Republic of Ghana
Ministry of Roads and Highways
Department of Urban Roads

Data Collection Survey on Intersection Improvement in Kumasi City of the Republic of Ghana

Final Report

February 2024

Japan International Cooperation Agency (JICA)

CTI Engineering International Co., Ltd.
Eight-Japan Engineering Consultants Inc.
Oriental Consultants Global Co., Ltd.

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[The Appendix data is for internal disclosure only.]

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Abbreviations

Abbreviation	Detail
DUR	Department of Urban Roads
ECOWAS	Economic Community of West African States
EIA	Environmental Impact Assessment
EPC	Environmental Protection Council
F/S	Feasibility Study
GRDA	Ghana Railway Development Authority
ITS	Intelligent Transport Systems
JICA	Japan International Cooperation
KMA	Kumasi Metropolitan Assembly
KTC	Koforidua Training Center
M/P	Master Plan
MRH	Ministry of Roads and Highways
JCCA	Civil Engineering Consultants Association

CHAPTER 1 Executive Summary

1.1 Background of the Project

Intersections in Kumasi targeted in this survey are located on the West Africa Growth Ring Corridor and also located on a part of international arterial road of Tema-Ouagadougou corridor, which is one of the priority corridors of Economic Community of West African States (ECOWAS). Also, the target intersections are on the connection points of the Inner Ring Road of Kumasi and the major arterial roads that lead to Accra. Therefore, traffic flows from major arterial roads into Kumasi cause chronic traffic congestion at the target intersections, and the intersections are known as traffic bottleneck. As shown in Figure 1-1 (left figure), intersection improvement in Kumasi is expected to contribute to not only mitigation of traffic congestion in urban area, but also improvement of logistics in wider range of West Africa Growth Ring Corridors. Moreover, population growth along with increase of traffic volume in Kumasi has been worsening the bottleneck situation. With a background like that, Ghana government has been exploring possibilities of improvement of the intersections for mitigation of traffic congestion.

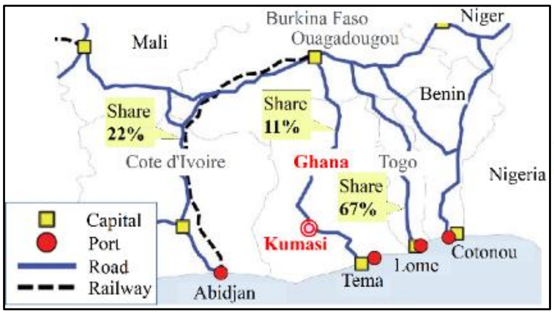
1.2 Outline, Objective, and Scope of the JICA Data Collection Survey

Outline, objective, and scope of the JICA data collection survey are shown below.

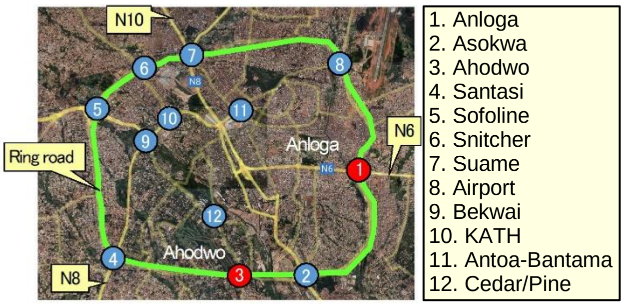
Table 1-1 Outline, Objective, and Scope of the JICA Data Collection Survey

Survey target	Major intersections in Kumasi city
Implementation agency	Department of Urban Roads (DUR)
Objective of the Survey	This survey aims to find out traffic situation and major issues of major road network in Kumasi city and select two (2) priority intersections for improvement that could be candidates for the Japan's grant aid project, targeting 12 intersections, which were studied in "The Study on the Comprehensive Urban Development Plan for Greater Kumasi, JICA 2013 (hereafter called, JICA Kumasi M/P 2013)", including "Anloga intersection" and "Ahodwo intersection" that Ghana government submitted the request form for. Also, the JICA survey aims to collect and analyze data necessary for estimation of approximate project cost & evaluation of project effect, targeting 2 priority intersections to be selected. Moreover, the JICA survey aims to study on applicability of "Japanese technologies" and "rapid construction schemes" that may be beneficial for improvement of major intersections on the West Africa Growth Ring corridors, which are located in urban areas like Kumasi.
Scope of the Survey	The survey aims to review the JICA Kumasi M/P 2013 and collect Kumasi-related data, such as change of traffic situation due to population growth, which is necessary for exploring possibility of the new projects.

Source：JICA survey team



Share of logistics among 3 neighboring corridors
Source: Prepared by JICA survey team, based on transit cargo information shown in "The Data Collection Survey for Development of African Corridors"



12 target intersections
Source: JICA survey team

Figure 1-1 Share of Logistics among 3 Neighboring Corridors and 12 Target Intersections

1.3 Outline of the Survey Result

1.3.1. Survey Schedule and Meetings with Ghana Government

Carrying out the 1st field survey on 10th July thorough 18th August and the 2nd field survey on 17th October though 1st November, JICA survey team had meetings with Ministry of Roads and Highway (MRH) and Department of Urban Roads (DUR) on selection of priority intersections and policy of intersection improvement planning. As a result, MRH and DUR agreed to the priority road/intersection improvement project (Combination Scheme-1; to be explained in "report section 1.3.2") that JICA survey team proposed. The meeting schedules are as follows.

- 12th July 2023: Explanation, to MRH and DUR, on Inception Report
- 26th July 2023: Explanation, to MRH and DUR, on basic approach to selection of priority intersections and study on intersection improvement scales/schemes
- 10th August 2023: Explanation, to MRH and DUR, on outlook for selection of priority intersections and study on intersection improvement scales/schemes
- 14th August 2023: Discussion with MRH Chief Director on selection of priority intersections and study on intersection improvement scales/schemes
- 19th October 2023: Discussion with MRH and DUR on selection of the priority project and determination of the road/intersection improvement scheme
- 11th November 2023: Discussion with MRH, DUR, and Ghana Railway Development Authority (GRDA) on rising profile of Inner Ring Road section around the Subi River that is necessary for the GRDA railway development project

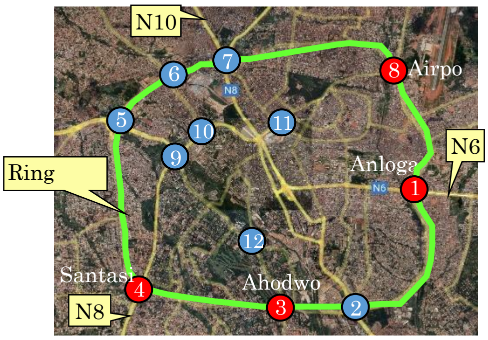
1.3.2. Outline of Study on the Priority Road/Intersection Improvement Projects

The plan for priority road/intersection improvement projects was conceived, conduction study on selection of priority intersections and planning of improvement schemes in the following steps.

- The 1st screening:
  Selection of four (4) intersections (Anloga, Santasi, Ahodwo, Airport) as candidates for the

priority intersections, excluding the following eight intersections.

1) Two (2) intersections already improved by other funds (Asokwa、Sofoline)
2) Five (5) intersections to be improved by Ghana government or other donors (Bekwai、KATH、Suame、Antoa-Bantama、Snitcher)
3) An intersection that is not the bottleneck of the road network (Cedar/Pine)



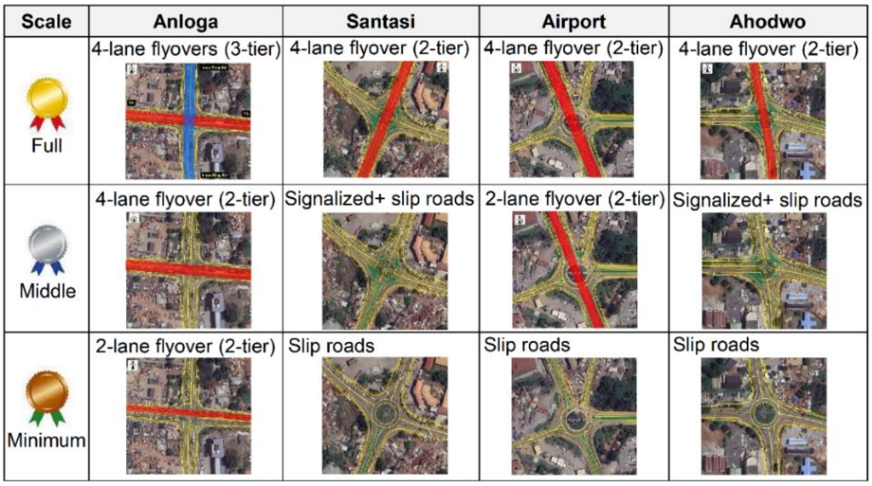
1. Anloga
2. Asokwa (Timber Gardens)
3. Ahodwo
4. Santasi
5. Sofoline
6. Snitcher
7. Suame
8. Airport
9. Bekwai
10. KATH
11. Antoa-Bantama
12. Cedar/Pine

Source：JICA survey team

Figure 1-2 4 Target Intersections Selected in the 1st Screening

- Study on project scales and intersection improvement schemes:
  In order to select optimal scale and scheme of intersection improvement under certain budget constraints, scale and scheme of intersection improvement (Ex. provision of slip roads, conversion of roundabout into signalized intersection, construction of flyovers) were studied targeting four (4) intersections selected in the 1st screening. The study was conducted under the prerequisite that Level of Service[1] D (LOS D) continues for the certain period of time. Three (3) types of schemes were studied for each intersection, namely 1) minimum-scale (continuation of LOS D for 3-5 years), 2) middle-scale (continuation of LOS D for approximately 10 years), 3) full-scale (continuation of LOS D for approximately 20 years)

[1] Level of Service (LOS) is defined as ranks of A to D, using the parameters of 1) ratio of traffic volume getting into intersection (V) to intersection capacity (C) (V/C; 1.0 or less) and 2) control time (vehicle delay time). In case that V/C is larger than 1.0, LOS is evaluated as E or F. Adoption of LOS D means intersection capacity is fully utilized.



Source：JICA survey team

Figure 1-3　Intersection Improvement Schemes Studied for Four (4) Intersections

- Estimation of service limit years (duration of Level of Service D, LOS D) of each intersection improvement scheme:

  Service limit years of each intersection improvement scheme was estimated by intersection congestion analysis, using "continuation of LOS D" as an indicator.

Table 1-2　Service Limit Years of Each Intersection Improvement Scheme

Intersection	Project scale	Minimum scale	Middle scale	Full scale
Anloga	Service limit year	2030	2038	2045
	Level of Service	D	D	B
	Control Delay	54.4	51.1	13.7
Santasi	Service limit year	2031	2036	2045
	Level of Service	D	D	D
	Control Delay	33.9	54.9	50.7
Airport	Service limit year	2031	2035	2045
	Level of Service	D	D	C
	Control Delay	34.8	32.4	17.8
Ahodwo	Service limit year	2032	2039	2045
	Level of Service	D	D	C
	Control Delay	33	54.1	22.1

LOS: Level of Service
Control Delay: Delay time of vehicles at intersections (sec./vehicle)

Source：JICA survey team

- The 2nd screening:

  Two (2) priority intersections were selected, evaluating the four (4) intersections selected in the 1st screening, using six (6) evaluation indicators. The indicators are 1) Road function (road class, logistics corridors), 2) traffic congestion (traffic volume, travel speed), 3) road safety and accessibility (the number of accidents, urban development & urban facilities), 4) road reliability (impassable frequency due to heavy rainfall, degree of road damage), 5) government priority. The study result was 1st-ranked: Anloga, 2nd-ranked: Santasi, 3rd-ranked: Ahodwo, and 4thranked: Airport. However, two (2) priority intersections (1st-ranked Santasi, 2nd-ranked Ahodwo) were selected in consideration of "continuation of project effect for the certain period of time" and "budget constraints" of the Japan's grant aid project scheme, judging that improvement of Anloga intersection is not possible under the project implementation scheme.

Table 1-3 Result of Evaluation of Improvement Priority of Selected Four (4) Intersections

Intersection Name / Criteria	Anloga Intersection		Santasi Roundabout		Airport Roundabout		Ahodwo Roundabout	
1-1 Road Function (Road Class)	National+National+IRR	10	National+National+IRR	10	Inter-regional+Others +IRR	2	Regional+Others+IRR	2
1-2 Logistic Corridors (Traffic volume of truck and trailer)	High (332 vehicles/hour)	10	Middle (158 vehicles/hour)	5	High (305 vehicles/hour)	10	Middle (133 vehicles/hour)	5
2-1 Traffic Congestion (Traffic Volume)	High 6,701 PCU/hours	10	Middle 4,399 PCU/hour	5	High 6,212 PCU/hour	10	Middle 3,810 PCU/hour	5
2-2 Traffic Congestion (Travel speed)	Middle	5	Low	10	Middle	5	Low	10
3-1 Road Safety and Accessibility (Number of accident)	High Risk (27 crashes in 2022-2021)	10	Middle Risk (17 crashes in 2022-2021)	5	Low Risk (Lower Top10)	0	Low Risk (Lower Top10)	0
3-2 Road Safety and Accessibility (Urban development/ urban facilities)	High Urbanized	10	Middle Urbanized	5	Middle Urbanized	5	Middle Urbanized	5
4-1 Road reliability (Impassable frequency)	High	10	Low	0	Low	0	Low	0
4-2 Road reliability (degree of road damage)	Middle	5	Middle	5	Middle	5	Middle	5
5 Government Priority	High (No.1)	20	Middle-high (No.2)	15	Middle-low (No.3)	10	Low (No. 4)	5
Project Importance (Sub-Total Score)	**No.1**	**90**	**No2**	**60**	**No.3**	**47**	**No.4**	**37**
6 Budget constraints & project effectiveness	**Over the budget or short-tem effect**	0	Under the budget and sufficient project effect	20	**Over the budget or short-tem effect**	5	Under the budget and sufficient project effect	20
Project Priority (Total Score)	**No.1**	**90**	**No.2**	**80**	**No.4**	**52**	**No.3**	**57**
Evaluation	**Excluded (not feasible)**		**Selected (No.1)**		**Excluded**		**Selected (No.2)**	

Source：JICA survey team

- Study on two (2) combination schemes for optimization of the project scope:

  With regard to Santasi intersection and Ahodwo intersection, which were selected as priority intersections, the following two (2) combination schemes were studied for optimization of the project scope in consideration of "continuation of project effect (LOS D for 10 years)" and "budget constraints" of the Japan's grant aid project scheme.

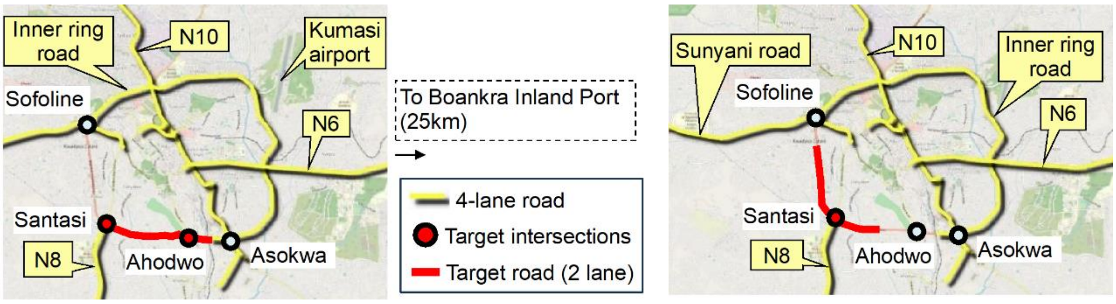
  1) Combination Scheme-1:

     Improvement of Santasi intersection (signalization + addtion of slip roads)
     + Improvement of Ahodwo intersection (signalization + addtion of slip roads)
     + Dualization of Santasi-Asokwa section (3.4km)

  2) Combination Scheme-2:

     Improvement of Santasi intersection (signalization + addtion of slip roads)
     + Dualization of Sofoline-Santasi section (2.5km)
     + Dualization of Santasi-Ahodwo section (1.2km): deteriorated section only

Combination Scheme-1 Combination Scheme-2



Source：JICA survey team

Figure 1-4 Combination Scheme-1 and Combination Scheme-2

- Pre-feasibility study of Combination Scheme-1 and Combination Scheme-2:
  For Combination Scheme-1 and Combination Scheme-2, design at pre-feasibility study level, estimation of approximate project cost, and evaluation of impact of the project on the surrounding social environment were carried out.
- Comparative study on selection of the priority project targeting two (2) combination schemes based on evaluation of project effect:
  A comparative study was conducted evaluating the following five (5) indicators of Combination Scheme-1 and Combination Scheme-2. The evaluation indicators were 1) project cost, 2) necessity of land acquisition, 3) the number of buildings for resettlement (approximate environmental category), 4) applicability of Japanese technology, and 5) project effect. As a result, Combination Scheme-1 was evaluated to be more superior to Combination Scheme-2 as priority project, from the view of "improvement of urban traffic", "Contribution to development of West Africa Growth Ring Corridor (strengthening of connection between N8 and N6)", and "improvement of traffic accessibility and logistics".

1.3.3. Overview of the Selected Priority Project

With regard to improvement of Santasi intersection and Ahodwo intersection that were selected as the priority intersections in the 2nd screening, the project scope was determined as follows in consideration of "budget constraints of Japan's grant aid project" and "duration of project effect (LOS D) for 10 years".

- Santasi intersection: Signalization + addition of slip roads
- Ahodwo intersection: Signalization + addition of slip roads
- Dualization of Santasi-Asokwa section (3.4km)

Combination Scheme-1

Source：JICA survey team

Santasi intersection:
- Signalization
- Addition of slip roads

Ahodwo intersection:
- Signalization
- Addition of slip roads

Figure 1-5 Overview of the Selected Priority Project

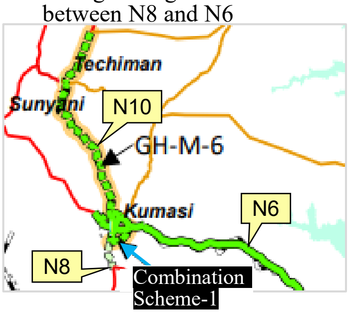
1.4 Project Effect of the Selected Priority Project

1.4.1. Outline of the Project Effect

Implementation of Combination Scheme-1 matches "middle-term policy" of the West Africa Growth Ring Corridor Master Plan developed in 2018 (strengthening of connection between N8 and N6), and large project effects can be expected in terms of the following points.

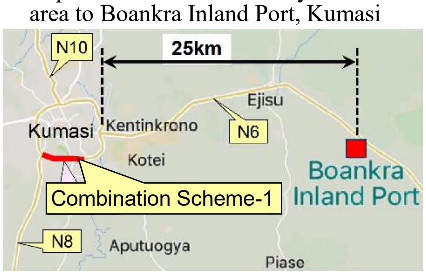
- Mitigation of traffic congestion at Santasi & Ahodwo intersections and Santasi~Asokuwa road sections (3.4km), reduction of traffic accident at Santasi & Ahodwo intersections
- High development potential of surrounding area of N6 (economic corridor) on the east side of Kmasi city (Ex. Existence of Kwame Nkrumah University of Science and Technology (KNUST), ongoing Boankra Inland Port project)
- Contribution to development of surrounding area along N6 (economic corridor) and N8 (transportation corridor) together
- Improvement of accessibility from N8 area to Boankra Inland Port, Kumasi airport, and Accra
- Contribution to improvement of surrounding road network linked to Boankra Inland Port (distribution base), which is indispensable and urgent (a part of middle-term policy of West Africa Growth Ring Corridor Master Plan)

Strengthening of connection between N8 and N6



Source: Prepared by JICA survey team using a figure from JICA Report for the Project on the Corridor Development for West Africa Growth Ring Master Plan

Improvement of accessibility from N8 area to Boankra Inland Port, Kumasi



Source: JICA survey team

Logistics routes based from Boankra Inland Port

Source: One World-Nations Online

Figure 1-6 Overview of the Selected Priority Project

1.4.2. Quantitative and Qualitative Indicators for Evaluation of the Project Effect

Qualitative and quantitative indicators for evaluation of the selected priority project are as follows.

- Improvement of connectivity to the Western Africa Growth Ring Corridors that are used as economic corridor (strengthening of connection between N8 and N6)
- Improvement of accessibility from N8 area to Boankra Inland Port, Kumasi airport, and Accra
- Mitigation of traffic congestion at Santasi & Ahodwo intersections and Santasi~Asokuwa road sections (3.4km), and improvement of vehicular travel time in the road sections from 18.0～30.9km/h to 50.0km/h. Judging the travel time by Level of Service, it is equivalent to LOS A or LOS B.

Value of total travel time savings (Sofoline ~ Santasi): 6,673,692USD USD/year

- Value of total travel cost savings (Sofoline ~ Santasi): 4,067,479USD USD/year
- Reduction of traffic accident at Santasi & Ahodwo intersections
- Improvement of road drainage system and road reliability, and improvement of accessibility to public facilities (schools, hospitals etc.)

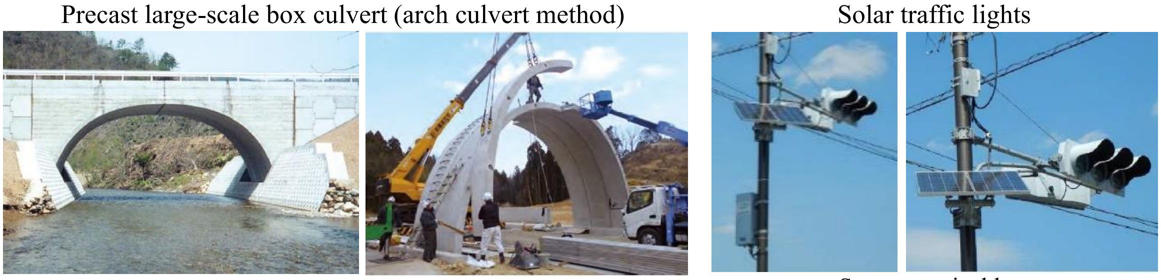
1.5 Study on Applicable Japanese Technologies & Rapid Construction Schemes

1.5.1. Applicable Japanese Technologies & Rapid Construction Schemes

As a result of study on Japanese technologies and construction schemes that are applicable in implementation of the selected priority project, the following two (2) technologies/schemes were recommended.

- Precast large-scale box culvert (rapid construction using precast concrete segments)
- Solar traffic lights (realization of sustainable traffic light function during power outage)

Precast large-scale box culvert (arch culvert method) Solar traffic lights



Source: Hirose co. ltd. Source: excite blog

Figure 1-7 Applicable Japanese Technologies & Rapid Construction Schemes

1.5.2. Recommendation for Similar Intersection Improvement Projects to be Implemented

For similar intersection improvement projects to be implemented in other countries, the following three (3) items were recommended.

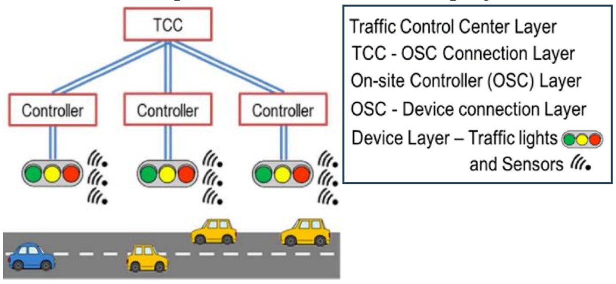
- Rapid construction scheme (from the view of construction methods): under strict project budget constraints, minimization of project scale within allowable range of project effect, and application of precast concrete structures (Ex. application of precast large-scale box culvert together with dualization of existing 2-lane roads

- Rapid construction scheme (from the view of construction planning): Study on construction planning using BIM (Building Information Modeling, Management) in design stage so that the 3D models created in the design stage in the subsequent construction stage for the purpose of construction productivity improvement
- Cooperative implementation of at-grade intersection improvement projects with ITS (Intelligent Transport Systems)-related projects (Ex. installation of ITS-related traffic lights and establishment of traffic control centers)

Construction planning using BIM

Source: BIM/CIM case studies (MLIT)

Cooperation with ITS-related project



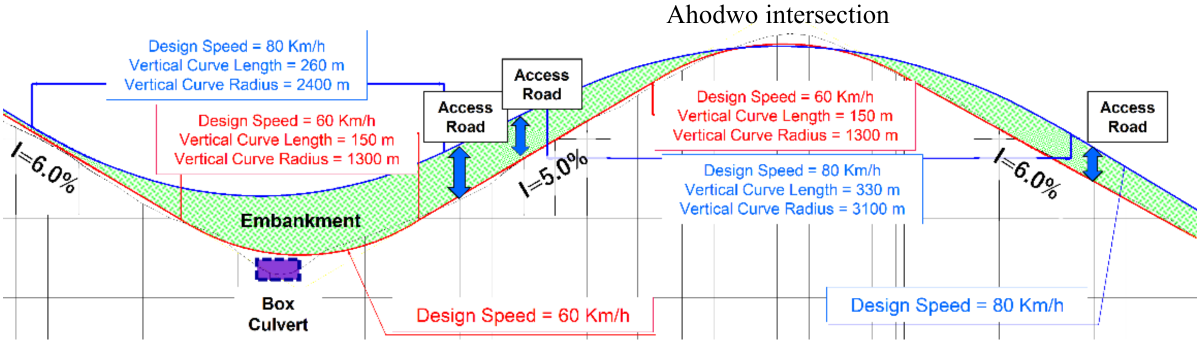
Source: Report of "Data collection survey for ITS in African region" (JICA, 2021)

Figure 1-8 Overview of the Selected Priority Project

1.6 Major Issues to be Considered in the Subsequent JICA Preparatory Survey

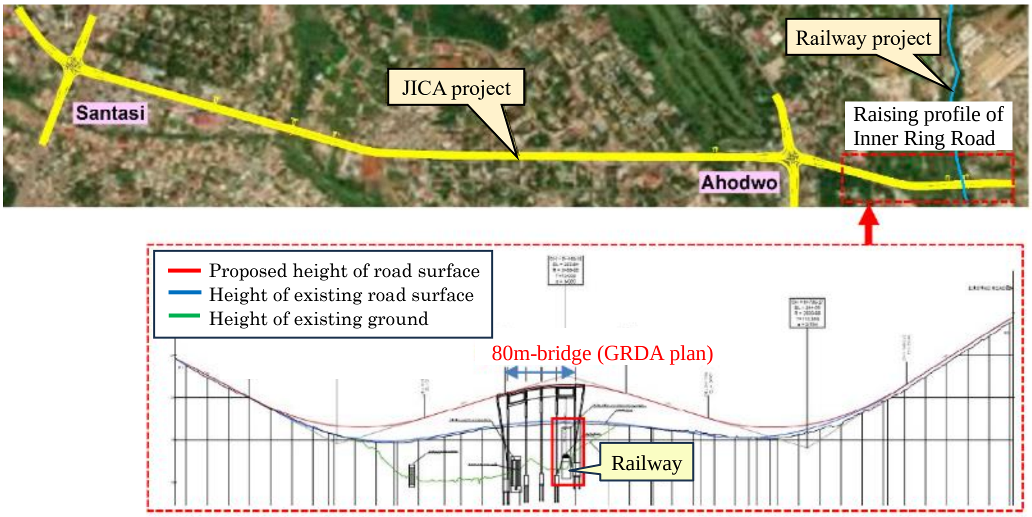
As the major issues to be considered in the subsequent outline design stage (JICA preparatory survey), the following six (6) issues were indicated.

- Determination of traffic growth rate based on result of OD (Origin-Destination) survey for future traffic volume forecast
- Securing of 8m-width for median in consideration of future expansion of carriageway lanes
- Study on milder-slope road profile at the road section around Ahodwo intersection
- Coordination with the GRDA railway development project for raising profile of Inner Ring Road section between Ahodwo intersection and Asokwa intersection
- Appropriate relocation of monuments installed at Santasi intersection & Ahodwo intersection
- Investigation of logistics situation from Takoradi to Sahel region via N8 & N10 for justification of the project effect (conduct of OD survey, analysis on logistics data at the Takoradi port)



Source：JICA survey team

Figure 1-9 Study on Milder-slope Road Profile at the Road Section around Ahodwo Intersection



Source：JICA survey team (The profile was prepared using a drawing provided by GRDA.)

Figure 1-10 Coordination with the GRDA Railway Development Project for Raising Profile of Inner Ring Road Section between Ahodwo Intersection and Asokwa Intersection

CHAPTER 2 Pre-Feasibility Study on Priority Road/Intersection Improvement Project

2.1 Design of Intersection Improvement, Road Dualization, and Road Structures

2.1.1. Outline of the Design

Pre-Feasibility Study (Fre-F/S) was carried out for the following two (2) combination schemes.

1) Combination Scheme-1:

Improvement of Santasi intersection (signalization + addtion of slip roads)
+ Improvement of Ahodwo intersection (signalization + addtion of slip roads)
+ Dualization of Santasi-Asokwa section (3.4km)

2) Combination Scheme-2:

Improvement of Santasi intersection (signalization + addtion of slip roads)
+ Dualization of Sofoline-Santasi section (2.5km)
+ Dualization of Santasi-Ahodwo section (1.2km): deteriorated section only

2.1.2. Road Design

2.1.2.1. Design Policy

The design policy is established with the aim of ensuring smooth and safe traffic flow in the target section. Based on the request from the Ghanaian government, the results of field surveys and discussions, the following basic design policy was established:

1) The road shall meet a trunk road equivalent as per the Ghanaian design standards.
2) The design shall maintain consistency with the Kumasi metropolitan area, including other sections.
3) The design shall fit with in the road right-of-way utilizing the existing roads and structures as much as possible.
4) The environmental and social impact shall be given due consideration.
5) The volume and characteristics of traffic, especially large vehicles like semi-trailers, shall be considered in the design.

2.1.2.2. Road Design Condition

Road design condition set in the pre-feasibility study is shown below. It should be noted that the road design condition is still tentative at the stage of the pre-feasibility study, and it could be changed in the later stage of the project.

(1) Design Standards

The Ghana Road Design Guide (RDG) is used as a standard in the designing of the road. The RDG is created by the JICA technical cooperation under "THE PROJECT ON CAPACITY BUILDING FOR ROAD AND BRIDGE MANAGEMENT (CBRB)". The design standard is scheduled to be officially approved by Ministry of Roads and Highways (MRH) within 2023 Fiscal Year.

(2) Road Standards

As per the Road Standards classification, this project road falls within the Design Class B. Considering the project is in Kumasi City (urban area), the specific Design Class will be B2 (Urban Major Arterial). In accordance with the road standard shown in Table 2-1, partial access control will be implemented considering the design class.

Table 2-1 Road Standards

<table>
<tr><th colspan="2">Design Class</th><th>Right of Way (ROW) (m)</th><th>Functional Class</th><th>Administrative Class</th><th>Access Control</th><th>Design traffic volume (AADT)</th></tr>
<tr><td rowspan="2">A</td><td>A1 - Rural Expressway/Motorway</td><td rowspan="4">90</td><td rowspan="4">National</td><td rowspan="2">GHA</td><td rowspan="2">Full</td><td rowspan="2">>10,000</td></tr>
<tr><td>A2 - Urban Expressway/Motorway</td></tr>
<tr><td rowspan="3">B</td><td>B1 – Rural Major Arterial</td><td rowspan="2">GHA</td><td rowspan="3">Partial</td><td rowspan="3">>3,000</td></tr>
<tr><td rowspan="2">B2 – Urban Major Arterial</td></tr>
<tr><td rowspan="3">60</td><td>Urban Road</td><td>DUR</td></tr>
<tr><td rowspan="2">C</td><td>C1 – Rural Minor Arterial</td><td>Inter-Regional & Regional</td><td>GHA</td><td rowspan="2">Partial/No</td><td rowspan="2">>1,000</td></tr>
<tr><td>C2 – Urban Minor Arterial</td><td>Urban Road</td><td>DUR</td></tr>
<tr><td rowspan="2">D</td><td>D1 – Rural Collector</td><td>45</td><td>Inter-District Connector</td><td>DFR</td><td rowspan="2">No</td><td rowspan="2">300-1000</td></tr>
<tr><td>D2 – Urban Collector</td><td></td><td>Urban Road</td><td>DUR</td></tr>
<tr><td>E</td><td>E - Local/Access</td><td>30</td><td>Local/Access</td><td>DUR/DFR</td><td>No</td><td><300</td></tr>
</table>

Source: Ghana Road Design Guide

(3) Design Speed

The design speed of the project road is set based on the design class and topography of the area. The project topography is dominated by Hilly terrain. Therefore, the design speed compatible for design class (B2) and hilly terrain is adopted. As illustrated in Table 2-2, the design speed is recommended within the range of 60 ~ 80 km/h, where the former is the absolute minimum speed, and the latter is the desirable speed for this class. Hence, a design speed of 80 Km/h will be used for the design.

Table 2-2 Design Speed

Design Class	Terrain	Design Speed (km/h) (Desirable)	Design Speed (km/h) (Absolute)
A1/A2	Flat	120	100
	Hilly	100	80
	Mountainous	80	60
B1/B2	Flat	100	80
	Hilly	80	60
	Mountainous	60	50
C1/C2	Flat	80	60
	Hilly	60	40
	Mountainous	50	30
D1/D2	Flat	60	40
	Hilly	50	30
	Mountainous	40	20
E	-	40	20

Source: Ghana Road Design Guide

(4) Standards of Geometric Design

The geometric design standards corresponding to the speed of V=80km/h are applied in the design as in the following Table 2-3 through Table 2-16. Each design parameters will be discussed in detail. The desirable and absolute minimum curve radius for the corresponding design speed is shown in Table 2-3. In this project, the minimum used horizontal curve radius is 420m which is desirable for the class.

Table 2-3 Minimum Curve Radius

Design speed (km/h)	Absolute			Desirable		
	e (%)	f	Radius (m)	e (%)	f	Radius (m)
20	9	0.15	15	5	0.09	25
30	9	0.15	30	5	0.09	50
40	9	0.15	50	5	0.08	100
50	9	0.14	85	5	0.08	150
60	9	0.13	130	5	0.08	220
80	9	0.13	230	5	0.07	420
100	9	0.12	370	5	0.06	700
120	9	0.12	540	5	0.06	1,030

Source: Ghana Road Design Guide

To attain safe driving experience and avoid abrupt steering, the minimum curve length is set in accordance with the design speed, refer to Table 2-4. Hence, the minimum curve length is kept above 140m throughout the project.

Table 2-4 Minimum Curve Length

Design speed (km/h)	Calculated length (m)	*Minimum curve length (m)
120	200	200
100	168	170
80	133	140
60	100	100
50	83	90
40	67	70
30	50	50
20	33	40

Source: Ghana Road Design Guide

In urban areas like Kumasi city, closely spaced at-grade intersections, accesses and traffic signals cause stoppages on the roadway. In such situations, lower superelevation is recommended at curved parts of the road. Hence, the maximum superelevation slope of five (5) % is applied accordingly.

Table 2-5 Superelevation Slope

Maximum superelevation (%)	Design Domain	Traffic function
5.0	Urban roads	Access
9.0	Rural roads & High-speed urban roads	Mobility

Source: Ghana Road Design Guide

The widening amount required at curved section is dependent on the characteristics of the vehicle and radius of the curve as shown in Table 2-6. Hence, widening of curved section is applied as appropriate to the standard.

Table 2-6 Curve Widening

Curve radius (m)		Widening amount (m) (one lane units)
Design by trailer	Design by large vehicle	
150 < R < 280	90 < R < 160	0.25
100 < R < 150	60 < R < 90	0.50
70 < R < 100	45 < R < 60	0.75
50 < R < 70	32 < R < 45	1.00
..	26 < R < 32	1.25
	21 < R < 26	1.50
	19 < R < 21	1.75
	16 < R < 19	2.00
	15 < R < 16	2.25

Source: Ghana Road Design Guide

The minimum values of the transition length are applied as per the RDG standard shown in Table 2-7.

Table 2-7 Transition Curve Length

Design speed (km/h)	120	110	100	80	60	50	40	30	20
Minimum transition length (m)	67	61	56	44	33	28	22	17	11

Source: Ghana Road Design Guide

The maximum curve radius required to use the transition length corresponding to the applied design speed is shown in Table 2-8. Curves below the design curve radius of 580m use a transition curve.

Table 2-8 Maximum Curve Radius for use of Transition

Design speed (km/h)	120	100	80	60	50	40	30	20
Calculated Curve radius (m)	1,305	906	580	326	227	145	82	36
Design Curve radius (m)	1,310	910	580	330	230	150	85	40

Source: Ghana Road Design Guide

Sight distance plays an important role in achieving safe and efficient driving experience. The driver's ability to see, predict and react to negotiate through road features is highly improved by providing relevant sight distance according to the design speed. Table 2-9 shows the minimum sight distance that is applied for the selected design speed.

Table 2-9 Sight Distance

Design speed (km/h)	Running speed (km/h)	f	0.694 V	0.00394 V2/f	S (m)	Minimum S.S.D (m)
120	(85%) 102	0.29	70.8	141.4	212.2	210
100	(85%) 85	0.30	58.9	94.8	153.7	160
80	(85%) 68	0.31	47.1	58.7	105.8	110
60	(90%) 54	0.33	37.4	34.8	72.2	75
50	(90%) 45	0.35	31.2	22.8	54.0	55
40	(90%) 36	0.38	24.9	13.4	38.3	40
30	(100%) 30	0.40	20.8	8.9	29.7	30
20	(100%) 20	0.40	13.9	3.9	17.8	20

Source: Ghana Road Design Guide

Table 2-10 provides lists the maximum grade corresponding to the applied design speed. The vertical grade along the project road is kept aligning with the existing road surface level as much as possible.

Table 2-10 Vertical Grade

Design Speed (km/h)	Vertical Gradient (%)		
	Maximum grade	Absolute grade	
		Motorway/Rural Road	Urban Road
120	2	5	-
100	3	6	-
80	4	7	-
60	5	8	7
50	6	9	8
40	7	10	9
30	8	11	10
20	9	12	11

Source: Ghana Road Design Guide

In consideration for the efficient operation of loaded trucks in the steep gradient, the length of the vertical grade shall not cause a speed reduction of 15 km/h or more. To ensure this, the maximum length of vertical grade is set accordingly. Table 2-11 shows the maximum length of vertical grades which become critical to affecting the corresponding design speed.

Table 2-11 Critical length

Design speed (km/h)	Maximum Grade (%)	Limit length of gradient	
		Absolute grade (%)	Critical length of grade (m)
120	2	3 4 5	800 500 400
100	3	4 5 6	700 500 400
80	4	5 6 7	600 500 400
60	5	6 7 8	500 400 300
50	6	7 8 9	500 400 300
40	7	8 9 10	400 300 200
30	8	9 10 11	400 300 200
20	9	10 11 12	300 200 100

Source: Ghana Road Design Guide

Minimum vertical curve radius and minimum vertical curve length presented in Table 2-12 and Table 2-13, respectively, shows the limit where the smooth transition between consecutive different grades can be achieved for the adopted design speed. Considering the project road is in the urban area where there is provision sufficient streetlight, the sag curve radius is set to 1800.

Table 2-12 Minimum Vertical Curve Radius

Design speed (km/h)		120	100	80	60	50	40	30	20
Crest curve (m)		11,100	6,400	3,000	1,400	800	400	200	100
Sag curve (m)	Where street lighting is provided	4,000	3,000	1,800	1,000	700	500	300	100
	Where street lighting is not provided	5,200	3,800	2,400	1,500	1,000	600	400	200

Source: Ghana Road Design Guide

Table 2-13 Minimum Vertical Curve Length

Design speed (km/h)	120	100	80	60	50	40	30	20
Minimum length (m)	100	85	70	50	40	35	25	20

Source: Ghana Road Design Guide

Table 2-14 show the cross slope for various road condition. The cross slope of 2.5% recommended for asphalt concrete surface is be applied. Road shoulder have rather different cross slope than the main carriageway. As shown in Table 2-15, the cross slope corresponding to hard surface is utilized.

Table 2-14 Cross Slope for Various Road Condition

Surface type	Cross slope (%)
Cement concrete	2.0
Asphalt concrete	2.5
Surface dressing	3.0
Gravel	4.0

Source: Ghana Road Design Guide

Table 2-15 Cross Slope of Various Shoulder Conditions

Surface	Cross slope (%)
Hard surface	2.0 - 5.0
Gravel	4.0 - 6.0

Source: Ghana Road Design Guide

The combined gradient of vertical and cross slope is limited to 10.5 as shown in Table 2-16.

Table 2-16 Combined Gradient

Design speed (km/h)	Maximum combined gradient (%)
120 or 100	10.0
80 or 60	10.5
50 or 40	11.5

Source: Ghana Road Design Guide

(5) Roadway Width

The lane width is set to 3.50m which is applicable to the design speed, design class and terrain of the project. Refer Table 2-17 and Table 2-18 for a lane with recommended for various design speed range and Design classes.

Table 2-17 Lane Width

Design speed (km/h)	Desirable lane width (m)
>80	3.65
60 – 80	3.50
40 – 60	3.25
<40	3.00

Source: Ghana Road Design Guide

Table 2-18 Standard Road Width

Design Class	Terrain	Standard width (m)	
		Desirable	Absolute
A1 - Rural Expressway/Motorway A2 - Urban Expressway/Motorway	Flat	3.65	3.50
	Hilly	3.65	
	Mountainous	3.50	
B1 - Rural Major Arterial B2 - Urban Major Arterial	Flat	3.65, 3.50	3.25
	Hilly	3.50	
	Mountainous	3.25	
C1 - Rural Minor Arterial C2 - Urban Minor Arterial	Flat	3.65, 3.50	3.25
	Hilly	3.50, 3.25	3.00
	Mountainous	3.25	3.00
D1 - Rural Collector D2 - Urban Collector	Flat	3.50, 3.25	3.00
	Hilly	3.25	3.00
	Mountainous	3.00	2.75
E - Local/Access	Flat	3.25	3.00
	Hilly	3.00	2.75
	Mountainous	3.00	2.75

Source: Ghana Road Design Guide

On the premises of the intersection, an additional lane of 3.50m width is provided instead of a standard width of 3.0m, shown in Table 2-19, to ensure safety and stability of operating large vehicles. The width of the through lane at an at-grade intersection is kept the same as the width of uninfluenced section (3.50) at a single road section.

Table 2-19 Width of Additional Lane Near Intersections

Rural	Desirable 3.50m or 3.65m Standard 3.00m Minimum 2.75m	Desirable 3.25m Standard 3.00m Minimum 2.75m
Urban	Desirable 3.25m Standard 3.00m Minimum 2.75m	

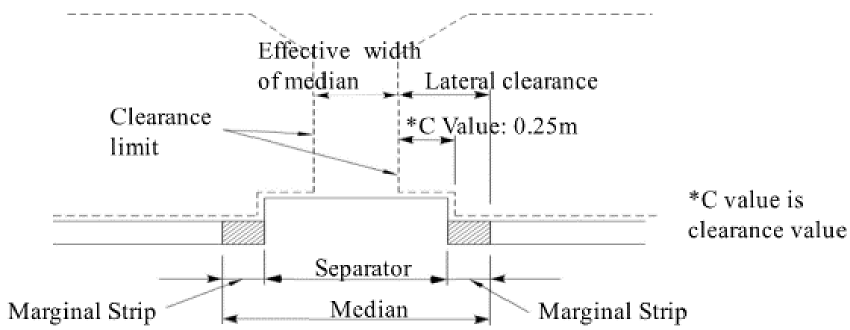
Source: Ghana Road Design Guide

Median: Median width at general road sections was set as 8.0m, based on the discussion with Ghana government, so that the number of carriageway lanes can be increased in the future.

Table 2-20 Median

Design Class		Median (m)	Borderline (m)	C value (m)
A	A1	10.0 (min)	1.2 (min)	0.50
	A2	2.0 - 4.0	0.50 - 0.75	0.25
B, C, D & E		1.0 - 4.0	0.30 - 0.50	0.25

Source: Ghana Road Design Guide



Source: Ghana Road Design Guide

Figure 2-1 Median

Road Shoulder: the standard road shoulder width for Design Class B is 2.5m. However, this consideration is suitable for rural areas. In urban areas, the road has a structure where the roadway and sidewalk will be separated by a curb. Therefore, in this project road a minimum road shoulder width of 0.50m will be used to provide clearance between the carriageway and sidewalk.

Table 2-21 Road Shoulder

Design Class	Shoulder (m)		
	Desirable	Absolute minimum	*Width for Partial shoulders
A	3.0	2.5	1.75
B	2.5	2.0	1.25
C	2.5	1.5	0.75
D	2.0	1.0	0.5
E	1.5	0.5	-

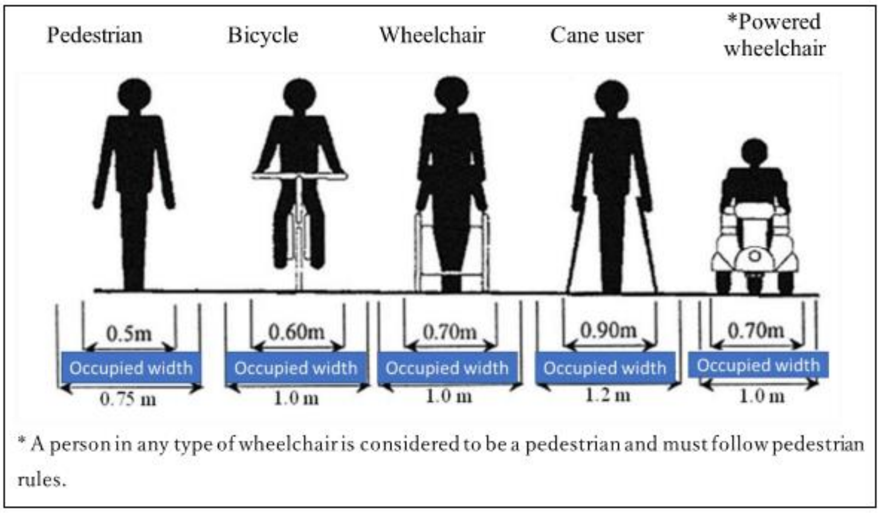
Source: Ghana Road Design Guide

Sidewalk Width: the width of the sidewalk is determined based on the number of pedestrians and bicycle users. Considering the pedestrians and bicycle users around the project road, a sidewalk width of 2.50 meters is applied. It is also equivalent to the current sidewalk width in the area. Table 2-22 and Figure 2-2 shows the various sidewalk users taken into consideration while setting the sidewalk width.

Table 2-22 Sidewalk Width

Non-Motorized Road Users	Specifications (m)			
Pedestrian	Occupied width			
	0.75			
Wheelchair	Occupied width			
	1.00			
Bicycle	Occupied width	Height	Length	Pedal height
	1.00	2.25	1.90	0.05
Cane user	0.90	-	-	-
Powered wheelchair	0.70	-	-	-
Handcart	0.70	-	-	-

Source: Ghana Road Design Guide

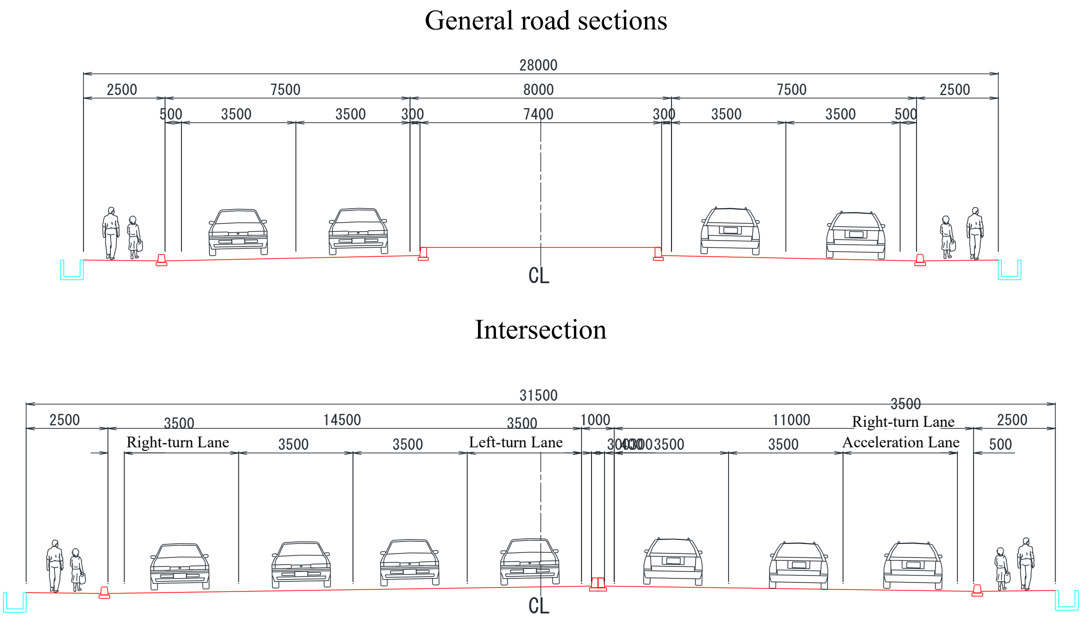


Source: Ghana Road Design Guide

Figure 2-2 Sidewalk Width

Typical Cross Section: a standard road cross section is classified into two, uninterrupted section and intersection section.

Uninterrupted section is the road section where there is no influence of the intersection on the characteristics of the road cross section. In this section, as shown in Figure 2-3, dual carriageway with 3.50 lane width is used. The median is 8.0m to account for future development of the corridor. In the intersection section, additional lanes are provided to smoothen the flow of through traffic and left/right turn traffic. In this section, the width of the median varies to accommodate the smooth flow of left turn traffic. The minimum median width is 1.0m.



Source: JICA survey team

Figure 2-3 Typical Road Cross-sections

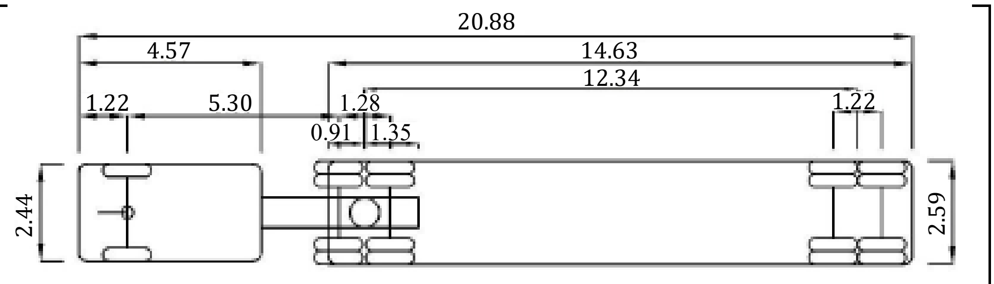
(6) Geometric Structure Standards Near Intersections

Design Vehicle: is decided based on the characteristics and volume of traffic along the project road. In this project, Trailer Type-2, design vehicle is used. The specification of the design vehicle is listed in Table 2-23. The configuration of the design vehicle is demonstrated in Figure 2-4.

Table 2-23 Design Vehicle

Design vehicle	Specifications (m)								Design Class**
Name	Symbol*	Length	Width	Height	Overhang Front	Overhang Rear	Axial distance	Minimum turning radius	
Small Vehicle (Saloon/Sedan)	S-5	4.7	1.7	2.0	0.8	1.2	2.7	6.0	A, B, C
Medium Vehicle (SUV, van, pick-up)	M-6	6.0	2.0	2.8	1.0	1.3	3.7	7.0	D, E
Large Vehicle Type 1 (Medium bus, light/medium truck)	L-9	9.1	2.4	4.1	1.2	1.8	6.1	12.7	
Large Vehicle Type 2 (Heavy truck/ large Bus)	L-12	12.0	2.5	4.0	1.5	4.0	6.5	12.7(bus) 15.6 (truck)	A, B, C
Trailer Type 1 (Light semi-trailer truck)	T-17	16.5	2.5	4.1	1.3	2.2	Front 4.0 Rear 9.0	13.7	
Trailer Type 2 (Heavy semi-trailer truck)	T-21	21.0	2.6	4.1	1.2	1.4	Front 5.9 Rear 12.5	13.7	

Source: Ghana Road Design Guide

Trailer Type 2 (T-21)	

Source: Ghana Road Design Guide

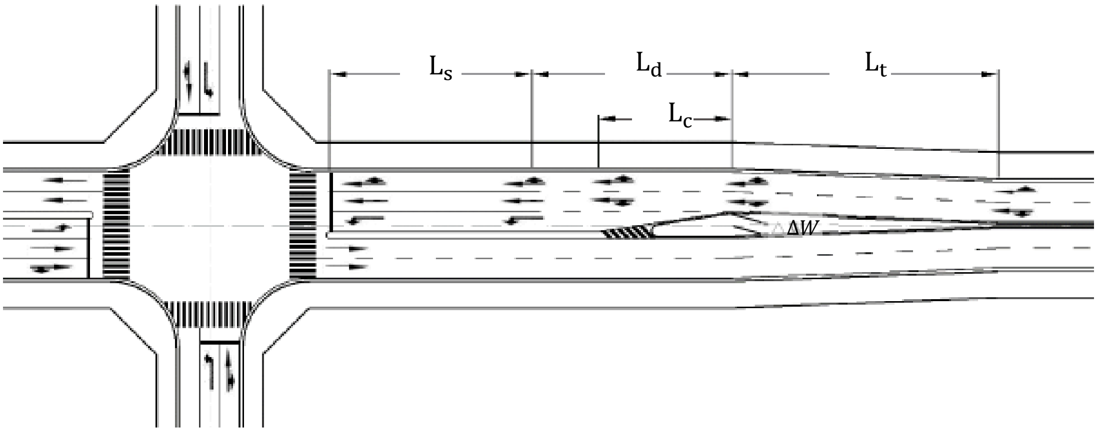
Figure 2-4 Design Vehicle

Lane Shift: to provide sufficient space for left-turn traffic, the through traffic will be shifted to the right. The run-off length required for smooth shifting of lanes for the corresponding design speed is listed in Table 2-24 through Table 2-27. The schematical illustration of the lane shift and total length require for left-turn lane is displayed in Figure 2-5 and Figure 2-6 respectively.

Table 2-24 Through Lane Shift

Design speed (km/h)	Rural		Urban	
	Equation	Minimum value (m)	Equation	Minimum value (m)
120	V×△W/2	-	V×△W/2	-
100		-		-
80		85		-
60		60	V×△W/3	40
50	V×△W/3	40		35
40		35		30
30		30		25
20		25		20

Source: Ghana Road Design Guide



Source: Ghana Road Design Guide

Figure 2-5 Length of Lane Shift Runoff and Left Turn Lane

The total length required for left-turn lane is a summation of the deceleration length (Ld) and storage lengths (Ls).

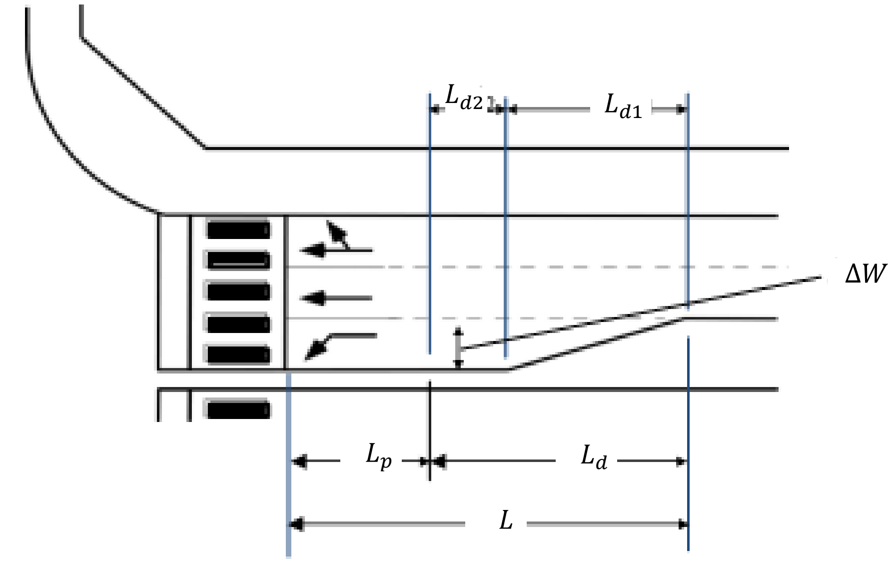
L=Ld+Ls

Where:

L: Length of left turn lane (m)

Ld: Deceleration length (m)

Ls: Storage length (m)



Source: Ghana Road Design Guide

Figure 2-6 Length of Left Turn Lane

Table 2-25 Length of Left Turn Lane

Design speed (km/h)	Rural			Urban		
	Taper length (m) Ld1	Parallel length (m) Ld2	Deceleration length (m) Ld	Taper length (m) Ld1	Parallel length (m) Ld2	Deceleration length (m) Ld
120	100	180	280	70	90	160
100	90	100	190	60	30	90
80	70	50	120	50	20	60
60	60	10	70	35	-	35
50	50	-	50	30	-	30
40	50	-	50	25	-	25
30	20	-	20	20	-	20
20	20	-	20	10	-	10

Source: Ghana Road Design Guide

In a situation where the taper width is greater than 3.5m, the taper length (Ld1) for transitioning from the through lane to the left-turn lane is given by the following equation.

$$L_{d1} = V \, x \, \frac{\Delta W}{6}$$

Where:

V: Design speed (km/h)

ΔW: Maximum shift in the transverse direction

Table 2-26 Length of Deceleration Lane

Design speed (km/h)	Rural			Urban		
	Parallel length, Lp(m)	Taper length, LT(m)	Length of Deceleration Lane, L (m)	Parallel length, Lp(m)	Taper length, LT (m)	Length of Deceleration Lane, L (m)
120	190	100	290	110	70	180
100	110	90	200	80	60	140
80	80	70	150	50	45	95
60	80	60	140	30	20	50
50	60	50	110	20	20	40
40	50	40	90	20	15	35
30	30	20	50	20	10	30
20	20	20	40	10	10	20

Source: Ghana Road Design Guide

Table 2-27 Length of Acceleration Lane

Design speed (km/h)	Rural			Urban		
	Parallel length, Lp (m)	Taper length, LT (m)	Length of Acceleration Lane, L(m)	Parallel length, Lp (m)	Taper length, LT (m)	Length of Acceleration Lane, L(m)
120	370	100	470	250	70	320
100	280	90	370	190	60	250
80	140	70	210	90	50	140
60	100	60	160	65	35	100
50	40	50	90	40	30	70
40	30	50	80	25	25	50
30	20	20	40	20	10	30
20	10	20	30	10	10	20

Source: Ghana Road Design Guide

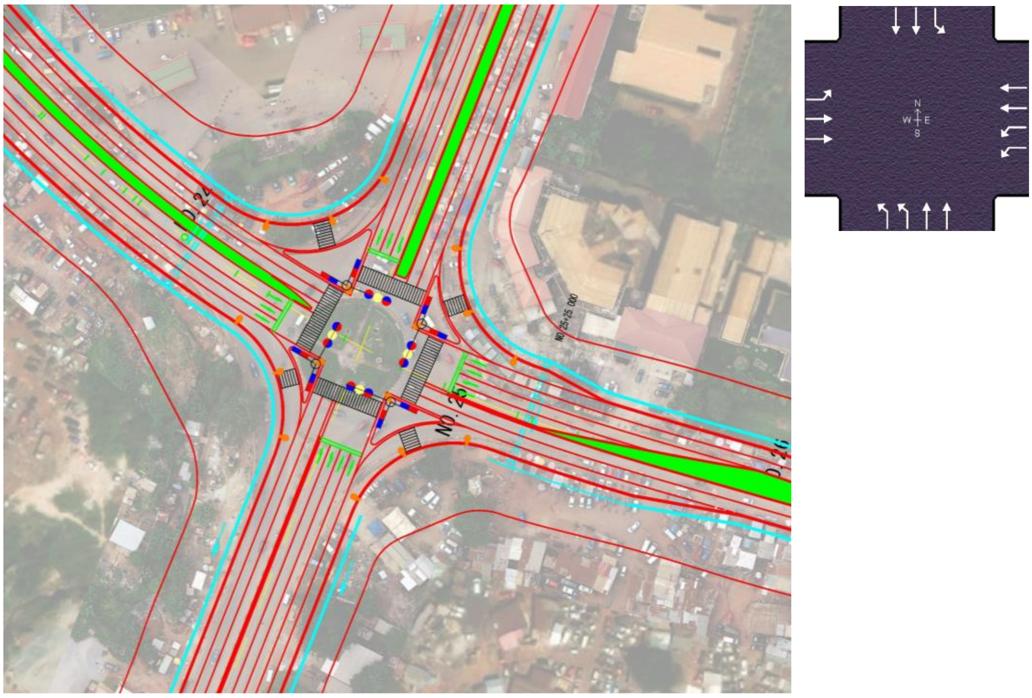
Right turn road channel: the shape of the right-turn road channel is determined based on the vehicle travel trajectory by the design vehicle (Trailer Type 2 T-21) adopted in this project. Table 2-28 lists the parameters used to produce the right-turn channel according to the design vehicle type and the outer radius of the channel.

Table 2-28 Road Channel

Outer Radius of Channel (m)		Width (m)	
More than	Less than	Trailer	Other vehicles
13	14	8.5	5.5
14	15	8.0	
15	16	7.5	5.0
16	17	7.0	
17	19	6.5	
19	21	6.0	4.5
21	25	5.5	
25	30	5.0	4.0
30	40	4.5	
40	60	4.0	3.5
60		3.5	

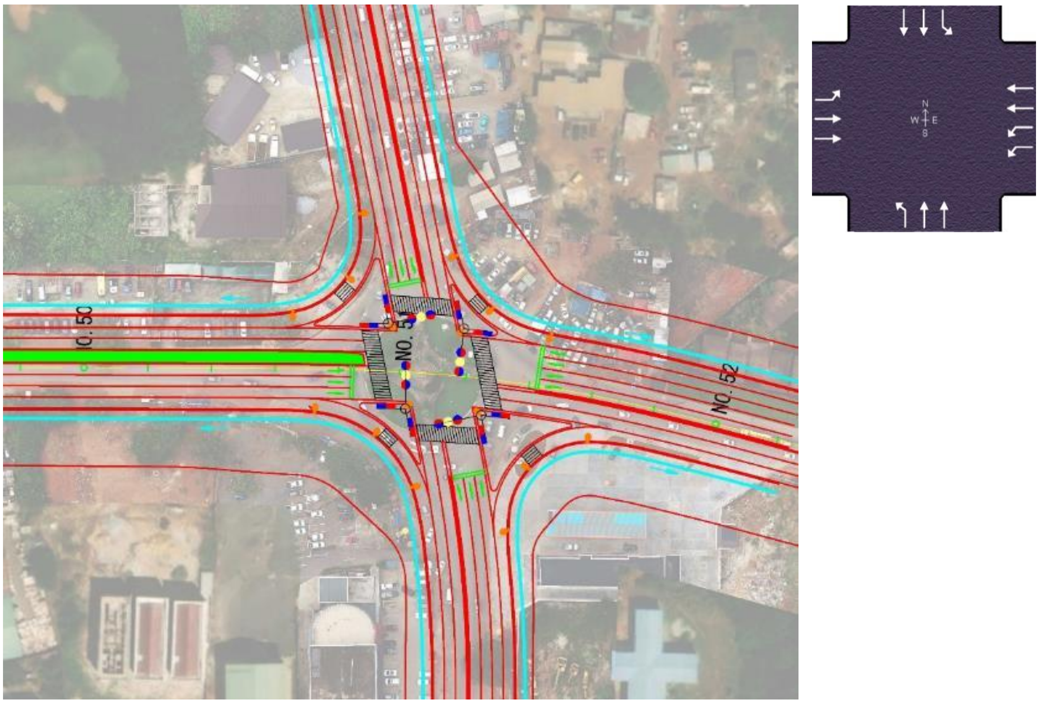
Source: Ghana Road Design Guide

Figure 2-7 and Figure 2-8 show result of pre-feasibility study on Santasi Intersection and improvement of Ahodwo intersection, respectively.



Source: JICA Survey Team

Figure 2-7 Plan view of Santasi Intersection



Source: JICA Survey Team

Figure 2-8 Plan view of Ahodwo Intersection

2.1.2.3. Overview of Road Design

(1) Horizontal Alignment of the Road

The following list of considerations are examined upon planning the horizontal alignment of the target intersection.

- The alignment should fit within the right-of-way and utilize the existing road alignment as much as possible.
- The 80km/h design speed will serve as the foundation for the designing of the horizontal alignment.

(2) Vertical Alignment of the Road

The following factors are taken into account when planning the road's vertical alignment.

- Due consideration is given to align the vertical grades with that of the existing road grades. This will reduce the necessity for large scale construction.
- The vertical alignment of the road is established in accordance with the design speed, which has been set at 80 km/h. Where the existing road has a steep grade, absolute values corresponding to the adopted design class is applied. Hence, the maximum vertical slope in the design is still lower than the existing grade.
- At the Ahodwo intersection, the crest section was repositioned towards the direction of Asokwa intersection to preserve the current intersection height. As a result, the vertical alignment was kept generally the same as the existing vertical alignment at Ahodwo intersection.

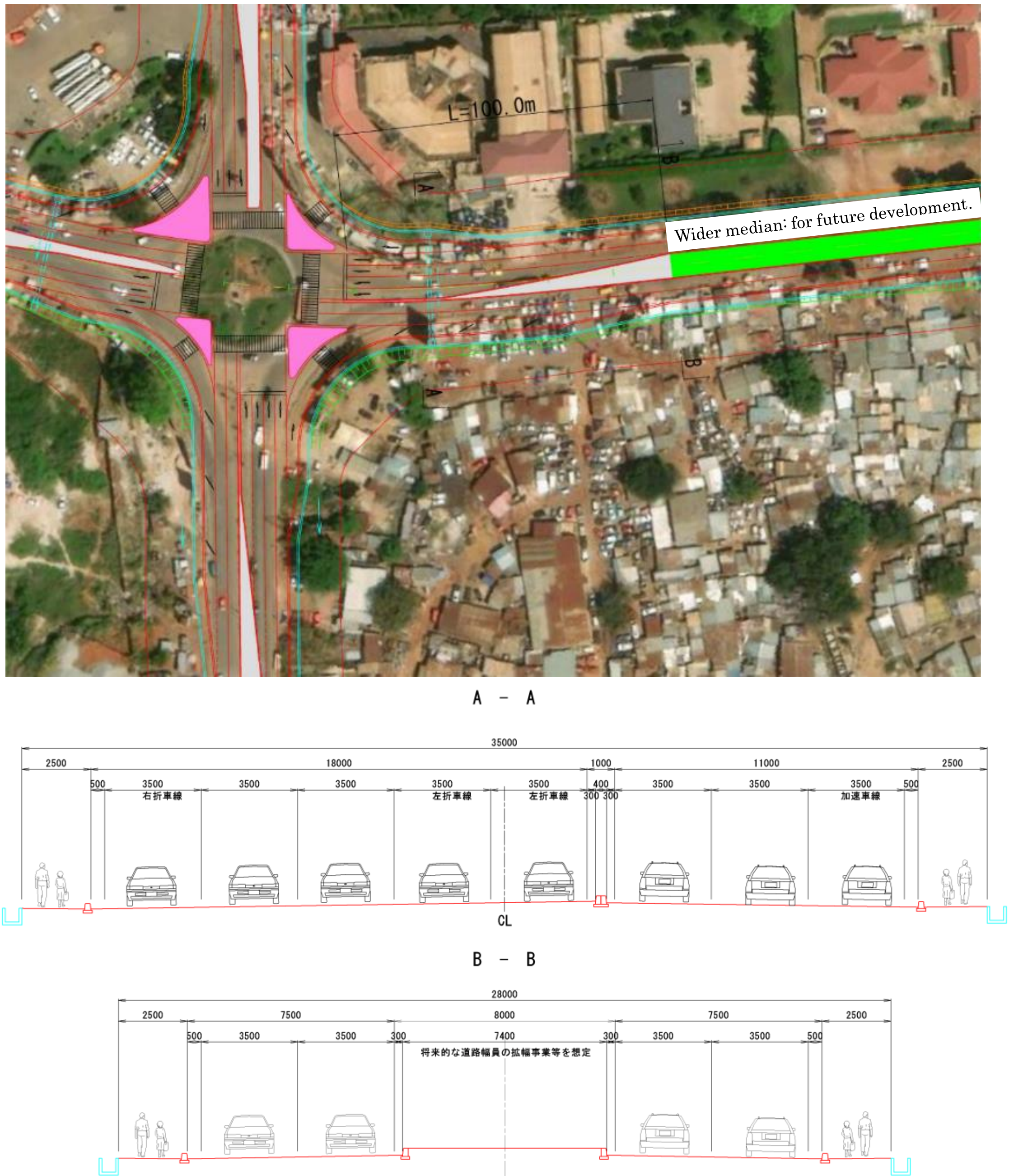
(3) Planning of the Intersections

- The shape of the intersection is determined by the travel trajectory of the design vehicle (Trailer Type 2 T-21). Semi-trailers use wider area when negotiating through sharp curves. Therefore, introducing a channel road for turning semi-trailer-coupled raises concerns about the potential instances where vehicles might encroach onto sidewalks or traffic islands. Such encroachments pose a threat to the safety of pedestrians and may disrupt the smooth flow of traffic, jeopardizing the overall road safety and stability.
- The cross-sectional configuration of the road near the intersection will keep the same lane width as the uninfluenced section. This implementation aims to meet the needs and challenges associated with the operation of large vehicles and create a safe and convenient driving experience.
- To achieve an uninterrupted and seamless traffic flow, the design speed at intersections will be the same as that of the uninfluenced sections, 80km/h. This will not only focus on improving the overall flow but also contributes to a safer and more predictable driving environment.

(4) Plan View of the Intersection

- Taking into account the potential future growth and development of the corridor, the median of the road will have a width of 8m.
- The widened median is applied only in the uninfluenced sections of the road, which is about 100m away from the stop line of intersection legs. It will not include areas within intersections.

The plan view and typical sectional view for intersection section and uninfluenced section are shown in Figure 2-9.



Source: JICA Survey Team

Figure 2-9　Plan View and Standard Cross-sections

2.1.3. Road Structure Design

2.1.3.1. Outline of Road Structure Design for Combination Scheme-1

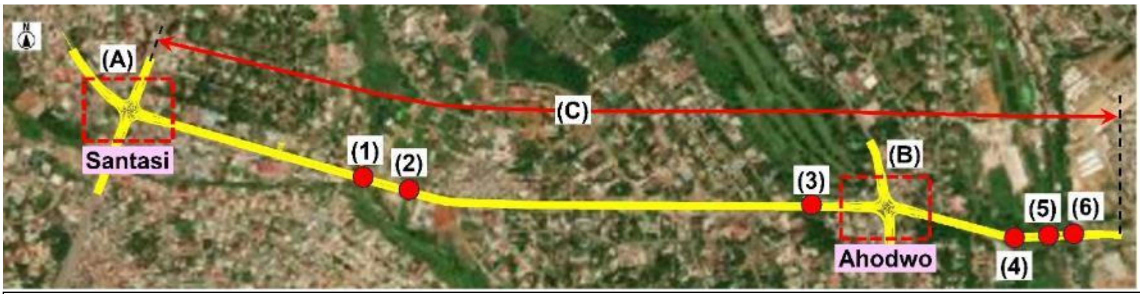
Basic information on structures included in Combination Scheme-1 is shown below. Also, locations of road structures in Combination Scheme-1 are shown in Figure 2-10, explaining outline of each structure afterwards.

Santasi ~ Ahodwo road section:

- Structure (1) STA No.32+80: Box culvert L=8m
- Structure (2) STA No.34+45: Box culvert L=3m
- Structure (3) STA No.48+40: Box culvert L=5m

Ahodwo ~ Asokwa road section:

- Structure (4) STA No. 55+80: Box culvert L=3m
- Structure (5) STA No.34+45: Box culvert L=8m
- Structure (6) STA No.34+45: RC hollow slab bridge L=13m



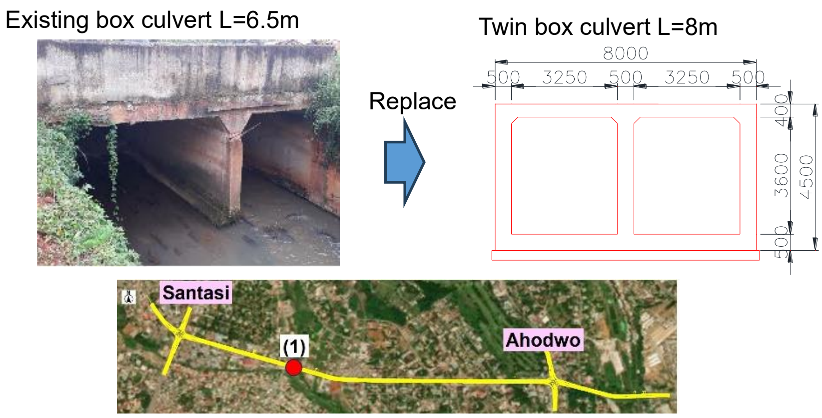
Legend: (A) Improvement of Santasi intersection, (B) Improvement of Ahodwo intersection, (C) Dualization of Inner Ring Road (3.4km), (1)~(6) Location of road structures

Source：JICA survey team

Figure 2-10 Locations of Road Structures in Combination Scheme-1

[Structure (1): Twin box culvert L=8m]

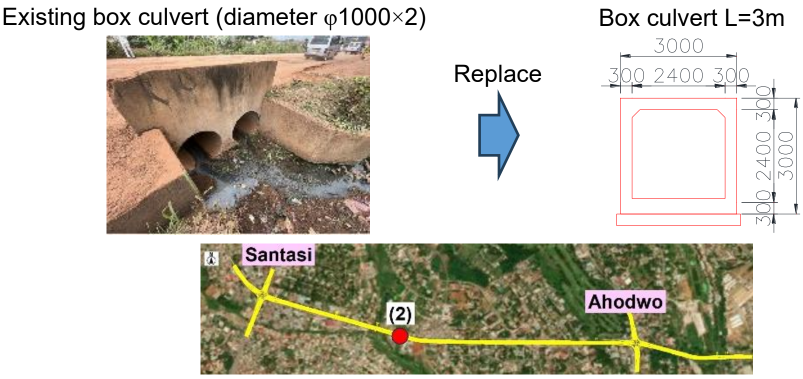
As shown in Figure 2-11, a box culvert (L=6.5m) exists at STA No.32+80 of Santasi ~ Ahodwo road section. The structure is to be replaced with a twin box culvert (L=8m).



Source：JICA survey team

Figure 2-11 Structure (1): Twin Box Culvert L=8m

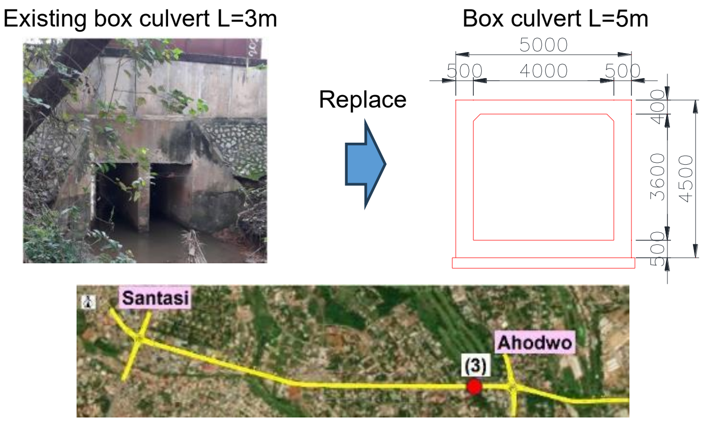
[Structure (2): Box culvert L=3m]
As shown in Figure 2-12, a box culvert (diameter φ1000×2) exists at STA No.34+45 of Santasi ~ Ahodwo road section. The structure is to be replaced with a box culvert (L=3m).



Source：JICA survey team

Figure 2-12　Structure (2): Box Culvert L=3m

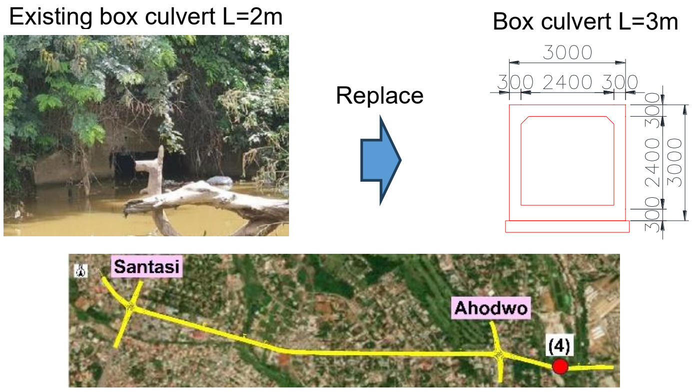
[Structure (3): Box culvert L=5m]
As shown in Figure 2-13, a box culvert (diameter φ1000×2) exists at STA No.48+40 of Santasi ~ Ahodwo road section. The structure is to be replaced with a box culvert (L=5m).



Source：JICA survey team

Figure 2-13　Structure (3): Box Culvert L=5m

[Structure (4): Box culvert L=3m]
As shown in Figure 2-14, a box culvert (L=2) exists at STA No.55+80 of Ahodwo～Asokwa road section. The structure is to be replaced with a box culvert (L=3m).

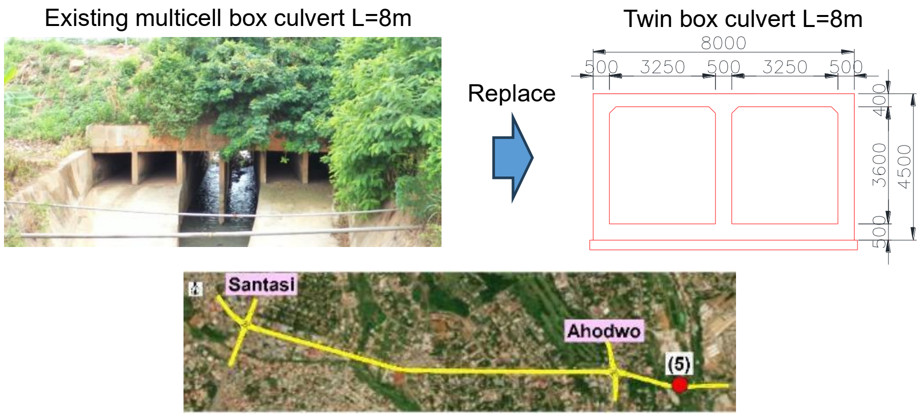


Source：JICA survey team

Figure 2-14　Structure (4): Box Culvert L=3m

[Structure (5): Box culvert L=8m]

As shown in Figure 2-15, a multicell box culvert (L=8) exists at STA No.57+00 of Ahodwo～Asokwa road section. The structure is to be replaced with a twin box culvert (L=8m).

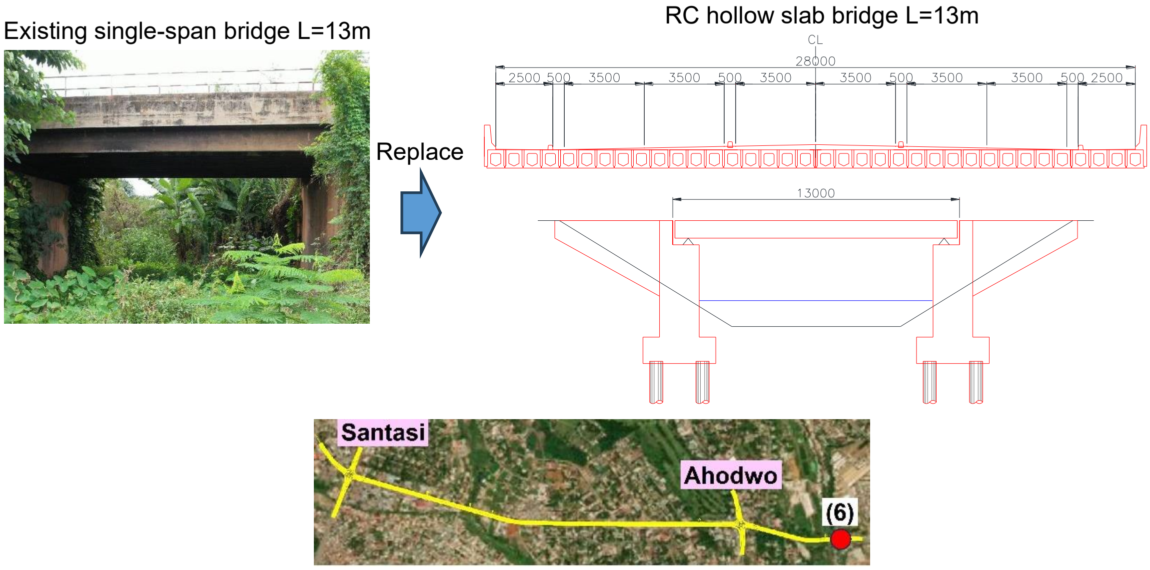


Source：JICA survey team

Figure 2-15　Structure (5): Twin Box Culvert L=8m

[Structure (6): RC Hollow Slab Bridge L=13m]

As shown in Figure 2-16, a single-span bridge (L=13) exists at STA No.57+50 of Ahodwo～Asokwa road section. The structure is to be replaced with a RC hollow slab bridge (L=13m).



Source：JICA survey team

Figure 2-16　Structure (6): RC Hollow Slab Bridge L=13m

2.1.3.2. Outline of Road Structure Design for Combination Scheme-2

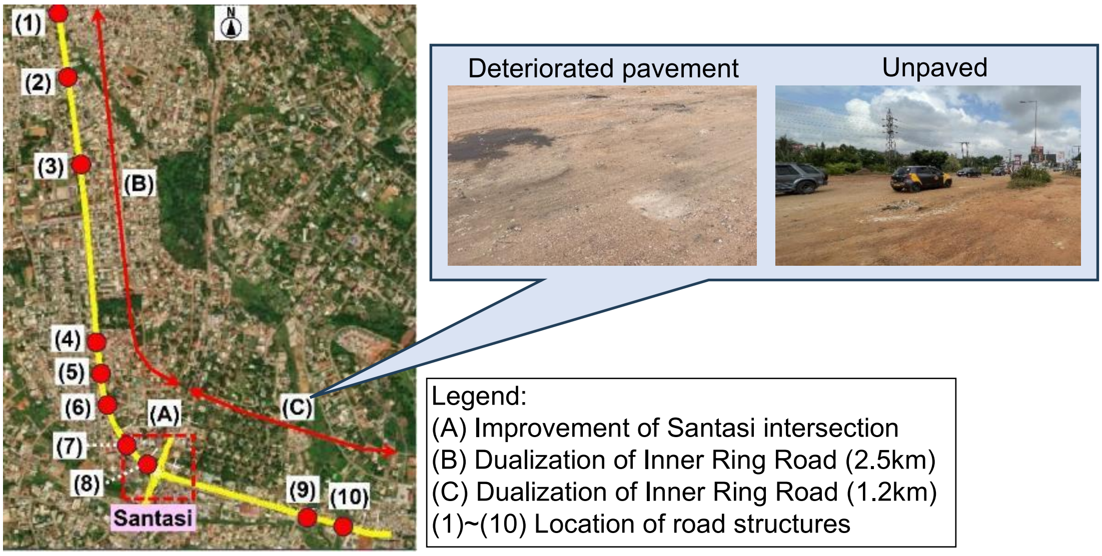
Basic information on structures included in Combination Scheme-2 is shown below. Also, locations of road structures in Combination Scheme-2 are shown in Figure 2-17, explaining outline of each structure afterwards.

<u>Sofoline ~ Santasi road section:</u>

- Structure (1) STA No.1+00: Box culvert L=1.26m
- Structure (2) STA No.2+50: Box culvert L=1.26m
- Structure (3) STA No.8+00: Box culvert L=1.26m
- Structure (4) STA No.17+40: Box culvert L=1.26m
- Structure (5) STA No.18+90: Box culvert L=1.26m
- Structure (6) STA No.20+50: Box culvert L=1.26m
- Structure (7) STA No.22+50: Box culvert L=1.26m
- Structure (8) STA No.24+40: Box culvert L=2.32m

<u>Santasi ~ Ahodwo road section (1.2km: Unpaved or deteriorated section):</u>

- Structure (9) STA No.32+80：Box culvert L=8m
- Structure (10) STA No.34+45: Box culvert L=3m



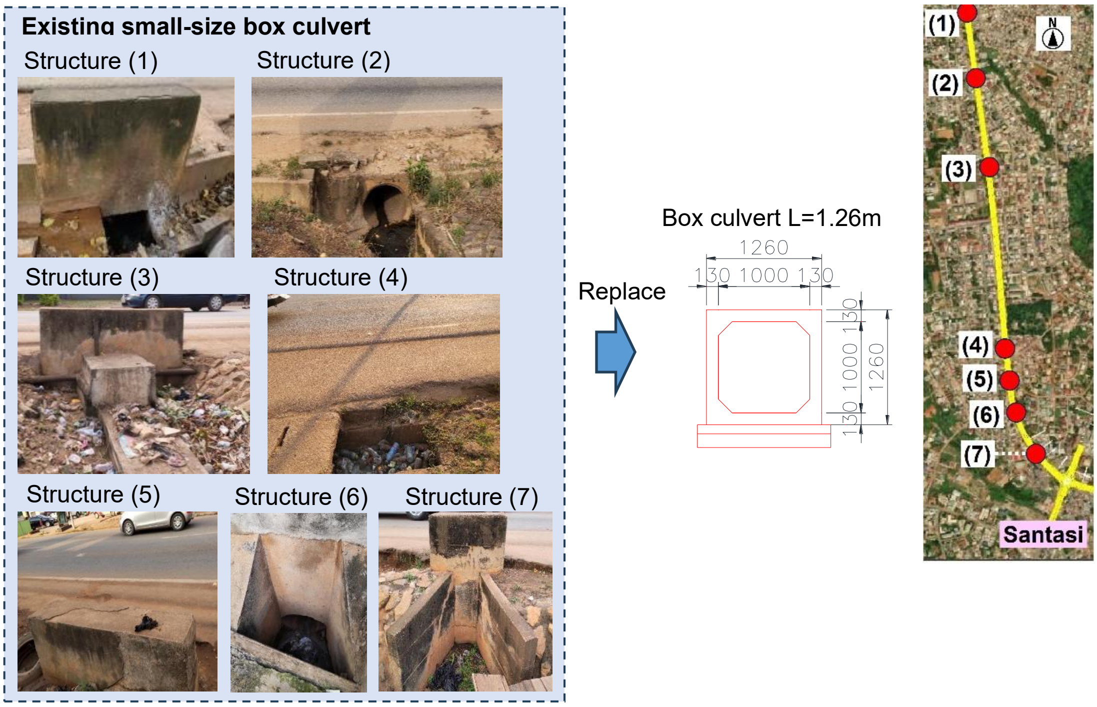
Source：JICA survey team

Figure 2-17 Locations of Road Structures in Combination Scheme-2

[Structure (1)~(7): Box culvert L=1.26m]

As shown in Figure 2-18, small-size box culverts exist in Sofoline～Santasi road section. The structures are to be replaced with box culverts (L=1.26m).

- Structure (1): Box culvert (cross-section width 0.9m)
- Structure (2): Box culvert (diameter φ800×1)
- Structure (3): Box culvert (cross-section width 0.85m)
- Structure (4): Box culvert (cross-section width 0.9m)
- Structure (5): Box culvert (cross-section width 1.93m)
- Structure (6): Box culvert (diameter φ600×1)
- Structure (7): Box culvert (inner section size 0.5m×1.0m)

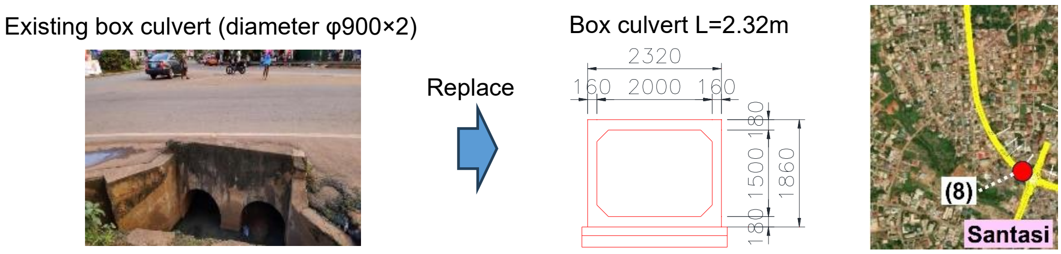


Source：JICA survey team

Figure 2-18　Structure (1)~(7): Box Culverts L=1.26m

[Structure (8): Box culvert L=2.32m]

As shown in Figure 2-19, a box culvert (diameter φ900×2) exists at STA No.24+40 of Sofoline～Santasi road section. The structures are to be replaced with box culverts (L=2.32m).

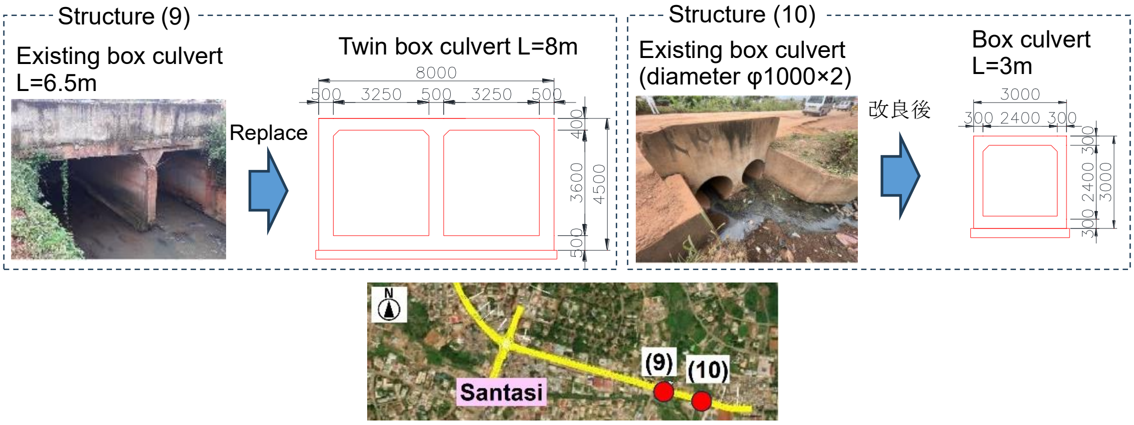


Source：JICA survey team

Figure 2-19　Structure (8): Box culvert L=2.32m

[Structure (9): Box culvert L=8m, Structure (10): Box culvert L=3m]

As already explained in detail for Combination Scheme-1, a box culvert (L=6.5m) exists at STA No.32+80, and a box culvert (diameter φ1000×2) exists at STA No.34+45 of Santasi ~ Ahodwo road section. As shown in Figure 2-20, the box culvert (L=6.5m) is to be replaced with a twin box culvert (L=8m), and the box culvert (diameter φ1000×2) is to be replaced with a box culvert (L=3m).



Source：JICA survey team

Figure 2-20 Structure (9): Box culvert L=8m, Structure (10): RC Hollow Slab Bridge L=13m

2.2 Estimation of Approximate Project Costs

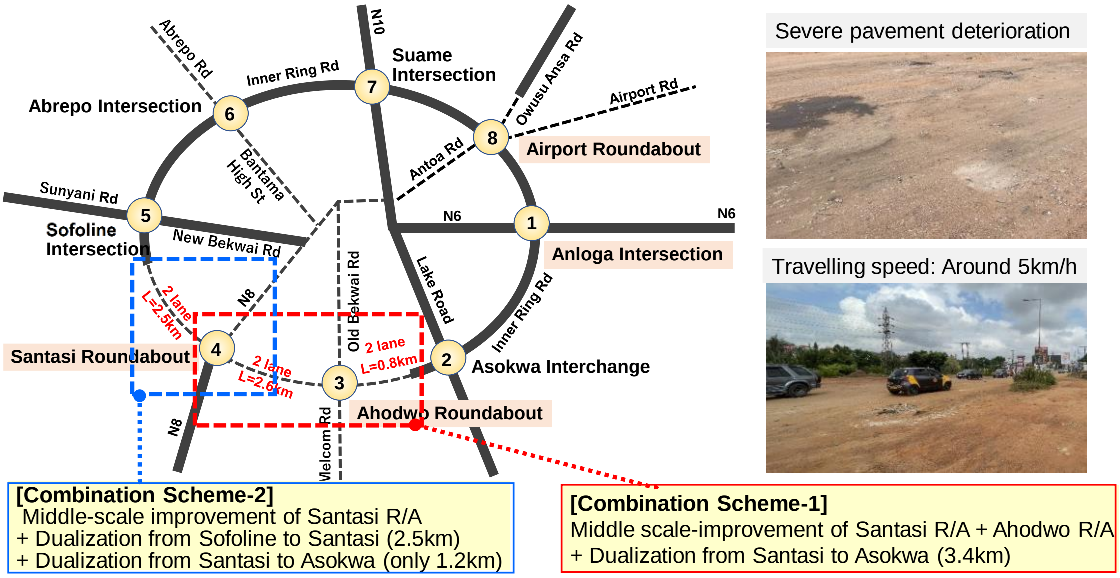
2.2.1. Project Outline of the Target Sections

Major road facilities/structures of the two (2) priority projects are summarized in Table 2-29. Also, location of the two (2) priority projects are show in Figure 2-21.

Table 2-29 Major Road Facilities/Structures of the 2 Priority Projects

	Combination Scheme-1	Combination Scheme-2
Dualization of each lane bet. Ahodwo-Asokwa	Improvement length：0.8km	—
Improvement of Ahodwo Intersection	Dualization of each lane at level intersection	—
	Provision of slip lanes	—
	Provision of Traffic lights and incidental facilities	—
Dualization of each lane bet. Santasi-Ahodwo	Improvement length: 2.6km	Improvement length: 1.2km
	Box culvert 5 units（L=3.0m～8.0m） Bridge 1 unit（L=13m）	Box culvert 2 units（L=3.0m, 8.0m）
Improvement of Santasi Intersection	Dualization of each lane at level intersection	Dualization of each lane at level intersection
	Provision of slip lanes	Provision of slip lanes
	Provision of Traffic lights and incidental facilities	Provision of Traffic lights and incidental facilities
Dualization of each lane bet. Sofoline-Santasi	—	Improvement length: 2.5km
	—	Box Culvert 8 units（L=1.2m～2.3m）

Source：JICA survey team



Source：JICA survey team

Figure 2-21 Location of the 2 Priority Projects

2.2.2. Setting of Unit Costs and Estimation of Approximate Construction costs

The unit costs of construction work items were set utilizing those of "the Project for the Improvement of the Tema Motorway Roundabout (Phase 2) in Ghana (2020)" and similar projects near Kumasi. The price increase rate of 2025 to 2020 was set as 1.2, based on 1) quotation of the materials, labor and machinery obtained in 2023, 2) the IMF price index, and 3) fluctuation of exchange rate of Ghana cedi to US dollar. Table 2-30 and Table 2-31 shows construction cost of Combination Scheme-1 and Combination Scheme-2, respectively.

Table 2-30 Construction Cost of Combination Sceme-1

Unit: Million yen

Work Item		Amount
Direct Cost		
Dualization of each lane bet. Santasi-Ahodwo-Asokwa（L=3.4km）		**787**
1	Earth Work	167
2	Pavement Work	217
3	Drainage Work	131
4	Incidental Works(Pedestrian Walkway, Median, Curb, Lane Marking, etc)	272
Improvement of Ahodwo Intersection		**142**
1	Earth Work	12
2	Pavement Work	48
3	Drainage Work	22
4	Traffic Light, Street Light	28
5	Incidental Works(Pedestrian Walkway, Curb, Lane marking, etc)	32
Improvement of Santasi Intersection		**146**
1	Earth Work	13
2	Pavement Work	52
3	Drainage Work	21
4	Traffic Light and Street Light	28
5	Incidental Works(Pedestrian Walkway, Curb, Lane Marking)	32
Civil Structures（Bridge, Box Culvert）		**337**
1	Bridge Works	185
2	Culvert Works	152
Sub-Total（Direct Cost）		**1,412**
Common temporary works		**212**
Site Office		**424**
Profit		**212**
Total Construction Cost		**2,260**

Source：JICA survey team

Table 2-31 Construction Cost of Combination Sceme-2

Unit: Million yen

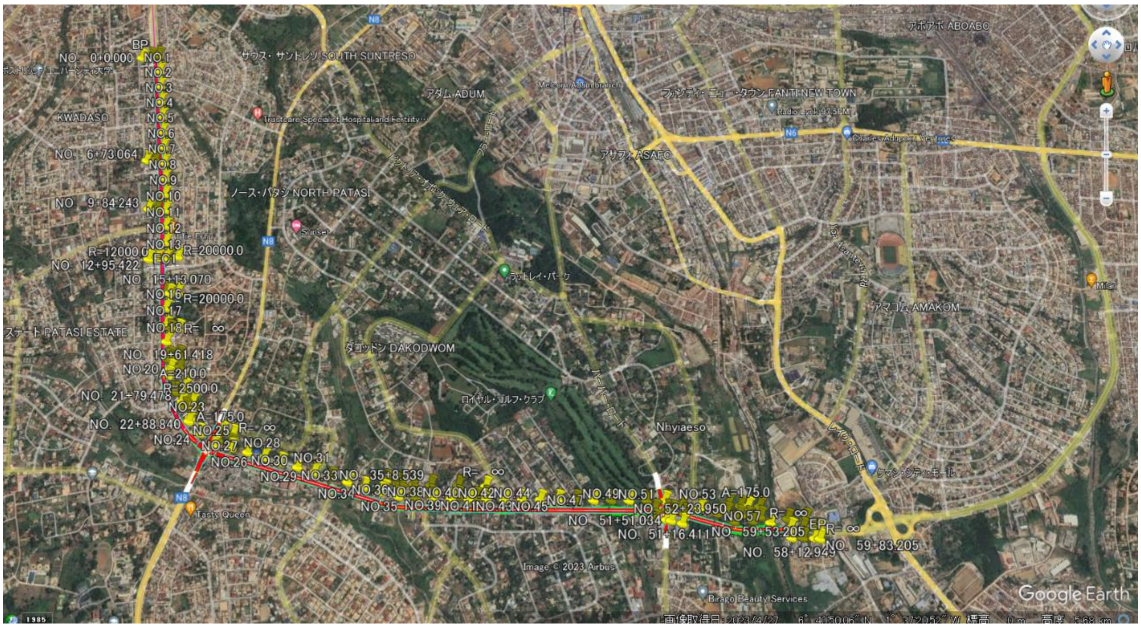
Work Item		Amount
Direct Cost		
Dualization of each lane bet. Sofoline-Santasi-Ahodwo（L=3.7km）		**822**
1	Earth Work	70
2	Pavement Work	244
3	Drainage Work	165
4	Incidental Work(Pedestrian Walkway, Median, Curb, Lane Marking, etc)	331
Improvement of Santasi Intersection		**146**
1	Earth Work	13
2	Pavement Work	52
4	Drainage Work	21
5	Traffic Light, Street Lht	28
4	Incidental Works(Pedestrian Walkway, Curb, Lane Marking, etc)	32
Civil Structure（Box Culvert）		**95**
Sub-Total（Direct Cost）		**1051**
Common Temporary Works		**158**
Site Office		**315**
Profit		**158**
Total Construction Cost		**1,682**

Source：JICA survey team

2.3 Impact of the Project on Surrounding Areas

2.3.1. Summary of Impact Study

In order to conduct an impact study for the priority improvement projects, the number of units of the structures affected by "1. Section of Intersections" and "2. Combination Schemes" were calculated. The scope of the study is shown in Figure 2-22.



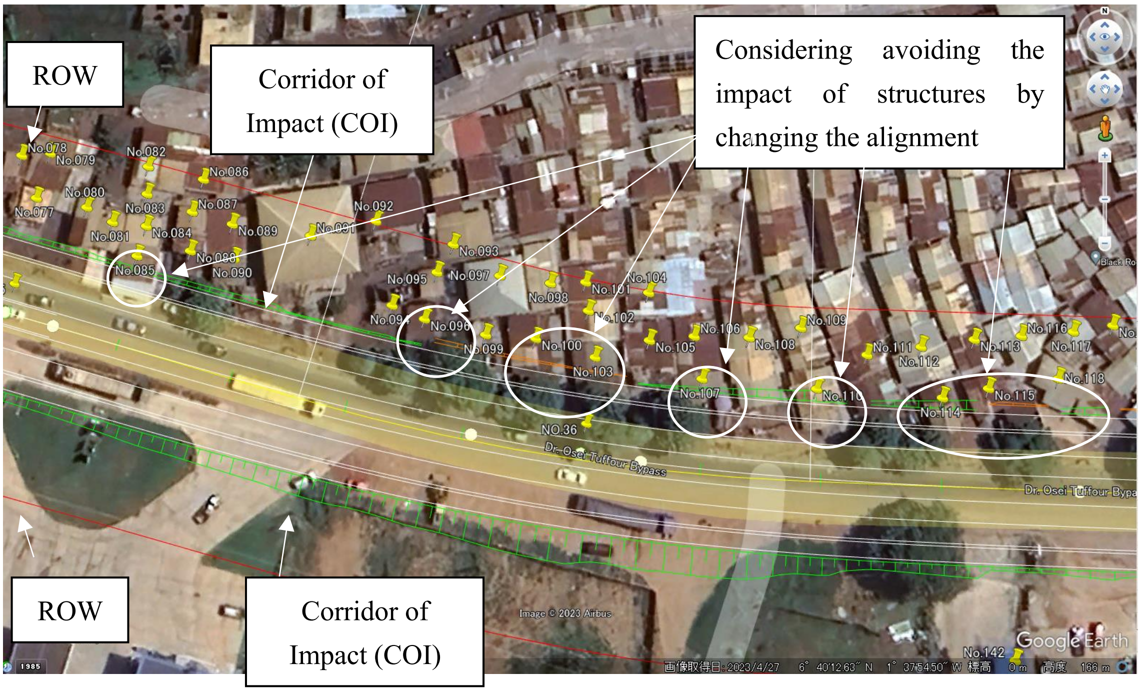
Source：JICA survey team

Figure 2-22 Scope of Impact Study on Surrounding Areas for Priority Projects (Calculation of Impacted Structures)

In studying the impact on priority improvement projects, the number of affected units was calculated in the following three cases.

- Case1: Case where Structures within the ROW are Removed.
- Case 2: Case where Structures within the Corridor of Impact (COI) (within the Design Zone) are Removed.
- Case 3: Case where Structures within the Corridor of Impact (COI) (within the Design Zone) are Considered to be Avoided by changing the alignment.

Examples of impact study map and counting tables are shown in Figure 2-23 and Table 2-32.



Source：Edited from Google Earth by JICA survey team

Figure 2-23 Example of the Number of Structure Units Affected by the Project (02 Santasi ~ Ahodwo)

Table 2-32 Example of Counting the Number of Structures Affected by the Project (02 Santasi ~ Ahodwo)

02 Impacted Structures (Santasi-Ahodwo) [Nos.]

No.	Case1: Within ROW	Case2: Within COI	Case3: Considering Avoiding the Impact of Structures by Changing the Alignment	Remarks	Range for Combination Scheme-1	Range for Combination Scheme-2	Remarks
080	√				√	√	
081	√				√	√	
082	√				√	√	
083	√				√	√	
084	√				√	√	
085	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
086	√				√	√	
087	√				√	√	
088	√				√	√	
089	√				√	√	
090	√				√	√	
091	√				√	√	
092	√				√	√	
093	√				√	√	
094	√				√	√	
095	√				√	√	
096	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
097	√				√	√	
098	√				√	√	
099	√				√	√	
100	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
101	√				√	√	
102	√				√	√	
103	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
104	√				√	√	
105	√				√	√	
106	√				√	√	
107	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
108	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
109	√				√	√	
110	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
111	√				√	√	
112	√				√	√	
113	√				√	√	
114	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
115	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
116	√				√	√	
117	√				√	√	
118	√	√		Possibility of Avoiding the Impact of Structures by Changing the Alignment	√	√	
119	√				√	√	
120	√				√	√	

Source: JICA survey team

2.3.2. Results of Impact Study

2.3.2.1. Evaluation by Section of Intersections

The results of the study, in which the number of affected structure units was counted for the intersection section, are shown in Table 2-33.

Table 2-33 Number of Units of Structures Affected by the Project

［Nos.］

No.	Section	Case1: Within ROW	Case2: Within COI	Case3: Considering avoiding the impact of structures by changing the alignment
01	Sofoline-Santasi	223	88	67
02	Santasi-Ahodwo	177	47	30
03	Ahodwo-Asokwa	25	9	3
Total		425	144	100

Source: JICA survey team

The estimated number of people affected by the project, assuming that all structures are houses and that four (4) people live in each structure[2], is shown in Table 2-34.

Table 2-34 Estimate of the Number of People Affected by the Project (Assuming 4 people Living in Each Unit)

［Number of People］

No.	Section	Case1: Within ROW	Case2: Within COI	Case3: Considering avoiding the impact of structures by changing the alignment
01	Sofoline-Santasi	892	352	268
02	Santasi-Ahodwo	708	188	120
03	Ahodwo-Asokwa	100	36	12
Total		1,700	576	400

Source: JICA survey team

[2] Assumed 3.96 persons/household (= 32.83 million/8.3 million households) from Ghana's population of 32.83 million and 8.3 million households in 2021. Referred to World Bank survey and other survey.
https://www.statista.com/statistics/1275442/number-of-households-in-ghana/#:~:text=In%202021%2C%208.3%20million%20households,conducted%20its%20previous%20population%20census.

2.3.2.2. Evaluation by Combination Scheme

The results of the study, which calculated the number of affected structure units for the combination proposal, are shown in Table 2-35 to Table 2-38.

The results of the estimation of the number of affected persons in the project show that Combination Scheme-1 (Table 2-36) has 152 persons in Case 3.

On the other hand, Combination Scheme-2 (Table 2-38) has 368 people in Case 3, which is a concern that the project will be JICA Environmental Category A as the number of affected people will be more than 200.

The affected structures are mainly located along the roadside, and although some properties can be seen as commercial uses with the possibility of simple structures, tents, etc., a detailed investigation should be carried out during the future preparatory survey and design phase, as well as avoiding any impact on the structures as appropriate.

Table 2-35 Number of Structure Units Affected by the Project (Combination Scheme-1)

[Nos.]

No.	Combination Scheme-1	Case1: Within ROW	Case2: Within COI	Case3: Considering avoiding the impact of structures by changing the alignment
01	Sofoline-Santasi	8	5	5
02	Santasi-Ahodwo	177	47	30
03	Ahodwo-Asokwa	25	9	3
Total		210	61	38

Source: JICA survey team

Table 2-36 Number of Structure Units Affected by the Project (Combination Scheme-1)

[Nos.]

No.	Combination Scheme-1	Case1: Within ROW	Case2: Within COI	Case3: Considering avoiding the impact of structures by changing alignment
01	Sofoline-Santasi	32	20	20
02	Santasi-Ahodwo	708	188	120
03	Ahodwo-Asokwa	100	36	12
計		840	244	152

Source: JICA survey team

Table 2-37 Number of Structure Units Affected by the Project (Combination Scheme-2)

[Nos.]

No.	Combination Scheme-2	Case1: Within ROW	Case2: Within COI	Case3: Considering Avoiding the Impact of Structures by Changing the Alignment
01	Sofoline-Santasi	223	88	67
02	Santasi-Ahodwo	123	37	25
03	Ahodwo-Asokwa	0	0	0
Total		346	125	92

Source: JICA survey team

Table 2-38 Estimate of the Number of People Affected by the Project (Assuming 4 People Living in Each Unit) (Combination Scheme-2)

[Number of People]

No.	Combination Scheme-2	Case1: Within ROW	Case2: Within COI	Case3: Considering Avoiding the Impact of Structures by Changing the Alignment
01	Sofoline-Santasi	892	352	268
02	Santasi-Ahodwo	492	148	100
03	Ahodwo-Asokwa	0	0	0
Total		1,384	500	368

Source: JICA survey team

CHAPTER 3 Evaluation of Project Effect of the Selected Priority Project

3.1 Selection of the Priority Project for Evaluation of Project Effect

Two (2) combination schemes selected in the 2nd screening were compared, comprehensively evaluating five (5) indicators namely 1) project cost, 2) necessity of land acquisition, 3) the number of houses to be resettled, 4) applicability of Japanese technologies, and 5) project effect. As a result, Combination Scheme-1 was selected as the priority project, which is superior to Combination Scheme-2 in terms of the followings.

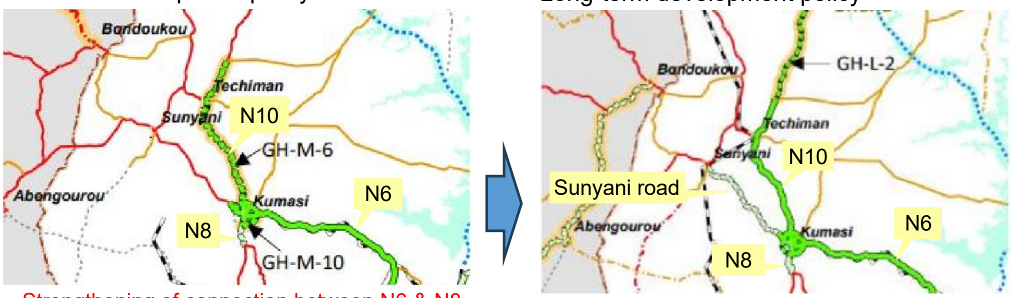
1) Improvement of urban traffic
2) Contribution to development of West Africa Growth Ring Corridor
3) Improvement of accessibility from N8 area to Boankra Inland Port, Kumasi airport, and Accra

Details of the evaluation results are shown in Table 3-1 and Table 3-2.

Combination Scheme-1 is considered to be immediately effective in terms of improvement of urban traffic due to 1) mitigation of traffic congestion at Santasi & Ahodwo intersections and Santasi ~ Asokuwa road sections (3.4km), and 2) reduction of traffic accident at Santasi & Ahodwo intersections. Moreover, as shown in Figure 3-1, Implementation of Combination Scheme-1 is consistent with mid-term development policy of the West Africa Growth Ring Master Plan, strengthening of connection between N6 and N8. Implementation of Combination Scheme-1 is expected to contribute to development of surrounding area along N6 (economic corridor) and N8 (transportation corridor) together and improve development potential of areas surrounding N8. Above all, implementation of Combination Scheme-1, which strengthens connection between N6 and N8, is considered to be indispensable and urgent since it will contribute to improvement of surrounding road network linked to Boankra Inland Port that is defined as important distribution base in the West Africa Growth Ring Corridor Master Plan.

On the other hand, although Combination Scheme-2 is considered to contribute to 1) improvement of urban traffic and 2) contribution to development of West Africa Growth Ring Corridor (strengthening of connection between N8 and N10), the project impact is smaller than that of Combination Scheme-1 in terms of improvement of urban traffic since the scheme targets only one (1) intersection. In addition, Combination Scheme-2 is considered to contribute to development of road network between N8 (transportation corridor) and N10, but there's not much freight transport to northern neighboring countries (Burkina Faso, Mali, Niger) via this route. Moreover, Combination Scheme-2 requires larger-scale resettlement of houses than Combination Scheme-1, which could lead to 1) increase of compensation fees to be shouldered by Ghana government and 2) longer design period due to implementation of IEE/EIA & ARAP.

Mid-term development policy　　　　　　　　Long-term development policy



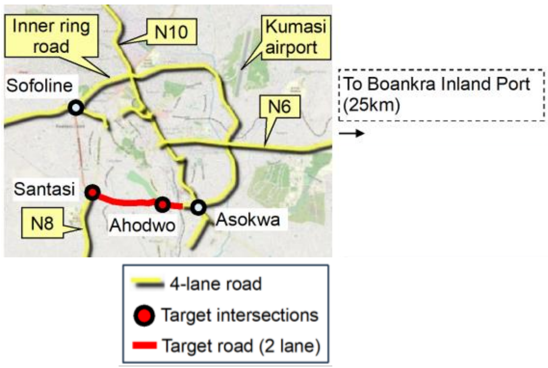
- Strengthening of connection between N6 & N8
  => **Combination Scheme-1**
- High-standardization of N10 (northern Kumasi)
- High-standardization of N8 (southern Kumasi)

- Strengthening of connection between N8 & Sunyani road => **Combination Scheme-2**
- Dualization of Sunyani road

Source：JICA Report for the Project on the Corridor Development for West Africa Growth Ring Master Plan

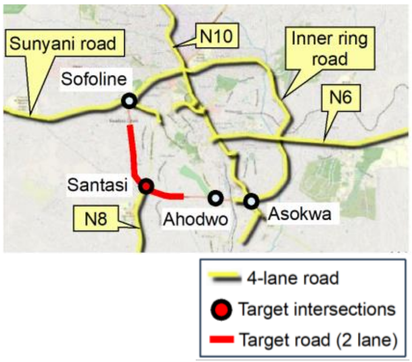
Figure 3-1　Corridor Development Policy

Table 3-1　Outline of Combination Scheme-1

Combination Scheme-1		
Outline	Improvement of Santasi intersection (signalization + addition of slip roads) + Improvement of Ahodwo intersection (signalization + addition of slip roads) + Dualization of Santasi-Asokwa section (3.4km)	
	Santasi intersection  Ahodwo intersection  	
Project cost	About 18 million USD	○
Resstlement	About 40 houses/buildings (Caterory B): Need for IEE & ARAP only	○
Project effect	Contribution to development of West Africa Growth Ring Corridor (strengthening of connection between N8 and N6): The improvement scheme matches "middle-term policy" of West Africa Growth Ring Corridor Master Plan.	○
	Value of total travel time savings (Santasi ~ Asokwa): 6,673,692USD/year	○
	Mitigation of traffic congestion at Santasi & Ahodwo intersections and Santasi~Asokuwa road sections (3.4km), reduction of traffic accident at Santasi & Ahodwo intersections	○
	Improvement of accessibility from N8 area to Boankra Inland Port, Kumasi airport, and Accra	○
Evaluation	(1) Immediate project effect through mitigation of traffic congestion and reduction of traffic accident at 2 intersections (2) Contribution to development of surrounding area along N6 (economic corridor) and N8 (transportation corridor) together (3) Contribution to improvement of surrounding road network linked to Boankra Inland Port (distribution base), which is indispensable and urgent (a part of middle-term policy of West Africa Growth Ring Corridor Master Plan)	○

Source：JICA survey team

Table 3-2 Outline of Combination Scheme-2

Combination Scheme-2		
Outline	Improvement of Santasi intersection (signalization + addition of slip roads) + Dualization of Sofoline-Santasi section (2.5km) + Dualization of Santasi-Ahodwo section (1.2km): deteriorated section only	
	Santasi intersection   Santasi ~ Ahodwo section Severely deteriorated (travel speed: 5km/h)  	
Project cost	About 14 million USD	○
Resstlement	About 90 houses/buildings (Caterory A): Need for EIA & RAP	△
Project effect	Contribution to development of West Africa Growth Ring Corridor (strengthening of connection between N8 and N10) The improvement scheme matches "long-term policy" of West Africa Growth Ring Corridor Master Plan.	△
	Value of total travel time savings (Sofoline ~ Santasi): 5,385,251USD/year	○
	Mitigation of traffic congestion at Santasi intersection, Sofoline~Santasi section (2.5km), and Santasi~Asokuwa road sections (1.2km: deteriorated section only), redustion of traffic accident at Santasi intersections	○
	Improvement of accesibility from N8 area to northern neighboring countries (Burkina Faso, Mali, Niger)	△
Evaluation	(1) Mitigation of traffic congestion and reduction of traffic accident at only 1 intersection (2) Contribution to development of road network between N8 (transportation corridor) and N10, but there's not much freight transport to northern neighboring countries via this route. (3) Need for large-scale resettlement: Possibility of large compensation fees & longer design period due to IEE/EIA & ARAP	△

Source：JICA survey team

3.2 Quantitative and Qualitative Evaluation of Traffic Impact through the Implementation of Priority Improvement Projects

3.2.1. Concept of Traffic Impact Evaluation for Intersection Improvement and Road Widening Projects

The general approach to estimating and quantifying/monetizing the project impacts of the project (conversion of the Santasi roundabout and Ahodwo roundabout to signalized intersections and dualization of Inner Ring Road Santasi ~ Asokwa section) is shown in Table 3-3. Quantification and monetization will be influenced by the availability of basic data, and in cases where data is difficult to obtain, a qualitative assessment will be made.

Table 3-3 Concept of Traffic Impact Evaluation

Type	Concept of Project Impact Evaluation	Methods of Quantification and Monetization	Concept
Economic Benefits	Connectivity to the West Africa Growth Ring (Economic Corridor)	Improved connectivity between NR 8 and (Transportation Corridor) and NR 6 (Economic Corridor)	Qualitative Evaluation
Economic Benefits	Improve accessibility from areas along NR 8	Improved accessibility to Boankra Inland Port (Logistics hub), Kumasi International Airport and Accra (Tema Port)	Qualitative Evaluation
Improve transport access	Implementation of the project will reduce traffic congestion at the intersections, road, and its vicinity, thereby reducing the time to the downtown area and other public facilities.	Prediction of travel speeds and delay times for single road sections that will become 4-lane and roundabouts that will become signalized intersections, using HCS7 analysis software.	Quantitative Evaluation
Travel Time Reduction	The amount of travel time reduction due to the implementation of the project is estimated by multiplying the time value by vehicle type. For the intersection improvement project, the amount of travel time reduction is estimated simply method by (travel speed) x (traffic volume) for each link around the intersection.	Updating the travel time value (GHC/vehicle hour) by vehicle type set in the JICA Kumasi Urban Development MP, and calculating it by travel time.	Monetization
Saving Travel Distance Cost	The amount of travel distance saving due to the implementation of the project is multiplied by the unit cost of travel expenses for each vehicle type to estimate the amount of travel distance saving. However, in the case of intersection improvement projects, since the improvement is made at a point, there is little change in the travel route to avoid traffic congestion, and therefore, in many cases, small reduction in travel distance cost saving is generated.	The travel distance cost (GHC/vehicle-km) by vehicle type and travel speed set in the JICA Kumasi Urban Development MP will be updated to calculate the benefits.	Monetization
Reduction in traffic accidents	Traffic accident reduction benefits are estimated by calculating the social losses from traffic accidents that could be avoided by implementing the project. In the case of intersection improvement projects, the number of traffic accidents that can be avoided is assumed to be the annual average number of traffic accidents that occur in the vicinity of the target intersection.	Collect and analyze existing information on human losses, property losses, and losses due to traffic accident. Establish a loss intensity per accident, but since basic data on the number of accidents themselves has not been developed, this will be a qualitative evaluation.	Qualitative Evaluation
Improve road reliability	The implementation of the project will avoid traffic blockade and detours due to disasters and the resulting time loss will be avoided.	The number of traffic disruptions due to rainfall disasters and the duration of traffic disruptions can be considered as quantitative indicators, but since there is no data on traffic disruptions, this will be a qualitative evaluation.	Qualitative Evaluation
Improved living environment	The project will reduce traffic congestion in the surrounding area and save time when the project site is on the access route from the city center or other hubs to facilities such as hospitals and schools.	The number of facilities located around the target intersection could be used as a quantitative indicator, but since it is difficult to set the starting and ending points and evaluate the time reduction effect of each route, a qualitative evaluation shall be conducted.	Qualitative Evaluation

Source: JICA survey team

3.2.2. Project Impact

3.2.2.1. Improving the Connectivity of the West Africa Growth Ring (Economic Corridor)

In terms of the positioning of the relevant roads in the West Africa Growth Ring M/P, National

Road N6 to National Road N10 are considered to be the backbone transportation infrastructure and development axis of the "Economic Corridor" that will be the center of growth in the country of Ghana. National Road N8 is considered a "Transport Corridor" connecting the Western Coastal Region of Ghana and Kumasi.

The area along N6 in Kumasi (east of the city of Kumasi), Ghana's central "Economic Corridor," is an area with high potential for population, industry, and infrastructure. For example, Kumasi International Airport and KNUST University are located there, and the Boankra Inland Port, the largest logistics hub in inland Ghana, is being developed. Meanwhile, N8 serves as a "Transportation Corridor" between Kumasi and the Western Coastal Region of Ghana, including the Takoradi Port.

The intersection improvement and road widening project proposed in this study is to improve the intersections on the Inner Ring Road where N6 and N8 connect and to widen the related road sections. The Inner Ring Road is expected to promote the development of the West Africa Growth Corridor, the logistics network, and the economic development of Kumasi City by efficiently connecting the "Economic Corridor" of N6 to N10 and the "Transportation Corridor" of N8.

3.2.2.2. Improvement of Accessibility from Areas along N8

Implementation of this project is expected to ease traffic congestion in and around the project area. This will strengthen connectivity between N8 and N6 (southeast section arc of the Inner Ring Road). Connecting N8 (Transportation Corridor) and N6 (Economic Corridor) is expected to unify the two (2) corridors and contribute to the promotion of development in the surrounding area. It is expected to improve the development potential along N8, where is an agricultural area. It is expected to improve accessibility to the Boankra Inland Port and Kumasi International Airport, which are important logistics hubs in the Kumasi Metropolitan Area. The project is expected to be highly effective in contributing to the expansion of the road network around the logistics hubs (connecting N8 and N6).

Using JICASTRAD OD table in JICA Kumasi Urban Development MP, traffic flow from the areas along N8 to the areas along N6 was analyzed. The results showed little increase in traffic flow from the area along N8 to the area along N6. As a reminder, the OD tables used in the above analysis are based on the results of a person-trip survey conducted by WB in 2011 for urban transportation planning purposes. It is considered insufficient for capturing long distance trip. Therefore, it is essential to conduct a roadside interview survey during the Outline design stage to grasp the long-distance traffic flow in order to grasp the effect of improving accessibility from the current areas along N8 through the implementation of this project.

3.2.2.3. Travel Speed Improvement

Traffic congestion in the vicinity of the project area will be improved by the implementation of the project. If the project area is on the access route from the city center or other urban hubs to the airport, bus terminal, etc., it will be possible to shorten the time.

Improvement of traffic access by implementing Combination Scheme-1 and Combination Scheme-2 was evaluated using the HCS7 analysis software to evaluate the improvement of travel speed on the Inner Ring Road. The results of the study are presented in Table 3-4.

In terms of average speed on road segment, the current 18.0 to 30.9 km/h is improved to 50.0 km/h by widening two-lane section to four lanes. This is equivalent to LOS A or LOS B when evaluated by Level of Service (LOS) based on travel speed.

In terms of travel delay at intersections, intersection improvements from roundabouts to signalized intersections and the addition of slip roads will reduce the current 6-minute delay at the Santasi intersection to 1-minute and 4-minute delay at the Ahodwo intersection to 1-minute. Current 29 minutes for the 7130 m section between Sofoline intersection and Asokwa intersection will be reduced to 14.6 minutes and 16.5 minutes for Combination Scheme-1 and Combination Scheme-2, respectively. The project is expected to improve transportation accessibility in the Kumasi Metropolitan Area.

Table 3-4 Travel Time Reduction of Inner Ring Road Sofoline ~ Asokwa Section

Items		Unit	Sofoline-Santasi	Santasi RA	Santasi-Ahodwo		Ahodwo RA	Ahodwo-Asokwa	Total
Distance		m	3,200.0	-	1,600.0	1,050.0	-	1,280.0	7,130.0
Travel Speed	Existing	km/h	24.3	-	18.0	19.2	-	30.9	
	Combination 1	km/h	24.3	-	50.0	50.0	-	50.0	
	Combination 2	km/h	50.0	-	50.0	19.2	-	30.9	
Travel Time	現況	min	7.9	6.0	5.3	3.3	4.0	2.5	29.0
	Existing	min	7.9	1.0	1.9	1.3	1.0	1.5	14.6
	Combination 1	min	3.8	1.0	1.9	3.3	4.0	2.5	16.5

Yellow coloring: Value to be improved by the Project
Note: Average speeds in the current conditions are the results of a travel speed survey conducted in July 2023.
Source: JICA survey team

3.2.2.4. Impact on Travel Time Saving

Monetization calculations were performed on the travel time reduction impact of implementing Combination Scheme-1 and Combination Scheme-2. The results are presented below.

Based on the unit cost of travel time by vehicle type established in the JICA Kumasi Urban Development MP, and assuming that it will change in proportion to GDP per capita in the future, the unit cost of travel time by vehicle type and on a PCU basis was calculated for 2023 and future. The results of travel time unit cost by vehicle type are shown in Table 3-5.

Table 3-5 Travel Time Unit Cost by Vehicle Type and PCU

Year	Car (US$/h)	Taxi (US$/h)	Bus (US$/h)	Truck (US$/h)	PCU (US$/h)	GDP per Capita (US$)
2012	2.32	0.72	0.21	2.37	1.56	1,537
2013	3.45	1.07	0.31	3.53	2.31	2,282
2014	2.93	0.91	0.27	3.00	1.97	1,943
2015	2.58	0.80	0.24	2.64	1.73	1,711
2016	2.87	0.89	0.26	2.94	1.92	1,900
2017	3.02	0.94	0.28	3.09	2.02	1,999
2018	3.29	1.02	0.30	3.37	2.21	2,180
2019	3.27	1.02	0.30	3.35	2.19	2,168
2020	3.29	1.02	0.30	3.36	2.20	2,177
2021	3.64	1.13	0.33	3.72	2.44	2,411
2022	3.29	1.02	0.30	3.36	2.20	2,176
2023	3.04	0.94	0.28	3.11	2.04	2,015
2024	3.04	0.94	0.28	3.11	2.04	2,013
2025	3.15	0.98	0.29	3.22	2.11	2,086
2026	3.28	1.02	0.30	3.36	2.20	2,173
2027	3.43	1.06	0.31	3.51	2.30	2,270
2028	3.59	1.11	0.33	3.67	2.40	2,376
2029	3.70	1.15	0.34	3.78	2.48	2,449
2030	3.81	1.18	0.35	3.90	2.55	2,524
2031	3.93	1.22	0.36	4.02	2.63	2,603
2032	4.05	1.26	0.37	4.15	2.72	2,684
2033	4.18	1.30	0.38	4.28	2.80	2,769
2034	4.32	1.34	0.39	4.41	2.89	2,857
2035	4.45	1.38	0.41	4.56	2.98	2,949
2036	4.60	1.43	0.42	4.70	3.08	3,044
2037	4.75	1.47	0.43	4.86	3.18	3,143
2038	4.90	1.52	0.45	5.02	3.29	3,247
2039	5.07	1.57	0.46	5.18	3.39	3,354
2040	5.23	1.63	0.48	5.35	3.51	3,466
2041	5.41	1.68	0.49	5.53	3.62	3,582
2042	5.59	1.74	0.51	5.72	3.75	3,703
2043	5.78	1.80	0.53	5.92	3.87	3,829
2044	5.98	1.86	0.55	6.12	4.01	3,960
2045	6.19	1.92	0.57	6.33	4.15	4,097

Source: JICA survey team

The travel time between Sofoline intersection and Asokowa intersection, approximately 7130 m, for Combination Scheme-1 and Combination Scheme-2 was calculated to determine the travel time savings impact. As shown in Table 3-6, under the existing conditions, the delay time at the intersection is as much as 10 minutes at two intersections, taking 29 minutes overall. As shown in Table 3-6, the project will improve the travel speed of the project section to 50km/h, and the delay time at the Santasi intersection and Ahodwo intersection will be reduced from six (6) and four (4) minutes, respectively, in the existing condition to about 1 minute, respectively. As a result, between Sofoline intersection to Asokowa intersection, travel time would be reduced to 14.6 minutes for Combination Scheme-1 (reduction of 14.4 minutes) and 16.5 minutes for Combination Scheme-2 (reduction of 12.5 minutes), respectively.

Table 3-6 Impact on Travel Time Reduction (Sofoline ~ Asokowa, 7130m)

	Travel Time (min)	Saving Time (min)	Annual Travel Time*PCU (PCU hour/year)	Annual Saving Time*PCU (PCU hour/year)	Annual Impact (US$/year)
Existing	29.0		5,680,901		
Combination 1	14.6	14.4	2,409,484	3,271,418	6,673,692
Combination 2	16.5	12.5	3,041,610	2,639,291	5,385,251

Source: JICA survey team

3.2.2.5. Impact on Travel Distance Cost Saving

Monetization calculations were performed to determine the travel distance cost savings of implementing Combination Scheme-1 and Combination Scheme-2. The results are shown in Table 3-7.

Based on the travel distance unit cost by vehicle type set in the JICA Kumasi Urban Development MP, the travel distance unit cost and fixed cost by PCU-based travel speed are calculated in 2023 and future, assuming that the travel distance unit cost will change in proportion to GDP per capita in the future.

Table 3-7 Travel Distance Unit Cost and Fix Cost

Year	Travel Distance Unit Cost (USD/pcu/km)							Fix Cost (USD/pcu/hour)
	5-10 km/h	10-15 km/h	15-20 km/h	20-25 km/h	25-30 km/h	30-35 km/h	35km/h & above	
2012	0.477	0.451	0.424	0.411	0.398	0.384	0.371	0.673
2013	0.708	0.669	0.630	0.610	0.590	0.571	0.551	0.999
2014	0.603	0.570	0.536	0.519	0.503	0.486	0.469	0.851
2015	0.531	0.502	0.472	0.457	0.443	0.428	0.413	0.749
2016	0.590	0.557	0.524	0.508	0.491	0.475	0.459	0.832
2017	0.620	0.586	0.551	0.534	0.517	0.500	0.483	0.875
2018	0.677	0.639	0.601	0.583	0.564	0.545	0.526	0.955
2019	0.673	0.635	0.598	0.579	0.561	0.542	0.523	0.949
2020	0.676	0.638	0.601	0.582	0.563	0.544	0.525	0.953
2021	0.748	0.707	0.665	0.644	0.624	0.603	0.582	1.056
2022	0.675	0.638	0.600	0.582	0.563	0.544	0.525	0.953
2023	0.625	0.591	0.556	0.538	0.521	0.504	0.486	0.882
2024	0.625	0.590	0.555	0.538	0.521	0.503	0.486	0.881
2025	0.647	0.612	0.576	0.558	0.540	0.522	0.504	0.914
2026	0.674	0.637	0.599	0.581	0.562	0.543	0.524	0.951
2027	0.705	0.665	0.626	0.607	0.587	0.568	0.548	0.994
2028	0.737	0.696	0.655	0.635	0.615	0.594	0.574	1.041
2029	0.760	0.718	0.676	0.654	0.633	0.612	0.591	1.072
2030	0.783	0.740	0.696	0.675	0.653	0.631	0.609	1.105
2031	0.808	0.763	0.718	0.696	0.673	0.651	0.628	1.140
2032	0.833	0.787	0.740	0.717	0.694	0.671	0.648	1.176
2033	0.859	0.812	0.764	0.740	0.716	0.692	0.668	1.213
2034	0.887	0.837	0.788	0.764	0.739	0.714	0.690	1.251
2035	0.915	0.864	0.813	0.788	0.763	0.737	0.712	1.291
2036	0.945	0.892	0.840	0.814	0.787	0.761	0.735	1.333
2037	0.976	0.921	0.867	0.840	0.813	0.786	0.759	1.377
2038	1.008	0.952	0.896	0.868	0.840	0.812	0.784	1.422
2039	1.041	0.983	0.925	0.896	0.867	0.838	0.810	1.469
2040	1.076	1.016	0.956	0.926	0.896	0.866	0.837	1.518
2041	1.112	1.050	0.988	0.957	0.926	0.895	0.865	1.569
2042	1.149	1.085	1.022	0.990	0.958	0.926	0.894	1.622
2043	1.188	1.122	1.056	1.023	0.990	0.957	0.924	1.677
2044	1.229	1.161	1.092	1.058	1.024	0.990	0.956	1.734
2045	1.271	1.201	1.130	1.095	1.060	1.024	0.989	1.794

Source: JICA survey team

The PCU hours and PCU kilometers between Sofoline intersection and Asokowa intersection (approximately 7130 m) for Combination Scheme-1 and Combination Scheme-2 were calculated to determine the travel distance cost savings. Under the existing conditions, there are delays at intersections and reduced travel speeds on the two-lane section of the Inner Ring Road. The travel speeds are increased by implementation of the Project and Total PCU travel time would be reduced by 3.3 million PCU hours/year and 2.6 million PCU hours/year for Combination 1 and 2, respectively. On the other hand, the travel PCU-km itself will not change with or without the implementation of the project, but the travel speed will increase, resulting in a lower unit cost of travel, which will generate benefits. The monetary benefits are $4.07 million/year and $4.14 million/year for Combination Scheme-1 and Combination Scheme-2, respectively. The higher benefit amount for Combination Scheme-2 is due to the longer distance of dualization section.

Table 3-8 Travel Distance Cost Saving (Sofoline ~ Asokowa, 7130m)

	Travel Time (PCU hour)	Travel Distance (PCU km)	Annual Cost(USD/year)			Annual benefit (USD/year)
			Fix Cost	Distance Cost	Total	
Existing	5,680,901	58,334,254	5,010,555	31,287,778	36,298,332	-
Combination 1	2,409,506	58,334,254	2,125,184	30,105,670	32,230,854	4,067,479
Combination 2	3,041,610	58,334,254	2,682,700	29,468,328	32,151,028	4,147,304

(annual benefit) = (total current cost) - (total cost of project case)

Source: JICA survey team

3.2.2.6. Traffic Accident Reduction

“The City of Kumasi traffic accident report for the 2020-2021” shows that the Santasi intersection on the Inner Ring Road had 17 accidents and one (1) fatality. The number of traffic accidents at Ahodwo intersection and the widened road section of the Inner Ring Road were not disclosed. It is expected that the project will reduce the number of traffic accidents since traffic safety facilities such as traffic signals, pedestrian crossings, and traffic signs will be installed along with the road improvement project. However, the lack of statistical information on the number of accidents and the fatality is making that it impossible to analyze the relationship between traffic volume and the number of traffic accidents, make it difficult to quantify the impact of the project.

Table 3-9 Top 10 Black Spots of Traffic Accident in Kumasi

Number of Accident（2020-2021）			Number of Fatalities（2020-2021）		
No.	Name of intersection/ junction/ roundabout	Number of crashes	No.	Name of intersection/ junction/ roundabout	Number of deaths
1	Boadi junction (N6)	40	1	Anloga junction (intersection) (N6)	7
2	Anloga junction (intersection) (N6)	27	2	Boadi junction (N6)	5
3	KNUST Police Station roundabout (N6)	27	3	Amakom traffic intersection	3
4	Abrepo junction (intersection)	26	4	Krofuom traffic intersection	3
5	Suame roundabout	26	5	Abrepo junction (intersection)	2
6	Siloam junction	23	6	Bekwai roundabout	1
7	Krofuom traffic intersection	18	7	Labour roundabout	1
8	Santasi roundabout	17	8	Santasi roundabout	1
9	Sofoline interchange	13	9	Siloam junction	1
10	Bekwai roundabout	12	10	Sofoline interchange	1

Source：KUMASI Road Safety Annual Report 2021

3.2.2.7. Road Reliability Improvement

Ahodwo intersection targeted in this project is less likely to be affected by flood inundation because the elevation of the intersection is higher than the surrounding topography and it is approximately 580 m away from the river. Santasi intersection is also located approximately 250m away from the river, and the elevation of the intersection is approximately 8m higher than that of the river. The area around the two (2) intersections can be said to be under relatively favorable drainage conditions.

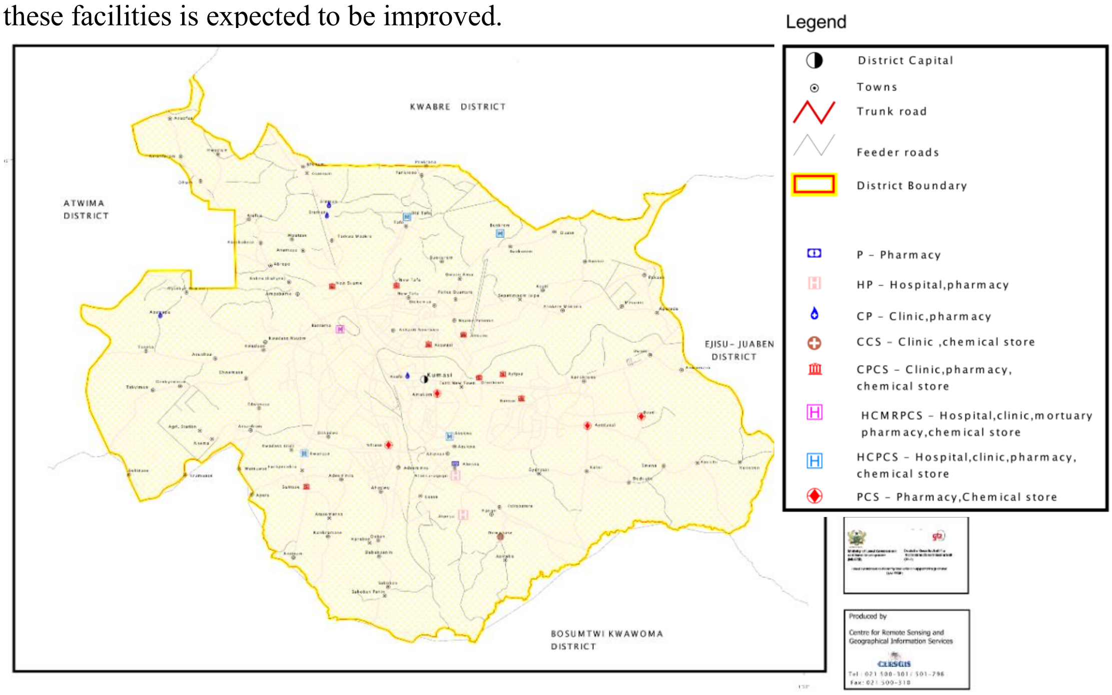
On the other hand, there is a small river in the widening section of the Inner Ring Road, although no road closures or other obstacles due to rainfall have been observed, insufficient road surface drainage has caused pavement damage and reduced vehicle travel speed.
In the section where this project will be implemented, there is no statistical information on the degree of travel speed reduction due to rainfall disasters, the number of cases of roadblocks, and the duration of roadblocks, so it is difficult to quantify these factors. However, the implementation of this project is expected to improve road reliability because road drainage facilities such as ditches, manholes, and culverts will be constructed at the same time.

Specifically, the drainage function of the road will be improved, lowering the risk of reduced travel speeds due to rainfall, and the risk of pavement damage will be lowered, reducing the economic losses associated with repairs.

3.2.2.8. Improved Living Environment

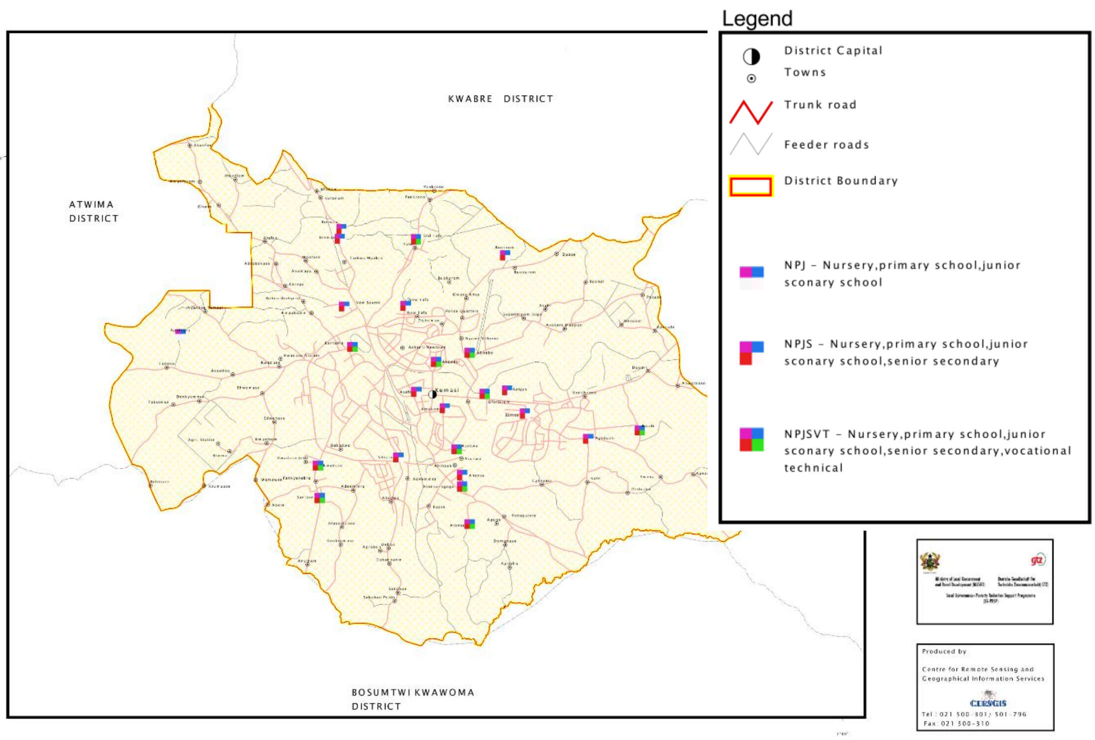
Implementation of this project is expected to improve access to urban living facilities such as hospitals and schools by reducing traffic congestion and improving traffic safety. As shown in Figure 3-2, Kwadaso Hospital is located near the Santasi intersection. In addition, as shown in

Figure 3-3, Nhiaso Elementary, Middle, and High Schools are located near the Ahodwo intersection. In addition, commercial facilities are located along Inner Ring Road, and access to these facilities is expected to be improved.



Source：KMA

Figure 3-2　Medical Facility Distribution in Kumasi



Source：KMA

Figure 3-3　Educational Facility Distribution in Kumasi

CHAPTER 4 Study on Applicable Japanese Technologies & Rapid Construction Schemes

4.1 Applicable Japanese Technologies & Rapid Construction Schemes

4.1.1. Precast Large-scale Box Culvert

4.1.1.1. Construction Situation of Large-scale Box Culvert by Local Contractors

Figure 4-1 shows construction situation of 3-cell box culvert (about 12m long) by local contractors at the arterial road section between Accra and Kumasi. At this construction site, a detour road is provided next to the existing road since there's no buildings nearby and enough space is available for it. However, the road section under construction has been a bottle neck of the traffic because the alignment of the detour is sharply curved and unpaved that make the traffic slow down. What is worse, construction of the cast-in-place concrete box culvert has been taking long time and disturbing smooth traffic for a long time.

3-cell box culvert | Construction of cast-in-place concrete box culvert | Situation of the detour road

Source：JICA survey team

Figure 4-1 Construction Situation of Large-scale Box Culvert by Local Contractors

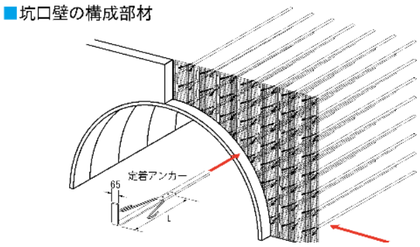
4.1.1.2. Shortening Construction Period by Application of Japanese Technology

There is an existing 2-cell box culvert (about 6.5m long) at Santasi~Ahodwo section of the Inner Ring Road, which is a part of the priority project selected in this JICA survey. If the box culvert was replaced by cast-in-place concrete box culvert as explained above, the location could be the bottleneck of traffic during the construction work. In consideration of such the circumstance, shortening construction period by application of precast large-scale box culvert is recommended. As an example of precast large-scale box culvert, precast arch culvert method is applicable. One example of the precast arch culvert method, TECH SPAN Method, is shown in Figure 4-2.

The TECH SPAN Method is a precast arch culver method that is formed by arch-shaped concrete members supported by three (3) hinges. The method is applicable up to the maximum span length of 20m and the maximum earth cover depth of 20m. The method is likely to be economical in cases that the method is applied instead of bridges or box culverts whose length are over 12m. As shown in Figure 4-2, the TECH SPAN Method is a structure in combination of precast arch member and embankment inside in it as one structure. The wall member of the arch culvert is usually designed as reinforced earth. Construction speed of the precast arch member installation is 10m per day that contributes to remarkable reduction of construction period, compared to those of bridges and cast-in-place box culverts. One of the major features of the method is that the arch culvert doesn't have lower slab to be embed into under the riverbed, the construction doesn't require temporary realignment of the existing river under the structure, which leads to remarkable labor-saving of the construction work.

Appearance of arch culvert

Precast arch-shaped member



Reinforced earth structure inside the arch culvert

Source: Hirose co. ltd.

Figure 4-2 Overview of the Arch Culvert Method (TECH SPAN Method)

4.1.2. Solar Traffic Lights

4.1.2.1. Necessity of Solar Traffic Lights

One of the Japanese technologies that could be effective for Ghana's road sector is solar traffic light whose power is generated by solar panels attached to the traffic light poles. Traffic lights often get unavailable due to power outages in Accra, which has been becoming a major social issue concerned by the public. Considering the situation of traffic disruptions and congestion due to unavailability of traffic lights, introduction and trial of solar traffic lights is recommended. Introduction of the traffic lights with solar panel and generator will contribute to remarkable power consumption of traffic lights in normal times and continuous function of traffic lights in times of disaster or power outages.

4.1.2.2. Example of Solar Traffic Lights in Japan

Solar traffic lights were installed for the first time in Japan for a trial purpose in 2011 when large-scale power outages occurred due to the Great East Japan earthquake in collaboration of a traffic lights system company with Kanagawa Prefectural Police. Figure 4-3 shows an example of solar traffic lights in Kanagawa Prefecture of Japan.

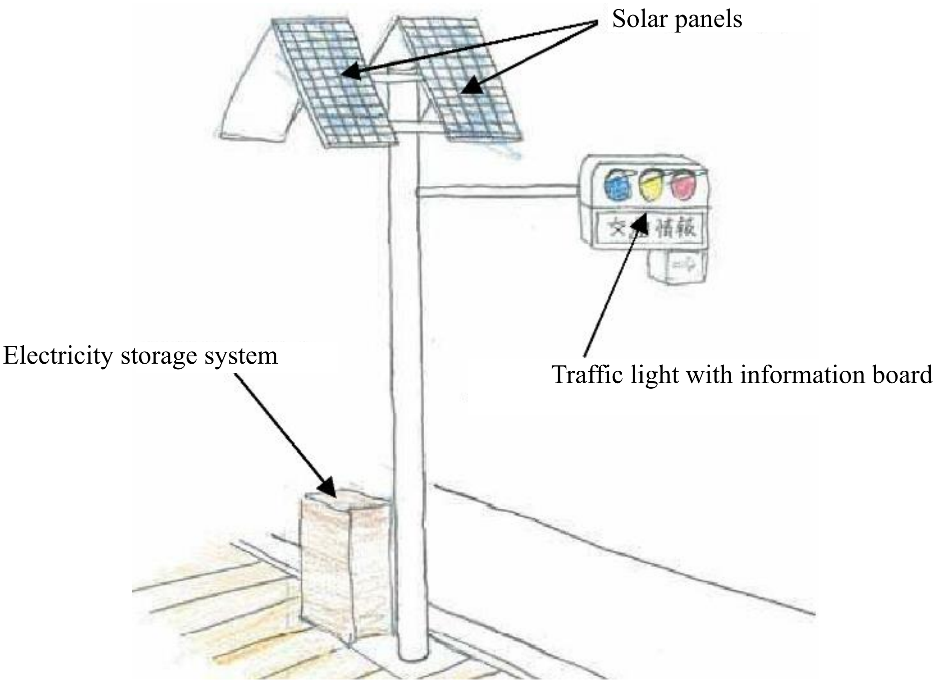
Appearance of solar traffic light | Solar panel | Solar generator

Source: excite blog (https://funatowato.exblog.jp/16354232/)

Figure 4-3 Example of Solar Traffic Lights in Kanagawa Prefecture of Japan

Moreover, overview of traffic lights with solar power generation, which is proposed by the Japan Civil Engineering Consultants Association (JCCA), is explained below. JCCA proposes establishment of self-independent solar traffic lights that generates power necessary for traffic light function, intersection by intersection, in order to reduce power consumption and store electricity in normal times and use the stored electricity in times of disaster. Major features of the traffic lights are as follows.

- Although solar traffic lights operation is affected by weather conditions, with the power storage function, the solar traffic lights are able to operate in the night-time and cloudy/rainy conditions, which contributes to reduction of power consumption of the traffic lights.
- The solar traffic lights are to be operated by external power supply only when enough power can’t be generated due to continuous cloudy/rainy conditions.
- Solar traffic lights are able to sustainably operate using stored electricity even in the time of power outages, which contributes to occurrence of heavy traffic congestion and assistance for smooth traffic of emergency vehicles.
- If the traffic lights are designed to have information boards that show letters/messages such as “impassable” or send detailed information to nearby vehicles by using visible light communication technology, it is possible to instruct drivers to go to the right directions. Also, if the solar traffic lights are installed in a wide area networking with other traffic lights, the traffic lights can be appropriately controlled while emergency vehicles such as ambulances or police cars are passing nearby.



Source: JCCA

Figure 4-4 Solar Traffic Lights Proposed by JCCA

4.2 Recommendation for Similar Intersection Improvement Projects in Other Countries

4.2.1. Rapid Construction Schemes from the View of Construction Methods

In approach to rapid construction schemes from the view of construction methods, the bridge structures are basically studied to be applicable to rapid construction methods in consideration of reduction of structural members, application of precast members or rigid frame structures. Table 4-1 summarizes overview of typical rapid construction methods.

Table 4-1 Overview of Typical Rapid Construction Methods

Type of Works		Rapid Construction Methods
Supers-truture	Steel girders	Erection of large block, rapid launching erection, Erection with movable bent supports
	PC girders	Erection of large precast segment block
	Composite floor slab bridge	Precast composite floor slab bridge (incorporation of steel beams into concrete deck slab)
Deck slab		Composite floor (no need for foam work), precast PC plates (no need for foam work), precast PC deck slab, steel deck
Substr-ucture	Pier coping	PC precast coping, steel coping
	Pier column	Precast column (Ex. steel pier)
	Footing	Precast footing (Ex. steel footing)
Foundation		Precast piles (Ex. steel pipe piles), 1 pile per 1 pier (Ex. large-diameter bored pile), precast large-diameter pile (Ex. caisson foundation)
Superstructure + substructure		Rigid frame structure of superstructure with substructure & erection of large block (Ex. rigid frame structure of steel girders with steel pier columns)
Approach road		Precast retaining wall, lightweight embankment

Source: JICA survey team

In general, the more steel materials are applied, the shorter construction periods become although construction cost including transportation cost increases in proportion to the amount of steel material. Also, in case of application of precast concrete members, construction cost increases due to transportation cost of the precast concrete members from the third countries since there's usually no local fabricators available in the target country or neighboring African countries. Therefore, if rapid construction schemes are studied from the view of construction methods, targeting intersection improvement in western African countries, the construction costs are considered to be higher than those in Japan. Based on the result of this JICA survey, there could be many cases that rapid construction schemes for intersection improvement to flyover can't be implemented due to the budget constraints of Japan's grant aid project.

On the basis of the above study result, precast large-scale box culvert was applied as a part of dualization of 2-lane road instead of construction of flyover using rapid construction methods. In conclusion, it is considered to be effective in similar projects of other west African countries to minimize the project scale within the range of allowable project effect and utilize precast structures.

4.2.2. Rapid Construction Scheme from the View of Construction Planning

As explained above, since there's limitation in application of rapid construction methods in terms of budget constraints, it is proposed to study minimizing the construction periods utilizing Building Information Modeling (BIM), creation of 3D models, in the design stage in order to improve construction productivity using the 3D models in the construction stage.

As shown in Figure 4-5, with the widespread use of BIM in civil engineering field of Japan, construction planning of bridges are likely to be studied utilizing 3D modeling by BIM. Specifically, regarding construction planning of bridges, as shown in Table 4-2, BIM has been utilized for 1) overall construction planning, 2) study on arrangement of temporary equipment & construction equipment, 3) construction planning & safety management, 4) construction planning of superstructures, 5) Simulation of girder erection, 6) checking of conflict in arrangement of substructure rebars, 7) Inspection of constructed substructure locations. Considering these examples, BIM is effective for shortening construction periods in terms of 1) shortening time of construction planning, 2) shortening time necessary for consensus building with stakeholders, and 3) avoiding rework during construction and troubles.

Construction planning in urban areas crowded with buildings, such as the area around Anloga intersection studied in this survey, where neighboring construction and residents agreement are required, utilization of BIM could largely contribute to shortening construction periods. Therefore, In the future intersection improvement projects, it is desirable to utilize BIM and crate 3D models of structures and pass the data files to construction stages in order for contractors to utilize the 3D models for construction planning in a smooth way.

Construction planning of substructures in an urban area

Construction planning of superstructures in an urban area

Source: BIM/CIM case studies (MLIT)

Figure 4-5 Examples of Construction Planning of Bridge Utilizing BIM

Table 4-2 Examples of Productivity Improvement Using BIM in Bridge Construction Projects

BIM/CIM Cases	Outline and Effectiveness
Overall construction planning	By visualizing complicated construction steps of intersection flyover structure, main road, on-ramp, and off-ramp, validity of the construction plans can be confirmed easily. Also, issues to be considered can be smoothly transmitted to the subsequent construction steps.
Study on arrangement of temporary equipment & construction equipment	By studying arrangement of heavy equipment, arrangement of water tanks and sprinkler trucks, the number of steel plates for stability, parking locations, using BIM, image of the construction yard was easily shared with the construction workers.
Construction planning & safety management	Visualization of construction planning utilizing BIM contributed to identification of inconsistency on drawings, clarification of structural details, and shortening of time of meeting among construction workers. Also, it supported workers to understand the construction safety briefing and take appropriate safety measures.
Construction planning of superstructures	Visualization of construction yard, obstacles, work range of construction machines in planning of girder erection, utilizing BIM, contributed to identification of all the obstacles related to construction planning.
Simulation of girder erection	Carrying out simulation of girder erection in the crowded urban area utilizing BIM contributed to avoidance of conflict between supporting elements of the crane and drainage ditches.
Checking of conflict in arrangement of substructure rebars	Visualization of high-density rebar arrangement utilizing BIM contributed to reduction of workdays to check the rebar arrangement on drawings.
Inspection of constructed substructure locations	Modeling of the abutment and surrounding terrain using BIM enabled construction workers to check positioning of the abutment footing underground as specified on the drawing without going to the site. It contributed to reduction of construction period.

Source: JICA survey team summarized the table based on BIM/CIM case studies (MLIT)

4.2.3. Collaboration of at-grade Intersection Improvement Project with ITS-related Projects

In case that at-grade intersection improvement schemes are studied like this JICA survey, it is considered to be effective to collaborate with ITS-related project. In addition to installation of solar traffic lights for sustainable power supply as proposed in this JICA survey, establishment of traffic control centers is expected to contribute to mitigation of chronic traffic congestion and optimization/enhancement of road management. As an example of ITS project in Accra, In 2019, AFD assisted introduction of traffic lights system to priority control of bus operation in wide area of Amasaman corridor, which the main route of Quality Bus Service in collaboration with the WB project for introduction of Quality Bus Service.

For your reference, in the report of "Data collection survey for ITS in African region" (JICA, 2021), ITS project in Kumasi is proposed as below. In the survey, two (2) ITS-related projects (short-term project and middle-term project) are proposed for development of traffic lights system as shown in Table 4-3.

Table 4-3 Proposed ITS-related Projects in Kumasi (Short-term and Middle-term)

Short-term project

Project Name	Outline	Implementing Agency
Project for development of unified traffic lights control system in corridors of Kumasi	- Introduction of unified traffic lights control system for corridor-based control in main corridors of Kumasi - As for existing roundabouts with innovative traffic lights installed, appropriate way to integrate them into the unified traffic lights control system is to be studied. - It is essential to establish the institutional framework for traffic lights operation since traffic lights on one corridor are managed by several different agencies.	DUR

Middle-term project

Project Name	Outline	Implementing Agency
Project for development of traffic lights control system in a wide area of Kumasi	- Project aims to develop traffic lights control system for corridor-based control in a wide area of Kumasi. - Introduction of probe cars for data collection/ utilization and reduction of the number of traffic volume measuring device - Establishment of the traffic control center	DUR

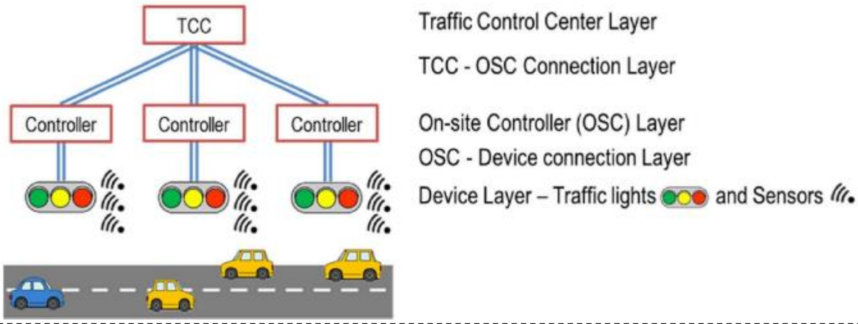
Source: Report of "Data collection survey for ITS in African region" (JICA, 2021)

As shown in Figure 4-6, 36 traffic lights are installed in road network of Kumasi as of 2021. These traffic lights were installed for the purpose of safety measures at the intersections such as managing increase of vehicle/pedestrian traffic and reduction of traffic accidents. However, the traffic lights are controlled individually, and unified traffic control system hasn't been introduced yet.

Source: Report of "Data collection survey for ITS in African region" (JICA, 2021)

Figure 4-6 Locations of Existing Traffic Lights in Kumasi

On the basis of status of traffic lights installation in Kumasi, in the JICA ITS study introduced above, introduction of "unified traffic lights control system" shown in Figure 4-7. In this case, there's a necessity of establishment of traffic control centers that control each existing traffic light signal.



Typical traffic lights system can be described as the simplified structure consisting of 5 layers (3 equipment layers + 2 device layers) as shown in the above figure.
- Equipment layer (3 layers): TCC, controller, and device
- Device layer (2 layers): Traffic lights and signal

Source: Report of "Data collection survey for ITS in African region" (JICA, 2021)

Figure 4-7 Schematic Diagram of Unified Traffic Lights Control System

CHAPTER 5 Major Issues to be Considered in JICA Preparatory Survey

5.1 Major Issues to be Considered

At the meeting with MRH/DUR on 19 October 2023, MRH requested that the following three (3) issues be considered in design of the selected priority project. However, considering budget and time constraints of JICA data collection survey, these issues were determined to be addressed in the subsequent JICA preparatory survey.

- Determination of traffic growth rate based on result of Origin-Destination (OD) survey for future traffic volume forecast
- Securing of 8m-width for median in consideration of future expansion of carriageway lanes
- Study on milder-slope road profile at the road section around Ahodwo intersection

On 19th October 2023, it was found during the meeting that GRDA railway development project was planned around the Subi river whose alignment crosses Ahodwo ~ Asokwa section of the Inner Ring Road (0.8km), which is the target section of Combination Scheme-1. As already explained in Chapter 2, the GRDA railway project plans to raise profile of the railway line as a countermeasure against flooding around the Subi river, and the profile of the Inner Ring Road, which crosses over the railway line, is planned to be raised accordingly. The issue was also determined to be resolved in the subsequent JICA preparatory survey since details of the GRDA railway project around the Inner Ring Road, including the implementing agency and budget, hasn't been fixed yet at the moment.

On 24th January 2024, it was pointed out by MRH that the monuments installed at Santasi intersection and Ahodwo Intersection were very significant, and they have to be appropriately relocated and taken care of during the time of construction. Therefore, at the time of JICA preparatory survey, the monuments have to be appropriately relocated in coordination with the DUR Kumasi office.

Furthermore, in consideration of the result of the JICA data collection survey conducted up until now, it is essential to investigate logistics situation from National Road No.8 (N8) and N.10 (N10) to northern neighboring countries such in Sahel region. Therefore, at the time of JICA preparatory survey, Origin-Destination (OD) survey has to be conducted at certain locations of N6, N8, N10, targeting long-haul trucks for interview. Also, it is necessary to obtain international transit data at the Takoradi port in order to analyze origin and destination of cargos transported by the trucks.

5.2 Determination of Traffic Growth Rate based on Result of OD Survey

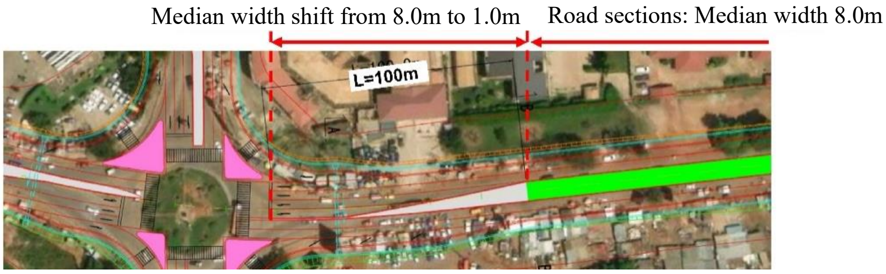
MRH asked a question regarding setting basis of traffic growth rate for future traffic demand forecast and requested that the traffic growth rate should be set based on result of Origin-Destination (OD) survey instead of setting the rate by vehicle type. The issue is to be considered in the subsequent JICA preparatory survey, conducting OD survey, since it can't be taken care of in the ongoing JICA data collection survey due to budget and time constraints.

5.3 Securing of 8m-width for median in consideration of future expansion of carriageway lanes

In consideration of future expansion of carriageway lanes (increase of the number of lanes), the median width was set as follows and agreed with MRH/DUR at the meeting held on 19th October 2023.

- Median width at general road sections: 8.0m
- Median width shift at intersections: Shifting from 8.0m to 1.0m

In addition, it should be noted that the median width was shifted from 8.0m to 1.0m at 100m away from the intersections in order to minimize the impact on the surrounding environment since the scale of the intersection and the impact becomes too large provided that the median width remains 8.0m within the intersections. Supplementarily, incase that BRT lanes are installed along the Inner Ring Road, BRT traffic can be prioritized by controlling the traffic signal using ITS-related traffic lights such as smart traffic lights applied in Japan.

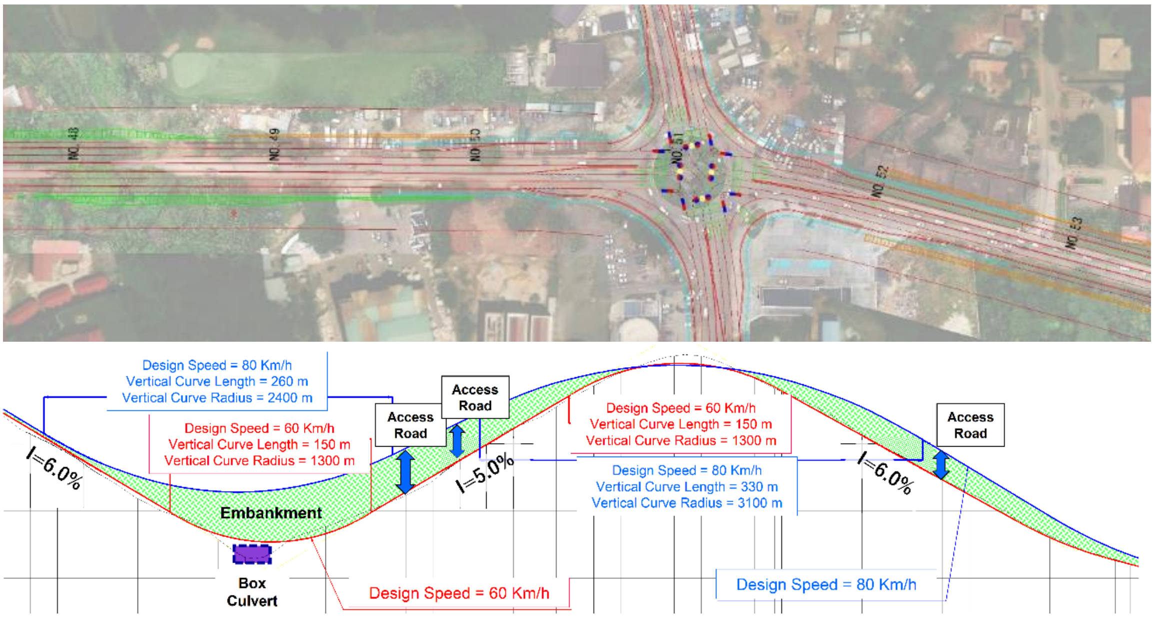


Source：JICA survey team

Figure 5-1 Median Width Shift at Intersections

5.4 Study on Milder-slope Road Profile at the Road Section around Ahodwo Intersection

MRH requested that milder-slope road profile at the road section around Ahodwo intersection should be studied by changing the terrain through cutting and filling as shown in Figure 5-2 in order to reduce traffic accidents of large trucks in the steep-slope road section. Likewise, the issue is to be considered in the subsequent JICA preparatory survey since it is difficult to conduct topographic survey and get approval of MRH for study on the road profile in the ongoing JICA data collection survey due to budget and time constraints.



Source：JICA survey team

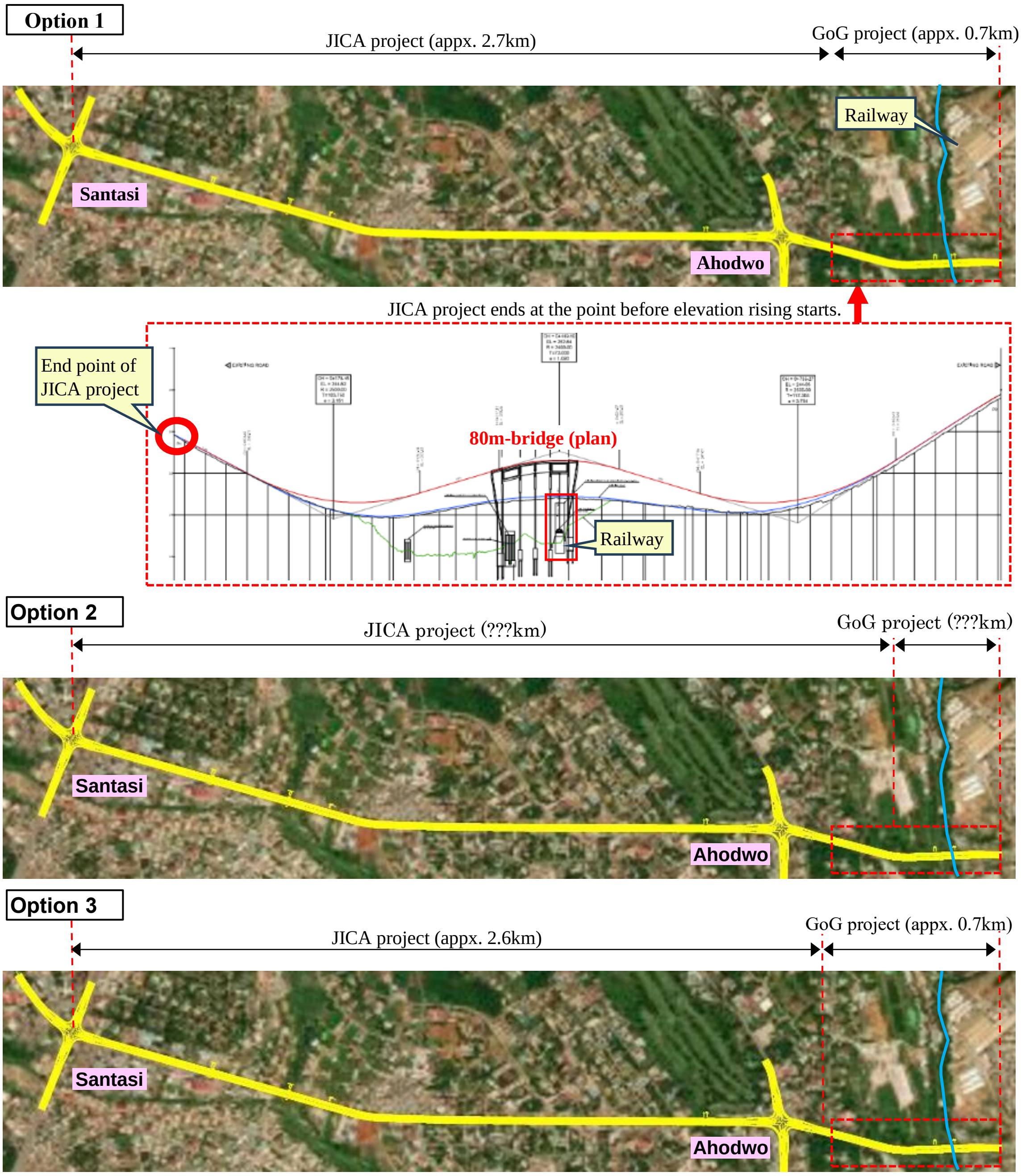
Figure 5-2 Study on Appropriate Road Profile at the Road Section around Ahodwo Intersection

5.5 Coordination with the GRDA Railway Development Project for Elevating Inner Ring Road Section

At the coordination meeting with MRH/DUR and GRDA on 1 November 2023, status of the GRDA railway development project was confirmed, and the project demarcation and fund were discussed. Then, JICA survey team proposed the following three (3) options regarding approach to raising profile of the Inner Ring Road section as shown in Figure 5-3.

- Option-1: Raising profile of Inner Ring Road section is implemented by the fund of Government of Ghana (as GoG project), and JICA project covers the road section up to the point of existing ground level where the road profile begins to rise; 0.7km of the Inner Ring Road section is to be excluded from scope of the JICA project.
- Option-2: In case that raising profile of Inner Ring Road section can't be implemented by GoG fund, JICA survey team and MRH/DUR continue discussion on the scope of the JICA project as much as possible within the budget allowed; the scope of this option could be the same as that of Option-1.
- Oprion-3: In case that the Project Plan of raising profile of the Inner Ring Road section is not fixed or finalized, JICA project ends at the end of the Ahodwo intersection. The requirement is that dualization of the remaining Inner Ring Road section has to be implemented by GoG project.

It is difficult to clarify the project demarcation among JICA, MRH/DUR and GRDA during the time of the ongoing JICA data collection survey in that this issue was suddenly found out at the closing stage of the JICA survey, and in that the Project Plan of raising profile of the Inner Ring Road section hasn't been fixed yet at the moment. Therefore, the project demarcation is to be determined in coordination with MRH/DUR & GRDA in the subsequent JICA preparatory survey.



Source : JICA survey team

Figure 5-3 Approach to Raising Profile of the Inner Ring Road Section