“Definition of roads interventions for the improvement of transport and logistics in Paramaribo”.

Final Report

Mexico City, February 2019

INDEX

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1. Introduction

The Inter-American Development Bank (IDB) is promoting an improvement initiative to help Suriname's transport in the Port of Paramaribo and its adjacent roads. The Improvement of Logistic and Transport in Paramaribo Program aims to increase Suriname's competitiveness and productivity in the agricultural sector by improving the transport logistics within and near the Dr. Jules Sedney Terminal. The program considers investments and activities throughout four inter-related fronts:

- Improvement of port access and land utilization;
- Optimization of port operation and customs inspections;
- Upgrade and climate adaptation of road infrastructure, bridges and secondary roads; and
- Modernization of traffic management.

To determine the scope of these components, the IDB has created a Technical Cooperation that seeks to prepare the key technical analysis for the design of the program, as well as to help identify strategic interventions that will help to fulfill the objectives.

The present document describes the activities carried out to identify the interventions in the roads adjacent to the port needed to improve the port operations and minimize frictions between trucks generated by the port and the urban demand.

2. Data collection

To gather the required information for the elaboration of the project, The IDB and the consultant team carried out a technical visit to Suriname, consisting of the following elements:

Road assessment and traffic counts:

- Traffic counts: For the traffic counting preparation, 8 members of the Ministry of Public Works and 2 from the Road Authority were trained to participate in the activity. Pneumatic counters were installed on relevant streets: 2 of them on Van 't Hogerhuysstraat (the first one south to Willem Campagnestraat, and the second one south to Slangenhoutstraat), and 1 in Molenpad west to Van 't Hogerhuysstraat. Additionally, 6 visual traffic counting locations were located along the roads to be intervened.

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- Directional traffic counts: Drone flights were planned to be executed during August, on the crossings of the access roads (Van ‘t Hogerhuysstraat, Willem Campagnestraat, Slangenhoutstraatm Molenpad and Hernhutterstraat)

- Travel time measurements: 15 GPS measurements were done to measure travel times in the roads to be intervened.

- Physical inspection of the site: Visual inspection of the roads to be intervened.

- Additional information gathering: Data generated with the drone flight was used to map the traffic and movement process.

The technical visit analysis focused on 8 km of roads, including alternate routes used by cargo heavy transport near the port.

Figure 1. Roads under analysis

Source: Transconsult

For the traffic counts, the consultant’s team installed pneumatic counters in three different locations where most of the traffic flows were observed. The installation process was done with help of the personnel from the Ministry of Public Works, Road Authority and the police.

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The pneumatic counters gathered information for 24 hours of traffic activity from Saturday July 28th 2018 to Friday August 3rd 2018.

Additionally, the consultant team trained eight members of the Ministry of Public Works and the Road Authority that helped to carry out the manual traffic counts. Manual counting was done in 8 locations to complement the gathered data from pneumatic counters in order to obtain further detail of the traffic flows. These manual counts included the registration of the vehicle types in both sides in both sides of the road.

The next map shows the traffic count locations:

Figure 2. Traffic count locations

Source: Transconsult

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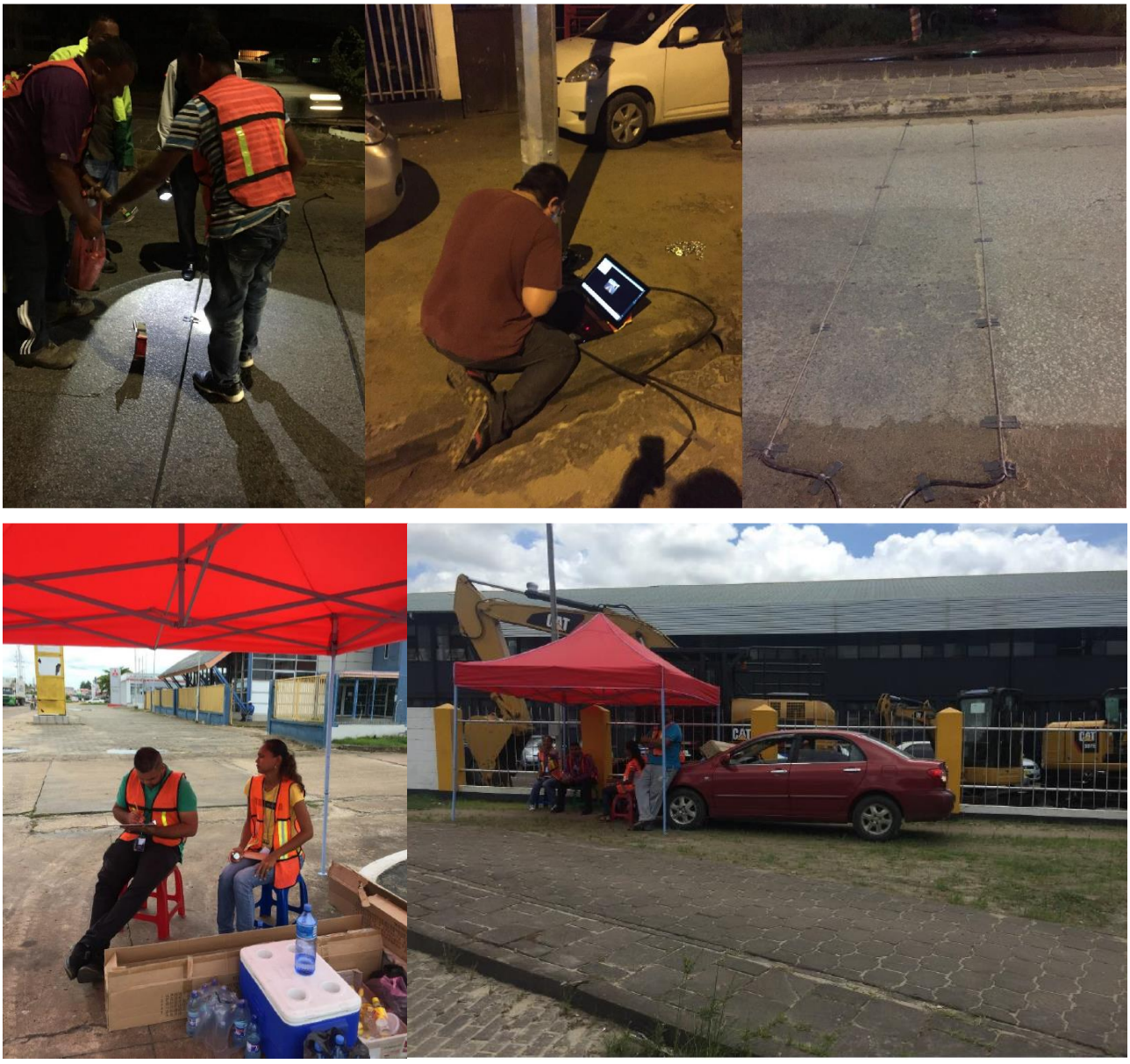
Figure 3. Installation of pneumatic and counts



Source: Transconsult

Finally, the information was complemented with drone flights that consisted on video recording 20 minutes at 120 m of altitude in each of the 8 intersections of the roads to be intervened; all footage was be filmed in peak hours (between 8 am and 10 am) in weekdays in order to obtain a representative sample of directional traffics in these intersections.

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Figure 4. Location of video footage over main intersections

Source: Transconsult

The flight plan was executed over the following mapped corridor by the Surinamese government certified supplier:

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Figure 5. Drone Fligth plan

Source: Transconsult

Preliminary findings from the technical visit show (counts and experts visual inspection) that there are 4 main bottlenecks in the analyzed roads:

1. **Van 't Hogerhuysstraat bridge conecting to Martin Luther Kingweg:** It has 3 lanes, one which is reversible to manage congestion during peak hours. This bridge can't support heavy vehicles traffic.

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2. **Van ‘t Hogerhuysstraat roundabout:** The driving rules of the roundabout generate queues on Jules Wijdenboschbrug and on Van ‘t Hogerhuystraat.

3. **Traffic light in the intersection between Van ‘t Hogerhuysstraat and Willem Campagnestraat:** Storage lanes reduced for right movements. The traffic lights phases and the vehicle flows are uncoordinated.

4. **Intersection between Willem Campagnestraat and Hernhutterstraat:** As with the second bottleneck, the driving rules of the roundabout generate queues between both roads.

Finally, for the road assessment, measurements of travel times were made in the corridors of analysis during peak hour. 15 measurements were done using the floating vehicle technique, using the results to calibrate the data from Google API Distance Matrix. A visual inspection was also executed with the help of the Ministry of Works to collect information on the condition of sewers and pavement.

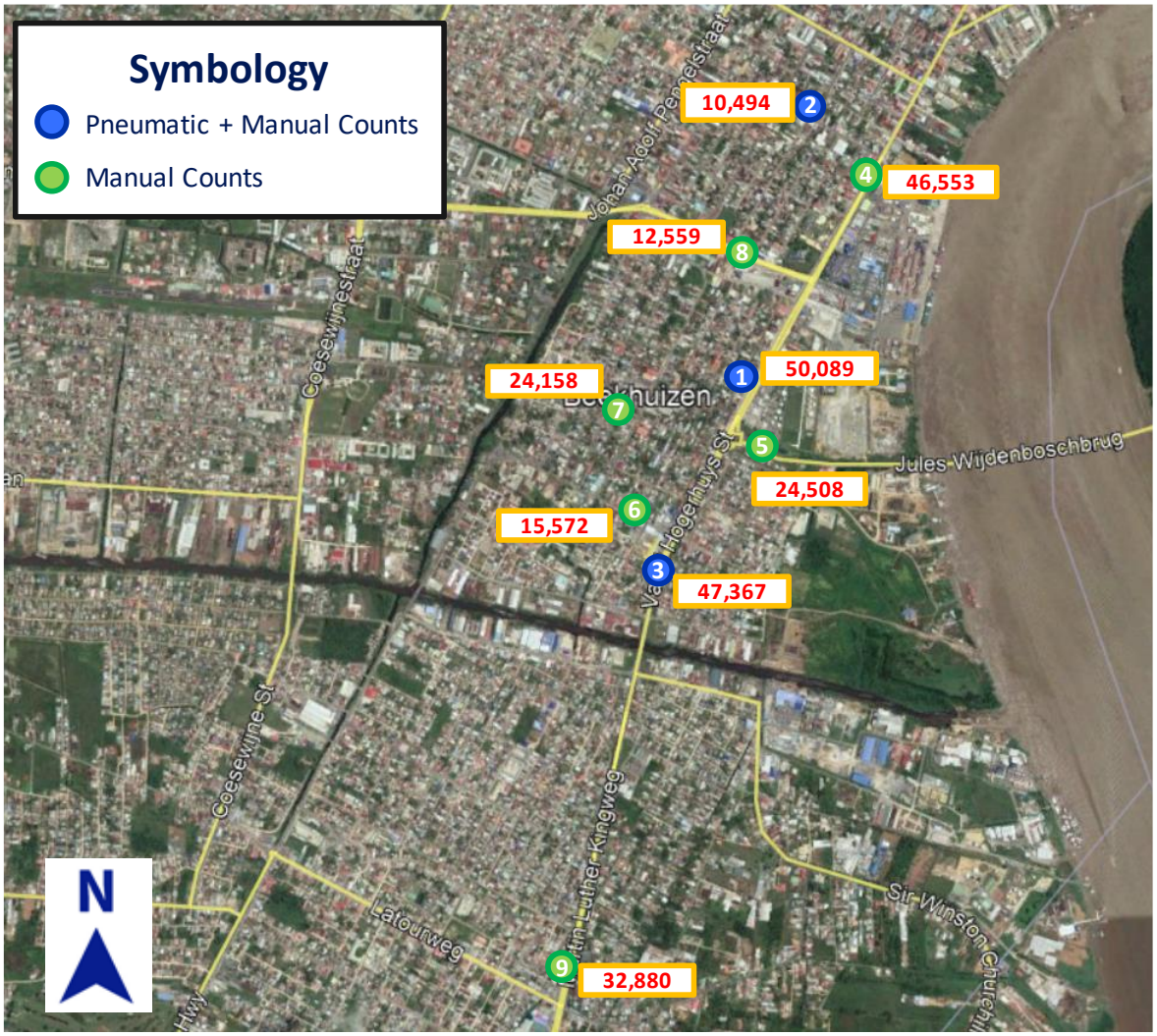
3. Current Traffic Conditions

In this section we have characterized and analyzed the traffic current situation in the roads in and around the Port. As the roads included in the scope of the study have an important share of urban traffic (over 97%), we have analyzed the traffic flows of: i) private cars and motorcycles, ii) heavyweight trucks, and iii) public transportation.

3.1 Traffic counts

For the analysis, de Weekly Average Daily Traffic (WADT) was calculated using the measurements of the installed counters. These were installed in strategic points that allowed a valid sample of measurements to characterize the traffic and vehicle dynamics of the corridor. Also, the manual counters where complementarily installed not only to register the number of vehicles, but also their direction and vehicle type:

Figure 6. WADT in the roads of analysis



Source: Transconsult

As can be seen from the de WADT of every counter, the section with the most congestion is Van ‘t Hogerhuysstraat after Saramacca Bridge and all the way to Molenpad, where some of the traffic is scattered to alternative roads. In this section, WADT reach more than 50,000 vehicles daily.

The traffic has the following composition:

- Private cars and motorcycles: 93%
- Heavyweight trucks: 3%
- Others: 4%, mainly public transport and motorcycles

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Some particularities of the analyzed roads are the following:

- Van ‘t Hogerhuysstraat has external lanes in each side of the road for motorcycles while other vehicles use internal ones. Pedestrian activity was observed, but it’s marginal in access roads.

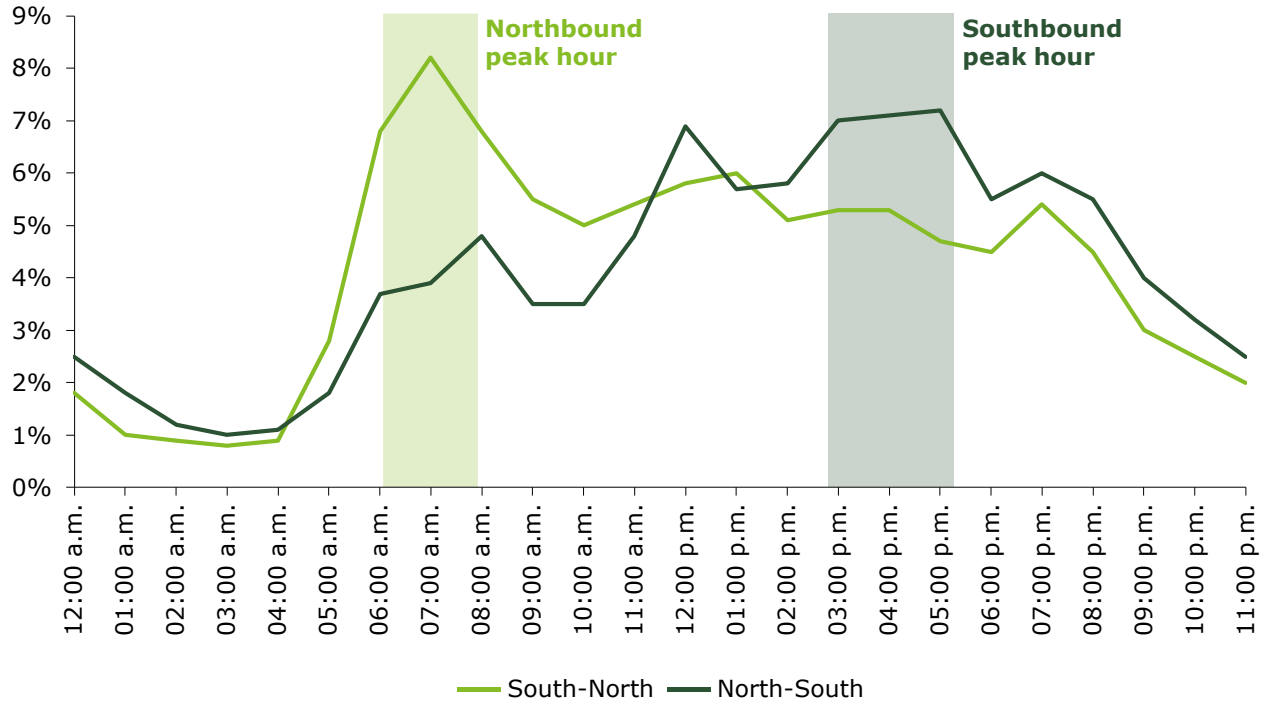
- Saramaccabrug, connecting Martin Luther Kingweg and Van ‘t Hogerhuystraat doesn’t have the capacity to withstand heavy traffic, thus making trucks to take detours that delay their trips.

- Illegal parking in some of the internal roads of the access roads to the port and on the proximity of the Historical Center of Paramaribo can also cause congestions or delay traffic.

- Current traffic lights are being manipulated by transit police at the morning peak hour

Analysis of the data from pneumatic counter allow identify the maximum demand hour (Peak hour). Peak hour was identified from 7:00 to 8:00 on traffic headed north.

Figure 7. Hourly Traffic profile per direction



Source: Transconsult based on data collected by pneumatic traffic counters

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The morning traffic has high volumes from 6:00 to 9:00 hours is caused for trips with purpose work and/or studies, generated in housing areas at south of Paramaribo with destination the center of the city.

To this traffic, we had to add transports heading to the port and other industrial areas nearby that creates further congestions.

There is another peak time with lowest intensity from 16:00 to 17:00 hours on the opposite direction (traffic headed south), due return to home from work and/or schools. However, this traffic is distributed in a larger time interval, which cases that the peak is not as accentuated for southbound traffic.

3.2 Directional flows

Additional to all the estimation of the total traffic flows in the roads, we have elaborated an analysis on the directional traffics in the eight main intersections in the peak hours. As stated previously the analysis of the drone flights that were done was done with help of specialized software.

Peak hour traffic was estimated from the counts of videos of 20 minutes over the main intersections of the network. A factor of 4.012 was used to expand the data to an hour. This factor was estimated based on the analysis of manual traffic counts. Data from other studies contracted by IDB was included to improve analysis.

Next figure shows the traffic flows for all movements in the intersections of study at peak hour.

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Figure 8. Traffic volumes at peak hour in main intersections

Source: Transconsult based on data collected by pneumatic traffic counters

As it can be seen, the roads attend from 2,000 to 5,000 vehicles per hour in all movements. The locations with most traffic are located in Van 't Hogerhuysstraat at the vicinity of the port, which ranges between the 4,000 and 5,000 vehicles. The most important movement is northbound direction with an average of 1,800 vehicles.

For illustrative purposes the three main intersections are presented, however, all data of directional traffic was analyzed.

1. Roundabout Jules Wijdenbochbrug

2. Intersection Van't Hogerhuysstraat- Willem Campagnestraat

3. Roundabout of Willem Campagnestraat and Herhutter

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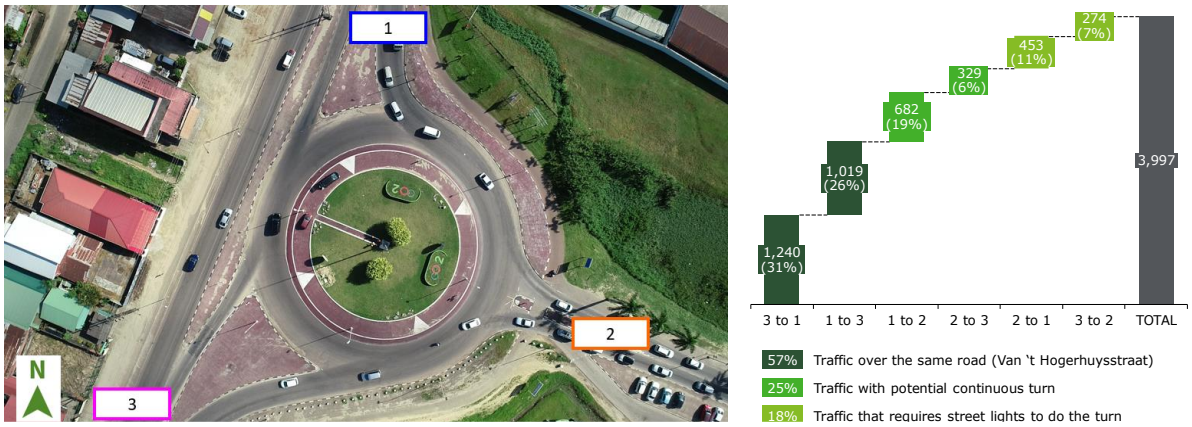
The following figures show the vehicular flow by movement that takes place at intersections. Labels in figures correspond to accesses of intersection as follows: 1) north, 2) eastern, south, and 4) west.

3.2.1 Roundabout Jules Wijdenboschbrug

One of the main bottlenecks identified in the roads is in the Jules Widenboschbrug roundabout, located in the southbound lane of Van't Hogerhuysstraat and the bridge. In the peak hours, this intersection has a hourly traffic volume of 3,997. The directional traffics are shown in the figure below:

Figure 9. Directional traffic at Jules Widenboschbrug roundabout



Source: Transconsult

It is important to mention that Van't Hogerhuysstraat accounts for 57% of all the traffic in the intersection (2,259 movements). Furthermore, 25% of the traffic can access/ exit this road from the Jules Widenboschbrug with continuous turns.

3.2.2 Intersection Van 't Hogerhuysstraat-Willem Campagnestraat

The second intersection analyzed is the Van't Hogerhuysstraat-Willem Campagne Straat, which has an hourly traffic volume of 4,886.

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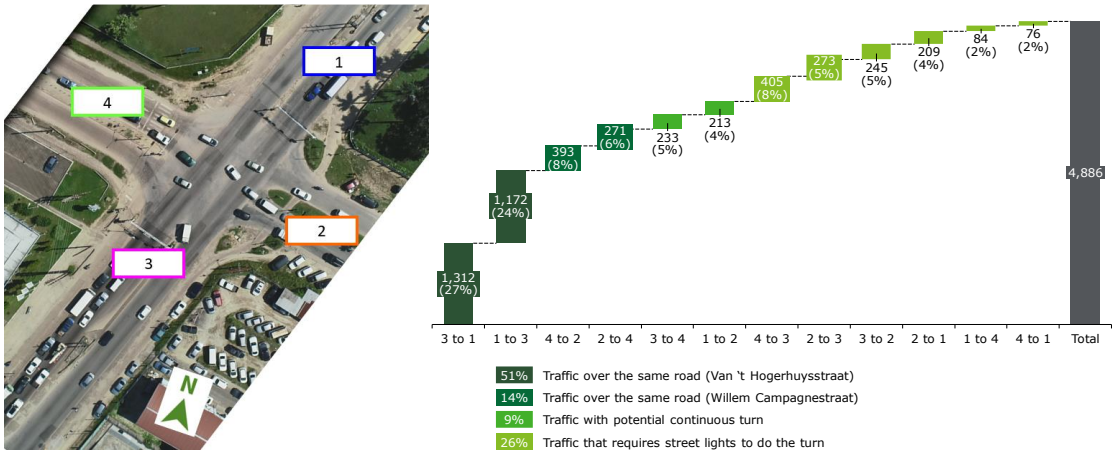
Figure 10. Directional traffic at Van 't Hogerhuysstraat-Willem Campagnestraat



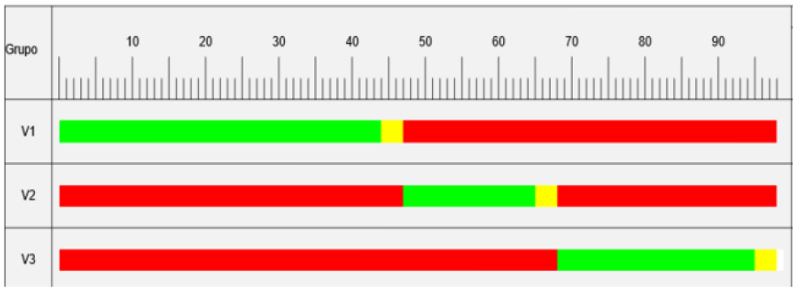
Source: Transconsult

Movements over the Corridor Van 't Hogerhuysstraat (north and southbound traffic) provides 51% of all the traffic in the intersection. The rest of movements are significant lower (<400 vehicles/hour).

This is the only signalized intersections within the roads included in the scope of the study. This intersection was identified as one of the most critical bottlenecks in the physical inspections. By comparing the traffic flows and directional traffics in the intersection, it can be seen that the intersection might be improved by changing the current phases for the traffic light.

The current traffic light has a cycle of 98 seconds divided in 3 phases of green as shown in the next figure:

Figure 11. Semaphoric cycle of Van 't Hogerhuysstraat-Willem Campagnestraat



Traffic flows	% Time	% Traffic
3-1, 3-4, 1-2, 1-3	48%	60%
1-4, 3-2	21%	7%
2-1, 2-3, 2-4, 4-1, 4-2, 4-3	21%	33%

Source: Transconsult

The analysis shows that traffic lights phases are uncoordinated with the traffic volumes, generating queues over Van 't Hogerhuysstraat and Willem Campagnestraat. As it can be seen in the previous chart, the V1 phase has 47% of circulation time and 60% of the volume, while the V3 phase has 21% of the circulation time (green and amber) and only 125 of the volume.

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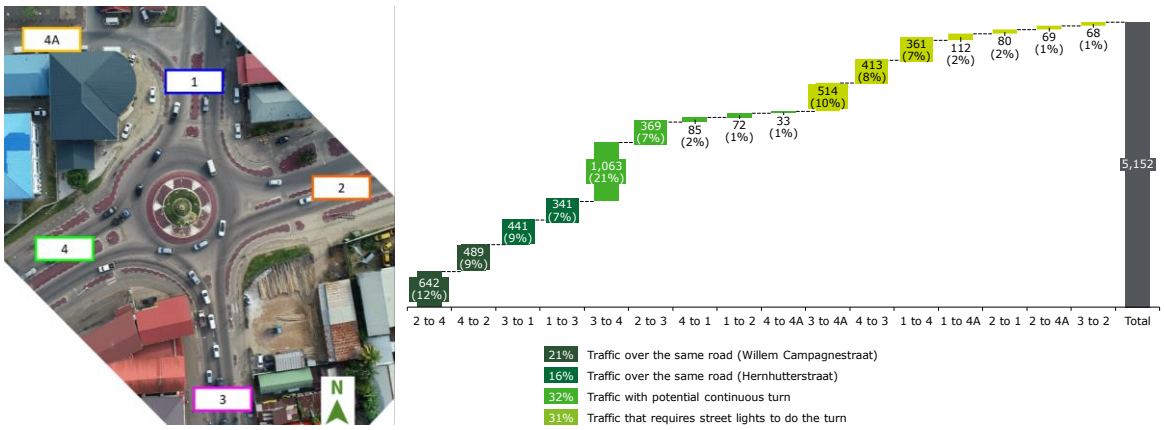
3.2.3 Roundabout of Willem Campagnestraat and Hernhutterstraat

The last analyzed intersection is the roundabout of Willem Campagnestraat and Hernhutterstraat. The current operation of this intersection contributes to log traffic jams located over Hernhutterstraat.

Figure 12. Directional traffic at roundabout of Willem Campagnestraat and Hernhutterstraat



Source: Transconsult

The main movements in this intersection are coming from south to west (3 to 4) and north (3 to 4a, and 3 to 1) accounts for 30% of all the movements. Some of these traffics are rerouted to this road due to the congestion and/or limitations over Van ‘t Hogerhuysstraat. Hernhutterstraat circulation is mainly northbound, but in this section, there is a dedicated lane for north-south-movement to access Kankantriestraat, which adds friction to the vehicles that circulate in the roundabout.

Other main movements are east-west (2 to 4) and vice versa (4 to 2) that accounts fro 16%

3.3 Speed in the network

The study road network was divided into 12 sections due speed or geometrical changes in the corridors of study.

The average speed of the study road network is 29 km/hr. The section 4-3 and 9-10 located in Van’t Hogerhuysstraat and Hernhutter Straat respectively, have speeds lower than 10 km/hr because the traffic volumes exceeds the capacity of the roundabouts.

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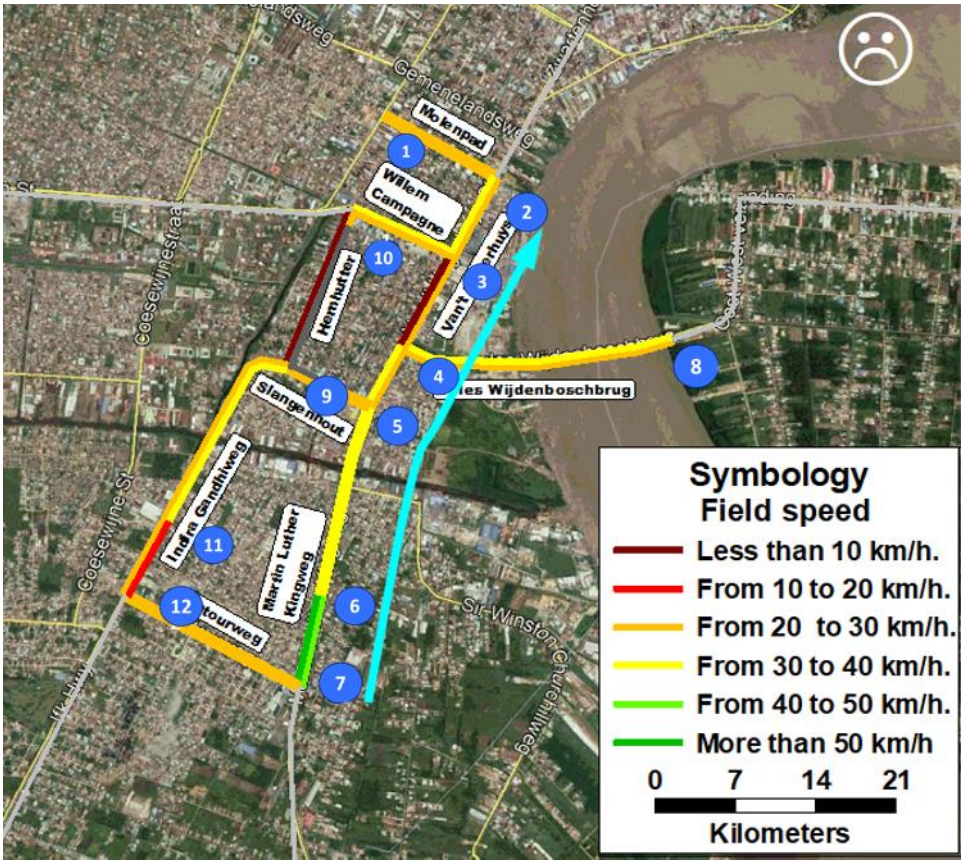
Figure 13. Speed in the network at morning peak hour



Source: Transconsult

As vehicles moves towards the urbanized areas, congestion worsens and the average speed decreases. Specifically, Hernhutterstraat presents the lowest average speeds for vehicles before reaching Willem Campagnestraat as well as the Van ‘t Hogerhuysstraat section before arriving to Dr. Jules Sedney Terminal entrance. Also, Jules Wijdenboschbrug presents a moderate speed when heading to Van ‘t Hogerhuysstraat that will eventually decrease if vehicles keep going north.

4. Microsimulation model

Transconsult has elaborated a model with the data gathered during the technical visit, which have been validated with information from previous studies. This microsimulation has been calibrated with the observations on site to effectively represent the operation of the road system.

The VISSIM software was used to analyze the operation conditions of the transit system. Developed by PTV firm, this is a state-of-the-art software used in international practice, the advantages it offers are: possibility of assigning the use of lanes for different modes of transport, for example, the use of bicycle lanes, managing driver behavior and implementation of various traffic control systems.

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Besides, VISSIM allows the evaluation and planning of urban and interurban infrastructure using current versions of international traffic manuals, such as the Highway Capacity Manual (HCM).

4.1 Parameters for the simulation of the current situation

The main parameters that have been considered for the design of the simulation include the following.

4.1.1 Modeling periods

The model simulates under peak hour because it must plan and design under critical conditions, allowing estimations with a high level of precision about the impacts of proposed interventions. This analysis was carried out from 7:00 to 8:00 in the morning in a weekday.

4.1.2 Network coverage

The microsimulation network is integrated by roads mention previously. Complementary roads have been integrated to represent inputs and / or exits of flows originally not included.

The main roads incorporated into the network are the following:

- Zwartenhovenbrug Straat
- Saramacca Straat
- Johan Adolf Pengel Straat
- Kankantrie Straat
- Calcutta Straat
- Jules Wijdenboschbrug
- Oud Pan Wanica
- Indira Ghandiweg
- Local streets in Hernhutter Straat and Martin Luther Kingweg

Additionally, it was included entrances and exits of the port and some internal roads and parking areas around the port. Next figures show the network considered for this analysis.

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Figure 14. Network coverage

Source: Transconsult

4.1.3 Performance metrics

The development and calibration of the model focuses mainly on achieving the representation of reality on a simulation platform (software) to test the conditions in two scenarios (current situation and with proposed interventions). The following metrics were considered for the analysis:

- **Speed road**: Arithmetic mean of the speeds of all vehicles that at a given moment are within a specific stretch of road

- **Travel times:** Travel-time analysis describes the amount of time it takes to get from one point to the next. Traffic volumes, traffic control devices, signal timing, and delay are all elements that affect actual travel time. Vehicular travel time is measured by driving a route with the regular flow of traffic and timing the duration of the trip

- **Magnitude of the delay:** Delay is defined as the excess time consumed in traversing a distance at a speed lower than speed of a free flow (Vo) that operates of vehicle

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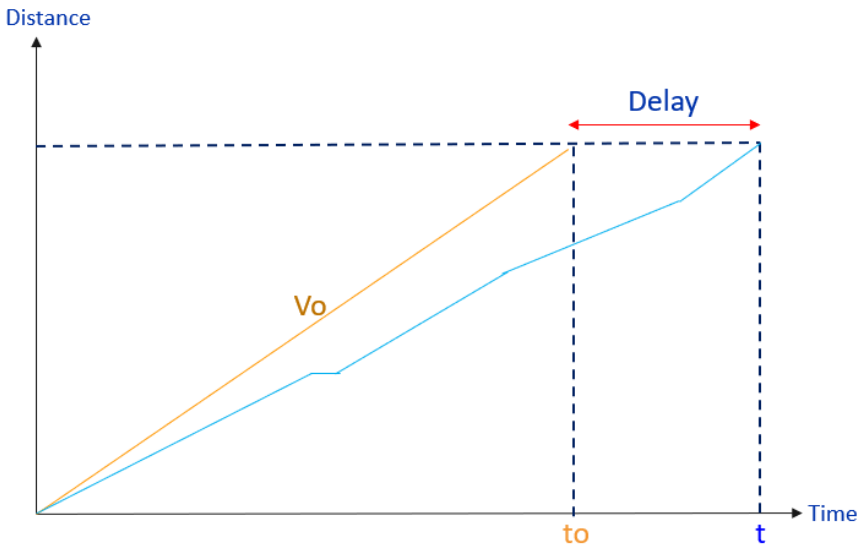
under conditions without congestion, as show in figure. Delay is a measure that most directly relates driver´s experience.

Figure 15. Delays definition



Source: Transconsult

- **Level of service:** The Level of Service (LOS) represents a measure of satisfaction of the user in the intersections given by the average delay of all movement of all the movements that interact in it.

- **Queue lengths:** The Highway Capacity Manual, HCM (2010), defines a Queue as: A line of vehicles, bicycles, or persons waiting to be served by the system in which the flow rate from the front of the queue determines the average speed within the queue. Queues are formed when the arrival rate is higher than the service rate.

4.1.4 Calibration of the model

The model was calibrated to ensure that the traffic flows within it were consistent with the volume obtained from the data collection. The most used parameter to measure the adjustment degree of the model is the R^2 parameter. Values of R^2 closer to 1 will mean that the adjustment is adequate.

The microsimulation model was calibrated with a R^2 value of 0.95, which indicates a correct representation of the current situation of the corridor. The next figure shows this adjustment:

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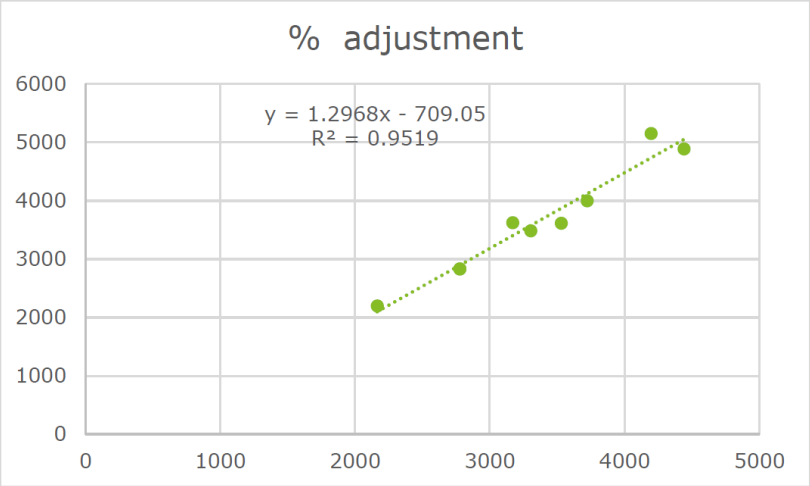
Figure 16. Adjustment percentage



Source: Transconsult

4.1.5 Travel times

The travel times were calibrated comparing speeds measured in the field, against the ones estimated by the model to ensure that the model correctly represents the observed conditions of the network. As an example, these are three possible routes in the peak hour:

- **Route 1 -** Martin Luther Kingweg (intersection with Latourweg) to Van 't Hogerhuysstraat (intersection with Molenpad): This route is used for urban traffic coming from the south to Paramaribo's center.

- **Route 2** - Latourweg-Indira Gandhiweg-Slangenhout-Hernhutter-Willem Campagne Straat - Van 't Hogerhuysstraat -Molenpad: This route is used for urban traffic coming from the south-east to Paramaribo's center, as well as all heavy vehicles coming to the port, which are detour due to the weight restrictions of the current bridge.

- **Route 3** - Jules Wijdenboschbrug - Van 't Hogerhuysstraat (intersection with Molenpad): This route is used for urban traffic coming from the west to Paramaribo's center.

Next table and figure shows the analysis for 3 routes that illustrate this process:

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Figure 17. Time per route (illustrative example)

Source: Transconsult

Table 1. Comparison of times. Observed vs modeled

Path	Time (minutes)		
	Field Measure	Modeled	% Error
1. Martin Luther Kingweg (intersection with Latourweg) to Van 't Hogerhuysstraat (intersection with Molenpad)	18	16	9%
2. Latourweg-Indira Gandhiweg-Slangenhout-Hernhutter-Willem Campagne Straat- Van 't Hogerhuysstraat-Molenpad	19	22	15%
3. Jules Wijdenboschbrug - Van 't Hogerhuysstraat-Molenpad	8	8	2%

Source: Transconsult

However, it is important to mention that, although travel times form the routes range from 8-22 km/h, there are sections where speed average declines to less than 10 km/h (i.e. Van 't Hogerhuysstraat between Jules Wijdenboschbrug and Willem Campagne Straat).

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4.1.6 Level of Service (LoS)

The main indicator to estimate the LoS at an intersection is the magnitude of the delay. The shorter the delay, the better. Categories of delays chan change from signalized to unsignalized intersections. The next tables show classification of LoS based on the delay for both intersection types:

Table 2. Level of Service Criteria for Unsignalized Intersections

Level of Service	Control Delay (sec/veh)
A	0 - 10
B	>10 - 15
C	>15 - 25
D	>25 - 35
E	>35 - 50
F	>50

Source: Highway Capacity Manual

Table 3. Level of Service Criteria for Signalized Intersections

Level of Service	Control Delay (sec/veh)	Description (Signalized Intersections)
A	≤10	Free Flow
B	>10 - 20	Stable Flow (slight delays)
C	>20 - 35	Stable flow (acceptable delays)
D	>35 - 55	Approaching unstable flow (tolerable delay, occasional delay for more than a cycle[1])
E	>55 - 80	Unstable flow (intolerable delay)
F	>80	Forced flow (jammed)

1[1] Semaphoric cycle: Time that takes a complete sequence of all signal indications of a traffic light.

Source: Highway Capacity Manual

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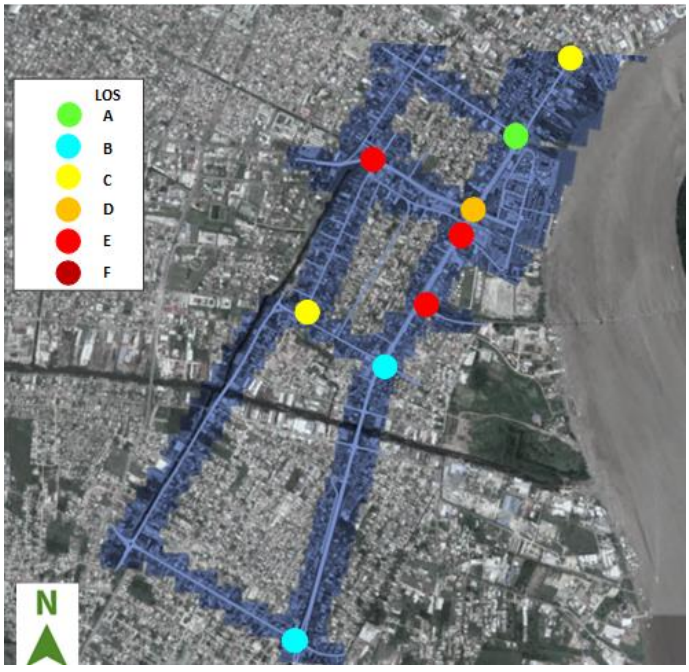
Currently the network has eight unsignalized intersections and only one that is signalized.

Based in the analysis performed with the microsimulation model for the main intersections, the conclusions are:

- Three intersections are at level of service E which indicate delays in travel time not acceptable to users due that demand overpass the capacity of the intersection. These intersections are located in the adjacent roads to the port.
- One intersection is at level of service D. This node corresponds to the only signalized intersection and is at the limit of user acceptance.
- Two intersections are at level of service C.
- Two intersections are at level of service B which are located at the south end of the system.
- One of the intersections is at level of service A, due to the traffic jams located in the previous intersection.

The levels of service A and B means for the user is travelling through the intersection without major delays.

Figure 18. Current Level of Service in main intersections



Source: Transconsult

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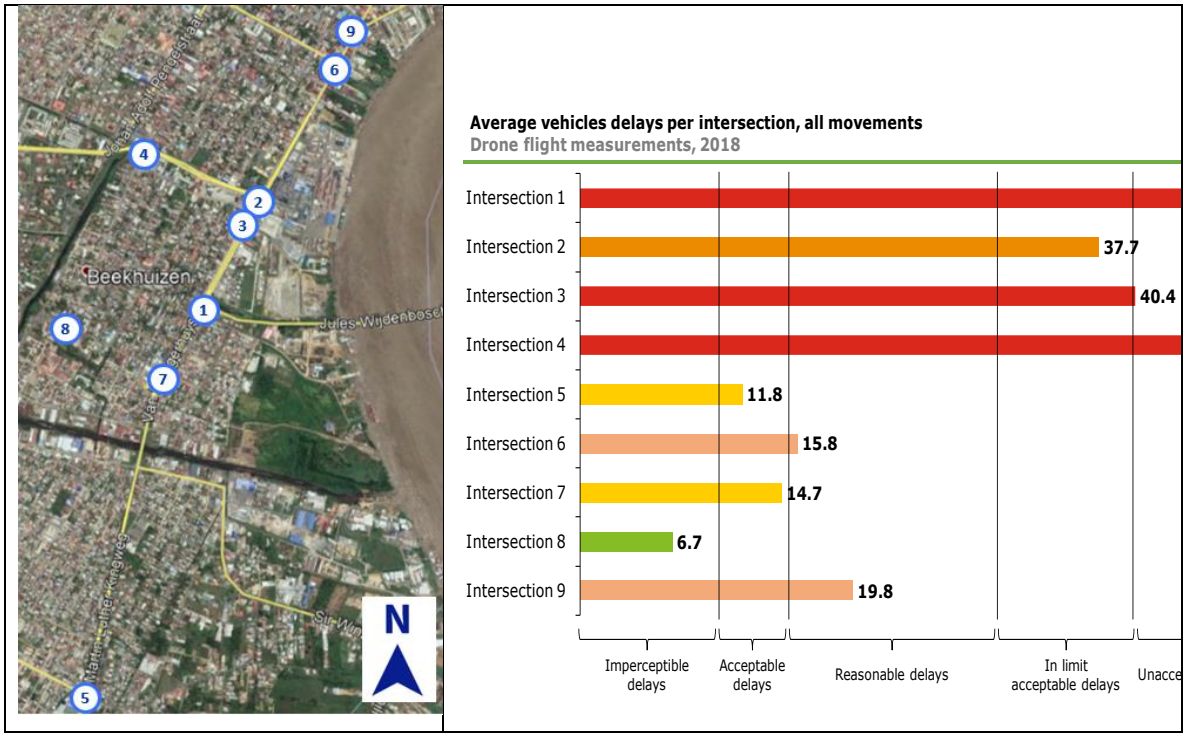
4.1.7 Delays

Next table and figure show average delay for all movements per intersection in the current situation

Figure 19. Average delays all movements



Source: Transconsult

- Intersections 1,3 and 4 present delays bigger than 40 seconds. This means that vehicles that are in the middle of the vehicles queue must wait half minute on average to cross the intersection.

- Intersection 2 has a delay of 37.7 seconds average for all movements that provoked that cars keep accumulating generating significant queues.

- These 4 intersections are the bottleneck of the system of study. The proposed alternatives will be focused in this area.

- The other intersections present delays with a range of 6 to 20 seconds. For drivers these magnitudes are acceptable detentions.

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4.1.8 Queue length

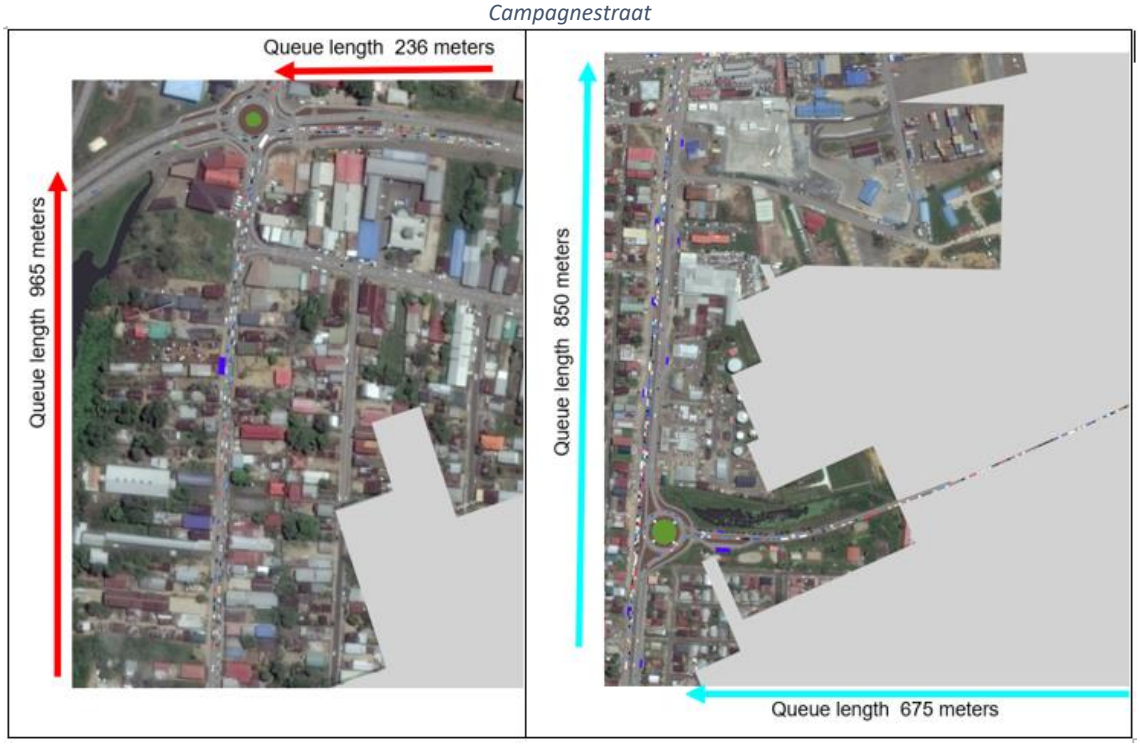
The maximum queue length it is an indicator of capacity of the intersection to clear its vehicular flow.

The critical queue lengths presented in the model are:

- At the intersection of the Van't Hogerhuysstraat and Willem Campagnestraat (intersection 2)
    - There is a queue length of 850 meters in Van't Hogerhuysstraat.
    - The queue length in Jules Wijdenbochbrug is 675 meters.
- At the roundabout Poelepantje (intersection 4)
    - There is a maximum queue length of 965 meters in Hernhutterstraat (The length of the street is 1.08 kilometers)
    - In the same intersection, the queue length is 236 meters in Willem Campagne Straat

Next figures show the queue length for intersection 2 and 4

Figure 20. Queues length at two main intersections: Roundabout Poelepantje and Van't Hogerhuysstraat and Willem Campagnestraat



Source: Transconsult

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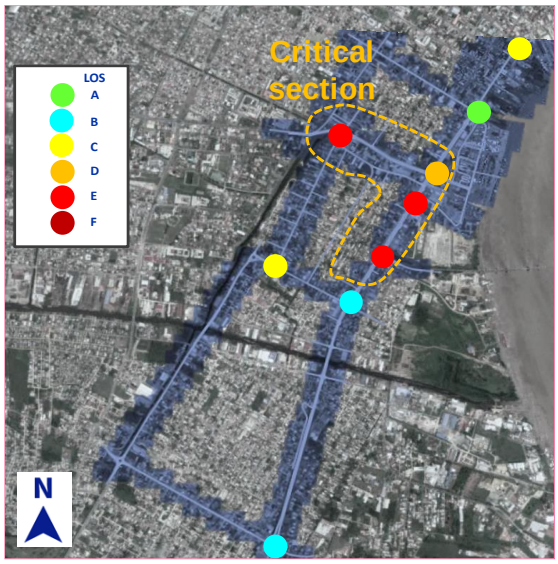
According to these, it might be concluded that the most critical intersections are located in Van ‘t Hogerhuysstraat.

Figure 21. Critical section of the network



Source: Transconsult

In these intersections, demand overpassed the capacity making unacceptable delays, that impacts in speeds lower than 10 km/hr that creates queue lengths that exceeds 500 meters of length in the most charged direction. Therefore, the propos interventions will be focused in the main intersections.

5. Proposed road interventions

The interventions were designed keeping in mind the prioritization of main flows thru two main actions

- Increase the capacity of the corridor (mainly in Martin Luther Kingweg- Van ‘t Hogerhuysstraat)
- Organize the flows in the intersections using traffic lights, giving more green time for the main flows (For the northbound direction, synchronization of traffic lights was included to generate green wave)

Proposed interventions were designed considering the available Right of Way (RoW) to avoid buying private property, expropriations or physical displacement of population in the surrounding areas to the corridors.

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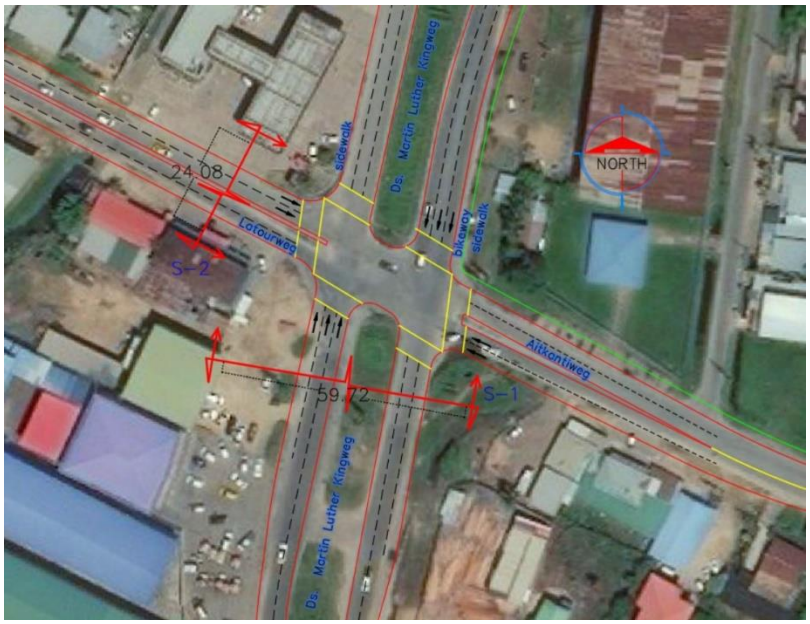
5.1.1 Martin Luther Kingweg and Van ‘t Hogerhuysstraat capacity expansion

Capacity expansion on the corridor is proposed from Martin Luther Kingweg and Latourweg to Van ‘t Hogerhuysstraat and Willem Campagnestraat. This expansion consists in an additional lane in each of the road sides, as well as some dedicated lanes to turning vehicles. The works are presented in the next images:

Figure 22. Floorplan of Martin Luther Kingweg and Latourweg



Source: Transconsult

The road expansion begins in Martin Luther Kingweg after the intersection with Latourweg. An additional lane would be made for each of the road sides; additionally, a new bikeway and sidewalks would be built.

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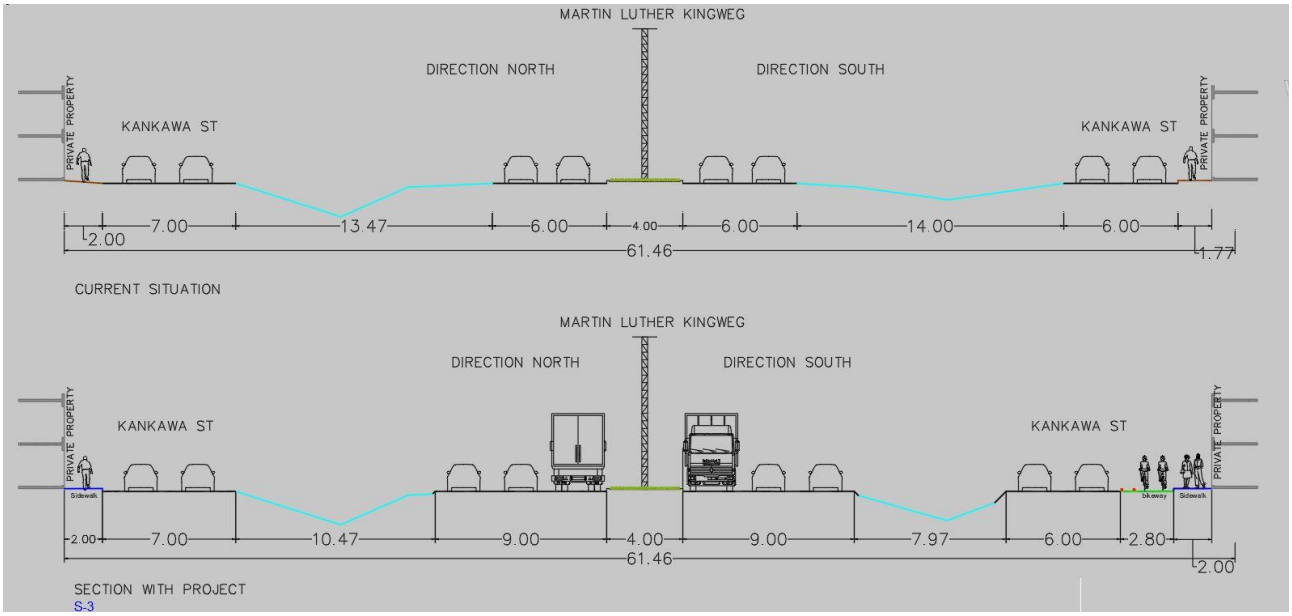
Figure 23. Cross-section (As-Is and with Proposed Interventions) of Van 't Hogerhuysstraat and Latourweg



Source: Transconsult

Taking in account the right of way limitations, there is section of 250 mts at the south of the Saramacca channel with 5 lanes where the center lane is proposed as reversible. This is the only section of the corridor that will not have 6 lanes.

Figure 24. Floorplan of Martin Luther Kingweg between Toekomstweg and Industrieweg Zuid

Source: Transconsult

As observed, the corridor capacity expansion continues after crossing the Saramacca Channel, maintaining the additional lane, new bikeway and sidewalks for each of the road sides.

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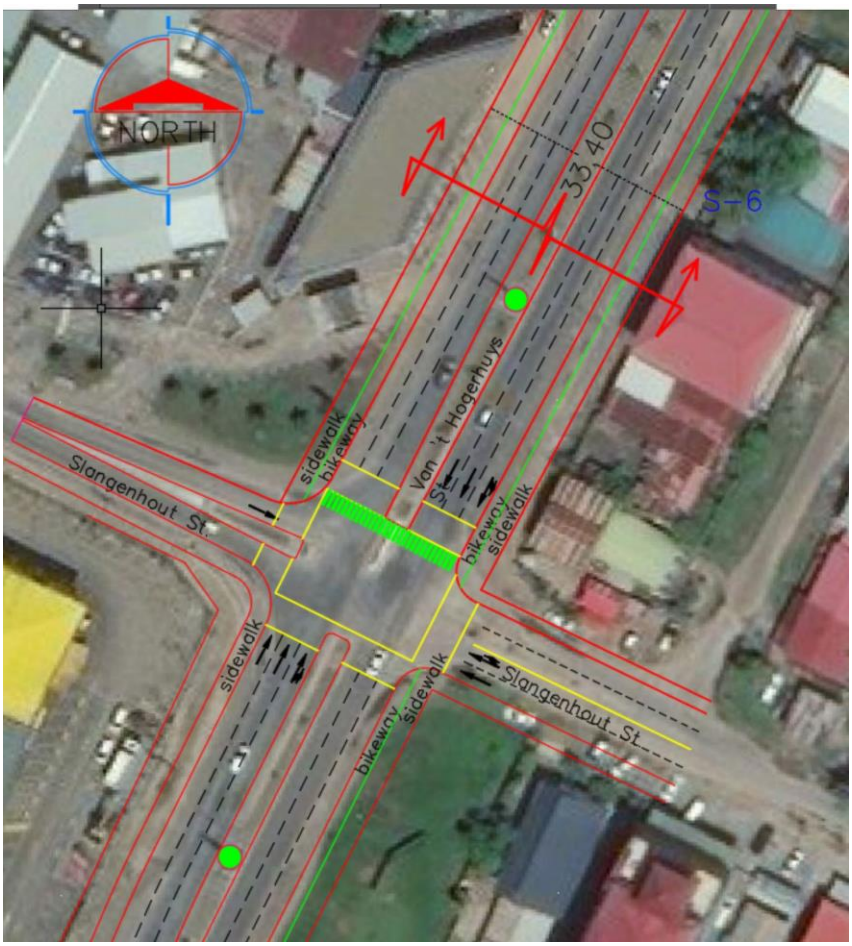
Figure 25. Floorplan of Van 't Hogerhuysstraat and Slangenhoutstraat



Source: Transconsult

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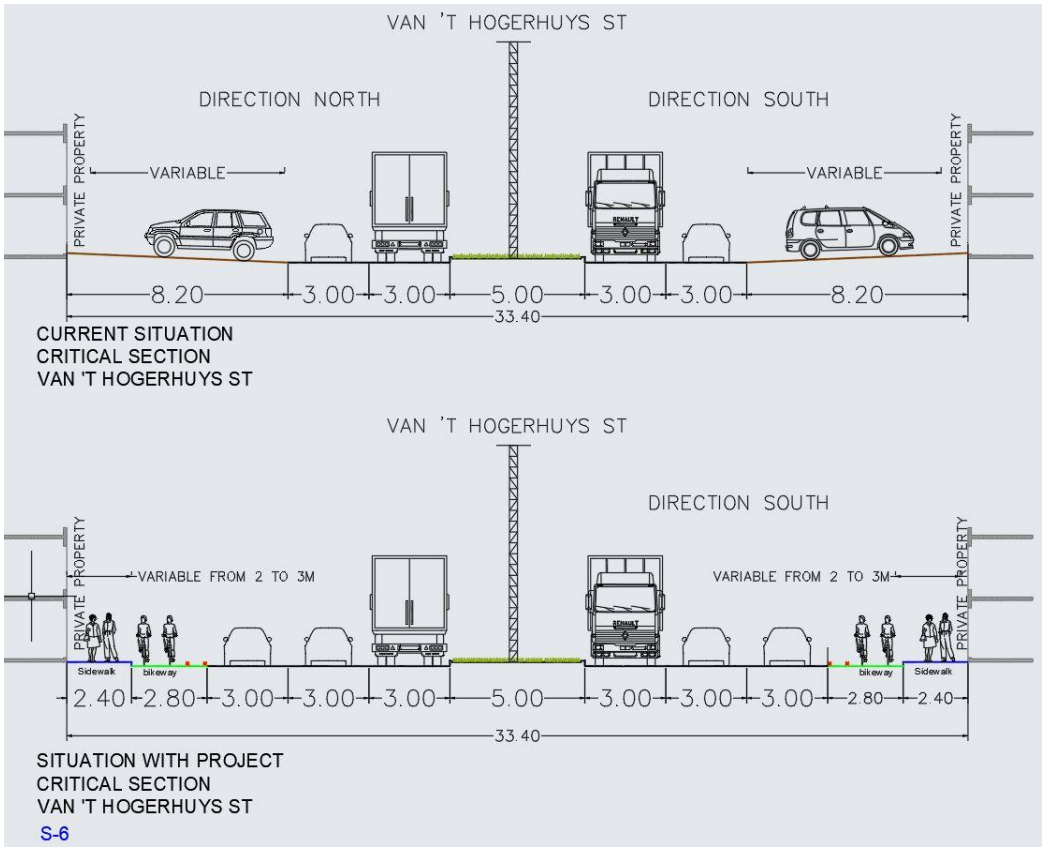
Figure 26. Cross-section (As-Is and with Proposed Interventions) of Van 't Hogerhuysstraat and Slangenhoutstraat

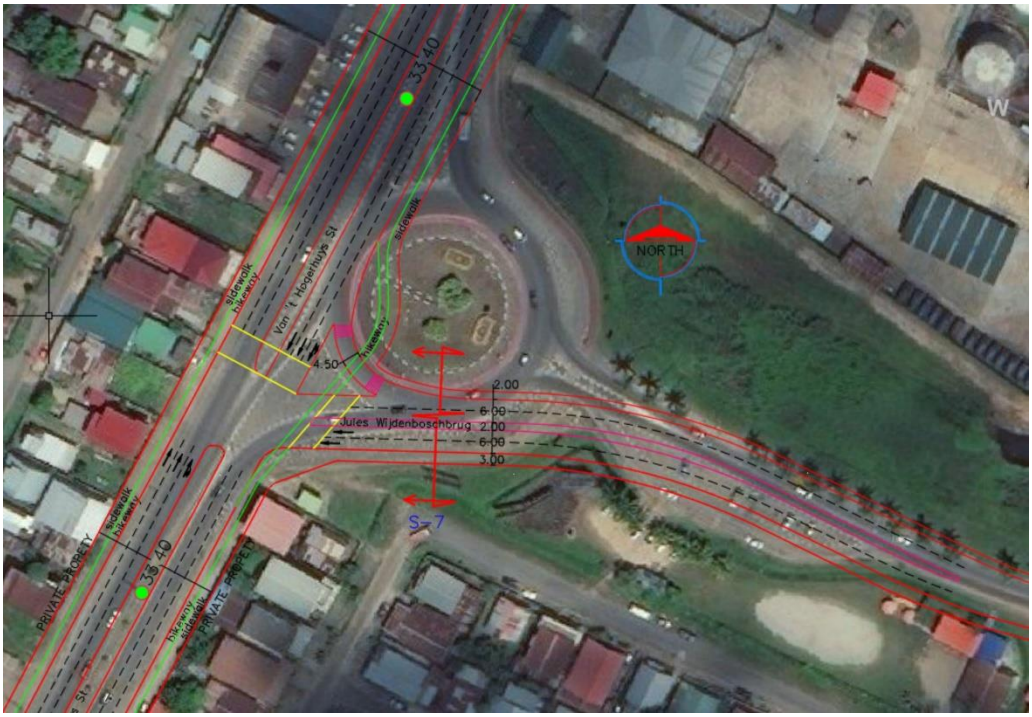


Source: Transconsult

This extension will help Van 't Hogerhuysstraat to withstand the current and future traffic, as well as to have specific delimited areas for pedestrians and bikes. Currently, there is underutilized space that is private vehicles sometimes use for illegal parking.

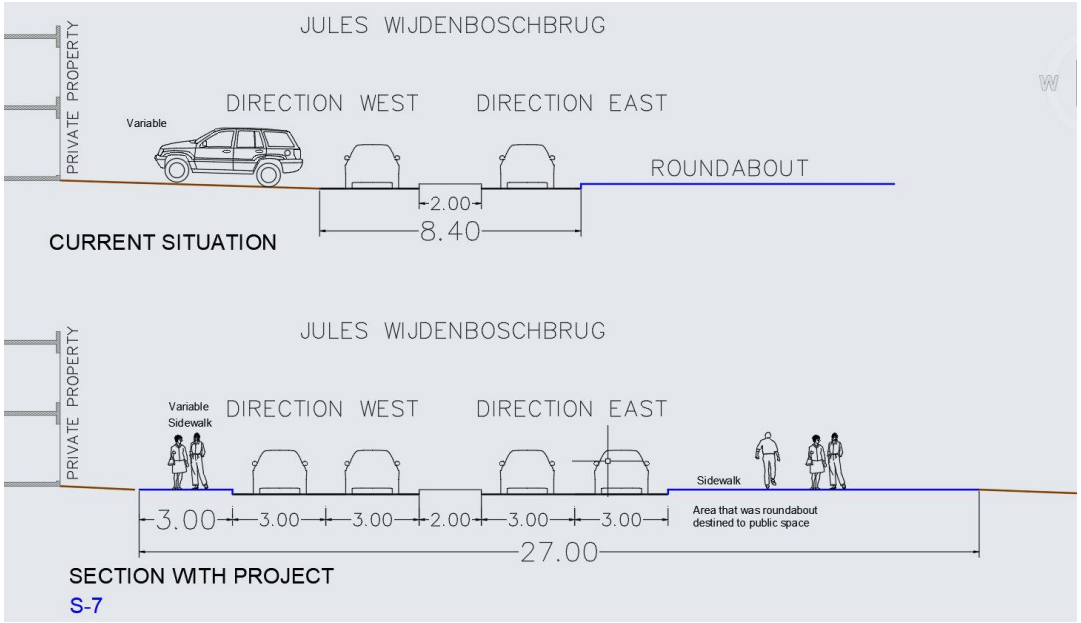
In the case of the intersection corresponding to the roundabout for Jules Wijdenboschbrug, a geometric modification is proposed. The roundabout doesn't have the capacity to withstand the movements from and to the bridge. In addition, the intersection proves to be problematic as the movements with the most traffic are not always prioritized. The geometric modification consists in having direct lanes instead of a roundabout to allow vehicles to quickly incorporate on their required route, as well as an additional lane in each direction.

Figure 27. Floorplan of Van 't Hogerhuysstraat and roundabout Jules Wijdenboschbrug



Source: Transconsult

Figure 28. Cross-section (As-Is and with Proposed Interventions) of Jules Wijdenboschbrug in the roundabout area



Source: Transconsult

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The additional lane would also have sidewalks in each side to help pedestrians move with more safety. As for the space of the roundabout, it could be recovered as a new public area for the people of Paramaribo. The public space could be used as a green area to create a king of urban park for the community. Conceptually, the next scheme presents an illustrative idea:

Figure 29. Proposal for recuperation of public space in roundabout Jules Wijdenboschbrug

Source: Transconsult

After the Jules Wijdenboschbrug roundabout, the vehicles approach the sections with the most congestion near the port's accesses.

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Figure 30. Floorplan of Van 't Hogerhuysstraat and Kankantriestraat

Source: Transconsult

To improve the access to the port and prevent trucks to create congestion, an storage extra lane is proposed to allow them to enter the port using Abattoirstraat, instead of the current entrance in Havenlaan Zuid. The usage of Abattoirstraat will prevent trucks from reaching the intersection of Van 't Hogerhuysstraat with Willem Campagnestraat, a current area with a lot of congestion, and arrive to the port before, using internal roads for their operations.

5.1.2 Repaving and improvement of other corridors

Repaving and improvement of the adjacent roads in the main corridor is also proposed in order to make circulation better and to make the network an integral project. The repaving method proposed consists on a process that includes the milling of the asphalt to ensure that the materials are evenly distributed and compacted on the road. The roads considered for these proposals are

- Latourweg
- Kankawastraat
- Slangenhoutstraat,
- Molenpad

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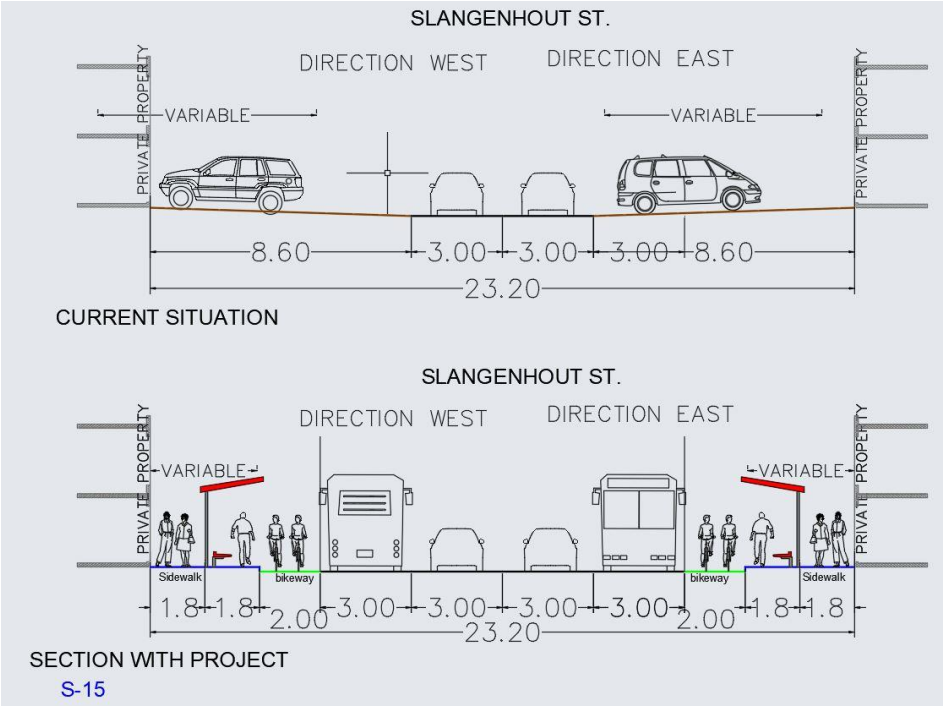
- Willem Campagnestraat
- Hernhutterstraat.

For Latourweg, the proposals include construction of 150 meters of storage lanes to avoid accumulation of vehicle in the intersection with Martin Luther Kingweg

The proposal for Kankawastraat intends to allocate the bike path and sidewalk parallel to Martin Luther Kingweg

The proposal for Slangenhoutstraat includes the construction of 350 meter off an additional lane. Construction of bus stops, sidewalks and bike paths are considered

Figure 31. Cross-section (As-Is and with Proposed Interventions) of Slangenhout straat



Source: Transconsult

Willem Campagnestraat proposed improvements take advantage of the available space between the roads and the private property to add sidewalks, a bikeway and public transport stops for users and pedestrians to take advantage of.

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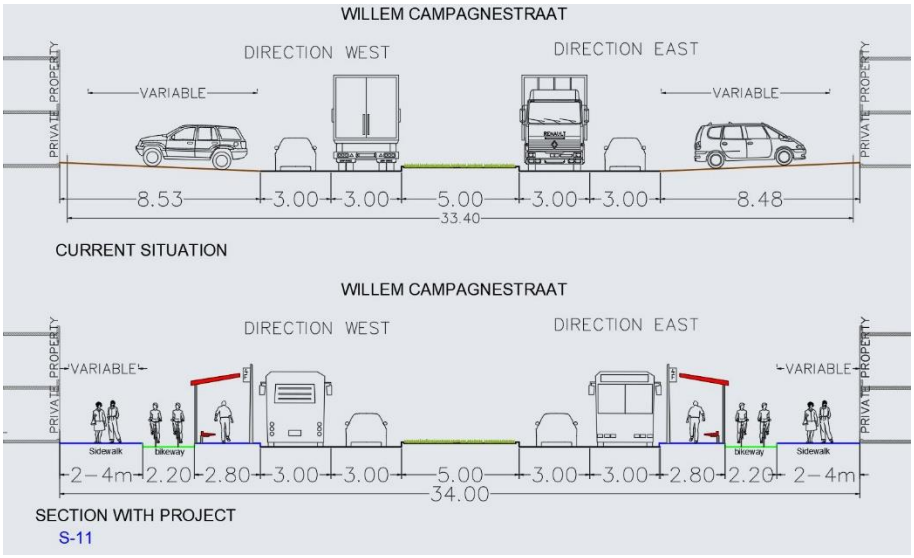
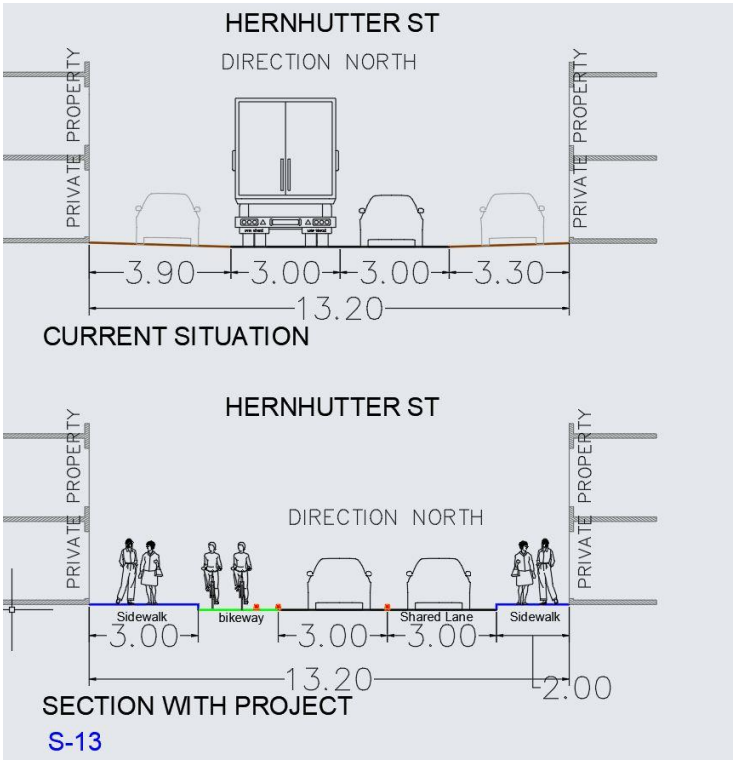
Figure 32. Cross-section (As-Is and with Proposed Interventions) of Willem Campagnestraat



Source: Transconsult

Hernhutterstraat interventions would also take advantage of the available space for sidewalks and a bikeway. There is no capacity expansion proposed for this street.

Figure 33. Cross-section (As-Is and with Proposed Interventions) of hernhutterstraat



Source: Transconsult

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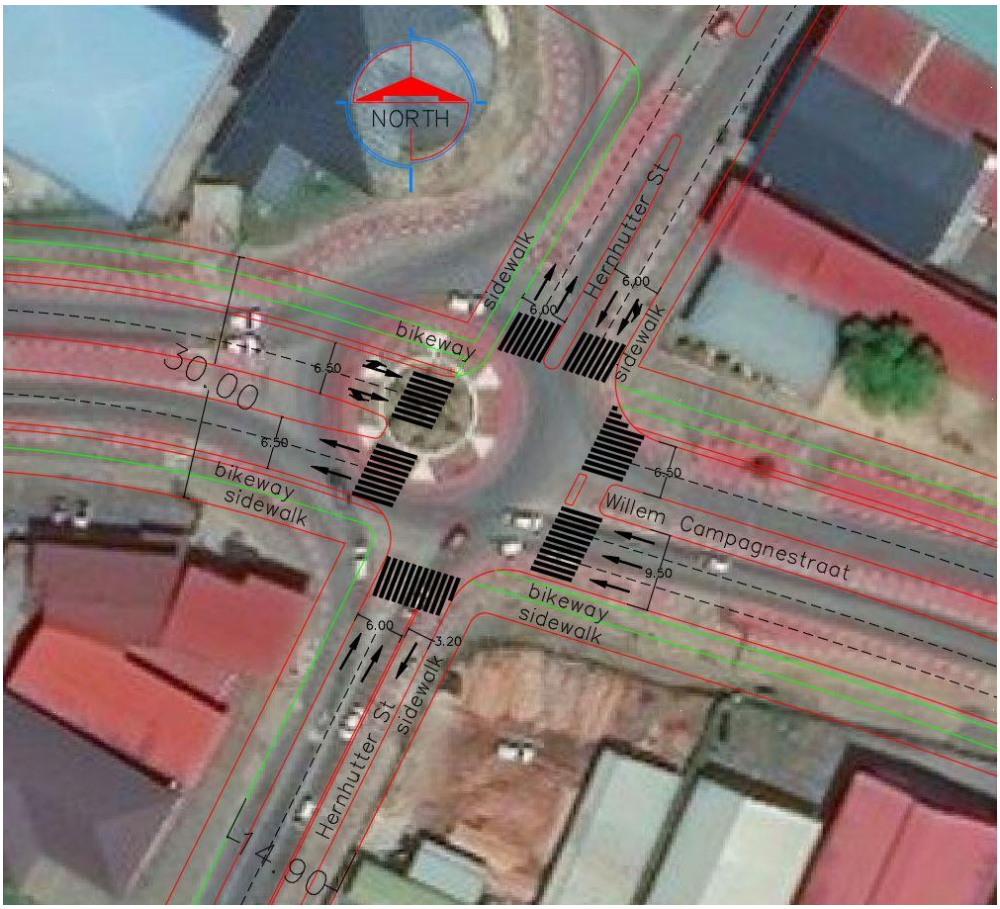
Finally, a second roundabout intervention is proposed in the intersection between Willem Campagnestraat and Hernhutterstraat. The queues in Hernhutterstraat can reach almost 1 km long, and the current roundabout doesn't allow a fluent vehicle movement. The intervention consists in removing the roundabout a create an intersection regulated by traffic lights that prioritize the movements with the most traffic and allows some continuous turns.

Figure 34. Floorplan of Willem Campagnestraat and Hernhutterstraat



Source: Transconsult

5.1.3 Bridge construction over Saramacca Channel

The current bridge over Saramacca Channel can't withstand the traffic of heavy vehicles, which causes trucks to detour to reach the port and areas near Downtown Paramaribo. The proposed intervention would maintain the additional capacity of Martin Luther Kingweg and Van 't Hogerhuysstraat to have a three-lane bridge per side, and also be built with the strength to allow the traffic of heavy vehicles. This new weight capacity improvement could potentially help not only trucks, but also the overall network as it would alleviate stress from secondary roads.

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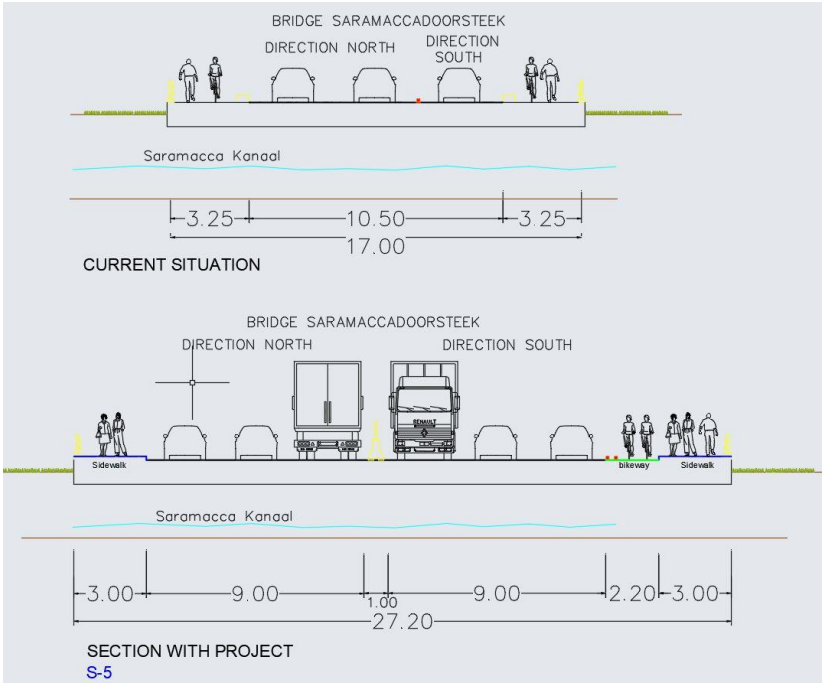
Figure 35. Floorplan of bridge over Saramacca channel

Source: Transconsult

Figure 36. Cross-section (As-Is and with Proposed Interventions) of bridge over Saramacca channel



Source: Transconsult

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This new bridge would increase the total width by 17.20 m compared with the current bridge, to make space for the additional lane in each side, but also to create pedestrian sidewalks and a bikeway.

5.1.4 Implementation and synchronization of traffic lights and a traffic control center

For the proposed interventions to work properly and in an organized manner, it is also required to have traffic lights in specific intersections that currently don't have them. As for the traffic lights that exist, they need to be synchronized with the new ones to provide green waves for the network, prioritizing the directions and routes with the most traffic. The only traffic light currently in place is the one in the intersection between Willem Campagnestraat and Van 't Hogerhuysstraat. Nine additional traffic lights are proposed for other intersections as the next map shows:

Figure 37. Proposal for locations of traffic lights

Source: Transconsult

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Table 4. List of Intersections to be intervened

ID	Intersection
1	Van ‘t Hogerhuysstraat and Willem Campagnestraat
2	Martin Luther Kingweg and Latourweg
3	Van ‘t Hogerhuysstraat and Slangenhoutstraat
4	Van ‘t Hogerhuysstraat and Jules Wijdenboschbrug
5	Van ‘t Hogerhuysstraat and Abattoirstraat (proposed new port entrance)
6	Van ‘t Hogerhuysstraat and Kankantriestraat
7	Hernhutterstraat and Willem Campagnestraat
8	Van ‘t Hogerhuysstraat and Molenpad
9	Zwartenhovenbrugstraat and Saramaccastraat
10	Van ‘t Hogerhuysstraat and Industrieweg Zuid

Source: Transconsult

For the synchronization of the traffic lights and the future operations, a Traffic Control Center should be installed as it will help to modify the overall phase if future traffic requirements in the network change as well as to face daily issues.

6. Microsimulation of proposed interventions

This section describes the impact in the performances metrics due to proposed interventions in the network for the peak hour in base year.

6.1.1 Travel times

In overall the proposed interventions will allow a reduction of 6 minutes in travel times for each user of the network

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Figure 38. Comparison of time. Current Vs with Proposed interventions

		Time (minutes)		Speed (Km/hr)		
Path	Length (Km)	Current	With Interventions	Current	With Interventions	% time improvement
	3.8	14.15	7.87	16	29	-44%
	5.07	14.06	9.54	22	32	-32%
	1.735	12.34	4.96	8	21	-60%

Source: Transconsult

The proposed interventions will reduce the travel time in 45 % (average) for the northbound movement in the corridors analyzed.

The speeds increase significantly in the critical section (Van 't Hogerhuysstraat between Jules Wijdenboschbrug and Willem Campagne Straat)

6.1.2 LoS

The proposed interventions have:

- An improvement of Los in 33 % of the analyzed intersections
- Another 33 % maintains the same Level of Service
- The rest decrease one category of LoS

Next figure shows the change in Los from current situation to scenario with proposed interventions

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Figure 39. Comparison of LoS. Current Vs with Proposed interventions

Los Current Situation

LoS with proposed interventions

Source: Transconsult

The interventions allow keep stable speeds higher than 30 km/hr in the whole network, even if there are some intersections where Los decreases.

6.1.3 Delays

Next table and figure shows the change of average delay for all movements per intersection in the current situation and with proposed interventions

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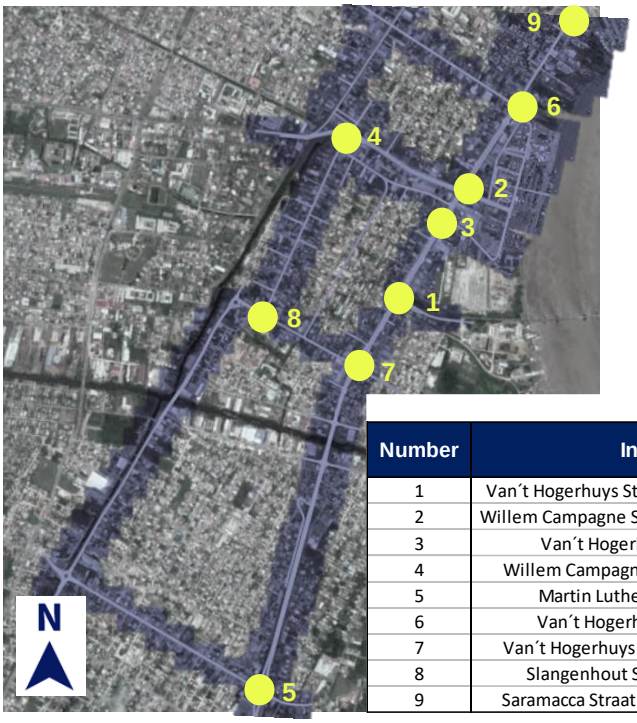
Figure 40. Comparison of Delays. Current Vs with Proposed interventions



		All movements average delay	
Number	Intersection	Current Situacion (s)	With Proposed interventions (s)
1	Van´t Hogerhuys Straat – Jules Wijdenboschburg	37.7	30.0
2	Willem Campagne Straat – Van´t Hogerhuys Straat	37.7	43.5
3	Van´t Hogerhuys Straat – Shell Gas	40.4	6.8
4	Willem Campagne Straat - Hernhutter Straat	46.6	56.2
5	Martin Luther Kingweg - Latourweg	14.7	33.0
6	Van´t Hogerhuys Straat - Molenpad	6.7	31.1
7	Van´t Hogerhuys Straat – Slangenhout Straat	11.8	25.4
8	Slangenhout Straat – Hernhutter Straat	15.8	1.7
9	Saramacca Straat – Zwartenhovenbrug Straat	19.8	23.1

Source: Transconsult

Even if in 6 of the 9 intersections increases their average delays, the proposed interventions balance the delays by movement thru traffic lights that were configured to provide greater time of green to the main flows

To illustrate, there are presented the flows and delays for current situation and with proposed interventions for

- Intersection Van't Hogerhuysstraat and Jules Wijdenboschbrug
- Van't Hogerhuysstraat and Willem Campagnestraat
- Intersection of Willem Campagnestraat and Hernhutterstraat

6.1.3.1 Intersection Van't Hogerhuysstraat and Jules Wijdenboschbrug

Currently the accesses 1 and 3 have the greater flows (80 % of all intersection) and priority in the internal circulation of the roundabout

Access 2 has the resting 20 % of the flow and due that the movements over Van't Hogerhuysstraat have priority, the users of this access have to wait until the roundabout lane is clear which creates queues that can reach the bridge.

Next figures show traffic share per access

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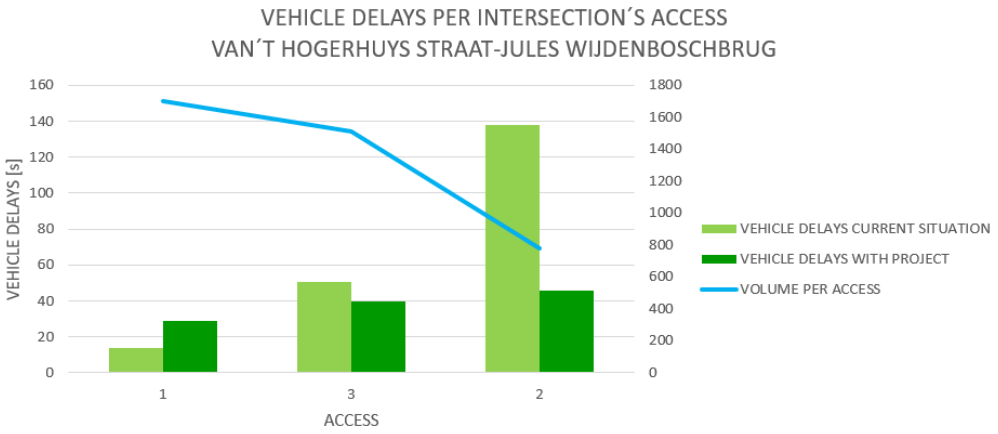
Figure 41. Comparison of Delays at Intersection Van't Hogerhuysstraat and Jules Wijdenboschbrug



Source: Transconsult

The roundabout reconfiguration and implementation of traffic light provides the next impacts

- Minus 70 % of delays in Access 2
- Minus 22 % of delays in Access 3
- Plus 4% of delays in access 1

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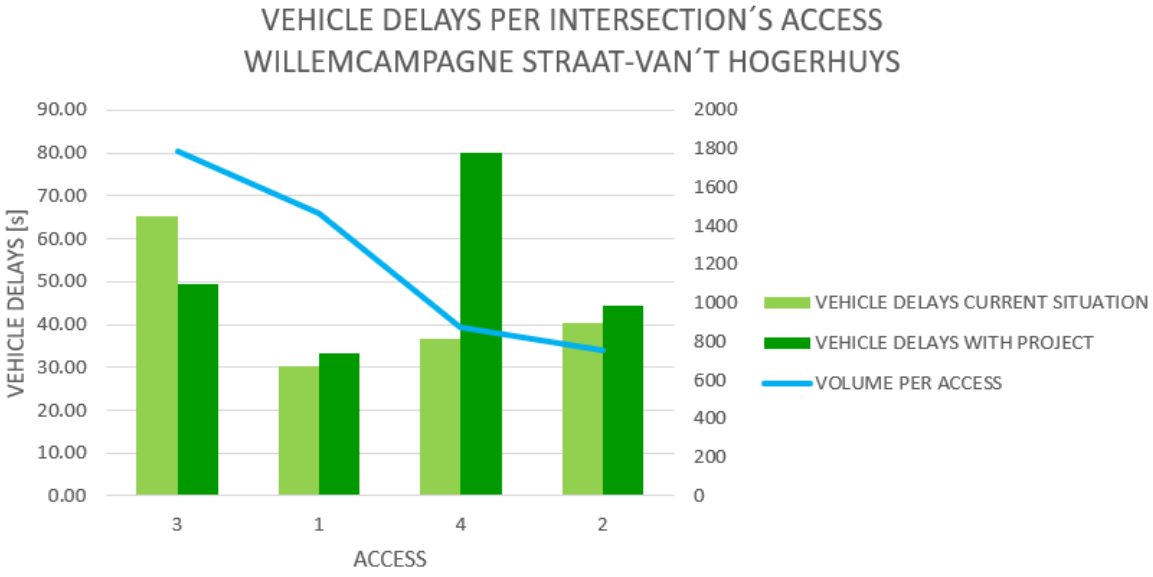
6.1.3.2 *Intersection Van 't Hogerhuysstraat-Willem Campagnestraat*

The current programing of traffic light in this intersection gives more green time for access 1,2 and 4, causing mayor delays in access 3 that correspond to the main movement in the peak hour (northbound)

Figure 42. Comparison of Delays at Intersection Intersection Van 't Hogerhuysstraat-Willem Campagnestraat



Source: Transconsult

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- The proposed traffic light programming gives priority to access 3 which has a greater vehicular flow reducing its delays 30%

- Access 1 practically maintains the same level of delays in both scenarios (current and with interventions)

- The rest of access that provide 30 % of the total flow in the intersection, increases their delays an average of 16 seconds.

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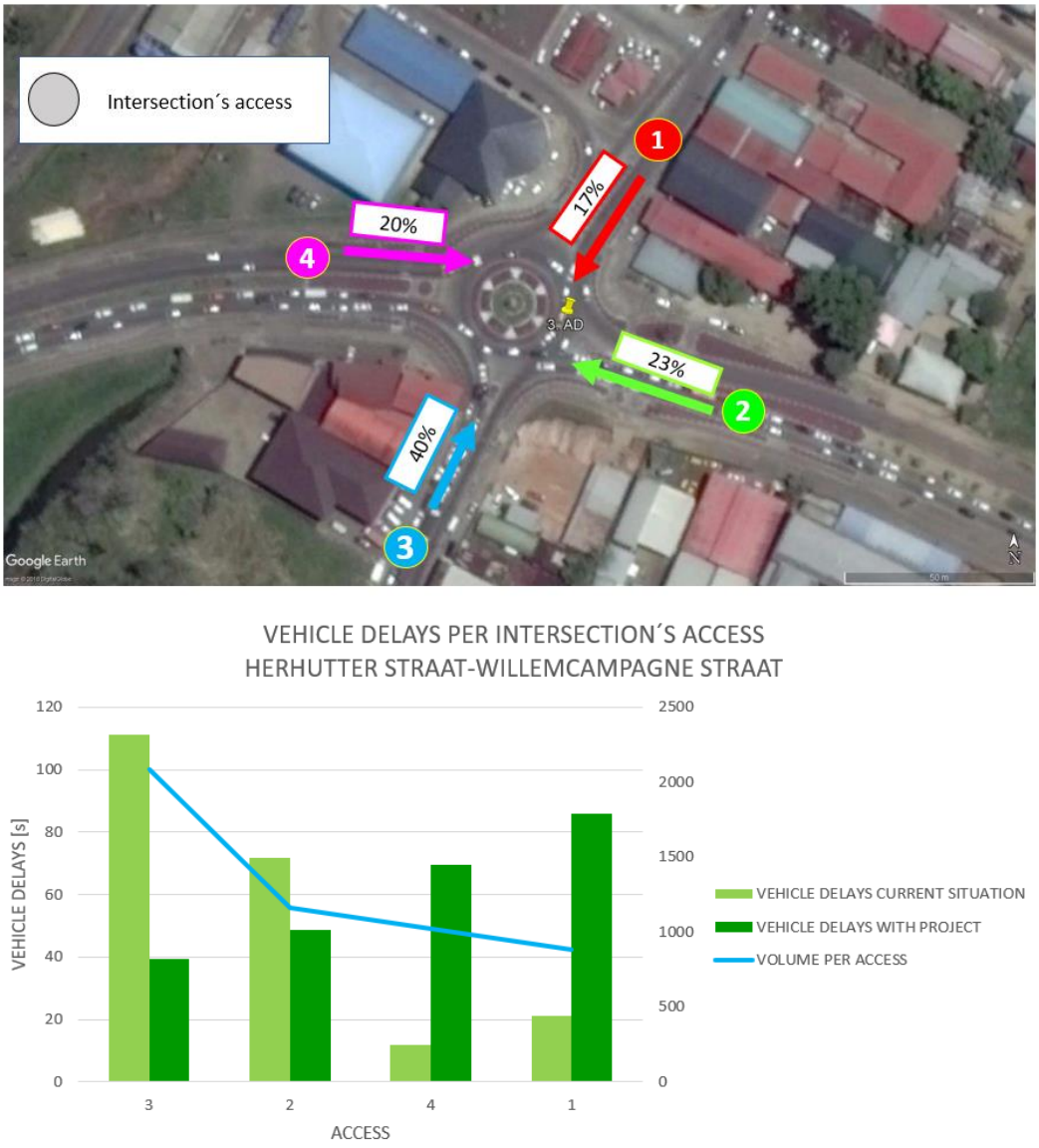
6.1.3.3 *Intersection of Willem Campagnestraat and Hernhutterstraat*

Figure 43. Comparison of Delays at Intersection Van 't Hogerhuysstraat-Willem Campagnestraat



Source: Transconsult

The proposed interventions reduce 50 % delays in accesses 2 and 3 that provides 63 % of traffic as follows

- Minus 70 seconds in Access 2
- Minus 21 seconds in Access 3
- Rest of access (37 % of traffic) increase delays an average of 50 seconds

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6.1.4 Queue length

One of the most significant impacts of the prosed interventions is the reduction of queues in the critical section of the networks. Impacts are described below.

6.1.4.1 Intersection Willem Campagnestraat and Hernhutterstraat

- Queues over Hernhutterstraat reduces 800 meters improving the speed from 16 km/hr to 40 km/hr
- Queues over Willlem Campagnestraat reduces 160 meters

Figure 44. Comparison of Queues. Willem Campagnestraat and Hernhutterstraat. Current Vs with Proposed interventions

Source: Transconsult

6.1.4.2 Intersection Van 't Hogerhuysstraat-Willem Campagnestraat

- Queues over Van 't Hogerhuysstraat reduces 660 meters improving the speed from 8 km/hr to 30 km/hr
- Queues over Jules Wijdenboschbrug reduces 500 meters

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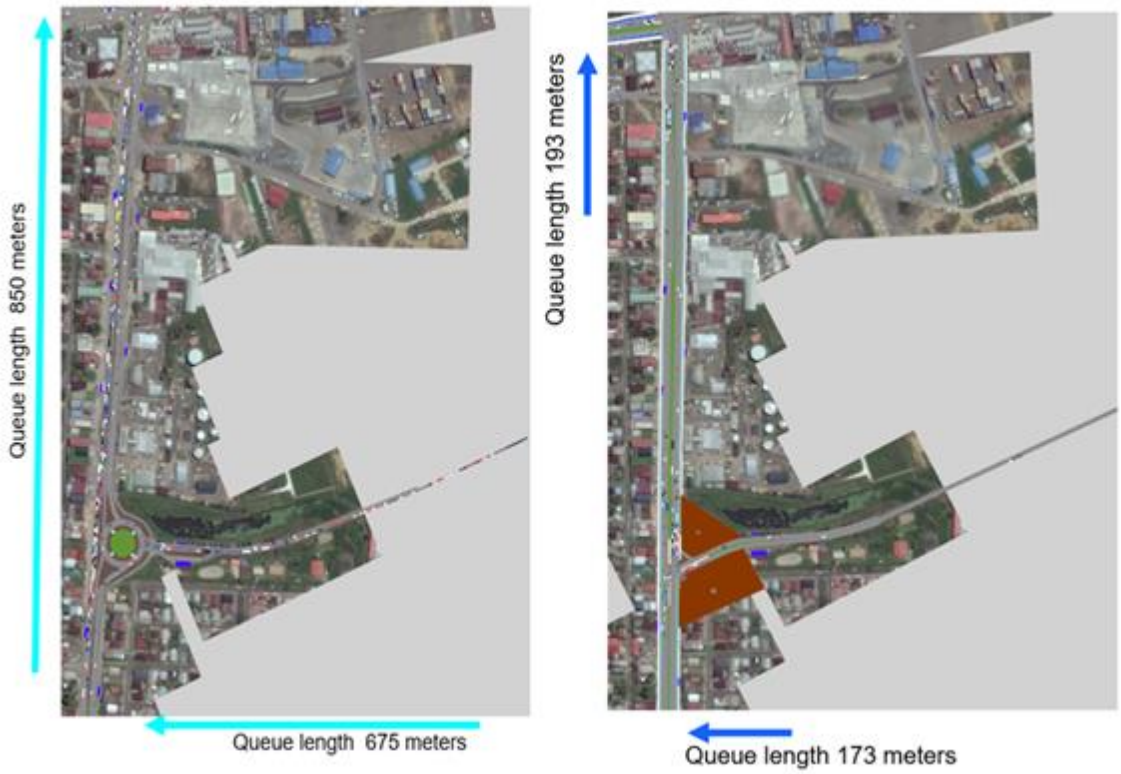
Figure 45. Comparison of Queues. Van 't Hogerhuysstraat-Willem Campagnestraat. Current Vs with Proposed interventions



Source: Transconsult

7. Traffic forecast

7.1.1 Socioeconomics variables

An analysis of socioeconomic variables has been carried out to estimate future demand f in Paramaribo area. The socioeconomic variables that have been analyzed are:

- Population
- Employment
- Gross domestic product

The analysis of the variables has been carried through at the national level since there is no data disaggregated at city level. Multiples sources has been used to complete the analysis

7.1.1.1 Population

According to the World Bank in 2017 the population in Suriname was 563,402 and approximately 40% of its population resides in the city of Paramaribo.

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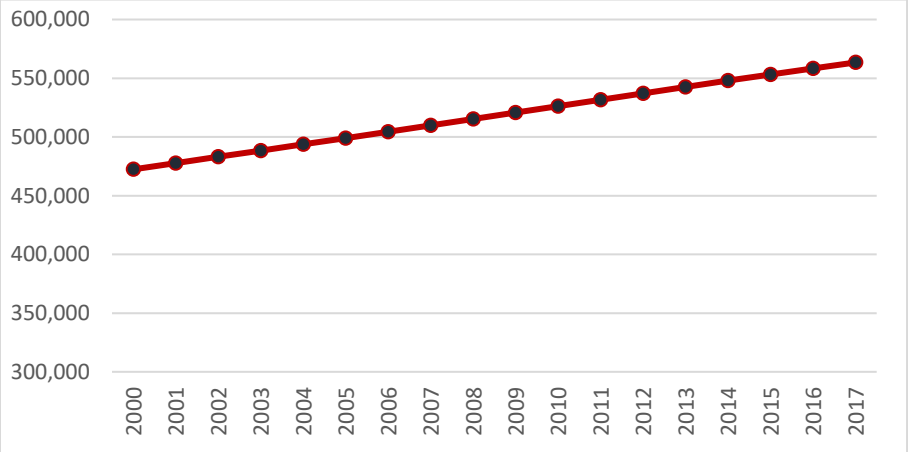
Figure 46. Historic population



Source: Transconsult based upon The World Bank.

During the period from 2000 to 2017 the population in Suriname went from 477,740 inhabitants to 563,402 with a Cumulated Annual Growth Rate (CAGR) of 1.03%.

7.1.1.2 Employment

According to the Suriname General Bureau of Statistics, the last published data of employment in Suriname was in 2011 recording 134,021 employed people. About 44% of the employed population is concentrated in public administration, education and health.

During the period from 2000 to 2011:

- The highest annual growth was in 2002 with an annual rate of 7.4%
- The years with the lowest growth were in 2004 and 2009.
- The CAGR of employment was 3.14%.

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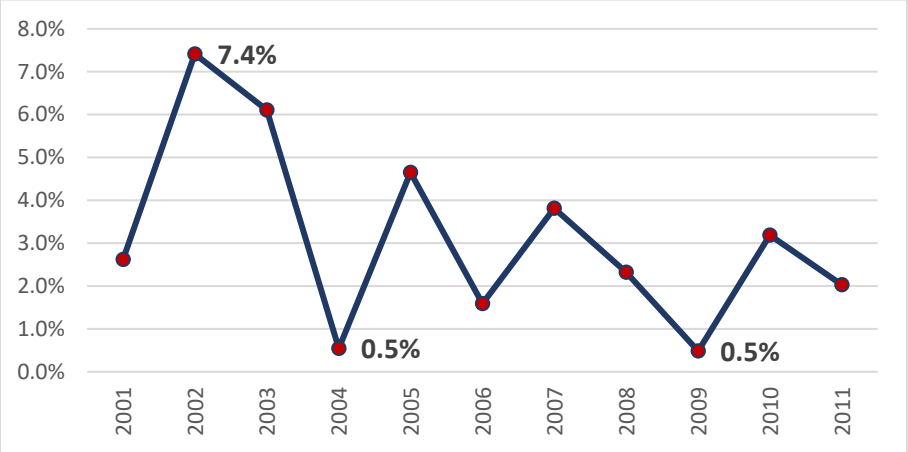
Figure 47. Historic employment growth rate



Source: Transconsult based upon Suriname General Bureau of Statistics.

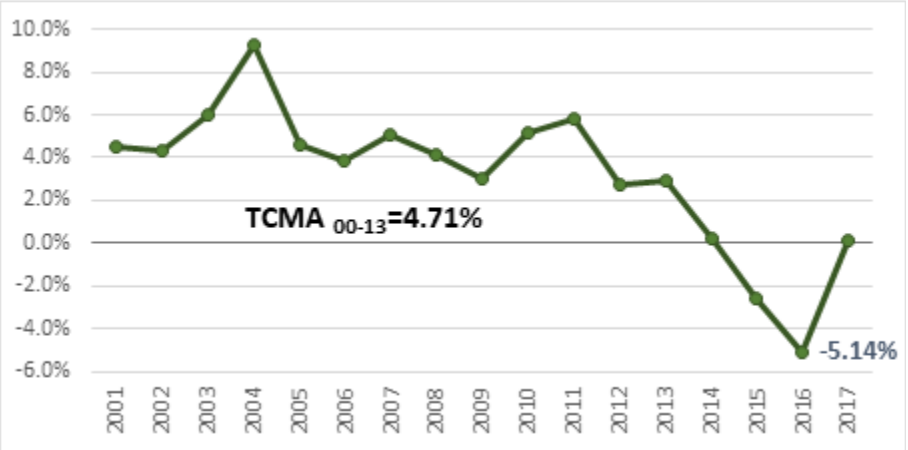
7.1.1.3 Gross Domestic Product

The dynamism of Suriname's economy was analyzed in two periods:

- 2000 to 2013: Suriname's economy remains stable with an average annual growth of 4.71%.
- 2013 to 2017: the economy in Suriname shows an economic recession mainly because of falling commodity prices such as aluminum and gold.

The following figure shows the historic performance of the Gross Domestic Product (GDP) of Suriname.

Figure 48. Historic real GDP growth rate



Source: Transconsult based upon The World Bank.

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In the period from 2000 to 2017 the economy grow 3.13%. In 2004 the country had the annual growth rate of 9.26%, the highest during the period. In 2016 it had a decrease of 5.14% in its economic activity due to falling commodity prices.

7.1.2 Traffic forecast

To estimate the traffic forecast in the city of Paramaribo over the next 10 years, the following activities were carried out:

1. The historical traffic behavior was analyzed.

2. Elasticities between the socioeconomic variables and the traffic were estimated in order to link the variable that best explains the traffic flows generation in the study area.

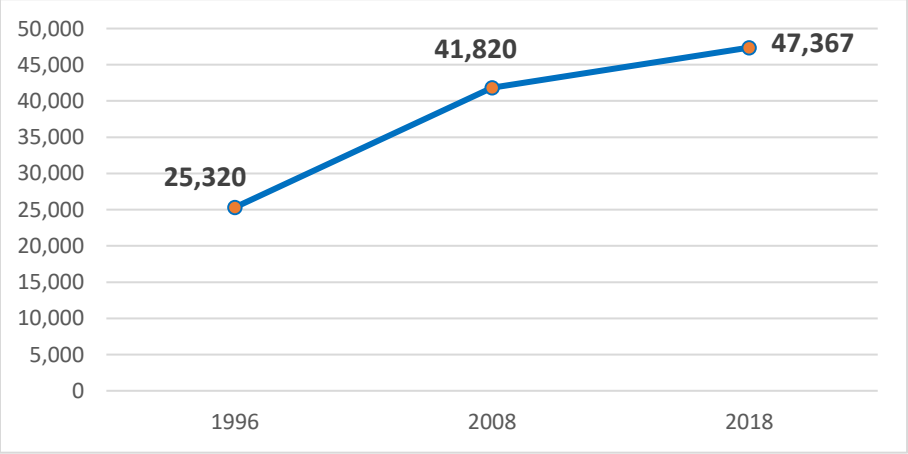
3. Once the elasticity was identified, the forecast of the explanatory variable was carried out for in the next 10 years.

4. Finally, the estimation of the capacity for the period from 2019 to 2030 was carried out.

7.1.2.1 Historic Traffic

According to data provided by the Ministry of Works of Suriname traffic on the bridge between 1996 and 2018 the CAGR was 2.9%.

Figure 49. Historic Traffic counts



Source: Transconsult based upon data provided by Suriname Ministry of Works and data collection

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7.1.2.2 Elasticities

The elasticity is a measure of the degree of sensitivity that a dependent variable has in front of the changes that an independent variable presents. This approach is used since there is not enough data to implement more complex models.

Growth rates of traffic was contrasted versus employment and GDP, to estimate a traffic elasticity to these variables. The following table shows the elasticities between traffic employment and GDP of Suriname.

Table 5. Traffic elasticitities to GDP/ Employment

Elasticities				
Variables	**CAGR (1996-2018)**	**CAGR (1996-2008)**	**CAGR (2008-2018)**	
Traffic	2.89%	4.27%	1.25%	
Employment	1.96%	3.17%	0.53%	
GDP	2.76%	3.98%	1.32%	**Average**
E. Traffic/employment	**1.473**	**1.348**	**2.355**	**1.725**
E. Traffic/GDP	**1.046**	**1.073**	**0.953**	**1.024**

Source: Transconsult

The traffic / employment and traffic / GDP elasticity for the different periods shows a positive relationship in terms of the variation of the socioeconomic variables.

The average traffic / employment elasticity indicates that, by increasing employment by one percentage, traffic will increase by 1.72%. The average traffic / GDP elasticity tells us that, by increasing one percentage point, GDP gives rise to an increase in traffic of 1.024%.

According to the above, the correlation that was chosen for the traffic demand model was based on the elasticity between traffic and GDP of Suriname due to the consistent historical behavior

The forecast of Suriname's GDP is then presented to estimate the growth of traffic over the next ten years.

7.1.2.3 Traffics growth prediction

Projection of the GDP was made considering the projections The International Monetary Fund (IMF) of 2018-2023, for the period of 2024-2030 the annual average growth rate of the period was considered, and it was linearized to reduce the long-term volatility.

Growth projections according to the Monetary Fund are expected to grow from 2018 to 2023 on average to 2.78%. For the period from 2024 to 2030 a growth of 2.19% was estimated.

The projection of the GDP for the period from 2018 to 2030 is estimated to be 2.44%.

Based on the forecast of Suriname's GDP, the traffic / GDP elasticity was applied to obtain the traffic forecast in the next ten years. The traffic is estimated to grow 2.5% on average.

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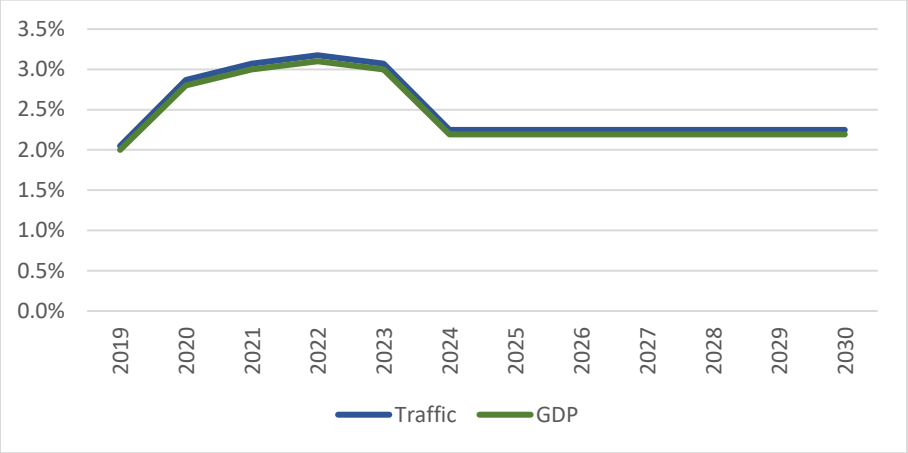
Table 6. CAGR for GDP and Traffic

Year	GDP	Traffic
2019-2022	2.97%	3.04%
2023-2026	2.19%	2.25%
2027-2030	2.19%	2.25%

Source: Transconsult

Table 7. Forecast of GDP and traffic



Source: Transconsult

8. Estimation of impacts in planning horizon

Demand forecast was introduced into the microsimulation model to estimate the impacts of proposed interventions in future under two conditions

- Current infrastructure conditions
- With proposed interventions

Microsimulation was run for a ten years period to avoid estimation of unrealistic speeds in the sections that currently have less 10 km/hr and with growth rate can reach walking speeds (2-3 km/hr)

The performance metric to estimate the impacts of proposed interventions was the change of speed in the sections of the roads of analysis. To conduct the analysis, the network was characterized in 38 sections as shown in next figure

This analysis will be a main input to conduct the Cost Benefit Analysis

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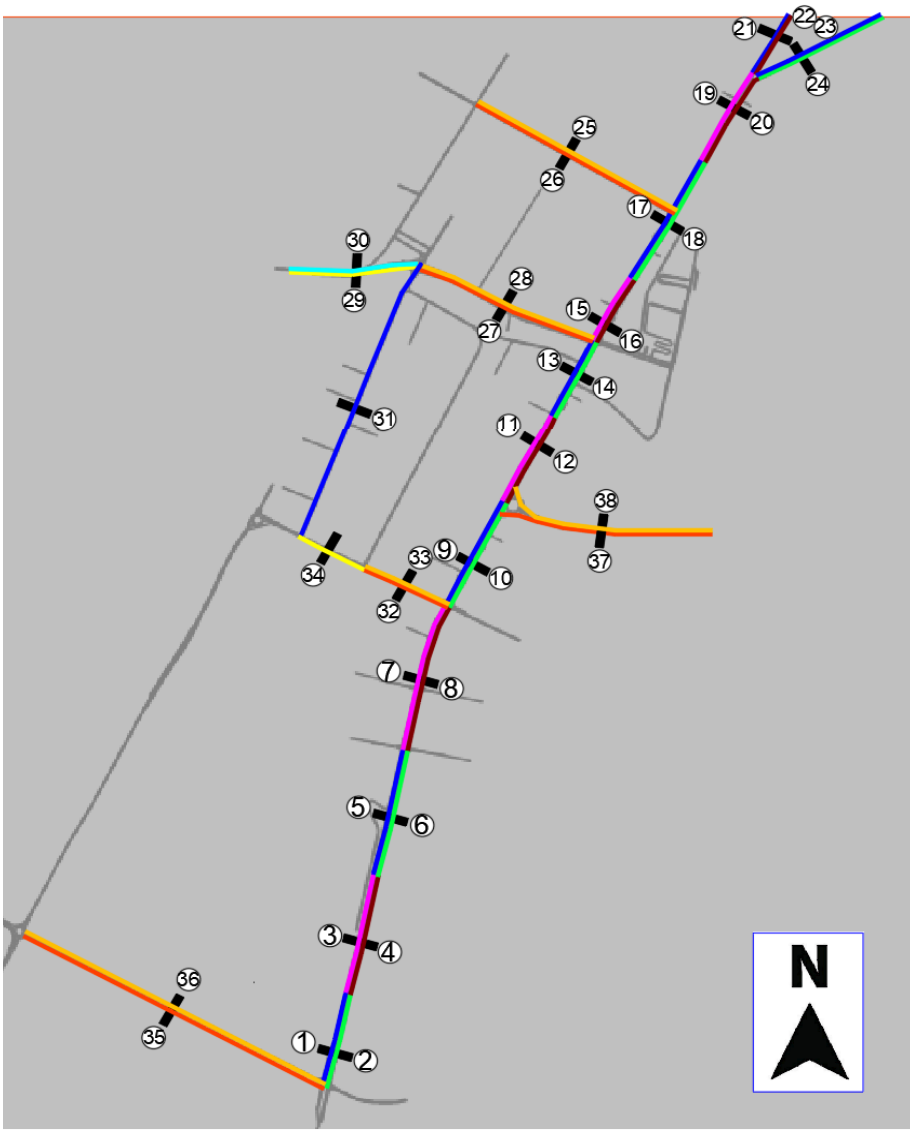
Figure 50. Sections of analysis



Source: Transconsult

Next table shows the main characteristics of the sections of network analyzed

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Table 8. Characteristics of section of analysis

ID	Road	ID Northbound	Length (km)
1	Martin Luther Kingweg	South to north	0.05
2	Martin Luther Kingweg	North to south	0.05
3	Martin Luther Kingweg	South to north	0.5
4	Martin Luther Kingweg	North to south	0.5
5	Martin Luther Kingweg	South to north	0.5
6	Martin Luther Kingweg	North to south	0.5
7	Martin Luther Kingweg	South to north	0.52
8	Martin Luther Kingweg	North to south	0.52
9	Van 't Hogerhuysstraat	South to north	0.5
10	Van 't Hogerhuysstraat	North to south	0.5
11	Van 't Hogerhuysstraat	South to north	0.5
12	Van 't Hogerhuysstraat	North to south	0.5
13	Van 't Hogerhuysstraat	South to north	0.35
14	Van 't Hogerhuysstraat	North to south	0.35
15	Van 't Hogerhuysstraat	South to north	0.25
16	Van 't Hogerhuysstraat	North to south	0.25
17	Van 't Hogerhuysstraat	South to north	0.5
18	Van 't Hogerhuysstraat	North to south	0.5
19	Zwartenhovenbrugstraat	South to north	0.58
20	Zwartenhovenbrugstraat	North to south	0.58
21	Zwartenhovenbrugstraat	South to north	0.562
22	Zwartenhovenbrugstraat	North to south	0.562
23	Saramaccastraat	South to north	0.644
24	Saramaccastraat	North to south	0.644
25	Molenpad	West to east	0.825
26	Molenpad	East to west	0.825
27	Willem Campagnestraat	East to west	0.707
28	Willem Campagnestraat	West to east	0.707
29	Willem Campagnestraat	East to west	0.462
30	Willem Campagnestraat	West to east	0.462
31	Hernhutterstraat	South to north	1.08
32	Slangenhoutstraat	East to west	0.33
33	Slangenhoutstraat	West to east	0.33
34	Slangenhoutstraat	East to west	0.255
35	Latourweg	East to west	1.247
36	Latourweg	West to east	1.247
37	Jules Wijdenboschbrug	East to west	0.518
38	Jules Wijdenboschbrug	West to east	0.518

Source: Transconsult

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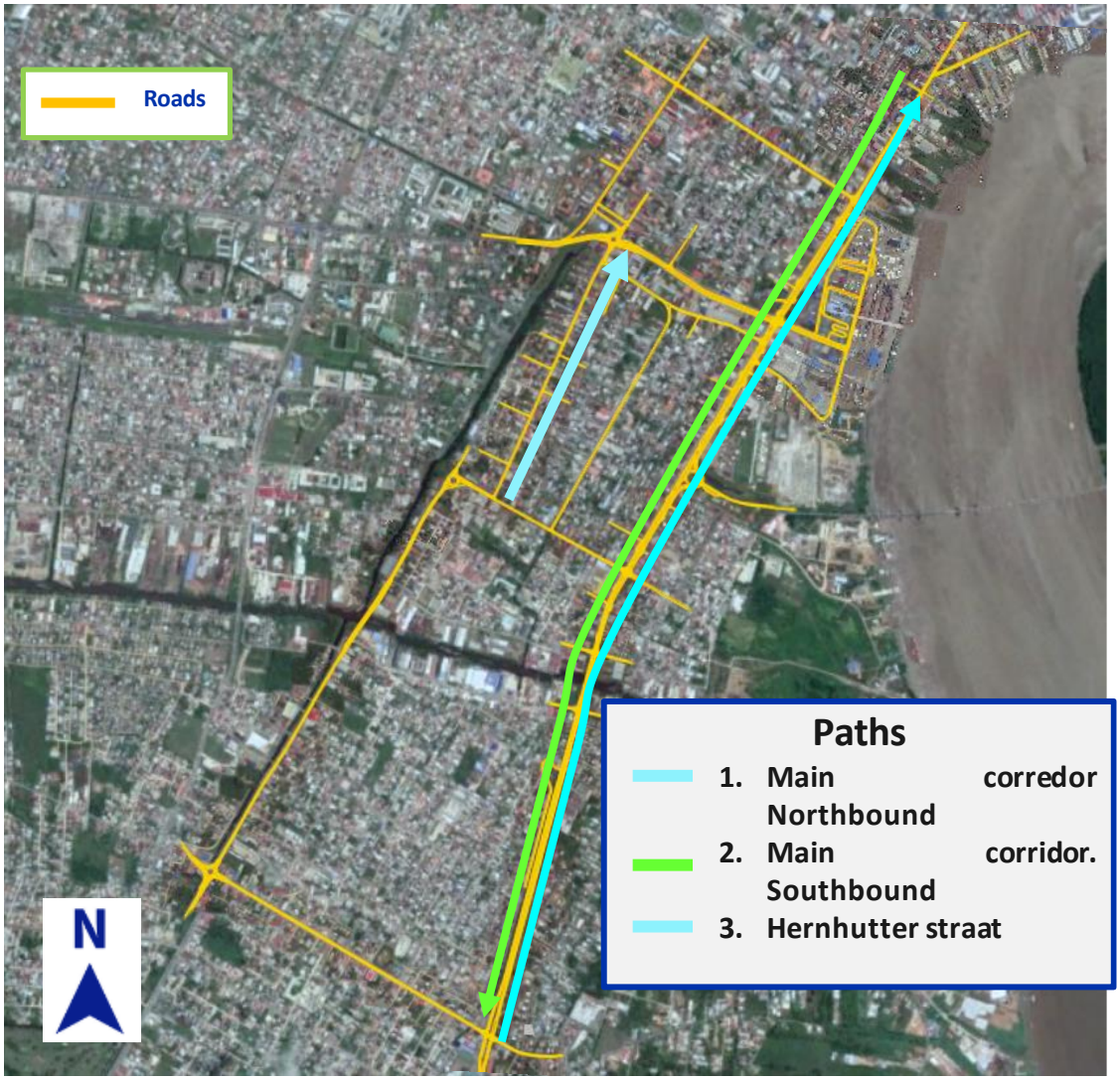
Estimation of traffic volumes and times were estimated for the planning horizon under two scenarios described below. Next figure shows cumulated time for 3 main roads of the scope of analysis.

1. Martin Luther King and Van´t Hogerhuystraat

2. Van´t Hogerhuystraat and Martin Luther King

3. Hernhutter straat

Figure 51. Time comparison for 3 main paths.



Source: Transconsult

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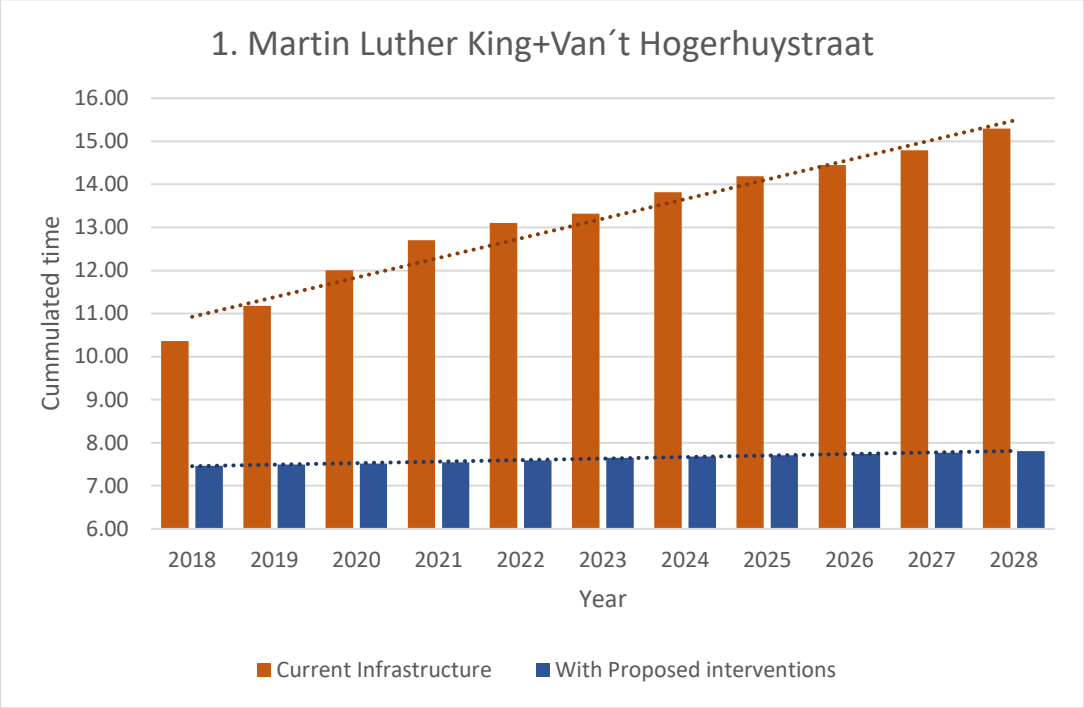
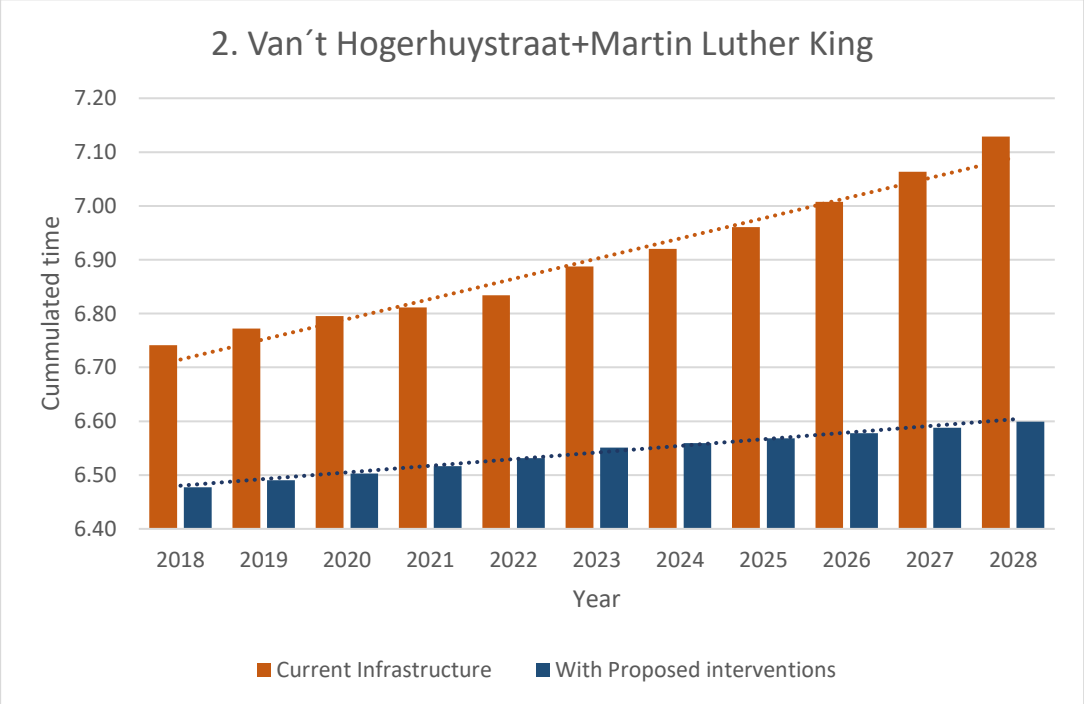
Next figure show time evolution on the corridors with current infrastructure and with proposed interventions

Figure 52. Time evolution for selected corridors





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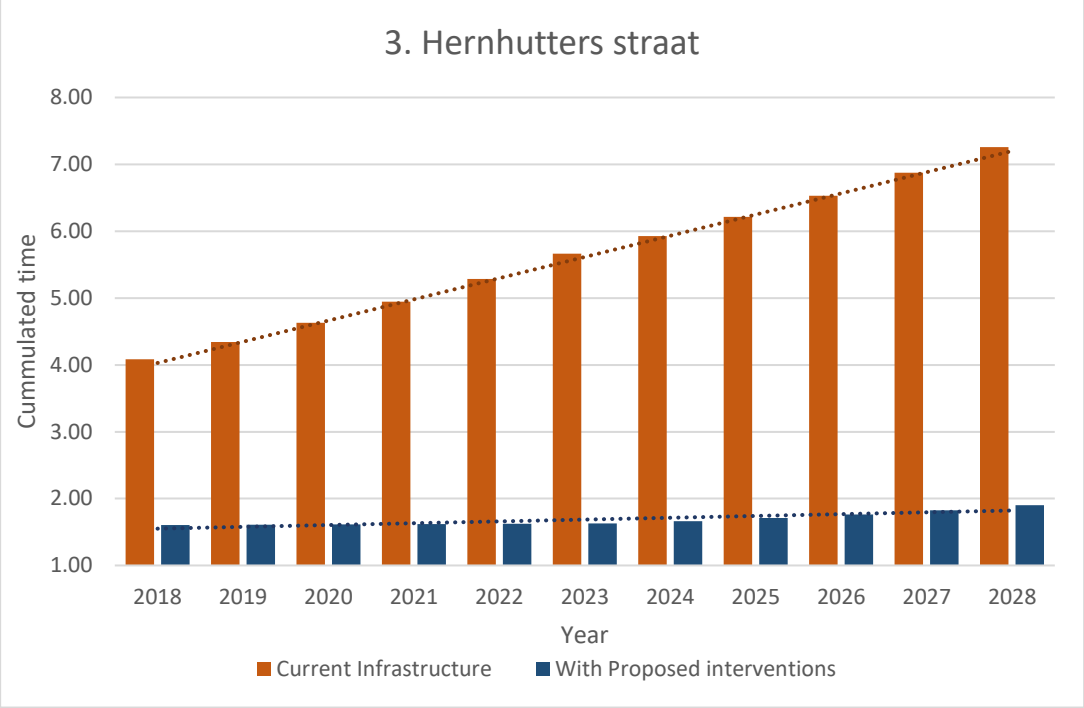

Source: Transconsult

Travel times will grow 50 % in the most congested sections (e.g. paths 1 and 3) under the scenario with current infrastructure, instead the travel times are very stable under the scenario with proposed interventions.

Data for the all sections will be delivered as an annex to this study.

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9. Conclusions

- Roundabouts are not efficient with the high levels of traffic that already use roads of analysis, creating queues in the morning peak hour in corridors that that are used in northbound direction as Van ‘t Hogerhuysstraat and its intersection with Jules Wijdenboschbrug. Same effect happens and Hernutterstraat and Willem Campagnestraat.

- Travel times can increase in ten years up + 50 % in a “Do-nothing” scenario, particularly those corridors that attends the peak hour northbound.

- The proposed interventions are based in expand the capacity of the corridor thru the construction of extra lanes and installation of traffic devices that aims to prioritize the main flows of the city

- The proposed interventions generate time savings equivalents 36 hours per year, creating continuous flow northbound, reducing the delays and queue lengths experienced by drivers, increasing speeds in road to a 30 -40 km/hr range

- The solutions also benefit to the trucks generated by the port by allowing a direct route to the port thru the construction of the bridge and dedicated storage to allow a direct access route to the port.

- The proposed interventions integrate road infrastructure and public space, enabling sidewalks and bicycle lanes, providing specific public transport stops and safe pedestrian crossings.

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