineering Corporation (CREC) (ITIE RDC, 2021). Attached to this MOU was already a list of infrastructure projects estimated at USD 6.5 billion (ITIE RDC, 2021).

This was then followed by the *Convention de Collaboration* of April 22, 2008, signed between the DRC and Sinohydro Corporation, which set out the detailed terms of the arrangement (Global Witness, 2011). The agreement established the SICOMINES consortium ("La Sino-Congolaise des Mines"), comprising Chinese state-owned enterprises CREC and Sinohydro, along with the DRC's state-owned mining company, Gécamines (Skaltsounis, 2025), with the Chinese side holding 68% and Gécamines the remaining 32% (ITIE RDC, 2021).

The consortium was granted access to vast copper and cobalt deposits in Lualaba and Haut-Katanga provinces. In exchange, the Chinese enterprises committed to investing $9.5 billion in the infrastructure and mining sector of the DRC ($6.5 billion in the infrastructure and $3 billion in the mining sector respectively). Funds would be provided by the Export-Import Bank of China (China Exim Bank), while the consortium would repay the loans through profits derived from the exploitation of natural resources (Skaltsounis, 2025). According to the deal, Gécamines would concede a number of deposits containing approximately 10.6 million tonnes of copper, of which around 6.8 million tonnes were classified as confirmed reserves, as well as approximately 626,000 tonnes of cobalt and other valorisable mineral substances yet to be determined (Global Witness, 2011; ITIE RDC, 2021).

The April 2008 deal set out a long list of railways, roads, bridges and airports to be built or rehabilitated. Furthermore, in line with Kabila's vision of the *cinq chantiers*, hospitals, clinics, hydroelectric dams, electricity distribution networks, housing and universities were set to be built too (Global Witness, 2011). The agreement also stipulated that feasibility studies had to demonstrate a minimum internal rate of return (IRR) of 19% from Sinohydro's perspective. If this threshold was not met, the DRC committed to taking all necessary measures to achieve it, including the concession of additional mineral deposits if the original ones proved insufficient (ITIE RDC, 2021). As Global Witness (2011) noted, this clause was highly unusual commercially: rather than the investor bearing the risk of insufficient returns, as would happen in any commercial agreement, this risk was effectively transferred to the Congolese state, which guaranteed the viability of a foreign company with its own natural resources.

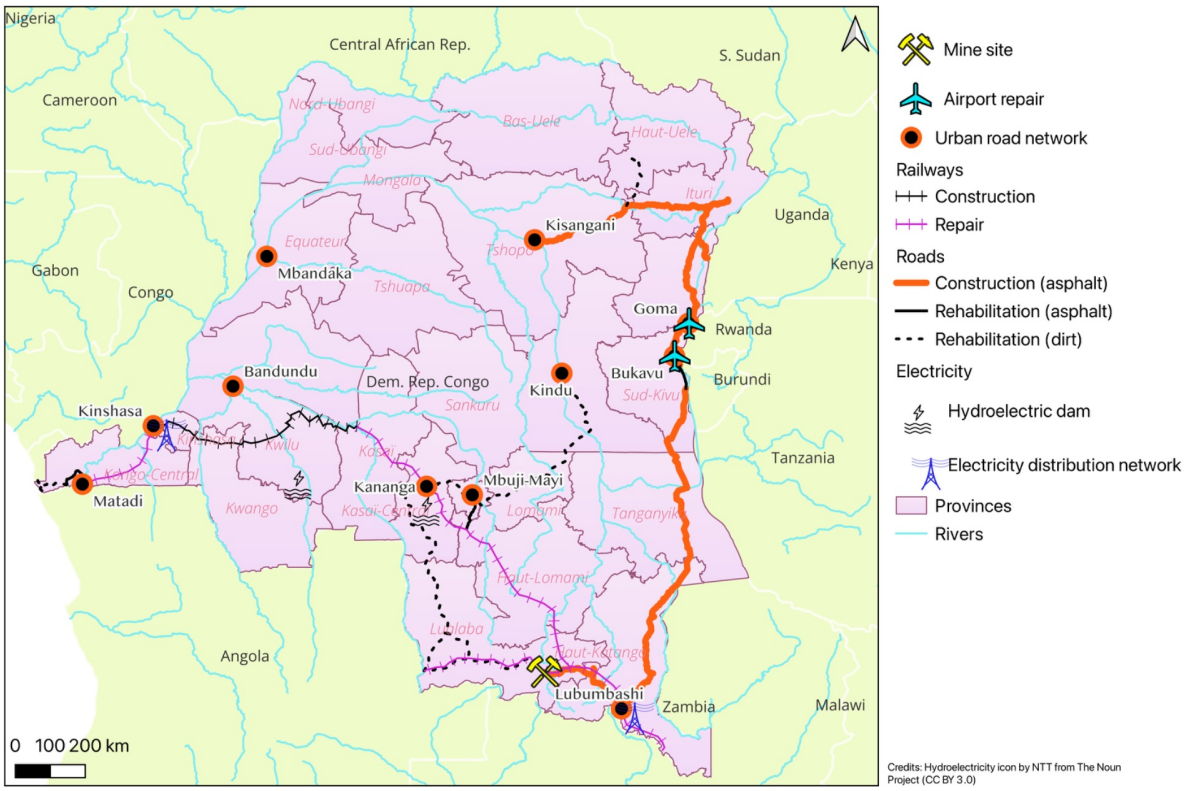


Figure 2: *Map showing mine sites and infrastructure planned under the agreement*

The original agreement also stipulated that if the consortium's profits were insufficient to repay the loans within 25 years, the DRC government would assume responsibility for the remaining balance (Skaltsounis, 2025). This dual exposure, guaranteeing both investor returns and debt repayment, raised strong opposition from the IMF, the World Bank and other DRC creditors, who argued it would make the country's public debt unsustainable. Following their pressure, the infrastructure component was reduced to $3 billion in 2009 and the government guarantee on the mining loan was removed, so, if profits proved to be insufficient to repay this portion of the debt, the responsibility would fall entirely on the SICOMINES consortium, relieving the DRC of any direct financial obligation related to the mining sector (Skaltsounis, 2025).

3.4.2 What was promised and what was delivered

Since its inception, the SICOMINES Agreement has been characterized by a lack of transparency that has undermined its legitimacy and accountability. Negotiations took place behind closed doors, without any open bidding and were led by a small cluster of Congolese government representatives (Global Witness, 2011). The deal was made public only after the initial MoU had already been signed and most members of the

Congolese parliament learned about the agreement only after its final approval (Skaltsounis, 2025). More importantly, it was unclear how the value of the natural resources SICOMINES would have access to would be calculated, and no framework or timeline was provided for the proposed Chinese infrastructure projects. Furthermore, although Gécamines participated in the consortium, decisions regarding its operations, such as mining production targets, exports, and labor recruitment, were made exclusively by the Chinese partners (Skaltsounis, 2025).

The DRC's weak negotiating position exacerbated these structural problems. The country was emerging from more than a decade of civil conflict, and corruption under Kabila's rule was among the highest in the world (Skaltsounis, 2025). An investigation by The Sentry (2021), based on the Congo Hold-up leak, the largest ever of African financial documents, found evidence of a corruption scheme in which a shell company, the Congo Construction Company (CCC), received approximately $55 million from sources linked to Chinese state-owned enterprises, which was then transferred through a bank controlled by Kabila's brother to the president's family and associates. Neither the Chinese companies nor Kabila responded to requests for comment about this (The Sentry, 2021).

The gap between what was promised and what was actually achieved is particularly evident on the infrastructure front. The report by ITIE RDC highlighted that, by the end of 2023, Chinese companies had earned nearly USD 10 billion in profits, whereas the DRC received only USD 822 million in infrastructure in return and neither hospitals nor universities had been built. This result was compounded by the full tax exemption granted to SICOMINES for the entire reimbursement period, meaning that the DRC received neither infrastructure nor tax revenues during these years (ITIE RDC, 2021). The ITIE RDC study came to the harsh conclusion that the joint-venture agreement presented an unprecedented harm in the history of the DRC (Rakotoseheno, 2024).

In contrast, progress in the mining sector has been considerably faster. By 2023, Chinese companies had invested over $2.45 billion in the mining sector, and mines had been operational since 2015 (Skaltsounis, 2025). This asymmetry between the two components of the agreement has become one of the central arguments for renegotiation under the current president, Félix Tshisekedi.

The opacity that characterized the initial 2009 negotiations persisted throughout the implementation of the agreement. The most striking example is Amendment No. 4, signed in July 2017 under Prime Minister Tshibala's transitional government. This amendment significantly reduced the percentage of SICOMINES's profits allocated to loan repayment, from

85% to 65%, diverting a larger portion directly to shareholders. Its dissemination was deliberately limited and most Congolese state institutions were unaware of its contents (ITIE RDC, 2021). The ITIE RDC report defined it as a fundamental threat to the Republic's financial interests, aggravated by the institutional context in which it was signed, during a period of political transition in which control mechanisms were weak.

The agreement also created big environmental costs. For example, in September 2016, SICOMINES dumped toxic chemicals into the Luilu River, resulting in tremendous damage and exposing thousands of inhabitants in Sapatelo, Yenge, Noa, and Sept to stinging odors and the risks of consuming contaminated fish (Skaltsounis, 2025).

3.4.3 The 2024 renegotiation

The new government, led by President Félix Tshisekedi, attempted to renegotiate the terms of the agreement with SICOMINES. The ITIE-RDC assessment, published in December 2021, proved to be particularly significant, concluding that the joint venture had caused unprecedented damage in the history of the Democratic Republic of the Congo (ITIE RDC, 2021). The assessment highlighted the asymmetric distribution of capital, the undervaluation of copper reserves, the diversion of profits under the 2017 amendment, and the failure to build promised infrastructure, despite the extensive tax exemptions granted to SICOMINES (Rakotoseheno, 2024).

Even before the report's publication, President Félix Tshisekedi had already expressed a desire to renegotiate unbalanced contracts in favor of “win-win deals”. Following the ITIE-RDC's findings, he instructed both the Ministry of Mines and the General Inspectorate of Finance, an auditing body in the public sector, to investigate the 2008 agreement and its subsequent amendments. He also set up a Sino-Congolese commission in charge of finding a better balance of interests, with contributions from ITIE-RDC (Rakotoseheno, 2024). The General Inspectorate of Finance's audit confirmed the ITIE-RDC's findings.

After President Tshisekedi visited China in May 2023, the DRC government announced in January 2024 the successful conclusion of the negotiations, formalized through a fifth amendment to the original agreement. Under the revised terms, the infrastructure budget was increased from $3 billion to $7 billion, more than double the previously agreed amount (Skaltsounis, 2025). Repayment of the loans, including principal and accrued interest, is expected to be completed by 2028, after which SICOMINES's share capital structure will be renegotiated (Rakotoseheno, 2024).

Nonetheless, important questions remain. The renegotiation itself was largely conducted behind closed doors: the new agreement was first made public during Tshisekedi's inaugural speech for his second term, surprising even civil society organizations that had called for transparency throughout the process (Livingstone, 2024). No details beyond the $7 billion figure were disclosed, and neither the Chinese embassy in Kinshasa nor the Congolese presidency commented on the terms (Livingstone, 2024). Analysts interviewed by VOA News described the final agreement as "largely favorable to China," noting that few of the original structural issues had been resolved: no reassessment of the mine's reserves had been conducted, and the $7 billion would be disbursed over 10-15 years in the form of interest-bearing loans, raising further concerns about the DRC's debt position (Livingstone, 2024). The Fifth Amendment has not been published in full, reflecting the limited dissemination that characterized the controversial Amendment No. 4 of 2017 (ITIE RDC, 2021).

3.5 Theoretical framework

3.5.1 Infrastructures and human capabilities

The very concept of development is itself debated and, for some, outdated. Post-development scholars argue that the dominant development paradigm, focused on economic growth, Western-style modernization, and the assumption that "underdeveloped" nations must "catch up" and live like the West, reproduces colonial hierarchies rather than dismantling them (Ziai, 2016). As Sachs (1999, p. 7, cited in Ziai, 2016, p. 6) states, "development always entails looking at other worlds in terms of what they lack, and obstructs the wealth of indigenous alternatives", a logic that assumes that external actors know what populations need and have the knowledge and legitimacy to provide it. From this perspective, infrastructure-led development risks becoming a reiteration of the same logic: external actors decide what populations need and provide it on their own terms. The SICOMINES agreement can be seen as an example of this dynamic: an agreement negotiated behind closed doors, without local consultation, in which the infrastructure to be built was decided by state actors in Kinshasa and Beijing, not by the communities it was intended to serve.

This thesis does not adopt a post-developmental stance but takes seriously the criticism that development cannot be reduced to GDP growth or, in this case, to infrastructure counting. Rather than measuring outcomes in aggregate terms, it asks what infrastructure means for people's real opportunities: their ability to reach a hospital when they're sick, to bring goods to a market, to send their children to school, to participate in economic and social life. The lack of infrastructure isn't simply an inefficiency, but it’s a limitation to what people can do and be.

The empirical literature on infrastructure, even when framed in conventional economic terms, provides evidence consistent with this broader view. Calderón and Servén (2010) find robust evidence across over 100 countries that infrastructure development is associated with both higher long-term growth and lower income inequality in sub-Saharan Africa, suggesting that infrastructure failures exacerbate existing disadvantages rather than simply slowing aggregate output. Limão and Venables (2001) demonstrate that inadequate infrastructure is a key driver of high transport costs, with particularly severe consequences for landlocked countries, a finding directly relevant to the Democratic Republic of the Congo where connectivity deficits exacerbate geographic disadvantage. Banerjee, Duflo, and Qian (2012) find a moderate positive effect of transportation access on GDP per capita levels in China, while noting that the benefits are heterogeneous and context-dependent: a finding that resonates with the DRC context, where the absence of roads is only one of many constraints on people's ability to access services and opportunities.

What these studies ultimately measure - travel costs, market access, connectivity - are indirect indicators of people's ability to participate in economic and social life. This is precisely what the accessibility analysis presented in Chapter 5 seeks to capture. Travel time to Mbuji-Mayi is not an abstract parameter: it measures how long it takes a sick person to reach a hospital, how far a trader must travel to sell his goods, and how isolated a community remains from the opportunities a good road would bring. In this sense, the gap between what was promised under the SICOMINES agreement and what was delivered is not just a matter of unfulfilled contractual obligations, but also of the possibilities denied to people who had no say in the agreement that was supposed to protect their interests.

However, measuring whether infrastructure has reached people and what impact it has had requires methods capable of generating independent evidence in contexts where official data are scarce, access is limited, and political sensitivities hinder research. Section 3.5.3 discusses how researchers have developed such methods in response to the opaqueness surrounding development funding in China; this dissertation adopts a GIS-based approach within this broader methodological landscape, producing verifiable evidence of road conditions independent of official data.

This, however, is not enough on its own. Font-Casaseca and Rodó-Zárate (2024) argue that GIS represents space in terms of coordinates, geometries, and attributes, and struggles to capture "place" as it is lived, shaped by everyday practices, relationships, and bodily experiences. The classification of road conditions and travel time estimates presented in this study describe the corridor in precisely these terms: as a series of segments with assigned speeds and lengths. What

this representation cannot capture - the lived experience of crossing the corridor, the decisions people make in response to its conditions, the everyday life it shapes - would require integrating this GIS-based analysis with interviews or other qualitative methods, an integration that, due to resource and access constraints, was beyond the scope of this study, but which future research could pursue (Section 7.3).

3.5.2 Spatial inequality and accessibility

Where people live determines the opportunities they have access to. This apparently simple observation has profound implications for our understanding of inequality: disparities in well-being are not only the product of differences in income or education, but also of geographic factors, that is, who lives near roads, markets, hospitals and schools and who does not. The economic geography literature has long recognized that the spatial distribution of economic activity is not random but tends to cluster in places that already have market access and connectivity, and to bypass places that do not. Krugman (1991) demonstrates that producers tend to locate where demand is higher, but demand is higher precisely where producers choose to locate: a self-reinforcing circularity that tends to favor already-connected places and leave peripheral ones behind. In this dynamic, transportation costs have a central role, because lower transportation costs between connected locations strengthen their attractiveness as production sites, further marginalizing places lacking connectivity (Krugman, 1991). In a country like the Democratic Republic of the Congo this logic is particularly evident: entire regions are effectively excluded from economic and social participation not by choice, but by a lack of investment in infrastructure.

Measuring the human consequences of this spatial exclusion, however, requires going beyond aggregate indicators. Accessibility, defined by Geurs and van Wee (2004, p. 128) as "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations" has emerged as one of the most meaningful spatial measures for assessing the distribution of people's actual opportunities across the landscape. Geurs and van Wee (2004) distinguish between different approaches to measuring accessibility, noting that person-based measures, which focus on the actual opportunities available to individuals based on their location and time constraints, are particularly relevant for assessing the human impact of infrastructure deficiencies. Unlike infrastructure-based measures, which simply record travel speed or congestion, person-based accessibility measures capture whether people can actually reach the services and opportunities they need, based on where they live and the transportation options available to them.

The link between road connectivity and rural livelihoods in sub-Saharan Africa is documented by Dorosh et al. (2010), who use GIS-based travel time data from 42 countries to demonstrate that agricultural production is strongly influenced by the time it takes to reach an urban market. Areas within four hours of a city of 100,000 people produce approximately 45% of their agronomic potential; those more than eight hours away produce only 5%. This is not because the soil is less fertile, but because poor connectivity makes it economically unviable to produce for unreachable markets. Dorosh et al. (2010) further demonstrate that their GIS-based travel time analysis can be used to compare the cost-benefit ratios of alternative road investments, highlighting the methodological potential of spatial accessibility modeling as a tool for assessing infrastructure priorities.

This body of literature provides the theoretical and methodological justification for the accessibility analysis conducted in Chapter 5. Spatial accessibility modeling, which uses GIS-based travel time data to measure who can get to what and in what time, offers a tool for making inequality visible and measurable in contexts where official data are scarce and independent verification is needed. Crucially, this approach is replicable: the same methodology could be applied to other RFI agreements in sub-Saharan Africa, contributing to a broader set of tools for accountability on Africa-China infrastructure financing.

3.5.3 Transparency, infrastructure accountability and independent verification

The previous sections have illustrated why infrastructure matters for human capabilities and how spatial inequality can be measured. This third framework addresses a more fundamental question: how can we know whether promised infrastructure has actually been built? In contexts where official data are scarce or unreliable, the answer requires methods capable of generating independent evidence and a theoretical justification for why such independence is important.

The opacity of Chinese development financing is well documented. Dreher et al. (2017) note that the Chinese government treats its international development financing program as a "state secret," failing to disclose comprehensive information on the foreign projects it finances or to publish a breakdown of its financing activities. This opacity is nothing new: as discussed in Section 3.1.2, Chinese bilateral loan agreements routinely contain confidentiality clauses that prevent borrowers from disclosing their terms, and major Chinese development financing institutions do not publish detailed activity reports (Gelpern et al., 2021). The practical consequence for researchers is that standard methods of evaluating development financing cannot be applied to Chinese-financed infrastructure because the underlying data simply do not exist in publicly accessible form (Dreher et al., 2017).

This has pushed researchers towards alternative methodologies. AidData's Tracking Under-Reported Financial Flows (TUFF) methodology, developed precisely in response to this opacity, triangulates information from news reports, official statements, embassy websites, and government records of recipient countries to construct a picture of Chinese financing activities that official sources do not provide (Dreher et al., 2017). Muchapondwa et al. (2014) also used AidData's approach and added field verifications, like site visits and interviews with project stakeholders, to verify whether projects recorded in open-source databases actually existed on the ground. Their findings were largely consistent, but they also revealed a key limitation: in-person interviews collected information on less than a third of the projects in the database, suggesting that field verifications alone are no substitute for systematic and scalable verification methods. More generally, they concluded that "existing reporting systems are not up to the task of tracking the activities of non-Western development financiers" making it "nearly impossible to objectively understand the nature, distribution, or effects of these activities without new methods of data collection" (Muchapondwa et al., 2014, 16).

It is precisely this gap that geospatial methods are particularly well-suited to fill. Unlike document-based or interview-based approaches, satellite imagery and GIS-based analyses do not depend on any party's willingness to disclose information, but instead directly observe infrastructures. Snyman and Coetzee (2024) demonstrate the practical value of this approach in data-scarce African contexts, showing that GIS-based accessibility modeling can produce meaningful results even where road network data is incomplete by supplementing available datasets with spatial proxies for unmapped routes.

Taken together, these methodological contributions point the way toward a broader accountability framework for infrastructure financing in opaque contexts. The SICOMINES case illustrates this potential: the ITIE RDC evaluation that led to the 2024 renegotiation explicitly relied on independently verifiable data to document the gap between promises and actual delivery (Rakotoseheno, 2024). This thesis extends this logic to the spatial level, using GIS-based accessibility modeling to produce a quantitative and independent assessment of infrastructure delivery and to demonstrate that this approach is replicable in other infrastructure resource exchange agreements where opacity remains the norm.

CHAPTER 4: METHODOLOGY

4.1 Research design

This study adopts a diachronic analysis approach, examining road conditions along the Munkamba - Mbuji-Mayi corridor over three different time periods - 2013 (considered as baseline), 2023 (pre-2024 renegotiation), and 2025 (post-renegotiation) - as well as a counterfactual scenario representing the road as it would have been built under the original SICOMINES agreement. The approach is quantitative and combines satellite imagery interpretation (Section 4.3.1), travel time modeling, population accessibility estimates (Section 4.3.2) and the counterfactual scenario (Section 4.3.3).

The choice of the Munkamba - Mbuji-Mayi corridor as a case study is justified for several reasons. First, the road was explicitly included in the infrastructure commitments of the 2008 SICOMINES agreement (Democratic Republic of the Congo and Groupement d'entreprises chinoises, 2008). Second, it’s part of Route Nationale 1 (RN1), the country's main land route. Third, it has national strategic importance and is considered a "route d'intérêt national" (La Tempête des Tropiques, 2023) connecting the western part of the country, where the capital Kinshasa is located, to Mbuji-Mayi, the third-largest city in the Democratic Republic of the Congo, passing through an agricultural area. Fourth, the progressive deterioration of the road over the study period is well documented by local sources and, finally, the human cost of this deterioration is concrete and measurable: the impassability of the corridor directly impacts the supply of food and goods to Mbuji-Mayi, with consequences for food security and economic activity in the region.

The analysis period goes from 2013 to 2025. The year 2013 was chosen as the baseline rather than 2008, the year of the agreement's signing, for two reasons. First, earlier years lacked sufficient satellite coverage over the full extent of the corridor for reliable visual classification. Second, 2013 captures the road's pre-intervention condition: according to the EITI evaluation report on the SICOMINES infrastructure programme, the Munkamba - Mbuji-Mayi segment does not appear among the fifteen eligible infrastructure projects executed between 2008 and 2018, confirming the absence of any SICOMINES related works on this corridor until that moment (ITIE-RDC, 2021). The 2023 scenario represents the situation immediately prior to the renegotiation of the agreement, providing evidence of the infrastructure gap that led to the 2024 revision and the 2025 scenario captures the first observable effects of the works following the renegotiation.

Although the original SICOMINES agreement did not include a formal implementation timetable, an expression of the structural opacity documented in the literature, the years between the baseline and the 2023 scenario provide a sufficient timeframe to assess the infrastructure's progress against the original commitment.

A counterfactual scenario was also developed to simulate travel times and accessibility for the population using the corridor if the road had been rehabilitated as stipulated in the contract. Annex C of the SICOMINES agreement classifies the Munkamba - Mbuji-Mayi corridor as "réhabilitation des routes en terre" (rehabilitation of unpaved roads), rather than as fully paved. The counterfactual scenario therefore simulates a situation in which the entire corridor is brought to "Fair condition" (Class 2), representing a rehabilitated but unpaved road, in line with the original contractual commitment. It functions as a "hypothetical" analytical tool, quantifying the accessibility cost of over fifteen years of non-construction and providing a benchmark against which to measure actual implementation.

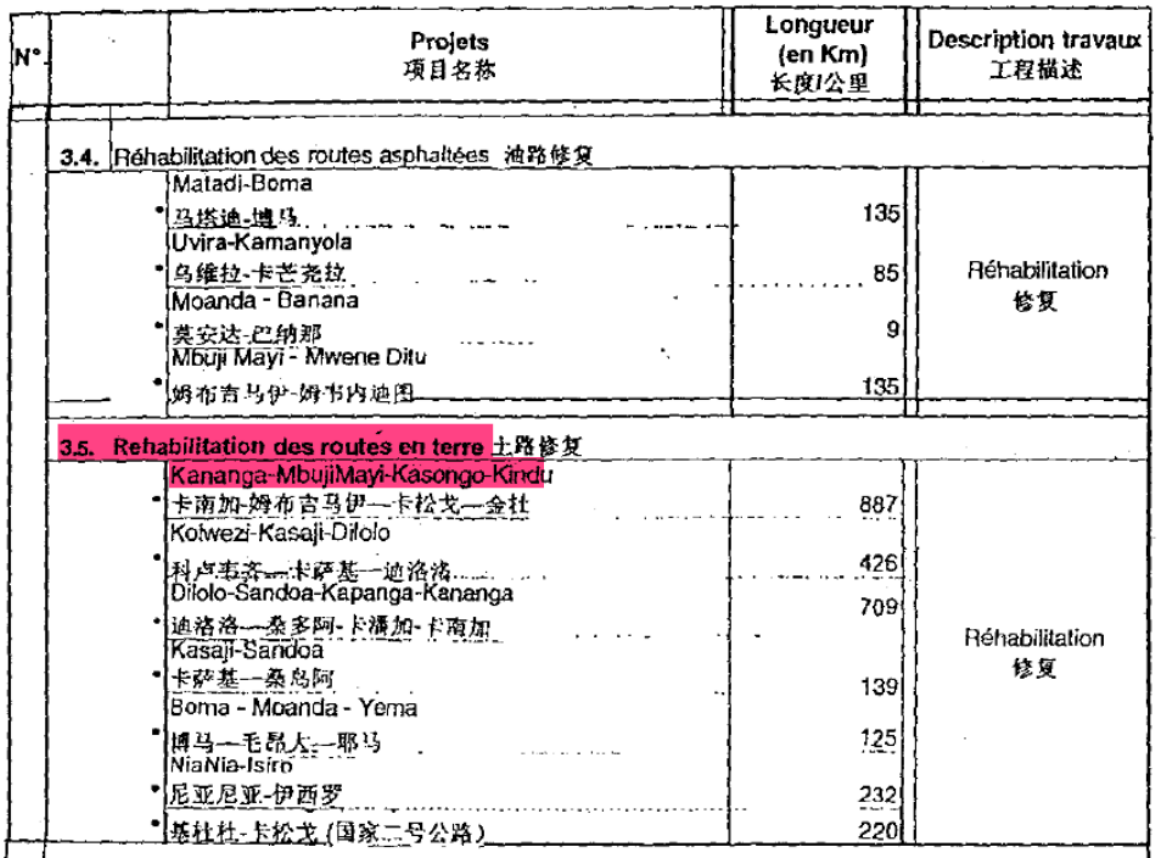
4.2 Data sources and collection

This study uses different data all coming from open-access sources. Satellite imagery was obtained from USGS Earth Explorer. The 2013 baseline uses a Landsat 5 image acquired on July 7, 2009 (Path 176, Row 064, 0% cloud cover), being the closest cloud-free image available for the baseline year. The 2023 and 2025 scenarios use Sentinel-2 Level 2A imagery acquired on August 31, 2023, and July 31, 2025, respectively, selected to minimize cloud cover over the corridor. Visual classification was conducted primarily using Google Earth, which provided additional temporal coverage and greater spatial resolution for sections where Landsat and Sentinel-2 imagery were insufficient.

Population data were obtained from WorldPop. The 2013 reference dataset originally used the country-specific dataset for that year (DOI: 10.5258/SOTON/WP00645), which, however, uses a different methodological framework than the datasets used for 2023 and 2025 (DOI: 10.5258/SOTON/WP00839), preventing direct comparisons over time. To ensure methodological consistency, the 2015 dataset, which belongs to the same series as the 2023 and 2025 datasets, was used as a proxy for the 2013, so that all three datasets share the same methodological framework, ensuring temporal comparability. The use of the 2015 data as a proxy for 2013 is recognized as a limitation and is discussed further in Section 4.5.

Administrative and geographical boundary data were obtained from two sources. The provincial and territorial boundaries of Kasaï Oriental, the national borders of the Democratic Republic of the Congo, and neighboring countries were obtained from the Humanitarian Data Exchange

(HDX), river networks were obtained from Natural Earth Data and Hydroelectricity icon by NTT from The Noun Project (CC BY 3.0).



N°	Projets 项目名称	Longueur (en Km) 长度/公里	Description travaux 工程描述
3.4.	Réhabilitation des routes asphaltées 油路修复		
	Matadi-Boma 马塔迪-博马	135	Réhabilitation 修复
	Uvira-Kamanyola 乌维拉-卡兰克拉	85	
	Moanda - Banana 莫安达-巴纳那	9	
	Mbuji Mayi - Mwene Ditu 姆布吉马伊-姆韦内迪图	135	
3.5.	Rehabilitation des routes en terre 土路修复		
	Kananga-MbujiMayi-Kasongo-Kindu 卡南加-姆布吉马伊—卡松戈—金杜	887	Réhabilitation 修复
	Kolwezi-Kasaji-Dilolo 科卢韦齐—卡萨基—迪洛洛	426	
	Dilolo-Sandoa-Kapanga-Kananga 迪洛洛—桑多阿-卡潘加-卡南加	709	
	Kasaji-Sandoa 卡萨基—桑乌阿	139	
	Boma - Moanda - Yema 博马—毛昂大—耶马	125	
	NiaNia-Isiro 尼亚尼亚-伊西罗	232	
	基杜杜-卡松戈(国家二号公路)	220	

Figure 3: *Extract from Annex C of the Convention de Collaboration of April 22, 2008 between the DRC and Sinohydro Corporation. Section 3.5 shows the Kananga - Mbuji-Mayi - Kasongo - Kindu corridor (887 km) among the unpaved roads intended for rehabilitation under the agreement (Réhabilitation des routes en terre). Source: Democratic Republic of the Congo and Groupement d'entreprises chinoises, 2008.*

The benchmark against which infrastructure implementation is evaluated is Annex C of the 2008 SICOMINES Collaboration Agreement (Democratic Republic of the Congo and Groupement d'entreprises chinoises, 2008), which lists all infrastructure projects covered by the agreement. This document serves as the contractual benchmark against which actual implementation is evaluated, measured through GIS analysis.

All spatial analyses were conducted using QGIS (version 3.42 Münster), an open-source geographic information system software. Road condition classification and corridor digitization were performed using Google Earth as the primary visual reference platform, complemented by Landsat and Sentinel-2 imagery loaded directly into QGIS. Population buffer analysis and zonal statistics were also performed using QGIS. The choice of open-source tools was

deliberate: the entire analytical workflow is freely replicable without proprietary software licenses, which is consistent with the study's goal of proposing a methodology applicable to resource-constrained research settings.

4.3 Data analysis

4.3.1 Road condition analysis

The classification of the road conditions was performed through visual interpretation of satellite imagery using a four-category scheme: Good, Fair, Poor, and Bad, in line with the classification framework proposed by Workman et al. (2023) for unpaved road networks in Africa. Workman et al. (2023) demonstrate that visual assessment of road surface conditions from satellite imagery can achieve 63-85% accuracy compared to actual field data, validating this method's feasibility in settings with limited data.

The corridor was manually digitized in QGIS as a series of line segments, each of which was assigned one of four condition classes based on observation on Google Earth imagery, supplemented by Landsat and Sentinel-2 imagery (Table 1).

Class	**Label**	**Visual indicator**
1	Good	Paved surface, smooth with clearly defined edges
2	Fair	Unpaved but with minimal erosion and compacted edges
3	Poor	Visible deterioration with surface erosion and irregular edges
4	Bad	Severe erosion with deep ruts, partially impassable

Table 1: *Road condition classification scheme used in this study, with visual indicators for each class.*

Speed values were assigned to each class based on the dry and wet season estimates provided in Ulimwengu et al. (2009), Table 1, adapted for this study by calculating annual averages as the mean of dry and wet season value, in order to reflect the mixed seasonal coverage of the satellite imagery used for classification. The resulting values are: Class 1 = 63 km/h; Class 2 = 23,5 km/h; Class 3 = 19,5 km/h; Class 4 = 2,5 km/h (Table 2).

Class	Label	Dry season (km/h)	Wet season (km/h)	Annual average (km/h)
1	Good	80	46	63
2	Fair	30	17	23,5
3	Poor	25	14	19,5
4	Bad	3	2	2,5

Table 2: *Speed assumptions by road condition for each class adapted from Ulimwengu et al. (2009), Table 1.*

Then digitization was performed independently for each of the three time periods 2013, 2023, and 2025. For each year, a new vector layer was created in QGIS, and the corridor was manually drawn as a series of contiguous line segments. Each segment was drawn to correspond to a visually homogeneous road section, where surface conditions appeared to be the same, and assigned a condition class from 1 to 4 based on the visual criteria described previously. Where conditions visibly changed along the corridor, a new segment was created and a new value was assigned.

The segment lengths in kilometers were calculated using the QGIS Field Calculator, after projecting each layer to EPSG:32634 (WGS 84/UTM Zone 34N) to ensure metric accuracy. The total kilometers per condition class per year was then derived using the Statistics by Categories tool in the QGIS Processing Toolbox, with “length_km” as the value field and the condition class field as the category variable.

Visual classification involves an element of interpretive judgment so, to minimize subjectivity, the classification criteria were applied consistently across all three time periods, and ambiguous segments were examined by comparing them with imagery from different dates, where available. The limitations of this approach are discussed in more detail in Section 4.5.

Class 1, Good

Class 2, Fair

Class 3, Poor

Class 4, Bad

Figure 4: *Classes for road classification.*

4.3.2 Accessibility analysis

Travel time along the corridor was calculated for each of the three scenarios (2013, 2023, 2025) and for the counterfactual scenario, using the following formula for each section:

$$t = d / v$$

where t is the travel time in hours, d is the segment length in kilometers, and v is the speed assigned to the segment's condition class in km/h. The total travel time for each scenario was calculated by adding the travel times for all segments.

The resulting travel times were compared across the different scenarios to quantify the variation in corridor accessibility over time and against the counterfactual benchmark. Travel times for the dry season and the rainy season were calculated separately using the disaggregated speed values from Ulimwengu et al. (2009), in addition to annual mean estimates, to illustrate the seasonal variability in accessibility.

A 5-km buffer was then generated around each year's road classification layer to approximate the corridor's direct influence zone. This threshold was selected because the Munkamba - Mbuji-Mayi corridor functions primarily as a motorized road, used by motorcycle taxis, trucks and vehicles transporting goods. The 5 km service area therefore includes the population living along the corridor most likely to rely on this road to reach the city of Mbuji-Mayi. WorldPop population rasters for 2015 (used as a proxy for 2013), 2023, and 2025 were then overlaid on the corresponding buffer using QGIS's Zonal Statistics tool. The “sum” statistic was selected, which aggregates the population values of all raster pixels falling within the buffer polygon, providing an estimate of the total population residing within the corridor's 5 km influence zone for each year.

4.3.3 The counterfactual scenario

The counterfactual scenario simulates travel times and accessibility for the population if the road had been rehabilitated as contractually required by the SICOMINES agreement. As noted in Section 4.2, Annex C classifies the Munkamba - Mbuji-Mayi corridor as a rehabilitated unpaved road, rather than a fully paved one. The counterfactual scenario therefore simulates a situation in which the entire corridor is brought to acceptable condition (Class 2=23,5 km/h), representing a fully rehabilitated but unpaved road, in line with the original contractual commitment.

The travel time in the counterfactual scenario was calculated by dividing the total length of the corridor for each year by the expected speed for Class 2 (23,5 km/h). The resulting value serves as a benchmark against which the observed travel times for each year of the scenario are compared. The difference between actual and hypothetical travel times, expressed in hours, represents the accessibility cost resulting from non-implementation: the additional time corridor users spent traveling each year compared to what they would have spent if the road had been rehabilitated as promised. This gap is calculated for each of the three scenarios (2013, 2023, 2025), so that it’s possible to track the cumulative effect of the implementation delay over time.

The counterfactual scenario does not simulate an optimal situation, but rather a contractual minimum, so what was explicitly promised in the agreement. The gap between actual and

hypothetical travel times therefore represents an estimate of the cost of over fifteen years of implementation delay.

4.4 GIS as a research methodology

In response to data scarcity and opacity issues, a growing body of research has turned to geospatial methods as an alternative source of evidence. The underlying logic is simple: documents can be obscured and statistics manipulated, physical infrastructure is visible from space, so that satellite imagery provides an independent and verifiable record of what has actually been built on the ground.

AidData, a research laboratory at the College of William & Mary in the USA, pioneered this approach in the context of Chinese development funding in Africa through what they termed "skytruthing", the use of satellite imagery to remotely monitor the progress of large-scale Chinese-funded projects visible on the ground. The method was developed precisely because field verification through visits is expensive and time-consuming, while satellite imagery offers a valid alternative for verifying projects in data-scarce contexts (Muchapondwa et al., 2014). Early applications of AidData focused on Chinese-funded stadiums across Africa, using Google Earth's timeline to document construction progress and verify that these projects existed (Perkins, 2014).

This thesis builds upon and extends this methodology. AidData's satellite-based verification approach demonstrated the feasibility of using satellite imagery to verify Chinese infrastructure projects, but it remained largely observational, documenting the presence or absence of construction rather than measuring changes over time or quantifying the impact on populations.

The approach adopted here goes further because it introduces a longitudinal and multi-scenario framework, so rather than a single snapshot, road conditions are classified based on three different time periods plus a counterfactual scenario, allowing for analysis of deterioration, partial rehabilitation and what should have been built. Also, it applies a systematic classification scheme to road segments, moving beyond the presence/absence dichotomy and relies on a four-category classification based on satellite-based visual interpretation. Finally, it integrates accessibility modeling: travel time calculations and population impact analysis translate road condition data into population-level impact estimates.

Critically, the whole workflow relies on open-source tools and freely available data, making it replicable and applicable to other resources-for-infrastructure agreements across Africa, where similar conditions of data opacity and scarcity exist.

Muchapondwa et al. (2014) demonstrated the limitations of field verification as a method for evaluating Chinese development finance projects in Africa: the approach proved to be costly, subject to significant selection bias, and capable of verifying only about two-thirds of known projects in Uganda and half of those in South Africa, even with considerable resources. The authors have called for new data collection methods capable of monitoring non-Western development financing on a large scale. This thesis takes a step in this direction, offering a systematic, longitudinal, and replicable approach to measure infrastructure construction through satellite-based verification. It does not, however, claim to resolve the broader methodological challenge: more robust evaluations of resources-for-infrastructure agreements would likely need to combine geospatial analysis with field research, an integration that remains a priority for future work in this area.

4.5 Methodological limitations

In interpreting the results of this study, several methodological limitations must be acknowledged.

First, road condition classification was performed through visual interpretation of satellite imagery, which implies an inherent degree of subjectivity. A fundamental difficulty concerns the distinction between Class 2 (Fair) and Class 3 (Poor). At the available spatial resolution, particularly for the 2013 Landsat reference imagery, both conditions can exhibit similar spectral signatures: an orange-brown earthy surface with variable texture, making differentiation sometimes difficult. To overcome this problem, classification decisions for ambiguous segments were based on documentary sources describing road conditions along the corridor. Minten and Kyle (1999), cited in Ulimwengu et al. (2009), describe much of the DRC's road network as "almost impassable," with significant sections severely deteriorated. Radio Okapi (2015) reported that the 180 km Kananga-Mbuji-Mayi section required 2 to 3 days of travel, implying average speeds well below the 23,5 km/h threshold associated with Class 2 conditions. On this basis, segments where visual interpretation was ambiguous between Class 2 and Class 3 were conservatively classified as Class 3, in line with documentary evidence and these classification criteria were applied consistently across all three time periods to ensure comparability.

Also, the speed values used in the travel time model are theoretical estimates derived from Ulimwengu et al. (2009) and represent average conditions during the dry and rainy seasons. They do not account for vehicle type variability - the study was calibrated for four-wheel drive vehicles - nor do they consider local factors such as river crossings or village traffic. Actual

travel times may therefore differ from modeled estimates, particularly on the Class 3 and Class 4 segments, where the type of vehicle significantly affects drivability.

Then, it's important to say that satellite imagery used for the classification covers multiple acquisition dates in different seasons across the three periods considered. Road surface appearance can vary significantly between the dry and rainy seasons, potentially impacting classification consistency. Where multiple acquisition dates were available for the same segment, the closest cloud-free image was used. This limitation is partially mitigated by the use of annual mean speed values, which account for both seasonal conditions.

Another challenge that occurred during the analysis was related to population datasets. Population estimates for the 2013 reference period use the WorldPop 2015 estimate from the same dataset product rather than a specific 2013 dataset. The WorldPop 2013 country dataset (DOI: 10.5258/SOTON/WP00645) was initially considered, but was found to use a different methodological framework than the datasets used for 2023 and 2025 (DOI: 10.5258/SOTON/WP00839), which are part of the newer WorldPop Global Project Population Dataset series. Using datasets with different methodologies would have caused comparability issues across the three time periods. The 2015 estimate from the newer series was therefore selected as the closest available year with a consistent methodology. This introduces a slight time bias of two years for the baseline population estimate, which should be taken into account when interpreting the 2013 demographic data.

Furthermore, the 5-km buffer used to estimate the corridor-dependent population represents an analytical choice rather than a standardized threshold. A wider or narrower buffer would produce different population estimates.

Finally, a limitation concerns the relationship between road deterioration and soil characteristics: in this study, no overlay between road condition classification and soil type data was performed, but such analysis is indicated as a possible direction for future research in Section 7.3.

CHAPTER 5: ANALYSIS

5.1 Introduction to case study

The Munkamba - Mbuji-Mayi corridor is part of Route Nationale 1 (RN1), the main overland route in the Democratic Republic of the Congo. The specific section analyzed in this study extends for approximately 83 km through the province of Kasaï Oriental, crossing the territories of Kabeya-Kamwanga, Miabi, and Tshilenge before reaching Mbuji-Mayi, the country's third-largest city and the economic capital of the Kasaï Oriental region. The corridor traverses a predominantly rural and agricultural area, serving as the main supply route for food, goods and essential services for the city of Mbuji-Mayi. The road is entirely unpaved, with the exception of a short, paved section at the Mbuji-Mayi end, documented since 2023, and is subject to severe seasonal deterioration during the rainy season, when erosion and flooding make some sections impassable.

Under the 2008 SICOMINES agreement, this corridor was included among the infrastructure commitments in Annex C, classified as "rehabilitation of unpaved roads," with a total promised length of 887 km for the Kananga - Mbuji-Mayi - Kasongo - Kindu axis. As demonstrated in the following sections, no rehabilitation work was carried out on this section, under the SICOMINES agreement, before the deal was renegotiated in 2024 (ITIE RDC, 2021).

The following analysis presents road condition classifications for three time periods selected (2013, 2023, and 2025) along with a counterfactual scenario, and translates these into travel time estimates and accessibility data for the population living along the corridor.

5.2 Road conditions over time

The classification of road conditions in the three empirical scenarios reveals a corridor in constant and progressive deterioration.

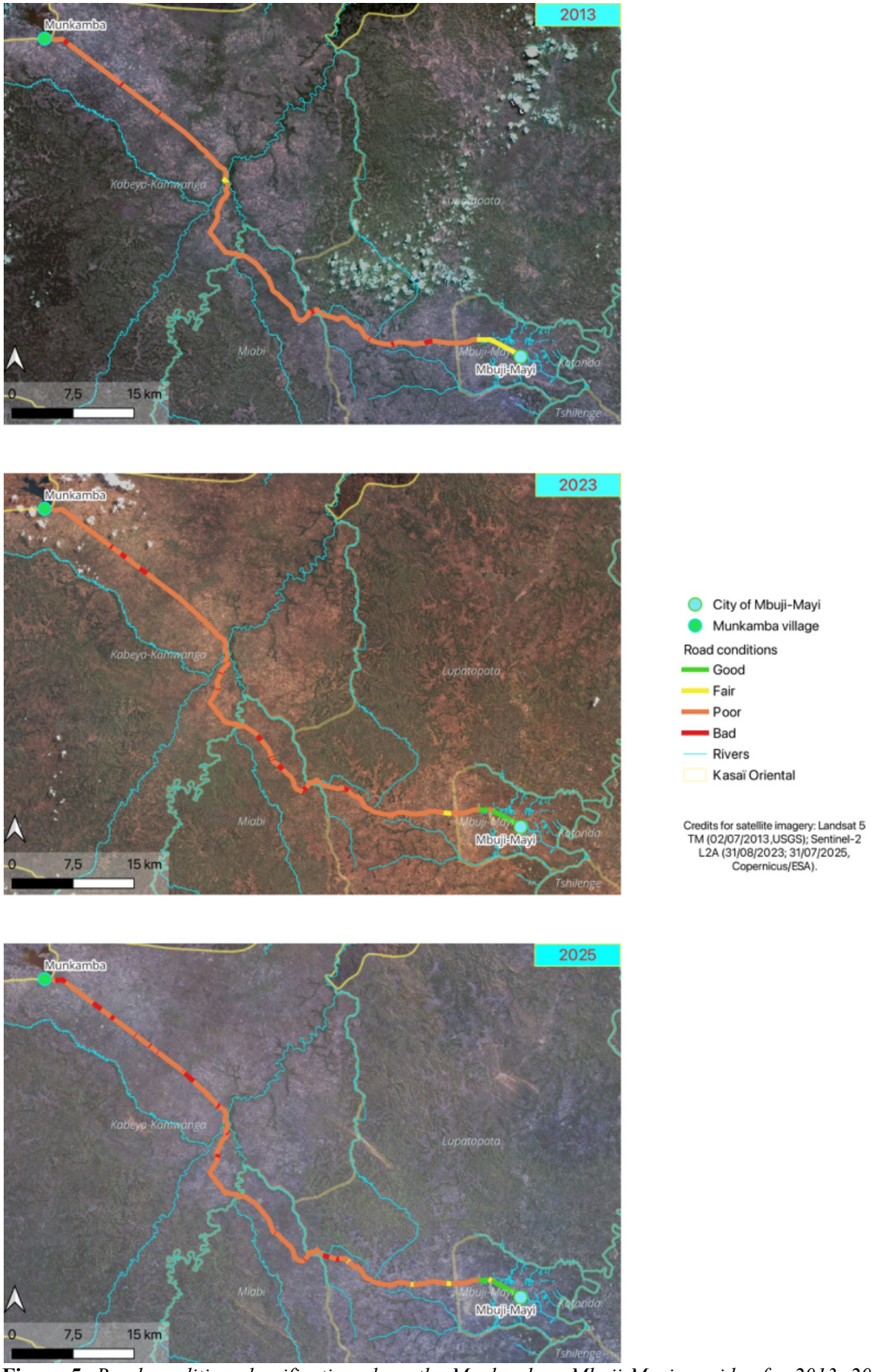


Figure 5: *Road condition classification along the Munkamba - Mbuji-Mayi corridor for 2013, 2023, 2025.*

Class	2013	2023	2025
1 - Good	0	5.44	5.47
2 - Fair	6.36	1.52	2.67
3 - Poor	73.11	71.64	68.22
4 - Bad	4.15	4.97	7.12
Total (km)	**83.62**	**83.59**	**83.48**

Table 3: *Road condition classification results by year (km).*

Class	2013	2023	2025
1 - Good	0%	6.5%	6.6%
2 - Fair	7.6%	1.8%	3.2%
3 - Poor	87.4%	85.7%	81.7%
4 - Bad	5%	5.9%	8.5%

Table 4: *Road condition classification results by year (%).*

In 2013, the corridor was classified predominantly in Class 3 (Poor), covering a length of 73.11 km, 87.4% of the total length. An additional 4.15 km (5%) was classified under Class 4 (Bad), with severe erosion making some sections partially impassable. Only 6.36 km (7.6%) was in Fair (Class 2) condition, and no paved sections (Class 1) were identified. This baseline situation confirms that the corridor was already in critical condition during the initial implementation phase of the SICOMINES agreement, consistent with documentation describing the DRC's road network as nearly impassable during that period (Ulimwengu et al., 2009).

By 2023, no significant improvement had been observed. Class 3 (Poor) remained predominant at 71.64 km (85.7%). 5.44 km of Class 1 (Good) road appeared for the first time, a short, paved section at the Mbuji-Mayi end of the corridor. The decrease in Class 2 (Fair), from 6.36 km in 2013 to 1.52 km in 2023, is likely attributable to the fact that sections previously classified as Fair were reclassified as Good following paving works. Class 4 (Bad) increased slightly to 4.97 km, confirming the continued degradation in the most affected sections of the corridor. The overall condition of the corridor had not improved despite the fifteen years that had passed since the agreement was signed.

The 2025 classification still shows no clear evidence of rehabilitation work following the 2024 renegotiation. The paved section (Class 1) remained stable at 5.47 km, with no significant growth of the paved surface. Class 3 (Poor) decreased marginally to 68.22 km, while Class 4 (Bad) further increased to 7.12 km, a 72% increase from 2013, indicating continued deterioration in the most critical sections. The whole picture shows marginal stability at the Mbuji-Mayi end of the corridor and continued degradation elsewhere, and this may reflect the initial post-renegotiation implementation phase since the works announced in April 2025 would not yet be visible in satellite imagery acquired in July 2025.

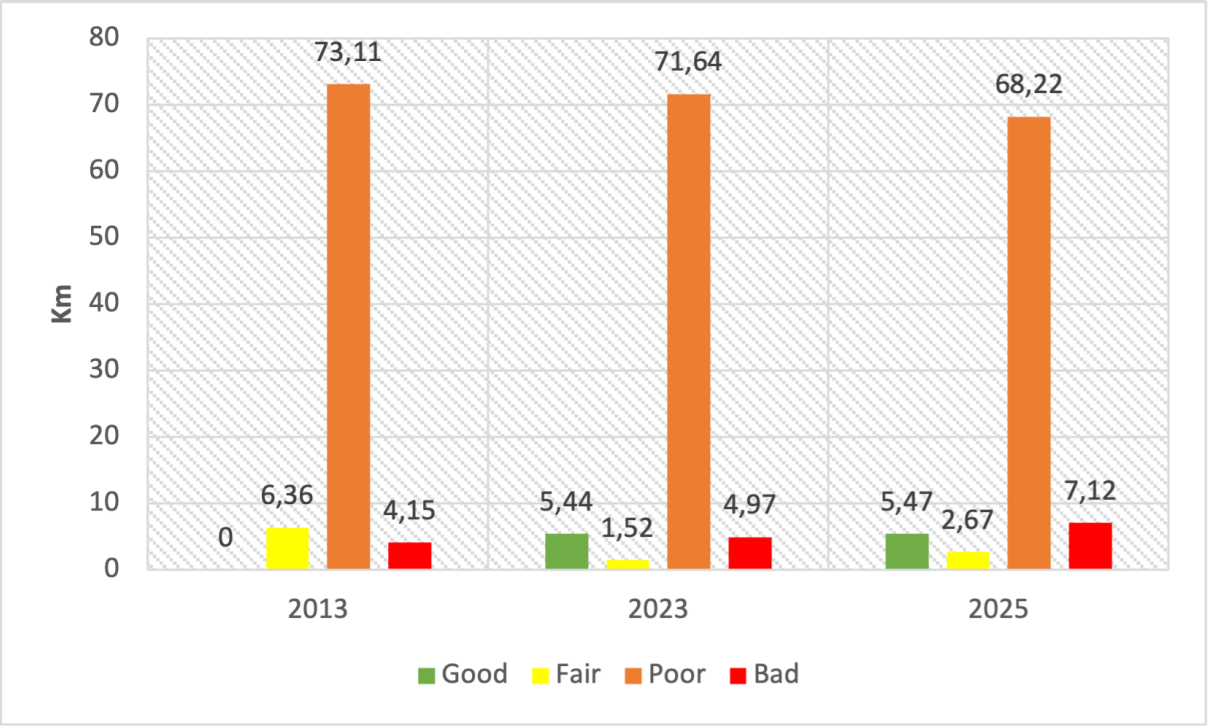


Figure 6: *Road condition classification along the Munkamba - Mbuji-Mayi corridor by year (km).*

5.2.1 The counterfactual: the road that should have been

To contextualize the observed road conditions compared to those anticipated in the contarct, a counterfactual scenario was modeled assuming the complete rehabilitation of the corridor to Class 2 (fair conditions). This is consistent with the commitment to rehabilitate unpaved roads specified in Annex C of the SICOMINES Collaboration Agreement (2008), which classified the Kananga - Mbuji-Mayi - Kasongo - Kindu corridor as an unpaved road requiring rehabilitation, not paving. The counterfactual scenario, therefore, does not assume an optimistic outcome of a completely paved road, but rather the minimum standard predicted by the agreement itself.

Scenario	2013	2023	2025
Observed	5,68 h	5,81 h	6,55 h
Counterfactual	3,56 h	3,56 h	3,56 h
Gap	2,12 h	2,25 h	2,99 h

Table 5: *Observed vs counterfactual travel times*

In this scenario, the entire 83 km corridor would be passable at the average speed associated with roads in fair condition in the DRC: 23.5 km/h (Ulimwengu et al., 2009). Travel time calculations for all three years yield a nearly identical result of approximately 3.56 hours, as the total corridor length remains constant across the three scenarios.

The gap between observed and counterfactual travel times has gradually expanded across the three periods: from 2.12 hours in 2013, to 2.25 hours in 2023, to 2.99 hours in 2025, equivalent to approximately 2 hours and 7 minutes, 2 hours and 15 minutes, and 2 hours and 59 minutes respectively. By 2025, a journey that would have taken approximately 3 hours and 34 minutes if the road had been rehabilitated as contractually agreed, instead takes approximately 6 hours and 33 minutes in dry season conditions and up to 8 hours and 38 minutes during the rainy season.

If the SICOMINES agreement had been implemented as it should have, the entire stretch of road would have been a passable dirt road, but the contrast with the conditions observed in all three scenarios is severe: in 2025, 90.2% of the corridor is still in poor or bad conditions, despite a contractual commitment that would have completely prevented this outcome.

It's important to note that the counterfactual scenario does not account for natural road degradation over time, because even a rehabilitated dirt road requires periodic maintenance to remain in reasonable conditions. The scenario therefore represents an optimal outcome with full and continuous implementation, rather than a precise prediction of what the conditions would have been.

5.3 Accessibility analysis: travel times across scenarios and population affected

This section translates the road condition data presented in the previous section into quantitative estimates of corridor accessibility, expressed in terms of travel times and population exposure. Travel time estimates were calculated for each scenario using the formula described in Section 4.3.2 ($t = d / v$) and Table 5 presents the results disaggregated by season and compared with the counterfactual benchmark.

Scenario	2013	2023	2025
Dry season	4.30 h	4.67 h	5.13 h
Annual average	5.68 h	5.81 h	6.55 h
Wet season	7.65 h	7.78 h	8.63 h
Counterfactual	3.56 h	3.56 h	3.56 h

Table 6: *Travel time estimates along the Munkamba - Mbuji-Mayi corridor by scenario and seasonal assumption.*

Considering all seasonal assumptions, travel time increased steadily between 2013 and 2025. Considering instead average annual speed, crossing the corridor took 5 hours and 41 minutes in 2013, rising to 5 hours and 49 minutes in 2023 and 6 hours and 33 minutes in 2025, a growth of approximately 52 minutes over twelve years.

Seasonal variability influences accessibility throughout the year, in fact during the dry season, travel time ranged from 4 hours and 18 minutes in 2013 to 5 hours and 8 minutes in 2025; during the rainy season, the same trajectory ranged from 7 hours and 39 minutes to 8 hours and 38 minutes. The gap between the estimates for the dry and rainy seasons, approximately 3.5 hours each year, confirms the corridor's vulnerability to weather conditions and the disproportionate burden on users during the rainy season, when erosion and flooding effectively render the most degraded sections impassable.

The counterfactual benchmark of 3 hours and 34 minutes, representing full restoration to acceptable conditions, as contractually stipulated in Annex C of the SICOMINES agreement, remained constant for all three years, as it models a uniform road surface rather than actual observed conditions. The gap between observed and counterfactual travel times progressively widened: from 2 hours and 7 minutes in 2013 to 2 hours and 15 minutes in 2023 and 2 hours and 59 minutes in 2025, based on annual average assumptions. By 2025, even under the most favorable dry season conditions, the observed travel time of 5 hours and 8 minutes exceeded the counterfactual one by nearly 1 hour and 35 minutes.

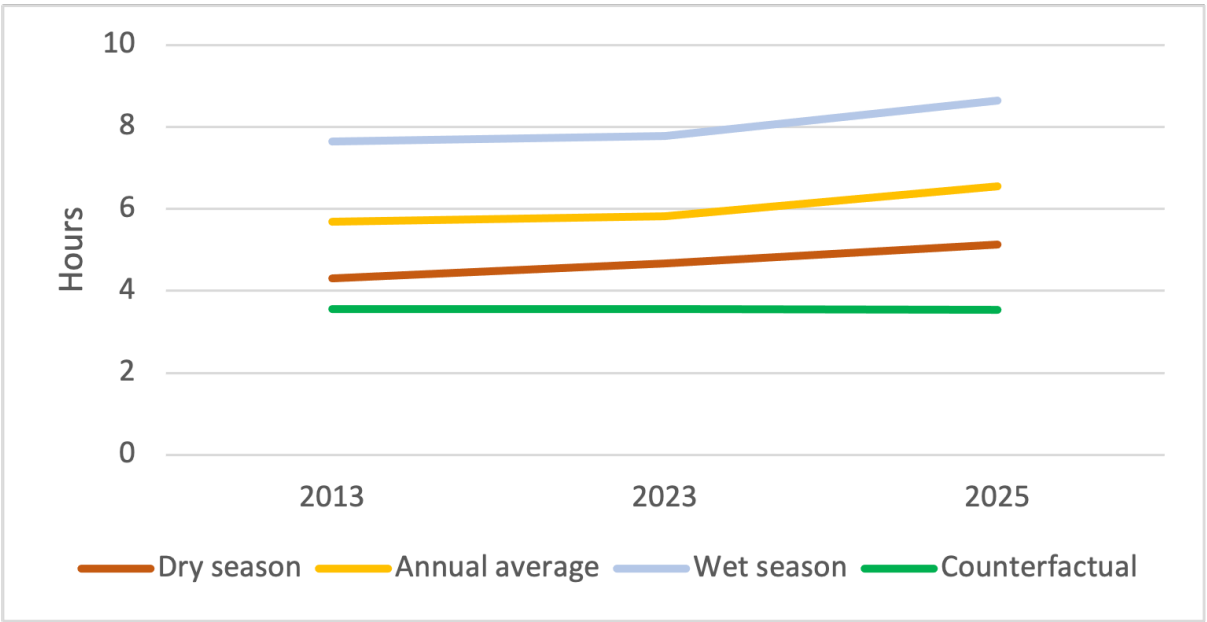


Figure 7: *Travel time estimates along the Munkamba - Mbuji-Mayi corridor by scenario and seasonal assumption, 2013-2025.*

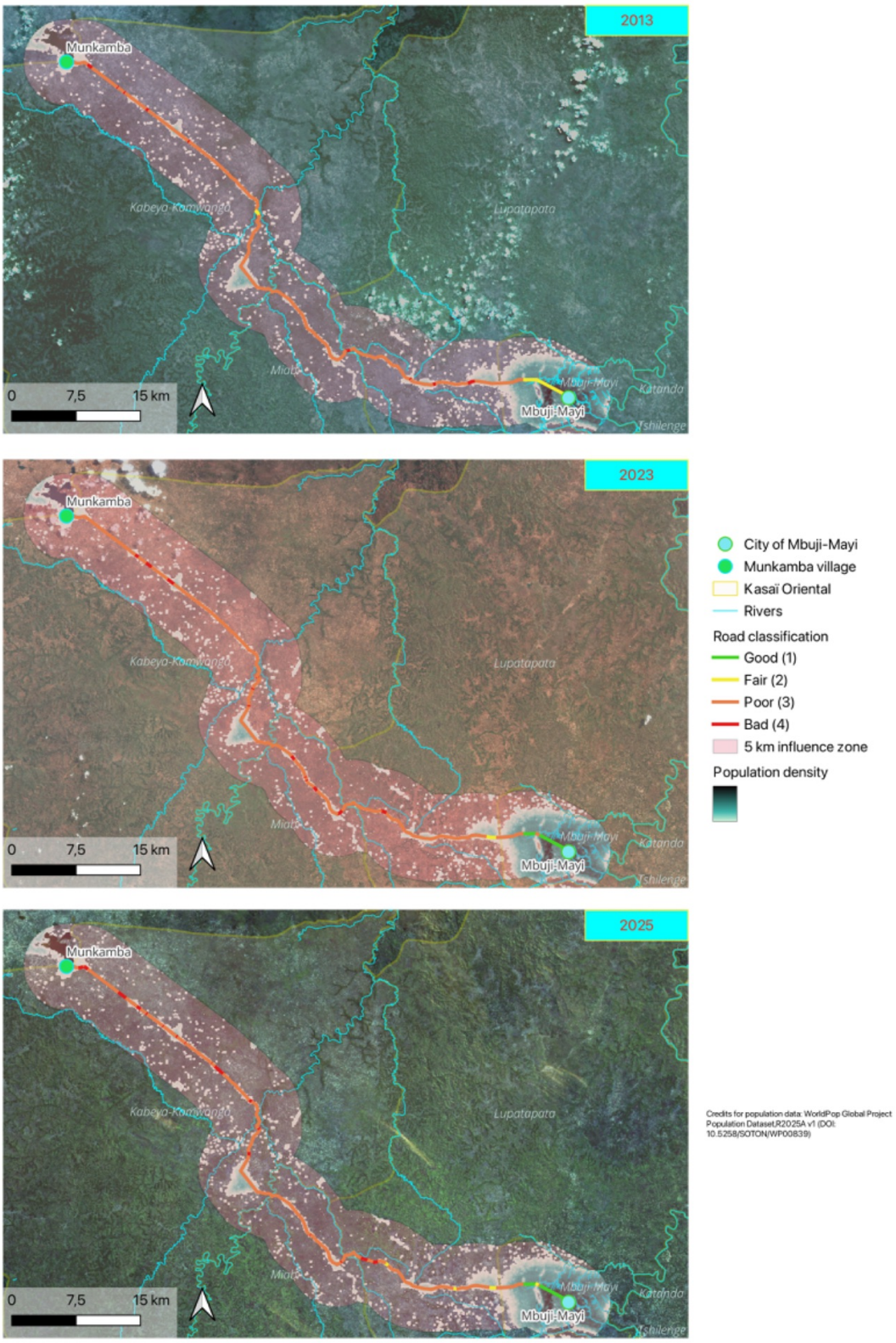


Figure 8: *Population distribution within the 5 km influence zone of the Munkamba - Mbuji-Mayi corridor, 2015 (proxy for 2013), 2023, and 2025. Population density is represented using WorldPop Global Project Population Dataset raster data, clipped to the corridor buffer. Road condition classification is shown for the corresponding year.*

The population living within a 5 km radius of the corridor increased significantly over the study period, from approximately 1.41 million in 2015 (the baseline for 2013, due to methodological incompatibility between the 2013-specific WorldPop dataset and the R2025A version used for 2023 and 2025) to around 1.84 million in 2023 to approximately 1.97 million in 2025, an increase of approximately 550,000 people (39%). This population growth exacerbates the previously documented accessibility deficit: a corridor that was already failing to meet contractual performance standards in 2013 has continued to deteriorate, while serving a significantly larger population by 2025.

Year	**Population within 5km buffer**
2015 (proxy 2013)	1,413,651
2023	1,841,233
2025	1,965,336

Table 7: *Estimated population residing within 5 km of the corridor, by year.*

CHAPTER 6: DISCUSSION OF THE RESULTS

6.1 The infrastructure gap in context

The results presented in Chapter 5 document a consistent and measurable infrastructure gap along the Munkamba-Mbuji-Mayi corridor over the study period. As shown in Tables 3, 4, and Figure 6, road conditions classified as Poor or Bad accounted for over 90% of the corridor's length at each observation point: 92.4% in 2013, 91.7% in 2023, and 90.2% in 2025. Within this overall picture of persistent deterioration, two internal trends are worth noting. First, the corridor's share of the worst-condition category, Class 4 (Bad), increased by over 70%, from 5.0% in 2013 to 8.5% in 2025 (Table 4). Second, Class 2 (Fair) has followed an irregular trajectory: its sharp decline between 2013 and 2023 is largely attributable to the reclassification of some Fair sections to Good following the paving work at the Mbuji-Mayi end of the road, as discussed in Section 5.2, rather than to actual deterioration; by 2025, its share had only partially recovered to 3.2%, still well below the 2013 level of 7.6% (Table 4). Compared to the counterfactual benchmark, developed based on Annex C of the SICOMINES agreement, which called for the rehabilitation of unpaved roads along this corridor, the road has not made progress towards the contractually promised standards. In contrast, the corridor's share of the worst category, Class 4 (Bad), has increased considerably over the twelve years.

Interpreting this finding requires placing it within the broader context of how these agreements operate. Dreher et al. (2017) document that Chinese development financing operates with limited public disclosure, without a comprehensive breakdown of financed projects available in an accessible form. Gelpern et al. (2021) extend this observation to the contractual level, demonstrating that confidentiality clauses in Chinese bilateral loan agreements typically limit the sharing of terms with third parties. The SICOMINES agreement reflects these features: its infrastructure commitments are specified in an annex that has not been officially published in full and Avenant No. 5 of the 2024 renegotiation does not include a detailed list of infrastructure obligations either. In this context, the gap documented in Chapter 5 cannot be interpreted as a simple case of non-delivery against known commitments, because it’s also the product of an institutional architecture in which verification through conventional means remains limited. No official monitoring reports document the conditions of the Munkamba-Mbuji-Mayi corridor during the study period, no public dataset records travel times or road surface quality for this section of RN1. The evidence presented in this work exists because satellite imagery and GIS-based analyses allow infrastructure to be observed independently of any party's willingness to disclose information, the function Muchapondwa et al. (2014) identified as necessary in opaque

contexts. There have been other independent reviews of SICOMINES's commitments, such as the 2021 ITIE RDC report that documented the implementation gap through a financial and contractual analysis, but the spatial dimension of it has not been addressed through this kind of analysis before.

6.2 What the gap meant for Kasaï Oriental

The road condition data presented in Chapter 5 describe both a physical and a human reality: surface condition classifications and travel time estimates document the state of the corridor and population accessibility analysis shows that approximately 1.97 million people lived within five kilometers of the road by 2025, directly exposed to these conditions. What GIS analysis cannot do, however, is capture what these conditions mean in practice for people living along the road. The impact of the infrastructure gap on daily life makes mobility possible or impossible: whether a sick person can reach a hospital in Mbuji-Mayi, whether a small trader can bring his produce to market before it spoils, whether a community remains connected or isolated from the province's economic and administrative center.

Route Nationale 1 is the only land connection between the Kasaï region and the rest of the country, and the territories crossed by the corridor, particularly Kabeya Kamwanga, already have below-average access to health and education services (Manyong et al., 2024). ACP (2021) reported that, even after maintenance work in 2020, the corridor had returned to a state of advanced deterioration, with mud patches, waterlogging, and erosion making heavy vehicle transit extremely difficult, conditions consistent with the "Poor" and "Bad" classifications that affect 90.2% of the corridor in 2025 (Table 4).

As argued in Section 3.5.1, drawing on Calderón and Servén (2010) and Limão and Venables (2001), inadequate infrastructure in sub-Saharan Africa not only slows economic growth but also compounds the disadvantages of already peripheral regions by increasing transportation costs, reducing access to markets, and decreasing agricultural yields. In Kasaï Oriental, a province with no rail links, no navigable waterway to the national network, and with the RN1 as the only land route to the rest of the country, these dynamics are very real, so the condition of this road directly determines whether goods reach markets, whether patients can reach hospitals, and whether the province remains economically integrated with the rest of the DRC or effectively isolated from it.

At the same time, GIS analysis has obvious limitations in capturing the human significance of this gap. Travel time is an indirect indicator of accessibility, and accessibility itself is an indirect

indicator of human capabilities. Geurs and van Wee (2004) define accessibility as the extent to which the transportation system allows individuals to reach the activities and destinations they need: a measure of potential, not of what people actually do or experience. In practice, this means that an estimate of travel time tells us how long a trip would take under given road conditions, but not whether people can afford it, have access to a vehicle, or what they give up when the trip becomes too expensive or too long. What satellite imagery and road classification cannot measure is the impact a deteriorating road has on daily life: the weight of vehicle damage on drivers and passengers, the seasonal periods when the road becomes impassable and communities are completely isolated, the physically exhausting and time-consuming journeys, or the decisions not made - postponed hospital visits, cancelled market trips - that never appear in any dataset. As discussed in Section 3.5.1, this is precisely the kind of gap Font-Casaseca and Rodó-Zárate (2024) identify between GIS's representation of space as coordinates and attributes and place as it is experienced. The analysis presented here documents the gap from above, the lived experience of this gap requires methods that this thesis does not employ.

This is not a reason to discredit the quantitative results, but rather a reason to interpret them correctly. The travel time values reported in Chapter 5 represent lower bounds, not upper bounds, on the true cost of the infrastructure gap. The actual burden on communities along the corridor is at least as great as the figures suggest, and likely even greater.

6.3 The cumulative cost of the infrastructure gap

Looking at travel times, it’s possible to understand the current state of the corridor and the practical cost of failing to meet the commitments made under the SICOMINES agreement. The counterfactual benchmark, a fully rehabilitated dirt road with a speed of 23.5 km/h, produces a travel time of 3.56 hours under average annual conditions, which were held constant throughout the study period as it represents a fixed rehabilitation standard (Table 5). The gap between actual and counterfactual travel times was 2.12 hours in 2013, 2.25 hours in 2023, and 2.99 hours in 2025 (Table 5), indicating not only that the corridor has not reached the promised standard, but also that the distance from it has increased over time.

This gap becomes even more significant when compared to the population. According to WorldPop data, in 2015 (a proxy for 2013), approximately 1.41 million people lived within 5 kilometers of the corridor, 1.84 million in 2023, and nearly 1.97 million in 2025, a 39% increase over the entire period studied (Table 7). Therefore, it’s not a fixed cost tied to a population that doesn't change, but rather a cost that has grown in absolute terms, as the number of people

affected by this gap is growing. Today, more people live in worse road conditions than at any other point in the study period, and the gap between actual and theoretical accessibility has persisted throughout the entire time period studied.

The conceptual framework of spatial inequality provides the interpretative tools to understand why this is structurally relevant. Dorosh et al. (2010), whose GIS-based analysis of travel times in 42 sub-Saharan African countries found that areas within four hours of a city of 100,000 people produce approximately 45% of their agricultural potential, while those more than eight hours away produce only 5%, offers a point of reference for contextualizing corridor values. The average annual travel times documented in Chapter 5, ranging from 5.68 hours in 2013 to 5.81 hours in 2023 and 6.55 hours in 2025 (Table 6), place communities along the Munkamba - Mbuji-Mayi corridor in a zone of critically limited market access, well above the four-hour threshold associated with significant agricultural participation and close to the eight-hour threshold associated with near-total market exclusion. In Kasaï Oriental, a predominantly agricultural province, this is not a marginal observation: market access determines whether production is economically viable at all. This is especially true given that these figures are annual averages and rainy season values are substantially higher (Table 6; Figure 7), further pushing communities toward this threshold for several months of the year.

As discussed in Section 3.5.2, Krugman's (1991) concept of self-reinforcing circularity is also evident here: he demonstrates that producers tend to locate where demand is higher, but demand is higher where producers locate and transportation costs are central to this dynamic, because poor connectivity reduces the attractiveness of peripheral locations as production sites, further marginalising places that are already disconnected. The fifteen-year absence of road rehabilitation projects along this corridor contributes to a self-perpetuating dynamic of spatial marginalization that the SICOMINES agreement, regardless of its original intentions, has done nothing to halt along this stretch. Even the modest improvement promised by Annex C, the rehabilitation of an unpaved dirt road, would have somewhat disrupted this circularity, reducing travel times from between 5.68 and 6.55 hours to 3.56 hours across the study period (Table 5), making markets and services more accessible for communities along the corridor.

Two caveats apply to the data presented above. First, the travel time data refers to a single trip between Munkamba and Mbuji-Mayi and it does not take into account the frequency with which people make this trip, their purpose, or the overall cost it entails for the entire population of the corridor. Second, WorldPop's population estimates also present uncertainties, especially in a province with limited census infrastructure, so the 39% population growth should be read as an

approximation rather than a precise count. Both elements point in the same direction: the time cost is likely underestimated because it doesn't take into account the frequency with which this journey is made, and the population figures may in turn underestimate the number of people affected. In both cases, the true impact on the communities crossed by the corridor far exceeds what these figures alone suggest.

6.4 The 2024 renegotiation

The signing of Avenant No. 5 of the SICOMINES agreement in 2024 represents the most significant formal revision of the agreement since its original signature in 2008. Its very existence is significant, since the renegotiation was preceded by an independent evaluation process coordinated through the Initiative for Transparency in Extractive Industries (ITIE RDC), which documented the gap between the agreement's original infrastructure commitments and their actual implementation (Rakotoseheno, 2024). The fact that an external accountability mechanism produced sufficient evidence to compel a formal renegotiation is precisely the dynamic that the transparency and accountability framework developed in 3.5.3 identifies as the function of independent verification in opaque financing contexts, namely, that independently verifiable evidence can have real consequences for the terms of RFI agreements even when contracting parties have strong incentives to avoid scrutiny. In this sense, the 2024 renegotiation is significant both politically and methodologically.

Article 1 of Avenant No. 5 establishes a total infrastructure investment of seven billion dollars, indexed to copper prices, to be allocated to national roads as defined by the Congolese side (Avenant No. 5, 2024). What it does not contain, however, is a description of which corridors will be rehabilitated, over what timeframe, or according to what standards, an absence that, as documented by Gelpern et al. (2021) and Dreher et al. (2017), is characteristic of Chinese bilateral loan agreements more broadly, where confidentiality clauses and lack of detailed public disclosure are recurring features rather than exceptions (Section 3.5.3). No delivery schedule and no independent monitoring mechanisms appear in the renegotiated terms. The causal link between the SICOMINES agreement and the roadworks launched in April 2025 on the Kananga - Mbuji-Mayi corridor cannot be established with certainty from publicly available sources. Although a South China Morning Post article (2024) documents SICOMINES funding for other segments of the N1, neither the official launch ceremony documented by Infos-Express (2026) nor the contract announcement reported by Actu30.cd (2025) explicitly reference SICOMINES as a financing mechanism.

This inability to link specific infrastructure projects to specific contractual obligations is not a gap in research, but rather an observation. The function of independent verification methods in opaque contexts is precisely to make visible what documentary sources conceal or omit. The GIS analysis presented in this thesis can document road conditions in the field, but it cannot replace the contractual transparency that would allow these field observations to be linked to specific commitments and specific actors. The persistence of opacity throughout the process, from the original 2008 agreement to the 2024 renegotiation, confirms that the structural transparency deficit identified in the literature is not a transitory characteristic of the early stages of Chinese development financing, but rather a permanent feature of the way these agreements are designed and maintained.

There is, however, a significant difference between the opacity of 2008 and that of 2024. Over the years of the agreement, Chinese development funding has come under increasing international scrutiny. Civil society organizations, investigative journalists, and researchers have systematically documented the gap between promises and delivery in RFI agreements across Africa (Muchapondwa et al., 2014; Dreher et al., 2017), while scholars have challenged the rhetoric of win-win cooperation that frames these agreements (Carrozza & Benabdallah, 2022). This pressure has led to some institutional adjustments, like the establishment of the CIDCA in 2018 was partly intended to address criticisms of transparency, but analysts remain skeptical of its actual impact, noting that project management remains largely unchanged and that opacity persists in practice (Rudyak, 2018; Yuan et al., 2022). The original SICOMINES agreement was negotiated without any systematic mechanism for external accountability. In contrast, the 2024 renegotiation took place in a context where the ITIE DRC evaluation had already produced independent evidence of the gap between promises made and results achieved, where civil society organizations had documented the discrepancy between promises and results, and where the DRC government was negotiating from a position informed by that evidence. The fact that the renegotiated agreement still lacks a detailed list of infrastructure commitments suggests that the opacity is not simply the product of an information asymmetry that better monitoring could resolve. Understanding why this situation persists and what would be needed to change it requires a political and institutional analysis that goes beyond what this study can provide.

6.5 Interpreting the results in relation to the research questions

The findings presented in the preceding sections make it possible to return to the three research questions that structured this thesis.

RQ1: What was promised under the 2008 SICOMINES agreement, and what does satellite evidence reveal about actual infrastructure delivery on the N1 Munkamba - Mbuji-Mayi corridor?

Annex C of the SICOMINES agreement specifies the rehabilitation of the Kananga - Mbuji-Mayi - Kasongo - Kindu road (887 km), which includes the Munkamba - Mbuji-Mayi section analyzed here, under the "dirt road rehabilitation" category, that is the restoration of an unpaved road to passable condition, defined in this thesis as a Fair (Class 2) standard. As shown in Section 6.1, this commitment has not been met: Poor or Bad conditions affected over 90% of the corridor throughout the study period (Table 4), the Class 4 (Bad) share increased by over 70% (Table 3; Table 4) and, despite some uneven movement in Class 2 (Fair), discussed in Sections 5.2 and 6.1, the corridor has not shown significant progress towards the Class 2 standard this study uses to identify what Annex C committed to deliver.

It's important to remember that the analytical reference point is 2013, not 2008, meaning that the gap documented here may predate the study period. The twelve years documented here therefore represent a conservative estimate of the overall duration of the failure to fulfill the commitments undertaken. Furthermore, the corridor-level findings cannot be generalized to the agreement as a whole: other segments of the N1 have received documented investments, and SICOMINES's infrastructure commitments extend beyond this corridor. Within these limits, satellite data show no evidence of the rehabilitation the agreement was intended to ensure and the gap between promise and implementation is measurable and persistent. This conclusion is possible only through the application of independent verification methods: there are no official monitoring reports documenting the conditions of this corridor during the study period, and the GIS-based analysis does not depend on the willingness of any of the parties involved to disclose information.

RQ2: How can GIS-based analysis measure and visualize infrastructure gaps in a data-scarce context and what are the methodological implications for Africa-China research?

By classifying road conditions across three distinct temporal levels using open-source satellite imagery (Figure 5), assigning literature-derived speed values to each condition class, and combining the results with open-access demographic data, the methodology translates visual observations into quantifiable and comparable indicators (condition classes, travel times, accessibility gaps) that can be monitored over time and measured against a contractual benchmark without relying on any official dataset. Building on the framework of

Muchapondwa et al. (2014) and Snyman and Coetzee (2024), this shows that independent geospatial verification can provide evidence of infrastructure delivery in contexts where RFI agreements typically produce no monitoring data of their own.

For Africa-China research, this implies that the approach is transferable: the same logic - diachronic analysis of satellite imagery, speed values derived from published literature, and freely available population data - could be applied to other SICOMINES commitments or comparable RFI agreements elsewhere in sub-Saharan Africa, with inputs adapted to local conditions. As discussed in Sections 4.5 and 6.6, the approach has concrete limitations, such as the interpretative subjectivity, the lack of field verification, and the reliance on a 2015 population dataset as a proxy for the 2013 baseline, which make it complementary, rather than a substitute, for field research. Within these limitations, it demonstrates that infrastructure implementation in opaque RFI agreements can be evaluated independently, transparently, and at low cost.

RQ3: What was the accessibility cost of the infrastructure gap for the population along the corridor, and what would delivery of the contractually specified standard have meant?

Geurs and van Wee's (2004) person-based accessibility framework provides the basis for answering this question quantitatively. As shown in Chapter 5 and discussed in Section 6.3, the average annual travel time from Munkamba to Mbuji-Mayi increased from 5.68 hours in 2013 to 6.55 hours in 2025, a deterioration of 0.87 hours, while the gap with the counterfactual benchmark widened from 2.12 to 2.99 hours over the same period (Table 5). Achieving the standard specified in Annex C would have meant a corridor that could be crossed in approximately 3.56 hours, regardless of the year (Table 5): communities would have faced a journey approximately two to three hours shorter than that actually experienced and, according to Dorosh et al. (2010), would have moved from an area of constrained market access to conditions associated with significant agricultural participation.

The demographic dimension, discussed in Section 6.3, further compounds this finding: the population exposed to accessibility issues grew by approximately 39% over the same period, from approximately 1.41 million to 1.97 million people (Table 7). The cost of accessibility is therefore cumulative rather than static, because over time more people have been affected. As noted in Section 6.3, both travel time and population data should be considered conservative: they measure a single representative trip and are subject to uncertainty, so the actual

accessibility burden for communities living along the corridor is likely greater than these figures alone suggest.

6.6 Contribution to knowledge

This thesis makes contributions on two levels: methodological and substantive. Although related but distinct, each deserves separate recognition.

6.6.1 Methodological contribution

This thesis makes a specific methodological contribution to Africa-China studies by demonstrating that diachronic GIS analysis can produce independently verifiable spatial evidence of infrastructure non-delivery in RFI agreements, evidence that complements what existing approaches can offer.

The ITIE RDC (2021) evaluation documented the implementation gap in the SICOMINES agreement through financial and contractual analysis, concluding that the DRC had received far less infrastructure than promised. This thesis supports that finding at the spatial level: the road condition classifications presented in Chapter 5 show that the Munkamba–Mbuji-Mayi corridor remained predominantly in Poor or Bad condition throughout the study period, with no evidence of the rehabilitation Annex C committed to deliver. The two forms of evidence, financial and spatial, are independent of each other and mutually reinforcing, which strengthens the overall accountability case.

Building on AidData's skytruthing approach, which demonstrated that satellite imagery could verify whether Chinese-funded projects existed on the ground (Muchapondwa et al., 2014), this thesis goes further by introducing a longitudinal framework (three temporal snapshots plus a counterfactual) that tracks not just presence or absence but the change over time and how far actual conditions fell short of what the agreement committed to deliver. It also translates road condition data into population-level accessibility estimates, connecting physical infrastructure conditions to people in a way that goes beyond what financial audits alone can provide.

The result is a replicable, low-cost framework applicable to other SICOMINES commitments or comparable RFI agreements in other parts of sub-Saharan Africa. It does not require field access, proprietary data, or cooperation from contracting parties, constraints that have historically limited research in this area.

This contribution must be understood within its proper context. The thesis does not propose GIS as a substitute for field research or qualitative methods: GIS cannot capture the lived experience of the communities they describe. The most productive application of this methodology in Africa-China studies would combine satellite-based classification with field surveys and interviews with corridor communities: an integration that resource and access limitations have prevented in this case, but which future research should pursue (Section 7.3). The contribution of this thesis is to demonstrate what is achievable with remote sensing alone, as a first step that can be replicated in a broader verification process.

6.6.2 Substantive contribution

At the substantive level, this thesis contributes primarily to the methodology of verifying RFI agreement delivery in Africa-China research, rather than to the broader political or diplomatic literature on Africa-China relations. The SICOMINES case has attracted considerable academic and journalistic attention, from the documentation of its original terms (Global Witness, 2011) to the analysis of its governance implications (Shirambere, 2020; Skaltsounis, 2025) and the financial assessment of its implementation status (ITIE RDC, 2021), but most existing analyses operate at the level of the agreement as a whole. This thesis operates at a different scale: a specific corridor, a specific commitment, a measurable gap. Aggregate assessments of RFI agreements, whether positive or negative, can mask significant variations in implementation across commitments, regions, and time periods. The finding that the Munkamba-Mbuji-Mayi corridor has not undergone significant rehabilitation interventions over the past twelve years does not characterize the SICOMINES agreement as a whole, but demonstrates that the infrastructure component of the agreement has not been implemented on this corridor and that this failure has had real and tangible consequences for the affected population.

The study also contributes to the debate on transparency and accountability in studies of Africa-China relations. The persistence of structural opacity during the 2024 renegotiation (Avenant No. 5 does not contain a detailed list of infrastructure commitments and the causal link between SICOMINES funding and roadworks begun in 2025 cannot be established from publicly available sources) confirms that opacity is not a transitory feature of early-stage Chinese development financing, but a lasting characteristic. At the same time, the fact that the ITIE RDC evaluation (2021) helped secure a renegotiation demonstrates that independent verification can have real consequences even within structurally opaque agreements. GIS-based analysis, such as the one presented here, extends the available tools for such verification to the spatial and infrastructural domain.

Finally, this thesis contributes to the literature on spatial inequality by demonstrating that the human cost of failing to deliver infrastructure is quantifiable even in data-scarce contexts. Building on the accessibility framework developed by Geurs and van Wee (2004) and the travel time thresholds proposed by Dorosh et al. (2010), the combination of travel time analysis and demographic data paints a picture of cumulative and growing accessibility deprivation: by 2025, approximately 1.97 million people experienced travel times that were nearly three hours longer than those considered by the agreement (Tables 5 and 6). Making this cost visible, and doing so with a methodology that is transparent about its assumptions and honest about its limitations, contributes to the broader effort to make infrastructure financing accountable to the populations it serves.

CHAPTER 7: CONCLUSION

7.1 Summary of findings

This thesis aimed to investigate whether the infrastructure commitments made under the 2008 SICOMINES agreement had actually been implemented on the Munkamba-Mbuji-Mayi section of National Route 1 and what the consequences were for the population of Kasaï Oriental, a province crossed by this corridor. Using a GIS-based diachronic analysis of satellite imagery spanning three time periods (2013, 2023, 2025), combined with travel time models and population accessibility estimates, this thesis finds that the rehabilitation works envisaged in Annex C were not implemented. Throughout the study period, "Poor" or "Bad" road conditions affected over 90% of the corridor, while the percentage in the worst category, Class 4 (Bad), increased by over 70%. Travel times have increased, the gap with contractually mandated standards has widened, and the population exposed to these conditions has grown by approximately 39%, reaching nearly 1.97 million people by 2025. Methodologically, this thesis demonstrates that diachronic, open-source GIS analysis can produce independently verifiable evidence of infrastructure delivery in a context of extreme data scarcity and structural contractual opacity, conditions common to many Chinese RFI agreements in sub-Saharan Africa. This approach does not address the opacity surrounding these agreements, nor does it replace the lived experience of affected communities; however, it makes visible, in a transparent and replicable way, a gap that would otherwise remain undocumented.

7.2 Recommendations

Given the limitations, discussed throughout this thesis, of what a corridor-level GIS analysis can determine regarding a complex agreement like SICOMINES, three points emerge from the findings.

First, this analysis suggests that GIS-based monitoring could usefully complement existing reporting mechanisms for RFI agreements, such as the ITIE RDC assessment process that preceded the 2024 renegotiation. Independent verification of infrastructure conditions using satellite imagery could provide periodic, low-cost evidence to support these processes, particularly where contractual commitments specify outcomes, such as road rehabilitation to a specified standard, that can be observed remotely.

Second, the absence of a delivery schedule in Annex C and a detailed list of infrastructure in Avenant No. 5 highlights a more general problem: infrastructure commitments specified

without timelines or detailed lists are by definition difficult to monitor, regardless of the methodology applied. To the extent that future agreements, in this or similar contexts, specify what must be completed, where, and by when, this would not only foster transparency but also make independent verification, such as the one attempted here, considerably easier.

Third, this thesis suggests that evaluations of infrastructure construction under RFI agreements would benefit from integrating accessibility and population-level indicators, in addition to the financial and outcome-based metrics that typically dominate such evaluations. A rehabilitated road has a different meaning depending on how many people depend on it and what alternatives are available to them, a dimension often absent from financial verifications, but one that the type of analysis presented here can help capture.

7.3 Limitations and future research

The limitations of the methodology adopted in this study have been discussed throughout: in the classification process itself, in the demographic data used as a proxy for the 2013 baseline, and in the broader trade-off between remote sensing and field methods. Taken together, these limitations do not undermine the main conclusion, but they mean it should be interpreted as independently verifiable evidence of a persistent gap and not as a comprehensive description of the corridor's conditions or of the agreement as a whole. This leads to four directions for future research.

The first concerns the classification itself. Distinguishing between "Fair" and "Poor" conditions required an element of interpretive judgment, particularly for the 2013 imagery. Field verification, comparing the satellite-based classification with field surveys, would make it possible to quantify the accuracy of this method, strengthening the validity of its use in similar contexts.

The second concerns what this analysis cannot capture: the lived experience of those who travel the corridor and the decisions they make in response to its conditions. Combining this type of diachronic GIS analysis with interviews or other qualitative methods would make it possible to directly address this issue and would also help verify, from the perspective of corridor users themselves, whether the classification of road conditions corresponds to their experience of the corridor over time.

The third point concerns the scope of the analysis. This thesis cannot establish whether the infrastructure gap documented here predates 2013, nor can its findings be generalized to the

SICOMINES agreement as a whole. Extending the analysis backward, where satellite coverage allows, would help determine how much of the gap predates the study period. Also, extending it to other corridors mentioned in Annex C would help establish whether the pattern found in the Munkamba - Mbuji-Mayi section is representative of the infrastructure component of the agreement more broadly, or specific to this corridor.

A fourth perspective concerns the physical geography of the corridor itself. As discussed in Section 2.3, the soils of the Kasaï Oriental, predominantly Ferralsol, Acrisol, and Arenosol, are particularly susceptible to compaction and erosion under seasonally saturated conditions, and the Kasaï sub-basin has been identified as having the highest specific rate of sediment export in the Congo River system. An overlay between the road condition classification presented in this study and the soil type data could help determine whether the deterioration documented here, and particularly the growth of Class 4 (Bad) segments, is more pronounced along stretches crossing soils more susceptible to erosion. Such an analysis would help distinguish the relative contribution of physical vulnerability and lack of maintenance to the corridor's deterioration, a distinction that this thesis, focused on verifying compliance with contractual commitments, has not explored in depth, but which would add an important dimension to understanding the reasons for this corridor's deterioration.

7.4 Concluding remarks

This thesis aimed to answer a specific question about a specific road section, using a methodology designed to work without the collaboration of the parties whose commitments were being discussed. The answer it reaches is precise but limited: on this corridor, during this period, the rehabilitation works promised in the agreement have not been achieved, and the population affected by this problem has grown considerably. What this thesis cannot answer, why this happened, what it means for the SICOMINES agreement as a whole, or what should be done about it, is beyond the capacity of corridor-level GIS analysis and has therefore been postponed to other studies or future work.

In contexts where formal monitoring is lacking and contractual terms remain undisclosed, infrastructure gaps of this type tend to remain invisible by default, not because they are not important, but because no method to constantly monitor them is applied. This study offers such a method, applied only once to a single corridor, documenting its assumptions and limitations along the way. The corridor will continue to be used by people whose daily lives are affected by its condition, whatever happens next with the agreement that was meant to improve it.

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