The Project for Urban Mobility Improvement in Kigali

The 6th Working Group 2 (2. Basic Design of Intersections (Civil Works))

22nd February 2023

AGENDA

Part A: Design Approach

1. General
- 1.1 Objective of Intersection Design
- 1.2 Target Intersections
- 1.3 Scope of Intersection Design
- 1.4 Workflow of Intersection Design

2. Design Conditions
- 2.1 Design Standard
- 2.2 Road Classification
- 2.3 Design Speed and Design Criteria

3. Design Traffic Volumes
- 3.1 Target Year
- 3.2 Design Traffic Volumes

4. Geometric Design
- 4.1 Basic Policy
- 4.2 Geometric Details

5. Consideration of DBL*

*Dedicated Bus Lane Project

Part B: Application to Each Intersection

Part A: Design Approach

1. General

1.1 Objective of Intersection Design

To prepare improvement design of intersections as part of the priority components of the Urban Mobility Improvement Project in Kigali (UMIK), which will result in the Action Plan of the Project.

1.2 Target Intersections

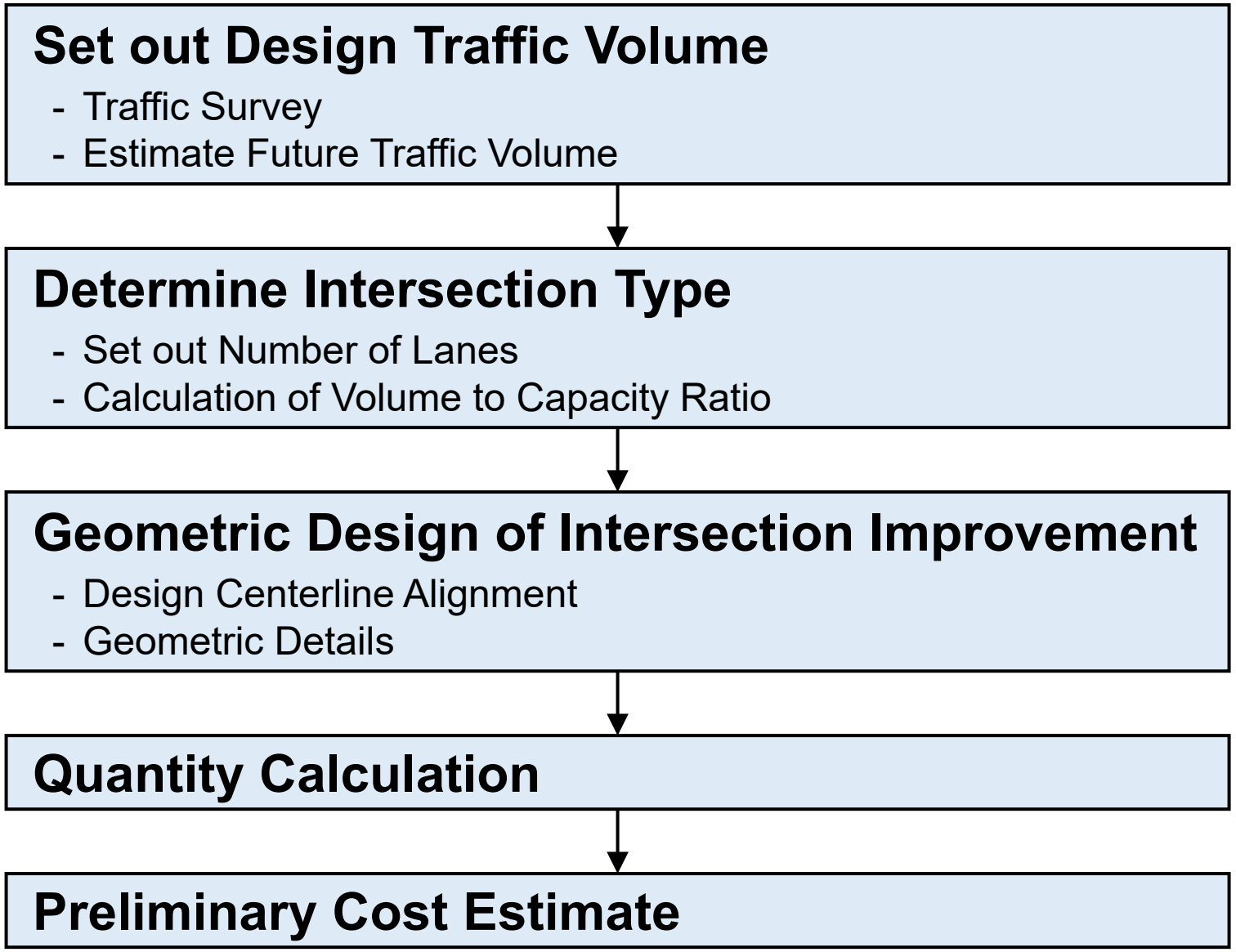
Original target: 50 Intersections
Additional target: 24 Intersections

Note: These numbers are subject to change depending on the actual situation of the site and/or results of traffic analysis.

1.3 Scope of Intersection Design

- Basic Design for Intersection Improvement Plan
- Preliminary Cost Estimate

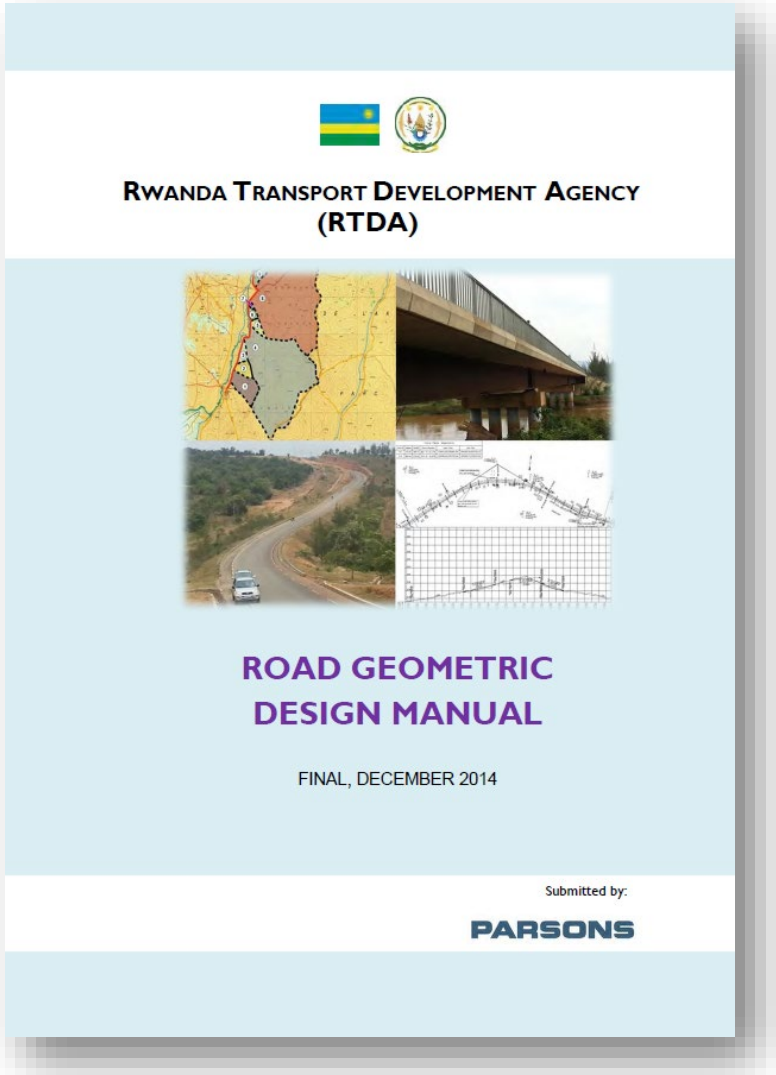
1.4 Workflow of Intersection Design



2. Design Conditions

2.1 Design Standard

Road Geometric Design Manual, RTDA (2014)



Chapter 10, At-Grade Junctions

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2.2 Road Classification

Ref.) P3-6, Road Geometric Design Manual, RTDA (2014)

Table 10-1: Road Function, Class, Name Conventions, and Access Control

Function	Class	Present Rwandan Road Class	EAC Name Conventions	Functional Classification Name Conventions
Mobility Roads	Class 1	[no expressways yet]	International trunk road National Trunk Road	Principal Arterial/ Freeway/ Expressway (2500 m spacing)
	Class 2	National Road	National Road Provincial Roads Regional Roads District Roads	Major arterial/Highway (800 spacing)
	Class 3	National Road (unpaved)	Regional Roads District Roads Secondary Roads	Minor arterial (600 m spacing)
Access Roads	Class 4	District Road 1 Other Roads	District Roads Secondary Roads	Collector roads (50 m spacing)
	Class 5	Local Streets Feeder Roads	Minor roads Local streets	Local streets (15 m spacing)

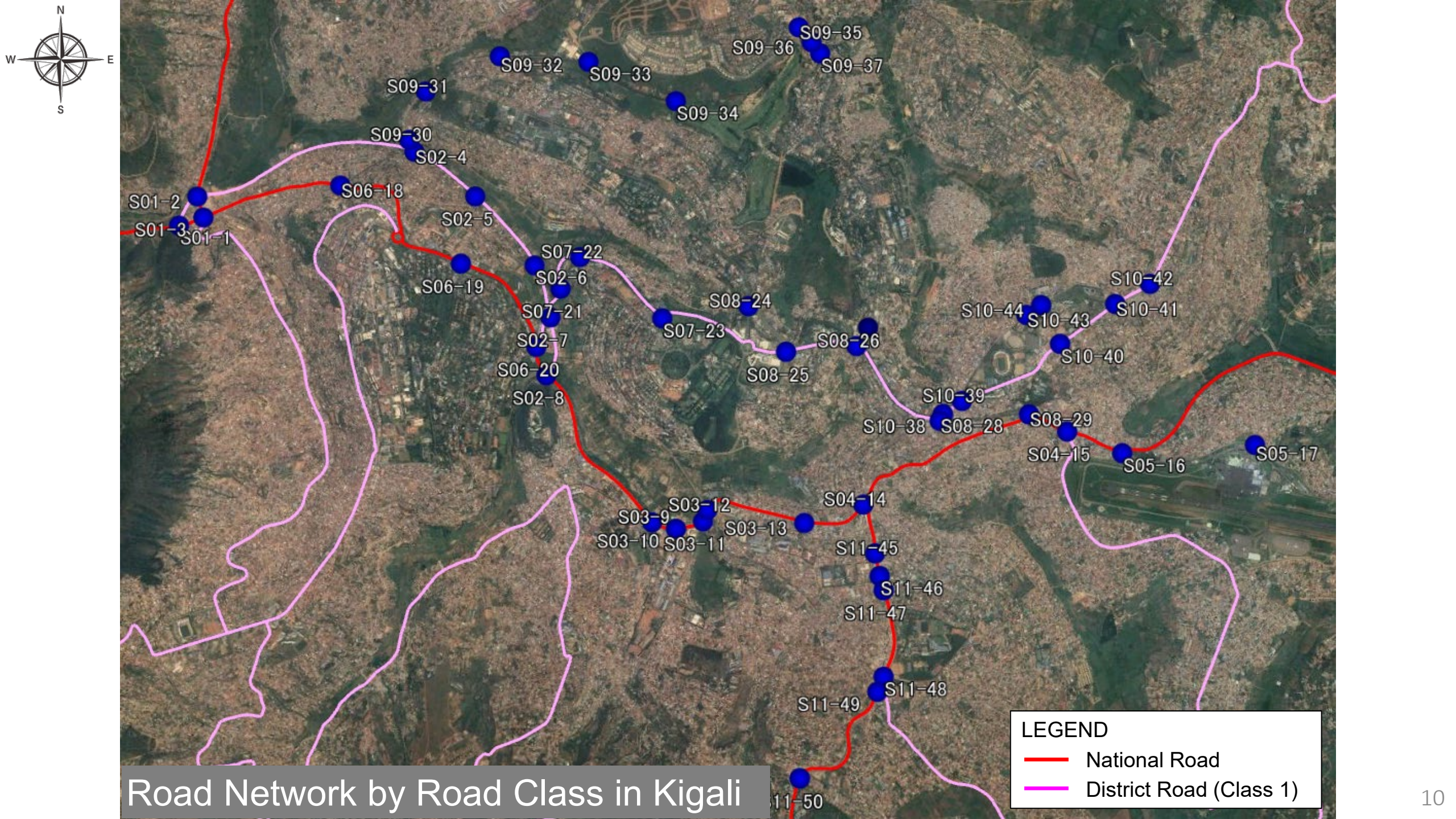
Design Class in this Project:

National Road -> Class 2

District Road 1 -> Class 3
(Considering target roads in Kigali can be categorized in Minor arterial)

Other Roads -> Class 4
(Considering target roads in Kigali can be categorized in Collector roads)

In the Rwandan context, there are presently no freeways or expressways, and although some of the present National Roads are international roads, they do not have the level of access control indicated in the above table for a Class 1 road. Roads at present District Road 1 can be placed in either Class 3 or 4, and Feeder roads and Local Streets fit into Class 5.



Road Network by Road Class in Kigali

2.3 Design Speed and Design Criteria

Ref.) P1-5, Road Geometric Design Manual, RTDA (2014)

Design Criteria for Class 2

Table 1-3: Geometric Design Parameters for Mobility Road Class 2 (Paved Roadway)

Design Element	Unit	Flat	Rolling	Mountain	Steep	Urban
Design Speed	km/h	110	80	50	50	50
Sight Distances						
Min. Stopping Sight Distance	m	220	130	65	65	65
Min. Passing Sight Distance	m	730	540	345	345	345
% Passing Opportunity	%	50	50	25	0	20
Horizontal Elements						
Side Friction Factor	f	0.11	0.14	0.16	0.16	0.21
Min. Horizontal Curve Radius[1]	m	560	250	90	90[2]	80
Transition Curves Required		Yes	Yes	No	No	No
Maximum Superelevation	%	6	6	6	6	4[3]
Vertical Elements						
Maximum Gradient (desirable/minimum)	%	4/5	5/7	7/9	8/11	8/11
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Minimum Crest Curve	k	74	26	7	7	7
Minimum Sag Curve	k	55	30	13	13	13
Cross Section Elements						
Width of Lane	m	3.5	3.5	3.5	3.5	3.5
Width of Shoulder	m	2.0	1.5	1.5	1.0	2.5[4]
Total Width	m	11.0	10.0	10.0	9.0	12.0
Normal Crossfall AC/DBST or stone	%	2.5/3.0	2.5/3.0	2.5/3.0	2.5/3.0	2.5/3.0
Shoulder Crossfall paved/unpaved	%	3.5/5.0	3.5/5.0	3.5/5.0	3.5/5.0	3.5/5.0
Right of Way	m	44	44	44	44	44

[1] At 6% maximum superelevation. For 4% maximum superelevation, see Chapter 3.
[2] For hairpin curves, the minimum radius is 30 meters
[3] If superelevation creates access and/or drainage issues, a normal crown may be specified.
[4] Parking lanes and footpaths may be required, see Chapter 4.

Design Speed in this Project:

National Road 60km/h
(Considering operational speed limit in Kigali is 60km/h in most sections)

District Roads / Other Roads 40km/h
(Considering urban context with rolling terrain)

2.3 Design Speed and Design Criteria

Ref.) P1-7, Road Geometric Design Manual, RTDA (2014)

Design Criteria for Class 3

Table 1-5: Geometric Design Parameters for Mobility Road Class 3 (Paved Road)

Design Element	Unit	Flat	Rolling	Mountain	Steep	Urban
Design Speed	km/h	100	80	50	40	50
Sight Distances						
Min. Stopping Sight Distance	m	185	130	65	50	65
Min. Passing Sight Distance	m	670	540	345	270	345
% Passing Opportunity	%	50	33	25	0	20
Horizontal Elements						
Side Friction Factor	f	0.12	0.14	0.16	0.17	0.21
Min. Horizontal Curve Radius[1]	m	435	250	90	55[2]	80
Transition Curves Required		No	No	No	No	No
Maximum Superelevation	%	6	6	6	6	4[3]
Vertical Elements						
Maximum Gradient (desirable/minimum)	%	5/6	7/9	10/12	10/12	10/12
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Minimum Crest Curve	k	52	26	7	4	7
Minimum Sag Curve	k	45	30	13	9	13
Cross Section Elements						
Width of Lane	m	3.5	3.5	3.5	3.5	3.5
Width of Shoulder	m	2.0	1.0	1.0	1.0	1.0[4]
Total Width	m	11.0	9.0	9.0	9.0	9.0
Normal Crossfall AC/DBST or stone	%	2.5/3.0	2.5/3.0	2.5/3.0	2.5/3.0	2.5/3.0
Shoulder Crossfall paved/unpaved	%	3.5/5.0	3.5/5.0	3.5/5.0	3.5/5.0	3.5/5.0
Right of Way	m	24	24	24	24	24

[1] At 6% maximum superelevation. For 4% maximum superelevation, see Chapter 3.
[2] For hairpin curves, the minimum radius is 15 meters
[3] If superelevation creates access and/or drainage issues, a normal crown may be specified.
[4] Parking lanes and footpaths may be required, see Chapter 4.

Design Speed in this Project:

National Road 60km/h
(Considering operational speed limit in Kigali is 60km/h in most sections)

District Roads / Other Roads 40km/h
(Considering urban context with rolling terrain)

2.3 Design Speed and Design Criteria

Ref.) P1-9, Road Geometric Design Manual, RTDA (2014)

Design Criteria for Class 4

Table 1-7: Geometric Design Parameters for Mobility Road Class 4 (Unpaved Road)

Design Element	Unit	Flat	Rolling	Mountain	Steep	Urban
Design Speed	km/h	80	60	40	40	40
Sight Distances						
Min. Stopping Sight Distance	m	130	85	50	50	50
Min. Passing Sight Distance	m	540	410	270	270	270
% Passing Opportunity	%	25	20	15	0	20
Horizontal Elements						
Side Friction Factor	f	0.14	0.15	0.17	0.17	0.25
Min. Horizontal Curve Radius[1]	m	250	135	55	55[2]	45
Transition Curves Required		No	No	No	No	No
Maximum Superelevation	%	6	6	6	6	4[3]
Vertical Elements						
Maximum Gradient (desirable/minimum)	%	6/8	7/10	12/14	15/18	15/18
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Minimum Crest Curve	k	26	11	4	4	4
Minimum Sag Curve	k	30	18	9	9	9
Cross Section Elements						
Width of Lane	m	3.0	3.0	3.0	3.0	3.0
Width of Shoulder	m	No Shoulder				0[4]
Total Width	m	6.0	6.0	6.0	6.0	6.0
Normal Crossfall	%	3.5	3.5	3.5	3.5	3.5
Shoulder Crossfall	%	5.0	5.0	5.0	5.0	5.0
Right of Way	m	24	24	24	24	24

[1] At 6% maximum superelevation. For 4% maximum superelevation, see Chapter 3.
[2] For hairpin curves, the minimum radius is 15 meters
[3] If superelevation creates access and/or drainage issues, a normal crown may be specified.
[4] Parking lanes and footpaths may be required, see Chapter 4.

Design Speed in this Project:

National Road 60km/h
(Considering operational speed limit in Kigali is 60km/h in most sections)

District Roads / Other Roads 40km/h
(Considering urban context with rolling terrain)

3. Design Traffic Volumes

3.1 Target Year

Consider Traffic Volumes in Year 2030

- Avoid the situation where intersections become saturated just after improvement.
- Social conditions and road network may be much different from the present condition and thus traffic demand forecast will be less accurate in the far future.

3.2 Design Traffic Volumes

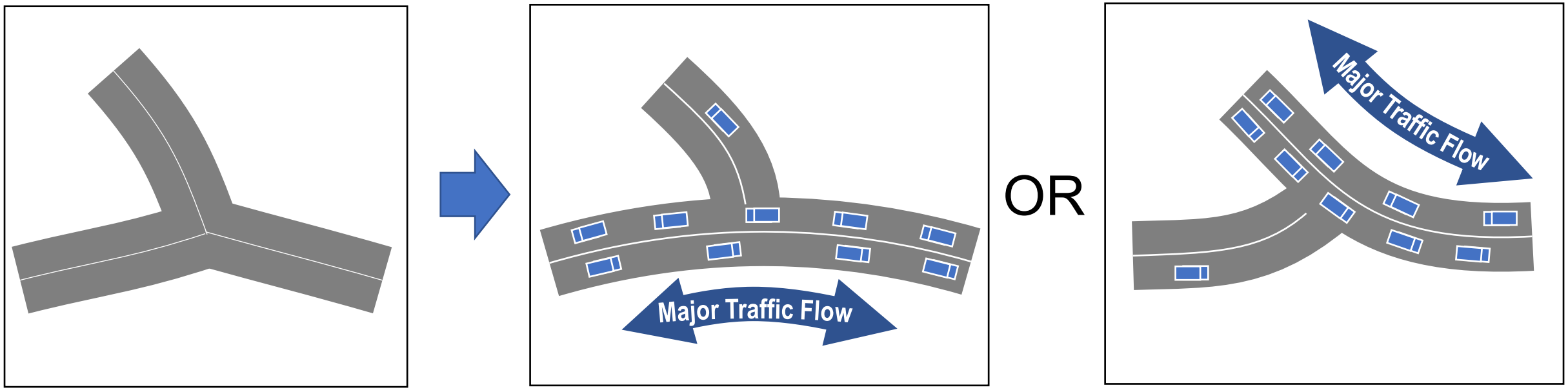
Design Traffic Volumes were determined by the directional traffic volumes surveyed in 2022 and multiplied by the growth rate between 2022 and 2030 obtained from the past study.

4. Geometric Design

4.1 Basic Policy

- Decide the major and minor traffic flows and at intersections based on directional traffic volumes.

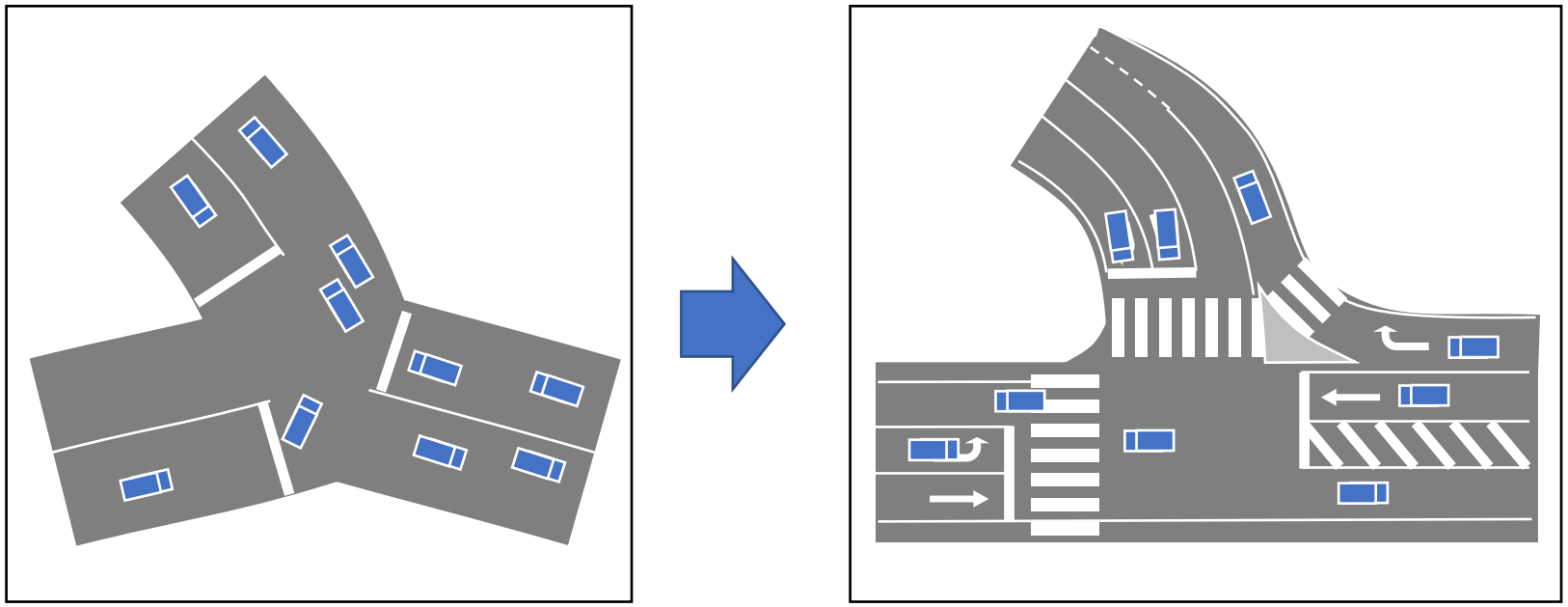
Give smooth alignment to Major Traffic Flow.



- Determine lane configurations and control types for accommodating traffic volume in each direction based on the intersection analysis.

4.1 Basic Policy

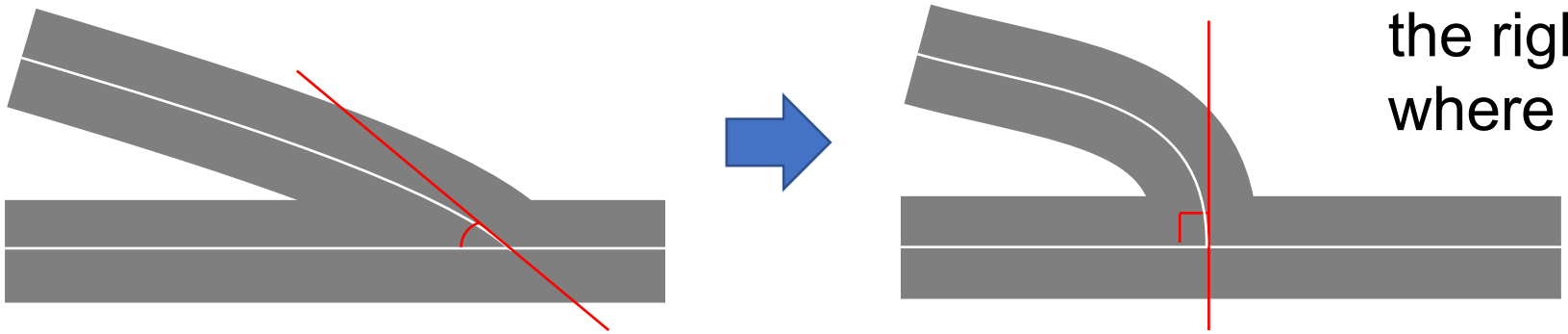
- Apply traffic islands or zebra strips to clearly show the vehicle movements in intersections.



- Try to reduce the size of the intersection.
- Avoid to design intersections with more than five legs.

4.2 Geometric Details

✓ Intersection Angles



- Rectify intersection angles to the right or near angles where possible.

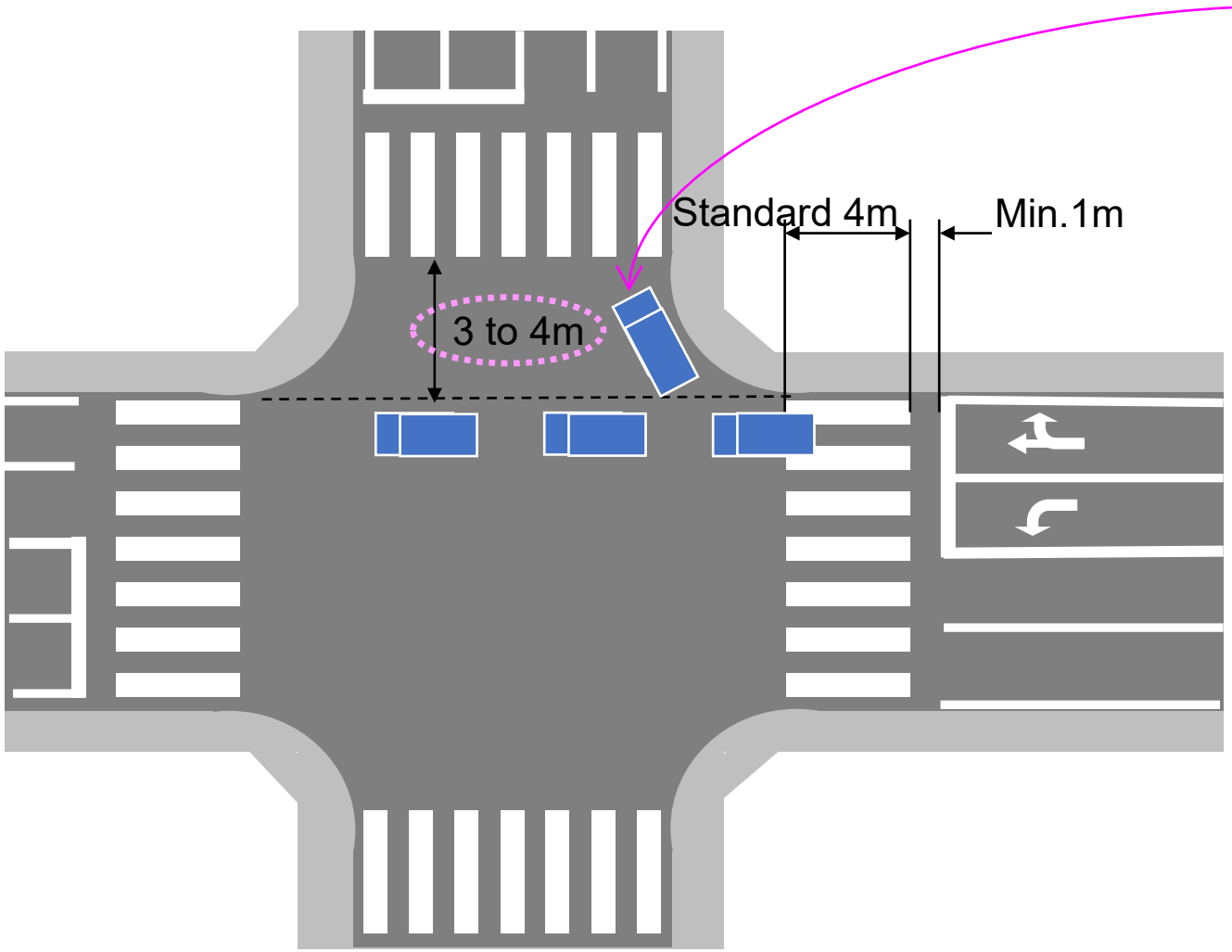
✓ Lane Widths in Intersections

- Reduce lane width in the intersection considering the following:
  - ➢ Vehicles move with less speeds in intersection.
  - ➢ Avoid or minimize the land acquisition even in case of increasing the number of lanes.

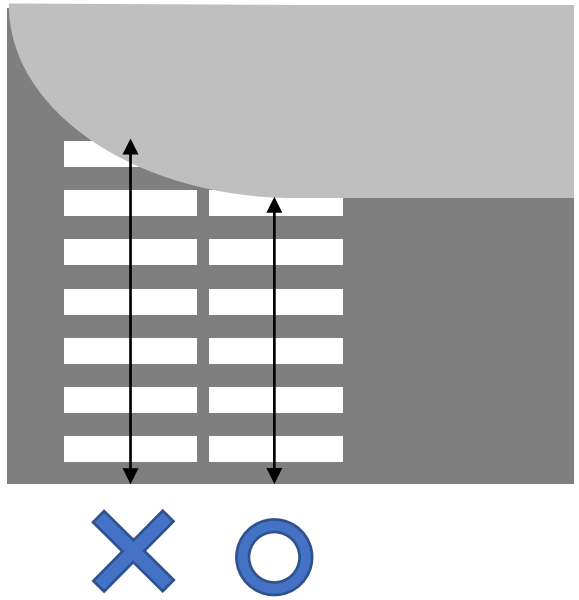
Road Category	General	Intersection
National Road	3.5m	3.25m
District Road	3.5m	3.25m/3.0m
Other Road	3.5m/3.0m	3.0m

4.2 Geometric Details

✓ Location of Stop Lines and Pedestrian Crossings



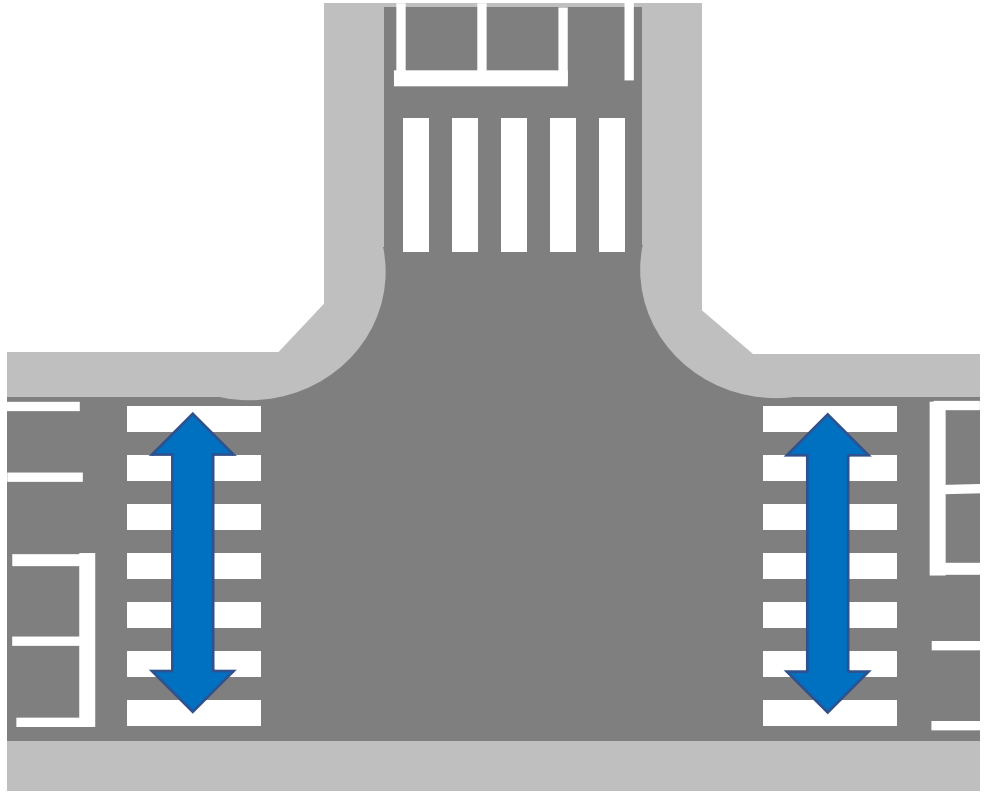
- Waiting without blocking thru traffic
- Pedestrian crossing should be located where the crossing distance is not too long.



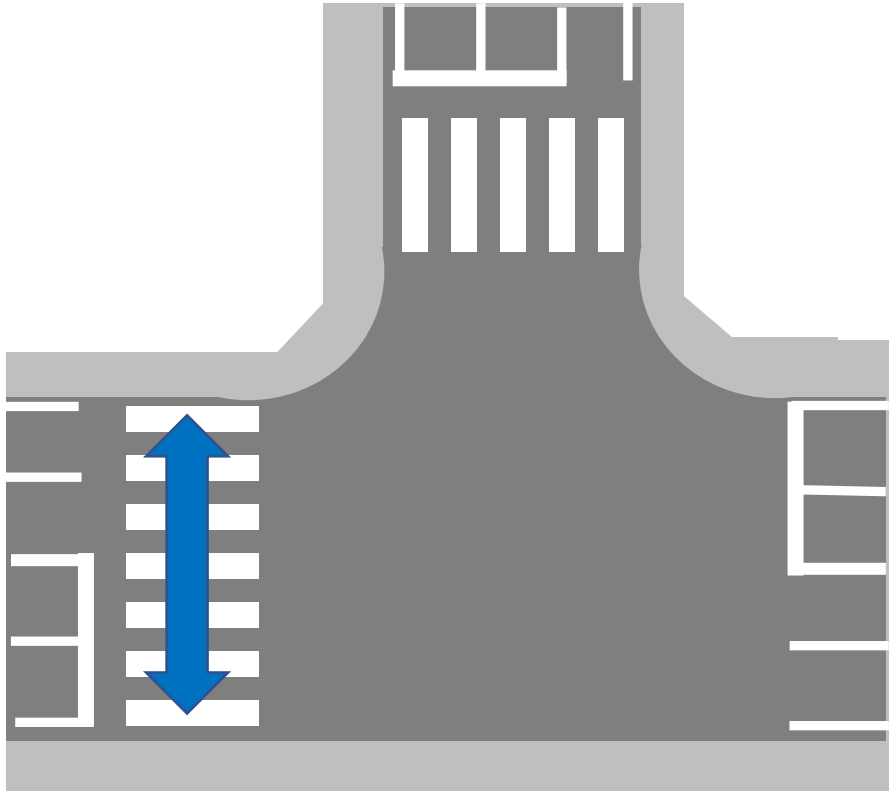
4.2 Geometric Details

✓ **Number of Pedestrian Crossings**

- Determine based on the Number of Pedestrian Crossing



(1) Daily crossing > 500 people

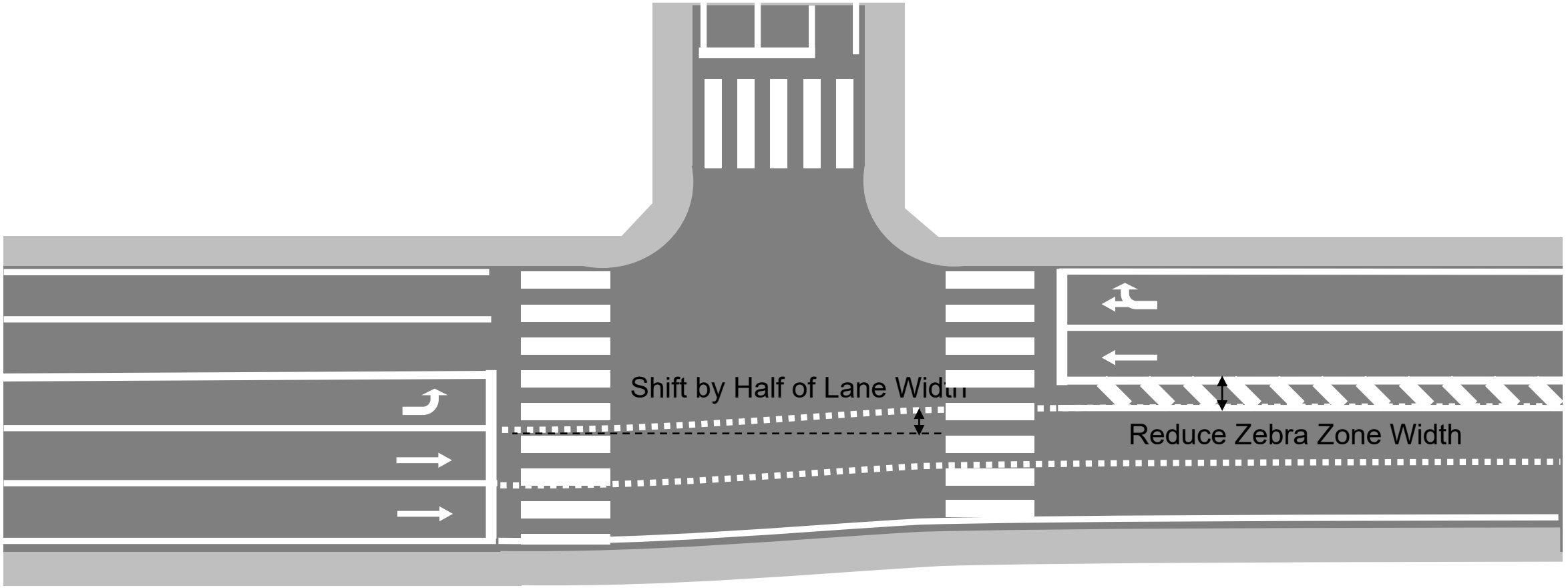


(2) Daily crossing < 500 people

4.2 Geometric Details

✓ **Zebra Width at the Exit**

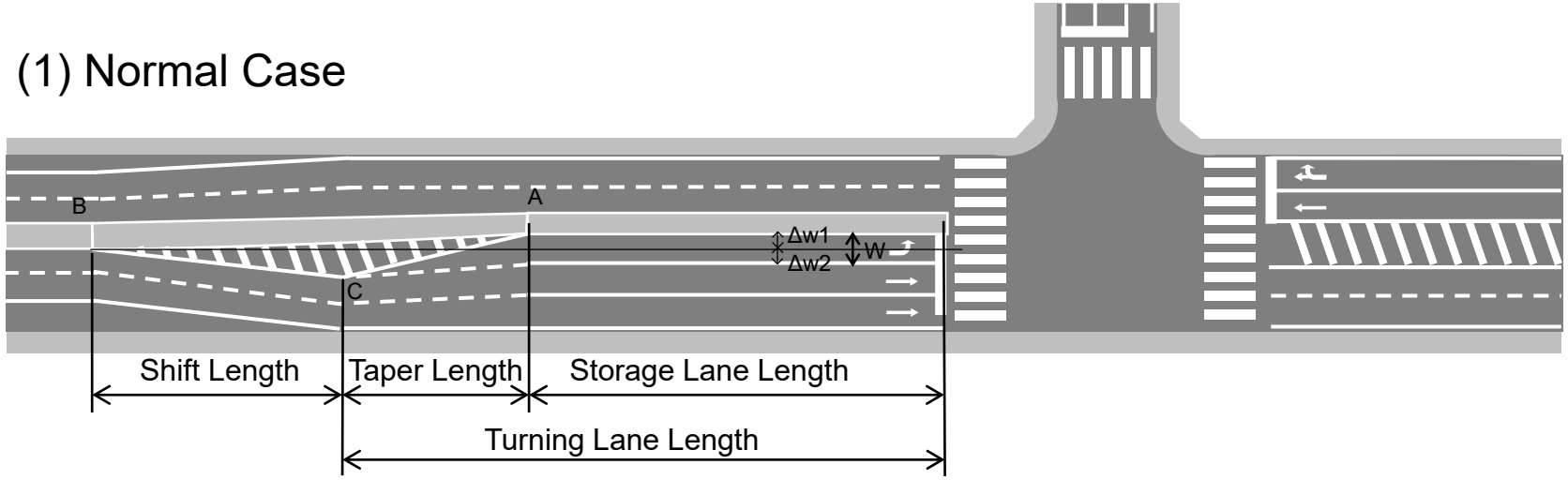
- Reduce Zebra Zone Width by Accepting Shift in Vehicle Movement in Intersection



4.2 Geometric Details

✓ Left Turn Lane Length

(1) Normal Case



$$\text{Shift Length} = \frac{V * \Delta w}{3} \text{ to } \frac{V * \Delta w}{2}$$

$$\text{Taper Length} = \frac{V * W}{6}$$

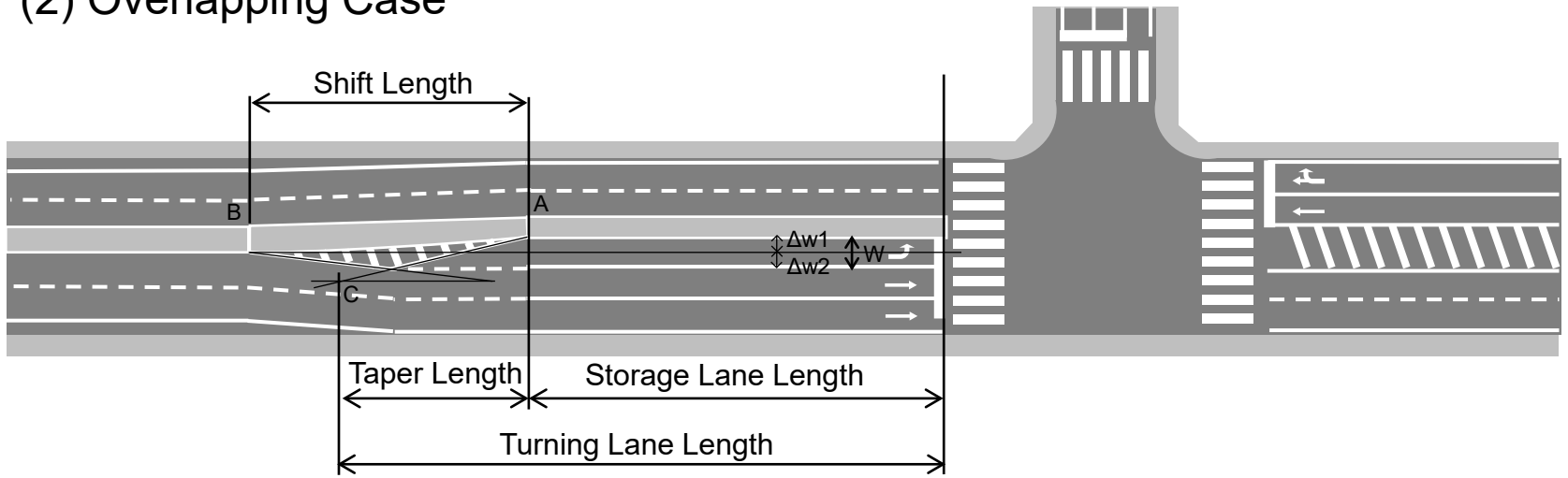
Δw = max (Δw1, Δw2)

Δw1: Shift of Carriageway Centerline

Δw2: Shift of Lane Boundary

W: Lane Width

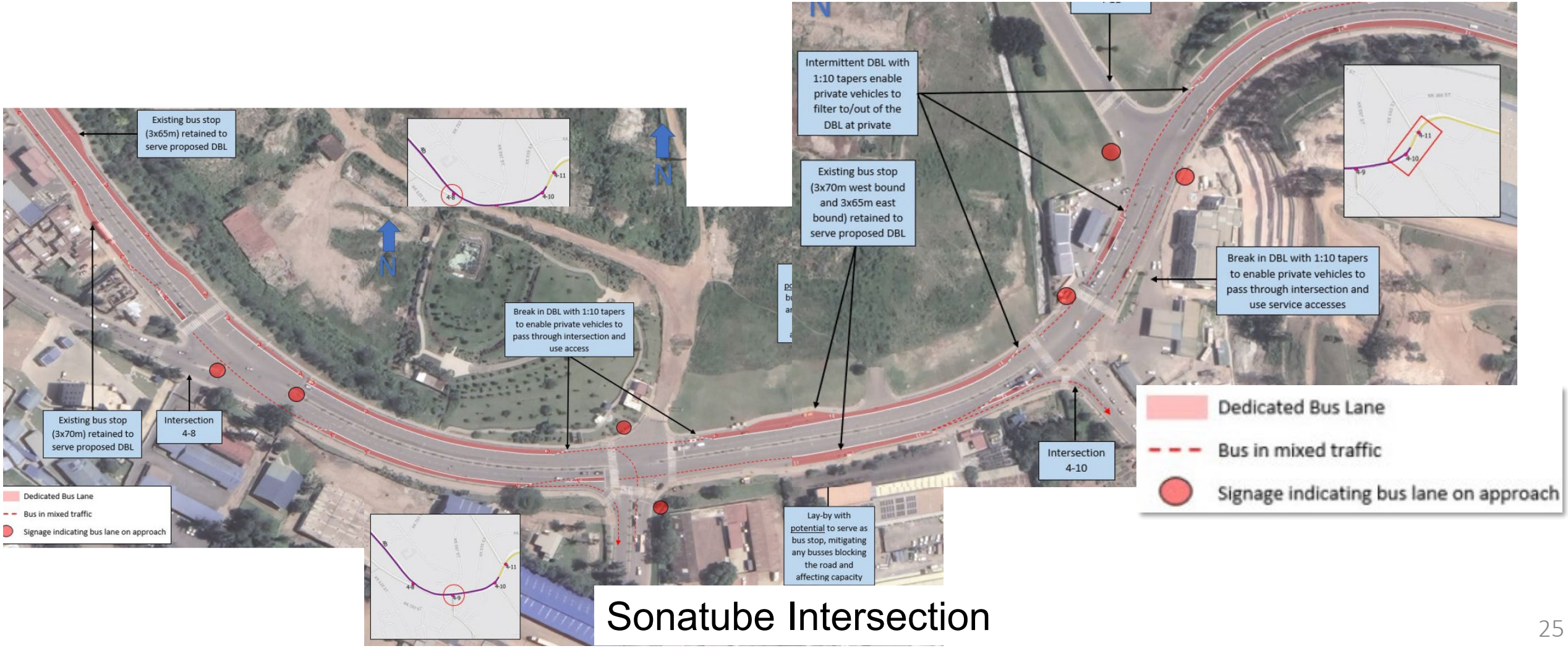
(2) Overlapping Case



5. Consideration of DBL

5.1 Concept Plans proposed by World Bank Study

One lane in each direction is going to be operated as “Bus Dedicated Lane” in peak time.
In WB Study, road widening is not proposed. They assume “15% Car and Truck Diversion” and “50% Modal Shift from Moto to Bus/Minibus and 5% modal shift From Car to Bus/Minibus”.



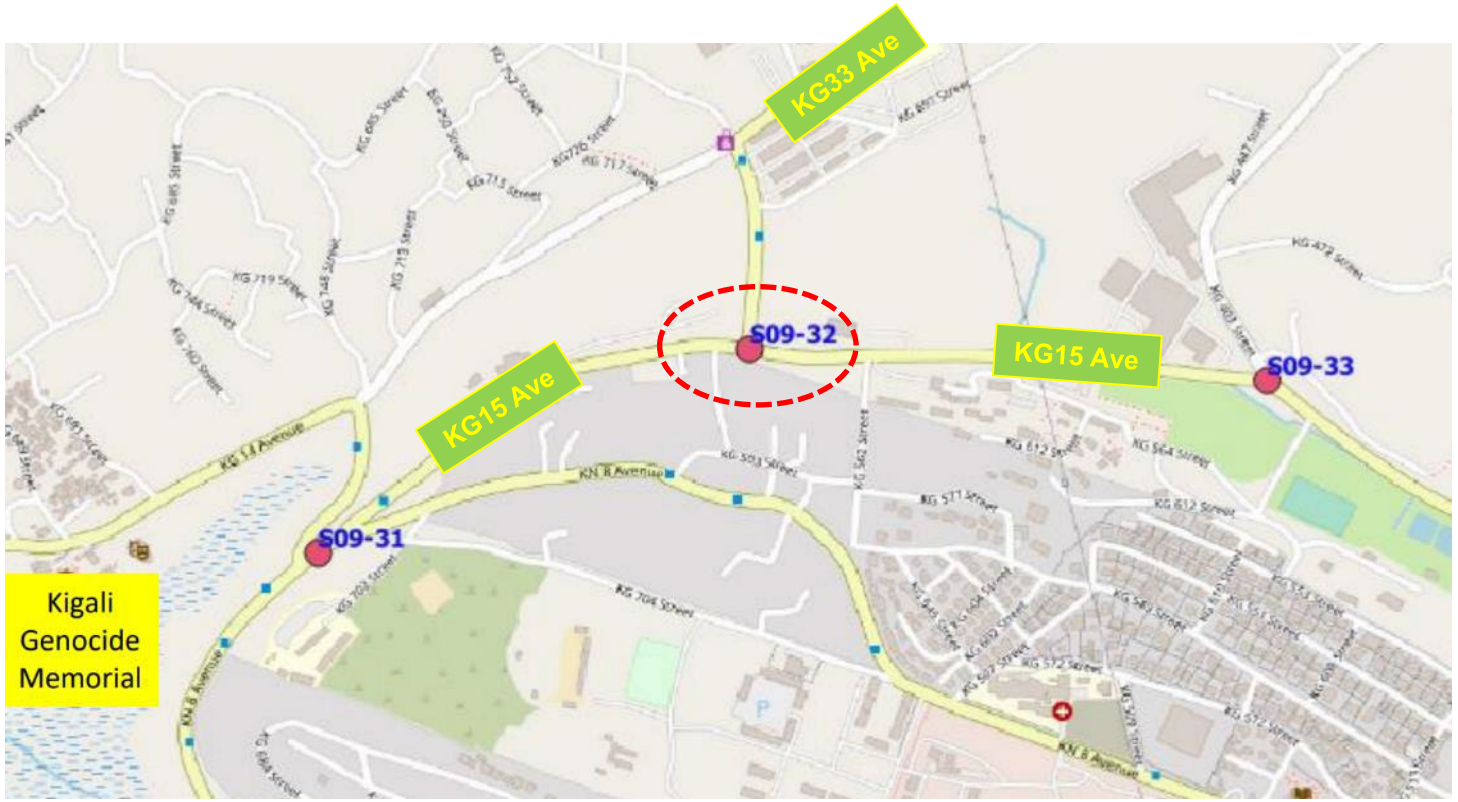
Sonatube Intersection

Part B: Application to Each Intersection

Details of Intersection Improvement Planning

Case-1: S09-32 (T-Shaped Intersection (Unsignalized ⇒ Signalized))

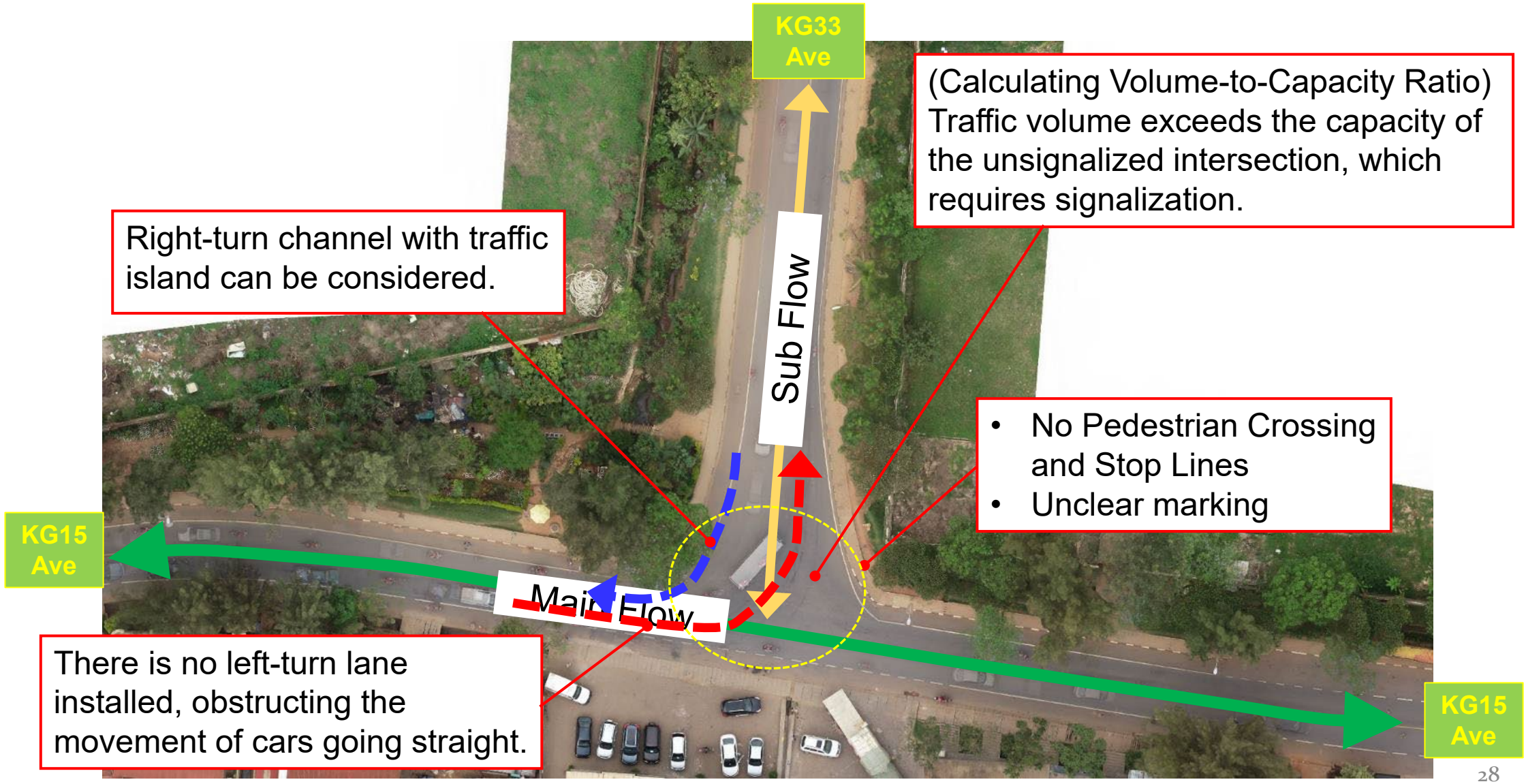
1) Location of the intersection



Details of Intersection Improvement Planning (Case-1: S09-32)

2) Identification of issues on present intersection

Unsignalized (Stop Control)



(Calculating Volume-to-Capacity Ratio)
Traffic volume exceeds the capacity of the unsignalized intersection, which requires signalization.

Right-turn channel with traffic island can be considered.

- No Pedestrian Crossing and Stop Lines
- Unclear marking

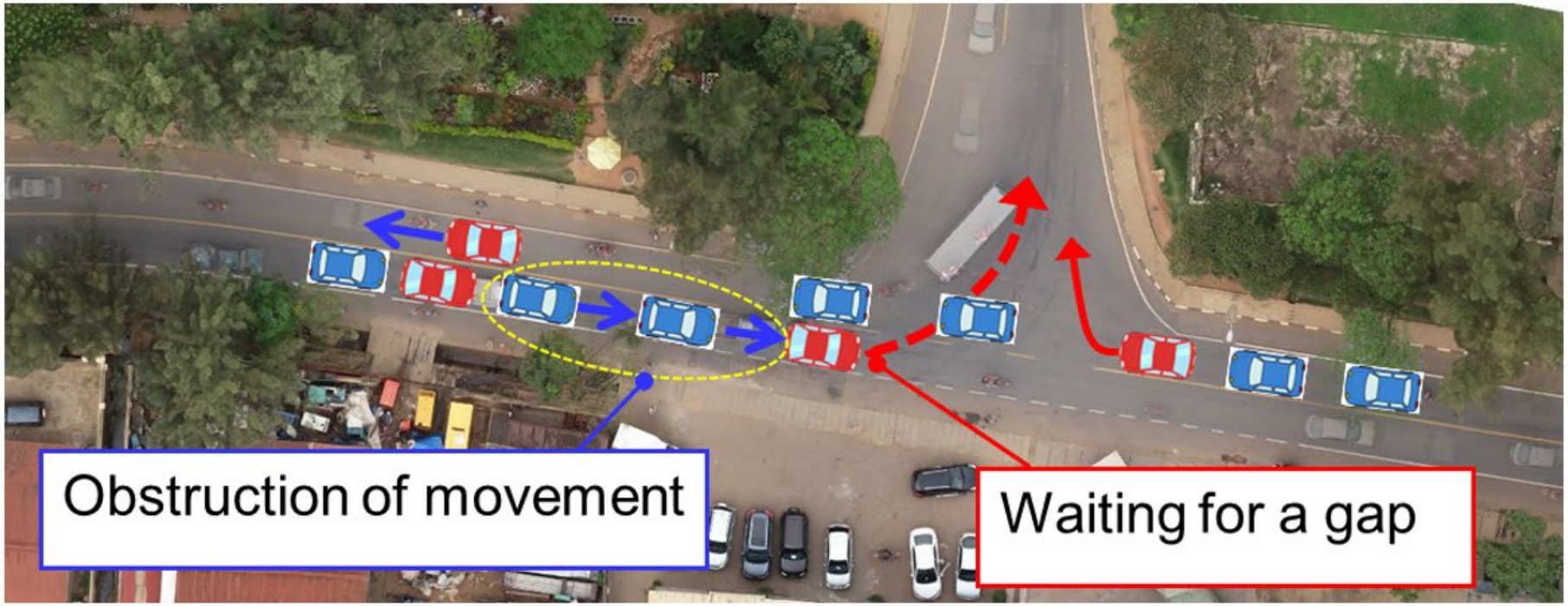
There is no left-turn lane installed, obstructing the movement of cars going straight.

Details of Intersection Improvement Planning (Case-1: S09-32)

2) Identification of issues on present intersection

Unsignalized (Stop Control)

There is no Left-Turn Lane installed, obstructing the movement of cars going straight.



Details of Intersection Improvement Planning (Case-1: S09-32)

3) Improvement Plan (Overall view)

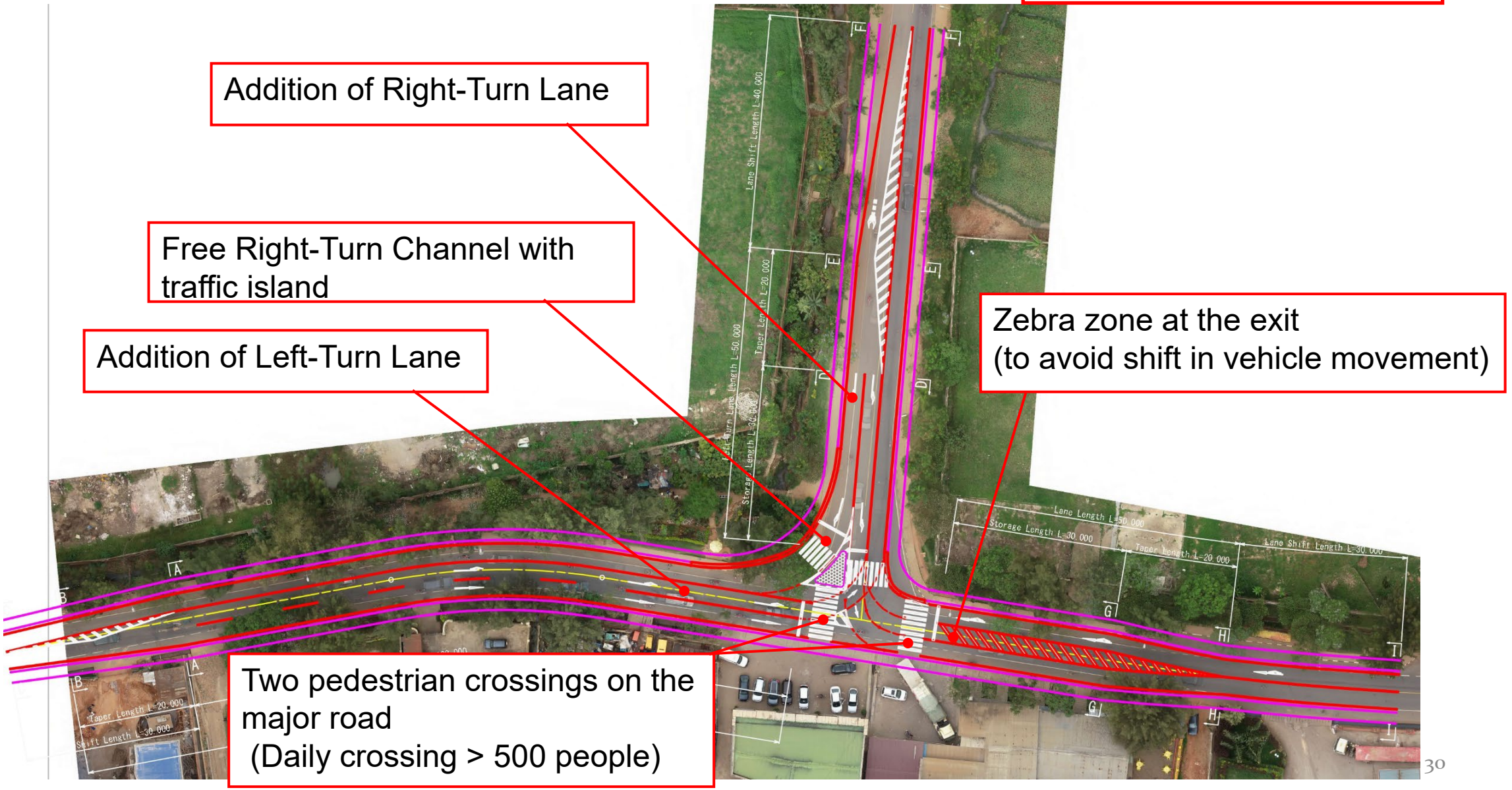
Signalized (Signal Control)

Addition of Right-Turn Lane

Free Right-Turn Channel with traffic island

Addition of Left-Turn Lane

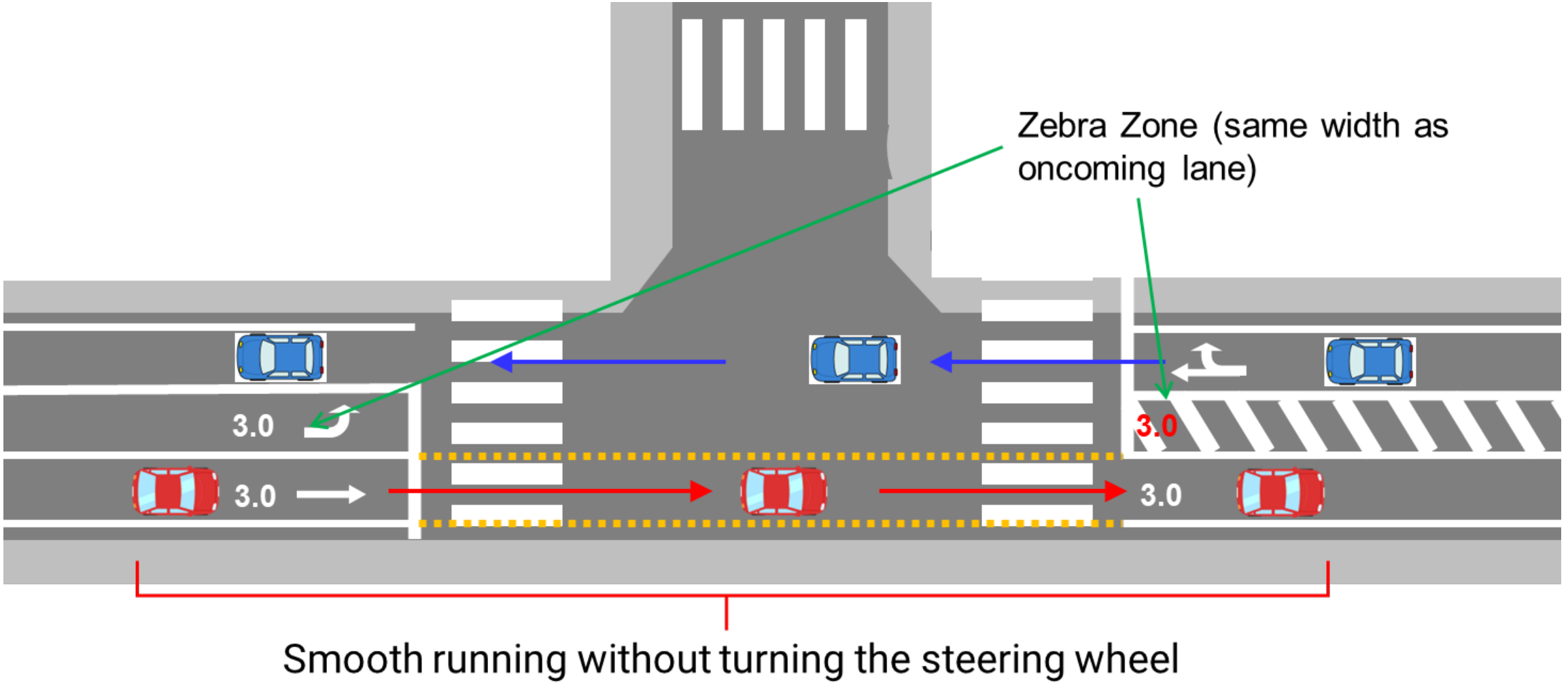
Zebra zone at the exit
(to avoid shift in vehicle movement)



Two pedestrian crossings on the major road
(Daily crossing > 500 people)

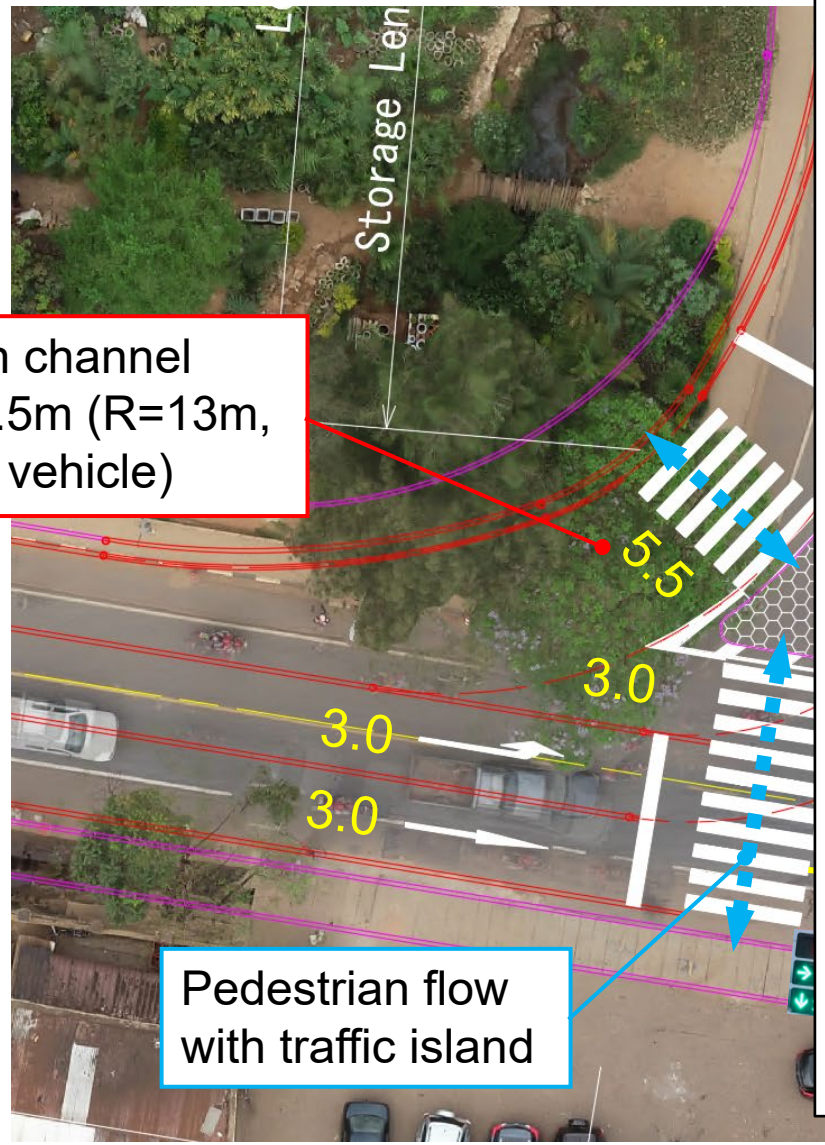
Details of Intersection Improvement Planning (Case-1: S09-32)

3) Improvement Plan (Installation of Zebra Zone at the exit)



Details of Intersection Improvement Planning (Case-1: S09-32)

3) Improvement Plan (Enlarged v



Right-turn channel width = 5.5m (R=13m, Standard vehicle)

Pedestrian flow with traffic island

Japanese design standard

(2) Channel width

Table 4.4.3 shows the standard values for the width of a channel for different combinations of the curve radius for channels, and types of design vehicles.

This table only gives the width of carriageway for a channel. Hence, when a channel is divided by islands or separators, about 0.5 m of lateral clearance width paved at the same level as the roadway should be provided. This lateral clearance may be included on the shoulder, the ditch, or the set back for a channel.

Tab.4.4.3 Channel Width

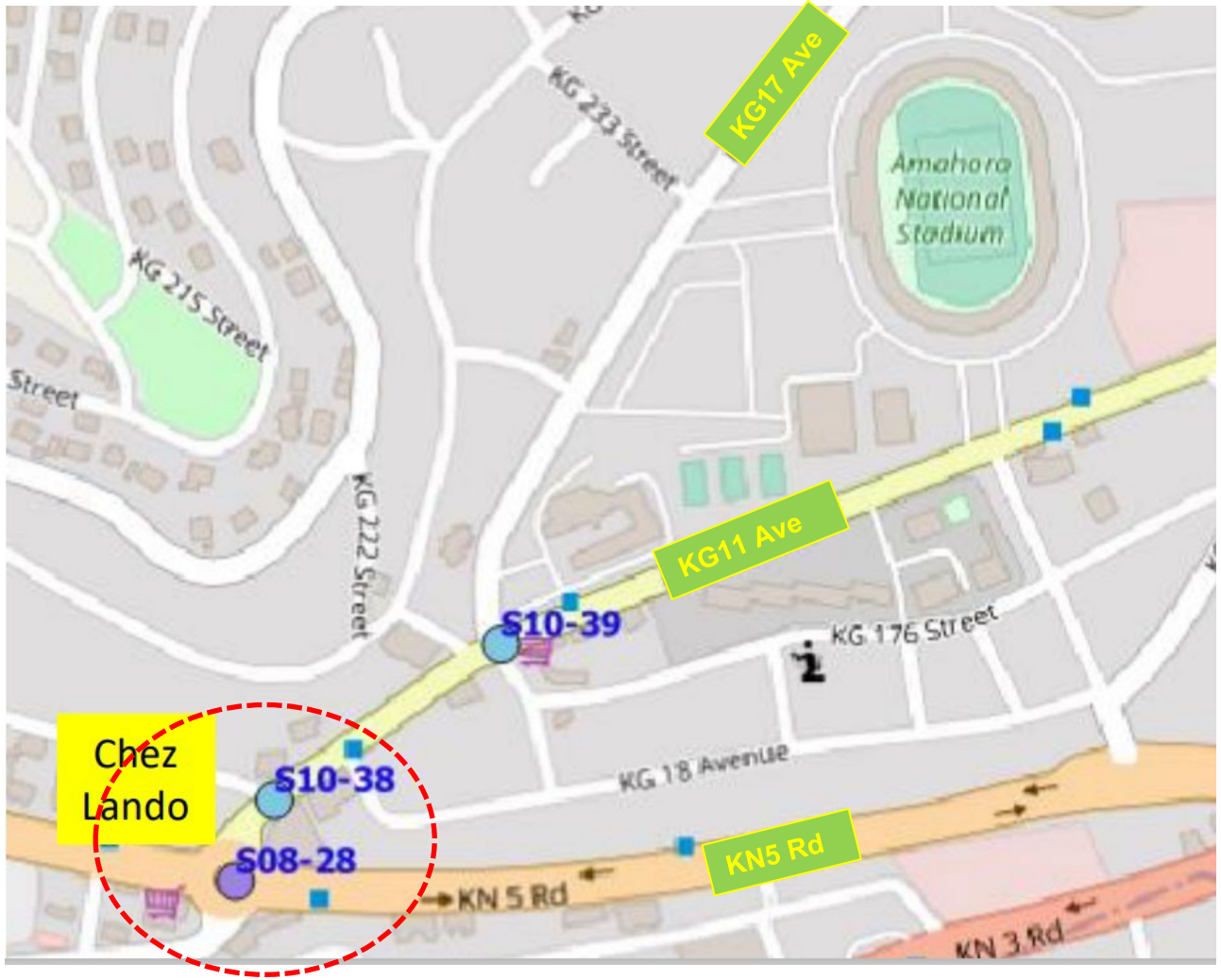
(Unit:m)

Design vehicle Outside radius of channel		Semitrailer (*)	Standard Vehicle (Others)
13 or more	14 less	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	

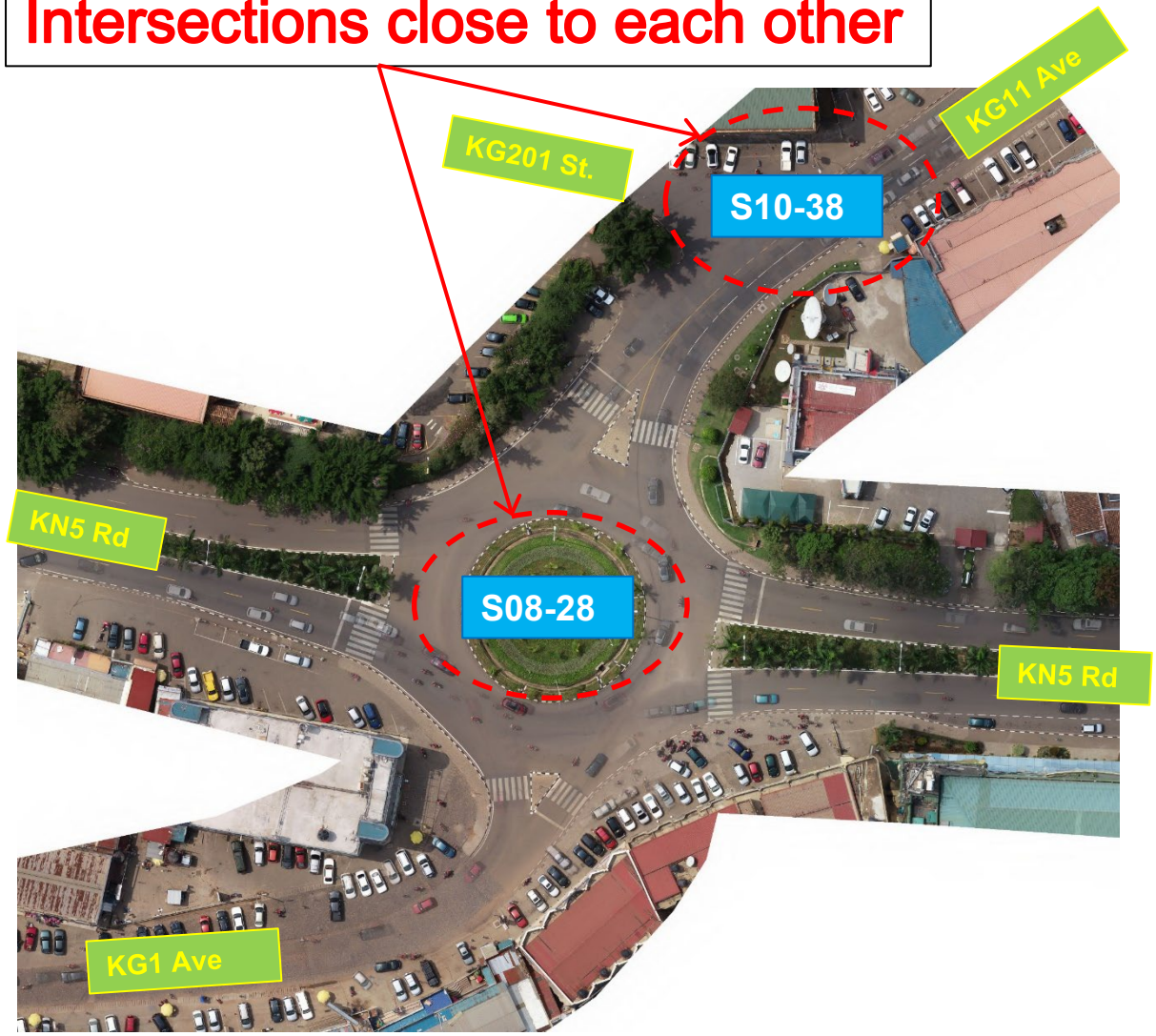
Details of Intersection Improvement Planning

Case-2: S08-28 & S10-38 (Roundabout ⇒ Signalized Intersection)

1) Location of the intersection



Intersections close to each other



Details of Intersection Improvement Planning (Case-2: S08-28 & S10-38)

2) Identification of issues on present intersection

Control delay and LOS for each approach and the roundabout as a whole

$d_{intersection} = \Sigma d_i v_i / \Sigma v_i$

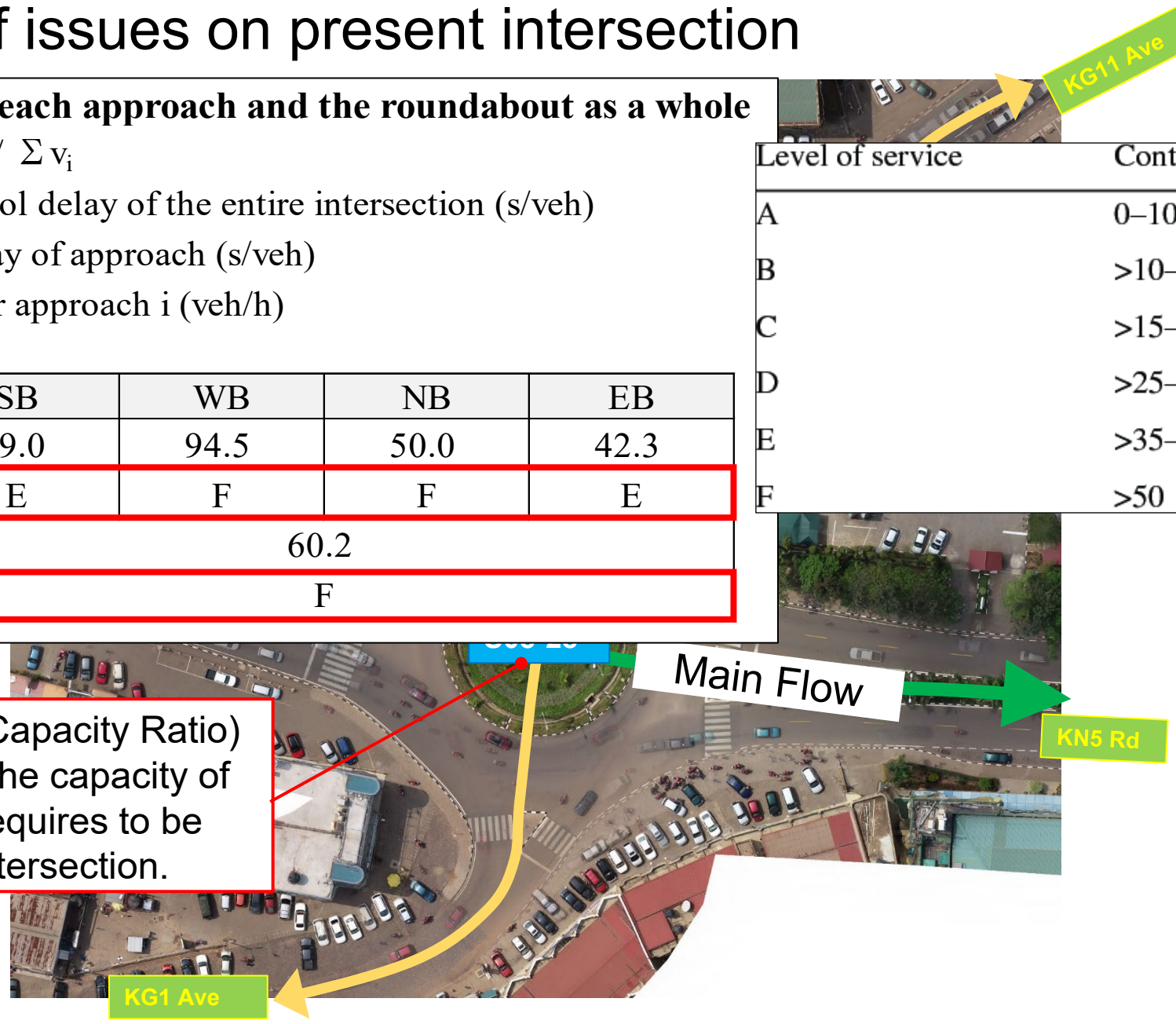
$d_{intersection}$: control delay of the entire intersection (s/veh)

d_i : control delay of approach (s/veh)

v_i : flow rate for approach i (veh/h)

	SB	WB	NB	EB
d_i	39.0	94.5	50.0	42.3
LOS_i	E	F	F	E
$d_{intersection}$	60.2			
$LOS_{intersection}$	F			

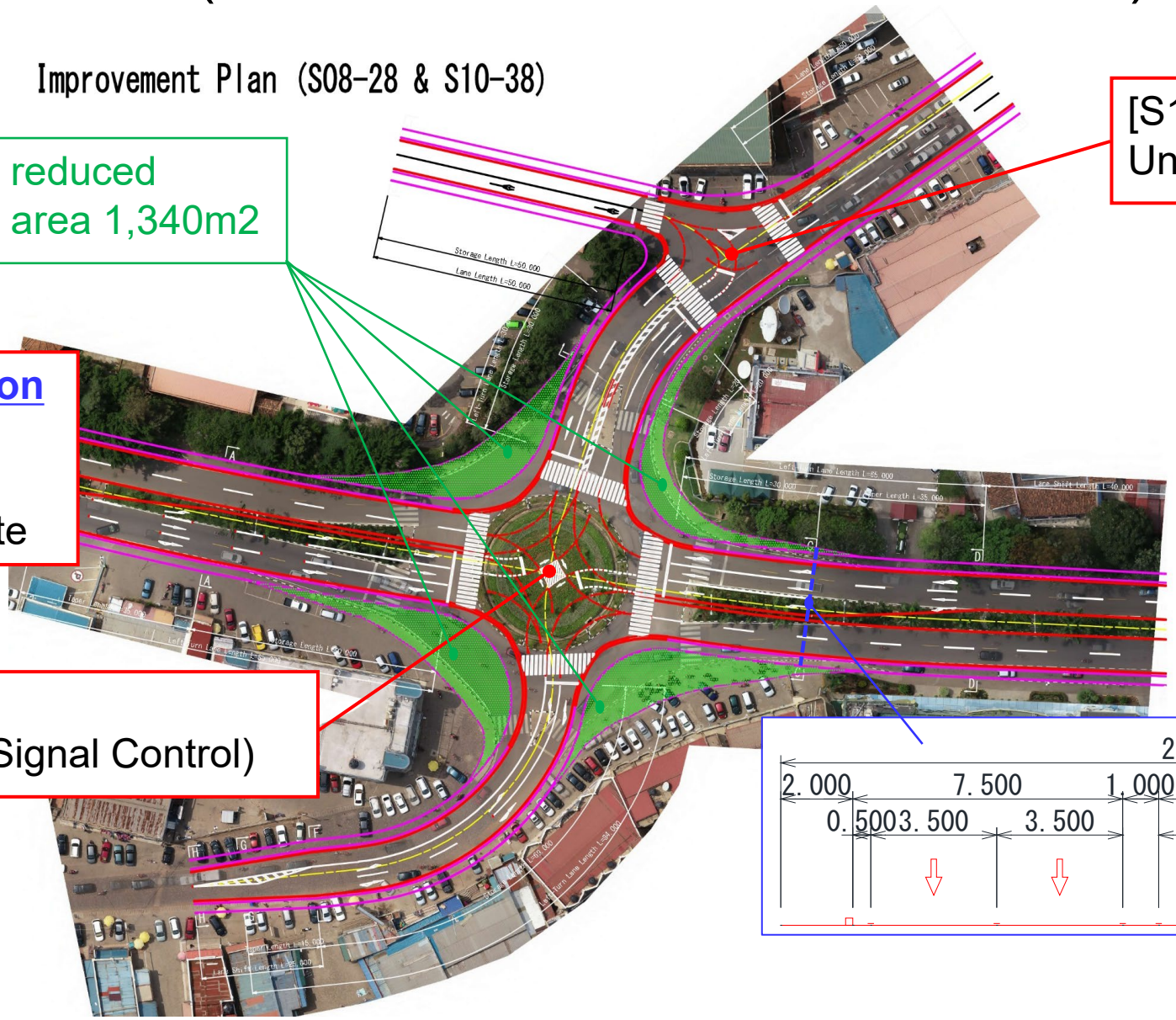
Level of service	Control delay (s/veh)
A	0–10
B	>10–15
C	>15–25
D	>25–35
E	>35–50
F	>50



(Calculating Volume-to-Capacity Ratio)
Traffic volume exceeds the capacity of the roundabout, which requires to be changed to signalized intersection.

Details of Intersection Improvement Planning (Case-2: S08-28 & S10-38)

3) Improvement Plan (Overall view of S08-28 & S10-38)



Area reduced
Total area 1,340m2

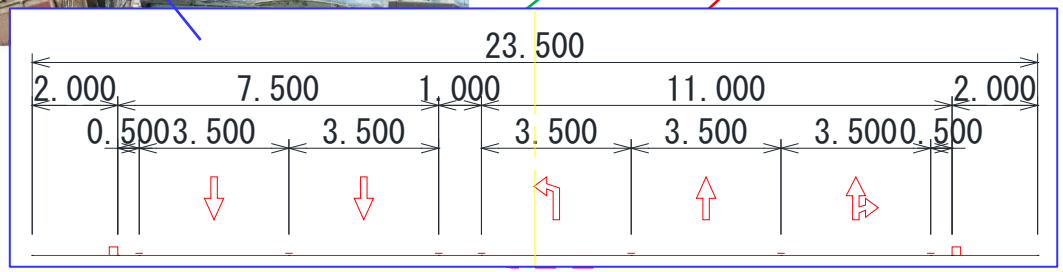
[S10-38]
Unsignalized (Stop Control)

Compact Intersection
- Increase in traffic handling capacity
- Clear running route

[S08-28]
Signalized (Signal Control)

Median

Left-Turn Lane (Additional)

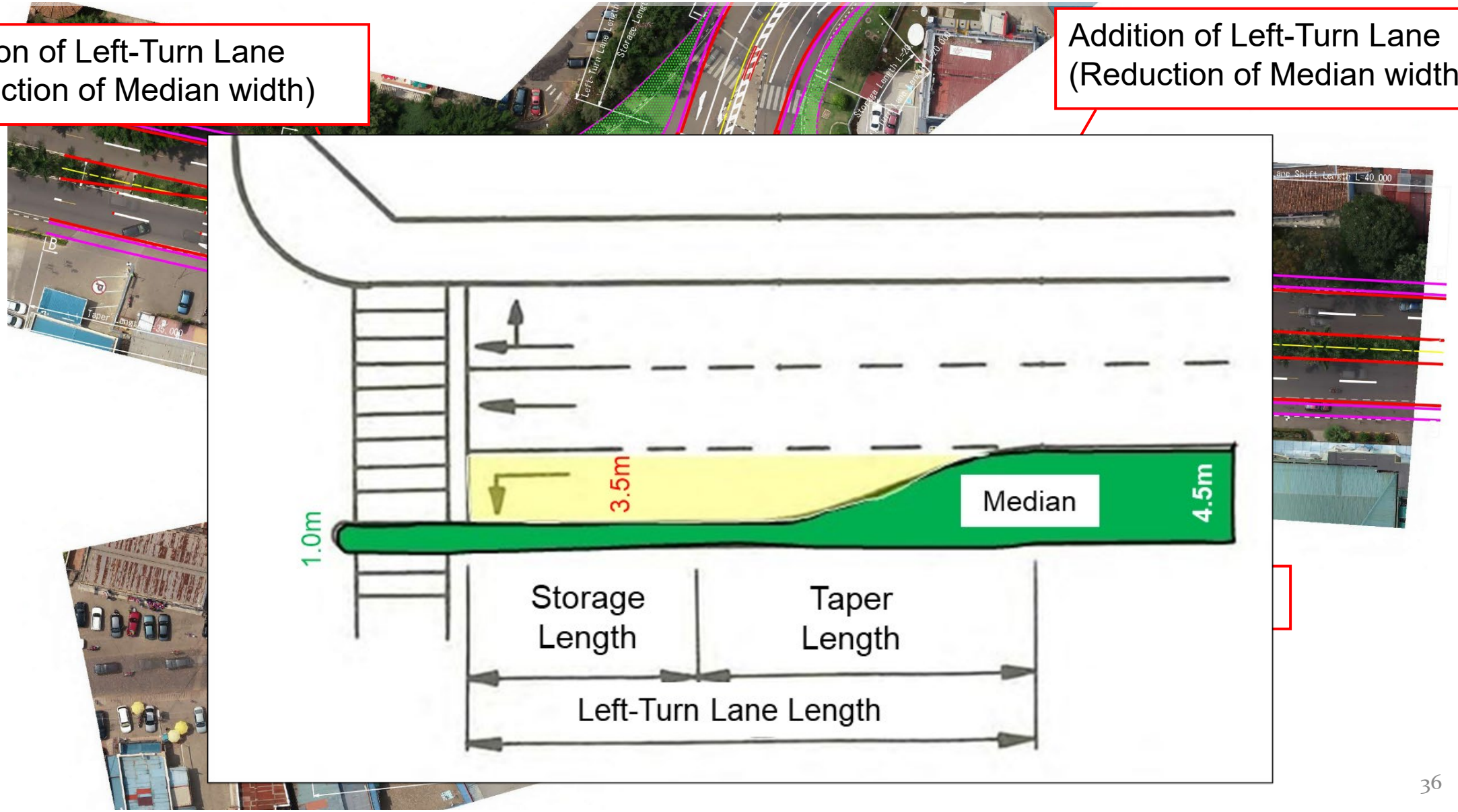


Details of Intersection Improvement Planning (Case-2: S08-28 & S10-38)

3) Improvement Plan (Overall view of S08-28)

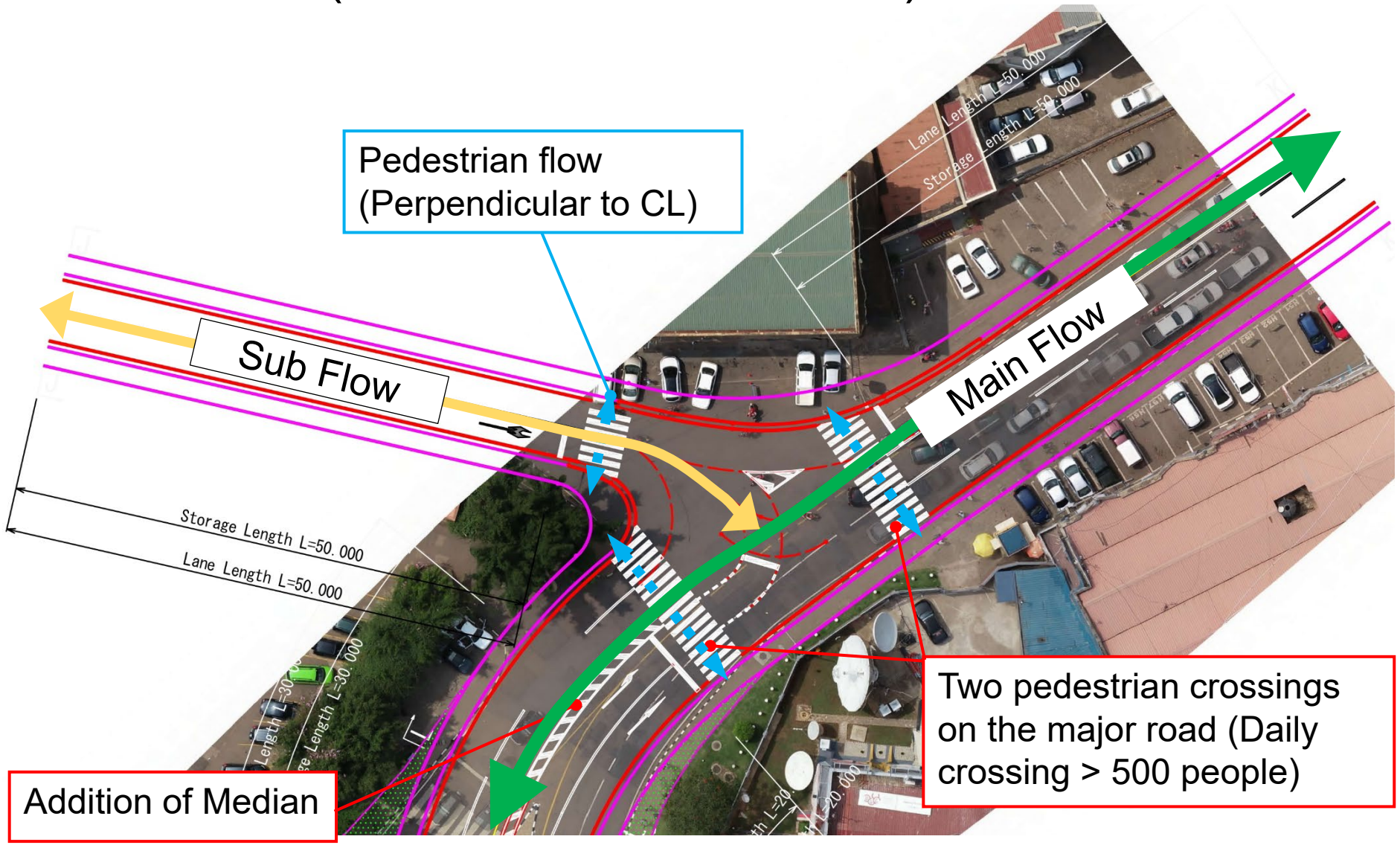
Addition of Left-Turn Lane
(Reduction of Median width)

Addition of Left-Turn Lane
(Reduction of Median width)



Details of Intersection Improvement Planning (Case-2: S08-28 & S10-38)

3) Improvement Plan (Overall view of S10-38)



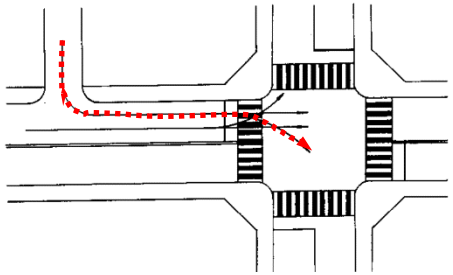
Details of Intersection Improvement Planning (Case-2: S08-28 & S10-38)

3) Improvement Plan (Spacing between Intersections)

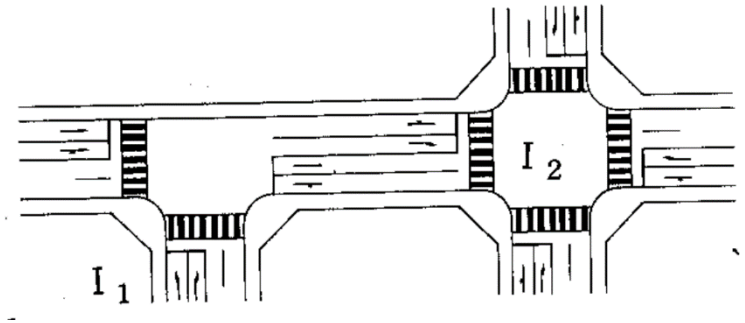
[Points to be considered]

Ideally, the spacing between intersections should be as far apart as possible.
Due to constraints by land use conditions, however, intersections may sometimes have to be located close to each other.
The 4 main factors that dictate the minimum spacing between intersections are;

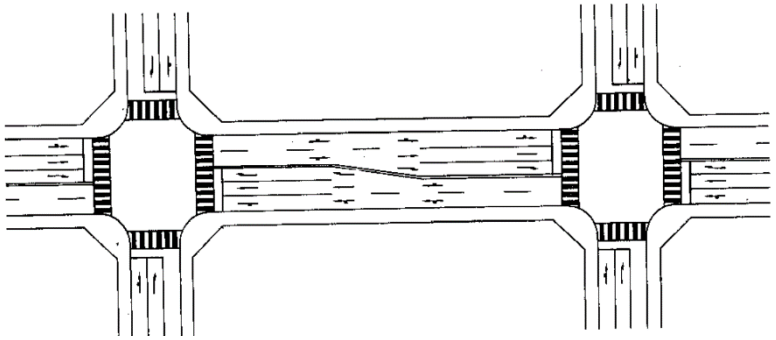
1. **Weaving Length**
2. **Storage Length**
3. **Length of the exclusive Left-Turn Lane and the Deceleration Lane length**
4. **Sight Distance**



1. Weaving Length



2. Storage Length



3. Length of the exclusive Left-Turn Lane